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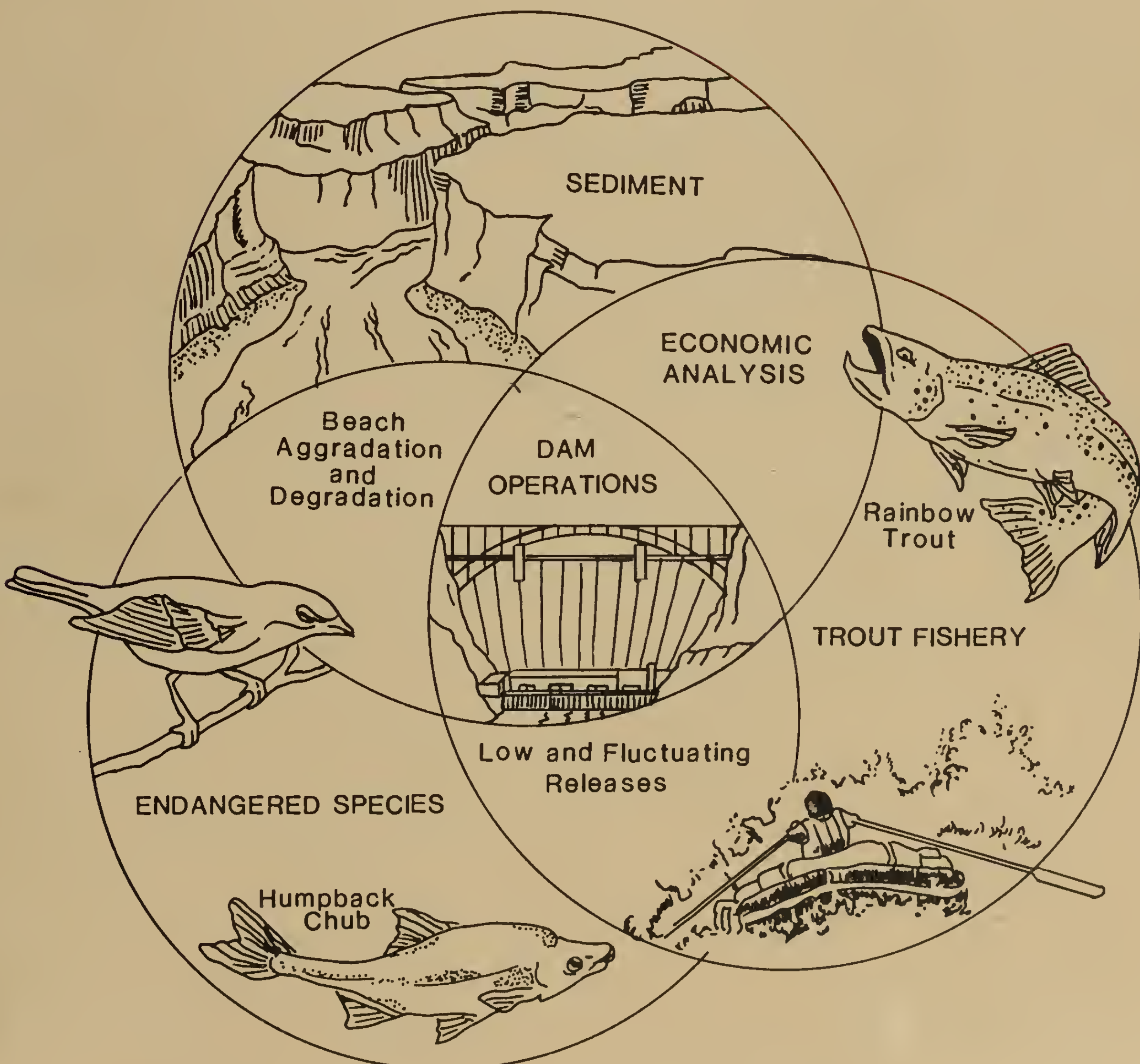
GLEN CANYON ENVIRONMENTAL STUDIES PHASE II

DRAFT INTEGRATED RESEARCH PLAN



Volume 2

AUGUST 1990

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

DRAFT

INTEGRATED RESEARCH PLAN

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NATIVE AND ENDANGERED SPECIES STUDIES

I. Issues

The native and endangered species studies reflect the Glen Canyon Environmental Studies (GCES) continued concern regarding an understanding of the impacts of the operation of Glen Canyon Dam on the downstream resources. The native and endangered species represent the last vestige of the aquatic life that populated the Colorado River prior to the closure of Glen Canyon Dam. The native and endangered species compose an assemblage of ecosystem responses that are directly impacted by any operational actions at Glen Canyon Dam.

The endangered species studies primarily reflect the concern that has existed that operation of Glen Canyon Dam has caused the demise of certain aquatic species. This concern was reflected in the 1978 Jeopardy Opinion on the operation of Glen Canyon Dam. This jeopardy opinion was taken into consideration in the development of the GCES Phase I studies. At the conclusion of the GCES Phase I efforts, the U.S. Fish & Wildlife Service and Reclamtaion reinitiated consultation on the operation of Glen Canyon Dam using the data that had been acquired during the GCES program.

The result of the most recent consultation process is a series of seven conservation measures. These conservation measures were developed by the Arizona Game & Fish Department, the National Park Service, the Fish & Wildlife Service, the Navajo Nation and Reclamation. A DRAFT non-jeopardy Biological Opinion was being prepared when the Secretary announced his decision to initiate the Glen Canyon Dam - Environmental Impact Statement. At that point, the Fish & Wildlife Service elected to withdraw the Biological Opinion until the preferred alternative was identified. However, the Fish & Wildlife Service stated that it would be in the best interest of the resource and Reclamation if the agreed upon conservation measures were initiated.

II. Objectives

The broad objectives of the GCES Native and Endangered Species Studies are stated as follows:

A. Determine the impact of the operations of Glen Canyon Dam on the native fish fauna in the Glen and Grand Canyon areas of the Colorado River.

B. Develop and implement the seven conservation measures agreed to by the Glen Canyon Dam consultation team. These conservation measures include specific studies on the ecology of the humpback chub and evaluation of the habitat characteristics and needs of the species.

C. Determination of the impacts to the native and endangered fish species in a manner that they can be used in the development of the Glen Canyon Dam - Environmental Impact Statement, and

D. Determination of the impacts of the operation of Glen Canyon Dam on the Southern Bald Eagle in the Grand Canyon.

III. Components of the GCES Phase II Native and Endangered Species Studies

The components of the GCES Phase II Native and Endangered Species studies can be separated into four areas and are depicted in Figure _8_.

A. Native Fish Studies - evaluation of the impact of Glen Canyon Dam discharges on the native fish species and their population levels in the mainstem Colorado River and the tributaries to the Colorado River.

B. Humpback Chub and other Endangered Fish Studies - evaluation of the impact of Glen Canyon Dam discharges on the endangered fish species in the mainstem Colorado River and the tributaries to the Colorado River, especially the Little Colorado River. Specific studies include:

1. Taxonomic Status of the Genus _Gila_.
2. Maintenance of a Hatchery Stock of Little Colorado River Humpback Chub.
3. Determination the flood frequency in the Mainstem Colorado River.
4. Development of a Management Plan for the Little Colorado River.
5. Identification of the Impacts of Glen Canyon Dam on the Humpback Chub.

    a) Habitat studies on the Little Colorado River and tributaries
    b) Early life history and habitat studies
    c) Adult habitat and movement studies
    d) Little Colorado River ecology
    e) Synthesis of Humpback chub information

6. Development of a long-term monitoring program for the Humpback Chub.
7. Development of a second spawning population of

humpback chub in the Colorado River.

C. Endangered Species Workshop - evaluation of the impacts of Glen Canyon Dam operations on the overall endangered species interactions in the Colorado River.

D. Southern Bald Eagle Studies - evaluation of the impacts of Glen Canyon Dam operations on the ecology of the Southern Bald Eagle in the Grand Canyon.

1. Bald Eagle surveys
2. Surveys of trout access to Nankoweap Creek and food availability
3. Avian Assessments

IV. Organization of the GCES Native and Endangered Species Studies

The overall organization of the GCES Native and Endangered Species studies will be guided by the GCES Aquatic Coordination Team. The GCES Aquatic Coordination Team will provide the primary guidance and integration of the studies and ensure that the minimal amount of research overlap occurs. The Aquatic Coordination Team will consist of representatives from Arizona Game & Fish Department, the Fish & Wildlife Service, the Navajo Nation, Arizona State University, GCES, the National Park Service and other contractors or researchers as needed.

The GCES Aquatic Coordination Team will be responsible for the integration of the native and endangered species studies into the GCES aquatic integration report and the overall GCES integration report.

Representation on the Aquatic Coordination Team will include but not be limited to, the following groups:

GCES - Aquatic Research Advisor (and/or the GCES Senior Scientist)
GCES Office
Arizona Game & Fish Department
Arizona State University
National Park Service
Navajo Nation
Fish & Wildlife Service
Contractors (as required)

Primary leadership of the Aquatic Coordination Team will lie with the GCES Aquatic Research Advisor or a designated alternate. The GCES Office will provide coordination and logistical support.

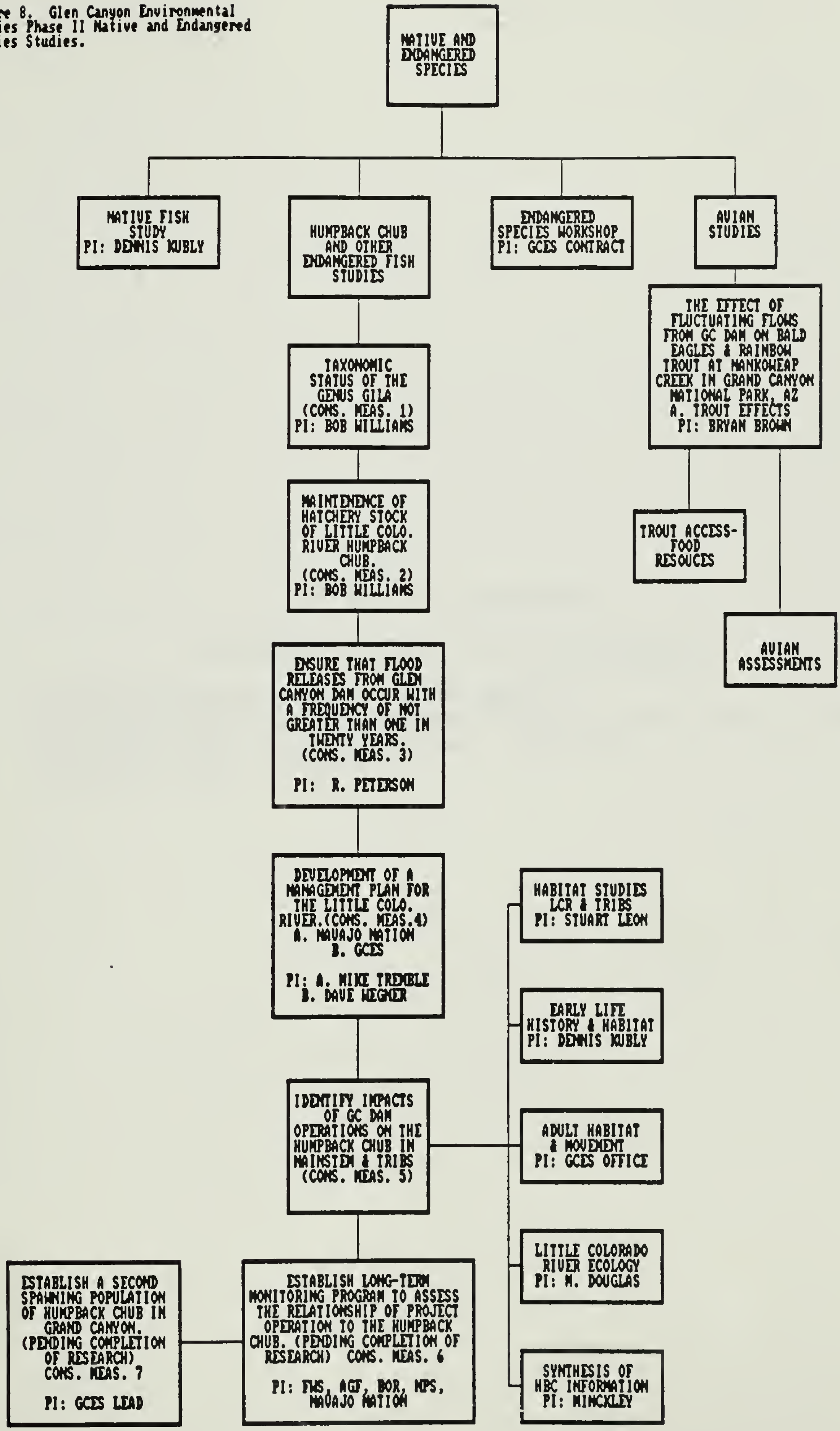
VI. Products to be Developed

The GCES Native and Endangered Species studies will be responsible for the completion of the following reports:

A. Individual Research Reports - as defined in the study plan.

B. Integrated GCES Native and Endangered Species Report - synopsis of the native and endangered species studies and identification of areas of conflict and concern.

Figure 8. Glen Canyon Environmental Studies Phase II Native and Endangered Species Studies.



CONSERVATION MEASURE 1

TAXONOMIC STATUS OF THE GENUS GILA

Program Responsibility - Reed Harris
Estimated Time for Completion - Fiscal year 1994 or 1995
Estimated Cost for Completion - $211,000
Funding Source - UBRIP

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ation of genetically wild and hatchery populations baseline data for wise management decisions.

ion of phenotypic changes over time and trying to e changes to habitat alteration.

y Methods and Approach. The U.S. Fish & Wildlife ently completed a Cooperative Agreement with the conduct the above work over the next four to five years. This work will be conducted as a part of the Upper Colorado River Basin Recovery Implementation Program.

The initial literature review on the status of the *Gila* taxonomy has begun. A work plan and protocol for collection of fishes is also being completed with a preliminary report due by October 1, 1989. Beginning in Fiscal Year 1990, the program manager will select an ad hoc review panel, the program manager will develop work statements, issue contracts, and review products as they are developed. Humpback chub from the LCR will be included as part of the overall upper basin contracts.

E. Timing of the Proposed Work. Work on the *Gila* taxonomy issue has already begun with an initial report due by October 1, 1989. Proposed efforts in Fiscal Year 1990 are now being reviewed by the Technical Group of the Upper Basin Recovery Implementation Committee. Beginning in Fiscal Year 1991, a three or four-year research program is anticipated to fully answer the *Gila* taxonomy questions.

F. Estimated Costs.

Fiscal Year 1989 .... $ 60,000
Fiscal Year 1990 .... $151,000
Fiscal Year 1991 .... $ unknown

The funding for this conservation measure is being programmed as part of the on-going Recovery Implementation Program.

G. Products Expected. End products of this conservation measure will include an accurate *Gila* taxonomy evaluation, field methods to allow discrimination among and between species, including the identification of hybrids, a system of low-risk tissue sampling, and a genetic baseline data set on wild and hatchery populations that will serve as the foundation for future propagation and genetic management.

5. Characterization of genetically wild and hatchery populations to generate baseline data for wise management decisions.

6. Identification of phenotypic changes over time and trying to relate those changes to habitat alteration.

D. Tasks, Study Methods and Approach. The U.S. Fish & Wildlife Service has recently completed a Cooperative Agreement with the Smithsonian to conduct the above work over the next four to five years. This work will be conducted as a part of the Upper Colorado River Basin Recovery Implementation Program.

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TAXONOMIC STATUS
OF THE
GENUS GILA

A. Lead Role and Participants. The U.S. Fish & Wildlife Service(Region 6)will be the primary lead for this effort. Dr. Wayne Starnes, Smithsonian Institute, Division of Fishes, will serve as the project leader for the basin wide review of *Gila* taxonomy. This conservation measure will be initiated as part of the Upper Basin Recovery Implementation Program (UBRIP) and will be under the general direction and receive funding from the Recovery Implementation Committee. The Management and Technical Groups of the Committee will ensure that research efforts are focused and contribute toward the recovery of *Gila* throughout the basin. Input into the studies has been and will continue to be sought from both upper and lower basin researchers. 1 Development of final research proposals and funding levels is an open process that allows government, academic, and private investigators to contribute.

B. Purpose and Background. The systematic and taxonomic evaluation of the *Gila* complex in the Colorado River has long been a subject of disagreement and discussion among fishery workers trying to identify, assess impacts to, and provide recovery for many of the formally protected native fishes. The three preeminent species include the endangered humpback chub, *Gila cypha*, and bonytail chub, *Gila elegans*, as well as the more common roundtail chub, *Gila robusta*. The relationship, genetically as well as taxonomically, of the Little Colorado River (LCR) humpback chubs to other humpback chubs in the basin needs to known to protect the heterozygosity of the species and to ensure that stocking programs, if implemented, will be compatible with existing wild stocks. Development of a program to maintain different genetic stocks in hatcheries or refugia is dependent upon a complete understanding of *Gila* taxonomy.

C. Objectives and Goals. The goal of this conservation measure is to clarify the systematic/ genetic/taxonomic relationship of the *Gila spp.* in the Colorado River Basin. Some specific objectives of this effort include:

1. Determining the genetic relationships between chubs at critical sites through the most advanced analytical methods (i.e., Mitochondrial DNA).

