

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.

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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.

Flow (water availability/releases) & Sediment/substrate

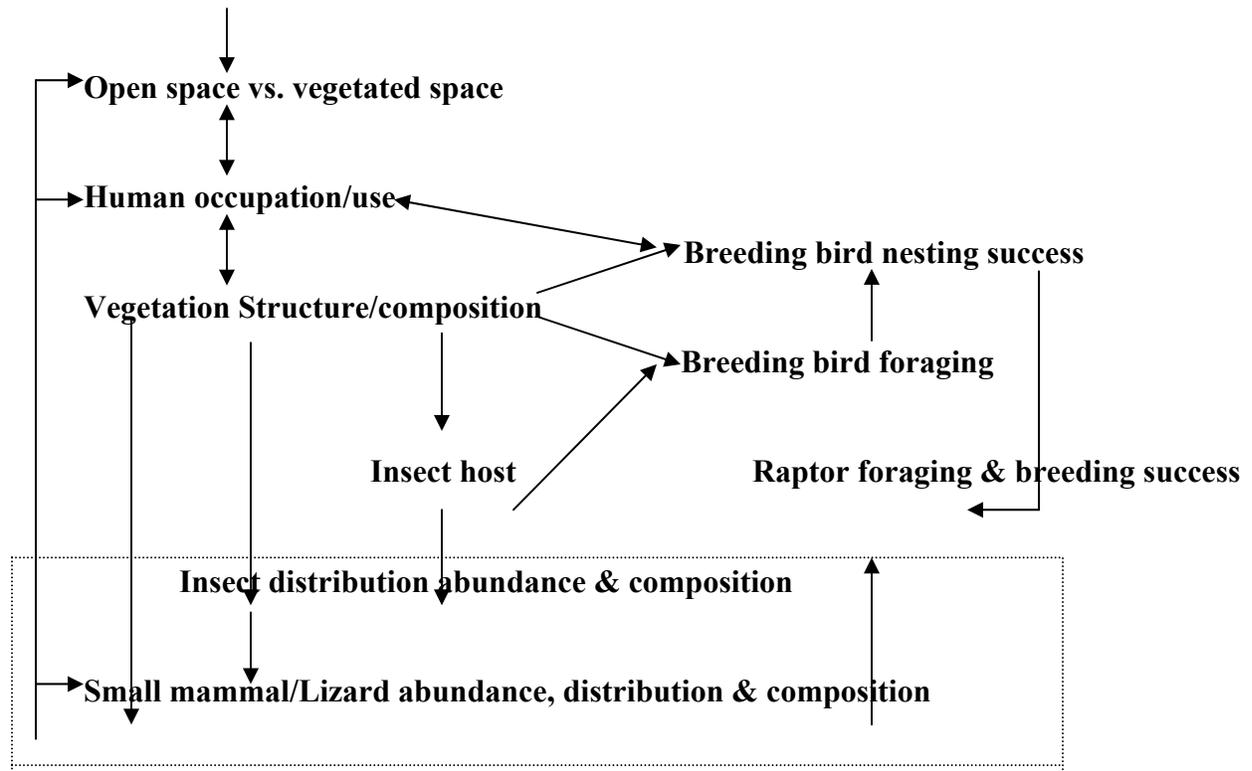


Diagram 1. A flow diagram that illustrates linkages between releases, space, vegetation, birds and their intermediate links, which are represented by those organisms circumscribed by the dotted line. Arrows that are two-sided reflect the reciprocal effects or feedback loop associated with those resources (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 (Urquhart 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 (Urquhart 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 sites, 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

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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.

