THE GRAND CANYON MONITORING AND RESEARCH CENTER

FISCAL YEAR 2002

MONITORING AND RESEARCH WORK PLAN

by

THE GRAND CANYON MONITORING AND RESEARCH CENTER

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GRAND CANYON MONITORING AND RESEARCH CENTER
FY 2002 MONITORING AND RESEARCH WORK PLAN

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CHAPTER 1

THE GCMRC FY 2002 ANNUAL WORK PLAN

INTRODUCTION

The Fiscal Year 2002 (FY 2002) Grand Canyon Monitoring and Research Center (GCMRC) Annual Monitoring and Research Work Plan (Work Plan) describes the scientific activities planned by GCMRC for FY 2002.[1] The FY 2002 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 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

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1 Current Management Objectives and Prioritized Information Needs adopted at the July 1998 AMWG meeting have been used by GCMRC as the basis for developing the FY 2002 Annual Plan (Appendix 1).
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.
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.

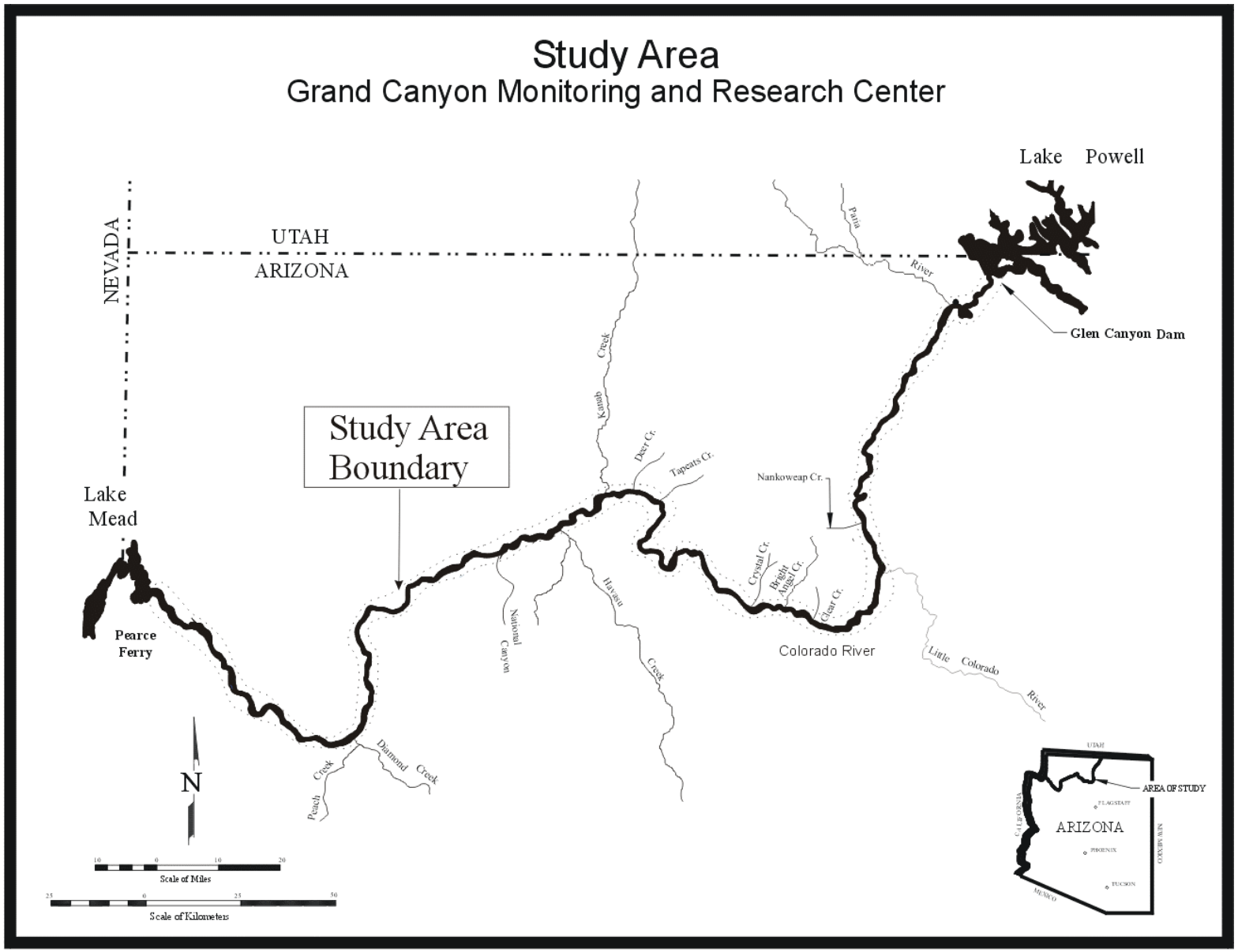

Figure 1.1 Map of Grand Canyon Monitoring and Research Center Study Area.

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, utilizing an ecosystem science approach."

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 operating protocols for GCMRC have been established[6]. The quality and objectivity of GCMRC research findings is ensured through competition and

4 As specified in the 1992 GCPA and in the Record of Decision for the Glen Canyon Dam EIS (DOI 1996).
5 See Appendix 2 for the GCMRC Mission statement and Roles and Responsibilities.
6 Operating Protocols for GCMRC, June, 1996 and GCMRC Peer Review Guidelines, May 31, 1997.

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 2002 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.

Inventorying is the measurement of environmental attributes at a given point in time to determine what is there. *Monitoring* is the measurement of environmental attributes over an extended period of time to determine status or trends in the environmental attribute being monitored. *Research* is the measurement of environmental attributes to test a specific hypothesis. An *environmental attribute* may be any biotic or abiotic feature of the environment which can be measured.

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 – Following are summaries of preliminary results of the current physical research and monitoring projects funded under GCMRC from FY 1998 through

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.

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 Suspended-Sediment Transport (Arizona District, Water Resources Division of the USGS): Under the current agreement with the USGS-Arizona District, unit-values for streamflow are 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 water quality 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). Emphasis for this work is currently on the reach between the dam and Phantom Ranch, although the Diamond Creek gage is still being maintained. 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.

Many of the final products associated with research goals the project has pursued under GCMRC funding since 1998 have been delayed owing to additional workloads imposed by the FY 2000 LSSF test. The USGS anticipates that all of the products described in the original FY 1998 agreement, and subsequent modifications, will be completed and delivered to the GCMRC during FY 2001. Despite these delays, the project has published several reports that provide new understanding about the fine-sediment mass balance of the ecosystem relative to current ROD operations. A memorandum summarizing the current state of knowledge of sediment resources was sent to the GCMRC Chief on August 29, 2000. The memo summarizes several significant findings related to conservation of fine-sediment resources under current operations, on the basis of monitoring and research conducted by USGS, Utah State University and Northern Arizona

University since the *Operations of Glen Canyon Dam – Final EIS* was completed in 1995.

Following, is an abridged excerpt from the memo:

"Sand bars and sandy banks of the Colorado River in Grand Canyon are maintained by the sand that is transported through the canyon. The high-elevation parts of these sand bars (those parts at elevations above peak power-plant discharge) can be constructed only by flows that exceed peak power-plant discharge (i.e. flows greater than 31,000 cfs); in the absence of such high flows, these high-elevation areas are eroded by lower flows or canyon winds or are rapidly colonized by both native and exotic vegetation. Flows above peak power-plant discharge are necessary to maintain these high-elevation sand bars, but are effective only when the river contains sufficient sand resources.

Evaluating restoration and sustainability of sand resources is a complicated problem that involves sand storage on the Colorado River's bed, tributary resupply of sand, sand deposition induced by flows above peak power-plant discharge, erosion and transport of sand during normal power-plant operations, and recolonization by vegetation. Improving or sustaining sand resources is a difficult challenge because Glen Canyon Dam traps all of the sediment from the upper Colorado River, resulting in an approximate 94% reduction (relative to pre-dam inputs) in the amount of sand supplied to the Colorado River at the upstream boundary of Grand Canyon National Park.

With respect to restoration and sustainability of sand bars, the Secretary of the Interior's 1996 Record-of-Decision (ROD) for operations of Glen Canyon Dam is based primarily on two hypotheses:

(1) that much of the sand introduced to the Colorado River by tributaries downstream from Glen Canyon Dam can accumulate in the channel over multiple years if dam releases do not exceed average volume, and

(2) that flows above peak power-plant release (such as the 45,000 cfs flow in 1996) can effectively move that accumulated sand from the channel bed to bars, thereby rebuilding sand bars that are eroded by typical dam releases.

Recent Findings

Work conducted since the 45,000 cfs release in 1996 has shown that the first hypothesis on which the 1996 ROD was based is false and that the second hypothesis is only partially true. The 45,000 cfs release in1996 increased the amount of sand at high elevations, but the sand that was deposited at high elevations came largely from the lower portions of the sand bars (Schmidt, 1999) and not from the channel bed as originally hypothesized.

Under the dam operations imposed by the 1996 ROD, most newly input sand is not stored on the channel bed for long periods of time. Flows above peak power-plant release cannot take advantage of multiple years of sand accumulation, because substantial multi-year accumulation of sand does not occur. Instead, this sand is transported downstream relatively rapidly. The time required to export (transport downstream past the Grand Canyon gage) one-half of a 500,000 metric ton input of tributary sand (the contribution of a typical, moderate, Paria flood) varies from less than one week (for dam discharges of 25,000-30,000 cfs) to roughly one year (for discharges of 10,000 cfs).

The time required to export the second half of a tributary input is greater than for the first half (for a constant water discharge), because the second half is coarser, as a result of winnowing of the bed. The remaining half, however, is not necessarily sufficient to enable both bar-building and a positive sand balance. For example, the 45,000 cfs release in 1996 exported

700,000 metric tons of sand from Marble Canyon in one week. Thus, a release above peak power-plant discharge is a double-edged sword: high discharges are indispensable for rebuilding high-elevation parts of bars, but high discharges deplete sand resources rapidly. Conducting a release above peak power-plant discharge when recent tributary sand inputs are greatest will tend to minimize the negative impact on the sand resources.

Since the 45,000 cfs release in 1996, six kinds of sediment and topographic data have been examined: sediment input and output, changes in grain size of sand on the river bed, changes in sand-bar size, geomorphic mapping, and changes in channel cross-sections. Some of these studies document rapid export of tributary sand (transport past the Grand Canyon gage), whereas others demonstrate a lack of substantial multi-year accumulation of sand, especially in upper Marble Canyon:

• Both measurements and calculations of sediment input and output have shown that most fine sediment (sand, silt, and clay) introduced by tributaries is exported within a few month. For example, field measurements show that most sediment introduced by floods on the Paria River in September 1999, was exported within 6 weeks. On a longer time scale (August 11, 1999, to May 14, 2000), the Paria supplied approximately 0.8 million metric tons of sand to the Colorado River, while roughly twice this amount of sand (1.5-2 million metric tons) was exported past the Lower Marble Canyon gage.

• Changes in grain size of sand on the river bed also demonstrate rapid export of tributary sand. The bed was measurably enriched in finer sand as a result of Paria floods in September 1998 (median grain size of Paria River sand is 0.11 – 0.13 mm). When sampled next (May, 1999), most of the new fine-grained sand on the bed had been winnowed. The remaining sand in the channel was generally too coarse to be transported onto the high-elevation areas of sand bars.

• Topographic surveys of 11 sand bars in the first 76 miles downstream from the dam document a continuing depletion of sand bar area from 1991 to 1999. High flows in 1996 and 1997 temporarily reversed this trend but did not halt the continuing decrease in sand bar area. The sand bars (above 20,000 cfs) were 22% smaller in surface area in 1999, although they contained 2-3% more sand than in 1991.

• Topographic surveys of 35 sand bar sites documented scour of sand during the 45,000 cfs release in 1996, followed by net accumulation. Comparison with tributary-input data for the same time, however, indicates that most of the observed accumulation occurred when there was no substantial tributary sand input.

• Repeated surveys of channel cross-sections from 1991 to 1999 have shown relatively large and rapid fluctuations in the amount of sediment present. These fluctuations are interpreted to represent temporary storage and subsequent down-river transport of sediment. These studies have not detected multi-year accumulation of sediment.

• Analysis of bed-elevation data at the historical Marble Canyon dam sites suggests considerable loss of sediment from the 1950's to the present. Not only does the post-dam river contain less sand than the pre-dam river, but the remaining sand is generally coarser.

• Geomorphic mapping indicates that deposition of the 45,000 cfs release in 1996 was least near Lees Ferry and was greatest downstream from the Little Colorado River. The magnitude of "improvement" is greatest further downstream where more tributaries have delivered fine sediment to the channel. Thus, the "improvement" caused by any specific release above peak power-plant discharge differs both temporally and spatially, depending on how enriched or depleted a particular reach is at the time.

Implications for Current Management Actions

The features listed above characterize a system where increases in sand abundance result not from incremental multi-year accumulation but rather from temporary storage of individual tributary inputs. In such a system, where increases in sand abundance are temporary, the goal for building sand bars should be to exploit tributary inputs as soon as possible, because the volume of sand available for bar-building is greatest immediately after large tributary inflows. To be effective in rebuilding sand bars, releases above peak power-plant discharge should occur soon after these tributary inflows, before the new sand is lost downstream.

Large Paria tributary inflows typically occur during late summer and early fall. Under the rules of the 1996 ROD, however, releases above peak power-plant discharge cannot be implemented on a schedule that takes advantage of such inputs. If a release above peak power-plant discharge cannot be scheduled immediately following a tributary input, another option might be to maintain low flows until a release above peak power-plant discharge could be implemented; the low flows would reduce the amount of sand lost downstream. The magnitude of an acceptable low flow that limits the rate of sand export depends on the volume of sand introduced by tributary flooding, the length of time following the tributary input, and what loss of sand downstream is considered acceptable. At dam releases that are typical of recent years, half of the sand introduced by a tributary flood can be exported within days or weeks. Retention of sand for more than a few months requires sustained dam releases at the lower discharges currently permitted under the ROD (8,000 -10,000 cfs).

Recommendations for Future Management Actions

Even if rules for releases above peak power-plant discharge are revised to allow scheduling during or shortly after periods of sand inputs, the objectives of improving or sustaining the desired abundance, form, and function of sand bars may still not be possible because the long-term sand supply from tributaries in critical reaches may be too small. The 76-mile reach downstream from Glen Canyon Dam has but one large sand source: the Paria River. The supply of sand from the Paria River is only about 6% of the sand that was supplied to this reach prior to the construction of Glen Canyon Dam. Natural floods from the Paria River may be too infrequent and too small to restore sand resources in this critical upstream reach, which includes the 60-mile length of Marble Canyon within Grand Canyon National Park.

Altering the timing of releases above peak power-plant discharge (or drastically reducing the dam's discharge until such flows can be released) may be insufficient to rebuild sand resources above existing levels or to achieve sustainability at present levels; additional monitoring will be required to see if these options are successful. If alternative timing of releases above peak power-plant discharge proves to be insufficient for sand bar management goals, then other more effective alternatives should be evaluated.

One approach would be to selectively add sand downstream of the dam. This alternative ("sediment augmentation") was considered and eliminated during the Operations of Glen Canyon Dam EIS process. We are unaware of engineering feasibility studies of such a program, but sediment by-pass is an attribute of some recently built dams, as well as harbors and estuaries. A review of sediment pipeline technology is included on the EPA web site, http://www.epa.gov/glnpo/arcs/EPA-905-B94-003/B94-003.ch5.html. Addition of enough sediment (continuously, seasonally, or perhaps only during releases above peak power-plant discharge) would offer greater flexibility in dam operations, and it is conceivable that such an approach might cost less than imposing new constraints on dam operations. It is possible that sediment augmentation, substantial seasonal modification of flows released from Glen Canyon Dam, or both, might be able to restore the sand

resources in the Colorado River ecosystem in Grand Canyon National Park without more extreme actions.

Conclusions

The post-dam Colorado River is depleted in sand resources relative to the pre-dam river. The existing management strategy permitted under the ROD is failing to restore sand resources in the ecosystem in Grand Canyon National Park. The bars are continuing to decrease in surface area, and no long-term retention of tributary sand has been detected.

Our opinion, based on the information presented in this summary, is that any of the following approaches will have a significantly greater likelihood of success in restoring or retaining sand resources in the Grand Canyon ecosystem:

(1) Implement releases above peak power-plant discharge immediately after substantial inputs of sand from tributaries.

(2) Maintain low flows following sand inputs until releases above peak power-plant discharge can be implemented.

(3) Add sediment downstream from the dam.

Dam operations of the last decade must have caused one of the following possible effects on sediment resources in the Colorado River ecosystem: sediment resources were enhanced or replenished relative to conditions in the early-to-mid 1990's, sediment resources were maintained in a degraded (post-dam) condition, or long-term export and loss of sediment resources is continuing. Distinguishing between such possibilities has been—and should continue to be—an important function of the GCMRC Adaptive Monitoring Program. The research reviewed above demonstrates that current operations are failing to increase sediment resources. At least one significant measure of sediment resources, surface area of sand bars above 20,000 cfs, documents continuing depletion of sand resources."

Ungaged Tributary Sediment Inputs (USGS): Webb and others, of the USGS, have estimated ungaged tributary contributions for both fine and coarse sediments between Glen Canyon Dam and Upper Lake Mead. Final results of this study have been published by Webb and others (2000) in a report entitled *Sediment Delivery by Ungaged Tributaries of the Colorado River in Grand Canyon*; a Water Resources Investigation Report (#00-4055) that will be distributed to the adaptive management group in fall 2000. The report concludes that fine sediment inputs from the Glen and Marble Canyon reaches of the ecosystem are, on average, likely to be a factor of two higher than the estimate used by the EIS team in preparing the historically based fine-sediment mass balance reported in the GCD-EIS. Although the fine sediment inputs into this critical upstream reach may be significantly higher than previously assumed, the grain-size data published in the report indicate that those sediment inputs are as fine or finer than inputs from the Paria River. This would suggest that while sand inputs from ungaged sources are significant and worth monitoring for management purposes, these inputs

likely have as short a residence time in critical reaches as those associated with the Paria River (see above). This is important information that further supports development of a fine-sediment budget for the ecosystem, as well as technical discussions about how best to conserve fine sediment inputs through dam operations.

Sediment Input Models for Paria and Little Colorado Rivers (USGS): Between 1991 and present, Topping 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. To further the verification process within one of the key modeling reaches (Lower Moenkopi Wash), a former USGS gage site on that LCR tributary is being partially reactivated in Water Year 2001, with the aim being to collect both streamflow record and suspended-sediment data for flow events on Moenkopi Wash. This project remains in-progress and is expected to be completed by the end of FY 2001, without additional funding from the GCMRC program. A one-year, no-cost extension was requested by the PI in September 2000, and the request was approved by the GCMRC. The new deadline for completion of the model is now December 2001.

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 in calendar year 2000.

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 or HMFs 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 releases above peak power plant discharge can be made under current hydrologic triggering criteria.

During FY 2001, this project has continued to move toward full completion of the products originally described in the FY 1998 agreement. Although several of the project's products have been delayed, including completion of digitization of all streamflow analog records for the Lees Ferry and Grand Canyon gage records, the team continues to contribute

significant new findings on relationships between historical dam operations and the downstream fine-sediment resources of the ecosystem.

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 summer 2000, in conjunction with the LSSF testing. Monitoring data through April 1999, indicate that high-elevation sand bars continued to erode following the 1996 BHBF-Test. The NAU data show that sand bar areas above the 20,000 cfs stage within Marble Canyon declined dramatically (22 percent) over the period between 1991 and 1999, despite bar restoration gains achieved by the BHBF test of 1996. The NAU time series (1991 through 1999) suggests that the long-term fate of monitored sites in the upper, critical reaches of the ecosystem will be continued decline under continued ROD operations. However, cooperating researcher believe that it is likely that eroding sand bars might rebuild significantly at higher elevations (between 20,000 and 45,000 cfs) if release above peak power plant discharge could be made immediately following average to above average sand inputs from major tributaries. A revised fact sheet reflecting the FY 2000 sand bar measurements is expected to be available from the NAU team in late fall 2000. These additional measurements will provide insight into the effects of the low steady summer flows, and related spike flows of summer 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.

Additional work was completed by Ecometric Research, Inc., in FY 2001, to develop a graphical user interface (GUI) called Colorado River Flow Stage and Sediment (CRFSS) that combines the flow modeling capabilities of the USGS UNSTEADY model (Flow attenuation and travel time for dam releases), with the Bureau of Reclamation STARS model (predicts stage elevations for dam releases at several hundred locations in the ecosystem). This GUI has been developed jointly by the GCMRC, Ecometric Research, Inc., USGS and the Bureau of Reclamation, for use on desktop PC's. It has been undergoing beta version testing among a subgroup of Grand Canyon managers and scientists, and is scheduled to be completed for wide distribution by the middle of FY 2002. The final version shall include an subroutine that allows users to estimate sand inputs from the Paria River based on user provided streamflow data from that tributary.

Biological Resources –

Terrestrial Biological Resources – Following are summaries of preliminary results of terrestrial biological monitoring and research projects funded under GCMRC from FY 1998 through FY 2000. Current contracts are separated into vegetation (Kearsley, NAU), avifauna (Spence, GCRA), and Kanab ambersnail (Meretsky, SWCA).

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 level. His work has been focused on evaluating and incorporating 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. In FY 2000, one breeding pair of Southwestern Willow Flycatcher was observed and one young is believed to have fledged.

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 – Following are summaries of preliminary results of aquatic biological monitoring and research projects funded under GCMRC from FY 1998 through FY 2000. 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– The U.S. Fish and Wildlife Service was the principal organization responsible for native fish monitoring in the mainstem in FY 1998 and FY 1999. 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 Resources–

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, Native American stakeholders, 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. Some surface erosion is due to natural processes that are unrelated to dam operations. Other sediment loss from erosional processes is 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., 2000). Generally, plant resources seem to be in good condition with some physical and visitor impacts noted at some locations.

Recently completed GCMRC projects 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 report (Neal et al., 2000) identifies data gaps in previously collected data. A stage flow and deposition modeling project provides 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. A final draft report is currently under review and will be finalized soon. A recent geomorphic report (Thompson and Potochnik, 2000) attempted to identify erosional processes that are related to dam operations versus naturally-occurring processes. The results of this study indicate that questions remain in distinguishing resource impacts that are related to dam operations. Finally, a cultural resource protocol evaluation panel (PEP) was held during Spring 2000. The panel's report (Doelle, et al., 2000) provided GCMRC and Reclamation with a series of recommendations for program coordination and future activities. The work activities described in this plan reflect the PEP recommendations.

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 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).

Recent Investigations**.** Recent GCMRC studies address campsite assessment and monitoring protocols through quantitative beach and sand bar measurements to detect area and volume change. The report of this work is in progress and will be available later in FY2001. An additional recreational study assessed recreational preferences relative to experiences (Stewart et al., 2000). Based on user surveys, this study indicates recreational preferences for camping beaches and activities such as white water rafting, day-use rafting in Glen Canyon, and fishing and recreation experiences. Studies of recreational safety and economic impacts to concessionaires relative to the low steady summer flows are ongoing. 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 2001 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 2001.

Information Technologies Program (ITP) –

Data Base Management System (DBMS) – During FY2000, work toward an integrated database proceeded along four general lines. First, historical electronic data sets located at GCMRC were identified, and placed into an archive. Second, the data storage and application needs of the scientific programs at GCMRC were reviewed, and a preliminary database design

was completed to facilitate the integrated decision support needs of the Center, and accomplished in part by evaluating the designs of existing ecosystem management databases. Third, selected original electronic data sets have been consolidated into an MS Access database, for ultimate conversion to an Oracle database. Data collected from the current year Native and non-native fish population samples have been consolidated into this MS Access database, and a fish sample data entry application has been written to facilitate the consistent use of database parameters between investigators. Work has begun developing corresponding tables in the Oracle DBMS, and selected tables have been imported from the Access system. During the remainder of FY2001, the services of a database consultant will be secured, the current design will be validated and extended to other data types, and data entry and analysis applications will be written that allow for Web access to the Oracle tables.

Geographic Information System (GIS) –During FY2000 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.

During FY2000, considerable progress was made in the development of spatial data standards, developing metadata standards, acquiring legacy data located at the BOR Technical Center in Denver, making additional spatial data available on the FTP site, and quality assuring spatial data coverages, and metadata delivered as part of the topographic base map development using LIDAR.

Library – The GCMRC library continues to make strides in organization and accessibility in FY2000:

- The library catalog is now accessible on-line through the GCMRC website.
- Aerial photographs are currently coming into the library on DVD. Very soon, the DVDs will be cataloged and a copy made for deep archive purposes. Users can then copy the DVD in house and take their copy with them off site.
- New furniture and shelving has augmented the organization and presentation of the library.
- The photograph collection is in the process of being cataloged and reorganized so that it is more easily accessible and better preserved.
- New materials are cataloged as they arrive.

Surveying - 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.

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 1998. In FY2000, the GCMRC collected high-resolution orthophotography and topography of the entire CRE. This dataset will provide one-foot resolution georeferenced and rectified imagery and one meter contours as well as a four-meter digital elevation model. In addition to sub-meter terrestrial base maps described above, we have high-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.

It is an objective of GCMRC to support 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 repeated since 1993 at 35 NAU sand bar sites (Hazel, et.al.1999; Kaplinski, 2000), 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.

In FY2000, hydrographic channel data was collected for 50 miles of the CRE.

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.

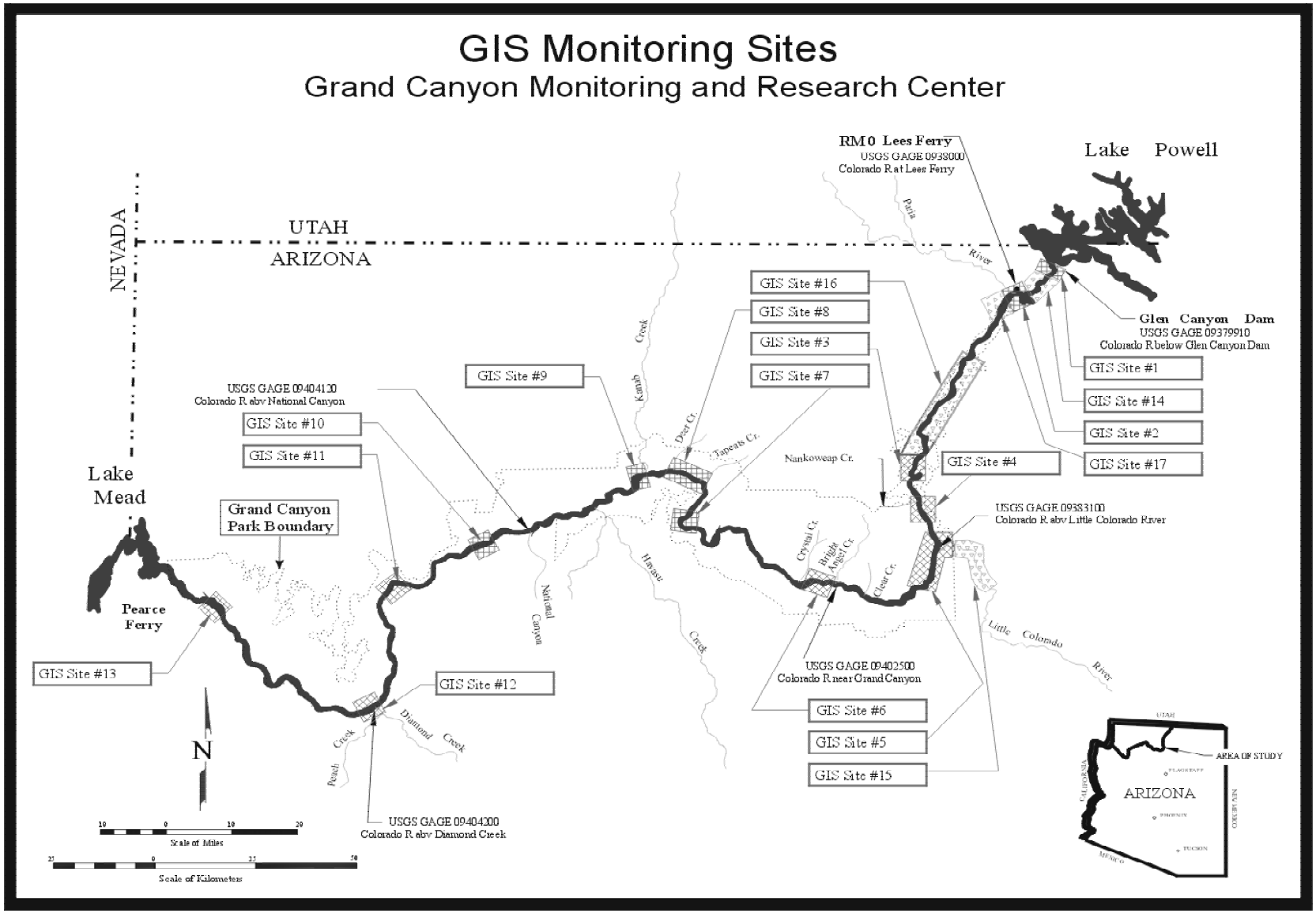

Figure 1.2 Map showing the location of the 17 GIS sites for which there are Sub-meter Accuracy Topographic Base Maps available.

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.

In FY2000 the survey department linked together and verified 30 control gaps between GCD and RM 72. The survey department also collected control data from RM 72 to RM 93, which is through the gorge and includes Phantom Ranch.

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.

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.

During FY2000, the remote sensing initiative assessed the information requirements of the research and monitoring programs in terms of parameters measured, current procedures for measurement, accuracy and spatial resolution required, and potential benefits of using remote sensing technologies to meet these requirements.

1. We determined that some of the parameters being measured or monitored can be better obtained using sensors that are not currently employed and that some parameters can be obtained using lower spatial resolutions than the 6-10-cm data currently being acquired. These issues will be fully addressed in FY2001 using the data that we collected during FY2000. Of course, some parameters related to water quality and topography cannot be approached effectively using remote sensing data.

2. Inventoried all existing remote sensing and GIS databases within GCMRC and examined existing methods, scanning equipment, storage media, data volume, and cost for conversion of the photographic image library to digital format. Created a list of recommendations on the fundamental characteristics for a digital archive and retrieval system based on experiences of personnel involved with large government archive systems. The photographic image archive in its current state is not being used to its full potential because the archive of over 32,000 photographs is analog. This archive needs to be converted to an on-line digital search and retrieval system as soon as possible so that more efficient monitoring can be performed using historical data. Because the requirements on an archive system differ among archive systems, the best approach to be taken by GCMRC is to implement a preliminary design for their archive system, allow users to interact with the system, and respond to user feedback on the functionality of the system for their needs.

3. Performed a market survey of existing LIDAR technology and providers and produced a ranked list of providers in terms of sensor capabilities, data processing procedures, experience, customer satisfaction, and cost. We found sensor capabilities to be similar among the different providers of LIDAR data, but the level of processing of the acquired data differs dramatically among providers. Critical criteria for selection of a provider includes their ability to obtain and process multiple returns from a single LIDAR pulse, horizontal and vertical accuracies, use of break lines in areas of abrupt change in slope, willingness to work with the

client to provide the best possible product, and experience in areas of high relief that differentiate between ground topography and canopy elevation.