2. Determining the source of variation within and among samples.

3. Identifying characters useful in discriminating among species and populations, particularly in the field.

4. Developing low-risk genetic sampling methods to identify, characterize, and mark discrete populations.

CONSERVATION MEASURE 2

MAINTENANCE OF HATCHERY STOCKS OF GRAND CANYON HUMPBACK CHUBS

Program Responsibility - Reed Harris
Estimated Time for Completion - Fiscal Year 1992
Estimated Cost for Completion - $35,000
Funding Source - UBRIP and GCES

MAINTENANCE OF HATCHERY STOCKS
OF LITTLE COLORADO RIVER
HUMPBACK CHUBS

A. Lead Role and Participants. The U.S. Fish & Wildlife Service (Region 6) will be the primary lead for this effort. Dr. W.J. Holt Williamson will serve as the Project Manager for the basin wide propagation and genetic management plan for the Colorado Squawfish, bonytail chub, humpback chub, and razorback sucker. This comprehensive program will be initiated as part of the Upper Colorado River Basin Recovery Implementation Program and will be under the general direction of and receive funding from the Recovery Implementation Committee. The Management and Technical Groups of the Committee will ensure that all endangered fish stocks both in existing hatcheries and the wild are considered in an overall effort to protect existing gene pools and at the same time evaluate the role hatcheries have in the recovery of the four protected or rare species. FWS and Reclamation are represented on the groups and committees and work statements are available for review by all interested parties prior to funding.

B. Purpose and Background. Concern for the protection of the Little Colorado River population of Humpback chubs stems from their isolation from other humpback chub stocks and their apparent genetic (phenotypic) uniqueness. Unfortunately, little is known about the genetic and taxonomic relationship of the Little Colorado River humpback chubs to other humpback chubs in the Upper Basin or other *Gila spp.* in general. For this reason this conservation measure will be conducted concurrently as a separate measure. The use of hatcheries for maintenance of genetic pools, brood stock for reintroduction and research, and as refugia should be analyzed basin wide to ensure that wild stocks are not needlessly exported to holding facilities without an overall understanding of the fishes' eventual use.

C. Objectives and Goals. The goal of the propagation and genetics management plan will be to provide a comprehensive rationale for the conservation, protection, and recovery of the four identified rare and endangered fish species in the Upper Colorado River Basin (as well as Little Colorado River humpback chub population) according to goals listed in appropriate recovery and implementation plans. The Little Colorado River population will be analyzed along with all other humpback chubs to evaluate their genetic integrity as well as the most feasible way to ensure their continued protection. Some specific objectives of the propagation and management plan include:

1. Selection of an ad hoc Propagation Work Group to review, update and expand the existing propagation and genetics management plan.

2. Updating of the short term (1990-1992) fish needs and review long term (15 years) fish needs for integration into research and hatchery designs and site evaluation criteria.

3. Implementation of a basin wide genetics management plan.

4. Determination of the type of facilities required to provide the fish stock necessary to meet both the short term and long term research and stocking needs.

5. Completing the design and development of a refugia for the rare and endangered fishes of the Colorado River Basin.

D. Tasks, Study Methods, and Approach. With the establishment of an ad hoc propagation work group, the Program Manager will revise the existing management plan to reflect current needs for endangered fish (both short and long term) for research, stocking, and maintenance of genetic integrity. The management plan will determine if existing facilities will meet future needs and will classify those needs by purpose -- research, augmentation, restoration, and will identify priority of location, species, population, and stock sizes and numbers.

The genetics management plan will be developed from historical information and taxonomy work currently being conducted. Genetic information will be sued to identify population status (self sustaining, migratory/non-migratory, population size, distribution, etc). Additional effort will be expended on brood stock development, marking and tagging, and enhancement of rare fishes propagation technology.

Once the needs for new facilities has been verified, managers will identify the type of facility required to meet the recovery goal. Specific designs and site evaluation would then be initiated.

Species in the most dire need of protection would be considered early on as candidates for refugia. Based on identified need, refugia options would be developed, classified and ranked according to their efficiency with which protection and preservation of unique qualities may be best accomplished. Sites may be either in situ or ex situ, however, implementation strategies will be required to maintain genetic diversity and structure in wild populations when the refugia is "out of place".

E. Timing of the Proposed Work. Initial development of propagation and genetics plan was completed during Fiscal Year 1989. Refinement of the existing plan will be on-going starting in Fiscal Year 1990 and reassessed annually through Fiscal Year 1992. Revision of the subject plan will include fish needs, genetic management, site evaluations, and refugia options.

F. Estimated Costs.

Fiscal Year 1990 .... $100,000
Fiscal Year 1991 .... $100,000
Fiscal Year 1992 .... $150,000

Funding for this conservation measure will be programmed as part of the on-going Recovery Implementation Program.

G. Products Expected. Annual Propagation and Management Plans will be developed by the work group. Final products will include development and implementation of a basin wide genetics management plan, identification of facilities required and site evaluation for the management of rare and endangered fish species, and the development and design of necessary refugia.

CONSERVATION MEASURE 3

ENSURE THAT FLOOD RELEASES
FROM GLEN CANYON DAM
OCCUR WITH A FREQUENCY OF NOT GREATER
THAN ONE IN TWENTY YEARS

Program Responsibility - Randall Peterson
Estimated Time for Completion - Fiscal Year 1992
Estimated Cost for Completion - $20,000
Funding Source - CRSP/GCES

ENSURE THAT FLOOD RELEASES FROM GLEN CANYON DAM OCCUR WITH A FREQUENCY OF NOT GREATER THAN ONE IN TWENTY YEARS

A. Lead Role and Participants. The Bureau of Reclamation will be the primary lead for this conservation measure. Mr. Randall Peterson will prepare the necessary data, perform the analysis to quantify the relationship, prepare the technical reports and provide a review of the impacts to the operation of Glen Canyon Dam.

B. Purpose and Background. Concern for the protection of the humpback chub habitat in the Colorado River has been the impetus for the development of this conservation measure. High flow releases from Glen Canyon Dam have been shown to have both positive and negative impacts to the environmental requirements for the humpback chub. While high flows do provide additional spawning and rearing area at the mouth of the Little Colorado River, the overall impact of high flows, above powerplant capacity, on the downstream environmental resources is detrimental. Therefore, the need exists to reduce the probability of flooding.

The Upper Colorado Region of the Bureau of Reclamation, in consultation with the seven Colorado River Basin States, have agreed to a management change at Glen Canyon Dam that will effectively reduce the probability of high flow releases from Glen Canyon DAm from one in four to one in twenty. The justification for this change in probability has knot been articulated to the general public. Therefore, this conservation measure will serve to provide the documentation required by the managers and researchers in their review of the overall impacts of the operation of Glen Canyon Dam.

C. Objectives and Goals. The goal of this measure is to provide numerical evidence of the risk of Glen Canyon Dam releases over the normal powerplant operations. Reclamation will continue to follow the operating criteria developed in 1988 that will reduce the probability of bypassing water to a frequency of less than one in twenty years and limit powerplant releases to more than 31,500 cubic feet per second. Exceptions to the flow limitations will be developed to provide for power emergencies and to prevent unforecasted spilling. Documentation will be provided to substantiate the quantification of this frequency of the risk of spills.

Further information will be collected during Phase II of the Glen Canyon Environmental Studies program to assist the Fish & Wildlife Service and Reclamation in the determination and definition of flood frequency and maximum releases necessary to achieve this objective. Additionally, long-term monitoring may be necessary to comprehend the dynamics of the fluvial system below Glen Canyon in order to predict changes in humpback chub habitat with any degree of certainty. It is possible that certain operational strategies that include high flows may be beneficial to the humpback chub if exotic fish competitors are disadvantaged by such operations. Information from other conservation measures may help in this determination.

D. Tasks, Study Methods, and Approach. Several techniques have been used to date to quantify risk of powerplant bypasses. These include the use of the Colorado River Simulation System (CRSS) model, evidence from historical operation, and the fives percent and 95 percent confidence intervals of the monthly runoff forecast.

We propose to perform a Monte Carlo type simulation of historic forecasts and runoff using current operating strategies. These strategies will include variables such as the January 1 target storage level in Lake Powell, the July 31 target storage level in Lake Powell, base monthly release patterns, and techniques for incorporating changes in the runoff forecast.

This analysis will provide us with the information necessary to evaluate the impact of runoff to the frequency of bypass releases at Glen Canyon Dam.

E. Timing of Proposed Work. The development of the computer model will be accomplished in fiscal year 1990. The calibration of the model parameters to replicate historic and current operation will be accomplished in fiscal year 1991. The presentation of the final report will be completed in fiscal year 1992.

F. Estimated Costs.

Fiscal Year 1990 - $ 5,000
Fiscal Year 1991 - $10,000
Fiscal Year 1992 - $ 5,000

Funding for this conservation measure will be programmed through the CRSP/GCES program budget.

G. Products Expected. It is anticipated that the final product for this conservation measure will be a report in fiscal year 1992 which will outline the logic, procedure, and statistical analysis for the development of the hydrological relationships.

CONSERVATION MEASURE 4

DEVELOPMENT OF A MANAGEMENT PLAN
FOR THE
LITTLE COLORADO RIVER

Program Responsibility - David L. Wegner
Estimated Time for Completion - Fiscal year 1991
Estimated Cost for Completion -
Funding Source - CRSP/GCES

DEVELOPMENT OF A MANAGEMENT PLAN FOR THE LITTLE COLORADO RIVER

A. Lead Role and Participants. The Glen Canyon Environmental Studies (GCES) project office will be the primary lead for the development of the management plan for the Little Colorado River (LCR). David L. Wegner, GCES Program Manager, will serve the key role in coordinating the development of this conservation measure. The development of the management plan for the LCR will require the involvement of managers who have mandated resource and operation responsibilities in the LCR basin. This will include but not be limited to, the U.S. National Park Service, the U.S. Bureau of Reclamation, the U.S. Geological Survey, the Bureau of Land Management, the U.S. Fish & Wildlife Service, the Department of the Interior, the Navajo Nation, the Hopi Nation, the State of Arizona and the Environmental Protection Agency.

B. Purpose and Background. Concern for the protection of the LCR population of humpback chubs includes not only the viability of the genetic aspects of the population but also the importance of the physical habitat in the LCR drainage. In a broad sense, the physical aspects of the LCR represent the critical habitat features of importance for the humpback chub.

The Endangered Species Act specifically identifies the necessity to protect not only the genetic viability of an endangered species, but where appropriate, also the habitat critical to the survival of the species. During the initial phase of the GCES program and through the other conservation measures of this biological opinion, the specific aspects of the critical habitat functions will be defined.

In order to protect the critical habitat of the LCR basin, a broad based management plan must be developed and implemented. The purpose of such a plan will be to assist in the identification of specific threats to the viability of the physical ecosystem, identification of potential remedial actions to guarantee the integrity of the LCR physical habitat, and provide a forum for the coordination of resource management activities.

C. Objectives and Goals. The overall goal of the development of the management plan for the LCR will be to provide a framework for the coordination and protection of the critical habitat features of the LCR. The critical habitat features of the LCR are of primary importance from the mouth of the LCR and the mainstem Colorado River to Blue Springs, a distance of approximately 14 miles. However, this section of the LCR drainage is affected by the management activities of the land and water resources upstream. An effective and usable management plan must take into consideration all important physical and management components which may impact the critical habitat downstream.

Six specific objectives have been identified for the completion of this conservation measure.

1. Establish an ad hoc LCR basin management group to review existing information, update existing information, identify jurisdictions and management responsibilities, and develop the work plan necessary to develop the LCR basin management plan.

2. To consolidate all available information on the LCR basin into a workbook of known facts and figures.

3. Identify specific management/basin threats to the continued stability of the critical Humpback Chub habitat in the lower portion of the LCR drainage.

4. Identify management actions that are necessary to maintain the stability of the critical Humpback Chub habitat.

5. Develop, where possible, agreements between agencies, Native American Nations, states and bureaus to assist in the protection of the critical Humpback Chub habitat.

6. Develop, as a supplement to the Region IX Mainland RRT Oil and Hazardous Substance Pollution Contingency Plan for the Colorado River, a contingency plan on how to deal with oil and hazardous material spills within the LCR drainage basin.

D. Tasks, Study Methods, and Approach. The GCES program office will take the lead in organizing an ad hoc LCR work group to complete the conservation measure for the development of the LCR management plan. Four tasks will be required for completion:

1. Initial coordination and development of study process.

2. Development of the technical information data bases.

3. Completion of the LCR drainage basin management plan and contingency plan for oil and hazardous substance contingency plan.

4. Development of cooperative agreements and required coordination documents for implementation of program features.

Task 1. Initial coordination and development of study process. The initial coordination and enactment of the ad hoc work group will require the development of an information gathering effort that will be structured similarly to the Department of the Interior, Office of Environmental Project Review, recent meeting on research that is ongoing in the Lower Colorado river basin. Specific researchers, managers and public will be invited to a meeting to discuss the LCR management plan effort and discuss the objectives of the program. The initial meeting will be primarily an information gathering session with additional meetings and timetable for completion to be outlined.

Task 2. Development of the technical information data bases.

The GCES program offices will take the lead on coordinating with the identified entities outlined in Task 1 and begin the procuring of the information that will be required in the definition of the LCR basin and in the development of the management plan. Specific areas of interest will include, but not be limited to:

a. Definition of the LCR basin.

   (1) Hydrology
   (2) Biology
   (3) Geology

b. Geomorphic and Morphological Description

c. Definition of Critical Habitat areas and criteria - what do we need to protect?

d. Identification of potential habitat and species threats

e. Identification of management responsibilities and priorities

The above information will be consolidated by the GCES staff into a series of technical documents which will be reviewed by the ad hoc work group. The review will consist of relevance to the overall conservation measure goals and objectives, reliability, and use in overall management requirements. A final set of technical data will be consolidated and reviewed for accuracy.

Task 3. Development of the LCR Management Plan and Contingency Plans.

Task 3 will require the assimilation of all of the technical material into two separate reports, the LCR Basin Management Plan and the LCR Contingency Plan. Each plan will utilize common information and will be a consolidation of material and activities from Tasks 1 and 2.

The LCR Basin Management Plan will focus on identifying potential threats and management actions that may have an impact on the protection of the critical Humpback Chub habitat in the LCR drainage basin. The report will summarize the material collected and analyzed in Task 2 and will also develop the following management related points:

a. Basin Threats

b. Management Options

c. Recommendations for Action

The LCR Contingency Plan will focus on the actions that should be taken if an oil or hazardous substance spill were to occur in the LCR drainage basin. The intent is not to provide a cookbook approach for DOI, Native American or State personnel but instead to identify the procedures that should be followed to ensure the active and correct reporting and response actions that should be followed. The LCR Contingency Plan will be provided as a supplement to the Region IX Mainland RRT Oil and Hazardous Substance Pollution Contingency Plan for the Colorado River. The EPA and the Department of the Interior have requested to be involved in the development of this contingency plan.

Task 4. Development of the agreements necessary to implement the LCR Basin Management Plan

Upon completion of the technical and report writing phase of this conservation measure, the ad hoc work group will identify the agreements necessary to implement the LCR Basin Management Plan. Since it is highly likely that the agreements will require groups and areas outside of Reclamation responsibility or jurisdiction, the program will require the coordination of the other agencies and groups to effect its consummation.

E. Timing of the Proposed Work. Upon agreement of the basic process for the completion of the conservation measure, the GCES program office will organize the first coordination meeting. It is anticipated that Tasks 1 and 2 will be completed within 12 months of the initiation of the program. Task 3 will follow with two drafts and one final document for both the LCR Basin Management Plan and the LCR Contingency Plan. It is anticipated that Task 3 will be completed in 9 months. Task 4 will require 6 months to complete.

The overall length of time required for completion of this conservation measure is 27 months.

F. Estimated Costs.

Fiscal Year 1989 .... $ 5,000.00
Fiscal Year 1990 .... $ 30,000.00
Fiscal Year 1991 .... $ 30,000.00

Funding will be programmed as part of the on-going GCES program requirements.

G. Products Expected. Annual reports on the progress of this conservation measure will be developed. This will include activities completed in Fiscal Year 1989 and 1990.

Final reports and plans will be the products developed during Fiscal Year 1991. Two specific products will be produced:

LCR Basin Management Plan

LCR Contingency Plan

As necessary appendices will be developed that will include any technical data necessary to implement the plans. The GCES program office will be responsible for the development and coordination of the documents.