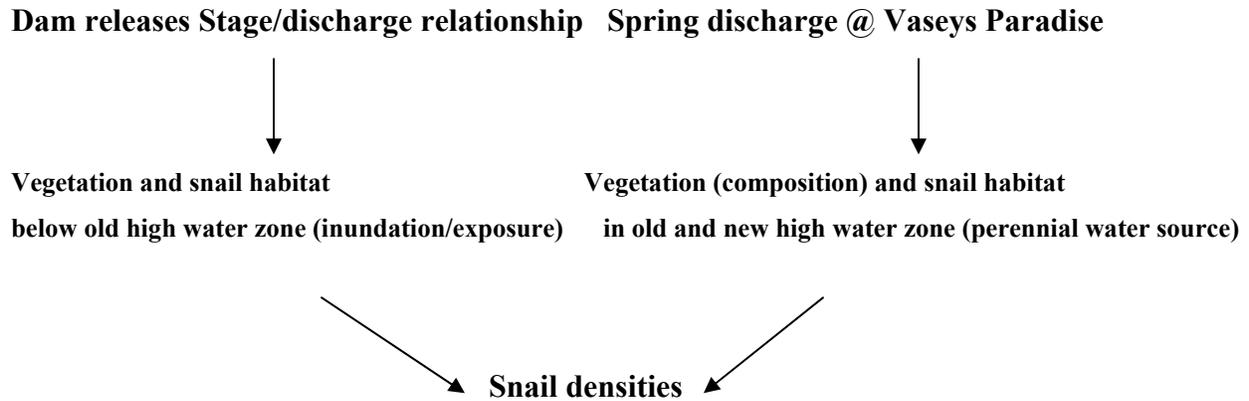


Diagram 2. Illustration of the interactions stage discharge, habitat and snail densities have at Vaseys Paradise. While the dam and the spring are responsible for habitat, stage discharge relationship has the effect of exposing or inundating habitat, while the springs affect moisture gradients at the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

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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

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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

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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

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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 georeference 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. They 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

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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.

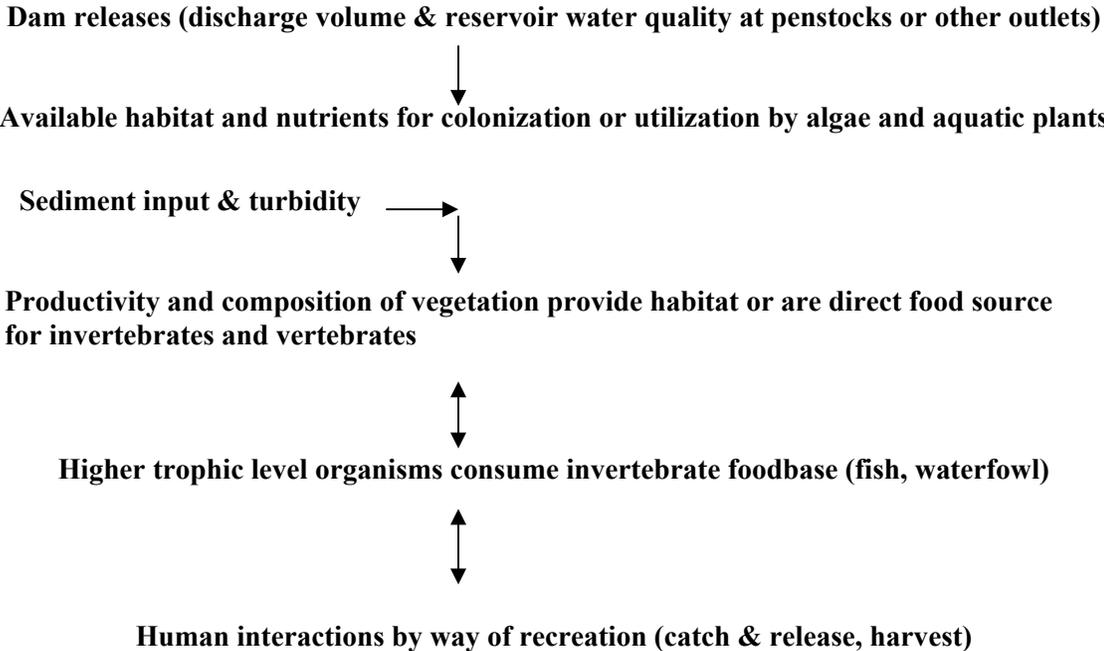


Diagram 3. Illustration of the links between operations, water quality, available aquatic habitat, productivity and consumption by higher level organisms. There are both bottom-up (sediment and water) and top-down (harvesting, population densities) interactions that affect this resource.

-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

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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.