4. Acquired low-resolution (4 m shot spacing) LIDAR for the entire canyon system from Glen Canyon Dam to Lake Mead in April. Acquired moderate-resolution (2 m shot spacing) for the canyon between Glen Canyon Dam and Phantom Ranch in August and in September. Acquired high-resolution (0.6 m shot spacing) for 5 sand bar reaches between Glen Canyon Dam and Phantom Ranch in August and in September. Although all of these data have not been fully processed and delivered, our contracting process has taught us that the statement of work for all remote-sensing tasks needs to be constructed carefully and with great detail. Our statement of work for remote sensing tasks has evolved this year to close to what is necessary to ensure that the products delivered meet our intended expectations. However, additional details need to be inserted into our current statement of work. We have also realized that we need to prepare a new RFP for our FY2001 remote sensing program that addresses the evolution in technologies that GCMRC has found appropriate for its monitoring program.

5. Acquired B&W digital imagery with GPS and IMU under clear sky conditions from Glen Canyon Dam to Lake Mead in April (low sun elevation) with one-foot spatial resolution and from Glen Canyon Dam to Phantom Ranch in August and in September (moderate sun elevation) at 0.6-foot spatial resolution. We have determined that it is critical to employ IMU devices on remote sensing data acquisitions because the gyro stabilizers on camera systems cannot always compensate for rapid aircraft movements caused by frequent occurrences of turbulence in the canyon. We have also determined that even under low sun elevations conditions (between September and April) B&W digital cameras provide superior image data over conventional photographic systems because the digital systems employ automatic gain adjustments for lighting conditions within a flight line. Thus, even though the data that we acquired have “apparent” shadows in certain areas of the canyon, the digital image data captured ground detail--within the shadows--which is brought out by image enhancement. At present there is no black and white imagery downstream of Phantom Ranch taken following the Fall 2000 spike flow.

6. Acquired color-infrared photography with GPS and IMU under clear sky conditions from Glen Canyon Dam to Lake Mead in April (low sun elevation) at one-foot spatial resolution and in July (high sun elevation) at 10-cm spatial resolution. Our color-infrared data shows what has been known for a few years: color-infrared image data is more effective than natural color photography for detecting vegetation. Our next goal is to directly acquire such data digitally because photographic film scratches easily (data loss) and require subsequent scanning that is very time consuming, costly, and quite an arbitrary process in terms of color balancing between flight lines.

7. Acquired color-infrared photography with GPS and IMU under totally overcast sky conditions from Glen Canyon Dam to Phantom Ranch in September (moderate sun elevation) at one-foot spatial resolution. These data show much more detail and information than data acquired with clear sky, high sun elevation conditions and the data have no shadows. Although it is more difficult to plan data acquisition for overcast conditions, because the condition is less likely than clear or partly cloudy conditions, our findings do widen the data acquisition window to now include both clear sky and overcast sky conditions.

8. Acquired digital multispectral (12 band data including thermal infrared) with GPS and IMU under partly cloudy sky conditions for a 42-mile segment (River Mile 30 to 72) in July (high sun elevation) using a helicopter flying at 1,200 feet above the ground. Although these data have not yet been analyzed to determine their potential benefits for the GCMRC program, this data acquisition did give us one important piece of information just from the flight and that is that GPS can be maintained at low altitude within the canyon if the aircraft proceeds slowly along its flight path. This observation now opens up the possibility of obtaining very-high resolution (cm scale) LIDAR data by helicopter for detailed monitoring of sand bars, even when the sand bar is heavily vegetated.

9. Compiled all published literature on remote sensing approaches relevant related to environmental research or monitoring and have completed review of one-half of the publications.

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 2002 Work Plan are intended to address the management objectives and prioritized information needs recommended by the AMWG to 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 1). 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.

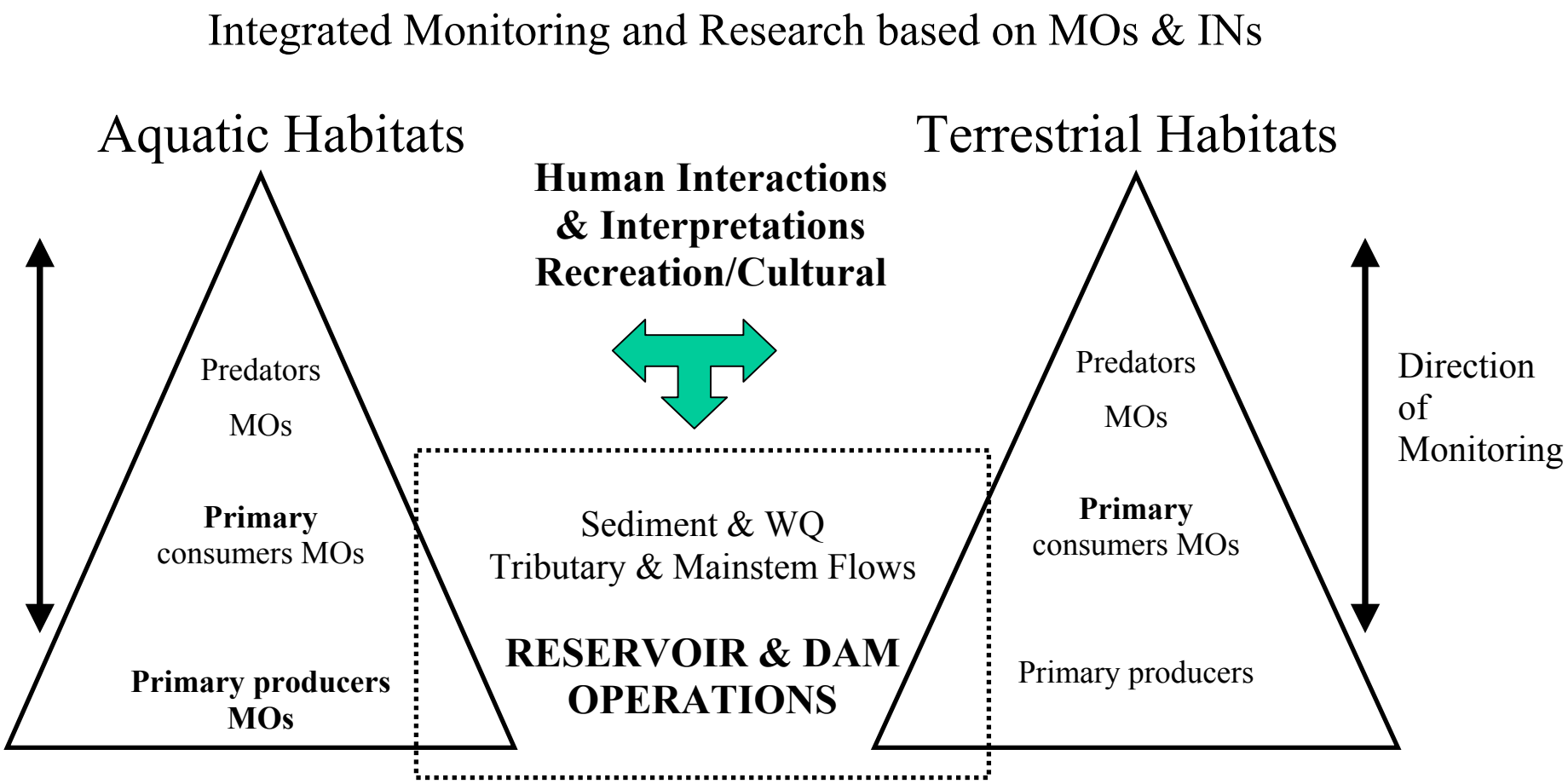

Figure 1.3 Integrated Long-term Monitoring and Research Program

PROTOCOL EVALUATION PROGRAM

The Protocol Evaluation Program (PEP) is intended to support decisions by the GCMRC as to the specific monitoring protocols that will be used.

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. Two PEP workshops will be conducted in FY2001. The first, a PEP workshop to review the IWQP, will be held from November 26 through December 2, 2000. The second, a PEP workshop to review the AFB and native fish monitoring program, will be held in the spring of 2001. The recommendations resulting from these workshops will be distributed to the TWG and AMWG and used to modify the FY 2002 work plans as appropriate. 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 releases above peak power plant discharge from Glen Canyon Dam. When triggered, these criteria provide little lead time for monitoring and research planning. In addition, hydrologic conditions can lead to unplanned release events which may 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.

Given the recent passage of the FY 2001 Energy and Water Appropriations Bill that includes language that caps funding from power revenues in support of the GCD AMP, a new mechanism for supporting additional monitoring and research activities resulting from implementing test flows in response to these triggering criteria needs to be developed.

SCIENCE SYMPOSIUM

The GCMRC has initiated a program of regular scientific symposia to discuss the current state of scientific knowledge 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 will host a scientific symposia in FY 2001. In FY 2002, GCMRC and participating scientists will present scientific information at the Biennial Colorado Plateau Symposium.

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).

The FY 2002 Work Plan is based on the assumption that the TCD, if built, will not be operational until FY 2004 and 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 2002 Work Plan is based on the assumption that the actual flows to be implemented will follow those in the plan prepared for GCMRC by SWCA, Inc. We also assume that a decision for implementation of SASFs in FY 2002 will not be made until January 2001, and given the short lead time, any supplemental activities will be implemented as modifications to contracts already in place. As with the issue of contingency planning discussed earlier, a mechanism for funding this additional work needs to be developed.

SCHEDULE AND BUDGET

The Annual Work Plan and budget described in this document were reviewed by the TWG in Fall 2000, and the AMWG recommended at their January 11-12, 2001, meeting that it be approved by the Secretary for implementation. The GCMRC FY 2002 Work Plan described in this document will be implemented for $6,576,000 provided from power revenues.

For information about AMP activities and budget, and the Programmatic Agreement, please contact Mr. Randall Peterson at the Bureau of Reclamation, Salt Lake City, Utah.

In addition, GCMRC is seeking $1,010,000 in appropriated funds to support the activities described in this plan. If these appropriated funds are not available, GCMRC will need to revise some of the activities described in this plan. Finally, GCMRC will be seeking $300,000 in support for the Integrated Water Quality Program.

Budget Review

Should the appropriated funds requested to support the GCMRC FY 2002 Work Plan not be fully funded, GCMRC will first work with the USGS to try and secure the required funds using all available budget mechanisms. Second, GCMRC will review the FY 2002 budget and identify specific work activities that could be deferred. The list of activities that could be potentially deferred will be discussed with the TWG and the AMWG. A recommendation supporting GCMRC's proposed prioritization and deferral of specific work activities in FY 2002 will be sought from the AMWG.

CHAPTER 2

SCIENTIFIC ACTIVITIES

INTRODUCTION

This chapter provides descriptions of individual monitoring and research projects to be initiated or continued as part of the GCMRC's FY 2002 integrated science program. These scientific activities are grouped into the following categories: (A) Terrestrial Ecosystem; (B) Aquatic Ecosystem; (C) Integrated Terrestrial and Aquatic Ecosystem; and (D) Remote Sensing. Individual projects and their relationship to current management objectives and information needs (Appendix 1) are summarized in Table 2.1 (Appendix 3). Management objectives and information needs are also given with the project description. Because the management objectives are currently being revised, the priorities may change when this work plan is implemented. In addition, resource ad-hoc groups may meet and suggest work plan modifications prior to plan implementation. Each of these projects are classified as: (1) Ongoing – meaning a continuation of efforts supported during FY 2001, or (2) New – meaning that the project represents initiation of long-term monitoring using current or new alternative methods and sampling design or a new research effort.

Additional information in Table 2.2 shows how total project costs and staff participation are estimated to be distributed across the GCMRC program. A key element in developing an ecosystem science design for long-term monitoring and research is the team approach to project design and oversight being advanced by GCMRC in the FY 2002 Work Plan.

A. TERRESTRIAL ECOSYSTEM ACTIVITIES

PROJECT TITLE AND ID: **A.1. TERRESTRIAL ECOSYSTEM MONITORING**

STATUS: **Ongoing. Originally Approved and Implemented in FY 2001**

General Project Description: The goal of this project is the collection of data necessary to monitor the effects of Glen Canyon Dam operations on terrestrial biological resources of concern. Analysis includes: (1) the relative abundance and distribution of waterfowl, raptors and riparian breeding birds (including southwestern willow flycatcher); (2) the composition, distribution and structure of vegetative communities and plant species; and (3) the abundance and distribution of faunal constituents linked to these vegetative communities. The project is multidisciplinary and will seek to include native American perspectives in ecosystem monitoring and interpretation.

Rationale/Problem Statement: The terrestrial ecosystem within the Colorado River ecosystem is comprised of habitat that varies from open beaches, debris fans, alluvial deposits like high terraces and talus slopes. Overlaid on these areas are plant communities that fall out along a moisture gradient (e.g., cattails by the river and cacti and mesquite farther away from the river). Along the river corridor, these plant communities can be delineated into pre-dam, or old high water zone vegetation and post-dam or new high water zone vegetation, including a marsh community (USBOR 1995). These plant communities or the space absent of vegetation influence or define the animal community. Vegetation provides either shelter or structure for nesting or foraging (either by direct consumption or indirectly by being the host for insects that are the food source). Likewise, space absent of vegetation also represents habitats. The presence or absence, distribution or abundance of plant species effects the distribution and abundance of animals, including humans, and collectively these species (plants and animals) reflect the quality of terrestrial habitats along the Colorado River ecosystem (see Diagram 1).

Plant communities and the space occupied or utilized by their associated animal species constitute resources that provide recreational and intrinsic benefit, are of cultural value to tribes (e.g., some plants, yellow birds, or eagles) or other entities, or are indicators of change and health of the

system (invasive exotic plant or high abundances of particular animal species like harvester ants or mice). The abundance and distribution of these resources are influenced by available habitat and inter-specific interactions. Elements addressed in this monitoring program are habitat structure and composition and distribution of plants as they relate primarily to bird abundance and distribution and to the river corridor itself within the zone affected by dam operations. Other aspects addressed include linkages to distribution, abundance and composition of birds and vegetation.

Monitoring the composition and structure of vegetation, and the abundance and distribution of plants and animals within the terrestrial zones (NHWZ and OHWZ): (1) allows managers to assess the status of terrestrial faunal diversity in association with biological, cultural and recreational resources; (2) provides data that allows identification and interpretation of linkages between physical and biological variables within the Colorado River ecosystem; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on higher trophic levels associated with terrestrial habitats.

-Integration: The primary goal of this project is to document significant changes in the abundance and distribution of terrestrial animals including waterfowl, nesting avifauna, raptors, and other culturally important birds and coordinate these with information on the vegetation communities. Other animals that are sampled are identified as links to these resources and will aid in discriminating between natural variation and the effects of operations on these resources. Other parameters that are collected under separately funded projects and that can be incorporated into analysis and interpretation of terrestrial ecosystem monitoring include discharge, camping beach area and fine sediment monitoring.

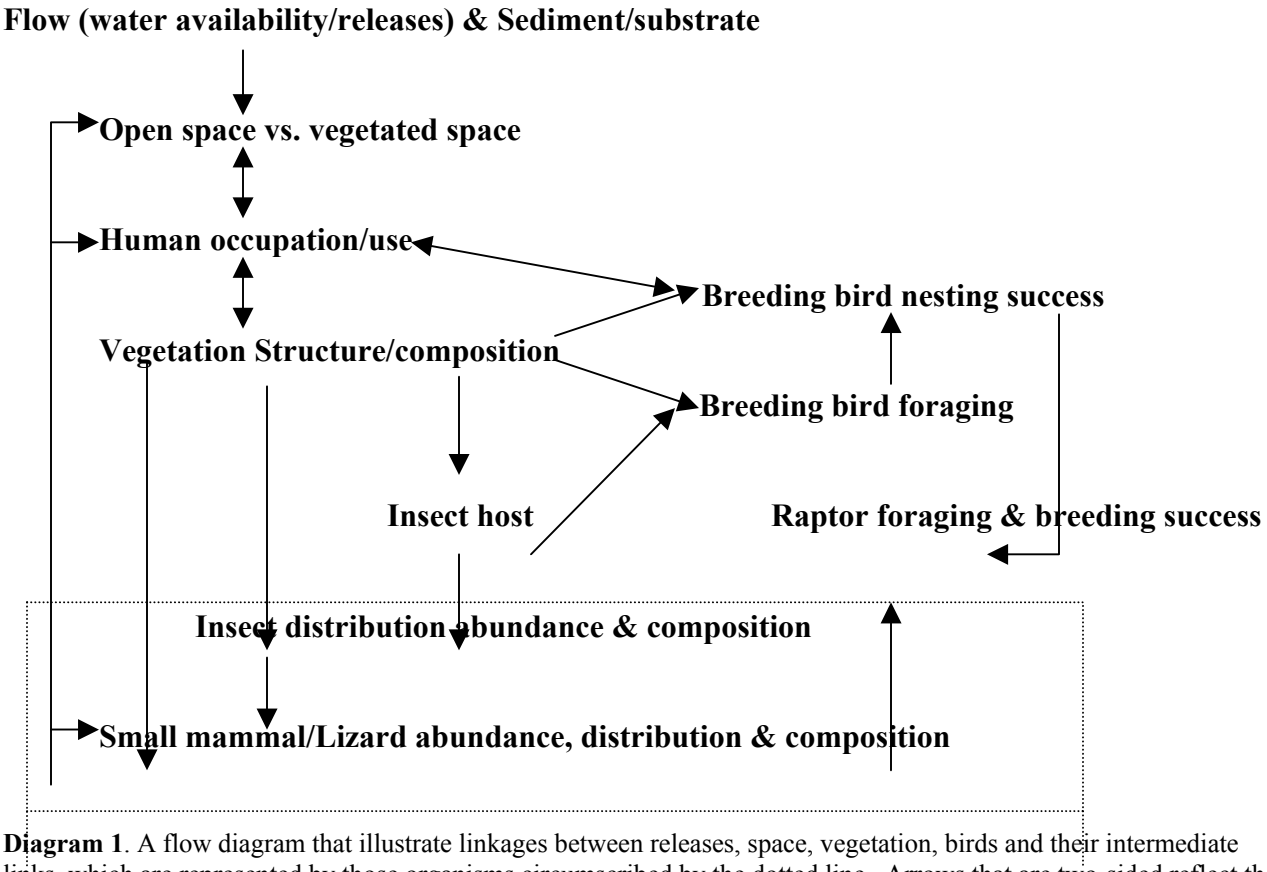

Diagram 1. A flow diagram that illustrate linkages between releases, space, vegetation, birds and their intermediate links, which are represented by those organisms circumscribed by the dotted line. Arrows that are two-sided reflect the reciprocal effects or feedback loop associated with those resources (e.g., human use can create disturbance that promotes weedy plant species and change foodbase composition (decline in some insects but an increase in seed production and an increase in small mammal populations) that can feedback to human occupation/use).

-**Protocol Evaluation Panel:** The biological PEP (Urqhuart et al., 2000), recommended that terrestrial resources, i.e., flora, fauna and physical habitat) be sampled in an integrated fashion. This recommendation was echoed by the physical and cultural PEPs, as well as the NRC (1999). In addition, the biological PEP recommended that vegetation sampling sites be expanded and that additional elements (i.e., insects, lizards, small mammals) be sampled at the same time. The recommendation for expanding vegetation sampling comes from the viewpoint that the 11 sites historically monitored do not reflect change along the channel margin, a similar recommendation associated with sediment came from the physical review panel. The inclusion of other elements to be sampled, like insects and small mammals, was recommended because single species monitoring (e.g., on SWWF, or species of concern) may fail to determine the variable that is affecting a change in a resource. For example, it may be that ROD flows reduce shoreline insects by destabilizing their

habitat. These species may be a food source for riparian birds as well as native fish. By counting only birds or fish and seeing a decline or an increase in these species one cannot attribute that change to either natural variation or to operations. Additionally, these other links can also serve as a metric for the level of impact a camping site may experience: increased abundances of mice or harvester ants (pogo ant) at a site may be an indication of a degraded, highly disturbed camp which feeds into recreational interests and human health issues. Multi-species monitoring is also supported by the conceptual model for the CRE (Walters and Korman, 2000). The model is based on trophic cascades and linkages and recognizes that linkages are not unidirectional, but have interactions within trophic levels and between trophic levels.

-MO's and IN's to be Addressed: The terrestrial ecosystem monitoring project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, evaluate and report structural and compositional changes in terrestrial vegetation zones (old and new high water zones) that support avifaunal and traditional cultural resources. These vegetation data will be related to changes in cultural, recreational and biological resources relative to annual operations of Glen Canyon Dam and fine-sediment monitoring data. Specific monitoring objectives of the project include change detection:

- Related to species abundance and distribution for waterfowl, breeding birds, nesting avifauna, raptors, other culturally important birds and associated fauna (insects, lizards, small mammals).
- Related to food availability and abundance and distribution.
- Related to encroachment of vegetation to campable area.
- Related to advancement of exotic plant species that diminish habitat quality.
- Related to species abundance of utilized cultural resources.
- Related to composition and structure of vegetation associated with nesting birds.
- Related to fine grain sediment deposition and erosion.

Expected Products: Annual delivery of data on changes in species abundance and distribution that result from interactions between available habitat and dam operations. Report delivery about the status of species abundance, distribution and compositional change. Data delivery and exchange for

integration with campsite monitoring regarding expansion of useable avifaunal habitat and reduced campable beach habitat.

Recommended Approach/Methods:

Sampling: The Biological PEP recommended expanding terrestrial flora and fauna surveys and to initiate monitoring utilizing randomly selected sampling sites based on a complete georeferenced map of the river corridor, requiring a two to three year effort (Urqhuart et al., 2000). We have proposed a mapping project that will result in a georeferenced map of the river corridor at the same time that we take a phased approach to the expanded and integrated monitoring recommended by the PEP.

Sample sites: A georeferenced map provides the ability to randomly select sampling sites and to determine variables that predict "good," "marginal" and "poor" habitat. Such a map would also allow the development of predictive responses and as a means of validating the conceptual model of how the CRE functions. Sampling for abundance and distribution of organisms will be coordinated so the data that is collected is representative of the overall river corridor and not of particular sites. This program will utilize randomly selected sampling sits, although some sites will be fixed by their nature (e.g., TCP). The initial sampling sites will be selected from historic bird survey sites (110 total sites are available). Each year 64 sites will be visited. The sites visited in FY2002 will overlap with but not be the same sites visited in FY2001 or FY2003. Vegetation structure measurements will be linked to bird sites, therefore the sites visited for vegetation structure and composition in FY2002 will similarly overlap with but not be the same as those sampled in FY2001 or FY2003. The sites sampled for vegetation structure will also represent an increase of at least 53 sampling areas beyond the existing 11 vegetation mapping/monitoring sites (Kearsley and Ayers, 1999). Sites where linkage data are collected will be fewer in number (16 sites) due to logistics, and will exhibit a similar year-to-year rotational approach as described above.

The sites to be sampled will be identified in a manner that can be incorporated into a georeferenced relational mapping effort. These sample sites will have GPS coordinates established when possible (depending on satellite availability within the canyon) so they can be added to the GIS system and linked to a river corridor map when it is available. By gathering these data (bird, vegetation, foodbase links) collectively and examining trends of bird abundance and composition

through time, for example, and within a GIS environment, we begin to fit together pieces that identify preferred habitat and better understand the implications (i.e., risk assessment) of management actions.

Sampling: Faunal monitoring data will be collected using primarily field-based survey measurements that include point-counts, walking surveys and live trapping for small mammals (Spence, et al., 1998, Sogge, et al., 1998, sample book). Surveys will consist of 5 12-18 day trips between the months of January through June and a fall trip in September. Survey sites, which include point-count stations, will occur in designated patches along the river within geomorphic reaches. A minimum of 57 patches will be visited each year below Lees Ferry, with 7 patches being visited above Lees Ferry. This number of samples is sufficient to characterize abundance and distribution of 15 most common bird, including Lucy's warbler (sensitive species elsewhere), blue grosbeaks, and yellow breasted chats (Spence, et al., 1998). Other species will also be counted; however, to expect to monitor birds that occur rarely or are sporadically distributed (i.e., site specific) in addition to corridor-wide surveys is unrealistic given the funding available. The exception to this case is the southwestern willow flycatcher--which is a listed species. In this case supplemental surveys will be conducted to assess breeding success of this bird (currently 1 pair in Grand Canyon). The birds listed above plus others may be considered surrogates or metrics of breeding bird habitat given that they occur in large enough numbers to detect changes in abundance.

Vegetation will be measured in a manner that captures composition and structure of habitats sampled for birds (Mills, et al., 1991). Data regarding annual changes in plant species abundance and distribution will be collected at sites that may be randomized or at designated monitoring sites depending on the resource in question (e.g., a TCP or an exotic perennial that is locally abundant or fixed vs. carex sp. or dogbane that are widespread in their distribution) and may include pre-dam river terraces where appropriate. Methods may include line transects along elevational gradients to the river, or relieve patches that visually estimate % cover and species list for samples. Available habitat associated with vegetation change and campsite areas will be extracted from campsite monitoring data. Structural and compositional habitat data collection will be scheduled to coincide with nesting avifaunal monitoring (April, May). Data collection associated with linkages will be conducted seasonally (e.g., January, April/May, September) and in concert with avifaunal

monitoring. Under contingency plans, additional measurements of vegetated habitat will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

-**Tribal Participation**: Tribal perspectives for terrestrial resources that are significant to the tribes will be included in this monitoring effort. This may be represented by transferring the information to the tribe for interpretation and subsequent reporting, augmenting monitoring methods with tribal monitoring methods and monitors, or by other means. These efforts would be funding at levels in addition to those already designated for this program and administered under a separate contract or agreement.

Schedule: This long-term monitoring was initiated in FY 2001 and will continue annually through at least FY 2003.

Budget:

FUNDING:

AMP	$386,730
TOTAL	$386,730

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**34,530**
	Biological Scientist (.05)	6,090	4,450
	Biologist (.20)	9,150	12,000
	Social Scientist (.10)	8,700	8,900
	Physical Scientist (.02)	1,740	1,780
	Database Manager (.10)		7,400
25.0	Contracts		**261,000**
	Biology	180,000	184,000
	Cultural	75,000	77,000
	Physical		
25.0	Services		**91,200**
	Logistics (6 12-18 day river trips)	32,000	88,200
	Survey		
	GIS (GIS Specialist 5%)		3,000
	TOTAL	**312,680**	**386,730**

PROJECT TITLE AND I.D.: A. 2. MONITORING KANAB AMBERSNAIL AND HABITAT AT VASEYS PARADISE

STATUS: Ongoing.

General Project Description: Data collection and analysis that permits the monitoring of the Kanab ambersnail habitat up to the old high water zone and provides population estimates of the snail within this area.

Rationale/Problem Statement: Kanab ambersnail is a federally listed endangered species occurring in one location in Grand Canyon: Vaseys Paradise. While the taxonomic ranking of this taxon is currently unresolved, it represents a taxon that is endemic to Vaseys paradise. The snail and its habitat is a unique ecosystem determined to be of concern by stakeholders. The site is also a traditional cultural resource to all Native American stakeholders. The abundance and distribution of the snail and the quality of its habitat is influenced by operations of Glen Canyon Dam, as well as by springs located at Vaseys Paradise (Diagram 2). Monitoring of quality, area and distribution occurs on a more detailed scale due to the limited nature of the habitat and surveys for animals are limited to snails. These surveys occur more than once per year. The relationships between operations from Glen Canyon Dam, habitat quality and its use by Kanab ambersnail at Vaseys Paradise are a management concern. Monitoring data on these ecosystem elements provide information on the effectiveness of the primary experimental flow treatment (Secretary's 1996 Record of Decision) relative to stated resource management objectives.

Monitoring of Kanab ambersnail densities, size classes and utilized habitat: (1) allows managers to assess the status of this endangered species; (2) provides data that allows identification and interpretation of linkages between physical and biological variables within the Colorado River ecosystem; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the population dynamics and habitat interactions of this species.

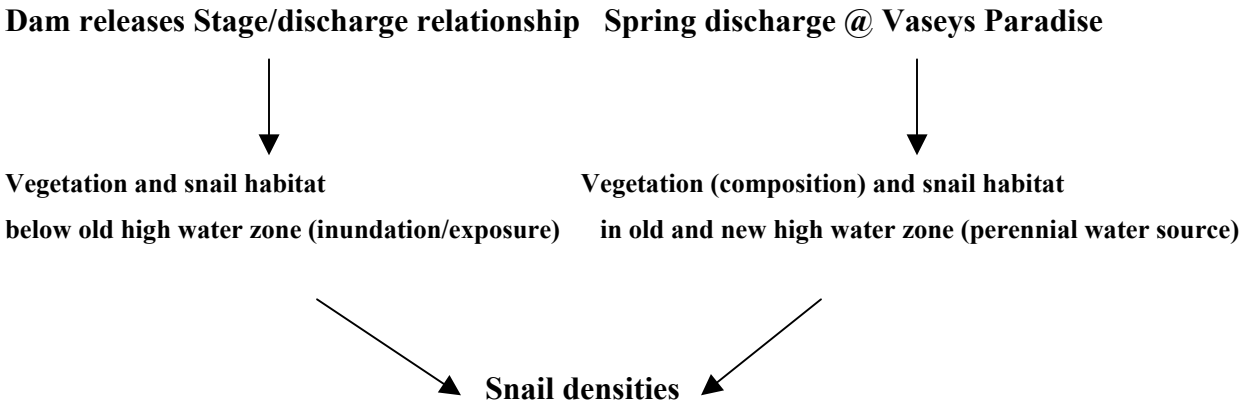

Diagram 2. Illustration of the interactions stage discharge, habitat and snail densities have at Vaseys Paradise. While the dam and the spring are responsible for habitat, stage discharge relationship has the effect of exposing or inundating habitat, while the springs affect moisture gradients at the spring and influence plant composition.

-Integration: Vaseys Paradise is a site that has is a unique physical feature that has biological, cultural and recreational value. In addition, the location is a sensitive cultural resource to Native American stakeholders. The primary goal for this monitoring project is to document significant changes in snail densities and size classes and available habitat at Vaseys Paradise resulting from interactions of dam operations and these variables.

-MO's and IN's to be Addressed: The Kanab ambersnail monitoring project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually and seasonally measure, evaluate and report on habitat quality and distribution and the density and size class changes in Kanab ambersnail. These data will be related to available habitat changes relative to annual operations of Glen Canyon Dam and life history requirement of the species of concern. Specific monitoring objectives of the project include change detection:

- Related to species abundance and distribution for Kanab ambersnail.
- Related to densities and size class distribution to available habitat.

Expected Products: Annual delivery of data on changes in species abundance and distribution that result from interactions between available habitat and dam operations. Report delivery about the status of species abundance, distribution and compositional changes associated with habitat.

Recommended Approach/Methods: Kanab ambersnail monitoring data will be collected using primarily field-based survey methods for snail densities and available habitat. Habitat will be measured when possible using remotely sensed methods to minimize impact to the site. Available habitat values are used for biological opinion consultation associated with special high releases (e.g., BHBF). Estimates for snail densities in inaccessible areas may be based on estimates of snail densities sampled in similar habitat that is accessible. Data regarding annual changes in species abundance and distribution will be collected and may include pre-dam river vegetated habitat. Collection of available habitat and snail density will be conducted in the spring and fall to assess overwintering survival and subsequent recruitment. These trips will be coordinated with population translocation site surveys located downstream. Project consultation will be conducted with Native American stakeholders. Under contingency plans, additional measurements of habitat will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring will be initiated in FY 2001 and continued annually through at least FY 2005 through contract and (or) cooperative agreements.