CONSERVATION MEASURE 5

CONDUCT RESEARCH TO IDENTIFY IMPACTS OF GLEN CANYON OPERATIONS ON THE HUMPBACK CHUB IN THE MAINSTEM AND TRIBUTARIES

Program Responsibility: Robert Williams and David L. Wegner
Estimated Time for Completion - Fiscal Year 1994
Funding Source - CRSP/GCES

Program Components

A. Habitat Use By Humpback Chub, *Gila cypha*, in the Little Colorado River and Other Tributaries of the Colorado River

Principle Investigator: Pinetop Fishery Assistance Office, U.S. Fish & Wildlife Service

B. Ecology and Conservation Biology of Humpback Chub, *Gila cypha*, in the Little Colorado River, Arizona

Principle Investigator: Arizona State University, Tempe, AZ

C. Evaluation of the Adult Movement and Habitat Relationships for the Endangered Humpback Chub, *Gila cypha*, in the Grand Canyon, AZ

Principle Investigator: U.S. Bureau of Reclamation (CONTRACT) & the Glen Canyon Environmental Studies

D. Native Fish Studies

Principle Investigator: Arizona Game & Fish Department Phoenix, AZ

E. Synthesis of Information on the Humpback Chub in the Colorado River Basin

Principle Investigator: Northern Arizona University Flagstaff, AZ

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

NATIVE FISH STUDIES

A RESEARCH PROPOSAL

SUBMITTED TO

BUREAU OF RECLAMATION
UPPER COLORADO REGION
SALT LAKE CITY, UTAH

BY

ARIZONA GAME AND FISH DEPARTMENT
2221 W. GREENWAY ROAD
PHOENIX, ARIZONA

AUGUST, 1990

NATIVE FISH STUDIES

Scope of the Proposal

This proposal addresses studies on the native fishes of the Colorado River and its tributaries in Glen and Grand canyons. It includes research and monitoring to satisfy informational needs for the Glen Canyon Environmental Studies (GCES), Glen Canyon Dam Environmental Impact Statement (GCD-EIS), and the Conservation Measures for the Section 7 Consultation on the Operation of Glen Canyon Dam.

Since 1987 the Arizona Game and Fish Department (AGFD) has conducted annual monitoring of native fishes in Grand Canyon, with emphasis on the endangered humpback chub (Minckley 1988, 1989, Kubly 1990). Monitoring activities have concentrated on the reproductive period for humpback chub, typically the month of May, and have included intensive sampling in the Little Colorado River (LCR) and mainstream backwaters. Proposed listing of razorback sucker, *Xyrauchen texanus*, and recent collections and observations in Grand Canyon have led to special consideration of that species (Hendrickson and Kubly 1990).

Our proposal is a continuation of AGFD's existing monitoring program in that it emphasizes repeated, standardized measurements directed at understanding the ecology of native fishes in Grand Canyon. It expands the monitoring program to address definitive research objectives which have had their genesis in results obtained during that effort. Within the LCR, however, system-wide studies previously conducted by AGFD largely will be assumed by Arizona State University and the Navajo Nation. AGFD will retain responsibility for studies on early life stages, with emphasis on the LCR and mainstream rearing habitats, and continue the monitoring program for all life stages in the lower 1200 m of that tributary during the reproductive period for humpback chub. The proposal presupposes that other investigators will have primary responsibilities for satisfying research objectives concerning habitat availability and use in tributaries (Fish and Wildlife Service) and in mainstream habitats other than those used during rearing by native fishes (BOR contractor).

Reference to native fishes in this proposal refers to all extant species in the Colorado River and its tributaries in the Grand Canyon whether common in occurrence, proposed for listing, or presently listed as endangered. We believe that an adequate understanding of the ecological factors limiting rare and endangered fishes in this system cannot be achieved without corollary information on other, more widely distributed and abundant species, both native and introduced. Successful recovery of listed fishes without undue negative effects on other natives or undesired benefits to introduced competitors and predators will depend on extensive knowledge of the ecological requirements of all species. The commonness of some species suggests that their ecological requirements are more closely met in the contemporary Colorado River and its tributaries than are those of less successful fishes. For rare species, these requirements may be lacking in the physical and chemical environments of the existing system, in habitats necessary for successful reproduction and growth, in lower trophic levels upon which the fishes are dependent for nourishment, or in their abilities to persist with competitors, predators, or parasites.

Problem Statement

Prior to the impoundment of Lake Powell by Glen Canyon Dam, eight native fish species inhabited the Colorado River and its tributaries in Glen and Grand canyons. Three of these--Colorado squawfish (*Ptychocheilus lucius*), bonytail chub (*Gila elegans*), and roundtail chub (*Gila robusta*)--have been extirpated from the reach. The latter was probably never widely distributed in this reach of the Colorado River, but collections do exist from the study area (W. L. Minckley, Arizona State University, personal communication). Humpback chub (*Gila cypha*) is listed as an endangered species by the U.S. Fish and Wildlife Service. Razorback sucker is rare in occurrence and proposed for listing as endangered; only five individuals have been collected since 1984 in Grand Canyon (Maddux et al. 1987, Minckley 1989, AGFD unpublished data), although the species persists in downstream reservoirs (Minckley 1983, Marsh and Minckley 1989, J. Sjoberg, Nevada Department of Wildlife, written communication). The three remaining species, speckled dace (*Rhinichthys osculus*), bluehead sucker (*Pantosteus discobolus*), and flannelmouth sucker (*Catostomus latipinnis*) are widely distributed in both tributaries and the mainstream (Maddux et al. 1987).

The role of Glen Canyon Dam in the reduction or demise of native fish populations in the Colorado River below that structure is not fully understood, but several interacting factors associated with emplacement and operation of the dam to produce "load-following" hydroelectric power undoubtedly have been contributory.

First, the dam serves as a barrier to fish migrations, which in some species or populations, e.g. Colorado squawfish (Tyus and Karp 1989) and razorback sucker (Tyus and Karp in review a), appear to be important components for successful completion of the life cycle. This factor is further exacerbated by the presence of Lake Mead and Hoover Dam, as further impediments to migration in lower Grand Canyon.

Second, deep hypolimnial release waters from Glen Canyon Dam are perennially cold. Existing downstream water temperatures can restrict successful reproduction (Hamman 1982, Marsh 1985), produce lethal thermal shock to early life stages (Berry 1986), and retard growth (Kaeding and Zimmerman 1983) in these warmwater fishes.

Third, operation of Glen Canyon Dam to produce "peaking power" has dramatically altered the hydrology of the Colorado River in the Grand Canyon region. Studies on threatened and endangered "big river fishes" of the Colorado River increasingly point to importance of the hydrograph as an environmental cue serving to initiate and segregate reproductive activity in these fishes (Tyus and Karp 1989, in review a, b, Karp and Tyus in review). The predictable seasonal variation in flows of the pre-dam annual hydrograph largely has been replaced by flow fluctuations occurring on a daily basis. Extended pre-dam summer floods carrying warm water have been replaced by cold water and daily changes in river stage at times reaching 13 vertical feet.

Daily flow fluctuations are important particularly in their effects on native fish rearing habitats. Changes in mainstream stage disrupt the stability of backwater habitats by alternately draining and filling them during the course of a 24-hour cycle. Daily incursion of cold mainstream waters affects the thermal regime of these habitats by largely precluding their warming, and potentially limits production of planktonic and benthic food resources for the young fish. In the extreme, larval fish face the alternatives of desiccation in dewatered rearing habitats or being displaced into less favorable habitats. Fluctuating flows also may contribute to the filling in of backwaters by erosion of beaches and aggradation of these sand deposits in the depressions.

Tributary mouths form a second potential rearing habitat affected by fluctuating flows. Because most tributaries are founded in canyons, high mainstream flows back up into their mouths forming lentic habitats of seasonally warm water having the capability of supporting rich plankton populations. During the pre-dam era, these habitats probably persisted for weeks, but under present hydrology tributary mouth impoundments form and disappear daily.

Fourth, presence of Glen Canyon Dam, Hoover Dam, and their respective reservoirs has encouraged deliberate stocking and inadvertent introduction of a host of potential competitors and predators of the native fish fauna. The list of fish species collected from the Colorado River in the Grand Canyon region has grown from the original eight to nearly thirty (Maddux et al. 1987). Although some of these species are rare and sporadic in occurrence, many are capable of rapidly increasing their distribution and abundance, given appropriate environmental changes in the mainstream, and of negatively impacting the remaining native fish fauna through competition and predation.

Study Objectives & Methods

Objective 3.1. Continue the AGFD monitoring and research program for native fishes of the Colorado River and its tributaries in Grand Canyon,

Background 3.1. The scope of work for the 1990 AGFD monitoring project in Grand Canyon contained 10 objectives (Hendrickson and Kubly 1990). The project, begun in 1987, has been an annual effort timed to coincide with the reproductive period of humpback chub in the LCR and with the presence of early life stages of other native fishes in tributary and mainstream rearing habitats. Research personnel entered the LCR via Salt Trail Canyon and occupied the tributary for approximately one month a year, typically May, since 1987. This effort was supplanted through additional personnel who traveled down the mainstream by boat and entered the LCR near the middle of the sampling period. These individuals augmented the LCR monitoring for five days in the course of a two week sampling of mainstream backwaters from Lee's Ferry to Diamond Creek or, as in 1990, Pierce Ferry (Minckley 1988, 1989, Hendrickson and Kubly 1990, Kubly 1990). Less intensive sampling of these habitats has occurred during July and September in some years.

Method 3.1. During the course of the present investigation, AGFD will continue efforts to attain objectives put forth in our monitoring program to the extent that these efforts do not conflict with those of other investigators. Standardized gear, sample sites, periodicity of sampling, and marking procedures (see Hendrickson and Kubly 1990) will be continued. We will use these methods throughout the study for comparisons with previous years' results to help satisfy needs of the GCD-EIS and to serve as a framework for the long-term monitoring program to be developed under the Section 7 Conservation Measures. For other than young-of-the-year fishes, however, our sampling in the LCR will be restricted to that reach potentially affected by mainstream flows, i.e. the lower 1200 m. Wherever necessary, we will increase our sampling effort or augment sampling gears in that reach to aid the efforts of the Fish and Wildlife Service's studies of habitat availability and use.

Objective 3.2. Identify temporal and spatial distribution patterns and movements of early life stages of fishes in the Little Colorado River and, if necessary, other tributaries.

Background 3.2. Past AGFD monitoring activities included limited attention to the ecology of early life stages (to ca. 100 mm TL). Larval seines, bag seines, minnow traps, and larval drift nets were used to investigate distribution, abundance, food resource utilization, and movement of early life stages (prolarvae to juveniles ca. 100 mm TL) in the LCR, but major emphasis was placed on collections of larger fishes with hoop and trammel nets. Collections of early life stages from other tributaries were even more restricted due to lack of sufficient time for intensive collections during monitoring river trips.

Our studies on early life stages of native fishes in the LCR will be directed at answering the following questions: (1) Is reproductive activity of native fishes temporally or spatially segregated?; (2) Can the timing and duration of reproductive activity for different species be related to a set of environmental conditions such as stage or direction of the hydrograph including presence or absence of previous flood events, water temperature (absolute or accumulated degree days), and photoperiod?; (3) Do early life stages of native fishes segregate their use of available habitats temporally or spatially?; (4) Do early life stages of native fishes drift in the tributary and, if so, what is the extent to which they drift into the mainstream under different Colorado River flow regimes?, and; (5) Do early life stages of native fishes feed selectively on available drift or benthic food resources and, if so, does this electivity result in reduced overlap in food resource utilization? Although primarily directed at the LCR, sampling also will be undertaken in other tributaries for comparative purposes provided collections do not conflict with those taken during Fish and Wildlife Service studies on habitat availability and use.

Reproductive periodicity of native fishes in the LCR has thus far been determined mainly from gonadosomatic indices and proportions of ripe individuals (Carothers et al. 1981, Minckley et al. 1981, Kaeding and Zimmerman 1983). Use of gonadosomatic indices requires sacrificing of adult fishes and expression of gametes by ripe individuals is possible for only a short period consequent with spawning. Collection of larval fishes and subsequent aging using daily growth rings on otoliths will add a powerful tool for determination of spawning dates for these individuals. If length and age are highly correlated and mortality is nearly uniform among spawning cohorts, the relatively expensive analysis of otoliths can then be supplemented or replaced by that of length frequency distributions.

The onset and duration of reproductive activity in fishes and other organisms is influenced by physiological state as acted on by a suite of environmental variables (Brown et al. 1970). Studies on endangered fishes of the Upper Colorado River Basin have shown that hydrology and water temperature are important, but probably not exclusive, environmental factors affecting the timing of reproduction (Tyus and Karp 1989). Available information from both upper and lower basin studies suggests that humpback chub spawn during or shortly after peak spring flows when water temperatures are in the range of 12-23 C (Valdez and Clemmer 1982, Kaeding and Zimmerman 1983, Archer et al. 1985, Minckley 1988, 1989, Kubly 1990, Kaeding et al. 1990, Karp and Tyus in review). Unfortunately, little is known of the remaining environmental cues that may complement hydrology and temperature as initiators of reproductive activity in this cyprinid.

With the exception of limited efforts expended during humpback chub monitoring in the LCR, no studies of larval drift have been attempted in the study area. Drift of larval native fishes, including *Gila* sp., has been measured in the Upper Colorado River Basin and shown to be an integral part of the life cycle of some species (Valdez et al. 1985, Tyus et al. 1987, Tyus and Karp 1989). It may be of considerable importance to native fishes in the LCR, including *Gila cypha*, because of the potential for these fish to be carried during mainstream fluctuations from warm tributary waters above the confluence zone into the perennially cold and turbulent Colorado River where they may well perish.

Very little is known of habitat use and segregation by early life stages of native fishes in Grand Canyon tributaries. Valuable data on this aspect of the ecology of these fishes will be gathered by the Fish and Wildlife Service study team. We propose to complement those data with direct behavioral observations of early life stages of native fishes in streamside habitats during spring to summer periods of base flow by extension of methods used by Valdez (1989) in the LCR. Valdez made behavioral observations of larval and larger young-of-the-year native fishes in streamside habitats followed by qualitative evaluations of habitat conditions during a period of clear water. He found what appeared to be spatial habitat segregation among species and temporal (diel) changes in habitat use within species.

Food habits of early life stages of native Colorado River fishes also have received limited attention. Collections of suspected young-of-the-year humpback chub were first made by Suttkus et al. (1976), but no detailed studies of the food habits of early life stages have been completed for fish collected in the Grand Canyon region. Minckley et al. (1981) reported dipterans (chironomids and dolichopodids) from stomachs of three young-of-the-year. They also observed foraging by individuals less than 50 mm TL at bottom, mid-water and surface depths, and assumed these fish were feeding on attached diatoms and small invertebrates. Grabowski and Hiebert (1989) found chironomid larvae and unidentified insect parts, invertebrate eggs, protozoans, and organic matter in stomachs of five larval *Gila* sp. collected from Green River (Island Park) backwaters near Vernal, Utah. No planktonic organisms were detected.

Gila sp. juveniles (21-80 mm TL) from Green River backwaters fed on a variety of food resources, but stomach contents were composed primarily of chironomids and other insects (Grabowski and Hiebert 1989). Algae, other than diatoms, were noticeably absent, although terrestrial plant seeds were present in some stomachs. Piscivory or scavenging of unidentifiable fish and *Notropis lutrensis*, presumably larval stages, was recorded in 7% of juveniles collected from Island Park and Jensen backwaters during 1988.

Method 3.2a. During the present investigation, considerably increased effort will be expended in the study of early life stages. Larval drift nets in the LCR during the initial year of sampling will be emplaced at three permanent locations--the two campsites proposed by Arizona State University and the Navajo Nation, and the confluence zone of the tributary and mainstream. Temporary nets will be emplaced below Atomizer Falls, at Sipapu, and other sites that may be warranted depending upon available manpower. All nets will either be metered or current velocities at their mouths will be measured at the beginning and ending of each sampling period.

Sampling in the first year (1991) will be intensive in order to detail the phenology of reproductive activity by different fish species. All larval drift nets will be fished for 1-2 hours at six-hour intervals to include crepuscular, daylight, and darkness hours during the reproductive period of native fishes, potentially March through June. If subsequent analysis shows that any of these diel periods are unproductive, they will be deemphasized during remaining years. Caution will be observed to make these determinations separately during periods of turbid and clear discharges.

Sampling every day during the entire reproductive period would be prohibitive, both in terms of manpower expenditures in the field and in subsequent sorting. Therefore, drift nets will be run every other day during periods of base flow with upper and confluence nets on the same schedule.

During spates which might increase the amount of larval drift, sampling at all nets will be accomplished daily. Placing these nets in the near vicinity of base camps will allow them to be emplaced in time to intercept increased flows, particularly if communication of impending events is communicated to the field by radio. Past experience has shown, however, that at flows of 400 cfs or more these nets begin to clog in 15 minutes or less. During these periods, it will be necessary to shake and brush nets at short intervals or to empty and replace. At flows above 500 cfs, it may be impossible to fish larval drift nets at other than nearshore locations even with the aid of boats. During times when use of these nets is precluded by high flows, sampling for larval fishes will be accomplished with tow nets and fine-meshed seines and minnow traps.

At a minimum, larval drift nets in the confluence zone of the Little Colorado and Colorado rivers will be fished during periods of moderate to low mainstream discharges (ca. 3,000-25,000 cfs). When mainstream discharge is high enough to completely impound the LCR, current velocities in the confluence zone may be insufficient to effectively use larval drift nets. During these periods, we will depend on tow nets, larval seines, and fine-meshed minnow traps to sample this area. Position of the confluence larval drift nets will be dependent upon mainstream stage. At high mainstream flows, Little Colorado River water is diverted to the channel south of the mouth island, whereas at low mainstream flows this channel is dewatered and the tributary discharges through the channel to the north of that island.