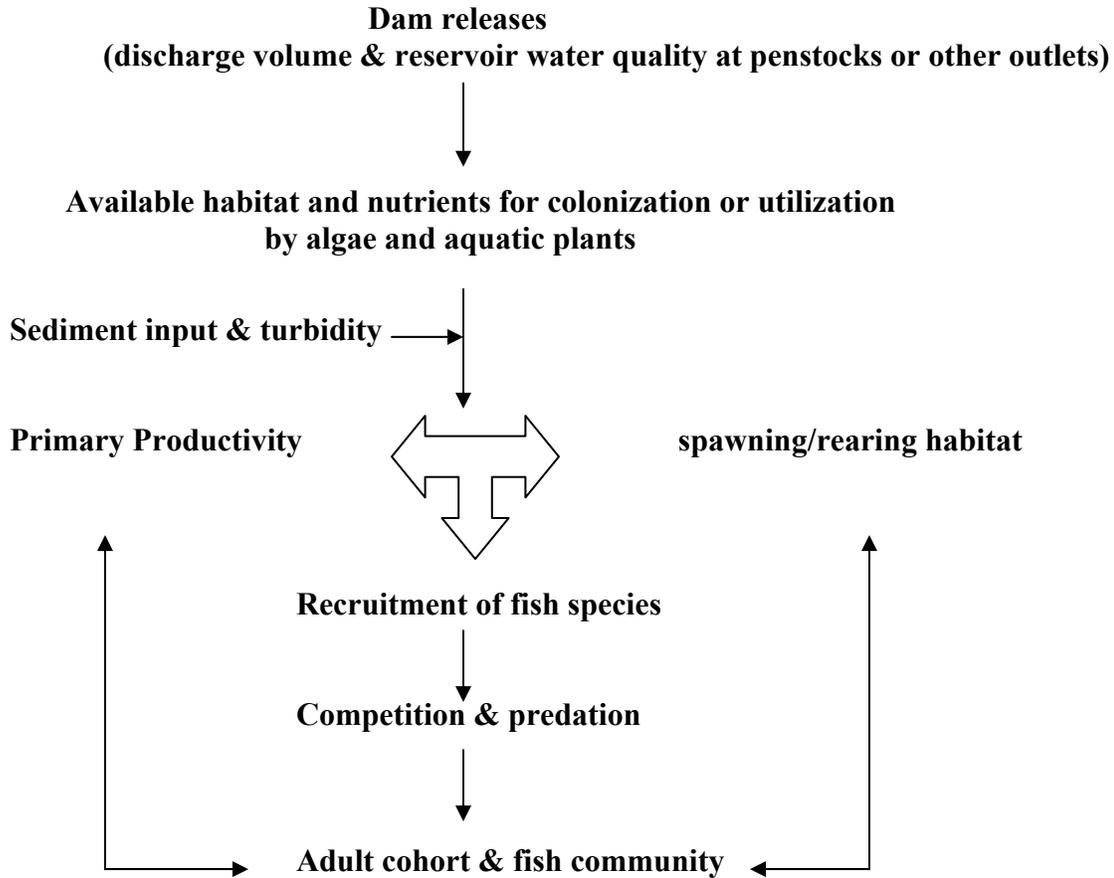


Diagram 4. Illustration of interactions and linkages between discharge, habitat, productivity and the fish community. There are bottom-up effects associated with operations, habitat and productivity and top-down, or fish species interactions that also come into play in this system.

-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	<u>\$200,000</u>
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

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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	\$	<u>137,830</u>
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

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PROJECT TITLE AND I.D.: B.4. ONGOING RESEARCH ASSOCIATED WITH POPULATION GENETICS OF HUMPBAC 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	<u>\$16,050</u>
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

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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

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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

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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 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 an 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 to 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

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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	<u>\$607,860</u>
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

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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; (4) 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	<u>\$130,260</u>
TOTAL	<u>\$130,260</u>

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.

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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	<u>\$166,510</u>
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

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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	<u>\$141,750</u>
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

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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	<u>\$99,250</u>
TOTAL	<u>\$99,250</u>

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

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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

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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](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

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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

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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	<u>\$440,180</u>
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

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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 Terrestrial & Aquatic Ecosystem Activities											
C-1	LT Mon. of Fine-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 Technologies⁹											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	Logistics¹⁰											0
J*	Independent Review Panels¹¹	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 shown 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		Appropriations Request
	Power	Revenues	
I. SCIENTIFIC OPERATIONS			
<u>A. TERRESTRIAL ECOSYSTEM ACTIVITIES</u>		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		
<u>B. AQUATIC ECOSYSTEM ACTIVITIES</u>		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		
<u>C. INTEGRATED TERRESTRIAL & AQUATIC ECOSYSTEM ACTIVITIES</u>		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		
<u>D. REMOTE SENSING ACTIVITIES</u>		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
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** Appropriated funding requested.

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

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