Budget:

FUNDING:

AMP	$80,650
TOTAL	$80,650

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**15,750**
	Biological Scientist (.05)	4,350	4,450
	Biologist (.10)	9,150	6,000
	Biology Assistant (.05)	900	850
	Social Scientist (.05)		4,450
25.0	Contracts		**10,000**
	Biology	10,000	10,000
	Cultural		
	Physical		
25.0	Services		**54,900**
	Logistics (2 10-15 day river trips)		39,200
	Survey		15,700
	Surveyor (.05)	4,150	4,300
	Surveying Technician (.20)	11,400	11,400
	GIS		
	TOTAL	**39,950**	**80,650**

PROJECT TITLE AND I.D.: A.3. NEW RESEARCH IN TERRESTRIAL ECOSYSTEMS

STATUS: New for FY2002

General Project Description: Funds for trophic interactive work and biological PEP activities in the amount of $93,000 will be available for new research in FY2002. Selection of a specific project will be done in consultation with the TWG in the spring of 2001. Potential uses of these funds include:

- Population model for Kanab ambersnail that examines operational scenarios and predicts outcomes.
- Used to augment mapping project if appropriated funds are not fully provided.

- Used to develop a leopard frog monitoring program that can be incorporated into KAS monitoring or general terrestrial monitoring.
- Used to determine the impacts of scientific study on the recreational experience.

Budget:

FUNDING:

AMP	$93,000
TOTAL	$93,000

OBJECT CLASS	DESCRIPTION	FY-2002	
11.0	Salary (includes benefits)		
25.0	Contracts		**93,000**
	Biology (from Trophic Research & PEP)	93,000	
	Cultural		
	Physical		
25.0	Services		
	Logistics		
	Survey		
	GIS		
	TOTAL	**93,000**	**93,000**

PROJECT TITLE AND ID: A.4 CULTURAL DATA BASE PLAN

Status: New for FY 2002

General Project Description: This project is a continuation of database planning efforts initiated by the BOR in FY 2001. The overall objective of this project is to consolidate cultural data for utilization by the AMP.

Rationale/Problem Statement: Cultural resource data currently exists in a number of locations, including federal agency and tribal databases. Consolidation of data will assist the AMP assessment efforts.

Initial efforts in FY 2001 under Reclamation's efforts include identification of existing and available data within the NPS units and within the tribal groups. Assessment of the type and extent

of data and existing data structures and systems will also be made. Issues of data sensitivity and appropriate dissemination will also be addressed.

MOs and INs To Be Addressed: This project addresses cultural resource management objectives and information needs (MO4, IN4.1) and implements recommendations by the cultural PEP.

PEP Recommendations: This project implements the recommendations of the Cultural Resource PEP to formulate a database plan to consolidate cultural data.

The project contributes to a portion of the overall Historic Preservation Plan suite of documents.

Integration: To achieve an ecosystem-level of understanding of the relationships between resources of the CRE and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. This project will provide a means to consolidate the cultural resource data to assist in an ecosystem assessment of the resources.

Project Goals and Objectives: As recommended by the Cultural Resource PEP, this project will provide a plan and structure to consolidate cultural resource data that is currently held in various locations. The plan will also provide a methodology for the appropriate transfer of data**.**

Expected Products/Deliverables: The project deliverables are a database plan for the continued consolidation of existing and new data for the AMP and public dissemination of information, as appropriate.

Recommended Approach/Methods: Efforts in FY 2002 will include, but are not limited to, formulating the appropriate data structure, given the existing types of available data and data structures, address data links with NPS and tribal locations, data compatibility with existing databases and GCMRC data bases, and data security. Development of the database plan will require close coordination and interface with all cultural resource entities.

Schedule: The project duration is anticipated to be one year.

Budget:

FUNDING:

AMP	$42,050
TOTAL	$42,050

OBJECT CLASS	DESCRIPTION	FY-2002	
11.0	Salary (includes benefits)		**17,050**
	Social Scientist (.15)	13,350	
	Computer Specialist (DBMS) (.05)	3,700	
21.0	Travel		
25.0	Contracts		**25,000**
	Biology		
	Cultural	25,000	
	Physical		
25.0	Services		**0**
	Logistics		
	Survey		
	GIS		
	TOTAL	**42,050**	**42,050**

PROJECT TITLE AND ID: A.5. CULTURAL MONITORING PLAN

Status: New for FY 2002

General Project Description: A long-term monitoring plan for cultural resources within the Colorado River Ecosystem (CRE), including resources addressed by Reclamation's Programmatic Agreement program, the GCMRC cultural resources and the tribal groups.

Rationale/Problem Statement: There are currently several monitoring efforts that are conducted within the CRE. This plan will provide direction for coordinated long- term monitoring efforts of the NPS, GCMRC, Reclamation and the tribes. The plan will directly link to the research design that will be prepared to address research and monitoring questions and resources.

MOs and INs To Be Addressed: This project addresses cultural resource management objectives and information needs (MO1, IN1.1).

PEP Recommendations: This project implements the recommendations of the Cultural Resource PEP to formulate a monitoring plan to coordinate monitoring efforts of several parties that conduct monitoring within the CRE. The project forms a portion of the overall Historic Preservation Plan suite of documents.

Integration: To achieve an ecosystem-level understanding of the relationships between resources of the CRE and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. This project will provide a means to consolidate the cultural resource monitoring to assist in an ecosystem assessment of the resources.

Project Goals and Objectives: As recommended by the Cultural Resource PEP, this project will provide a plan to consolidate agency, program, and tribal monitoring efforts to interpret and assess cultural resources. The objective of this project is to develop a long-term monitoring plan for the BOR's cultural program and provide long-term monitoring guidance to the GCMRC cultural effort. The project plan will provide greater coordination and efficiency between program monitoring activities and ensure that there are no duplication of efforts. The monitoring plan will be prepared after the completion of the research design (in FY 2001) and the plan will provide a mechanism for focusing field activities.

Expected Products/Deliverables: The project deliverables are a monitoring plan for the coordination and integration of existing and future monitoring activities.

Recommended Approach/Methods: The development of the monitoring plan will require consultation with NPS, Reclamation, tribal groups and GCMRC to formulate a strategy for coordinated monitoring that is responsible to the Historic Preservation Plan.

Schedule: The project duration is anticipated to be one year.

Budget:

FUNDING:

AMP	$40,130
TOTAL	$40,130

OBJECT CLASS	DESCRIPTION	FY-2002	
11.0	Salary (includes benefits)		**15,130**
	Social Scientist (.15)	13,350	
	Research Information Analyst (.02)	1,780	
25.0	Contracts		**25,000**
	Biology		
	Cultural	25,000	
	Physical		
25.0	Services		**0**
	Logistics		
	Survey		
	GIS		
	TOTAL	**40,130**	**40,130**

PROJECT TITLE AND ID: A.6 TERRESTRIAL HABITAT MAP AND INVENTORY

Status: New for FY2002

General Project Description: Data collection and analysis that permits the development of a geo-referenced, GIS based map of the terrestrial environment including physical (geomorphic at least Holocene deposits) and biological coverages (vegetation communities within the old and new high water zone).

Rationale/Problem Statement: Terrestrial mapping of 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. Attributes associated with a coverage type can also be used as a predictive tool for monitoring and research.

Mapping requires a combination of field surveys and remotely-sensed data (photogrammetry, LIDAR). Field surveys yield a very high precision DTM with a contour resolution of 25 to 50 centimeters (cm). The accuracy is dependent on the geodetic control available. Photogrammetry data, as in our current GIS sites, are sub-meter precision and are displayed at one half-meter contour. 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. Coverages that identify vegetation communities and Holocene terrace deposits would be layers applied to the topographic base map.

We currently have sub-meter accuracy terrestrial topographic coverage of approximately 80 miles of the CRE in 17 areas of concentrated scientific effort that we refer to as GIS sites. In some of these areas, geomorphic base maps have been made (Hereford 1993; Hereford et al., 1993, 1995, 1996). Coverages for vegetation communities have not been inventoried in a system-wide sense (within all GIS sites) since 1992 (Waring, 1993). In the absence of a system-wide topographic map being available, an updated coverage of the vegetation communities within the existing geo-reference sites would provide information about the total area of vegetation within these GIS sites and can form the basis for expansion throughout the canyon as the system-wide topographic base map is developed.

Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the CRE and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The inventory and mapping of system-wide geomorphic features and substrates and vegetation communities provides information about changes in open and vegetated areas (camping beaches) and changes in the old and new high water vegetative communities as a whole (e.g., how have marsh community areas changed since 1992?). The primary goal for this project is to document geomorphology, including Holocene deposits, and compositional changes in the vegetated terrestrial habitat at an 80 mile coverage, at least, to complement field based surveys that occur at a fine scale.

MO's and IN's to be Addressed: Several MOs and INs are addressed by this project. The include MO 11, IN 11.5 (terrestrial); MO 1, IN 1.1 (cultural); MO 1, IN 1.5 (sediment); and MO2, IN 2.2 (recreation). These are shown in Table 2.1.

PEP Recommendations: This project addresses recommendations made by the terrestrial, cultural resource, and sediment protocol review reports.

Project Goals and Objectives: To measure, record and map terrestrial habitat throughout the river ecosystem, including the various geomorphic features and substrates, and vegetation communities. These data will be related to available habitat relative to annual operations of Glen Canyon Dam and compared with change since 1992. Specific objectives of the project include:

- Mapping of vegetation communities, area covered and distribution in old and new high water zones.
- Mapping of the Holocene terrace deposits within the canyon to geomorphically define the area potentially affected by dam operations relative to sediment deposits, cultural, and recreational resources.

- Provide a focal area for the investigation of geomorphic processes and linkages with dam operations and the archaeological remains.

Expected Products: Delivery of map data including geomorphic and terrestrial coverages. The terrestrial map coverage will provide information on changes in community composition, area and distribution that result from interactions between available habitat and dam operations. The vegetation data will be compared to 1992-year data to detect and study changes.

Recommended Approach/Methods: The overall mapping effort will use photo interpretation and ground-truth methodologies. The vegetation community designation will use methods that conform to national vegetation mapping standards. Finer scale community delineation may occur for some community associations. Digital overflight data (CIR) will be provided by GCMRC for the vegetation mapping project. Those areas that are currently within GIS sites will be mapped. If additional areas become spatially rectified these will be added, pending budgetary constraints.

In the area of geomorphology, this project will provide a companion effort to a BOR workshop to be held in FY 2001. That workshop will define available and existing information and resources to accomplish geomorphic mapping. It is anticipated that much of the necessary information to complete this project may exist or has been previously collected. Existing sources of information may include previously mapped areas, remotely sensed data, and modeled information and the underlying data sources.

Schedule: This project will be initiated in FY 2002 and will be a two-year effort. This project may be amended in scale of effort and duration based on the outcome of the BOR FY 2001 scoping workshop. In the area pertaining to cultural resources, the project may also be revised based on the recommendations of a cultural resource research design that addresses numerous issues, including geomorphic research issues, that will be completed prior to the initiation of the proposed project.

Budget:

FUNDING:

AMP	$157,100
Appropriations	$200,000
TOTAL	$357,100

OBJECT CLASS	DESCRIPTION	FY-2002
11.0	Salary (includes benefits)	**11,900**
	Biologist (.05)	3,000
	Social Scientist (.05)	4,450
	Physical Scientist (.05)	4,450
25.0	Contracts	**300,000**
	Biology	
	Cultural	100,000
	Physical	
	Other	200,000
25.0	Services	**45,200**
	Logistics (2 10-15 day river trips)	39,200
	Survey	
	GIS (GIS Specialist .10)	6,000
	TOTAL	**357,100**

B. AQUATIC ECOSYSTEM ACTIVITIES

PROJECT TITLE AND I.D.: **B.1. MONITORING AQUATIC FOODBASE AND EVALUATING ITS QUALITY FOR UTILIZATION**

STATUS: Implemented in FY 2002. May be revised based on PEP recommendations.

General Project Description: The collection of data that monitors the influences of Glen Canyon Dam operations on the productivity and quality of the aquatic foodbase (phyto-benthic community) in the CRE as it relates to higher trophic level needs.

Rationale/Problem Statement: The aquatic foodbase refers to the phyto-benthic community (algae, macrophytes and invertebrates) that are utilized by consumers such as fish, birds. Like the vegetative communities on the terrestrial side of the fence, the algae and macrophytes either form habitat that is utilized by invertebrates and vertebrates, or provide a source of food to consumers. The composition, density and structure of the foodbase are affected by operations (volume, water quality of discharge), colonizing substrate (sand or cobble) as well as top down effects (overpopulation, overgrazing). Its condition is the basis for the status of higher-level species such as trout and waterfowl, and native fish (see Diagram 3). The occupation and use of these habitats or resources by all organisms is dependent on their quality, distribution and availability. The relationships between operations from Glen Canyon Dam, natural fine and coarse-sediment inputs that form substrate for aquatic habitats and their colonization and use along the Colorado River ecosystem resources are a management concern. Monitoring data on these ecosystem elements provide information on the effectiveness of the primary experimental flow treatment (Secretary's 1996 Record of Decision) relative to stated resource management objectives.

Monitoring of phyto-benthic communities and evaluating their quality for utilization: (1) allows managers to assess the status of this community throughout the Colorado River ecosystem; (2) provides data that allows identification and interpretation of linkages between physical and biotic variables; (3) provides data on the effect of periodic management of sediment

through high flows under the Record of Decision on the phyto-benthic community and higher trophic levels.

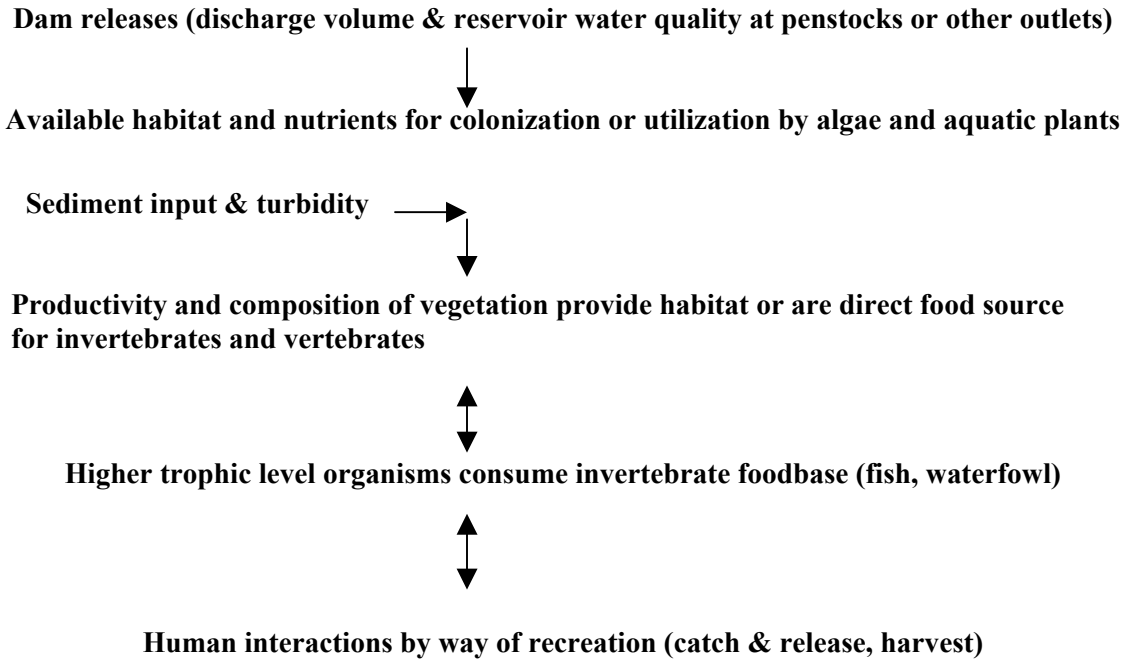

Diagram 3. Illustration of the links between operations, water quality, available aquatic habitat, productivity and consumption by higher level organisms. There are both bottom-up (sediment and water) and top-down (harvesting, population densities) interactions that affect this resource.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal is to document significant changes in the composition, structure and volume/density of the phyto-benthic community within the main channel resulting from interactions of dam operations, changes in sediment supply (substrate) within the context of the Colorado River's geomorphic framework that may affect higher trophic level organisms.

-MO's and IN's to be Addressed: The aquatic foodbase monitoring and evaluation project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, evaluate and report compositional and volume/density changes in the phyto-benthic community that supports the aquatic resources including native and sport fish, avifauna and cultural and recreational interests. These phyto-benthic data will be related to changes relative to annual operations of Glen Canyon Dam and coarse and fine-sediment monitoring data, downstream of the dam. Specific monitoring objectives of the project include change detection:

- Related to sediment inputs and available habitat vs. habitat colonized and utilized by the phyto-benthic community.
- Related to composition and structure of aquatic plant community to benthic colonizers.
- Related to water quality associated with reservoir and dam operations.

Expected Products: Annual delivery of data on changes in species abundance of aquatic plants and invertebrates that are important to the structure of the aquatic community that result from interactions between sediment supply and dam operations. Annual preliminary report(s) on community structure and compositional changes and data delivery and exchange for integration with avifaunal and coarse and fine sediment and water quality monitoring.

Recommended Approach/Methods: The methods for monitoring the phyto-benthic community will undergo protocol review (PEP) in March of 2001. The review will include the downstream fish monitoring program and elements of the water quality program. The panel will participate in a downstream river trip along with PI's to see first hand logistic constraints of the system. Included in the PEP will be discussion of existing sites, sampling methodology visitation of tributary mouths and integration of sampling with fishery monitoring. The results of that panel review will help determine the methods and approaches for long-term monitoring of this resource.

One element that will likely be incorporated is developing a tighter link between sampling of the aquatic vegetation and invertebrates and fish. Sampling currently takes place at fixed locations. Future sampling may become randomized. Additionally, the Glen Canyon area--which is currently not included with downstream sampling--will be included into the sampling domain. The intent to effectively measure and characterize changes in available river channel habitat and the benthic communities' composition and structure as prescribed. Structural and compositional data collected may be scheduled to coincide with important seasonal changes or projected changes in operations.

Under contingency plans, additional measurements of the phyto-benthic community will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: While long-term monitoring will not become officially instituted until FY2002, the current phyto-benthic monitoring contains elements that are similar to projected long-term monitoring goals. Integration of current and future monitoring techniques will be initiated in FY 2002 and continued annually through at least FY 2005 through contract and (or) cooperative agreements determined through competitive RFP.

Budget:

FUNDING:

AMP	$312,030
TOTAL	$312,030

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**18,230**
	Biological Scientist (.05)	4,350	4,450
	Biologist (.05)	1,220	3,000
	Biologist (Aquatic) (.05)	3,050	3,000
	Ecologist (.10)	6,100	6,000
	Physical Scientist (.02)	1,740	1,780
25.0	Contracts		**235,000**
	Biology	230,000	235,000
	Cultural		
	Physical		
25.0	Services		**58,800**
	Logistics	10,000	58,800
	Survey		
	GIS		
	TOTAL	**256,460**	**312,030**

PROJECT TITLE AND I.D.: B.2. MONITORING OF THE STATUS AND TRENDS OF DOWNSTREAM FISH COMMUNITY

STATUS: Implemented in FY 2002. Will be revised based on PEP recommendations.

General Project Description: Collection of data that monitors the influences of Glen Canyon Dam operations on the fish community in the Colorado River ecosystem including those native fish found (e.g., Flannelmouth suckers) in the Glen Canyon reach.

Rationale/Problem Statement: The downstream fish community is an assemblage of native and non-native fish that occur in the Colorado River ecosystem. This assemblage is exclusive of the trout fishery that is managed in Glen Canyon by Arizona Game and Fish. The constituents include four native fish and introduced competitors/predators like rainbow trout, brown trout, channel catfish, carp, and striped bass. The status and trends of the fishery are regulated by biotic and abiotic mechanisms that may in turn be affected by the operations of Glen Canyon Dam. Community traits such spawning and recruitment are influenced by the quality of substrate, water, and food. Competitive interactions between fish species also account for species abundance and distribution. The relationships between operations from Glen Canyon Dam, natural fine and coarse-sediment inputs that form substrate for aquatic habitats and their colonization and use by fish along the Colorado River ecosystem resources are a management concern (Diagram 4). Monitoring data on these ecosystem elements provide information on the effectiveness of the primary experimental flow treatment (Secretary's 1996 Record of Decision) relative to stated resource management objectives.

Monitoring of the fish community: (1) allows managers to assess the status of this community throughout the Colorado River ecosystem; (2) provides data that allows identification and interpretation of linkages between physical and biotic variables; (3) provides data on the effect of periodic management of sediment and flow under the Record of Decision on the fish community and the resources on which it depends.

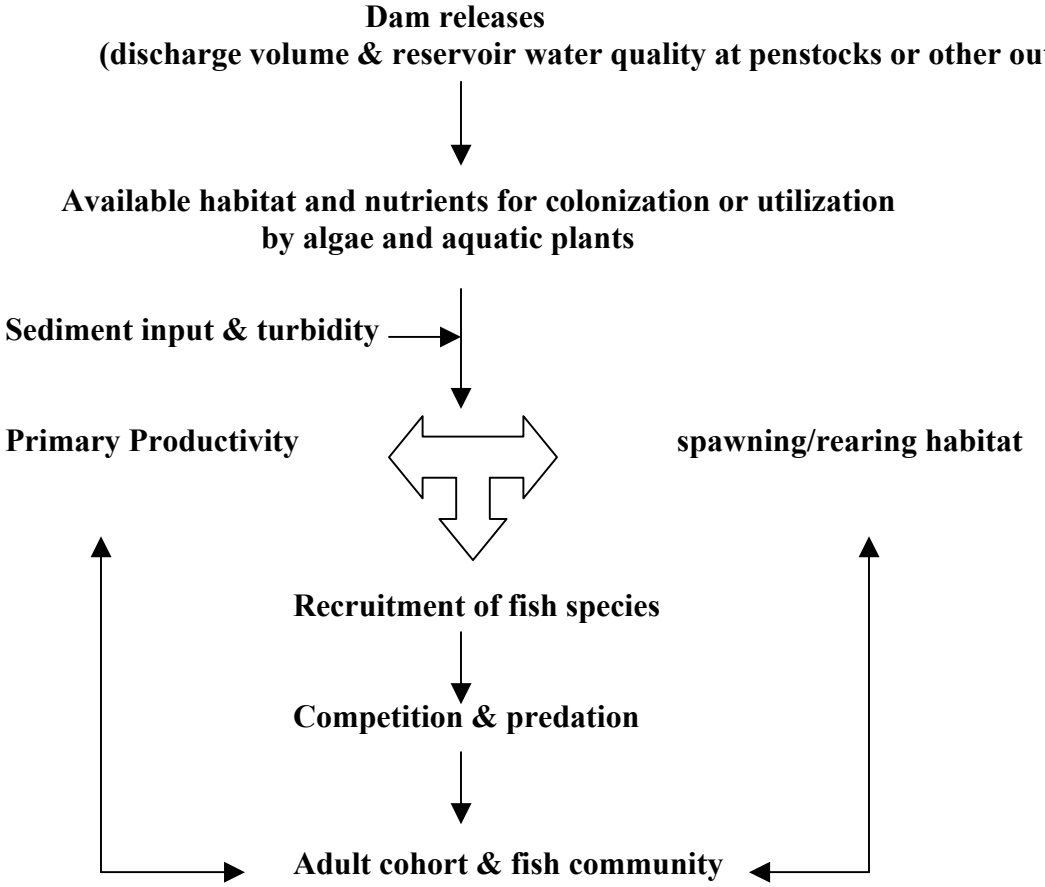

Diagram 4. Illustration of interactions and linkages between discharge, habitat, productivity and the fish community. There are bottom-up effects associated with operations, habitat and productivity and top-down, or fish species interactions that also come into play in this system.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal is to document significant changes in the abundance and distribution of the fish community within the main channel resulting from interactions of dam operations, changes in sediment supply (substrate), fish community and the phyto-benthic community within the Colorado River ecosystem.

-MO's and IN's to be Addressed: The fish community monitoring and evaluation project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, assess and report abundance and distribution in the fish community. These data will be related to changes relative to annual operations of Glen Canyon Dam, sediment inputs (coarse and fine) monitoring data, and phyto-benthic monitoring data downstream of the dam. Specific monitoring objectives of the project include change detection:

- In community structure related to sediment inputs and available habitat for spawning, survivorship recruitment and foraging.
- Related to distribution and relative abundance of native fish in relation to inter-specific competitive and predation from non-native fish.
- Related to water quality associated with reservoir and dam operations that affect spawning, survivorship and recruitment.

Expected Products: Annual delivery of data on changes in species abundance, distribution and age structure of sampled fish community. Annual preliminary report(s) on community structure and compositional changes and data delivery and exchange for integration with phyto-benthic community monitoring and coarse and fine sediment and water quality monitoring.

Recommended Approach/Methods: Fish community data will be measured using field-based survey measurements to provide population estimates for those fish that exist in sufficient numbers to characterize change in the fish community. This is a similar approach used in terrestrial monitoring for bird (sampling provides estimates of change for the 15 most abundant species of birds). With respect to fish species, those species likely to be estimated are humpback chub, flannelmouth sucker, rainbow trout, brown trout and carp.

Parameters of interest with respect to humpback chub are population estimates in the Little Colorado River (LCR) and spawning success and recruitment in the LCR, and distribution of adults and juveniles in the mainstem. Similar information will be needed for each species and will include sampling flannelmouth sucker spawning sites in Glen Canyon and at the Paria River mouth. Data collected (shocking effort) in Glen Canyon for the trout system will be incorporated into downstream monitoring. And the shocking effort in Glen Canyon will help in the calibration of this gear-type downstream. If additional gear types need to be deployed in the Glen Canyon reach for

flannelmouth sucker, it will be this project that will be responsible for deployment and data collection.

Community change data associated with food or habitat resources will be extracted from phyto-benthic and sediment monitoring data. Field data associated with the fish community will be scheduled to coincide with important life history stages (e.g., spawning/overwinter survival, fall recruitment). Under contingency plans, additional measurements of the fish community will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: While long-term monitoring will not become officially instituted until FY2002, the current fish community monitoring contains elements that are similar to projected long-term monitoring goals. Integration of current and future monitoring techniques will be initiated in FY 2002 and continued annually through at least FY 2005 through contract and (or) cooperative agreements. The RFP will be released in summer of 2001.

Budget:

FUNDING:

AMP	$672,830
Appropriations	$200,000
TOTAL	$872,830

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
AMP Funding			
11.0	Salary (includes benefits)		**27,630**
	Biological Scientist (.05)	4,350	4,450
	Biologist (Aquatic) (.10)	6,100	6,000
	Biologist (.05)	1,220	3,000
	Ecologist (.15)	9,150	9,000
	Biology Assistant (.20)	3,600	3,400
	Physical Scientist (.02)	1,740	1,780
25.0	Contracts		**469,000**
	Biology	460,000	469,000
	Cultural		
	Physical		
25.0	Services		**176,200**
	Logistics (2-15 day river trips + trips to tributaries)	90,000	176,200
	Survey		
	GIS		

	TOTAL	576,160	672,830

PROJECT TITLE AND I.D.: B.3. MONITORING OF THE STATUS AND TRENDS OF THE LEES FERRY TROUT FISHERY

STATUS: Ongoing from FY2001.

General Project Description: Monitoring the influences of Glen Canyon Dam operations on the Lees Ferry trout fishery in the Colorado River ecosystem.

Rationale/Problem Statement: The Lees Ferry trout fishery refers to the tailwaters portion of the Colorado River ecosystem managed by Arizona Game and Fish Department. This fishery represents an important recreational and economic resource. This assemblage includes flannelmouth suckers and competitors such as carp and catfish. The status and trends of the fishery is linked to the phyto-benthic community and to operations of Glen Canyon Dam. Community traits such as spawning and recruitment are influenced by the quality of substrate, water, and food. Competitive interactions between trout and other fish species and among trout also account for population status. The relationships between operations from Glen Canyon Dam, natural fine and coarse-sediment inputs that form substrate for aquatic habitats and their colonization and use by trout in the Glen Canyon portion of the Colorado River ecosystem resources are a management concern (Diagram 4). Monitoring data on these ecosystem elements provide information on the effectiveness of the primary experimental flow treatment (Secretary's 1996 Record of Decision) relative to stated resource management objectives.

Monitoring of the rainbow trout population: (1) allows managers to assess the status of this population in Glen Canyon; (2) provides data that allows identification and interpretation of linkages between physical and biotic variables; (3) provides data on the effect of periodic management of sediment and flows under the Record of Decision on the trout population in Glen Canyon and the resources it depends on including the phyto-benthic community.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term

monitoring between physical, cultural, biological, and recreational resources is required. The primary goal is to document significant changes in the abundance, age structure and condition of the trout population in Glen Canyon resulting from interactions to dam operations, changes in sediment supply (substrate), and the phyto-benthic community within the Colorado River ecosystem. These data are used to augment downstream fish community monitoring.

-MO's and IN's to be Addressed: The trout population monitoring and evaluation project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To annually measure, assess and report on abundance, age structure and condition of the rainbow trout population in Glen Canyon. These data will be related to changes relative to annual operations of Glen Canyon Dam, sediment inputs (coarse and fine) monitoring data, and phyto-benthic monitoring data downstream of the dam. Specific monitoring objectives of the project include change detection:

- In community structure related to sediment inputs and available habitat for spawning, recruitment and foraging.
- Related to condition factor of trout population.
- Related to water quality associated with reservoir and dam operations (e.g., nutrients, temperature) that affect spawning and recruitment.

Expected Products: Annual delivery of data on changes in species abundance, age-class structure and condition of sampled trout population. Annual preliminary report(s) on community structure and compositional changes and data delivery and exchange for integration with phyto-benthic community monitoring and coarse and fine sediment and water quality monitoring. Annual fact sheet and delivery of graphics and summary for SCORE report.

Recommended Approach/Methods: The trout population data will be collected using a field-based survey method that characterize changes in the trout fishery in Glen Canyon (see Lees Ferry Protocol document: www.gcmrc.gov). Annual changes in trout size class distribution, recruitment and condition will be measured at monitoring sites. Populations change data associated with food or habitat resources will be extracted from phyto-benthic and sediment monitoring data. Field data associated with the trout population will be scheduled to coincide with important life history stages

(e.g., winter spawning, summer recruitment). Under contingency plans, additional measurements of the trout population will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: Long-term monitoring will be initiated in FY 2001 and continued annually through at least FY 2005 through contract and (or) cooperative agreements.