The number of larval drift nets necessary to adequately sample a transect of the LCR presently is unknown. At a minimum, we anticipate two nets set in the current, one nearshore and in the major current, will be needed. Present indications are that these nets should be set in currents exceeding 0.5 ft sec^{-1} and 1.0 ft sec^{-1}, respectively, to adequately collect larvae of humpback chub and the two resident suckers (K. Bestgen, Larval Fish Laboratory, personal communication). We suspect that the number of larval drift nets necessary to allow statistical comparisons among net locations, periods of the day, and days within sampling periods may be prohibitively large. However, in order to determine the precision gained from additional nets, we will initially place six or more nets equidistant across a test transect, sort the samples taken at six hour intervals during a day, and calculate variance estimates to determine sample sizes necessary for different levels of significance (Elliott 1971). If increasing net numbers to a reasonable level (assumed six or fewer per station) allows statistical comparisons to be made, and these comparisons are deemed important by the Aquatic Coordination Team, we will request addition of sufficient manpower to make these collections.

Catchability of larval fishes by drift nets diminishes with increasing fish size and locomotor ability. Therefore, this gear type will have to be supplemented with, and later replaced by, fine-meshed seines and minnow traps. *A priori* determination of the period during which larval drift nets will be effective is impossible, but rather the timing of transition to other gears will depend upon the reproductive periodicity of the fishes of interest.

Method 3.2b. Information to determine the timing and duration of reproductive activity for different fish species will be provided by analysis of daily growth rings in otoliths (see Objective 3.7) and, if applicable, subsequent analysis of length frequency distributions of early life stages. Assuming that modes in length frequency distributions of native fish early life stages represent peaks in past spawning activity, i.e. length is highly correlated with age and mortality rates have been similar for different spawning classes, these distributions can provide valuable information on past spawning dates at considerably reduced cost and without sacrifice of adult fishes.

The relationship between length and age has not been quantified for native fishes in Grand Canyon under natural conditions, and it is probable that this relationship varies somewhat among temporally segregated spawning cohorts due to both environmental and genetic factors. As indicated above, however, this relationship can be determined through analysis of otoliths from fish of known length over the reproductive period. Measurement of survivorship in early life stages and, in particular, differential survival among spawning cohorts represents a monumental task.

Method 3.2c. Determination of major spawning dates and measurement of contemporaneous environmental conditions will allow delineation of cues that potentially serve to initiate this activity. Close-interval measurements of discharge and water temperature will be available from U.S. Geological Survey stations on the LCR at Cameron and above the mouth. The Cameron station also includes a stage-initiated sampler that will provide indices of other downstream conditions including suspended sediment and water chemistry measurements. Installation of meteorological stations at the ASU/Navajo camps will add an additional suite of meteorological variables to this database.

Statistical techniques such as canonical correlation analysis or multiple regression with and without time lags may allow development and refinement of predictive equations for timing and duration of reproductive activity over the course of several years of investigation. Time series data of environmental conditions may not be suitable for parametric statistical tests, however, and analagous nonparametric analyses may have to be utilized (see e.g. Prager and Hoenig 1989).

Method 3.2d. At base flow, which is expected during the majority of the reproductive and rearing season for native fishes, we will use direct observation and video cameras to record behaviors and habitat use by early life stages in relatively shallow, clear water, streamside pool habitats. These observations will include schooling, spatial segregation among species and among age classes within species, agnostic interactions, feeding, and selection for cover.

In order to quantify behaviors and movements of small fishes within pools, we will insert stakes into pool bottoms to form a two-dimensional matrix of cells. Each of the stakes also will be painted at 5 cm intervals to provide a third dimension.
When captured on video camera using continuous filming or time-lapse procedures, observations can be preserved for later analysis to supplement initial field findings.

Objective 3.3. Provide for the propagation of native fishes of the Colorado River in Grand Canyon for use in laboratory or hatchery based studies necessary to satisfy the needs of the Section 7 Conservation Measures.

Background 3.3. Some studies on native fishes of the Grand Canyon cannot be completed effectively in the field and will need to be conducted under controlled conditions in a laboratory or other off-site environment. Examples include effects of thermal shock, swimming ability at different current velocities, growth in different thermal regimes, and biological interactions among fish species. Many of these studies will be directed at early life stages of native fishes, and they will require a dependable supply of experimental animals of various ages. It is doubtful that this supply can be obtained reliably from field collections, given the logistical difficulties of removing identified early life stages from Grand Canyon. Therefore, adults or fertilized eggs will have to be removed to a hatchery setting for propagation. Which of these two courses of action will be taken is a decision that undoubtedly will be made by the Aquatic Coordination Team.

Method 3.3. Adult native fishes or fertilized eggs will be transported by helicopter to the AGFD Bubbling Ponds Hatchery at Page Springs, Arizona. This facility presently is used for hatching and rearing of Colorado squawfish and razorback sucker destined for reintroduction in Arizona waters. All fish will be held in an above-ground circular raceway to ensure against accidental release into the Verde River drainage. Gonadal maturation, fertilization, hatching, and rearing will be accomplished with methods used successfully by Hamman (1982) and Inslee (1982). Progeny from these rearings will be made available for studies deemed advisable by the Aquatic Coordination Team.

Logistical Support. At a minimum, helicopter transport of fishes or reproductive products out of Grand Canyon will be necessary. Most efficient and rapid transport would be accomplished by continuing by helicopter to Page Springs, but vehicular transport from a developed roadway might be an acceptable alternative.

Objective 3.4. Determine changes in environmental conditions in mainstream and tributary confluence zone native fish rearing habitats under different flow regimes.

Background 3.4. Exact environmental conditions for successful rearing of native fishes in the Colorado River in Grand Canyon are unknown, but larval to young-of-the-year distributions suggest preferences for nearshore, low velocity habitats, such as backwaters, having warmer water than that of the perennially cold mainchannel (Maddux et al. 1987, Kubly 1990). Many tributaries to the Colorado River also serve as important breeding and rearing habitats, although use of some streams may be largely seasonal with native fishes replaced by trout during winter and early spring. During this time of year, tributary water temperatures can have daily minima below those of the mainstream (Maddux et al. 1987).

Water temperatures in Colorado River backwaters vary with time of year and amount of water exchange between the perennially cold mainchannel and these habitats. Maddux et al. (1987) reported water temperatures in some backwaters exceeded 20 C during summer months under high, steady mainstream flows having temperatures of about 10 C, but found winter temperatures could be lower than those of the mainchannel. Subsequent measurements made in May during periods of fluctuating flows indicated that warming of backwaters, although measurable, was greatly diminished by daily exchange with cold mainchannel waters (Kubly 1990).

Water temperatures in all measured tributaries to the Colorado River in Grand Canyon exceed those of the mainstream during the spring to early summer peak reproductive period of native fishes (Cole and Kubly 1976, Carothers et al. 1981, Maddux et al. 1987). Impoundment of tributary flows by high mainstream stages has been observed by Minckley et al. (1981) and Maddux et al. (1987), who proposed that these impounded confluence regions might serve as important warmwater, low current velocity staging sites for adult native fishes and rearing sites for young-of-the-year. Under fluctuating flow regimes, however, confluence zone water temperature and current velocity vary through the course of each diel cycle in conjunction with changes in mainstream stage (Kubly 1990, AGFD unpublished).

Method 3.4. Water depth, water temperature, pH, dissolved oxygen, specific conductance, and redox potential will be measured by automated continuous or manual recording instruments in backwaters, tributary mouths, and adjacent mainchannel sites under a variety of controlled flows. Supplementary interval measurements also will be made of air temperature, solar radiation, turbidity or light extinction at depth, and current velocity. All measurements will be made for a minimum of two flow cycles at consistent locations within each habitat. Number of sampling locations will depend upon the number of measuring devices, but we hope to develop a gridded network sufficient to determine the extent of spatial and temporal heterogeneity within and among habitats at different flows. The sampling network will be superimposed on topographic maps showing water perimeters and depth contours at measured flows. Construction of these maps will require the assistance and equipment of the U.S. Geological Survey using methods employed to map spawning bars in the Lee's Ferry reach.

Water samples will be collected for analysis of dissolved and total phosphate, nitrate-nitrite nitrogen, ammonia nitrogen, Kjeldahl nitrogen, particulate organic matter, dissolved organic matter, and chlorophyll *a*. Samples will be taken from the open water and from pore water in underlying sediments. Two series will be taken during each flow period, steady or fluctuating, to represent expected extreme conditions. Sediment cores will be taken for measurement of particle size distribution, organic matter content, total phosphate, and Kjeldahl nitrogen within strata.

Major emphasis will be placed on backwaters above and below the Little Colorado River between Kwagunt and Unkar rapids (RM 55-76) and on the mouth of that tributary. Additional backwaters will be monitored in the river reach between Glen Canyon Dam and Lee's Ferry in conjunction with trout and limnological studies. The extent of measurements made in other tributaries (Paria, Shinumo, Kanab, and Havasu) and backwaters below Havasu Creek will depend upon available time, equipment, and manpower. We anticipate that our measurements will be augmented by those made by the U.S. Geological Survey and by the Fish and Wildlife Service sampling program for habitat evaluation. Use of dye tracers by U.S. Geological Survey personnel to measure water exchange between backwaters and adjacent mainchannel habitats and between tributaries and the mainchannel will be encouraged.

<u>Logistical Support</u>. Access to all backwater and tributary habitats will require transportation of research crews down the Colorado River. Boats will have to be of two types--large vessels for transporting crew and equipment, and smaller vessels for moving among research sites, particularly in the reach above and below the Little Colorado River. Necessary support from the U.S. Geological Survey will include one or more individuals skilled in surveying methods and necessary equipment to map habitats. Mapping will be tied to the

Geographical Information System database wherever possible. Distribution and abundance of rearing habitats should be measured from aerial photography at different flow levels to complement earlier GCES Phase I efforts. Timely analysis of water chemistry samples undoubtedly will require helicopter transport out of Grand Canyon, at least from Phantom Ranch.

Objective 3.5. Determine algal and invertebrate standing crops and their relative contributions to diets of young native fishes in tributary, backwater, and mainchannel habitats under different flow regimes.

Background 3.5. Zooplankton and benthic invertebrates are known food resources for young-of-the-year native fishes in the Colorado River (Minckley et al. 1981, Jacobi and Jacobi 1982, Maddux et al. 1987, Grabowski and Hiebert 1989). Early life stages of razorback sucker appear to be largely dependent upon zooplankton (Marsh and Langhorst 1988), and minimum densities for survival of these fish have been determined in laboratory experiments (Papoulis 1986). Algal contributions to the diets of young native fishes apparently are more limited, although this component seemingly has received less attention by most investigators.

Haury (1986) speculated that backwater and other slackwater habitats might be important sites of zooplankton reproduction in the Colorado River, but he concluded that most zooplankton in the tailwater probably originated in Lake Powell. Mean density of zooplankton collected in backwaters of the Colorado River in Grand Canyon during May of 1987-1989 under fluctuating flows exceeded that of the mainchannel by a factor of four (Kubly 1990, see also Grabowski and Hiebert 1989 for Upper Basin comparisons). Taxonomic divergence also was apparent between the two habitats, with cladocerans forming a much larger fraction in backwaters than in the mainchannel.

Due to mainstream sampling difficulties, similar quantitative comparisons are not available for benthic organisms. Carothers et al. (1981) noted, however, that "side eddies" and backwaters often contained considerably higher densities of benthic invertebrates than did the mainchannel. No attention has thus far been given to the effects of dewatering and desiccation in backwater habitats on taxonomic composition or abundances of benthic invertebrates.

Carothers et al. (1981) and Hofknecht (1981) found densities and diversities of benthic macroinvertebrates in tributary confluence zones were generally lower than those of upstream (200 m) sites. They attributed decreases in confluence zones to the wide range of physical and chemical conditions brought about by daily infusion of mainstream waters and, in some tributaries, to less suitable substrates at lower sites.

Method 3.5a. Exchanges of zooplankton, drift organisms, and particulate organic matter (POM) between backwaters and mainchannel and tributary mouths and mainchannel will be measured with samplers situated interior to the mouths of backwaters and tributaries. One set of samplers will be open to the mainchannel, but closed by a net on the backwater/tributary side. A second set of samplers will be oriented in the opposite direction to collect organisms and POM moving out of backwaters and tributaries. All samplers will have narrow-mouthed orifices holding funnels passed through stoppers to increase surface of the sampling area but prevent organisms and POM from exiting once in the sampler. These samples will be supplemented with backwater and mainchannel collections taken with a diaphragm pump. Zooplankton will be analyzed taxonomically by life stage and as a fractional component of POM imported and exported to and from backwater and tributary mouth habitats.

Changes in zooplankton communities during the full course of controlled steady and fluctuating flow periods (maximum 11 days) will be evaluated in backwaters in the Lee's Ferry reach. If the projected controlled steady flows of 8,000 cfs and 11,000 cfs are insufficient to inundate backwaters to sufficient depth, we will employ "limnocorrals" to isolate zooplankton communities in deeper eddies under fluctuating flows. Limnocorrals will allow us to remove the effects of current velocity and water exchange with the mainstream, but they will not provide increases in water temperature that would occur in backwaters. Further resolution of the effects of different flow regimes on zooplankton populations will require additional controlled flows or, potentially, studies in laboratory settings.

Method 3.5b. Benthic invertebrates will be sampled on transects at rearing habitats to include sampling locations within and without the zone of fluctuations during controlled flows. These samples will be taken after various periods of fluctuations to ensure that benthic invertebrates have experienced different times of dewatering and desiccation. The short periods available for any controlled flow, variation in flow regimes preceding these periods, and the limited time available for sampling any rearing habitat may confound results from transect sampling. This will be particularly true of sites that can only be reached by downstream river trips. In order to offset these difficulties to the greatest extent possible, we will sample backwaters in the Lee's Ferry reach intensively. These habitats can be reached during the full course of the controlled periods. Their proximity and accessibility will also allow for the use of artificial or sterilized natural substrates to remove the effects of varying antecedent conditions from the analysis.

Method 3.5c. Samples of larval to juvenile native and introduced fishes will be collected from backwaters, tributary confluences, tributaries above the confluence zone, and outlying mainchannel habitats for analysis of digestive tract contents. The analysis will compare digestive tract contents with available food resources in these respective habitats for evidence of selectivity and as corollary information for determination of movements among habitats. Percentage fullness will also be measured after the method of Jacobi and Jacobi (1982) to determine whether any evidence exists for interruption of feeding during particular flows or in different habitats with due attention to time of collection. Corollary laboratory studies evaluating time to starvation or growth rates for different food resource levels at different water temperatures and current velocities will be proposed to the Aquatic Coordination Team if this line of investigation is deemed worthy of further pursuit.

Logistical Support. Needs for this objective are incorporated under those for Objective 3.3.

Subcontracts. Expertise for taxonomic determination of pro- to mesolarval stages of fishes and plankton food resources of these fishes will have to be obtained through contracting. The Larval Fish Laboratory at Ft. Collins, Colorado has been contacted concerning AGFD needs for these services.

Objective 3.6. Determine the behavioral responses of larval to juvenile native fishes to changing environmental conditions in rearing habitats during controlled flows.

Background 3.6. Of all studies completed to date on native fishes of the Colorado River in Grand Canyon, only Kaeding and Zimmerman (1983) and AGFD (see Kubly 1990) were afforded the opportunity of extended sampling periods at prescribed sites. Neither of these studies concentrated on flow-mediated changes in breeding or rearing habitats and, in particular, those changes effected by fluctuations in mainstream stage. In like manner, only Maddux et al. (1987) were able to sample native fishes in backwaters during a period of controlled flows. Unfortunately, their sampling occurred during September and October, a period when young-of-the-year fishes had grown to a size at which they were probably less affected by fluctuating flows.

Maddux et al. (1987) noted that early life stages of native fishes displaced from rearing habitats into the mainchannel might suffer increased predation, starvation, damage from river currents and rapids, or drift into less favorable rearing habitats. They admitted, however, that some level of flow fluctuation or other environmental change in rearing habitats might be less detrimental to native fishes than to introduced species. There is a need to quantitatively assess changes in environmental conditions that occur during diel changes in mainstream flows in native fish rearing habitats and resulting responses of larval to juvenile stages of the resident fishes. These measurements cannot adequately be made by conventional monitoring or survey approaches where investigators travel downriver making measurements of multiple habitats during the course of a single day. The controlled steady and fluctuating flows provided during the GCES Phase II research program, although unfortunately short in duration both individually and in total, provide a window of opportunity to make sustained measurements of environmental changes and fishes' responses to these changes under known flow conditions.

Method 3.6. The measurement of associated behavioral responses by young fishes to different flow regimes will be limited by duration of controlled flows, the even shorter time available for sampling at given locations, and the unpredictable presence of the fish in these habitats. Our major objective is to document the species composition and size distribution of fishes in different habitats and to measure their movements (active or passive) within and between habitats during different flow regimes. Sampling of fishes in these habitats will be restricted largely to direct observation or passive gears in order that the activity of making collections provides minimum disturbance to the fishes or their habitat. Direct observations will, of course, be restricted largely to daytime in clear, relatively shallow waters. Therefore, we will depend largely on passive gear types such as minnow traps or larval drift nets that can be deployed and retrieved with minimal disturbance to the habitats. Minnow traps will be emplaced at locations very near to those at which measurements of environmental conditions are taken and retrieved at six hour interval intervals scheduled to capture extremes in the daily hydrograph. Collecting periods will encompass successive fluctuating and steady flow periods to segregate behavioral responses to different flows from normal diel activity patterns. Each trap will have an attached loop of nylon cord which is secured to a small float or to an object on shore to allow retrieval from a bank location. The traps will be oriented in a variety of directions and fiberglass screens will be secured at their midpoint intersections in an attempt to determine extent and direction of movement. Larval drift nets will be used in tributaries above the zone of mainstream influence to measure drift of early life stages and their potential passage into the mainstream.

All fish of sufficient size will receive a fin-clip unique to the habitat denoting their original capture in the backwater, tributary mouth, upstream tributary or mainchannel. We are also investigating the use of immersion dyes as an alternative to fin-clip markings. At the end of the sampling period, a representative sample of fish will be preserved for analysis of otoliths and stomach contents. Otolith analyses, as described below, will be used to compare early life stages from tributary and backwater habitats in an attempt to determine the origins of these fishes (cold mainstream versus warmer tributaries), time of passage if spawned in tributaries and drifted into the mainstream, and their growth rates in these respective habitats.

Objective 3.7. Determine age structure and growth rates of native fishes of the Colorado River in Grand Canyon. Relate these life history features to hydrologic and thermal conditions experienced by the fishes during their growth to present size.

Background 3.7. Information on the age structure and age-growth relationship of the native fish populations in Grand Canyon is limited. Carothers et al. (1981) analyzed scales for speckled dace and opercles for bluehead sucker, flannelmouth sucker, and humpback chub. Kaeding and Zimmerman (1983) provided growth estimates for humpback chub based on scale annuli, but their results were not verified and they qualified their determinations by stating "...we believe that age estimates derived from the scales of humpback chubs from the Colorado are not reliable because some fish formed an annulus near the end of their first year of life, whereas other fish did not." They noted apparent marked differences in growth rates between fish taken in the mainstream and those from the LCR. Carothers et al. (1981), Kaeding and Zimmerman (1983), and Maddux et al. (1987) used length-frequency distributions to measure growth to ages I or II, but the latter two groups of investigators noted their data displayed such heterogeneity at age II and greater that further length-frequency based approaches to ageing this species were rendered largely useless.

Knowledge of age class structure is important to understanding of the reproductive biology and dynamics of native fish populations in Grand Canyon. Reliable methods will have to be developed to interpret the relationship between age and growth in order to determine effects of cold mainstream temperatures on the life cycle of these fishes. Preliminary age estimates from otoliths of chub captured during 1989 in the Little Colorado River indicate extreme variation in the strength of year classes over the past decade or two. From the management perspective, correlation of any such peaks in recruitment as reflected in the current age distribution with historic hydrograph data, as well as experimental flows, are likely to provide valuable insights for design of appropriate future management strategies.

Determination of ages of native fishes in the Grand Canyon is potentially complicated by effects on otolith or other bone and scale structure of temperature transitions associated with movements of individuals between tributary and mainstream habitats. What might appear to be typical "annual" marks may prove to be artifacts of movements between habitats which might be produced on other than an annual basis. It is therefore necessary to characterize marks in bony structures and relate them to environmental and seasonal factors. The methods described for otoliths in this proposal are directed at humpback chub, but we intend to apply them additionally to at least the native suckers of Grand Canyon during the course of this study. Furthermore, although our methods are described for field collections, we fully realize that many of these techniques could be applied with considerably better controls in laboratory or hatchery settings. If, as we propose elsewhere, a decision is made to remove native fishes from Grand Canyon for propagation of experimental animals, these studies should be conducted in the environments most conducive to their successful completion.

<u>Method 3.7a</u>. To analyze short term effects on otolith and other bone structure of transitions between mainstream and tributary (LCR) habitats, experimental groups of young-of-the-year or 1 year old humpback chub caught in the tributary will be caged and subjected to diverse treatments. A control group will remain in the LCR outside of the mainstream influence zone, a second will be drifted through the transition zone and held in a mainstream habitat outside of the LCR influence zone, and a third will be exposed alternately over the same study period (9 days) to mainstream and LCR environments.

Our preliminary studies indicate that daily growth increments are clearly visible in lapilli of young humpback chub, so otoliths will be removed from the sacrificed experimental animals, and structure of the edge increments examined for evidence of treatment effects. If variation in growth increments of humpback chub reflects temperature effects as demonstrated by Brothers (in press) for various salmonids, a series of hypotheses can be tested. Fish held in warm LCR water should display widely spaced daily growth increments extending from capture to the edge of the otolith. Those moved from the LCR and held in the mainstream should show a single transition in spacing of increments from one day to the next from wide to narrow. Fish alternated between mainstream and LCR would be predicted to show patterns of alternating wide and narrow spacing of increments on a three day periodicity. If otolith structure in these experimental animals is as hypothesized, this experiment will confirm the presence and nature of marks produced by inter-habitat movements. It will also simultaneously confirm the daily periodicity of increment formation in this species and the effect of low temperatures on growth increment formation and visibility.

Rapid (presumed one day to the next) transitions in spacing of growth increments are visible in a small, preliminary sample of lapilli of humpback chub taken in 1989 from the LCR which has been examined. If these prove to be produced by movements between tributary and mainstream, and movements between these habitats occur only once, or a fixed number of times annually, such marks may prove useful in ageing older fish. Conversely, accurate ageing may not be possible with these marks if frequency of movements across this thermal gradient varies among individuals. Regardless of the utility of these marks for ageing specimens, valuable information regarding movement history (e.g. chronology of mainstream to tributary movements) of individuals may be retrievable. It is probable that this experiment will be repeated in an off-site controlled environment.

Method 3.7b. Otolith growth is related to fish growth in all species studied to date, but the nature of this relation in humpback chub remains to be described. In some species, it has been found that growth rate inversely affects otolith size (Secor & Dean 1989, Radtke 1989a, Resnick et al. 1989). It is here proposed to describe relationships among otolith dimensions and fish body size for subsequent application in back-calculation of size of sacrificed specimens at earlier ages and for use in age verification when combined with study of otoliths of tagged and recaptured specimens. Attempts also will be made to correlate otolith size with growth rate as recorded in width of daily growth increments. Since humpback chub apparently are long-lived, any past differences in age-specific growth rates among year classes that might be discovered could prove valuable to managers. Correlations of such data with hydrographs, for example, might indicate a past relationship of growth rate and physical habitat factors that could be applied to influence or predict growth rate of humpback chub.

Selected recaptured tagged individuals will be sacrificed and lapilli analyzed. Specimens originally tagged at a small size and that have been at large for two or more years since original capture will be selected. Tetracycline injections will be used in this group of fish to provide a time-of-tagging mark in the bony structures. The large absolute amount of growth such individuals should have experienced in the known elapsed time between original tagging, weighing and measuring, and recapture, and known elapsed time, will be compared with back-calculated lengths and age determinations from otoliths. If otolith ageing techniques are valid, back-calculated ages and lengths at time of original tagging should approximate values recorded by field personnel at that time. The use of PIT tags in individuals as small as 150mm TL beginning in 1989 and even smaller in 1990 make individuals tagged in those years very valuable for this study if recaptured in 1991.

In order to facilitate communication and coordination of research efforts relevant to tag-recapture and growth, AGFD will provide lists of all tagged humpback chub in Grand Canyon to participating investigators. We will indicate on those lists which fish would be particularly useful for age-growth determinations and ask that these specimens be taken if encountered in the course of sampling.

Objective 3.8. Compare otolith edge chemistry of native fishes collected in tributary and mainstream habitats for use in growth and movement analysis.

Background 3.8. Recent studies have demonstrated differences in chemical composition of otoliths of various species inhabiting different environments (e.g. Edmonds et al. 1989, Radtke et al. 1988, Radtke 1989b). In many such cases, these differences have proven useful in strain recognition or have been found to provide valuable insights into life history of individuals. Using recently developed technology for micro-scale chemical composition sampling along transects across otoliths, chemical composition changes associated with changes in the chemical environment can be detected among growth increments. For native fishes of the Colorado River and its tributaries in Grand Canyon, this method may provide a reliable means of determining during which times and over what periods analyzed individuals were present in mainstream and tributary habitats. Integration of this method with ageing techniques using otoliths presents a great potential for deciphering the relationships between age, growth, and habitat conditions.

<u>Method 3.8</u>. Given the large chemical differences between the waters of the mainstream Colorado River and Little Colorado River in Grand Canyon (Cole and Kubly 1976), we hypothesize that individual humpback chub which move between these environments will express chemical heterogeneity in otoliths along axes extending distally from the origin. Additionally, chemistry at the edge should reflect the environment in which the specimen was captured.

Chemical composition of otolith specimens of uncertain history caught in each river, and specimens of certain history from the experiment in Objective 3.5, Method 3.5a (above) will be sampled along transects originating at the focus and extending to the edge. Sampling interval will be approximately 10 μm or smaller (1 μm resolution theoretically is possible with electron microprobe). Chemical composition sampling method has not yet been determined, but a variety of techniques, including inductively coupled plasma atomic emission spectrometry, electron microprobe, laser ablation ICP mass spectroscopy, or tunable laser dye mass spectroscopy can be attempted.

Subcontracts. Otolith and microchemistry analyses will be provided in part through a consultant, Dr. E. B. Brothers of EFS Consultants and Cornell University.

Objective 3.9. Determine the extent to which limnological factors, with emphasis on water chemistry and aquatic productivity, potentially limit the distribution and abundance of native fishes in the Little Colorado River and other tributaries which might serve as streams for augmentation of humpback chub in Grand Canyon.

Background 3.9. Successful reproduction of humpback chub in Grand Canyon is thought to be largely, if not exclusively, restricted to the LCR (Carothers et al. 1981, Kaeding and Zimmerman 1983, Maddux et al. 1987, Kubly 1990). No collections of larval humpback chub have been made from other tributaries to the Colorado River in Grand Canyon and reports of other life stages have been few and sporadic in occurrence (Kubly 1990). These observations suggest that the LCR has attributes necessary for reproduction and rearing of this species not found in other tributaries. The extent to which various structural, hydrological, or limnological attributes are important in determining relative acceptability of various tributaries to humpback chub remains largely unknown.

Although the lower 21 km of the LCR is a perennial stream fed by a series of saline springs (Johnson and Sanderson 1968), humpback chub collections largely have been restricted to the lower 15 km of the tributary (Kaeding and Zimmerman 1983, Minckley 1988, 1989, Kubly 1990), Paucity of humpback chub in the upper 6 km of the perennial LCR likely is due to restrictions from large travertine dams and falls or from high levels of dissolved carbon dioxide in spring outflows.

Waters emanating from the series of saline springs are highly charged with carbon dioxide and carry large amounts of calcium bicarbonate in solution (Cole 1975). As these waters pass downstream, carbon dioxide evolves to the atmosphere and calcium carbonate precipitates. The precipitating calcite imparts increasing turbidity to the water passing downstream, forms large travertine dams and cements substrates, filling the interstices and restricting interstitial flow.

As indicated by catch rates from a variety of gear types, humpback chub abundances in the LCR also vary considerably among seasons with higher numbers present in spring and summer (Carothers et al. 1981, Kaeding and Zimmerman 1983, Maddux et al. 1987). Higher catch rates consistently have been recorded during the period of reproductive activity, and they apparently are due at least in part to immigration of individuals from the Colorado River into the tributary (Kaeding and Zimmerman 1983, Kubly 1990). Corollary reasons for declines in abundance during other seasons are unknown, but diminished numbers of humpback chub during these periods assumedly result from unfavorable conditions relative to the mainstream into which these fish must pass when leaving the LCR.

Little information exists to assess the capacity of the LCR or other tributaries to support native fishes during different seasons or at different stages of the hydrograph. Inter- and intratributary comparisons of food resources are nonexistent for tributary reaches more than 200 m above the mouths. In some tributaries, however, distinct changes that undoubtedly affect aquatic productivity occur with upward progression away from the mouth as described above for the LCR.

Floods are a factor dramatically affecting the temporal distribution of algal and invertebrate productivity in southwestern desert streams (Gray 1981, Fisher et al. 1982). In Grand Canyon, floods occur during spring from snowmelt runoff and during summer as a result of intense, localized thunderstorms. During these times of year, food resources for desert stream fishes can decline precipitously. There are, however, distinct life history adaptations in desert stream flora and fauna that allow for rapid completion of the life cycle, multiple generations within seasons, and rapid recolonization of disturbed habitats.

<u>Method 3.9a</u>. Our approach to limnological investigations in the LCR or other tributaries suggested for augmentation of Grand Canyon humpback chub will be to concentrate on

factors that might affect the success of fish introductions. Primary consideration will be given to water chemistry and hydrologic events (floods) as they affect the distribution and abundance of fishes directly and secondarily through impacts on productivity of algal and invertebrate food resources used by fishes in these streams.

Sampling of water chemistry, and algal and invertebrate standing crops will be accomplished quarterly in the LCR. Access will be by helicopter at Blue Springs for a party of five individuals and equipment. These individuals will pass down through the LCR sampling water, algae, and benthic invertebrates at approximately 1 km intervals and at all springs and side canyons. To the extent possible, all nonconservative ions and dissolved gases will be analyzed in the field.

Quarterly surveys will be supplemented by samples taken during periods of extended stay by AGFD personnel responsible for sampling of native fishes. These samples will to some extent be opportunistic in timing in order that effects of floods on algal and invertebrate populations can be determined. Artificial or cleaned natural substrates also will be emplaced in the region of the permanent camps in order that they can be sampled at regular intervals after flood events to determine recolonization rates for algae and invertebrates.

Logistical Support Helicopter transport of personnel and equipment into the canyon of the Little Colorado River at Blue Springs and subsequent evacuation of these individuals from the mouth of the LCR will be necessary on a quarterly basis.

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Budget Request

Little Colorado River-Humpback chub research

I. Personnel Services	
1 Wildlife Specialist I - 12 months	$18,000
3 Wildlife Assistant II - 12 months	$17,000
9 Wildlife Assistant I - 6 months @ $1,250 mo.	$67,500
TOTAL PERSONNEL SERVICES	$102,500
II. Employee Related Expenses .25 personnel services	$25,625
III. Overtime pay as mandated by the Fair Labor Standards Act	$45,000
GRAND TOTAL LABOR COSTS	$173,125

IV. Travel and perdiem[1]	
Vehicle Mileage - 40,000 miles @ 0.45	$18,000
Commercial Airlines	$2,000
Department Aircraft 80 hours @ $80.00	$6,400
Per diem 1,080 days @ according to state policy	$21,600
GRAND TOTAL TRAVEL AND PER DIEM	$48,000

[1] Cost assumes BR logistic support

V. Equipment	
Vehicles - 1 4X2 truck	$10,000
Miscellaneous field equipment Water quality sampling equipment, larval drift nets, rubber raft and motor, camping equipment, etc.	$25,000
Holding facilities for humpback chub propagation	$10,000
GRAND TOTAL EQUIPMENT	$45,000

Little Colorado River-Humpback chub research

VI. Subcontracts for aspects such as stomach analysis	$20,000
VII. TOTAL DIRECT COSTS	$266,125
Indirect costs @.08 of direct costs	$21,290
YEAR ONE TOTAL COSTS	$287,415
YEAR TWO BUDGET (Year 1 minus $40,000 equipment factored by 5% inflation)	$259,785
YEAR THREE BUDGET (Year 2 @ 5% inflation)	$272,775
YEAR FOUR BUDGET (Year 3 @ 5% inflation X .33)	$94,517

Deliverables

AGFD will provide to the Bureau of Reclamation quarterly and annual progress reports, both tendered within 30 days of the ending date of the relevant period. These reports will include summaries of all previously collected data and syntheses of relevant findings. A draft final report will be submitted to Reclamation for review by March 31 of the fourth contract year, and review comments will be incorporated into the final version within 60 days of their receipt. The final report will address all objectives included in this proposal, integrate all data gathered during the course of field work, and incorporate findings of other investigators involved in these studies. The report will be in a format acceptable for publication in a major refereed journal. AGFD prefers that this format be that of the Transactions of the American Fisheries Society, but will defer that decision to comply with Reclamation's wishes. Copies of the report will be provided to the GCES Program Manager, the GCES Senior Scientist and his Research Advisory Panel, principal investigators of other research projects on native fish in Grand Canyon, and agency representatives of the Section 7 Consultation Team on the Operation of Glen Canyon Dam. All data gathered during the course of this investigation will be entered into the AGFD dBASE III database on fishes of Grand Canyon.

HABITAT USE BY HUMPBACK CHUB, *GILA CYPHA*, IN THE LITTLE COLORADO RIVER AND OTHER TRIBUTARIES OF THE COLORADO RIVER

TECHNICAL PROPOSAL

Submitted by:

Pinetop Fishery Assistance Office
U.S. Fish and Wildlife Service
Pinetop, Arizona

To:

U.S. Bureau of Reclamation
Glen Canyon Environmental Studies
Flagstaff, Arizona

30 July 1990

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I. Purpose and Background

The humpback chub (Gila cypha) was described in 1946 from a single specimen from an unknown location in the Grand Canyon (Miller 1946). It is a long term resident in the Colorado River as evidenced by remains in Indian ruins near Hoover Dam (Miller 1955). Humpback chub historically reached their greatest abundance in inaccessible canyon areas of the mainstem Colorado, and the Green, Yampa, White, and Little Colorado rivers (Smith 1960, Sigler and Miller 1963, Holden and Stalnaker 1970, 1975, Vanicek et al. 1970).