Budget:

FUNDING:

AMP	$137,830
TOTAL	$137,830

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002	
11.0	Salary (includes benefits)			**18,230**
	Biological Scientist (.05)	4,350	4,450	
	Biologist (Aquatic) (.05)	3,050	3,000	
	Biologist (.05)	1,220	3,000	
	Ecologist (.10)	6,100	6,000	
	Physical Scientist (.02)	1,740	1,780	
25.0	Contracts			**90,000**
	Biology	120,000	90,000	
	Cultural			
	Physical			
25.0	Services			**19,600**
	Logistics (2-3 3-day river trips)	10,000	19,600	
	Survey			
	GIS			
26.0	Supplies		10,000	**10,000**
	TOTAL	**146,460**		**137,830**

PROJECT TITLE AND I.D.: B.4. ONGOING RESEARCH ASSOCIATED WITH POPULATION GENETICS OF HUMPBACK CHUB IN COLORADO RIVER ECOSYSTEM

STATUS: Ongoing.

General Project Description: Patterns of genetic diversity within and between Humpback chub aggregations.

Rationale/Problem Statement: Humpback chub is a federally listed endangered fish species that occurs in Grand Canyon. Plans are either in place or are being developed to address elements of the Biological Opinion. The status of this species and other native fish species is a management concern. These plans center on providing mainstem habitat that permits spawning and recruitment. Determining the relationship of chub aggregates found in the mainstem and in the Little Colorado River will help in the evaluation and success of these management strategies.

Determining the genetic diversity of humpback chub aggregates: (1) allows managers to predict the effects of managed flows or selective withdrawal on recruitment by this species; (2) provides data that allows fish and wildlife personnel to recommend alternative management strategies or actions that will assist the species.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring, research and management is required. The primary goal of this project is to document the genetic diversity that exists among humpback chub aggregates that provides managers information regarding the origin of humpback chub in the mainstem and its tributaries.

-MO's and IN's to be Addressed: The humpback chub genetics project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: Understanding the intra-population relationships are integral to management actions associated with endangered fish. To collect sufficient samples to quantify genetic variation that exists within and between humpback chub aggregates found in the Colorado

River ecosystem and provide information on the relationship of mainstem aggregates to those fish found in the Little Colorado River. Information about these relationships will be used to determine the best methods available to assist the species towards recovery.

Expected Products: Delivery of a preliminary and final report on the genetic diversity of humpback chub aggregates in the Colorado River ecosystem. Delivery will be provided in a format and manner that are useful to managers involved with experimental flows research or hatchery programs.

Recommended Approach/Methods: The project will use molecular techniques that sufficiently quantify genetic diversity. Sufficient sample size will also be determined and obtained in order to address the goals of this project. Under contingency plans, no additional measurements will occur.

Schedule: This will be the second of a two year funded project through contract and (or) cooperative agreements.

Budget:

FUNDING:

AMP	$16,050
TOTAL	$16,050

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**12,150**
	Biological Scientist (.05)	4,350	4,450
	Biologist (Aquatic) (.05)	3,050	3,000
	Biologist (.05)	3,050	3,000
	Biology Assistant (.10)	1,800	1,700
25.0	Contracts		
	Biology	50,000	
	Cultural		
	Physical		
25.0	Services		**3,900**
	Logistics (1-2 river trips)	2,000	3,900
	Survey		
	GIS		

	TOTAL	64,250	16,050

PROJECT TITLE AND I.D.: B.5. NEW RESEARCH ASSOCIATED INTERACTIONS BETWEEN NATIVE AND NON-NATIVE FISH SPECIES

STATUS: New.

General Project Description: Examining gut contents of fish to determine the predation rates by non-native fish (rainbow trout, brown trout) on native fish. Using this information to determine if predation is a significant source of mortality for native fishes.

Rationale/Problem Statement: Non-native fish (brown trout, rainbow trout and catfish to name a few), are predators on native fish, and exist in great enough numbers in the mainstem to potentially pose a problem to native fish recruitment. Several proposed management strategies to increase native fish recruitment (temperature control device, experimental flows for fish) may also benefit non-native fish recruitment and increase predation pressure on native fish. The habitats that young native fish are found in are well documented. However, how the predation rates change on young fish as these variables change is not well known. Determining predation rates associated with variables like turbidity, temperature and velocities will help identify mainstem habitats or conditions that merit monitoring and possibly mitigation during flows designed to help native fish species recruitment. However, predation rates and susceptibility of young fish to these variables are not well known.

Collecting and analyzing data about fish species predation rates: (1) allows managers to assess the effects of dam operations aimed at supporting native fish on young fish and predators; (2) provides data that allows identification of potential threats to a resource that can be monitored, and mitigated for, during a proposed action.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal of this project is to determine relationships between habitat and fish interactions in the mainstem.

-MO's and IN's to be Addressed: The fish interactions project provides information needs related to management objectives as shown in Table 2.1.

Project Goals and Objectives: To measure, evaluate and report patterns associated with predation rates on native fish and changing habitat variables. Identify variables that have the greatest effect on predation. These data will be related to changes relative to annual operations of Glen Canyon Dam and native fish recruitment.

Expected Products: Delivery of report and data that identifies key habitat variables that affect predation on young native fish. Delivery of data and report on predation rates as variables change.

Recommended Approach/Methods: Analyze fish stomachs that were taken from Rainbow trout and brown trout during the months of June -September in Summer 2000 (steady flows, warmer temperatures) and in the year following (fluctuations). Determine seasonal changes in predation, if it exists and estimate amount of predation for each species studied.

Schedule: This project will be funded for two years.

Budget:

FUNDING:

AMP	$63,450
Appropriations	$125,000
TOTAL	$188,450

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
AMP Funding			
11.0	Salary (includes benefits)		**22,450**
	Biological Scientist (.05)	4350	4,450
	Biologist (Aquatic) (.10)	6100	6,000
	Ecologist (.20)	12200	12,000
25.0	Contracts		**41,000**
	Biology (Contract cost est $40,000 - $90,000)	40000	41,000
	Cultural		
	Physical		
25.0	Services		
	Logistics		
	Survey		
	GIS		
	TOTAL	**62650**	**63,450**

PROJECT TITLE AND I.D.: B.6. INTEGRATED WATER QUALITY MONITORING

STATUS: New. A revised IWQP will be implemented based on the recommendation of the December 2000 IWQP PEP.

General Project Description: The collection of data that monitors the influences of Glen Canyon Dam operations on the water quality in Lake Powell and downstream in the Colorado River ecosystem.

Rationale/Problem Statement: Water quality refers to the physical, chemical and biological characteristics of water. The components effect higher-level community composition, quality and interactions and represent a cornerstone resource upon which all other aquatic and terrestrial resources depend. The water quality parameters are linked to upper basin inflows, reservoir dynamics, and operations of Glen Canyon Dam, and downstream tributary inputs. The relationship between operations of Glen Canyon Dam and water quality variables affecting downstream resources is a management concern. Monitoring data on these ecosystem elements provide information on the effectiveness of the primary experimental flow treatment (Secretary's 1996 Record of Decision) relative to stated resource management objectives.

Monitoring of the water quality parameters: (1) allows managers to assess the effects of dam operations on downstream water quality; (2) provides data that allows identification and interpretation of linkages between physical, chemical and biotic variables; (3) provides data on the effect of periodic management of sediment through high flows under the Record of Decision on the water quality in the reservoir (forebay) and downstream water quality.

-Integration: To achieve ecosystem-level scientific understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. The primary goal of this project is to document significant changes in the physical, chemical and biological constituents associated with water quality that can be linked to other Colorado River ecosystem resources.

-MO's and IN's to be Addressed: The water quality monitoring project provides information needs related to management objectives as shown in Table 2.1 and in greater detail in the Integrated Water Quality Plan (Vernieu and Hueftle, 1999).

Project Goals and Objectives: The goals are to provide further understanding of linkages between dam operations, water quality, and the aquatic ecosystem of the Colorado River. Understanding is achieved by the following objectives measure, evaluate and report patterns of change in water quality parameters in the reservoir, tailwaters and downstream, and to describe changes that differ from expected or historic values associated with the reservoir and downstream water quality. Information associated with water quality will be shared with other monitoring projects like the phyto-benthic and fish community monitoring projects. Specific monitoring objectives of the project include change detection:

- Related to detectable levels of chemical constituents (organic, inorganic) that affect biological processes and associated recreational and cultural resources.
- Related to mainstem temperature that effect biological and subsequently recreational and cultural resources.
- Related to phytoplankton community that affects downstream aquatic resources and related terrestrial resources.

Expected Products: Annual delivery of data associated with biological, chemical and physical constituents of water quality. Annual preliminary report(s) on status and changes in these parameters and the effects of reservoir operations and dam operations on reservoir water quality/dynamics and concomitant downstream effects. Timely data delivery and exchange for integration with phyto-benthic community monitoring and fish community monitoring and parties associated with upper basin water quality (Lake Powell cooperators group).

Recommended Approach/Methods: The monitoring program will undergo protocol review in December 2000. The recommendations from the PEP panel will be used to revise the parameters to be monitored and the methods used in the long-term monitoring program, as appropriate. The data for the water quality monitoring project will be collected using both field and remotely-based survey methods (dataloggers) that characterize changes in water quality at prescribed long-term monitoring

sites in the reservoir and along the Colorado River mainstem and its tributaries (see Vernieu and Hueftle, 1999). Field data associated with water quality will be scheduled to coincide with important seasonal changes associated with reservoir dynamics and that coincide with changes in dam operations. Under contingency plans, additional measurements of the water quality parameters will occur in the event of large-scale flow experiments (e.g., BHBF and SASF, temperature modification).

Schedule: Long-term monitoring is to be instituted in FY2002. Integration of current and future monitoring techniques will be initiated in FY 2002 and continued annually through at least FY 2005 through contract and (or) cooperative agreements, or completed using GCMRC's personnel.

Budget:

FUNDING:

AMP	$180,980
TOTAL	$180,980

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**81,280**
	Biological Scientist (.07)	6,090	6,230
	Biologist (Aquatic) (.05)	3,050	3,000
	Hydrologist (.30)	28,000	29,000
	Hydrologist (Limnologist) (.30)	28,000	29,000
	Hydrologic Technician (.30)	12,000	12,000
	Ecologist (.02)	1,220	1,200
	Biology Assistant (.05)	900	850
25.0	Contracts		**84,000**
	Biology		84,000
	Cultural		
	Physical		
25.0	Services		**15,700**
	Logistics	8,000	15,700
	Survey		
	GIS		
	TOTAL	**87,260**	**180,980**

C. INTEGRATED TERRESTRIAL AND AQUATIC ECOSYSTEM ACTIVITIES

PROJECT TITLE AND I.D.: C.1. LONG-TERM MONITORING OF FINE-GRAINED SEDIMENT STORAGE THROUGHOUT THE MAIN CHANNEL

STATUS: Ongoing. Originally Approved and Implemented in FY 2001.

General Project Description: Fine-grained deposits (sand and finer) of the main channel constitute a major storage component of the Colorado River ecosystem's sediment budget. Glen Canyon Dam operations influence fine deposits in ways that affect aquatic and terrestrial habitats over both short and long periods. The emphasis of this long-term sediment monitoring project shall be to document system-wide changes in fine-grained deposits relative to dam operations and natural inputs, with emphasis on key storage settings within critical reaches. This project was initiated through release of a competitive solicitation process in October 2000, and shall be continued into year two during FY 2002.

Rationale/Problem Statement: Relationships between Glen Canyon Dam operations, fine-sediments input from gaged and ungaged tributaries below the dam, and interrelated downstream biological, socio-cultural resources are of primary management concern. Monitoring data on fine-grained deposits, linkages with physical habitats and relationships to non-physical resources and processes offer insight on the effectiveness of the current experimental flow treatment (Secretary's 1996 Record of Decision) relative to management objectives.

Annual monitoring of fine-grained sediment storage provides data: (1) to managers who need to assess the status of near-shore aquatic and terrestrial habitats where vegetation and associated fauna, socio-cultural resources are of management concern; (2) on the availability of fine-grained sediment that can be periodically manipulated through controlled floods to preserve and sustain downstream resources dependent on fine sediment; (3) that allow identification and interpretation of linkages between dam operations and changes in physical habitats and related ecosystem resources. All three areas of information support science-based evaluations of large-scale

flow experiments (e.g., the Secretary's actions), and associated decision responses required for adaptive management to succeed.

-Integration: Fine-sediment deposits along the main channel form many physical habitats for both terrestrial and aquatic organisms of the ecosystem; including ethno-botanical resources. They are also comprise sources and sinks for nutrients, recreational campsites and settings for in-situ preservation of cultural resources. Information on the distribution and characteristics of these deposits must be measured in ways that can be related to dam operations. Further, the measurements must be made over spatial and temporal scales that allow fine-sediment related resources to be linked to changing conditions of the sediment budget.

-MO's and IN's to be Addressed: This integrated long-term monitoring project shall provide data related to management objectives and information needs as indicated in Table 2.1. Annual surveys of channel-stored fine deposits shall provide information on the condition of both terrestrial and aquatic sand bar morphologies and grain-size characteristics, including return-current channels (backwaters) and riparian plant substrates. In addition, fine-grained terraces that are relicts of the pre-dam system shall be remotely monitored to detect lateral erosion, and any trends will be evaluated relative to historical changes in terraces determined through current synthesis research. A system-wide subset of terrestrial sand bars will also be evaluated for recreational camping suitability at elevations above the 25,000 cfs stage.

Project Goals and Objectives: The *primary goal* is to annually measure, report and evaluate system-wide relative changes in the morphology, volume and grain-size characteristics of fine-sediment deposits in aquatic and terrestrial settings of the main channel. These monitoring data will mostly be comprised of field measurements made using standard hydrographic and surveying methods within designated monitoring reaches. Of particular concern are deposits within the first 240 miles downstream of the dam related to near-shore, terrestrial habitats, and recreational campsites, and areas where cultural resources occur. Habitats influenced by dam operations and fine-sediment storage include: aquatic near-shore habitats important to fish (backwaters and sandy shorelines that support vegetation), channel environments where benthic organisms occur and are affected by fine-sediment flux (cobble bars, debris fans and talus shorelines), terrestrial habitats that support riparian vegetation and associated fauna, terrestrial substrates used by recreational

backcountry visitors, and terrestrial substrates that support and preserve cultural resources (frequently inundated sand bars and up to the tops of pre-dam river terraces).

Secondary goals shall be to relate changes in fine-sediment storage to dam operations, and to the distribution and condition of physical habitats of the aquatic and terrestrial ecosystem related to biological and socio-cultural resources of concern. These physical resource data provide information needed to interpret changes in cultural, recreational and biological resources relative to annual operations of Glen Canyon Dam. Specific monitoring objectives of the project include change detection data:

- For pre-dam river terraces needed to determine the ongoing stability or erosion of these relict fine-sediment deposits of the pre-dam river associated cultural resources (biennial measurements),
- For near-shore aquatic and terrestrial substrates and associated fauna related to biological and cultural resources (annual measurements),
- On grain-size (relative texture) and abundance (relative volume) of fine-sediments available for use in restoring and preserving sediment-dependent resources through periodic flow manipulation (annual measurements),
- Availability and quality of recreational campsites in critical reaches and system-wide (biennial measurements).
- On the system-wide, channel-bed distribution of fine- versus coarse-sediment substrates (annual measurements).

Expected Products: Annual data on main channel topographic and grain-size changes of fine-sediment deposits that result from interactions between sediment supply and dam operations. Also required, shall be a system-wide, GIS-based map of the main channel documenting the distribution of channel-bed substrates, with specific emphasis on fine- versus coarse-sediment and bedrock. Annual interpretive reports based on change-detection data for fine-sediment deposits documenting relationships between the above physical data sets and related Colorado River ecosystem attributes. Emphasis shall be on relationships between fine-sediment distribution and near-shore aquatic and terrestrial habitats where vegetation and associated fauna, recreation and cultural resources are of management and scientific concern.

Expected products from this project include:

- Semi-annual progress reports on status of the monitoring project, and annual reports describing achievement of goals (e.g., time series depicting changes in the volume, area and grain-size distributions of fine-sediment storage, changes in pre-dam terraces related to cultural preservation sites, or changes in recreation camping beach availability above the 708 cms stage),
- Annual GIS data sets related to change detection analyses related to main channel storage of fine sediment that result from tributary events, and interactions with dam operations,
- Annual technical presentations at GCMRC Science Symposia or Technical Workgroup meetings on the project's progress and results,
- Annual color Fact Sheets that summarize long-term monitoring trends in fine-sediment storage through the main channel of the Colorado River ecosystem,
- Participation in conceptual modeling workshops and related planning meetings that are periodically convened by GCMRC program staff and other cooperators.

Recommended Approach/Methods: Fine-grained sediment storage data will be measured throughout monitoring reaches upstream of Phantom Ranch annually using a combination of remote and ground-based topographic survey and sedimentology measurements that characterize changes in grain-size, morphology and storage volume changes in fine-sediment deposits at prescribed long-term monitoring sites. Existing monitoring reaches above and below Phantom Ranch will be surveyed on a annual schedule, with special emphasis on reaches where relations between physical habitat and endangered native fishes are of interest (second population of Humpback chub), or in years when changes in fine-grained sediment storage are influenced by flood flows.

Campsite areas will be included within monitoring reaches as a subset of deposits monitored, and may include a sub-sample of as many as fifty campsites, located within reaches designated as "critical." Campsite assessments shall be conducted annually within critical reaches using existing survey methods to document campable areas at elevations above 25,000 cfs. Campsites outside of critical reaches will be monitored on a biennial schedule. These data shall be related to stages up to at least 45,000 cfs, and possibly higher.

Side-scan sonar surveys may be conducted on a system-wide basis in February or March to map the distribution of fine versus coarse sediment and bedrock channel-bed substrates. However,

the need for these data is still be evaluated as part of the long-term monitoring plan for sediment and ecological resources. If collected on an annual basis, then substrate map data shall be processed in a timely manner that allows wide use of these data by other cooperating scientists during the monitoring period and immediately following the end of the funding cycle.

Under contingency plans, additional measurements of fine-sediment storage, channel-bed substrates and grain-size characteristics shall be conducted using additional fiscal resources in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring program will be continued into its second year in FY 2002, and will be continued annually through at least FY 2005 through an annually renewed group of technical service contract(s) and through one or more cooperative agreement(s). Status of the monitoring program methods, temporal and spatial scale shall be evaluated through a PEP-SEDS approach during years 4-5; with special focus on the level of integration with biological resource management and information needs.

Budget:

FUNDING:

AMP	$492,160
TOTAL	$492,160

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		13,660
	Physical Scientist (.10)	8,700	8,900
	Biological Scientist (.02)	1,740	1,780
	Ecologist (.02)	1,220	1,200
	Social Scientist (.02)	1,740	1,780
25.0	Contracts		348,000
	Biology	30,000	31,000
	Cultural	85,000	87,000
	Physical	225,000	230,000
25.0	Services		130,500
	Logistics (2 16-day river trips)	60,000	117,600
	Survey (Surveyor (.15)	12,450	12,900
	GIS		
	TOTAL	**425,850**	492,160

PROJECT TITLE AND I.D.: C.2. LONG-TERM MONITORING OF STREAMFLOW AND FINE-SEDIMENT TRANSPORT IN THE MAIN CHANNEL COLORADO, PARIA AND LITTLE COLORADO RIVERS

STATUS: Ongoing. Approved and Implemented in FY 2001 through a Sole Source award to the USGS.

General Project Description: This is the core of the long-term monitoring effort for sediment and streamflow resources. The project is intended to document: (1) discharges from Glen Canyon Dam at the existing Glen Canyon streamgage; (2) streamflows and fine-sediment inputs entering the Colorado River ecosystem from the Paria and Little Colorado Rivers at existing streamgages; (3) combined streamflows and fine-sediment transport along the main channel at the existing streamgages at Lees Ferry, upstream of the confluence with the Little Colorado River, Grand Canyon, and Diamond Creek (river miles -14, 0, 61, 87, and 225, respectively); (4) evaluate model-derived estimates of fine-sediment inputs from the Paria and Little Colorado Rivers with sediment-transport field measurements; (5) monitor model-reach characteristics before and after major tributary floods and evaluate channel changes with respect to model variables and modeling assumptions associated with those variables; (6) "event" monitoring of streamflow floods that occur in significant ungaged drainage areas in Glen and Marble Canyons to verify existing estimates for discharge and sediment inputs from ungaged tributaries; (7) quality of water data from the above sites that contribute to water quality information needs, as well as development of a system-wide nutrient budget.

Rationale/Problem Statement: Glen Canyon Dam operations prescribed by the Secretary's Record of Decision and their relationship with downstream resources of management concern are the primary focus of the ongoing adaptive management program. It is therefore necessary that discharges from the dam be measured and reported, as well as additional streamflows and fine-sediment inputs that result downstream from gaged and ungaged tributaries. Recent findings by USGS researchers on the relationships between ROD dam operations and fine-sediment dynamics of the ecosystem support further efforts to closely track sand fluxes into and out of the ecosystem.

Inflows from the Paria and Little Colorado Rivers are a major source of both inorganic and organic fine-sediments that support physical and biological habitats of the ecosystem. Therefore, field measurements of these inputs are required for tracking the system-wide fine-sediment and nutrient budgets. In addition, measuring export of fine-sediment out of the ecosystem is another vital component of the system-wide sediment and nutrient budgets related to estimating the residence time for inputs. Residence time and fate of nutrients and fine inorganic sediments is related to dam operations, and influences the stability and characteristics of physical habitats, as well as biological processes.

Monitoring streamflow and fine-grained sediment transport: (1) allows managers to track the status of fine-sediment flux into and out of the ecosystem on a seasonal to annual basis; (2) provides data that allow development of a 1-dimensional model for routing fine sediment through the main channel related to tributary sediment inputs "events" that can dramatically influence Colorado River ecosystem resources in both aquatic and terrestrial habitats; (3) provides data that supports interpretation of other monitoring data on the availability and grain-size of fine-grained sediment stored within geomorphic environments of the main channel.

-**Integration:** Streamflow is the fundamental parameter linking dam operations with changing conditions of downstream resources. Streamflow plays an integral part in driving sediment transport, and thus in relating dam operations to changes in downstream resources that are linked to the sediment budget. Streamflow also links with nutrient flux between Lake Powell, the Paria and Little Colorado River and hundreds of ungaged tributaries downstream from the dam that input both organic and inorganic constituents. Data on streamflow, sediment transport and quality of water need to be documented consistently throughout the ecosystem so that trends in non-physical resources downstream of the dam can be linked back to dam operations, or to non-dam related factors.

-MO's and IN's to be Addressed: This integrated physical resource monitoring project provides information needs related to management objectives as described in Table 2.1. Management objectives and information needs associated with long-term monitoring of dam operations, fine-grained sediment flux and streamflow throughout the main channel shall be obtained through this project under an interagency agreement with the U.S. Geological Survey. Additionally, key water quality parameters related to main channel, and gaged tributaries shall be obtained through

the existing USGS stream gage network in support of biological management objectives and information needs.

Project Goals and Objectives: The major emphasis of this project will be to document the flux of streamflow and fine-grained sediments system-wide through an existing network of USGS operated streamgages and numerical models developed for the gaged tributaries.

The *primary goal* is to document the flux of fine inorganic sediment into and out of the main channel of the ecosystem and relate this flux to data on system-wide storage of fine-sediment in the main channel. *Secondary goals* include improved understanding of streamflow and sediment-transport processes in gaged tributaries and along the main channel; continued data collection that supports flow and sediment model development and verification; and a consistent process for segregating sediment samples into their respective organic and inorganic components to support development of a nutrient budget—with an emphasis on organic Carbon. Both inorganic and organic components of the fine-sediment budget are known to influence organisms of the food base, as well as physical habitats of the aquatic and terrestrial ecosystem, such as aquatic near-shore habitats important to fish, terrestrial habitats that support riparian vegetation and associated fauna, terrestrial substrates used by recreational backcountry visitors, and terrestrial substrates that support and preserve cultural resources.

These physical resource data shall be related to changes in cultural, recreational and biological resources relative to annual operations of Glen Canyon Dam and fine-sediment inputs downstream of the dam. Specific monitoring objectives of the project:

- Measurement of unit-value discharge and fine-sediment transport along the main channel Colorado River between Glen Canyon Dam and river mile 225.
- Measurement of unit-value discharge and fine-sediment transport of the Paria and Little Colorado Rivers.
- Characterize grain-size of channel-bed and transported fine sediments where discharge measurements are made, as well as at key intermediate locations.
- Monitor channel attributes of the Paria and Little Colorado Rivers within modeling reaches and compare these data with assumptions associated with flow and sediment input model performance estimated for these tributaries.

- Evaluate and report on annual flux of fine sediment with respect to data for similar periods on status of channel-storage component of system-wide fine-sediment budget.

Expected Products: Annual data reports on main channel and gaged tributary streamflows and sediment transport that reflect tributary inputs and interactions between those inputs and dam operations. These measurements will reflect two key elements of the fine-sediment and Carbon budgets–inputs, and export from the Colorado River ecosystem (as determined at the Diamond Creek, Grand Canyon and gage immediately upstream of the Little Colorado River confluence). Annual data and interpretive report(s) on streamflow and sediment transport relationships between tributary inputs and the main channel of management and scientific concern. Of particular concern will be reports and presentations to the GCMRC and SAB assessing the performance of geomorphically based flow and sediment models for the Paria and Little Colorado Rivers.

Streamflow will be measured and reported in 15-minute unit values, and posted along with daily mean values on the USGS web site. Suspended-sediment and bed-sediment, and water quality samples will be collected and analyzed throughout the monitoring period on a daily to weekly basis and reported annually through the USGS web site. Monitoring of tributary model reaches shall be conducted periodically as needed relative to flows that have potential for changing channel characteristics related to model parameters and assumptions.

Recommended Approach/Methods: Ongoing measurement of streamflow, water quality, suspended-sediment concentration and grain-size, and bed-sediment grain-size characteristics at five main channel locations downstream of Glen Canyon Dam, and on established gages located on the Paria and Little Colorado Rivers. These measurements will be made using standard protocols established and maintained by USGS at similar monitoring sites nationwide. Analyses of sediment and water samples will be conducted by USGS personnel using standard methods at the Coastal and Marine Geology Sediment Laboratory located at Menlo Park, California, office of the USGS, and other national laboratories as needed for nutrient budget purposes.

Motorized trips will be conducted to maintain five existing main channel streamgage sites, and to deploy intensive sediment sampling teams at above sites on a seasonal basis. Under contingency plans, additional measurements of streamflow, suspended and bed sediment

concentration and grain-size characteristics will occur in the event of large-scale flow experiments (e.g., BHBF and SASF).

Schedule: This long-term monitoring project was initiated in FY 2001, and will be continued annually through at least FY 2005. The annual work plan for this project remains in draft format and is subject to ongoing negotiations between GCMRC program managers and the Arizona District to ensure flexibility in the program needed to address evolving information needs of the adaptive management program. This draft work plan is the basis for a memorandum of understanding between the GCMRC and the Arizona District of the U.S. Geological Survey-Water Resources Division. During FY's 2004 through 2005, this core long-term monitoring program will be evaluated through the PEP-SEDS external review process to ensure efficiency and effective integration are being achieved.

Budget:

FUNDING:

AMP	$607,860
TOTAL	$607,860

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**25,560**
	Physical Scientist (.10)	8,700	8,900
	Physical Science Assistant (.70)	0	11,900
	Biological Scientist (02)	1,740	1,780
	Ecologist (.02)	1,220	1,200
	Social Scientist (.02)	1,740	1,780
21.0	Travel		
25.0	Contracts		**480,000**
	Biology	70,000	72,000
	Cultural		
	Physical	400,000	408,000
25.0	Services		**102,300**
	Logistics (6 8-day river trips; 1-14 day trip)	50,000	98,000
	Survey (Surveyor .05)	4,150	4,300
	GIS		
	TOTAL	**537,550**	**607,860**

PROJECT TITLE AND I.D.: C.3. LONG-TERM MONITORING OF COARSE-GRAINED SEDIMENT INPUTS, STORAGE AND IMPACTS TO PHYSICAL HABITATS

STATUS: Ongoing. Originally Approved and Implemented in FY 2001.

General Project Title: Monitoring Glen Canyon Dam operations and their interactions with coarse-grained sediment deposits that structure the geomorphic framework of the Colorado River ecosystem. Specifically, interactions between coarse-sediment deposits introduced to the main channel by tributary debris flows and Glen Canyon Dam operations, relative to system-wide distributions of aquatic and terrestrial habitats. This sediment monitoring activity consists mainly of change detection with respect to coarse-sediment inputs and channel features that support physical habitats, such as debris fans, cobble bars, and channel-bed topography and distribution of channel-bed coarse-sediment substrates.

Rationale/Problem Statement: Coarse-grained sediment deposits (composed of particles larger than sand-sized) are influenced by dam operations, and are also linked to biological, physical and recreational resources. Specifically, coarse-sediment deposits containing boulders form debris-fans that are stable features of the main channel. Debris fans impinge on the flow of the channel at hundreds of locations, and thus control streamflow and fine-sediment deposition throughout the ecosystem. Dam operations influence continued inputs of coarse-grained sediment from tributaries in unique ways that modify upper pool and downstream eddy environments where fine sediments are stored.

With respect to biological resources, coarse sediments form the substrates needed by benthic organisms associated with the food base, as well as spawning habitats for fish. Coarse-sediment deposits contribute to the formation and maintenance of hundreds of rapids that attract whitewater recreation enthusiasts; supporting a tourism industry that contributes substantially to the regional economy. Recent research has also documented that recreational camping areas are periodically degraded through erosion and (or) burial when tributary debris flows deposit coarse sediments along the main channel of the ecosystem (Melis, et al., 1994). Results from the 1996 Beach/Habitat-

Building Test, indicate that dam operations can be used to manage new coarse-sediment deposits through river reworking during controlled floods (Webb, et al., 1999).

Monitoring tributary debris-flow impacts and resulting coarse-sediment deposits, with respect to operations of Glen Canyon Dam, provides data on: (1) changing physical-habitat conditions related to coarse sediment that influence biological resources (such as the food base and spawning habitats for fish) and are of interest to scientists conducting related monitoring projects; (2) changing navigational conditions of whitewater rapids; (3) degradation of camping areas owing to erosion and (or) burial by coarse debris; () system-wide influences of flow regulation on the geomorphology of the main channel with respect to potential distribution and storage of fine sediment deposits.

-**Integration:** Coarse sediments of the main channel provide both substrates and a geomorphic framework that makes the Colorado River in Grand Canyon unique. Coarse lag deposits of the channel such as cobble bars and debris fans are physical habitats that support the benthic organisms of the food base, and support spawning and rearing habitats. Consistent measurements of changes in coarse-grain sediment storage are essential to linking dam operations to food base trends and patterns of fish behavior related to physical habitat use.

-MO's and IN's to be Addressed: This integrated long-term monitoring project provides data related to management objectives and information needs as described in Table 2.1. Information shall be provided on changes in the navigational characteristics of rapids, degradation of terrestrial sand bars, enhancement of sand-storage potential within upper pools and recirculating zones (eddies), distribution of cobble bars, and other aspects of physical habitat characteristics related to channel geomorphology.