Within the native range, the species is now restricted to the Green River in Desolation, Gray and Labyrinth Canyons (Holden and Stalnaker 1975, Holden 1978, Tyus et al. 1982a, 1982b, 1987) and in Dinosaur National Monument (Miller 1964, Holden and Stalnaker 1975, Holden and Crist 1980, Miller 1982a, Tyus 1982b); the Yampa River in Dinosaur National Monument (Miller 1964, Holden and Stalnaker 1975, Seethaler et al. 1979, Miller et al. 1982b, Tyus et al. 1982a, 1987); the Colorado River in Black Rocks, Westwater, De Beque Canyons (Kidd 1977, Valdez and Clemmer 1982, Valdez et al. 1982, Archer et al. 1985); in Marble and Grand Canyons (Suttkus et al. 1976, Suttkus and Clemmer 1977, Minckley et al. 1981); and from the mouth, 13 km upstream in the Little Colorado River. The reduction in areas of occurrence and population densities have led to the species being declared endangered.

Much of the habitat use information available for humpback chub concerns juveniles and adults taken during April through October (Valdez et al. 1987). Adult humpback chub have been reported to generally be associated with fast current and/or deep channels (Holden and Stalnaker 1975, Kidd 1977, Seethaler et al. 1979). However, Valdez et al. (1982) and Fish and Wildlife Service (1986) reported preferred habitat of adults to be waters less than 9.1 m deep, over silt, sand, boulder or bedrock, at water velocity less than 30 cm/s. In the Little Colorado River, Minckley et al. (1981) reported the species was taken from a variety of habitats, including pools adjacent to eddies, large pools with little or no current, and areas below travertine dams.

Previous efforts have concentrated on locating and describing the extent of humpback chub populations; limited information has been collected on the life history and ecology of the species. In the lower Colorado River most, if not all, of the successful spawning takes place in the Little Colorado River (Kaeding and Zimmerman 1983, Minckley 1987). Continued survival of the populations in the lower river appear to be contingent upon the survival of this population.

The purpose of the proposed study is to quantify habitat use by humpback chub in the Little Colorado River and other tributaries of the Colorado River, evaluate the potential for establishing a second spawning aggregation and, to the extent possible, evaluate how these populations are affected by the operation of the Glen Canyon Dam which controls the Colorado River environment in the Grand Canyon.

II. Scope of Study

The proposed research is for the collection and analysis of information to partially satisfy Conservation Measures 5 and 7, "Conduct Research to Identify Impacts of Glen Canyon Dam Operations on the Humpback Chub in the Mainstem and Tributaries" and "Establish a Second Spawning Aggregation of Humpback Chub in the Grand Canyon". This study will evaluate the specific habitat requirements of various age classes of humpback chub and other native and introduced fish species in the tributaries of Colorado River and the availability of these habitats at changing discharges. Tributaries proposed for inclusion in this study are Little Colorado River (LCR), Paria River, and Bright Angel, Shinumo, Tapeats, Deer, Kanab, and Havasu creeks.

Specific objectives of the proposed study include:

1) Identify and quantify preferred habitats of juvenile and adult humpback chub and other fish species in the LCR.

2) Identify and quantify seasonal habitat use patterns of juvenile and adult humpback chub and other fish species in the LCR.

3) Identify and quantify humpback chub spawning habitat in the LCR.

4) Identify potential humpback chub habitats within the various tributaries of Colorado River and evaluate suitability of these habitats to recovery efforts.

5) Develop discharge-frequency and flow-duration curves at locations of interest in the LCR to determine how flood stages affect humpback chub habitats.

6) Identify information and future research required for the possible enhancement of environmental conditions to protect and promote fish and wildlife populations in the LCR and other tributaries.

Analysis and interpretation of habitat data is based upon these initial hypotheses:

H_0: Juvenile and adult humpback chub are uniformly distributed throughout all available habitats;

H_0: Habitat use patterns of juvenile and adult humpback chub do not vary seasonally;

H_0: Habitat use patterns among differing age classes of humpback chub do not vary from uniform;

H_0: Habitat availability and consequent habitat use does not vary over a continuum of flow volumes.

It is anticipated that the data will be combined with information on the impacts of dam operations on habitat availability and critical life history requirements to make recommendations for the possible enhancement of environmental conditions to protect and promote the recovery of the humpback chub population in the Grand Canyon. The proposed research would also aid in the identification of suitable habitat for the establishment and future maintenance of a second spawning aggregation of humpback chub in the Grand Canyon.

III. Methodology

Procedures to evaluate habitat of humpback chub and other native species will include survey and estimation of seasonal habitat availability (macrohabitat) in tributaries, measurement of habitat characteristics specific to locations of fish capture (microhabitat), and mapping of tributary - Colorado River confluence zones before, during, and after the GCES experimental releases emanating from Glen Canyon Dam.

IIIa. Microhabitat

Little Colorado River

Characterization of microhabitat use of humpback chub and other native species in the LCR will be conducted concomitant with the LCR seasonal fish sampling program. The sampling area will include the confluence with Colorado River and extend upstream 21 river kilometers to Blue Springs. Characteristics of microhabitat will be measured during seasonal 20-day (or longer) sampling trips conducted with the Navajo Tribe and Arizona State University biologists (N/ASU), and biologists of the Arizona Game and Fish Department (AGFD). Initially, the sampling area will be subdivided into three 7-kilometer subreaches to ensure uniform dispersal of sampling efforts among available habitats. Within each subreach, four 1-kilometer segments will be randomly selected each season and all distinct habitats will be sampled. Net-specific point measurement grids will be used to characterize the physical and chemical characteristics of habitats at the time of passive net placement or active sampling, with additional water quality analyses conducted during daytime, night time, and crepuscular periods. During subsequent years, subreach sampling areas may be redefined on the basis of resolved habitat use patterns and other ecologically meaningful relationships interpreted from sampling efforts in the first year.

The tendency of fishes to specialize on specific habitat types has been documented (Zaret and Rand 1971, Mendelson 1975, Gorman and Karr 1978). Although the various passive and active sampling techniques proposed for use in the LCR are effective in capturing humpback chub and other native species, functional relationships between occurrence of an individual or group of individuals and specific physical-chemical characteristics of the sampled hypervolume are often obscured by instantaneous sampling of relatively large habitat volumes, the obliteration of information on small-scale distributional relationships among species as a result of inadequate sampling methods, and the lack of behavioral information. Relationships between physical habitat and organization in stream fish assemblages are further obscured when the interface between the tributary and the mainstream represents a discontinuity in the stream continuum (Gorman 1986). Additional difficulties are encountered in attempts to differentiate between incidental use of habitats and active habitat selection, especially during periods of fish migrational surges into adventitious streams.

Various sampling methods have previously been used to provide indirect evidence that habitat is a major dimension of niche partitioning in stream fishes (Sheldon 1968, Mendelson 1975, Gorman and Karr 1978, Baker and Ross 1981, Schlosser 1982, Felley and Hill 1983). The following net-specific procedures are proposed to lessen the severity of habitat quantification problems inherent in the various sampling methodologies to be used in the LCR.

Trammel nets. Trammel nets have consistently and successfully been used in efforts to sample humpback chub in the LCR (Carothers et al. 1981, Kaeding and Zimmerman 1983, Maddux et al. 1987, Kubly 1990). During periods of reduced discharges, trammel nets will be placed perpendicular to stream flow and subdivided into 1-m subsections, with each partition among subsections denoted with a marker adhered permanently to the float line. Immediately following appropriate placement of trammel nets within the stream channel, point measurements of water velocity, water depth, and substrate complexity will be obtained juxtapositioned to the net at each 1-m interval. Temperature profiles at successive 1-m intervals of depth will be obtained at net termini and at net center during daytime, night time, and crepuscular periods of sampling. Concomitant with temperature profiles, the water column will be sampled at surface, mid-depth, and bottom to obtain depth-specific turbidity, dissolved oxygen, pH, and conductivity values. When possible, additional information will be obtained regarding quality and quantity of cover and the proximity of cover to specific net partitions.

Data on fish will include total length, standard length, individual biomass, depth and orientation (upstream or downstream) in the water column, with associated water velocity, water depth, and substrate complexity derived as an average of values from the two nearest partitions. Depth-specific averages of temperature, turbidity, dissolved oxygen, pH, and conductivity will be calculated relative to the actual capture location of individual fishes.

Detailed habitat availability information will be taken following removal of trammel nets. Water depth, water velocity, and substrate type will be measured a 1-m intervals along two upstream and two downstream transects. Transects will be perpendicular to the direction of flow and located about 15-m apart. Point measurements along transects (including the trammel net transect) are assumed to characterize average values of water velocity, water depth, and substrate for an area 15 m^2. The amount of surface area for each interval of depth, velocity, and substrate will be calculated by summing the areas of those segments of each respective depth, velocity, and substrate interval (Orth et al. 1982). Frequencies of occurrence of humpback chub and other species in one-way depth, velocity, and substrate tables will be divided by the estimated amount of area available in each respective interval to obtain estimates of relative density. When possible, a Kolomorogov-Smirnov test (Sokal and Rohlf

1981) will be used to test the null hypothesis that densities along each habitat variable do not vary from uniform.

Seines. Seines have been used successfully in the LCR to collect humpback chub during all seasons, with higher catch rates occurring in summer (Carothers et al. 1981, Maddux et al. 1987, Kubly 1990). While this method is inappropriate for detailed analysis of microhabitat use patterns in fish communities, it may provide inferential assessments of habitat relationships (Gorman 1987). Various habitat types sampled effectively with seines include ephemeral backwaters, shoreline runs, side channels, some eddies and other slackwater areas. Following visual inspection, areal expanses within available habitat types that are relatively homogenous in water depth, current velocity, and substrate complexity will be sampled. Point measurements of water depth, velocity, and substrate complexity will be taken at 1-m intervals along transects perpendicular to the shoreline or discharge vector of the main LCR channel. Transects will be located at successive 3 to 5-m intervals throughout the sampled area, with each point measurement assumed to represent an average habitat measurement of an area 3 to 5 m^2. The amount of surface area of similar average values of water depth, water velocity, and substrate will be summed across multiple sampling events within seasons. Frequency of occurrence of humpback chub in one-way depth, velocity, and substrate tables will be divided by the estimated amount of area available in each respective interval to obtain estimates of relative density and to test the hypothesis that densities along each habitat variable do not vary from uniform.

At two points within each of the previously sampled areas, mid-depth water samples will be collected to examine water temperature, dissolved oxygen, turbidity, pH, and conductivity. Measurements from these two points will be combined to derive average water quality characteristics for each sampled area. Additional information relative to maximum and minimum size (length and width), instantaneous discharge volume of the sampled area, available cover, underlying geologic strata, and general channel morphology will be recorded for each area sampled.

Hoop nets. Hoop nets have been highly efficient at capturing most fish species in the LCR (Kubly 1990). Habitat within areas sampled using these nets will be quantified by a series of five water depth, velocity, and substrate complexity point measurements located at 1-m intervals along transects perpendicular to the longitudinal net axes. Each point measurement will be assumed to represent an average habitat measurement of an area 5 m^2.

A minimum of two transects will be used to determine average values of specific habitat characteristics. In all cases, the initial transect will be located with the central point measurement next to the net entrance. A second transect will be located 5 m removed from the net entrance but parallel to the initial transect. Where a lead net is used to direct fishes into the primary capture net, additional transects will be placed at 5-m intervals along the entire length of the lead; the central point of each transect will be juxtapositioned to the lead net. Mid-net values for water temperature, dissolved oxygen, turbidity, pH, and conductivity will be measured at the entrance to the hoop or fyke net.

The amount of surface area of similar average values of water depth, water velocity, and substrate will be summed across multiple sampling events within seasons. Frequency of occurrence of humpback chub in one-way depth, velocity, and substrate tables will be divided by the estimated amount of area available in each respective interval to obtain estimates of relative density. A Kolomorogov-Smirnov test (Sokal and Rohlf 1981) will be used to test the null hypothesis that densities along each habitat variable do not vary from uniform.

Minnow traps. Various habitats including ephemeral backwaters, side channels, and other slackwater areas may be sampled with minnow traps to collect the larvae or fry of humpback chub and other species. Measurements of water depth, water velocity, and substrate will be taken at fixed points along the axes of an X-Y coordinate plane with the center of each minnow trap representing the origin or point of capture (Leon et al. 1987, James 1989). Temperature, dissolved oxygen, pH, turbidity, and conductivity will be measured at the origin during daytime, night time, and crepuscular sampling periods.

The total area quantified for each minnow trap will be equivalent to 4 m^2; axes will be 2 m in length with two points in each direction located at 0.5-m intervals. The amount of surface area of similar average values of water depth, water velocity, and substrate will be summed across multiple sampling events within seasons. Frequency of occurrence of humpback chub in one-way depth, velocity, and substrate tables will be divided by the estimated amount of area available in each respective interval to obtain estimates of relative density and to test the hypothesis that densities along each habitat variable do not vary from uniform.

In situ Observations. Recent studies have used direct observational techniques to provide detailed analysis of single species habitat use patterns and habitat segregation in whole assemblages (Gorman 1983, Moyle and Vondracek 1985, James 1989). When conditions permit, underwater observation will be used in the LCR to further define microhabitat use by humpback chub. The observational method may prove invaluable in determining the habitat necessary for successful spawning. Measurements of depth, water velocity, and substrate will be taken along the axes of an X-Y coordinate plane with one point, the center, representing the precise location of first encounter. Mean values of each habitat variable will be used to indicate habitat preferrence, and for placement of data into one-way depth, velocity, and substrate tables.

Tributaries of the Colorado River

Measurements of microhabitat characteristics relative to occurrence or absence of humpback chub in the various tributaries of Colorado River will be conducted using methods analogous to those proposed for the LCR. These tributaries include Paria, Bright Angel, Shinumo, Tapeats, Deer, Kanab, and Havasu creeks. Prior to conducting microhabitat analyses, tributaries of interest will be surveyed during macrohabitat mapping procedures (following section). Macrohabitat information will delineate the quantity and quality of tributary reaches that necessarily should be sampled for fish and microhabitat analyses.

IIIb. Macrohabitat

Little Colorado River

Macrohabitat quantification of the LCR will be conducted initially along a series of 22 permanent transects perpendicular to flow and extending upstream at 1-km intervals from the confluence with Colorado River to LCR km 21. Measurements will be taken during low flow conditions typically occurring between periods of snow-melt and summer rain.

Physical characterization of the habitat will consist of measurements of water velocity, depth, and substrate complexity at individual points located at 1-m intervals along each permanent transect. Water velocity will be measured with a Marsh McBirney or equivalent current meter at 0.6 of the depth; water depth will be measured with a metric wading rod; and substrates will be classified according to the Modified Wentworth Particle Size Scale (Bovee and Cochnauer 1977). Mixed substrates will be assigned intermediate values. Point substrate measurements will be subject to verification using a standard U.S. Geological Survey sieve series. Substrates occurring in exposed bank areas along transects will also be classified. Additional information relative to general channel morphology inclusive of width, stream gradient, underlying geologic strata, and types of cover will be recorded for each transect.

Initially, point measurements along transects are assumed to characterize average values of water velocity, water depth, and substrate type for an area 1000 m^2. No further analysis will be conducted among successive transects which exhibit congruency in geologic strata; however, areas between successive transects which show disparities in geologic strata or channel morphology will be further subdivided with additional transects. The amount of surface area within each site for each interval of velocity, depth, and substrate will be calculated by summing the areas of those segments of each respective velocity, depth, and substrate interval (Orth et al. 1982).

The influence of mainchannel flows on LCR habiats will be investigated during periods of experimental releases from Glen Canyon Dam (lasting through July 1991), and seasonally thereafter. Habitat quanitification will be conducted along a series of permanent transects positioned at about 50 to 100-m intervals perpendicular to tributary flow and extending upstream a distance of about 1200 m.

Physical characterization of the habitat will consist of measurements of water velocity, depth, and substrate at individual points located along each transect at standardized intervals. Actual interval distances will be established following reconnaissance visits to the confluence area of the LCR. Other characteristics of habitat including areal extent of the confluence area, wetted perimeter, temperature, and various water quality variables will be measured before and during experimental releases and at differing mainchannel flows each season. The type and quantity of water quality information needed for resolution of mainchannel influences in the LCR will be coordinated with AGFD and the Aquatic Coordination Team (ACT).

Tributaries of the Colorado River

With the exception of streamflow analysis, quantification of macrohabitat within the various tributaries of Colorado River will be conducted using methods analogous to those proposed for the LCR. Tributaries of interest include Paria, Bright Angel, Shinumo, Tapeats, Deer, Kanab, and Havasu creeks. Permanent transects situated perpendicular to stream flow will be located at 1-km intervals extending from the confluence areas to areas upstream where channel morphology discourages or precludes fish passage. Additional transects will be placed between successive permanent transects that show disparity in underlying geologic strata or channel morphology. Stream discharges will be monitored using the best information available to ensure that macrohabitat measurements are taken at low flows.

Mainchannel influences on tributary habitats will be investigated opportunistically at various tributary and mainchannel flows. Permanent transects will be established at 50 to 100-m intervals within zones of influence for purposes of physical characterization of habitats. Water quality information needs will be assessed in coordination with AGFD and the ACT.

IIIc. Streamflow analysis of the Little Colorado River System

The macrohabitat evaluation outlined above provides habitat availability information for periods of low flows, and serves as a reference data set for the more complex problem of predicting habitat availability at varying discharges. The main purpose of this portion of the study is to perform a streamflow analysis of the Little Colorado River and evaluate the impacts of streamflow fluctuations on fish habitat.

If streamflow records for several years are available they will be used for streamflow frequency analysis and development of flow-duration curves. The reliability of this method will be dependent on the representativeness of the data. A 50-year or longer period of records is satisfactory. For a shorter period, a statistical analysis of the precipitation data will be performed to assess the representativeness of streamflow data. This is done by comparing the statistical characteristics of the entire period of precipitation records with the period of precipitation records relative to the period of available streamflow records. If there is no significant statistical difference between the two time series then it will be assumed that the streamflow records are representative. In this case there will be no need for stochastic generation of streamflow sequences and the analysis will proceed with the water surface profile calculations, streamflow frequency analysis and development of flow-duration curves at locations of permanent macrohabitat transects.

If streamflow data are not representative of the river flow system then synthetic streamflow sequences using a stochastic model will be generated. Many stochastic models have been tried for the simulation of the daily streamflows over the past twenty years. There are two possible approaches to the stochastic modeling of daily streamflow sequences: 1) build a stochastic model for the daily precipitation and use a transfer function to map the precipitation sequences into streamflow sequences (Chang et al. 1982, Pegram 1981; Kottegoda and Horder 1980); 2) build a daily runoff model without reference to the precipitation data (Kelman 1980; O'Connell and Jones 1979; Weiss 1973; Quimpo 1967). In the event of a need for stochastic streamflow generation, studies will be conducted in order to select and apply the proper approach.

The representativeness of the streamflow data from the USGS gaging station near Cameron, the closest stream gage to the study area, will be investigated. However, streamflow data collection and analysis at specific locations of the LCR reach under study will be required.

Water surface profiles associated with streamflow discharges will be used to delineate flow depths along macrohabitat transects and other points of interest. After the flow discharges are determined, water surface profiles will be computed. The HEC-2 Water Surface Profiles Program developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC, 1982) will be used. This computer program has the capability to compute one-dimensional steady, gradually varied flow water surface profiles in natural or constructed channels. Both subcritical- and supercritical-flow regimes can be modeled, and the effects of obstructions to flow such as bridges, culverts, and weirs in the floodplain may be included. The program has a variety of optional analytic capabilities and numerous options for defining input and specifying output.

Streamflow information derived from water surface profile calculations and streamflow frequency analysis will be used to develop flow-duration curves at points of interest along the river system. In addition to flow-duration curves, typical curves of equal velocity will be developed to describe flow velocity distribution at each macrohabitat cross section. This information will facilitate the delineation of potential fish habitats.

The following section describes briefly the general steps that will be undertaken to meet the objectives of this study.

1) On a map of the study area, locate watershed boundaries, index points where flow-duration curves will be required, and available precipitation and stream gages.

2) Obtain precipitation and streamflow data for gages within the basin and for gages, in close proximity, outside of the basin.

3) Perform statistical analysis of precipitation and streamflow data, and consider the possibility of using a stochastic model for synthetic streamflow sequences generation.

4) Decide on what synthetic streamflow generation method to use and set up required data accordingly.

5) Estimate routing parameters for selected stream reaches.

6) Compute steady-state water surface profiles.

7) Develop flow-duration curves for the locations of interest.

IV. Data Analysis

Frequency distributions of water depth, current velocity, and substrate values from locations of fish capture compared using Kolomorogov-Smirnov tests (Sokal and Rohlf 1981) will determine whether juvenile and adult humpback chub occupy areas of depth, velocity, and substrate in proportion to availability. The defined preferred ranges of depths, velocities, and substrates may then be compared among age classes and among seasons using standard parametric and nonparametric statistical procedures. For example, contrast analysis (Systat; Wilkinson 1988) may be used with Analysis of Variance (Sokal and Rohlf 1981) to determine seasonal differences in water depth preferences, whereas Dunn's procedure (Hollander and Wolfe 1973) may be used in conjunction with Kruskal-Wallis tests (Sokal and Rohlf 1981) to determine seasonal differences in substrate and current velocity preferences.

Assuming that humpback chub occurrence at any site is determined by physical-chemical cues, habitat data inclusive of all measured physical-chemical characteristics will be compared for areas of juvenile and adult humpback chub occurrence and absence. Initial evaluation of habitat attributes will be conducted using Principal Components Analysis (Johnson and Wichern 1982) and interpretation of the sorted, varimax-rotated loadings. The re-evaluated matrix of selected habitat characteristics will be divided into two groups based on presence or absence of humpback chub and used in a stepwise discriminant function analysis to determine which variables are most important in distinguishing between presence and absence of juveniles and adults. The resultant discriminant function will be used to predictively classify areas within tributaries relative to habitat suitability for humpback chub.

To the extent possible, resolved patterns of habitat use by humpback chub populations in the LCR and other tributaries of the Grand Canyon will be compared to existing habitat information for populations in the upper Colorado basin. The proposed study provides the opportunity to test habitat suitability index (HSI) models developed for humpback chub in the upper basin (Valdez et al. 1987); however, recent evidence suggests that HSI models are not generally applicable as habitat assessment tools (Propst 1982, Hubert and Rahel 1989). HSI models are often based on incomplete data on species habitat requirements and suffer from the lack of a conceptual framework to guide the process of developing a composite habit score from individual habitat ratings. Correlations between a species standing stock and various physical-chemical features of the environment have been derived using standard statistical procedures (Layher and Maughan 1985, Layher et al. 1987, Hubert and Rahel 1989).

V. Schedule

The proposed research will commence in autumn 1990 in coordination with scheduled activities of the N/ASU research contingent. Initial activities will include reconnaissance visits to the LCR throughout autumn and winter to establish "permanent" macrohabitat transect locations, identify in general the quantity and distribution of distinct habitat types, achieve resolution regarding necessary sample sizes within stream subreaches, and participate in efforts to establish base camps at Salt Canyon and the confluence area. Implementation of microhabitat procedures in the LCR are dependent on the scheduled activities of the N/ASU and AGFD research groups. We anticipate full implementation of these procedures in spring 1991.

Key LCR field personnel will be identified and hired during late summer-early autumn 1990. Masters Degree candidates will be identified prior to the spring semester at the University of Arizona and serve as the "macrohabitat crew" in the LCR during spring-summer 1991. During this period, the graduate students will receive technical field training in macro- and microhabitat procedures that will be necessary in the surveys of other tributaries. Scheduling of events in this manner will allow for proper training, ensure consistency of data acquisition among the LCR and other tributaries, allows time for the development and refinement of the various academic questions to be addressed in the tributaries, and allows for development of preliminary habitat models in the LCR.

One (1) team leader and two (2) field technicians in the LCR will be diverted each spring-summer period to assist AGFD in larval humpback chub research. Through July 1991, these individuals will also serve as the core team to quantify habitat availability within the LCR confluence area during GCES experimental releases.

Anticipated "milestones" of the proposed research are based on completed calendar year efforts:

1990 -project personnel identified
-base camps established
-reconnaissance visits completed
-detailed sampling regime formulated

1991 -preliminary models to quantify seasonal humpback chub habitats
-humpback chub spawning habitat quantified
-LCR habitat availability quantified experimental release impacts on habitat availability in confluence area
-redefinition of subreach sampling areas as a result of resolved habitat use patterns

1992 -refinement, through continued data acquisition and testing, of LCR seasonal and age specific humpback chub habitat models
-habitat availability quantified in other tributaries
-determination of impacts of increased discharges to humpback chub habitat availability in LCR

1993 -LCR seasonal and age-specific humpback chub models finalized
-humpback chub habitat in tributaries identified
-completion of academic questions posed by graduate students

1994 -final report submitted with all objectives of this proposal quantitatively addressed.

VI. Deliverables

Pinetop Fishery Assistance Office, U.S. Fish and Wildlife Service, will be responsible for submission of quarterly and annual written reports. Quarterly reports will detail field efforts of the previous three-month period, present all significant findings, and discuss actions that may be taken to enhance the proposed research and coordination among the various entities involved. Annual Reports will summarize and interpret all information accumulated during the previous year and will necessarily integrate all results with the findings of the N/ASU and AGFD research groups. Annual reports will be submitted not later than 1 October of each project year.

A draft final report will be submitted to the U.S. Bureau of Reclamation prior to 31 March of the final contract year. The draft final report will include analysis and interpretation of all data taken in the LCR and other tributaries, inclusive of data taken to address the specific objectives of this proposal and the various academic questions formulated by the participating graduate students. Upon receipt of review comments, Pinetop Fishery Assistance Office will provide a final report within 60 days. All raw field data will be submitted with the final report.

VII. Project Personnel

Primary administrative oversight of the proposed research will be the responsibility of James N. Hanson, Supervisory Fishery Management Biologist, Pinetop Fishery Assistance Office, U.S. Fish and Wildlife Service. Mr. Hanson will ensure that necessary staffing commitments are met, the professional conduct of all individuals and activities, and the timely delivery of all reports.

Technical oversight will be the responsibility of O. Eugene Maughan, Unit Leader and Professor, Arizona Cooperative Fish and Wildlife Research Unit, University of Arizona, and Stuart C. Leon, Fishery Biologist, Pinetop Fishery Assistance

Office, U.S. Fish and Wildlife Service. Primary responsibilities of the co-investigators will be the design and implementation of field studies, data analysis, and preparation of quarterly and final reports.

Drs. William J. Matter, Associate Professor of Wildlife and Fisheries Science, Vicente L. Lopes, Assistant Professor of Watershed Hydrology, and Kenneth G. Renard, Research Hydraulic Engineer and adjunct faculty member, University of Arizona, provide additional technical expertise and oversight through existing cooperative relationships with the Arizona Cooperative Fish and Wildlife Research Unit. Vitae of all technical investigators are included in Appendix 1.

Coordination and supervision of LCR and other tributary field personnel will be provided by a single field supervisor to be stationed in Flagstaff, Arizona. The field supervisor will direct all habitat-related activities and be responsible for ensuring effective integration of these activities into the routines of the N/ASU and AGFD research teams. Other LCR project personnel include two (2) team leaders, two (2) full-time field technicians, one (1) doctoral candidate, and three (3) part-time field technicians. Each team leader will optimally have an earned Masters Degree in fisheries or related discipline, and be responsible for responding to the directives of the field supervisor and the initial acquisition of data. Full-time technicians will have Bachelors Degrees in fisheries or limnology or have equitable fisheries experience (or both) and support all data collection activities. We anticipate the part-time technician positions will be filled with members of the Navajo Tribe; however, in the event that Navajo personnel are not available, members of the White Mountain Apache Tribe or other qualified Native Americans will most likely be used to fill these positions.

Upon appropriate completion of training in the LCR, four (4) Masters Degree candidates will concentrate their efforts among the other tributaries. One (1) Masters Degree candidate will be rotated back to the University of Arizona to develop discharge-frequency and flow-duration curves for locations of interest in the LCR. Training and coordination of these positions will be the responsibility of the field supervisor and the project technical co-investigators. Eight to 10 (8-10) field technicians will be necessary to support data collection activities within the tributaries. These field technicians will be taken from applicants resident at the University of Arizona and/or one of the Tribal entities along the Colorado River.

VIII. Safety

An acute awareness of basic safety procedures is fundamental to success of the proposed field investigations. Pinetop Fishery Assistance Office, U.S. Fish and Wildlife Service, will furnish safety training to all permanent full-time and graduate student field personnel involved with the proposed research. Training will minimally include courses in first aid, defensive driving, and river rafting safety. It is anticipated that all personnel will have completed these courses by the end of calendar year 1991.

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X. Budget

Fiscal Year 1990

Wages

PFAO Pinetop - Support	$ 2,725.00	
Fishery Biologist PFAO-Flagstaff GS-11/1 2.5 pp	$ 3,781.00	
Doctoral Candidate U of A 834 * 1 mo.	$ 834.00	
Technicians 4 GS-3 2.5 pp	$ 5,963.00	
2 Temps (Native American) 14 days, 10 hours a day 6.50 hr + 7.65% (SS)	$ 1,960.00	
	Subtotal	$ 15,263.00

Travel - Per Diem

Biologists and Technicians 8 x 14 days (1 U of A)	$ 2,666.00	
Field Support 2 x 14 days	$ 666.00	
Automotive Fuel	$ 750.00	
	Subtotal	$ 40,082.00

Equipment

Vehicles 2 Suburbans 4 x 4 1 3/4 T ext. cab 4 x 4	$ 51,000.00
Flow Meters/Marsh McBirney 2 @ 2,800 ea	$ 5,600.00
Water Quality Analysis- Hydrolab Surveyor II 6 @ 6,490 ea	$ 38,940.00

Nephalometer/Hach 2 ● 850 ea	$ 1,700.00		
Personnel Field Supplies	$ 11,000.00		
Laptop Computer	$ 3,500.00		
386 - class microcomputer w/80 mg Harddrive-math coprocessor	$ 6,200.00		
Software	$ 1,500.00		
Laser Printer	$ 2,500.00		
FAX machine	$ 1,500.00		
Miscellaneous	$ 17,500.00		
	Subtotal	$140,940.00	
	Total		$160,285.00
	15% overhead FWS		$ 28,285.00
	U of A overhead (10%)		$ 130.00
	Grand Total		$188,699.00

Fiscal Year 1991

Wages

PFAO Pinetop - Support	$ 18,466.00	
Fishery Biologist PFAO-Flagstaff		
GS-11/1 24 pp	$ 37,745.00	
GS-11/2 3 pp	$ 4,876.00	
Doctoral Candidate U of A 834 * 12 mo.	$ 10,008.00	
Master Candidates 5 @ 834/mo x 12 mo	$ 50,040.00	
Technicians 4 GS-3 27 pp	$ 68,850.00	
3 Temps (Native American) 80 days, 10 hours a day 6.50 hr + 7.65% (SS)	$ 16,794.00	
Overtime 7 x 600	$ 4,200.00	
	Subtotal	$210,979.00

Travel - Per Diem

Biologists and Technicians 4 trips 8 x 20 days (1 U of A)	$ 32,000.00	
Doctoral Students 4 trips 20 days	$ 4,000.00	
Master Candidates 4 trips 5 x 20 days	$ 20,000.00	
Field Support 4 trips 3 x 20 days	$ 12,000.00	
Automotive Fuel	$ 3,000.00	
	Subtotal	$ 71,000.00

Equipment

Flow Meters/Marsh McBirney 4 @ 2,800 ea	$ 11,200.00	
Water Quality Analysis- Hydrolab Surveyor II 4 @ 6,490 ea	$ 13,850.00	
386 - class microcomputer w/80 mg Harddrive- math coprocessor	$ 6,200.00	
Software	$ 1,500.00	
Miscellaneous	$ 10,000.00	
	Subtotal	$ 28,900.00

Support

Clerical 2 mo. @ 750	$ 1,500.00	
Photocopying 5000 pp @ .05/p	$ 250.00	
Film Development	$ 225.00	
	Subtotal	$ 1,975.00

Total	$312,854.00
15% overhead FWS	$ 55,210.00
U of A overhead (10%)	$ 9,506.00
Grand Total	$377,570.00

Fiscal Year 1992

Wages

PFAO Pinetop - Support	$ 20,600.00	
Fishery Biologist PFAO-Flagstaff		
GS-11/2 24 pp	$ 40,570.00	
GS-11/3 3 pp	$ 5,236.00	
Doctoral Candidate U of A 834 * 12 mo.	$ 10,008.00	
Master Candidates 5 @ 834/mo x 12 mo	$ 50,040.00	
Technicians 4 GS-3 27 pp	$ 71,604.00	
3 Temps (Native American) 80 days, 10 hours a day 6.50 hr + 7.65% (SS)	$ 16,794.00	
8-10 Part Time U of A	$ 40,000.00	
Overtime 7 x 600	$ 4,200.00	
	Subtotal	$259,052.00

Travel - Per Diem

Biologists and Technicians 4 trips 8 x 20 days	$ 32,000.00	
(1 U of A) 4 trips 8 U of A @ 20 days	$ 32,000.00	
Doctoral Students 4 trips 20 days	$ 4,000.00	
Master Candidates 4 trips 5 x 20 days	$ 20,000.00	
Field Support 4 trips 3 x 20 days	$ 12,000.00	
Automotive Fuel	$ 3,000.00	
	Subtotal	$103,000.00

Equipment and Maintenance

Vehicle Maintenance 3 @ 1250 yr	$ 4,000.00		
Equipment Repair	$ 2,000.00		
Personnel Field Supplies	$ 3,000.00		
Miscellaneous	$ 10,000.00		
	Subtotal	$ 19,000.00	