Project Goals and Objectives: The *primary goal* is to annually document and evaluate coarse-sediment inputs from tributary debris flows and floods. *Secondary goals* include evaluating annual coarse-sediment inputs to: local and system-wide changes in aquatic and terrestrial physical habitats, storage settings for fine-sediment deposits, impacts to campsites caused by debris-flow deposits, changes to navigational characteristics of rapids, etc. Specific monitoring objectives of the project include change detection:

- Distribution and abundance of coarse substrates associated with biological habitats.
- Quality of recreational campsites and navigational conditions in rapids.

- For conditions and potential for fine-sediment storage in pools and rapids.

Expected Products: Annual data on coarse-sediment inputs to main channel that result from tributary events, and interactions between coarse-sediment storage and dam operations. Annual interpretive report(s) on ecological linkages between the above data sets and related Colorado River ecosystem resources, including changing conditions of biological habitats, recreational resources and main-channel fine-sediment storage.

Expected products from this project include:

- Semi-annual progress reports on status of project, and annual reports describing achievement of goals (for example, incorporation of historical data into conceptual sub-model for geomorphic framework during year one),
- Annual data on coarse-sediment inputs to main channel that result from tributary events, and interactions between coarse-sediment storage and dam operations. Annual interpretive reports on progress of the monitoring project, as well as collaborative efforts with GCMRC conceptual modeling group(s) toward simulating ecological linkages between the above data sets and related Colorado River ecosystem resources, including changing conditions of biological habitats, recreational resources and main-channel fine-sediment storage.
- Annual GIS data sets related to change detection analyses related to inputs and related impacts of coarse-sediment that result from tributary events, and interactions with dam operations,
- Annual technical presentations at GCMRC Science Symposia or Technical Workgroup meetings on the project's progress and results,
- Annual color Fact Sheets that summarize long-term monitoring trends in fine-sediment storage through the main channel of the Colorado River ecosystem,
- Participation in conceptual modeling workshops and related planning meetings that are periodically convened by GCMRC program staff and other cooperators.

Recommended Approach/Methods: A combination of remotely and field-based survey measurements documenting annual impacts from tributary debris flows and floods on the texture and topography of debris fans of the main channel, substrates of the terrestrial and aquatic habitats, and characteristics of rapids and campsites. These data shall be used in combination with annual

channel-substrate mapping data collected as part of the long-term monitoring of fine-sediment storage to assess the magnitude of pre- versus post-tributary event impacts.

Schedule: Ongoing in FY 2002, and anticipated to continued annually through at least FY 2005 through a cooperative agreement.

Budget:

FUNDING:

AMP	$130,260
TOTAL	$130,260

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**13,660**
	Physical Scientist (.10)	8,700	8,900
	Biological Scientist (.02)	1,740	1,780
	Ecologist (.02)	1,220	1,200
	Social Scientist (.02)	1,740	1,780
25.0	Contracts		**77,000**
	Biology		
	Cultural		
	Physical	75,000	77,000
25.0	Services		**39,600**
	Logistics (1 16-day river trip)	18,000	35,300
	Survey (Surveyor .05)	4,150	4,300
	GIS		
	TOTAL	**110,550**	**130,260**

Note - Flood flows in excess of 45,000 cfs shall be of special interest to this monitoring program since none have occurred since the time that the ROD has been in effect.

PROJECT TITLE AND I.D.: C.4.A. STREAMFLOW AND SUSPENDED-SEDIMENT TRANSPORT MODELING WITHIN THE COLORADO RIVER ECOSYSTEM

STATUS: Ongoing. Originally Approved and Implemented in FY 2001.

Part A ***MODELING REACH-AVERAGED SAND BAR EVOLUTION IN RESPONSE TO A RANGE OF DISCHARGE AND SEDIMENT CONDITIONS ALONG THE MAIN CHANNEL***

Note: Originally proposed as two separate research efforts in the FY 2001 annual plan, these two modeling projects described below have been combined into one effort. The main reasons for combining the two projects was to promote scientific integration in the models development, as well as cost efficiency among the two projects, as they are intimately related to one another.

General Project Description: Development of a sediment-transport model capable of predicting 3-dimensional sand bar evolution under a range of dam operations and sediment supply conditions in selected geomorphic reaches of the main channel. The model development shall be conducted in a way that results in predictions of reach-averaged sand bar responses within geomorphic reaches identified by GCMRC and Ecometric Research, Inc., in advance of the project (FY 2000 activity). The model will also be able to simulate changing bar conditions at specific sites of concern, provided that high-resolution channel geometry is available for the reach or site of interest.

Rationale/Problem Statement: One useful method that has been used to screen options for managing fine-grained sediment deposits along the main channel has been development of a conceptual model that includes flow routing and sedimentation sub-routines. Unfortunately, the existing model lacks the capability to predict sand bar deposition and erosion locally at sites where 3-D bar morphology and process-rate information is needed (fate of backwater habitats, for example). By selecting representative sub-reaches in which process-based sediment-transport and streamflow modeling can be developed, estimates of sand bar responses can be predicted in ways that allow for 3-D bar morphologies to be better anticipated under changing flow and sediment supply conditions.

Predicting sand bar size and morphology is critical for anticipating how sand bars supporting physical habitats will respond over short and long periods to a range of sediment supply conditions and experimental dam operations, such as the current treatment. This modeling capability also allows for large-scale flow experiments, especially those intended for sand bar restoration, to be evaluated in advance of conducting field tests. Screening of large-scale experiments through preliminary modeling is one way to assess and minimize risks associated with alternative flood-flows, such as BHBFs of variable duration and floods in excess of 45,000 cfs under varied sediment supply conditions. In addition, sand bar simulations allow managers and scientists opportunities to better design flood experiments related to key hypotheses that need to be addressed, such as short and longer-term impacts to the system's fine-sediment budget, distribution and characteristics of camping beaches, abundance and availability of backwater habitats, and potential for fine-sediment deposition along river terraces containing cultural resources.

-**Integration:** Sand bar distribution, size and morphology are related to habitat types thought to be important to biological organisms of the ecosystem, such as early life stages of the Humpback chub. Dam operations affect not only the fine-sediment budget of the system, but also the individual characteristics of sand bars that support habitat types, such as backwaters. In addition, sand bar characteristics also affect recreational campsites and settings where cultural resources are preserved. As a result, being able to predict how the range of dam operations and sediment conditions relate to sand bar abundance and morphologies can help promote integrated understanding of how physical and non-physical resources are related to dam releases.

-MO's and IN's to be Addressed: This integrated physical resource research project shall provide information needs related to predicting influences of dam operations on fine sediment and related resources as described in Table 2.1. This research project shall provide: (1) greater understanding of flow and depositional processes related to sand bar evolution; (2) predictive insight into the fate of individual sand bar types and site-specific morphologies under a range of hypothetical conditions; and (3) sand-storage exchange data between eddies and the main channel within key reaches where 1-dimensional fine-sediment export predictions are needed.

Part A Project Goals and Objectives: The *primary goal* is to advance the understanding of sediment and flow processes along the main channel, while developing reach-averaged estimates of sand bar deposition and erosion under varied sediment supply conditions and dam operations up to

100,000 cfs. These estimates shall be based on selected portions of individual geomorphic reaches defined on the basis of average channel attributes and (or) proximity to points of major sediment inputs.

Secondary goals are: to produce data on estimated exchanges of fine-sediment transfer between eddies and the main channel for use in development of a 1-dimensional sand-transport model for routing fine sediment inputs through the main channel to Upper Lake Mead; to evaluate evolution of specific sand bar types related to backwaters and other physical habitats; to better estimate sand bar building flows related to distribution of camping areas, and to assess sand-bar deposition and erosion potential along pre-dam terraces where arroyo development threatens *in-situ* preservation of cultural resources. Because all flood flows must be routed through the relatively sediment-depleted Glen Canyon reach, it is crucial to conduct simulations to determine whether such flows are likely to erode pre-dam river terraces.

Expected Products: Numerical model code and documentation on model development and use within study reaches of the main channel. Model output data on flow and sediment-transport simulations for a range of conditions as specified by the GCMRC. Interpretive report(s) on model theory and assumptions related to sediment storage changes along geomorphic reaches related to dam operations and fine-sediment flux.

Recommended Approach/Methods: Limited development and verification of similar modeling capability has been previously undertaken by the U.S. Geological Survey, for the reach between river mile 61 and 72 below Glen Canyon Dam. Results of these activities indicate good correspondence with documented floods in 1993 and 1996 that have resulted in bar building in this reach. Methods similar to these are currently being used in the same reach to support information needs related to the cultural resources program. It is assumed that such methods will likely be successful when applied to other geomorphic reaches throughout the ecosystem.

Part A Schedule: This research was initiated in FY 2001, through release of a competitive solicitation, and will likely continue through at least FY 2003. Progress in modeling will be partially dependent on the GCMRC's ability to provide 3-D geometry data for selected reaches of the main channel. Emphasis for model development will focus on critical upstream reaches first where

physical habitats are of most interest, where sediment supplies are most limited, and where impacts of dam operations are most exaggerated.

Budget:

FUNDING:

AMP	$166,510
TOTAL	$166,510

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002	
11.0	Salary (includes benefits)			**11,010**
	Physical Scientist (.05)	4,350	4,450	
	Biological Scientist (02)	1,740	1,780	
	Biologist (.05)	3,050	3,000	
	Social Scientist (.02)	1,740	1,780	
25.0	Contracts			**103,000**
	Biology			
	Cultural	25,000	26,000	
	Physical	75,000	77,000	
25.0	Services			**52,500**
	Logistics (1 16-day river trip)	18,000	35,300	
	Survey (Surveyor .20)	16,600	17,200	
	GIS			
	TOTAL	**145,480**	**166,510**	**166,510**

PROJECT TITLE AND I.D.: C.4.B. STREAMFLOW AND SUSPENDED-SEDIMENT TRANSPORT MODELING WITHIN THE COLORADO RIVER ECOSYSTEM *(Cont.)*

STATUS: Ongoing. Originally Approved and Implemented in FY 2001.

Part B *DEVELOPMENT OF A ONE-DIMENSIONAL FINE SEDIMENT-ROUTING MODEL ALONG THE MAIN CHANNEL*

General Project Description: A research program to develop an efficient numerical method for evaluating the influence of dam operations on tributary sediment inputs (sand and silt/clay) and the related fine-sediment budget. A numerical method of routing fine-sediment through the ecosystem

is needed to track the fate of channel-stored sediment over short periods following tributary floods from the Paria and Little Colorado Rivers. This capability is also needed to make advance estimates of fine-sediment export from the ecosystem that result from planned or unplanned flood flows, as well as to simulate impacts of alternative dam operations. Because the grain-size distribution of channel-stored fine sediments directly impacts transport rates, this model will focus on tracking sediment loads in 1-dimension (tied to existing flow-routing model) for several size classes of sand, as well as silt and clay.

Rationale/Problem Statement: At present, the instability of bed-storage grain-size distributions and related sediment-transport rating curves for measurement sites on the main channel (Lees Ferry, above confluence with Little Colorado River, Grand Canyon, and above Diamond Creek) make it impossible to estimate changes in the ecosystem's fine-sediment budget over time frames of interest to managers (hours to seasons). To document changes in the storage of fine sediment in critical reaches, the current approach is to make relatively intensive field measurements for suspended-sediment transport. Such measurements are difficult to obtain for extended periods, costly to analyze, and are often associated with errors large enough that long-term sediment budgeting has little meaning. Development of a fine-sediment routing model that can track the fate of tributary inputs over hours to weeks can provide rapid evaluation of short-term changes in the system-wide flux of fine sediment needed to evaluate the influence of dam operations.

-Integration: The ability to accurately estimate the export of fine sediment from the ecosystem following tributary floods is vital for predicting the potential for restoration of sediment-dependent resources through controlled floods. A major premise of the management program is that downstream resources may be preserved and sustained when a positive fine-sediment budget is maintained–one where sand supplies are available for manipulation through controlled floods. Sediment routing models allow for evaluations on how effective current dam operations are at maintaining a positive supply of stored fines in the main channel. This information is another source of information that can be used to relate non-physical resources back to dam operations.

-MO's and IN's to be Addressed: This sediment-transport research project provides information needs related to predictions about how dam operations influence fine sediment and related resources, as described in Table 2.1. Successful development of this model and predictive capability has the potential for allowing managers to more quickly assess the system-wide influences

of dam operations on fine-sediment inputs from gaged tributaries, while reducing the need for intensive field measurements and delays caused by laboratory analyses of sediment-transport samples.

Part B Project Goals and Objectives: The *primary goal* is to obtain a 1-dimensional sediment routing model that links streamflow to suspended transport of fine sediment between, at a minimum, Glen Canyon Dam and the Grand Canyon streamgage near Phantom Ranch. *Secondary goals* include improved understanding of relationships between suspended-sediment transport and grain-size evolution of fines stored on the channel bed; improved ability to track fine-sediment budget within critical reaches for periods of weeks to months following gaged tributary floods; improved estimates of the residence time for storage of fine inputs in main channel eddies and pools relative to ROD dam operations.

Expected Products: Numerical model code and documentation on 1-D routing model development and use within the main channel below Glen Canyon Dam. Model output data on flow and sediment-transport simulations. Interpretive report(s) on model theory, linkages with results of 3-D eddy and sand bar simulations, and descriptions of the key model assumptions related to numerical estimation of fine-sediment flux along critical reaches related to dam operations and gaged tributary fine-sediment flux.

Recommended Approach/Methods: Conceptually, this sediment routing model shall combine the existing streamflow routing model (USGS) with results from 3-D sand bar evolution simulations, as well as existing reach-averaged channel geometry data, sediment-transport theory, and ongoing sediment-transport and streamflow monitoring data collected as part of core long-term monitoring of streamflow and sediment. Input data for model simulations will include unit-value discharge data from Glen Canyon Dam and associated downstream gage network site, fine-sediment input data from the Paria and Little Colorado Rivers (existing flow-based sediment models), and estimated antecedent conditions of grain size for main channel bed storage.

The model's initial development will be followed by an intensive verification period in which streamflow, suspended-sediment concentration and grain size, and bed grain-size distribution data (above the confluence of the Little Colorado River and Grand Canyon gages) will be compared

with model simulation outputs. The length of this required verification period will be dependent on the desired range of dam operations for which the model is intended to be used, and level of tributary flood activity that occurs following model development.

Part B Schedule: This research was initiated in FY 2001, through release of a competitive solicitation and will likely continue as a research effort through at FY 2003. The post-development verification may last an additional period of several years, but will be supported through collection of ongoing streamflow and sediment-transport data at main channel gage sites. Emphasis for development of sediment routing prediction will be on critical upstream reaches where fine-sediments and related physical habitats are of most interest; Glen Canyon Dam to river mile 87 (Grand Canyon gage). Ultimately, the point at which sediment export is simulated may extend down to Diamond Creek. This project shall be highly supported by the long-term monitoring program for streamflow and sediment transport (USGS, Arizona District). Eventually, the successful development of this sediment routing model may reduce the need for intensive suspended-sediment sampling of the mainstem that is currently required to track the fine-sediment flux following large floods on the Paria and Little Colorado Rivers.

Budget:

FUNDING:

AMP	$141,750
TOTAL	$141,750

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**4,450**
	Physical Scientist (.05)	4,350	4,450
25.0	Contracts		**102,000**
	Biology		
	Cultural		
	Physical	100,000	102,000
25.0	Services		**35,300**
	Logistics (1 16-day river trip)	18,000	35,300
	Survey		
	GIS		
	TOTAL	**122,350**	**141,750**

PROJECT TITLE AND I.D.: C.5. ADVANCED CONCEPTUAL MODELING OF COARSE-GRAINED SEDIMENT INPUTS RELATED TO EVOLVING PHYSICAL HABITATS AND AQUATIC PROCESSES

STATUS: Ongoing. Originally Approved and Implemented in FY 2001.

General Project Description: Development of advanced simulations to predict long-term impacts of river regulation and inputs of coarse-grained sediments from ungaged tributaries at hundreds of sites along the main channel.

Rationale/Problem Statement: Since closure of Glen Canyon Dam in 1963, local geomorphic changes have continued to occur at sites along the main channel owing to coarse-grained sediment inputs that result from debris flows in ungaged tributaries. Because of the reduced flood frequency imposed by the dam, the natural level of reworking of coarse sediments in the main channel is drastically reduced compared with pre-dam annual floods. However, the 1996 controlled flood experiment was shown to be an effective means of partially reworking rapids and debris fans aggraded by recent debris flows. Inputs of coarse sediments to the system-wide sediment budget of the ecosystem have been shown to have implications for enhanced storage of fine sediment in upper pools and eddies, as well as for increasing navigational hazards in rapids.

In addition, coarse-grained deposits generally bury or degrade sand bars used by recreational camping, while at the same time adding to coarse substrates on which the food base relies (benthic organisms). Simulation of long-term trends in physical habitats related to coarse sediments and ongoing inputs shall provide information on how biological and socio-cultural resources are likely to respond to increased storage of coarse sediments along the main channel under regulated flows. Information on the potential degree to which deposits, such as cobble bars, rapids and debris fans, can be reworked by controlled floods to mitigate impacts of coarse inputs that may not be desired. Long-term trends that might be countered by dam operations include periodic reworking of aggraded rapids that become impassable owing to debris flows, or flood-induced restoration of camping sand bars following burial by debris flows.

-Integration: As physical habitats of the main channel evolve in response to regulation and continued inputs of coarse sediments, resources are likely to follow in ways that may or may not be fully anticipated. As a result, it is vital to further develop abilities to simulate how long-term trends in the coarse-sediment budget might influence the food base, campsite availability, spawning habitats for fish, or fine-sediment storage along the main channel. Advanced development of geomorphic and biological sub-models of the conceptual ecosystem model shall provide opportunities for scientists from varied disciplines to test hypotheses about how the geomorphic framework of the Colorado River will evolve under regulated flows, and more importantly, how such changes will influence the biological processes of the main channel.

-MO's and IN's to be Addressed: This integrated physical resource monitoring project provides information needs related to management objective as described in Table 2.1. Information on the estimated trends related to changing navigational conditions of rapids system-wide is an obvious initial area where information will be gained. Additionally, information about how physical habitats and camping areas will be changed under future conditions shall also provide greater understanding about how dam operations will influence downstream resources in the long term.

Project Goals and Objectives: The *primary goal* is to develop a geomorphic sub-model of the main channel that simulates long-term trends in local and reach-averaged changes in fine-sediment storage settings, physical habitats such as cobble bars and debris fans that support the food base, and degradation of recreational camping areas that result from continued inputs of coarse-grained sediments (debris flows). *Secondary goals* are to improve current understanding of how coarse-grained sediment inputs and dam operations relate to the ongoing channel framework evolution that results from regulation, and to promote further understanding of how the fine and coarse sediment budgets of the Colorado River are linked to the bottom-up structure and function of the ecosystem.

Expected Products: Advanced physical and biological sub-models that further advance the conceptual model's ability to simulate long-term physical changes in the geomorphic framework of the Colorado River ecosystem. The advanced biological sub-model shall link the projected geomorphic changes to biological processes of the river. The advanced geomorphic sub-model shall link the projected physical changes to potential for fine-sediment storage and camping area navigational conditions of rapids that evolve through time. One integrated modeling workshop, to

be co-convened by the GCMRC and Ecometric Research, is anticipated during FY 2002, to evaluate implications of geomorphic framework simulations.

Recommended Approach/Methods: The basis for development of these additional sub-models will be integration of all existing physical data sets for the Colorado River ecosystem, estimates for long-term inputs of fine and coarse-grained sediments from gaged and ungaged tributaries, statistically derived probabilities for tributary debris flows for all ungaged tributaries, and associated resource area data sets. Development of the advanced sub-models will be facilitated through a workshop approach, similar to that used to initially develop the Colorado River ecosystem conceptual model.

Schedule: This research was initiated in FY 2001, with the drafting of a work plan and budget with Ecometric Research, and will likely continue through at least FY 2002. This project will be accomplished through a continuation of the Ecometric Research, Inc., agreement, and in collaboration with GCMRC staff and cooperating scientists. Emphasis will be on critical upstream reaches first where physical habitats and the food base are of most interest with respect to native endangered fishes. Integration with other physical and biology monitoring programs shall be required to simulate future impacts of coarse inputs on recreational camping areas and food base.

Budget:

FUNDING:

AMP	$99,250
TOTAL	$99,250

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**22,250**
	Physical Scientist (.15)	13,050	13,350
	Biological Scientist (.05)	4,350	4,450
	Social Scientist (.05)	4,350	4,450
25.0	Contracts		**77,000**
	Biology		
	Cultural		
	Physical	75,000	77,000
25.0	Services		
	Logistics		
	Survey		
	GIS		
	TOTAL	**96,750**	**99,250**

PROJECT TITLE AND ID: C.6 - DEVELOPMENT OF A CRE CONTROL NETWORK

Status: Ongoing. Originally approved and implemented in FY2000

General Project Description: GCMRC researchers and contractors requiring data collection in the Colorado River Ecosystem (CRE) need geographic control to spatially position their data. Geographic control is the infrastructure to any mapping product. Aerial photography, digital elevation models (DEM), or orthometrically rectified stereo photography are common types of geographic control. However, the most common reference to control pertains to survey control points that consists of well-defined and monumented location within the study areas. Survey control points typically represent the highest accuracy possible given the available technology. GPS or conventional survey technology is generally used to establish control points.

Rationale/Problem Statement: Currently, only about half of the CRE has adequate geographic control meets the needs of near and long-term monitoring and research plan. Survey control is required throughout the remainder of the CRE to fully implement the monitoring and research plan.

-Integration: Accurate spatial positioning of scientific data facilitates integration across resource areas by providing common geographic framework to store and analyze data. Many resource monitoring programs depend upon changes in the spatial distribution of resources as the basis of their monitoring strategy. Spatial analysis tools such as a GIS depend upon accurate geo-referencing of data to provide meaningful analysis. Without geographic control, geo-referencing of resource data and subsequent spatial analysis is impractical.

-MO's and IN's to be Addressed: The survey control network is fundamental to spatially positioning all scientific data collected as part of the GCDAMP. This project will address MO's and IN's identified in all integrated terrestrial and aquatic ecosystem activities. Please refer to this section for a comprehensive list.

PEP Recommendations: The preliminary physical science PEP conducted in the summer of 1998 has recommended the continued development of a control network in their list of action items. In

addition, all cultural, biological, physical, and remote sensing PEP's recommended scientific activities that require a control network throughout the canyon.

Project Goals and Objectives: The objective of this project is to develop a high-precision control network throughout the CRE. Control monuments will be established at a line-of-sight interval depending upon terrain.

Expected Products: The products of the CRE control network project will be:

- A network of survey control points established at line-of-sight intervals in the CRE from the GCD to the headwaters of Lake Mead.
- A report describing the methods, its construction, and control identifiers and locations.
- An index map showing the location of control points using the 2000 orthophotography as a backdrop.

Recommended Approach/Methods: Control points will be established using two industry standard survey methods, GPS and conventional survey practices. In the CRE, conventional survey practices means the use of a total station and one or more survey targets. Conventional traverse control involves starting at a known reference point, then setting a series of line-of-sight points and closing out at the point of beginning or another known reference point. Conventional survey methods will always be required to fill-in where satellite visibility is too obstructive for GPS. Conventional methods are used for all types of location surveys including topography and site location.

GPS technology will be used to set accurate control as well as measuring topography. GPS is utilized to establish high order control points in the Canyon. This requires that a receiver or receivers be placed at known control points on the rim or in the canyon. Then additional receivers are used to set new points.

Schedule:

FY2000 Activities: Extend the State Plane coordinate (SPC) control network from river mile 72 to 93. The fieldwork and data reduction should be completed by December of 2001, resulting in continuous SPC control from GCD to river mile 99.

FY2001 Activities: Extend the State Plane coordinate (SPC) control network from river mile 99 to 120. The fieldwork and data reduction should be completed by December of 2001, resulting in continuous SPC control from GCD to river mile 123.

FY2002 Activities: Extend the State Plane coordinate (SPC) control network from river mile 123 to 143. The fieldwork and data reduction should be completed by December of 2002, resulting in continuous SPC control from GCD to river mile 145. A dedicated Control data collection trip will take place in February of 2002. All other control operations will take place concurrently with their associated projects in 2002.

FY2003 Activities: Extend the State Plane coordinate (SPC) control network from river mile 145 to 180. The fieldwork and data reduction should be completed by December of 2003, resulting in continuous SPC control from GCD to river mile 183. A dedicated Control data collection trip will take place in February of 2003. All other control operations will take place concurrently with their associated projects in 2003.

FY2004 Activities: Extend the State Plane coordinate (SPC) control network from river mile 183 to 280. The fieldwork and data reduction should be completed by December of 2004 resulting in continuous SPC control from GCD to river mile 280. A dedicated Control data collection trip will take place in February of 2004. All other control operations will take place concurrently with their associated projects in 2004.

Budget:

FUNDING:

AMP	$18,280
TOTAL	$18,280

OBJECT CLASS	DESCRIPTION	FY-2002
11.0	Salary (includes benefits)	**18,280**
	Surveyor (.08)	6,880
	Surveying Technician (.20)	11,400
25.0	Contracts	
	Biology	
	Cultural	
	Physical	
25.0	Services	
	Logistics	
	Survey	
	GIS	
	TOTAL	**18,280**

PROJECT TITLE AND ID: C.7 - DEVELOPMENT OF CRE HYDROGRAPHIC MAPPING PROGRAM

Status: Ongoing. Originally approved and implemented in FY2000.

General Project Description: The hydrographic mapping program is to facilitate all monitoring efforts requiring sub-aqueous measurements. The two areas of hydrographic mapping consist of an ongoing system-wide channel map and a repeatable reach monitoring for annual change detection.

Rationale/Problem Statement: Hydrographic mapping is the only method currently available to measure sub-aqueous topography.

-Integration: Hydrographic technology is used in the Grand Canyon primarily to measure changes in the river channel. The primary changes that occur are due to the movement of sediment. These changes are monitored by hydro-acoustic measurements that are accurately positioned over the course of the river channel. The hydrographic data collection method is designed to develop required monitoring and research products such as topographic maps, digital terrain models, sediment aggregation and degradation, hydrologic stage discharge modeling, and cross-section analysis. These products support the following projects: system wide channel mapping, fine-grained sediment storage, coarse-grained sediment, streamflow and fine-grained sediment transport, modeling reach-averaged sand bar evolution, and aquatic bio-monitoring.

-MO's and IN's to be Addressed: Hydrographic channel mapping addresses MO's and IN's associated with the Physical Science Program's Sand Storage Change Detection Monitoring and Channel Modeling project.

PEP Recommendations: The GCMRC is actively engaged in investigating alternative ways to fulfill science program survey requirements using minimum tool and less intrusive techniques. A primary objective of the GCMRC Protocol Evaluation Program (PEP) is to reduce the impact of resource monitoring and research in the Canyon. Multibeam technology was recommended for evaluation by the GCMRC sponsored PEP for remote sensing and physical science resource monitoring in the summer of 1998. (Final Report GCMRC Remote Sensing Protocols Review Panel

and Preliminary Report of the Physical Resources Monitoring Peer Review Panel [SEDS I] [GCMRC's Protocol Evaluation Program (PEP)]), respectively. (Http://www.gcmrc.gov/pep).

Project Goals and Objectives: The objective of the project is to develop:

- Complete mapping sections of river between GDC and Phantom Ranch in 2002.
- Monitor approximately 30 miles of river channel annually for repeatable change detection of the river channel.

Expected Products: The products of the hydrographic channel-mapping project will be:

- A complete hydrographic channel map of the CR to Phantom Ranch at a resolution that would allow a contour interval of a quarter-meter without interpolation in 2002.
- A DEM of the CR channel bottom from the GCD to Phantom Ranch in 2002.
- A report describing the hydrographic mapping and data processing methods used in the map and DEM production.

Products will conform to GCMRC data standards and be integrated with terrestrial base maps produced as part of the FY2000 terrestrial mapping project (i.e., the LIDAR mapping). The combined terrestrial and hydrographic maps and DEM's will provide the most accurate three-dimensional canyon geometry obtained so far.

Recommended Approach: The multibeam approach will be used for most of the data collection because of its higher resolution and productivity. Multibeam technology is the only method available to accomplish the objectives within the projected time frame.

Schedule:

FY2000 Activities: Fifteen miles of channel have been mapped and repeated throughout the LSSF experiment.

FY2001 Activities: All existing GIS areas will be hydrographically mapped from GDC to Phantom Ranch. These trips will occur in May and September. LSSF reaches will be repeated for monitoring. These trips will occur in March and April.

FY2002 Activities: Dedicated channel mapping trips would be deployed in January and May of 2002. A change detection monitoring trip would be scheduled in March or April. Base Maps and data would be delivered by the end of December 2002.

FY2003 Activities: Dedicated channel mapping trips would be deployed in January and May of 2003 and would map from Phantom Ranch to river mile 160. A change detection monitoring trip would be scheduled in March or April. Base Maps and data would be delivered by the end of December 2003.

FY2004 Activities: Dedicated channel mapping trips would be deployed in January and May of 2004 and would map from river miles 160 to 225. A change detection monitoring trip would be scheduled in March or April. Base Maps and data would be delivered by the end of December 2004.

Budget:

FUNDING:

AMP	$32,580
TOTAL	$32,580

OBJECT CLASS	DESCRIPTION	FY-2002
11.0	Salary (includes benefits)	**32,580**
	Surveyor (.18)	15,480
	Surveying Technician (.30)	17,100
25.0	Contracts	
	Biology	
	Cultural	
	Physical	
25.0	Services	
	Logistics	
	Survey	
	GIS	
	TOTAL	**32,580**

PROJECT TITLE AND ID: C.8 PUBLIC OUTREACH ACTIVITIES

Status: Ongoing. Originally Approved and Implemented in FY 2001.

General Project Description: Dissemination of information collected within the GCMRC cultural resource program for the benefit of the Adaptive Management Program Stakeholders and the interested public.

Rationale/Problem Statement: In conjunction with an ad hoc group of the AMWG and pursuant to Executive Orders relative to Tribal consultation , GCMRC is developing public outreach activities. To complement GCMRC's overall public outreach efforts, an outreach project is proposed that links the Socio-cultural Program and the IT Program with the dissemination of cultural resource data. Issues concerning culturally sensitive data and dissemination processes will be discussed with Native American groups prior to project implementation.

MO's and IN's To Be Addressed : This project addresses cultural resource management objectives and information needs (MO1, IN1.1).

PEP Recommendations: This project implements the recommendations of the Cultural Resource PEP to coordinate with AMP stakeholders and the Native American representatives to disseminate information. The project forms a portion of the overall Historic Preservation Plan suite of documents.

Integration: To achieve an ecosystem-level of understanding of the relationships between resources of the Colorado River and Glen Canyon Dam operations, integration of long-term monitoring between physical, cultural, biological, and recreational resources is required. This project will provide a means to disseminate cultural resource information concerning the ecosystem resources.

Project Goals and Objectives: The goals of this effort include the dissemination of GCMRC data by and for stakeholders and the participation of the stakeholders in the dissemination process. Information dissemination is a part of publicly funded projects.

Expected Products/Deliverables: A variety of avenues for the dissemination of information are possible including presentations, workshop materials, and scooping efforts to expand dissemination efforts in the future.

Recommended Approach/Methods: Methods will range from material for articles to videotapes describing the adaptive management program and associated scientific activities, to providing GCMRC staff to speak at different meetings. Included within this project are funds to appropriately disseminate cultural information, employ student interns from stakeholder groups for resource projects; and to sponsor tribally hosted lectures and talks to present cultural information.

Schedule: The project duration is anticipated to be one year.

Budget:

FUNDING:

AMP	$43,680
TOTAL	$43,680

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**10,680**
	Social Scientist (.10)	8,700	8,900
	Research Information Analyst (.02)		1,780
25.0	Contracts		**33,000**
	Biology		
	Cultural	35,000	33,000
	Physical		
25.0	Services		**0**
	Logistics	15,000	
	Survey		
	GIS		
	TOTAL	**58,700**	**43,680**

REMOTE SENSING ACTIVITIES

PROJECT TITLE AND ID: D.1 – EVALUATING GROUND-BASED AND AIRBORNE REMOTE SENSING TECHNOLOGIES

Status: Ongoing. Originally Approved and Implemented in FY2000.

General Project Description: The primary goal of the remote sensing project is explore and to capitalize on new remote sensing technologies and data processing techniques in order to provide to the research and monitoring projects supporting data that have the following characteristics: non-invasive data acquisition; sufficient spatial resolution; broadest application across all research disciplines; broader area coverage; high accuracy, long-term reliability (reproducibility); and cost-effectiveness. These efforts will lead to a general operational plan for data acquisition and data analysis for many of the objectives of the other programs

Rationale/Problem Statement: In March 1997, GCMRC proposed lowering flows from Glen Canyon Dam to 5,000 cubic feet per second (cfs) in support of Labor Day aerial photography. Members of the Technical Work Group (TWG) opposed this proposal. Their main concern was that lowering flows in "high-water" years could have a negative effect on the very resource GCMRC was trying to monitor (i.e., the monitoring protocol represented a treatment potentially more harmful to downstream resources than current dam operations). In response to the discussion around lower flows for conducting aerial photography, the suggestion emerged from the TWG that GCMRC investigate the potential of expanded use of remote-sensing technologies for data collection. To facilitate this process, GCMRC convened a PEP of remote sensing experts in May 1998. Methodologies and protocols used in current GCMRC research projects were presented to the panel. The panel subsequently made recommendations of potential new technologies that might better meet GCMRC monitoring and research needs.

-Integration: The evaluation of remote sensing technologies is intended to address monitoring and research needs of the biological, cultural, and physical resource programs at the

GCMRC. If successful, remotely-sensed data sets could be utilized for multiple monitoring and research projects and provide spatial integration of multiple resource parameters.

-MO's and IN's to be Addressed: Remote sensing technologies will be evaluated for all MO's and IN's relating to resource projects currently underway or planned within the next five years for which a remote sensing solution might exist. MO's and IN's specifically addressed by the remote sensing evaluation will be identified utilizing the process described below under Recommended Approach/Methods.

PEP Recommendations:

1. Explore alternative remote sensing technologies for system-wide studies.
2. Use color-infrared imagery for riparian vegetation studies in leaf-on conditions.
3. Use high-resolution aerial photography for studying terrace stability of archeological sites and use color-infrared imagery for ethnobotanical studies.
4. Use radar imagery to characterize rapids and debris fan and eddy complexes.
5. Use underwater videography and multispectral imagery for studying aquatic productivity.
6. Use multispectral imagery to study mainstem sediment input.
7. Explore multispectral image data (including thermal infrared) for studying water quality attributes.
8. Explore use of AVHRR and Landsat image data for studying basin characteristics associated with sediment source regions.
9. Explore use of sonar for channel geometry and grain-size determinations.
10. Explore use of GPS-based photogrammetry to monitor shoreline topography.
11. Use aerial photography or multispectral data to map habitats for endangered species.
12. Acquire airborne data under conditions and with instruments that minimize shadows.
13. Explore alternative sensors for all of the above.
14. Image analysis: hire a senior scientist in remote sensing and image processing and exploit image processing and photogrammetry software packages.
15. Prepare assessment of the information requirements of the various research and monitoring programs.
16. Conversion of hardcopy photographic archive to permanent digital archive that is accessible through the internet.

Project Goals and Objectives: GCMRC proposed the evaluation of ground-based and airborne remote sensing technologies with the goal of finding technologies and protocols that would result in a long-term monitoring program that is:

- Cost-effective (reduced costs over conventional approaches)
- Less intrusive (the monitoring doesn't have a greater effect on the system than normal dam operations)
- Expanded spatial coverage (has the ability to capture denser spatial data than can be gathered by field-based efforts)

FY2002 Activities:

- Preparation of operational plan for remote monitoring
- Test the operational plan.
- Report on the test.
- Completion of the conversion of hardcopy photographic archive to digital format.
- Implementation of the digital archive design that allows internet search and retrieval.

Recommended Approach/Methods: Ground-based and Airborne Remote Sensing Technologies will be identified, tested, and evaluated using the following steps:

1. Identify the GCMRC science program information needs that could be obtained through the use of ground-based and/or airborne remote sensing technologies.
2. Determine what technologies exist or are being developed that could collect the data required in support of GCMRC science program information needs.
3. Convene a PEP to recommend potential ground-based and airborne remote monitoring technologies.
4. Evaluate through literature reviews and expert opinion ground-based and airborne remote monitoring technologies based on science information needs and sensor specifications and capabilities.
5. Prioritize promising technologies based on this evaluation into ones that deserve further evaluation and possible field testing.

6. Conduct pilot field tests of selected technologies and evaluate the results of those field tests.
7. Recommend to the GCMRC Chief which, if any, of the ground-based and airborne remote sensing technologies should be utilized in the Grand Canyon.
8. Develop the needed protocols and implement a ground-based and airborne remote sensing program, as appropriate.

Schedule: The remote sensing initiative begins in FY 2000 and continues for three years through FY 2002. A report summarizing the evaluation is scheduled for 2003.

Budget:

FUNDING:

AMP	$440,180
TOTAL	$440,180

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
11.0	Salary (includes benefits)		**19,580**
	Research Information Analyst (.22)	8,700	19,580
25.0	Contracts		**400,000**
	Biology		
	Cultural		
	Physical		
	Other	400,000	400,000
25.0	Services		**20,600**
	Logistics		
	Survey (Surveyor .10)	8,300	8,600
	GIS (GIS Specialist .20)	6,100	12,000
	TOTAL	**423,100**	**440,180**

TABLE 2.2 Summary Table of Projected FY 2002 Power-Revenue Budget for Projects

ID	Project Descriptions	Salary	Operating Expenses	Capital Equip.	Contracts Biology	Contracts Cultural	Contracts Physical	Other Contracts & Services	Logistics Support	Survey Support	GIS Support	TOTAL[1] PROJECT COST
SCIENTIFIC ACTIVITIES												
A	**Terrestrial Ecosystem Activities**											
A-1	Terrestrial Ecosystem Activities[2]	34,530			184,000	77,000			88,200		3,000	386,730
A-2	Monitoring Kanab Ambersnail	15,750			10,000				39,200	15,700		80,650
A-3	New Research in Terrestrial Ecosystems[3]				93,000							93,000
A-4	Cultural Data Base Plan[4]	17,050				25,000						42,050
A-5	Cultural Monitoring Plan[4]	15,130				25,000			0			40,130
A-6*	Terrestrial Habitat Map & Inventory[5]	11,900				100,000			39,200		6,000	157,100
B	**Aquatic Ecosystem Activities**											0
B-1	Mon. Aqua. Foodbase & Eval. Qual.[6]	18,230			235,000				58,800			312,030
B-2*	Mon. Status & Trends of Downstream[7]	27,630			469,000				176,200			672,830
B-3	Mon. Status & Trends of Lees Ferry	18,230	10,000		90,000				19,600			137,830
B-4	Ongoing Population Genetics of HBC	12,150							3,900			16,050
B-5*	New Research Native & Non-Native	22,450			41,000							63,450
B-6	Integrated Water Quality Monitoring[8]	81,280			84,000				15,700			180,980

TABLE 2.2 (Cont'd)

ID	Project Descriptions	Salary	Operating Expenses	Capital Equip.	Contracts Biology	Contracts Cultural	Contracts Physical	Other Contracts & Services	Logistics Support	Survey Support	GIS Support	TOTAL PROJECT COST
C	**Integrated Terrestria1 & Aquatic Ecosystem Activities**											
C-1	LT Mon. of Find-Grained Sed. Storage	13,660			31,000	87,000	230,000		117,600	12,900		492,160
C-2	LT Mon. of Streamflow & Fine-Sediment	25,560			72,000		408,000		98,000	4,300		607,860
C-3	LT Mon. of Coarse-Grained Sediment	13,660					77,000		35,300	4,300		130,260
C-4a	Modeling Reach-Averaged Sand Bar	11,010				26,000	77,000		35,300	17,200		166,510
C-4b	Dev. Of a 1-Dimensional Model	4,450					102,000		35,300			141,750
C-5	Adv. Conceptual Modeling of Coarse Grained	22,250					77,000					99,250
C-6	Control Network	18,280										18,280
C-7	Channel Mapping	32,580										32,580
C-8	Public Outreach	10,680				33,000						43,680
D	**Remote Sensing**											
D-1	Eval. Remote Sensing Technologies	19,580						400,000		8,600	12,000	440,180
E	**Unsolicited Proposals**				72,000	51,000						123,000
F	**In-House Research**							20,000				20,000
G	**AMWG/TWG Support**							61,000				61,000
H*	**Information Technologies**[9]											0
	Data Base Management System	56,240	16,000	19,000				10,000				101,240
	Geographic Information System	91,450	23,000	35,000								149,450
	Library	47,500	13,000	5,000								65,500
	Survey Services	35,550	35,000									70,550
	Systems Administration	61,450	31,000	80,000								172,450
	World Wide Web							60,000				60,000

TABLE 2.2 (Cont'd)												
ID	Project Descriptions	Salary	Operating Expenses	Capital Equip.	Contracts Biology	Contracts Cultural	Contracts Physical	Other Contracts & Services	Logistics Support	Survey Support	GIS Support	TOTAL PROJECT COST
L	**Logistics**[10]											0
J*	**Independent Review Panels**[11]	15,200						179,000				194,200
K	**Administration & Personnel**											
	Administrative Operations	283,540	321,000	20,000				193,000				817,540
	Biological Resources Management	124,230	8,000									132,230
	Physical Resources Management	34,360	4,000									38,360
	Socio-Cultural Resources Management	53,810	4,000									57,810
	Information Technologies Management	59,520	8,000									67,520
	AMWG/TWG	77,810	12,000									89,810
	TOTAL	**1,386,700**	**485,000**	**159,000**	**1,381,000**	**424,000**	**971,000**	**923,000**	**762,300**	**63,000**	**21,000**	**6,576,000**

* Additional funding sought from appropriations.

1 Total project costs differ from those presented in the summary budget table of 9/06/00 as a result of a more thorough accounting of salary and other project support costs based on data developed in FY-2000

2 Combines the monitoring of avifauna and terrestrial habitat activities presented in the summary budget table of 9/06/00.

3 This project replaces the ongoing trophic interactions project shown in the summary budget table of 9/06/00 and includes support from the PEP line item show in the summary budget table of 9/06/00.

4 These projects replace the development of historic contexts project shown in the summary budget table of 9/06/00.

5 An additional $200,000 in appropriated funds will be sought for this project.

6 Same as the ongoing monitoring of the phyto-benthic community shown in the summary budget table of 9/06/00.

7 Same as the ongoing monitoring of downstream fish shown in the summary budget table of 9/06/00. An additional $200,000 in appropriated funds will be sought to support this project.

8 GCMRC will also seek $300,000 from BOR O&M funds to support related water quality work in Lake Powell.

9 An additional $180,000 is being sought from appropriated funds to support these projects.

10 All logistics costs have been distributed in support of projects.

11 An additional $50,000 is being sought from appropriated funds to support this activity.

TABLE 2.3 Funding Sources

SUMMARY BY PROJECT	AMP Power Revenues		Appropriations Request
I. SCIENTIFIC OPERATIONS			
A. TERRESTRIAL ECOSYSTEM ACTIVITIES		799,660	
1. Terrestrial Ecosystem Monitoring	386,730		
2. Monitoring Kanab Ambersnail & Habitat at Vasey's Paradise	80,650		
3. New Research in Terrestrial Ecosystems	93,000		
4. Cultural Data Base Plan	42,050		
5. Cultural Resource Monitoring Plan**	40,130		200,000
6. Terrestrial Habitat Map and Inventory	157,100		
B. AQUATIC ECOSYSTEM ACTIVITIES		1,383,170	
1. Mon. Aquatic Foodbase & Evaluating its Quality for Util.	312,030		
2. Mon. of the Status and Trends of Downstream Fish Comm.**	672,830		200,000
3. Mon. of the Status and Trends of the Lees Ferry Trout Fishery	137,830		
4. Ongoing Research Assoc. with Population Genetics of HBC	16,050		
5. New Research Assoc. Inter. Between Native & Non-Native Fish**	63,450		125,000
6. Integrated Water Quality Monitoring	180,980		
C. INTEGRATED TERRESTRIAL & AQUATIC ECOSYSTEM ACTIVITIES		1,732,330	
1. LT Mon. of Fine-Grained Sed. Storage throughout Main Channel	492,160		
2. LT Mon. of Streamflow and Fine-Sed. Trans. in the Main Chan.	607,860		
3. LT Mon. of Coarse-Grained Sed. Inputs, Storage & Impacts	130,260		
4a. Modeling Reach-Averaged Sand Bar Evol. In Response	166,510		
4b. Dev. Of a One-Dimensional Fine Sed-Routing Model	141,750		
5. Advanced Conceptual Modeling of Coarse-Grained Sediments	99,250		
6. Control Network	18,280		
7. Channel Mapping	32,580		
8 Public Outreach	43,680		
D. REMOTE SENSING ACTIVITIES		440,180	
1. Evaluating Ground-Based & Airborne Remote Sensing Tech.	440,180		
II. MANAGEMENT AND BUDGET			
E. UNSOLICITED PROPOSALS	123,000	123,000	
F IN-HOUSE RESEARCH	20,000	20,000	
G. AMWG/TWG REQUESTS	61,000	61,000	
H. INFORMATION TECHNOLOGIES PROGRAM SUPPORT		619,190	
Data Base Management System	101,240		
Geographic Information System	149,450		
Library	65,500		
Survey Services**	70,550		50,000
System Administration	172,450		
World Wide Web	60,000		
Aerial Photography**	0		135,000
I. LOGISTICS OPERATIONS (ALLOCATED TO PROJECTS)	0	0	
J. INDEPENDENT REVIEW PANELS**	194,200	194,200	50,000
K. ADMINISTRATION & PERSONNEL**	1,203,270	1,203,270	250,000
TOTAL	6,576,000	6,576,000	1,010,000

** Appropriated funding requested.

FUNDING SOURCES	TOTAL
ADAPTIVE MANAGEMENT PROGRAM - Power Revenues	6,576,000
APPROPRIATED FUNDING REQUEST	1,010,000
TOTAL	7,586,000

CHAPTER 3

MANAGEMENT AND BUDGET

UNSOLICITED PROPOSALS

The GCMRC proposes to retain $123,000 in FY 2002 to support unsolicited proposals. This will allow for flexibility in the program and help ensure that GCMRC can address critical issues in a timely fashion. It will also provide GCMRC the ability to fund a truly outstanding proposal that addresses a key concern which may be overlooked in the research planning process. All unsolicited proposals will be discussed with the TWG and will undergo independent, external peer review prior to funding.

The GCMRC encourages Tribal groups to submit proposals for projects that address resource issues related to Management Objectives and Information Needs. Because these groups define their resource issues from tribal perspectives and formulate their work proposals, the GCMRC considers these submittals as unsolicited proposals. These proposals are reviewed by internal and external peer reviewers to evaluate the proposed project methodologies relative to the project objectives. Unsolicited proposals may be submitted to the GCMRC at any time. Examples of current tribal proposals include an ethnobotanical monitoring project by the Hopi Tribe and a public outreach project conducted by the Southern Paiute Consortium to disseminate their ethnobotanical information.

IN-HOUSE RESEARCH

The GCMRC supports in-house research by GCMRC Program Mangers and scientific staff. In-house research is supported as a means of ensuring that GCMRC program managers and scientific staff remain subject area experts in their respective fields through the conduct of their own research on the Colorado River ecosystem. Funds totaling $20,000 will be available to support these activities in FY 2002.This also ensures that they are able to provide the highest quality of technical assistance in the form of expert analysis, opinion, and advice to the Chief, TWG and the AMWG as requested. In-house research may be in the form of original research or synthesis. In all cases, GCMRC in-house research proposals undergo the same independent external review as all GCMRC proposals.

AMWG & TWG SUPPORT

In addition, GCMRC will retain $61,000 in FY 2002 that can be used by GCMRC staff in support of requests that arise from the TWG during the course of the year. Such funds may be used to

gather data, conduct analyses, support the convening of a group of scientists to provide an analysis of a given issue (i.e., the annual BHBF resources evaluation) or to obtain expertise not contained within the GCMRC staff or contractors.

TECHNICAL SUPPORT SERVICES:

Information Technologies

The GCMRC has extensive historical data and information collected over many years relating to the condition of resources in the Colorado River ecosystem. This information represents an extremely valuable asset to the Glen Canyon Dam Adaptive Management Program (GCDAMP). Its potential for problem solving, improving management guidelines, modeling relationships, or increasing understanding of the key resources and systems under study requires placing this legacy data into an ecologically integrated database and geographic information system (GIS).

The goal of the Information Technology Program (ITP) is to *satisfy the information needs of the GCDAMP relative to the Colorado River ecosystem* in terms of content and delivery. Key to achieving this goal is the development and maintenance of three core information technologies: 1) a data base management system (DBMS) for tabular information and other electronic non-spatial information, 2) a geographic information system (GIS) for electronic spatial information, and 3) a library for hardcopy information (Figure 3.1). Content of these systems consists of all information gathered as the result of GCMRC investigations, GCES investigations, and additional information relating to the Colorado River ecosystem.

Data in itself is of little use without sufficient information as to its context, quality, and comparability. Therefore, data standards have been be developed which preserve the context under which the data was collected and ensures its quality and comparability from year to year, place to place, researcher to researcher, and discipline to discipline. Data collection efforts supported by the GCMRC incorporate strict data standards and protocols that provide consistency in data collection, storage, and delivery from disparate sources.

Delivery of electronic content will be automated where possible using user-friendly World Wide Web browser interfaces. Library content, while not deliverable across the Internet, has been cataloged and is searchable electronically utilizing similar interfaces.

Warehoused data conforms to the National Information Infrastructure (NII), the National Biological Information Infrastructure (NBII), and the National Spatial Data Infrastructure (NSDI). Guidelines and protocols promulgated by these infrastructures is being incorporated into GCMRC database design and delivery systems whenever possible.

DBMS, GIS, and library operations together form the core information system infrastructure for storing and retrieving information at the GCMRC. Data standards and protocols ensure the quality and compatibility of the information contained within those systems. World Wide Web browsers provide intuitive, consistent interfaces to the information. However, information technology at the GCMRC goes beyond the content and delivery of information. In addition, the ITP also provides:

- Computer support to GCMRC staff
- Survey support to researchers
- Development of remote sensing applications

These additional services augment the core information infrastructures by providing the support, training, technology transfer, and development necessary to provide a comprehensive ITP.

Information Technology Program Functions

To accomplish the goal of *satisfying the information needs of GCDAMP relative to the Colorado River ecosystem,* in FY2002, the IT program will focus on 7 functions: 1) database management, 2) GIS operations, 3) library operations, 4) survey operations, 5) systems administration, 6) world wide web services, and 7), aerial photography. Each function of the IT program is described in detail below. Descriptions include general information concerning the role of the function within the GCMRC, proposed objectives to be accomplished in FY2002, and proposed budgets. IT functions are either performed by GCMRC, staff or procured through a contracting process. Non-contracted program budgets include operating costs and salaries that combine to represent the total cost of the function (less the cost of space rental and administrative overhead). Operating costs include equipment, supplies, technical training, and travel relating to program functions. Contracted IT functions represents the total cost of the contracted service or product to GCMRC less the cost of administrating the contract by the appropriate contracting officers technical representative.

Non-contracted IT program functions have associated with them ongoing objectives that are necessary to organize and manage the various types of scientific data acquired by GCMRC or its

contractors. These ongoing objectives may be different depending on the function. They include administration of the function, servicing work request, servicing data request, incorporating new data into developed data systems, and performing annual inventories.

Data Base Management System

The purpose of the GCMRC DBMS is to store and deliver all tabular and other electronic non-spatial information gathered as the result of GCMRC investigations, and legacy data. Developing the DBMS requires inventorying, organizing, archiving, and developing delivery systems for many years worth of environmental data collection activities representing a vast array of disparate data including physical, biological, cultural, socio-economic, and climatic information. Some data resides on mature DBMS systems but much of it is stored on floppy disks or hard disks on personal computers using PC type spreadsheet and database formats. Although the objective of the information technology program is to provide a centralized database management system (DBMS), it is our policy not to duplicate fully developed and accessible data warehousing already provided by other entities. In these circumstances it is preferable to interrogate the off-site database remotely when possible. However, the GCMRC will act as a clearinghouse of data owned by other entities in the case where remote database interrogation is not possible. The DBMS program is currently working on bringing together years of disparate historical data collected by multiple entities located in databases across the southwest in an organized fashion and then deliver it transparently to an equally disparate group of stakeholders and researchers for decision making and modeling purposes. In addition, the DBMS program is developing a process that includes adequate documentation and training for users to easily access, query, and obtain data from the information system.

The Oracle data base engine was selected for GCMRC data base development. Oracle is a state-of-the-art data storage and delivery system that can function either as a centralized or distributed data base and incorporates a high degree of information technology integration. Important features of the DBMS are:

1. All data is being ecologically integrated. Meaning that data is being stored in a consistent format relative to time, space, researcher, and discipline. This is essential for comprehensive ecological analysis. Appropriate data standards and protocols have been, or in some cases, will be developed to regulate this feature.

2. Spatial data is being geographically integrated. Although the database does not contain a spatial data analysis engine, the GIS used by the GCMRC will be highly integrated with, and dependent upon, the database for storing attribute data associated with spatial features. Data contained in the database is being spatially referenced within the database where appropriate.
3. Public data will be freely available. Sensitive data will be protected. User accessibility is being configured item by item.
4. The database will be searchable over the Internet using browser interfaces. Intuitive browser interfaces will be the primary method used to interrogate the database.
   The GCMRC data base development is occurring over a two-year period ending in December 2002.

Ongoing Activities:

- Administer the database
- Service data requests
- Integrate current year data into data system

FY2002 Activities:

- Complete the design of data entry, analysis and web interfaces–fish, cultural, and water quality components
- Complete the migration of historical fish, cultural, and water quality data from legacy data systems
- Document installation and administration procedures–completed for applications written to date

Complete design and program data entry, analysis and web interfaces

During FY2002, key computer applications will be written that will allow information users to easily enter newly collected data to the Oracle system, and also to retrieve and analyze that information.

Migrate historical data from legacy data systems

In order to make use of data collected in the past, the Oracle database must be populated with historical information. During FY2002 GCMRC will complete this process for physical, biological, and water quality data. Consistent with the recommendations of the Cultural Program protocol evaluation panel and subsequent guidelines being developed by GCMRC and cooperating organizations, GCMRC will

also consolidate cultural data within a GCMRC database. One of the challenges in this process is to protect sensitive information from public access.

Document installation and administration procedures

Accurate and complete documentation is critical not only to the success of maintaining a complex database, but also to making it a success for users of the information it stores. All procedures used in the creation of database tables, loading historical information, and also the creation of user applications will be documented, and will be made available to interested parties.

The cost of these ongoing and three additional activities in FY2002 is:

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
AMP Funding			
	Data Base Management System		**56,240**
11.0	Salary (includes benefits)		
	Computer Specialist (1-fte) (76%)	73,000	56,240
	Operating Expenses:		**45,000**
21.0	Travel		3,000
25.0	Contracts (Oracle)	160,000	10,000
25.0	Services		3,000
26.0	Supplies and Materials		10,000
31.0	Equipment		19,000
	TOTAL	**233,000**	**101,240**

Geographic Information Systems

A GIS is the second of the three core information technologies being used by the GCMRC. Its purpose is to provide spatial analysis capabilities to GCMRC staff and stakeholders and maintain a library of GIS thematic coverages of the study area. GIS is an important analytical tool for change detection of biological, cultural, and physical data.

The GCES program developed up to 20 thematic coverages associated with spatial relationships of biological, cultural and cultural resources at 17 GIS sites (Figure 1.2) within the Colorado River ecosystem (CRE). Tabular attribute data exists as part of these data sets. These data sets are known as "base data". In addition, other GIS data sets which were constructed as part of past GCES-supported investigations and delivered as part of a final product. These data sets are known as "contributor data". Efforts are now underway to catalog, describe, and distribute base and contributor data. The GCMRC is working to increase the GIS coverage of the CRE by using modern light detection and ranging (LIDAR) mapping techniques.

Ongoing GIS activities are:

- Administer GIS data systems
- Service GIS map, data, and analysis request
- Integrate current year data into data systems

FY2002 GIS activities are:

- Complete development of the Internet map server (IMS)
- Complete integration of legacy base data
- Continue to provide GIS support to the remote sensing initiative
- Migrate GIS data from INFO to oracle database

Complete development of the Internet map server (IMS)

The IMS will allow our staff, contributing scientists, AMWG/TWG members and the general public to browse our spatial data holding and produce maps over the internet through their web browsers (Netscape Navigator or Microsoft Internet Explorer). The user will be able to search for data by subject (physical, biological, cultural), temporally (when the data was collected), or spatially (where was the data collected). Multiple data layers can be overlayed on a map and simple spatial analyses will be available through the on-line mapping tool. The results of the search can be printed as a map from the users' local machine. Once data has been identified by the user, he/she can download the data and use a GIS package such as Arc/Info to conduct complicated GIS and statistical analyses.

Complete integration of legacy base data

Legacy base data sets represent considerable time, effort, and expense in their collection. In addition, those data offer snapshots of the past conditions that cannot be derived in any other way. Legacy datasets can be used, in conjunction with current datasets, to produce information regarding change in resource quantity and condition over time in resources areas where legacy data exists (change detection analysis). Integrating these data sets in a usable way presents several challenges including the lack of descriptive information about the data or how it was collected (metadata) making it difficult to assess the accuracy and usefulness of those data for a particular study. The GIS program is currently inventorying all legacy datasets that were collected during the GCES period and before and is attempting to create modern meta data for those data. This is a time consuming and difficult process. Once the inventory and metadata is complete, the legacy data will be stored in its appropriate place in the same databases as current and future data.

Provide GIS support to the remote sensing initiative

The GIS program supports the remote sensing initiative by developing protocols for seamless integration into existing datasets, ensuring that the delivered products meet contract technical specifications and conform to GCMRC data standards, and assisting in program development and execution by recommending sites where remote sensing evaluations would be most useful and cost effective and providing logistical support in data collection.

Migrate GIS data from INFO to Oracle database

GCMRC's selection of the Oracle database engine presents additional challenges to the GIS. Currently GIS data layers are stored in an obsolete database called INFO. Advances in software allow us to migrate this data from INFO to the Oracle relational database system while maintaining all the mapping and analysis capabilities of the GIS. Using a software called Spatial Database Engine, GIS information and tabular data will now be stored in a single Oracle database management system, allowing us to fully integrate tabular data with spatial layers developed through remote sensing or the GIS program. In addition, the GIS will now be able to take advantage of modern database tools that are available in the Oracle software and not in the INFO software.

Budget:

The cost of these ongoing and three additional activities in FY2002 is:

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
AMP Funding			
	GIS Services		**149,450**
11.0	Salary (includes benefits)		91,450
	GIS Specialist (1-fte) (56%)	48,800	33,600
	GIS Assistant (1-fte) (95%)	42,000	40,850
	GIS Student Asst (.5-fte) (100%)		17,000
21.0	Travel		4,000
25.0	Services		8,000
26.0	Supplies and Materials	12,000	11,000
31.0	Equipment		35,000
	TOTAL	**102,800**	**149,450**

Library Operations

Library operations provide the last of the three core information technologies being used by the GCMRC ITP. Its purpose is to facilitate research by providing a centralized repository for hard copy information such as books, reports, maps, photography, and videos. The scope and purpose of the library is to collect, archive and deliver those materials that assist the center in its efforts to administer long-term monitoring and research.

Inherent in the administration of long term monitoring and research plans is the delivery of hard copy documents, photographs, slides, videotapes, and ARC/Info coverages. A policy for loaning these materials is developed in a manner that is most parsimonious to all researchers, with underlying GCMRC staffing resources determining the ability to deliver and track loaned materials. Delivery of materials also emphasizes technologies that permit remote multi-user access.

Secondary to providing funded researchers access and use of the library's materials is providing non-funded researchers and the general public access to documents unique to GCMRC's holdings (duplicate documents available at other institutions provide non-funded researchers access to these materials). The singularity of a document requires special policy concerning the borrowing of these materials. Because these unique documents are considered part of the public domain, their availability to the public is required

Collection of materials for the purpose of research and monitoring efforts are coordinated with program managers and information technology managers. Criteria for the accession of materials include:

1. Applicability of materials to specific research efforts and to overall research and management goals; adequacy of the facility and equipment needs of the GCMRC to house materials; Ability of the staff to archive and deliver materials;
2. Availability of funding for materials (e.g., general reference books, government publications, CD ROM's, etc.).

Collection also includes the accessioning of documents that are the product of research funded by GCMRC.

Library holdings included the following:

1. Hard copies and electronic copy of final funded research reports.
2. Reprints of articles resulting from funded research.
3. Books resulting from research efforts associated with GCMRC.

4. Books and articles related to Grand and Glen Canyon.
5. Books and articles related to natural and controlled riverine environments.
6. Photographs and slides developed by GCMRC staff (aerial and field documentation).
7. CD-ROM versions of aerial photographs and slides.
8. Videotapes (overflights, programs related to Glen and Grand Canyon).
9. Maps (topographic, flightline maps, Arc/Info Coverages, Orthophotos).

Archival materials are one of a kind, or hard to replace items (e.g., original aerial photographs, slides, videotapes). Utilizing imaging technology (e.g., CD-ROM's) and electronic media to develop copies of archived materials should always be investigated and promoted so that copies of these materials can be made available to the general collection, and thus reducing the incidence of loss of unique and irreplaceable materials.

Ongoing library activities are:

- Administer library operations
- Service library requests
- Integrate current year data into library
- Annual inventory

FY2002 library activities are:

- Complete cataloging library content
- Continue conversion of catalog
- Continue making content available on-line

Complete cataloging library content

The library cataloging needs to be completed. Presently, books and monographs have been cataloged according to title, author, publisher, and content. This information has been placed into Follett library software and is accessible on-line. The photo and video collection has been cataloged on paper, but this information has not yet been put into the Follett software; this will be completed by FY2002. Subject headings for each item will also be added to each cataloging record for more comprehensive and flexible searching abilities.

Continue conversion of catalog

Currently, all items in the library collection are identified using call numbers based on the Bureau of Reclamation's Record Management System. By the end of FY2002, the library collection will be converted from the Bureau of Reclamation's record management system to a more standardized system such as Dewey Decimal or Library of Congress call numbers. This means that items on the same subject will be grouped together and the collection will be easier to "browse" for information.

Continue making content available on-line

The Follett library catalog is now available on-line through the GCMRC web page. FY2002, items that were previously available only through the library will also be available on-line such as reports and aerial photography.

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002	
AMP Funding				
	Library			
11.0	Salary (includes benefits)			**47,500**
	Technical Info. Spec (1-fte) (95%)	51,000	47,500	
	Operating Expenses:			**18,000**
21.0	Travel		1,500	
25.0	Services		1,500	
26.0	Supplies and Materials		10,000	
31.0	Equipment		5,000	
	TOTAL	**51,000**	**65,500**	**65,500**

Survey Operations

The Survey department's mission is to provide survey support for spatial measurement and referencing of scientific data collected in the Colorado River ecosystem by GCMRC programs. This support may be in the form of precise measurement of geographic coordinates of a sample collected in the Canyon or in the generation of topographic maps used for erosion monitoring of terraces adjacent to the Colorado River. The Survey department is also responsible for establishing and maintaining accurate geographic control in the Canyon that is essential for accurate geo-referencing of remotely sensed data and change detection of resource data using modern image processing and GIS technologies. These technologies are critical to the integration and analysis of the diverse scientific data that have been

collected in the Canyon over the past 15 years. Products of the Survey department include precise sample location coordinates, topographic maps, river channel maps and cross sections, digital elevation models, and digital terrain models. This information provides the basis for spatial analysis of data within the ecosystem using GIS software that in turn provides area and volumetric change detection capabilities of resources.

The Survey department is responsible for the development of sound topographic and mapping control required to build accurate spatial data sets that can be used for reliable change detection. David Evan's and Associates and Banner and Associates were hired in 1990 to establish a reliable geodetic control network. In 1991 Joseph Mihalko (NPS surveyor) occupied the Banner ground control points for a soil mapping project by the USGS. He found that the control points did not meet their claimed accuracy and precision. As a result, GCES established a survey department to correct all previously established survey control as well as meet research needs of the future.

The Survey department uses a variety of technology to assist in accomplishing its mission in a timely, cost effective manner that utilizes a minimum amount of personnel. These technologies include global positioning systems, multibeam acoustic technology, and conventional total station survey technology.

Ongoing activities are:

- Administer the survey program
- Service survey work requests

FY2002 activities are:

- Provide survey, control, and GPS support to remote sensing initiative
- Complete organization of legacy data

Provide survey, control, and GPS support to remote sensing initiative

Survey operations provide support to GCMRC remote sensing activities in the form of providing control and GPS base station data. Data provided from these activities is crucial to the geopositioning and rectification of remotely sensed data collected by the initiative and is fundamental to the application of remote sensing technologies in the CRE.

Complete organization of legacy data

As in other IT program functions, there is large amounts of legacy survey data pertaining to CRE resources that is worth keeping. This information will be inventoried, described, and translated into modern data systems. Survey operations will complete this activity in FY2002.

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002	
AMP Funding				
	Survey Services			
11.0	Salary (includes benefits)			**35,550**
	Surveyor - (1-fte) (5%)	33,200	4,300	
	Surveying Technician (1-fte) (25%)	37,050	14,250	
	Student Asst - Survey (.5-fte) (100%)	20,000	17,000	
	Operating Expenses:			**35,000**
21.0	Travel	2,000	2,000	
25.0	Services		6,000	
26.0	Supplies and Materials	6,000	27,000	
	TOTAL	**98,250**	**70,550**	**70,550**

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
Appropriations - Requested Funding			
25.0	Services - Surveying		**50,000**
	TOTAL		**50,000**

Systems Administration

The GCMRC computing environment is a complex system of servers, workstations, laptops, printers, plotters, modems, routers, hubs, switches, copy machines, FAX's, and telecommunications equipment networked together using 100baseT networking media. Most of the computers are of the PC type running the Windows NT/2000 operating system. In addition, over 50 applications are utilized by GCMRC scientists and support personnel in carrying out the collective mission of the GCMRC. Applications are primarily off-the-shelf products but in many cases are highly specialized.
Ongoing activities are to:

- Administer GCMRC network, computers, and software
- Troubleshoot day-to-day computer problems
- Upgrade existing computing infrastructure and provide new functionality

Budget:

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002	
AMP Funding				
	Systems Administration			
11.0	Salary (includes benefits)			**61,450**
	Res. Info Analyst (Prg Mgr) (1-fte) (5%)		4,450	
	Systems Administrator (1-fte) (95%)	61,000	57,000	
	Operating Expenses:			**111,000**
21.0	Travel		2,500	
25.0	Services		3,500	
26.0	Supplies and Materials	120,000	25,000	
31.0	Equipment		80,000	
	TOTAL	**181,000**		**172,450**

World Wide Web Services

Through the World Wide Web (WWW), general information about the GCMRC, its science programs, and the adaptive management program are provided there. In addition, Web interfaces to GCMRC databases, GIS data, library content, and other information will be provided through this medium.

Ongoing activities are:

- Administer the GCMRC website
- Troubleshoot day-to-day web problems

FY2002 objectives will focus on improving the quality of the website by:

- Creating more and better web content
- Making more frequent updates
- Creating more user friendly web interfaces
- Creating more easily navigable web pages
- Creating seamless integration of FTP content

Budget:

OBJECT CLASS	DESCRIPTION	FY-2002
AMP Funding		
	World Wide Web	
25.0	Contracts	**60,000**
	TOTAL	**60,000**

Aerial Photography

Aerial photography is a data collection function of the GCMRC ITP. Aerial photography is utilized by multiple researchers conducting scientific investigations in the Colorado River ecosystem. In FY2002 GCMRC will collect digital color infrared aerial photography with a ground resolution less than one foot. GCMRC will collect aerial photography on an annual basis to maintain a continuous photographic record of the Canyon started in 1990 at least until the protocol evaluation panels and remote sensing initiative conclude in 2002. The need for collecting annual aerial photography after 2002

will be reevaluated at that time. After 2002 it may continue, be discontinued, or modified based on the recommendations of the review panels and remote sensing report.

Budget:

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
Appropriations - Requested Funding			
	Aerial Photography		
25.0	Contracts		**135,000**
	TOTAL		**135,000**

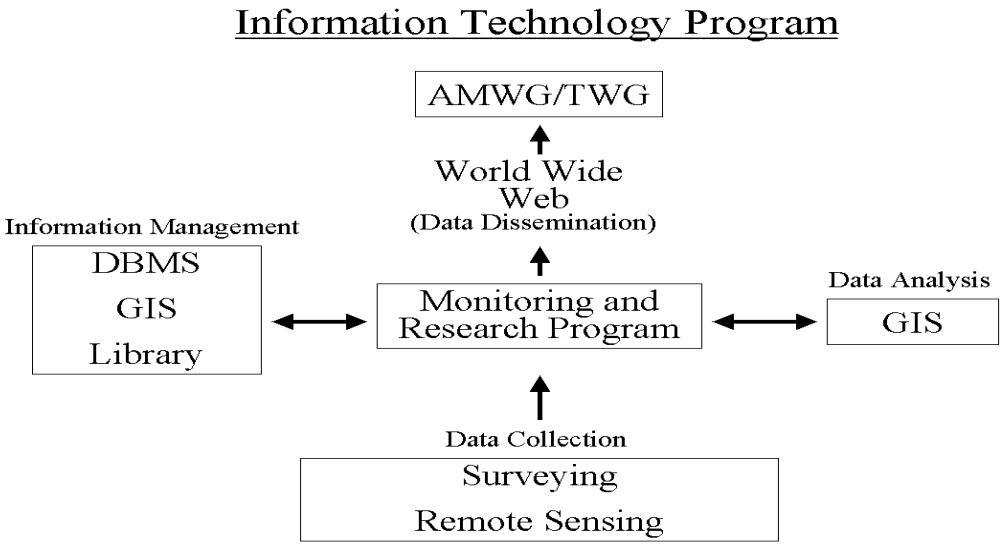

Figure 3.1. – Schematic illustrating the relationship of various Information Technology Program functions to the GCMRC monitoring and research program and the AMWG and TWG.

LOGISTICS

GCMRC monitoring and research programs are conducted by contracted Principal Investigators (PIs) whose work is administered by Program Managers in physical, biological and social-cultural resource programs. GCMRC staff also initiate some of their own in-house scientific activities which require logistical support, including the Integrated Water Quality Program. The GCMRC also supports Reclamation's logistics needs, including activities conducted by Native American groups under the Programmatic Agreement program and activities conducted to meet Reclamation's needs concerning endangered species. In addition, GCMRC provides logistics support for any contingency plans or experimental floods.

To meet these responsibilities, the GCMRC supports approximately 50 downriver trips annually on the Colorado River through Grand Canyon. These trips range from four to thirty-two people in size, seven to twenty days in length, and are comprised of a variety of combinations of oar and motor-powered boats. Trip planning begins in the fall, when a draft schedule of trips for the next fiscal year is generated by the PIs, GCMRC Logistics Coordinator and GCMRC Program Managers. Launch and take-out dates, boats to be used, trip rosters and itineraries are firmed up as soon thereafter as possible, and *must* be finalized 60 days prior to launch date and submitted to the Logistics Coordinator in order to meet the 45 day deadline for submitting launch permit application packets for each trip to the GCNP/NPS.

The GCMRC uses a "partially in-house" method of supporting trips in which government-owned boats and river logistical equipment are used in conjunction with four contracted vendors who supply Boat Operators, food packs, river put-in and take-out transportation and equipment rentals when needs exceed GCMRC inventory. Taken together, competitive bids from multiple subcontractors and better oversight over trip particulars that most influence cost (number of boats and Boat Operators, food packs, shuttle services) give the GCMRC much more control over trip costs.

In addition, the GCMRC in-house Logistics Coordinator and Program Managers are more able than subcontracted vendors to accommodate scientists who may be leaders in their field, but new to the Colorado River Ecosystem. More effective communication with PIs, and greater sensitivity to and awareness of the challenges they face in implementing their studies, enable the GCMRC to offer more tailored (and therefore more cost-effective) logistical support than any subcontracted vendor. Retaining more control over the process of supporting trips also facilitates better compliance with NPS regulations, and enables the GCMRC to match PIs with the best Boat Operators for their particular study.

A full-time Logistics Coordinator and Warehouse Manager are necessary under this approach. The partially in-house approach has proven to be most cost-effective because rental of frequently used

river equipment is minimized, while Boat Operators, drivers, and the capital-intensive, high maintenance vehicles used for put-ins and take-outs can be retained as needed through subcontractors.

Arrangements for operations services (Logistical and Technical Boat Operators) and support services (food packs, put-in/take-out transportation, equipment rentals) are made two to four weeks prior to launch date. Operations services are obtained through one of two contracted vendors, while support services are obtained through one of three contracted vendors. In certain cases, when the necessary expertise is available "in house," some operational and support services may be supplied by either GCMRC and/or the PI without the use of contracted vendors.

Logistics costs have been distributed to projects.

Budget:

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002	
11.0	Salary (includes benefits)			98,300
	Logistics Operations Specialist (95%)	55,000	51,300	
	Supply Technician "Warehouse" (75%)	30,000	30,000	
	Logistics SummerAid (100%)		17,000	
21.0	Travel			
25.0	Contracts			557,000
	Logistics Contracts	525,000	500,000	
	Permitting Contract	54,000	57,000	
25.0	Services			37,000
	Helicopter Support	30,000	31,000	
	Emergency Evacuation	6,000	6,000	
26.0	Supplies and Materials			5,000
	Warehouse Supplies	5,000	5,000	
31.0	Equipment	30,000	65,000	65,000
41.0	Grants, Subsidies and Contributions			
81.0	Intra-Office/Inter-Bureau			
	Non-salary logistics costs	650,000	664,000	
	Subtotal all logistics costs	735,000		762,300
	Allocation to Projects	437,000		762,300
	TOTAL	298,000		0

INDEPENDENT REVIEW PANELS

Peer Review

All of GCMRC's scientific activities undergo an independent, external peer-review. This is true for all proposals, whether unsolicited, submitted in response to an RFP, or an in-house proposal. Similarly all draft reports received by GCMRC undergo independent, external peer-review. The peer-review protocols developed by GCMRC meet or exceed the standards articulated by the Secretary of the Interior for Department of the Interior.

Peer-review for proposals received by GCMRC in response to an RFP is conducted through a panel process, while peer-review for unsolicited and in-house proposals, as well as project reports is conducted thorough the mail. In all cases, the peer-reviewers are offered anonymity and the individual and panel reviews, where applicable, are provided to the PIs along with comments from GCMRC.

The GCMRC review process is handled by a report review coordinator to ensure that the peer-review process is conducted one-step removed from the GCMRC program managers to guard against any conflicts of interest, real or perceived. Strict conflict-of-interest guidelines are adhered to. GCMRC annually recruits new individuals to join the ranks of its peer-reviewers and maintains a data base of almost 500 potential reviewers, organized by areas of expertise. GCMRC peer-reviewers come from academia, Federal, State and Tribal government, non-governmental organizations, and the private sectors. Reviewers are selected on the basis of their record of scientific accomplishment and expertise.

Science Advisory Board

The GCMRC established a Science Advisory Board (SAB) in FY 2001 as one of its independent review panels. The SAB is an advisory and not a decision-making body. It is an interdisciplinary board, composed of scientists who are qualified, based on their record of publication in the peer-reviewed literature, or other demonstrable scientific achievements.

The SAB together and individually will be expected in FY 2002, among other things, to review and comment to the AMWG and GCMRC on: (1) GCMRC's annual work plan and budget proposal, (2) GCMRC's long-term monitoring and research plan, (3) the results of GCMRC's completed monitoring and research activities, (4) the results of any synthesis and assessment activities initiated by the GCMRC, and (5) any other activities (i.e., program specific scientific advice) it is asked to address by the GCMRC Chief or the AMWG.

Budget – Independent Review Panels:

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
AMP Funding			
11.0	Salary (includes benefits)		**15,200**
	Chief (.10)		15,200
25.0	Contracts		
	Biology		
	Cultural		
	Physical		
25.0	Services		**179,000**
	RFP Review	65,000	66,000
	SAB Review	80,000	82,000
	Technical Report Review	25,000	26,000
	Unsolicited & In-House Proposal Review	5,000	5,000
	TOTAL	**175,000**	**194,200**
Appropriations - Requested Funding			
25.0	Contracts (Executive Secretary)		50,000
	TOTAL		50,000

PUBLIC OUTREACH

In conjunction with an ad hoc group of the AMWG, GCMRC is developing public outreach activities. These will range from material for articles to videotapes describing the adaptive management program and associated scientific activities, to providing GCMRC staff to speak at different meetings. To complement GCMRC's overall public outreach efforts, an outreach project is proposed that links the IT Program and Socio-cultural Program with the dissemination of cultural resource data. This effort is described as project C.8 in Chapter 2.

ADMINISTRATION & PERSONNEL

The GCMRC will be administered by a Chief and four program managers (physical, biological, socio-cultural, and information technologies) to oversee the individual resource areas and an extensive program of data analysis and management, GIS technology and information transfer, surveying and evaluation of remote sensing technologies. Together with the Chief, they will focus on program

integration and evaluation of Colorado River ecosystem resource interactions in response to dam operations.

In addition to their program management responsibilities, the program managers are also expected to remain subject area experts in their respective fields through the conduct of their own research on the Colorado River ecosystem. It is important that GCMRC program managers and scientific staff maintain this expertise so they can provide high quality technical assistance in the form of expert analysis, opinion, and advice to the Chief, TWG and the AMWG as requested. This will include but is not limited to the annual State of the Canyon Resources Report, evaluation of the BHBF resource criteria, preparing draft biological assessments and other such synthesis and activities which may be requested. The Socio-cultural Program Manager will also function as the Native American coordinator called for in the EIS. The program managers will supervise additional technical and support staff.

The GCMRC will continue to conduct all logistics for its programs internally in FY 2002, with direct coordination with appropriate NPS offices. This approach has proven its cost-effectiveness. In addition to cost savings, by running the logistics program in-house, GCMRC is able to ensure compliance with all NPS directives, consolidate and coordinate river trips, and create a level playing field so all researchers have an equal chance at competing for proposals and successfully implementing their projects. All river trip logistics and permitting, air photography, rescue, etc., is overseen by the logistics coordinator in cooperation with the NPS. GCMRC expects to initiate between 45 and 50 river trips in FY 2002. Running this many river trips requires a full-time logistics coordinator and a full-time warehouse technician.

All completed proposals, Principal Investigator reports, GCMRC reports, cooperative programs, etc., are subject to independent peer review according to GCMRC's peer-review protocols. Monitoring and research proposals are subjected to independent external peer- review and awards are made competitively based on these reviews. Also, all research proposed by GCMRC program managers and scientists undergoes an independent external review. Similarly, all PI reports and GCMRC reports are subject to independent external review. Managing GCMRC's peer-review process requires 3 to 6 person-months and is the responsibility of the Librarian/Review Coordinator. The Review Coordinator reports directly to the Chief and serves to see that the peer-reviews are overseen by someone one-step removed from the program activities to ensure the objectivity of the review, as specified in the DOI peer-review guidelines.

A Cultural Resources Task Group operates to facilitate the incorporation of cultural concerns within all GCMRC program areas to assist the GCMRC in the development of a more integrated program that incorporates Native American perspectives in project development and work plans. The Task Group consists of the GCMRC Socio-cultural Resources Program Manager, Reclamation's Regional Archaeologist, NPS managers, and Western Area Power Administration's Archaeologist, and Tribal representatives.

A Biological Opinion Task Group operates to ensure appropriate coordination between GCMRC and the monitoring and research needs of the Bureau and USFWS under various biological opinions. The Task Group consists of the GCMRC Biological Resources Program Manager and appropriate representatives of Reclamation, FWS, AGFD, Tribal governments, and other AMWG and TWG members. All proposed activities are reviewed by the TWG.

The Information Technologies program has personnel with specific responsibility for its Systems Administration, Data Base Management, GIS, Remote Sensing, and surveying activities. These personnel assure critical timely support to managers and other stakeholders in their interactions with the GCMRC, especially in their requests for information. For example, the surveying department is staffed by two full-time surveyors and a staff assistant who provide GCMRC and PIs with high quality, cost-effective, and timely support of their program and activities in the areas of terrestrial and bathymetric surveying. Having in-house capability ensures familiarity with the challenges of surveying in the canyon and promotes reproducible, quality data critical to sound monitoring and research programs.

As called for in the GCDEIS, independent review panels are utilized to evaluate GCMRC's Annual Plan, review proposals submitted to GCMRC for potential funding, review reports resulting from GCMRC sponsored activities, and provide advice to GCMRC and the AMWG. With respect to the SAB, GCMRC will designate a person to serve as the Executive Director who can provide leadership to the SAB and serve as the liaison officer to the AMWG and the GCMRC. It is anticipated that the role of Executive Director will require one to three person-months annually.

Budget – Administration and Personnel

FUNDING:

AMP	$1,203,270
Appropriations	$250,000
TOTAL	$1,453,270

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002	
AMP Funding				
	Administrative Operations			**817,540**
11.0	Salary (includes benefits)	318,000	283,540	
	Chief (1-fte) (40%)		60,800	
	Secretary (1-fte) (88%)		37,840	
	Administrative Officer (1-fte) (90%)		54,900	
	Administrative Assistant (1-fte) (100%)		37,000	
	Student Assistant - Secretary (.5-fte) (100%)		16,000	
	Student Assistant - Program Sup (.5-fte) (100%)		16,000	
	Logistics Operations Specialist (1-fte) (5%)		2,700	
	Supply Technician "Whse Mgr" (1-fte) (25%)		10,000	
	Biological Scientist (Program Mgr) (1-fte) (5%)		4,450	
	Biologist (General) (1-fte) (5%)		3,000	
	Biologist (Aquatic) (1-fte) (5%)		3,000	
	Ecologist (1-fte) (5%)		3,000	
	Physical Scientist (Program Mgr) (1-fte) (5%)		4,450	
	Social Scientist (Program Mgr)(1-fte) (5%)		4,450	
	Research Info. Analyst (Program Mgr (1-fte) (5%)		4,450	
	GIS Specialist (1-fte) (5%)		3,000	
	GIS Assistant (1-fte) (5%)		2,150	
	Computer Specialist, DBMS (1-fte) (5%)		3,700	
	Computer Specialist, Administrator (1-fte) (5%)		3,000	
	Technical Information Specialist (1-fte) (5%)		2,500	
	Surveyor (1-fte) (5%)		4,300	
	Surveying Technician (1-fte) (5%)		2,850	
	Awards	12,000		
21.0	Travel	33,000	25,000	
23.0	Payments Made to GSA		216,000	
	Space and Telecommunications	180,000	184,000	
	Vehicle Lease	30,000	32,000	
24.0	Printing and Reproduction		5,000	
	GPO Copy Agreement	5,000	5,000	
25.0	Services and Contracts		27,000	
	Office Equipment Maintenance & Repairs	6,000	7,000	
	Training Attendance	18,000	18,000	
	Vehicle Maintenance & Repairs	2,000	2,000	
26.0	Supplies and Materials	45,000	48,000	48,000
31.0	Equipment	20,000	20,000	20,000
81.0	Intra-Office/Inter-Bureau		193,000	
	Administrative & Network Support - USGS/FFC	64,000	65,000	
	Regional Office Administrative Support	125,000	128,000	

OBJECT CLASS	DESCRIPTION	FY-2001	FY-2002
	Biological Resources Management		**132,230**
11.0	Salary (includes benefits)	116,370	124,230
	Chief (1-fte) (5%)		7,600
	Secretary (1-fte) (2%)		860
	Administrative Officer (1-fte) (2%)		1,220
	Biological Scientist (Program Mgr) (1-fte) (35%)		31,150
	Biologist (General) (1-fte) (35%)		21,000
	Biologist (Aquatic) (1-fte) (55%)		33,000
	Ecologist (1-fte) (32%)		19,200
	Student Assistant - Biology (.5-fte) (60%)		10,200
21.0	Travel	8,000	8,000
	Physical Resources Management		**38,360**
11.0	Salary (includes benefits)	46,710	34,360
	Chief (1-fte) (5%)		7,600
	Secretary (1-fte) (2%)		860
	Administrative Officer (1-fte) (2%)		1,220
	Physical Scientist (Program Mgr) (1-fte) (22%)		19,580
	Student Assistant - Physical (.5-fte) (30%)		5,100
21.0	Travel	4,000	4,000
	Socio-Cultural Resources Management		**57,810**
11.0	Salary (includes benefits)	53,490	53,810
	Chief (1-fte) (5%)		7,600
	Secretary (1-fte) (2%)		860
	Administrative Officer (1-fte) (2%)		1,220
	Social Scientist (Program Mgr)(1-fte) (17%)		15,130
	Economist - Harpman (TSC) (100%)		12,000
	Student Asst - Cultural Resources (.5-fte) (100%)		17,000
21.0	Travel	4,000	4,000
	ITP Program Management		**67,520**
11.0	Salary (includes benefits)		59,520
	Research Info. Analyst (PrG. Mgr) (1-fte) (56%)	78,300	49,840
	Chief (5%)		7,600
	Secretary (2%)		860
	Administrative Officer (2%)		1,220
21.0	Travel	8,000	8,000
	AWG/TWG		**89,810**
11.0	Salary (includes benefits)		77,810
	Chief (1-fte) (30%)		45,600
	Secretary (1-fte) (4%)		1,720
	Administrative Officer (1-fte) (2%)		1,220
	Biological Scientist (Program Mgr) (1-fte) (5%)		4,450
	Physical Scientist (1-fte) (5%)		4,450
	Social Scientist (Program Mgr)(1-fte) (5%)		4,450
	Research Info. Analyst (Program Mgr) (8%)		7,120
	Surveyor (1-fte) (4%)		3,440
	GIS Specialist (1-fte) (4%)		2,400
	Computer Specialist (Database) (4%)		2,960
21.0	Travel	12,000	12,000
	TOTAL	1,188,870	**1,203,270**
Appro-priations			
11.0	Administrative Support Personnel (2 positions)		**120,000**
81.0	Administrative Support from Flagstaff & USGS Regions		**130,000**
	TOTAL		**250,000**

Program Schedule

The tentative schedule for implementation of the FY 2001 Monitoring and Research Plan (annual plan) is as follows:

January 11-12, 2000	AMWG review of FY 2002 Annual Plan and recommendations for implementation
March 2001	Review of FY 2000 program accomplishments
April 2001	First Progress Report due on FY 2001 program activities
April-May 2001	Release of RFPs
July 2001	Second Progress Report due on FY 2001 program activities
July 2001	Receipt of Proposals for FY 2002 program
August 2001	Panel Review of FY 2002 Proposals
September 2001	Notification of Intent for FY 2002 Awards
September 2001	Draft Final Reports due on FY 2001 program activities
Sept./Oct. 2001	FY 2002 Awards
October 2001	Develop Logistics Plan for FY 2002 program
October 2001	Draft FY 2003 Annual Plan and FY 2001 "State of the Colorado River Ecosystem Resources" report for review by TWG/AMWG
December 2001	Final "State of the Colorado River Ecosystem Resources" report to AMWG.
December 2001	Final Reports on FY 2001 programs with all contract deliverables
January 2002	AMWG review of FY 2003 Annual Plan and recommendations for implementation

GCMRC Budget

The total FY2002 budget for the GCMRC is $7,893,000. This includes $300,000 programmed for the IWQP in Lake Powell from Reclamation operation and maintenance funds and $1,010,000 in funds requested from appropriations.

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APPENDIX 1

MANAGEMENT OBJECTIVES AND INFORMATION NEEDS

A. Introduction

Management objectives and information needs help to define measurable standards of desired conditions which will serve as targets expected to be achieved by the participants in the AMP. The objectives and information needs also drive the strategic planning process and they provide the basis for the formulation of the long-term monitoring research program described elsewhere in this plan.

Historical Development Of The Management Objectives And Information Needs

Using the nine resource areas in the EIS, the Upper Colorado Regional Office of the Bureau of Reclamation worked with a subgroup of the Transition Work Group to develop management objectives intended to guide the development of GCMRC monitoring and research activities. This group was disbanded with the completion of their assignment and release of their July, 1996 recommendations.

Many stakeholders that participated in the Transition Work Group now serve in the AMWG and the TWG, providing continuity for the AMP. Also in 1996, under the guidance of GCMRC, several workshops were held with scientists who had conducted research under the auspices of GCES to define information needs associated with the various management objectives.

In July 1997, AMWG requested that the TWG proceed with the evaluation and revision of Management Objectives and the prioritization of Information Needs. The revision represents a concerted effort by the stakeholders to identify objectives as desired resource conditions sought by various stakeholders, and describe information needs in a way that clarifies the required data for assisting stakeholders in determining the condition of these resources, and how conditions are affected by management actions.

Revision Process and Prioritization Planning

Starting in January 1998, an ad hoc group from the TWG met to address the Management Objectives and Information Needs. Meetings were held to discuss general procedures for the revision process and the objectives and information needs by resource area. The purpose of the meetings was to review and revise management objectives and information needs, to establish relative priorities by study type, resource class, and research/monitoring question. The group was also tasked with reporting to the TWG during the process and to present recommendations on the revised information to the AMWG for adoption. The details of the prioritization process and the revised management objectives and prioritized information needs which provide the direction for strategic planning can be found in section B of this Appendix.

The prioritized information needs will permit the GCMRC to stage the various information needs currently specified by stakeholders over years FY2000 to 2004. High priority information needs will be initiated in years FY2000 and FY2001 whereas other monitoring and research needs may be delayed for initiation until FY2002 or beyond. As a result of developing this strategic plan, it has become clear that not all of the information needs currently proposed by stakeholders can be addressed in the next 5 years. Because the information needs are so extensive, and because many relate to annual or intermittent monitoring requirements, it is anticipated that about one-third to one-half of the information needs specified will actually be completed in the 5-year planning period and much monitoring is expected to continue into an extended 10-year program.

B. Summary

Table 2.4 Summary of MOs & INs. (See June 10, 1998, Management Objectives and Information Needs document for more detail.)

Resource Category	Short Name	Mgt Obj	Info Need	O	X	Mon or Res
Ecosystem assessment	Conceptual model	MO 1:	IN 1.1	7	14	R
Aquatic foodbase	Aquatic foodbase - monitor	MO 1:	IN 1.1	10	9	M
Aquatic foodbase	Aquatic foodbase - dam FX	MO 1:	IN 1.2	10	9	R
Aquatic foodbase	Aquatic foodbase for fish	MO 1:	IN 1.3	10	10	R
Trout	Trout population dynamics	MO 2:	IN 2.1	8	9	R
Trout	Trout population trends	MO 2:	IN 2.2	5	5	M
Trout	Trout condition #1	MO 2:	IN 2.3	2	1	M
Trout	Trout spawning habitat availability	MO 2:	IN 2.4	4	4	R
Trout	Trout condition #2	MO 2:	IN 2.5	4	0	M&R
Trout	Trout maintenance RX#1	MO 2:	IN 2.6	4	3	R
Trout	Trout/foodbase trophic dynamics	MO 2:	IN 2.7	3	4	R
Native Fish	HBC population dynamics	MO 3/4:	IN 3/4.1	10	10	M&R
Native Fish	HBC recruitment	MO 3/4:	IN 3/4.2	11	8	M&R
Native Fish	HBC winter survival	MO 3/4:	IN 3/4.3	10	8	R
Native Fish	HBC intrxn with NN fish	MO 3/4:	IN 3/4.4	2	0	R&M
Native Fish	HBC habitat availability	MO 3/4:	IN 3/4.5	10	6	R
Native Fish	HBC protocol and recreation FX	MO 3/4:	IN 3/4.6	2	1	Protocol R
Native Fish	HBC trophic dynamics	MO 3/4:	IN 3/4.7	7	6	R
Native Fish	HBC YOY habitat and NNS interxs	MO 3/4:	IN 3/4.8	7	6	R
Native Fish	HBC population loss to flows	MO 3/4:	IN 3/4.9	6	5	R
Native Fish	HBC good year strategy	MO 3/4:	IN 3/4.10	4	2	Admin.
Native Fish	HBC downstream transport	MO 3/4:	IN 3/4.11	6	3	R
Native Fish	HBC flow-related take	MO 3/4:	IN 3/4.12	9	8	R
Native Fish	HBC flow criteria to limit take	MO 3/4:	IN 3/4.13	8	7	Admin.
Native Fish	Threatened fish - RPM test flows	MO 3/4:	IN 3/4.14	5	4	R
Native Fish	Native fish – mainstream thermal	MO 5:	IN 5.1	6	2	R
Native Fish	Native fish – thermal mod FX#1	MO 5:	IN 5.2	10	10	R
Native Fish	Native fish – thermal mod FX#2	MO 5:	IN 5.3	14	14	R
Native Fish	Thermal mod impacts on LP fish	MO 5:	IN 5.4	7	2	R

Native Fish	NN fish control – temperature and	MO 5:	IN 5.5	9	9	R
Native Fish	HBC population mgt. criteria	MO 6:	IN 6.1	9	8	R
Native Fish	HBC 2nd pop. Feasibility study	MO 6:	IN 6.2	9	7	R
Native Fish	RBS 2nd pop. Feasibility study	MO 7:	IN 7.1	7	5	R
Native Fish	Native fish pop. Status	MO 8:	IN 8.1	9	8	M
Native Fish	Native fish pop. Dynamics#1	MO 8:	IN 8.2	7	4	M
Native Fish	Native fish historic pop. dynamics #1	MO 8:	IN 8.3	3	1	M&R
Native Fish	Native fish historic pop. dynamics#2	MO 8:	IN 8.4	5	2	M&R
Native Fish	Native fish flow regime FX	MO 8:	IN 8.5	7	4	R
Native Fish	Native fish maintenance criteria	MO 8:	IN 8.6	7	4	R
Native Fish	Native fish experimental flows design	MO 9:	IN 9.1	3	2	R
Native Fish	Native fish experimental flows design	MO 9:	IN 9.2	5	1	R
Native Fish	Native fish trib flows and recruitment	MO 9:	IN 9.3	7	3	M&R
Native Fish	Native - NN fish nearshore intrxns	MO 9:	IN 9.4	6	1	R
Native Fish	Native/NN fish intrxns #1	MO 10:	IN 10.1	6	5	R
Native Fish	Native/NN fish intrxns #2	MO 10:	IN 10.2	4	3	R
Native Fish	Native/NN fish mitigation intrxns	MO 10:	IN 10.3	3	3	R
Native Fish	NN fish distrib. And natural history	MO 10:	IN 10.4	5	2	M
Native Fish	Native/NN fish intrxns #3	MO 10:	IN 10.5	6	2	R
Native Fish	Native and NN fish autecology	MO 10:	IN 10.6	6	2	M&R
Riparian	Autecology of riparian species	MO 11:	IN 11.1	9	9	M&R
Riparian	Riparian population variability	MO 11:	IN 11.2	4	6	M&R
Riparian	Riparian SOC population changes	MO 11:	IN 11.3	2	4	M&R
Riparian	Riparian species habitat distribution	MO 11:	IN 11.4	5	7	M&R
Riparian	Riparian habitat map	MO 11:	IN 11.5	5	4	R
Riparian	Monitor leopard frogs	MO 11:	IN 11.6	6	8	R
Riparian	Feasibility of 2nd leopard frog	MO 11:	IN 11.7	1	1	Admin.
Riparian	Evaluate amphibian sensitivity	MO 11:	IN 11.8	2	3	R
Riparian	Riparian spp – dam FX on	MO 12:	IN 12.1	6	8	R
Riparian	Riparian spp – ranges	MO 12:	IN 12.2	1	1	R
Riparian	Riparian spp – age classes	MO 12:	IN 12.3	0	0	R
Riparian	Riparian spp – dam FX on	MO 12:	IN 12.4	2	2	R
Riparian	Riparian spp – general dam FX	MO 12:	IN 12.5	1	1	R&M
Riparian	Riparian food webs: SOC	MO 13:	IN 13.1	7	7	R&M
Riparian	Riparian food webs: birds	MO 13:	IN 13.2	6	8	R
Riparian	Pefa - aerie distribution	MO 13:	IN 13.3	1	1	R&M
Riparian	Pefa - population dynamics	MO 13:	IN 13.4	2	2	R
Riparian	Bald eagle - dam FX	MO 13:	IN 13.5	3	3	R&M
Riparian	KAS - habitat RX #1	MO 14:	IN 14.1	9	8	M
Riparian	KAS - special flow impacts	MO 14:	IN 14.2	7	7	R&M
Riparian	KAS - habitat RX #2	MO 14:	IN 14.3	8	8	R&M
Riparian	KAS - monitor exceptional flow	MO 14:	IN 14.4	7	7	M
Riparian	KAS - life history schedule	MO 14:	IN 14.5	7	7	R&M
Riparian	KAS - monitor #1	MO 14:	IN 14.6	11	10	R&M
Riparian	KAS - monitor #2	MO 14:	IN 14.7	5	6	M
Riparian	KAS - genetic relationships	MO 15:	IN 15.1	7	5	R
Riparian	KAS - habitat propagation	MO 15:	IN 15.2	6	4	R

Riparian	Riparian veg – distribution: all #1	MO 16:	IN 16.1	5	6	M
Riparian	Riparian veg – distribution: OHW	MO 16:	IN 16.2	4	5	R&M
Riparian	Riparian veg – maintain and restore	MO 16:	IN 16.3	0	0	M
Riparian	Riparian veg – dam FX	MO 16:	IN 16.4	4	4	R&M
Riparian	Riparian veg - life histories	MO 16:	IN 16.5	2	2	R
Riparian	Riparian veg – NNS and dam FX	MO 16:	IN 16.6	4	5	R&M
Cultural	Cultural sites – monitor	MO 1:	IN 1.1	12	13	M
Cultural	Cultural sites – risk assessment	MO 1:	IN 1.2	6	4	R
Cultural	Cultural sites – info needs	MO 1:	IN 1.3	7	7	Admin.
Cultural	Cultural sites – monitor risk	MO 1:	IN 1.4	6	5	R&M
Cultural	Cultural sites – preserve terraces #1	MO 1:	IN 1.5	5	2	M
Cultural	Cultural sites – preserve terraces #2	MO 1:	IN 1.6	6	2	R&M
Cultural	Cultural sites & recreation FX	MO 1:	IN 1.7	1	0	R
Cultural	Cultural sites – mitigation strategies	MO 2:	IN 2.1	9	9	Admin.
Cultural	Cultural sites – data recovery	MO 2:	IN 2.2	5	2	Admin.
Cultural	Cultural sites – characterize dam FX	MO 3:	IN 3.1	9	6	R
Cultural	Cultural site data management	MO 4:	IN 4.1	7	5	Admin.
Socioeconomic	Socioeconomics - monitor hydropower	MO 1:	IN 1.1			M
Socioeconomic	Socioeconomics - costs of ROD	MO 1:	IN 1.2			M
Socioeconomic	Socioeconomics - research costs	MO 1:	IN 1.3			M
Socioeconomic	Socioeconomics - integrated systems	MO 1:	IN 1.4			Admin.
Water	Flow - monitor releases	MO 1:	IN 1.1			M
Water	Flow - monitor WQ and dam FX on	MO 2:	IN 2.1	9	9	M
Water	Flow - thermal modification	MO 2:	IN 2.2	6	6	R&M
Sediment	Sediment – historic distribution & flow	MO 1:	IN 1.1	5	7	R&M
Sediment	Sediment – minimum storage for	MO 1:	IN 1.2	9	11	R
Sediment	Sediment – monitor flow FX by reach	MO 1:	IN 1.3	7	10	R
Sediment	Sediment - monitor inputs: all	MO 1:	IN 1.4	8	10	R&M
Sediment	Sediment – GCNRA bar distribution,	MO 1:	IN 1.5	5	6	R&M
Sediment	Sediment - bar & backwater	MO 2:	IN 2.1	1	1	M
Sediment	Sediment – establish baselines	MO 2:	IN 2.2	3	2	Admin.
Sediment	Sediment – monitor sand bar	MO 2:	IN 2.3	3	5	R&M
Sediment	Cultural - monitor terraces	MO 2:	IN 2.4	2	3	M
Sediment	Sediment - bar & backwater	MO 2:	IN 2.5	3	3	R&M
Sediment	Sediment - bar, backwater and camp	MO 2:	IN 2.6	6	8	R&M
Sediment	Sediment - bar & backwater	MO 2:	IN 2.7	2	5	R
Sediment	Flow - spillway impacts on bed and	MO 2:	IN 2.8	1	1	R&M
Sediment	Backwater distribution: '90-91, 96-97	MO 3:	IN 3.1	4	3	R
Sediment	Backwater distribution: '90-91, 96-97	MO 3:	IN 3.2	3	2	R
Sediment	Sediment - bar & backwater	MO 3:	IN 3.3	3	4	R&M
Sediment	Sediment – linkage to biota	MO 3:	IN 3.4	7	8	R
Sediment	Backwater distribution: '90-91, 96-97	MO 3:	IN 3.5	2	3	R
Sediment	Backwater distribution: '90-91, 96-97	MO 4:	IN 4.1	6	6	R&M
Sediment	Sediment - model dam FX on bars,	MO 4:	IN 4.2	4	6	Admin.
Sediment	Sediment – assess dam FX on bars,	MO 4:	IN 4.3	5	5	Admin.
Sediment	Sediment - monitor inputs: Marble	MO 4:	IN NH1.	3	3	R&M
Sediment	Sediment – GCNRA high terrace	MO 4:	IN NH2.	1	1	R

Sediment	Sediment - monitor inputs: GCNRA	MO 4:	IN NH3.	2	2	R
Sediment	Sediment – GCNRA high terrace	MO 4:	IN NH4.	2	1	R&M
Sediment	Sediment – GCNRA bed morphology	MO 4:	IN NH5.	2	4	R
Sediment	Sediment – GCNRA grain size	MO 4:	IN NH6.	1	1	R
Sediment	Sediment – historic distribution & flow	MO 4:	IN NH7.	0	2	R&M
Sediment	Sediment – historic distribution & flow	MO 4:	IN NH8.	2	3	R&M
GIS	GIS - map topography, geology, soils	MO 1:	IN 1.1	1	1	R
GIS	GIS - data archival and storage	MO 1:	IN 1.2	0	2	Admin.
Recreation	Recreation – experience	MO 1:	IN 1.1	4	9	R&M
Recreation	Recreation – monitoring and research	MO 1:	IN 1.2	2	5	R
Recreation	Recreation – mitigate negative flow FX	MO 1:	IN 1.3	4	10	Admin.
Recreation	Recreation – angler satisfaction, use	MO 1:	IN 1.4	2	3	R&M
Recreation	Water - heavy metal impacts on fish	MO 1:	IN 1.5	0	0	R
Recreation	Recreation – camp	MO 2:	IN 2.1	1	10	R&M
Recreation	Recreation - dam FX on camp	MO 2:	IN 2.2	6	8	Admin.
Recreation	Recreation – develop campsite	MO 2:	IN 2.3	1	3	Admin.
Recreation	Recreation – model flow FX on	MO 2:	IN 2.4	2	2	R
Recreation	Recreation safety - boating: GCNRA	MO 3:	IN 3.1	1	3	R&M
Recreation	Recreation safety - boating: all	MO 3:	IN 3.2	3	3	R&M
Recreation	Recreation safety - boating: Grand	MO 3:	IN 3.3	2	1	R&M
Recreation	Ecosystem Assessment - FX of flows	MO 3:	IN 3.4	1	0	Admin.
Recreation	Recreation – Resource conflicts with	MO 3:	IN 3.5	2	1	Admin.
Recreation	Trout - flows RX for 100k trout	MO 4:	IN 4.1	2	7	R
Recreation	Waterfowl – hunter use, satisfaction,	MO 5:	IN 5.1	1	2	R
Lake Powell	Water - Lake Powell WQ	MO 1:	IN 1.1	10	14	R&M
Lake Powell	Water - dam FX on Lake Powell WQ	MO 1:	IN 1.1 (Biol)	5	12	R
Lake Powell	Water - Lake Powell, selenium	MO 1:	IN 1.2	1	0	R
Lake Powell	Water - water temperature impacts in	MO 2:	IN 2.1	1	9	R
Lake Powell	Lake Powell - dam FX on surface flux	MO 2:	IN 2.2	0	1	R&M
Lake Powell	Water - Lake Powell, selenium	MO 2:	IN 2.3	0	0	R
Lake Powell	Lake Powell – dam FX on advective	MO 2:	IN 2.4	0	1	R&M
Lake Powell	Lake Powell - fish: dam FX on pred-	MO 2:	IN 2.5	1	1	R
Lake Powell	Lake Powell - fish: dam FX on	MO 2:	IN 2.6	1	5	R
Aquatic foodbase	Fisheries – habitat distribution:	MO 1:	IN 1.7	1	3	R
Aquatic foodbase	GIS - aquatic habitat map by stage	MO 1:	IN 1.8	1	1	R
Aquatic foodbase	Fisheries - dam FX on habitat	MO 1:	IN 1.9	2	4	R
Aquatic foodbase	Aquatic foodbase - exposure FX	MO 1:	IN 1.10	2	3	R
Aquatic foodbase	Aquatic foodbase - dam FX on	MO 1:	IN 1.11	0	0	R
Aquatic foodbase	Water - selenium impacts on	MO 1:	IN 1.12	1	0	R
Native fish	FMS spawning hab. distrib. #1:	MO 8:	IN 1. (App.)	3	1	R&M
Native fish	FMS adult origins	MO 8:	IN 2. (App.)	2	2	R&M
Native fish	FMS spawning hab. distrib. #2: Glen	MO 8:	IN 3. (App.)	3	1	R&M
Native fish	FMS mechanisms of spawning failure	MO 8:	IN 4. (App.)	2	1	R
Native fish	Native fish - FMS dam FX on	MO 8:	IN 5. (App.)	3	2	R
Native fish	Native fish – spawning and trib.	MO 8:	IN 6. (App.)	2	1	R&M
Native fish	Aquatic foodbase - dam FX on	MO 8:	IN 7. (App.)	0	0	R&M
Native fish	Native fish - FMS habitat RX	MO 8:	IN 8. (App.)	1	0	R

Native fish	Native fish - FMS spawning hab.	MO 8:	IN 9. (App.)	1	0	R&M
Native fish	Native fish - MS spawning hab. distrib.	MO 8:	IN 10.	0	0	R&M
Native fish	Native fish - FMS population model	MO 8:	IN 11.	2	1	R
Native fish	Native fish - FMS habitat modification	MO 8:	IN 12.	1	0	Admin.
Native fish	Native/NN fish intrxns #4	MO 8:	IN 13.	2	0	R
Native fish	Water - selenium FX on native fish	MO 8:	IN 14.	0	0	R

APPENDIX 2

GRAND CANYON MONITORING AND RESEARCH CENTER (GCMRC)

MISSION

To provide credible, objective scientific information to the Adaptive Management Program on the effects of operating Glen Canyon Dam on the downstream resources of the Colorado River ecosystem, utilizing an ecosystem science approach.

ROLES AND RESPONSIBILITIES OF GCMRC

1. Advocate quality, objective science and the use of that science in the adaptive management decision process.
2. Provide scientific information for all resources of concern identified in the "Operation of Glen Canyon Dam Final Environmental Impact Statement."
3. Support the Secretary's designee and the Adaptive Management Work Group in a technical advisory role.
4. Develop research designs and proposals for implementing, by GCMRC and/or its contractors, monitoring and research activities in support of information needs identified by the Adaptive Management Work Group.
5. Coordinate review of the monitoring and research program with independent review panel(s).
6. Coordinate, prepare, and distribute technical reports and documentation for review and as final products.
7. Prepare and forward technical management recommendations and annual reports, as specified in Section 1804 of the Grand Canyon Protection Act to the Technical Work Group.
8. Manage all data collected as part of the Adaptive Management Program. Serve as a repository (source of information) for others (stakeholders, students, public, etc.) in various formats (paper, electronic, etc.) about the effects of operating Glen Canyon Dam on the downstream resources of the Colorado River ecosystem and the Adaptive Management Program.
9. Administer research proposals through a competitive contract process, as appropriate.
10. Manage GCMRC finances and personnel efficiently and effectively.

July 1999

APPENDIX 3

Table 2.1. Summary table of FY2002 Project titles and associated Management Objectives and Information Needs.

A. TERRESTRIAL ECOSYSTEM ACTIVITIES	
Project Title and ID: A.1. Terrestrial Ecosystem Monitoring	
Status: Ongoing, originally initiated in FY2001.	
MANAGEMENT OBJECTIVE	INFORMATION NEED
TERR MO 11: 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. **TERR MO 12:** Maintain a natural age-class distribution of wildlife species throughout the majority of natural range in Glen and Grand Canyon… **AVI MO 13:** Protect, restore, and enhance survival of native and special status avifauna.	TERR IN 11.1 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 TERR IN 11.2 Determine species population characteristics to detect departures from natural range of variation. TERR IN 11.3 Determine changes, declines in special status species and characterize ecosystem changes to benefit species. TERR IN 12.1 Identify terrestrial species potentially affected by dam operations and determined effects on distribution, abundance and population structure. AVI IN 13.2 Determine impacts of dam operations under approved operating criteria on avifauna food chain associations
Project Title and ID: A.2. Monitoring kanab ambersnail and habitat at Vaseys Paradise	
Status: Ongoing.	
KAS MO 14: Sustain populations of Kanab ambersnail wherever they currently exist within the Colorado River ecosystem.	KAS IN 14.4 Survey KAS habitat before and after any flow greater than 25,000 cfs to determine population and its species response to disturbance and ability to recover. (T&C 4, p.42; and RPM) KAS IN 14.7 Determine changes in populations, health and character of Kanab ambersnail.
Project Title and ID: A.3. New research in terrestrial ecosystems	
Status: New for FY2002	
PLACE HOLDER FOR SEVERAL POTENTIAL PROJECTS	**PLACE HOLDER FOR SEVERAL POTENTIAL PROJECTS.**

Project Title and ID: A.4. Evaluation of cultural resource monitoring and mitigation strategies	
Status: New for FY2002	
CULT MO 1: Conserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in the Colorado River ecosystem.	CULT IN 1.1 Monitor cultural sites potentially impacted by Glen Canyon Dam operations to determine present condition and rate of change to assess: types of degradation, threats; rates of degradation; define immediacy of threats to resources; protection methodologies; protection, monitoring and research costs.
CULT MO 2: If *in situ* conservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with a scientific approach	CULT IN 2.1 Characterize through scientific study and data development all assumed historical and current values, including scientific values, of resources to tribal nations and to the general public.
Project Title and ID: A.5. Development of historic contexts to evaluate the significance of cultural resource data	
Status: New for FY2002	
CULT MO 4: Maintain and integrate all appropriate cultural data recovered from monitoring, remedial, and mitigative action and incorporate these data into the evolving research designs and mitigative strategies for understanding the human occupation and use of the Colorado River ecosystem.	CULT IN 4.1 Develop evolving research designs and/or other methods including synthesis of existing available data and GIS for understanding human occupation and use.
Project Title and ID: A.6. Terrestrial habitat map and inventory	
Status: New for FY2002	
TERR MO 11: 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	TERR 11.4. Identify and characterize riparian wildlife habitat types along the river corridor

B. AQUATIC ECOSYSTEM ACTIVITIES

Project Title and ID: B.1. Monitoring aquatic foodbase and evaluating its quality for utilization

Status: Ongoing. Originally approved and implemented in FY2001. May be revised based on PEP recommendations.

AFB MO 1: Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam.	AFB IN 1.1 Determine status and trends in aquatic food base species composition and population structure, density and distribution and the influence of ecologically significant processes. AFB IN 1.2 Determine the effects of past, present, and future dam operations under the approved operations criteria on the aquatic food base species composition, population structure, density, and distribution in the Colorado River ecosystem. AFB IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado River ecosystem. HBC IN 3/4.7 Determine origins of fish food resources, energy pathways, and nutrient sources important to their production, and the effects of Glen Canyon Dam operations on these resources. (RPM 1.C.vi) Evaluate linkages between the aquatic food base and the health and sustainability of HBC populations.

Project Title and ID: B.2. Monitoring of the status and trends of the downstream fish community

Status: Ongoing. Originally approved and implemented in FY2001. Will be revised based on PEP recommendations.

HBC MO 4: Maintain or enhance levels of recruitment of HBC in the mainstem 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.) **FMS MO 8:** Achieve healthy, self-sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon based upon the capability of the habitat to support those fishes. **MO 10**: Minimize to the extent possible, competitive and predatory interactions between native & non-native fishes.	HBC IN 3/4.1 Determine adult HBC populations and evaluate life history schedules, population health, and reproductive success. *(Fall 97 RPM 1)* HBC IN 3/4.2 Determine levels of recruitment of humpback chub in the mainstem and the LCR. FMS IN 8.2 Determine population dynamics, distribution, and other life history traits of native fish species. FMS IN 8.3 Determine historic and current character and structure of native fish populations. IN 10.1. Define areas and conditions of existing and potential interations. N/NN FISH IN 10.4 Determine the species composition, relative abundance, and size class structure of non-native fishes in the Colorado River ecosystem and important tributaries.

Project Title and ID: B.3. Monitoring the status and trends of the Lees Ferry Fishery	
Status: Ongoing. Originally approved and implemented in FY2001.	
TROUT MO 2: In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, foodbase and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (Wr) of at least 0.90.	TROUT IN 2.2 Determine trends in rainbow trout population size, character and structure in Glen Canyon. TROUT IN 2.3 Evaluate harvested and field sampled rainbow trout to determine the contribution of naturally reproduced fish to the population in Glen Canyon.
Project Title and ID: B.4. Ongoing research associated with population genetics of HBC in Colorado River ecosystem	
Status: Ongoing.	
HBC MO 6: Establish a second spawning aggregation of HBC downstream of Glen Canyon Dam (RPM 4).	HBC IN 6.1 Develop criteria for defining self-sustaining populations of HBC. HBC IN 6.2 Assess feasibility of establishing a second population of HBC downstream of Glen Canyon Dam including other current aggregations.
Project Title and ID: B.5. New research associated with interactions between native and non-native fish species	
Status: New.	
N/NN FISH MO 10: Minimize, to the extent possible, competitive and predatory interactions between native and non-native fishes.	N/NN FISH IN 10.1 Define areas and conditions of existing and potential interactions. N/NN FISH IN 10.4 Determine the species composition, relative abundance, and size class structure of non-native fishes in the Colorado River ecosystem and important tributaries.

Project Title and ID: B.6. Integrated Water Quality Monitoring	
Status: New. A revised IWQP will be implemented based on the recommendation of the IWQP PEP that will be held in December 2000.	
LP WQ MO 1: Prevent impacts that adversely affect the water quality (physical, chemical, biological) of Lake Powell due to dam operations and ensure that fully informed AMWG decisions are possible both now and in the future.	LP-LIMNO IN 1.1 Determine the effect of current dam operations (under approved operating criteria) on reservoir water quality, including but not limited to the following: (a) Determine near dam hydrogen sulfide levels (and other hazardous chemical constituents) within the hypolimnion occurring under current dam operating criteria. (b) Determine the dynamics of lake stratification and advective flows and their effects on chemical constituents (c) Determine/quantify the dynamics of major cations, anions, and nitrate/phosphate ratios resulting from dam operations (d) Determine the effects of dam operations (under approved operating criteria) on the physical/chemical dynamics of Lake Powell side channels and embayments LP-BIO IN 1.1 Determine the impacts of dam operations and resulting water quality on primary and secondary productivity of Lake Powell, including: • **algae (phytoplankton, periphyton)** • Macrophytes • **Zooplankton**
WATER MO 2: (water resources) Maintain water quality at levels appropriate to support physical, biotic, and human resource needs…	WATER IN 2.1 Monitor water quality, composition, temperature (a more comprehensive list of the INs that are addressed by the IWQP can be seen in Table 1 of the IWQP plan (Vernieu and Hueftle, 1999).

C. INTEGRATED TERRESTRIAL AND AQUATIC ECOSYSTEM ACTIVITIES

Project Title and ID: C.1. Long-term monitoring of fine-grained sediment storage throughout the main channel

Status: Ongoing. Originally approved and implemented in FY2001.

SED MO 1: (sediment resources) Maintain a long-term balance of river-stored sand to support maintenance flow, BHBF flow and unscheduled flood flows…	SED IN 1.1 Define historical and current levels of river stored sediment. SED IN 1.2 Define minimum levels of river stored sediments necessary to maintain sandbars, backwaters and in-stream sediment deposits. SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources. SED IN 1.5 (sediment) Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment. SED IN 2.4 Evaluation of flow regime (under the approved operating criteria) impacts on terrace and cultural resources SED IN 2.6 Determine implications of dam operating criteria on beach and sandbar and backwater character and structure, including suitability of camping beaches. SED IN 2.7 Quantify the extent and location of existing sandbars, beaches and backwaters along the Colorado River corridor SED IN 4.1 Define character and structure of all beaches and backwaters in system after 1996 test flows
SED MO 2: As a minimum for each reach, maintain the number and average size (area and thickness) of sandbars and backwaters between the stages associated with flows of 8,000 and 45,000 cfs that existed during the 1990/91 research flows.	REC IN 2.2 Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure. REC IN 2.3 Develop methodology to evaluate distribution, quantity and quality changes in all campable beaches through time
SED MO 4: Maintain system dynamics and disturbance by	AFB IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado

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 BHBF hydrologic and resource criteria are met. **REC MO 2:** Maintain flows (under approved operating criteria) and sediment processes that create an adequate quantity, distribution and variety of beaches for camping, as long as such flows are consistent with management of natural recreation and cultural resource values (other natural resource values). **AFB MO 1:** Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam. **TROUT MO 2:** In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, food base and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (Wr) of at least 0.90. **HBC MO 4:** Maintain or enhance levels of recruitment of HBC in the mainstem 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.) **CULT MO 1:** Conserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in the Colorado River ecosystem.	River ecosystem. TROUT IN 2.4 Determine the availability and quality of spawning substrates in the Glen Canyon reach, necessary to sustain the rainbow trout fishery. HBC IN 3/4.5 Determine the effects of mainstem hydrology on the number of nearshore rearing habitats, environmental conditions in these habitats, and their successful utilization by HBC. (RPM 1.C.iii) HBC IN 3/4.8 Determine effects on physical habitat used by young fishes, food base, and direct effect on larval, juvenile, and adult native and non-native fishes of 1996 BHBF. Develop methods to detect changes in numbers of HBC or their habitat from 1996 BHBF. (1996 BHBF HBC RPM 3) CULT IN 1.4 Preservation, stabilization and/or documentation of cultural resources as impacted by sediment resources associated with alternative operating criteria CULT IN 1.5 Preservation, stabilization of flood terraces holding cultural resources CULT IN 1.6 Evaluate flood terrace stability necessary to maintain cultural resources and terraces at pre-dam conditions

Project Title and ID: C.2. Long-term streamflow and fine sediment transport in the main channel Colorado, Paria and Little Colorado Rivers	
Status: Ongoing. Approved and implemented in FY2001 through a sole source award to the USGS.	
WATER MO 1: …Operate GCD in a manner fully consistent with the ROD and subject to the "Law of the River"…	WATER IN 1.1 Annually collect and report GCD flow release information.
WATER MO 2: Maintain water quality at levels appropriate to support physical, biotic, and human resource needs of various ecosystems downstream of Glen Canyon Dam as mandated by the Grand Canyon Protection Act and incorporated into the Record of Decision.	WATER IN 2.1 Characterize sandbar/backwater baselines and character and structure in 1990/1991 WATER IN 2.2 Working with various resource agencies and specialists, select most appropriate flow levels/regimes under the approved operating criteria to determine baseline for comparisons for all resources.
SED MO 1: 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. 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 cfs and maximum power plant capacity.	SED IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment.
SED MO 4: 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 BHBF hydrologic and resource criteria are met	SED IN 4.2 Develop methodologies to define future flow regimes under approved operating criteria to maximize benefit to sediment and backwater character and structure SED IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges
REC MO 4: Maintain flows (under approved operating criteria) and habitat suitable for quality cold water fishery opportunities in Glen Canyon.	REC IN 4.1 Determine flow regimes (under approved operating criteria) necessary to maintain fish populations of 100,000 adult Trout (age class II plus)

Project Title and ID: C.3. Long-term monitoring of coarse-sediment inputs, storage and impacts to physical habitats	
Status: Ongoing. Originally approved and implemented in FY2001.	
REC MO 1: Provide quality recreation experiences consistent with other resource objectives.	REC IN 1.1 Determine criteria and aspects that are important to or detract from recreational experience.
SED MO 1: 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. 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 cfs and maximum power plant capacity.	SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources
AFB MO 1: Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam.	AFB IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado River ecosystem.
TROUT MO 2: In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, food base and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (Wr) of at least 0.90.	TROUT IN 2.4 Determine the availability and quality of spawning substrates in the Glen Canyon reach, necessary to sustain the rainbow trout fishery.
FMS MO 8: Achieve healthy, self-sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon based upon the capability of the habitat to support those fishes.	FMS IN 8.4 Determine historic and current ecosystem requirements (habitat, spacing, food source, interdependencies, etc.) of native fish species.
TERR MO 11: 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.	TERR IN 11.4 Identify and characterize riparian wildlife habitat types along the river corridor
VEG MO 16: Maintain, enhance or restore vegetative communities made up of diverse groups of native riparian and upland species with special emphasis on preservation of unique plant communities and special status species at different stages of succession and at different elevations above the water line.	VEG IN 16.1 Determine distribution and abundance of native and non-native riparian and upland vegetation, including federal-, state- and tribal-listed sensitive species, old high water zone, new high water zone, and nearshore marshes

Project Title and ID: C.4.A. Modeling reach-averaged sandbar evolution in response to discharge and sediment conditions	
Status: Ongoing. Originally approved and implemented in FY2001.	
SED MO 1: 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. 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 cfs and maximum power plant capacity. **SED MO 2:** As a minimum for each reach, maintain the number and average size (area and thickness) of sandbars and backwaters between the stages associated with flows of 8,000 and 45,000 cfs that existed during the 1990/91 research flows. **SED MO 4:** 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 BHBF hydrologic and resource criteria are met.	SED IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment. SED IN 2.4 Evaluation of flow regime (under the approved operating criteria) impacts on terrace and cultural resources SED IN 4.2 Develop methodologies to define future flow regimes under approved operating criteria to maximize benefit to sediment and backwater character and structure SED IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges
Project Title and ID: C.4.B. Development of one-dimensional fine sediment routing model along the main channel	
Status: Ongoing. Originally approved and implemented in FY2001.	
SED MO 1: 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. 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 cfs and maximum power plant capacity.	SED IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits SED IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment

Project Title and ID: C.5. Advance conceptual modeling of coarse-grained sediments related to evolving physical habitats and aquatic processes	
Status: Ongoing. Originally approved and implemented in FY2001.	
SED MO 1: 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. 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 cfs and maximum power plant capacity. **SED MO 4:** 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 BHBF hydrologic and resource criteria are met. **REC MO 2:** Maintain flows (under approved operating criteria) and sediment processes that create an adequate quantity, distribution and variety of beaches for camping, as long as such flows are consistent with management of natural recreation and cultural resource values (other natural resource values).	SED IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources. SED IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3) understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment. SED IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges REC IN 2.1 Determine adequate beach quantity, quality, distribution, character and structure for camping throughout system. REC IN 2.2 Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure.
Project Title and ID: C.6. Development of a CRE Control network	
Status: Ongoing. Originally approved and implemented in FY2000.	
Project Title and ID: C.7. Development of CRE Hydrographic Mapping Program	
Status: Ongoing. Originally approved and implemented in FY2000.	
Project Title and ID: Public Outreach Activities	
Status: Ongoing. Originally approved and implemented in FY2001.	

D. REMOTE SENSING	
Project Title and ID: D.1. Evaluating ground-based and airborne remote sensing technologies	
Status: Ongoing. Originally approved and implemented in FY2000.	
GIS MO 1: Creation of GIS base coverages in support of integrated monitoring efforts.	GIS IN 1.1 Develop a comprehensive GIS base map for topography, geology and soils for the Colorado River ecosystem