Support

Clerical 4 mo. @ 750	$ 3,000.00		
Photocopying 5000 pp @ .05/p	$ 250.00		
Film Development	$ 225.00		
Mainframe Computer Time	$ 1,500.00		
	Subtotal	$ 4,975.00	

Total	$386,027.00
15% overhead FWS	$ 68,122.00
U of A overhead (10%)	$ 17,839.00
Grand Total	$471,988.00

Fiscal Year 1993

Wages

PFAO Pinetop - Support	$ 21,424.00	
Fishery Biologist		
PFAO-Flagstaff		
GS-11/3 27 pp	$ 43,561.00	
GS-11/4 3 pp	$ 5,613.00	
Doctoral Candidate U of A		
834 * 12 mo.	$ 10,008.00	
Master Candidates		
5 @ 834/mo x 12 mo	$ 50,040.00	
Technicians		
4 GS-3 27 pp	$ 71,604.00	
3 Temps (Native American)		
80 days, 10 hours a day	$ 16,794.00	
6.50 hr + 7.65% (SS)		
8-10 Part Time U of A	$ 40,000.00	
Overtime		
7 x 600	$ 4,200.00	
	Subtotal	$263,244.00

Travel - Per Diem

Biologists and Technicians		
4 trips 8 x 20 days	$ 32,000.00	
(1 U of A)		
4 trips 8 U of A @ 20 days	$ 32,000.00	
Doctoral Students		
4 trips 20 days	$ 4,000.00	
Master Candidates		
4 trips 5 x 20 days	$ 20,000.00	
Field Support		
4 trips 3 x 20 days	$ 12,000.00	
Automotive Fuel	$ 3,000.00	
	Subtotal	$103,000.00

Equipment and Maintenance

Vehicle Maintenance 3 @ 1250 yr	$ 4,000.00		
Equipment Repair	$ 2,000.00		
Miscellaneous	$ 10,000.00		
	Subtotal	$ 16,000.00	

Support

Clerical 11 mo. @ 750	$ 8,250.00		
Photocopying 20,000 pp @ .05/p	$ 1,000.00		
Film Development	$ 225.00		
Mainframe Computer Time	$ 1,500.00		
Meeting Attendance	$ 1,500.00		
	Subtotal	$ 12,475.00	

Total	$394,719.00
15% overhead FWS	$ 69,656.00
U of A overhead (10%)	$ 18,422.00
Grand Total	$482,797.00

Fiscal Year 1994

Wages

PFAO Pinetop - Support	$ 21,424.00	
Fishery Biologist PFAO-Flagstaff GS-11/3 27 pp	$ 52,534.17	
Doctoral Candidate U of A 834 * 12 mo.	$ 10,008.00	
Master Candidates 5 @ 834/mo x 3 mo	$ 12,510.00	
Technicians 4 GS-3 27 pp	$ 75,130.00	
	Subtotal	$171,606.00

Travel - Per Diem

Biologists and Technicians 2 trips 5 x 20 days (1 U of A)	$ 10,000.00	
Doctoral Student 2 trips 20 days	$ 2,000.00	
Field Support 2 trips 3 x 20 days	$ 6,000.00	
Automotive Fuel	$ 3,000.00	
	Subtotal	$ 19,000.00

Equipment and Maintenance

Vehicle Maintenance 3 @ 1250 yr	$ 4,000.00	
Equipment Repair	$ 2,000.00	
Miscellaneous	$ 10,000.00	
	Subtotal	$ 16,000.00

Support

Clerical 11 mo. @ 750	$ 8,250.00		
Photocopying 20,000 pp @ .05/p	$ 1,000.00		
Film Development	$ 225.00		
Mainframe Computer Time	$ 1,500.00		
Meeting Attendance	$ 1,500.00		
	Subtotal	$ 12,475.00	
	Total		$219,081.00
	15% overhead FWS		$ 38,661.00
	U of A overhead (10%)		$ 3,807.00
	Grand Total		$261,549.00

ECOLOGY AND CONSERVATION BIOLOGY OF HUMPBACK CHUB, *Gila cypha*, IN THE LITTLE COLORADO RIVER, ARIZONA

TECHNICAL PROPOSAL

Submitted by

Arizona State University
Tempe, Arizona
85287

to

U.S. Bureau of Reclamation
Glen Canyon Environmental Studies
P.O. Box 1811
Flagstaff, AZ 86002

30 July 1990

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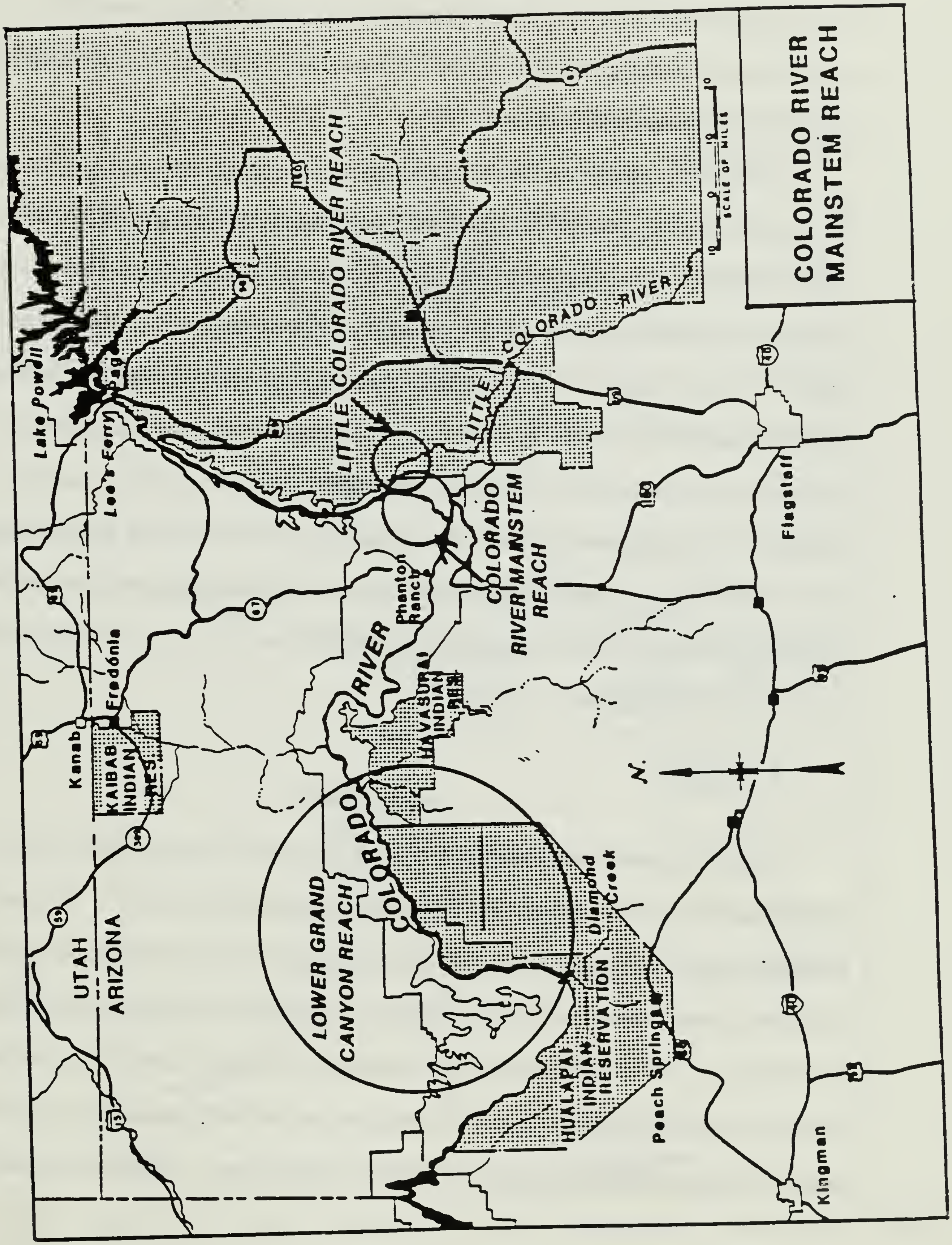
INTRODUCTION

The humpback chub (*Gila cypha*) is a cyprinid fish endemic to the Colorado River system of western North America (Miller 1946). Once considered widespread and abundant, its distribution and numbers have declined dramatically in recent decades, in response to anthropogenic modifications to its physical and biological environment (Minckley 1973, U.S. Fish and Wildlife Service [USFWS] 1984). The species is now federally listed as endangered (USFWS 1983). The largest known population of humpback chub resides within the Colorado River and its tributaries in Grand Canyon, Arizona. Therein, the fish is documented to congregate and reproduce in substantial numbers only in a single major tributary, the Little Colorado River (LCR).

The Grand Canyon population of humpback chub has been a subject of study for a number of years (e.g., Arizona Game and Fish Department [AZGFD] unpublished data, Carothers and Minckley 1981, Kaeding and Zimmerman 1983, Maddux et al. 1987, Minckley 1977, 1979, 1989) but intensive research has been conducted primarily during the reproductive season, when availability of chubs is greatest. Other times of year have received only sporadic and generally cursory attention. Further, because the species is available in abundance primarily within the confluence of the Colorado and Little Colorado rivers, most activity has been focused in that area. Although research to date has provided valuable information pertaining to life history and ecology of humpback chub in the Grand Canyon, a number of critically important questions remain unresolved, and data are required for future management of this unique and imperiled species. In particular, the duration and extent of movements by juvenile and adult humpback chub in the LCR, and their span of residency within that

Figure 1, General Study Area



river are generally unknown, as is the basic reproductive biology of this fish. Investigations that will quantitatively define these major life-history characteristics are the focus of this research proposal.

A number of humpback chub studies have been proposed under the aegis of U.S. Bureau of Reclamation/Glen Canyon Environmental Studies (USBR/GCES), and USFWS Conservation Measures for Humpback Chub in the Grand Canyon. Included are routine monitoring during the spring-summer humpback chub spawning period (AZGFD); habitat studies in the LCR and other Colorado River tributaries (USFWS); additional native fish studies by AZGFD; and the present study of reproduction, movements and distributions of juvenile and adult chub in the LCR. When fully integrated, results of these projects should provide a clearer picture of the biology and environmental requirements of humpback chub in the Grand Canyon, and enable informed decisions to be made regarding management of the Colorado River and its constituent native species.

I. STUDY AREA

The study area encompasses 21 km of the lower LCR, from Blue Spring downstream to confluence with the mainstem Colorado River (Fig. 1). For purposes of this investigation, the study area will be subdivided into the following four regions: the confluence area proper, and three sequential 7-km stream reaches (LCR1 through LCR3; Fig. 2). Two of these sequential reaches (LCR2 and LCR3; Fig. 2) will be further subdivided into individual 1-km sections, so that fish populations therein can be sampled using stratified random methodology (see below). Aspects of research

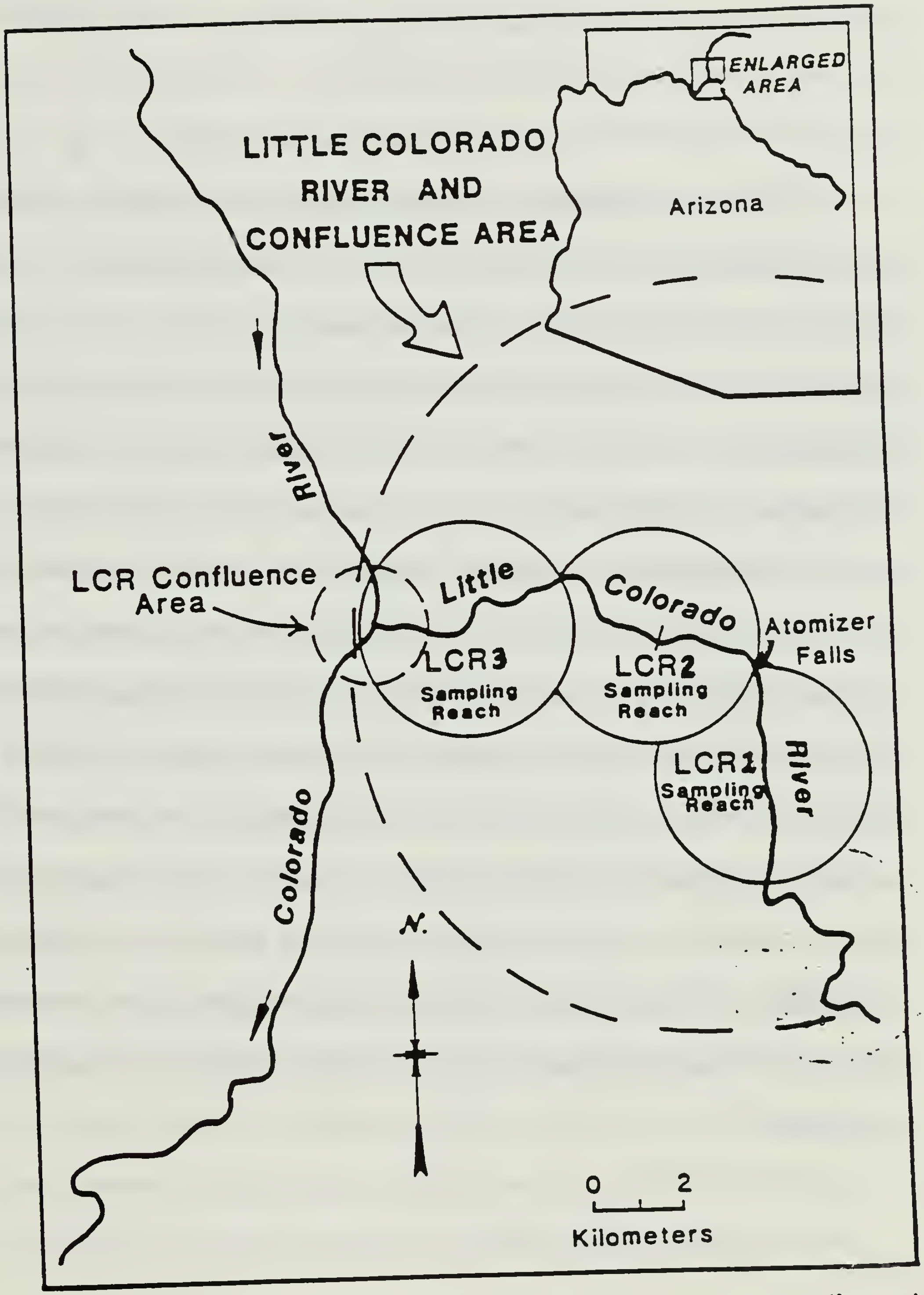


Figure 2. Map of study area with locations of sampling strata.

documented herein for the confluence area and the upstream reaches will be performed in conjunction with AZGFD, USFWS, and an as yet unnamed USBR contractor. Areas of intergradation will be so indicated in the proposal.

II. LOGISTICAL SUPPORT

A. Base of Operations. Successful conduct of the proposed research will require establishment of two, semi-permanent (4-year) installations at locations central to activities on the LCR. The intersection of the Salt Canyon with the LCR, and a site approximately 3 km upstream from the confluence are the most practical locations for these facilities. The specific sites will be identified during preliminary field reconnaissance during autumn 1990, with site selection hinging upon both safety from flood and accessibility by helicopter. Each site will contain a wooden platform, to be constructed on site, for support of three canvas wall tents. These will serve as living quarters, storage area for equipment, and for support of research operations (e.g., specimen analysis, record keeping, communications, etc.). An outdoor kitchen area at each site will be equipped with propane stove, secure food storage facilities, and necessary supplies for meal preparation. A small, portable gasoline generator will supply electricity for lights, computer, microscope illumination, radio equipment, battery recharging, etc., and will allow conduct of routine duties beyond limitations of daylight. Generator fuel will be stored on site in a drum or carboys, to be renewed as necessary.

All materials for fabricating and outfitting the base camp facilities will be delivered to the respective sites by helicopter (II. C., below), as coordinated by the GCES Program Manager.

B. Radio Communications. Communications capabilities between base camps and (a) the south rim of the Grand Canyon (U.S. National Park Service [USNPS]); (b) Flagstaff (GCES); (c) Window Rock (Navajo Natural Heritage Program [NNHP]); and (d) work crews on the LCR, are imperative for the successful coordination and completion of this project. This communication system will be multi-purpose, and will serve to: (1) notify authorities in event of emergency, (2) coordinate resupply needs and scheduling, (3) contact senior personnel when they are off site, and (4) coordinate among individual crews on the 14 km of river. Communications hardware will include the following: base units at both LCR facilities, at GCES (Flagstaff), and at NNHP (Window Rock); canyon-rim antenna/repeater(s), accessible from the base units and elsewhere within the LCR canyon; and ten hand-held units (seven in-use plus three backups) for use by field crews when away from the facility. Repeaters have already been placed within the Grand Canyon proper by GCES (in conjunction with USNPS), and permission to access these units by field crews in the LCR is currently being developed by GCES.

The base camps and facilities, described above will enable LCR operations to be conducted throughout the year, not only by field crews associated with this project, but also by AZGFD and USFWS. These camps will thus be occupied continuously during spring and summer (March through August), and intermittently for periods of 15 to 30 days, as required during other seasons. We believe these installations will greatly enhance research capabilities and effectiveness relative to that experienced in the past by alleviating constraints and hardships imposed by "bare-bones" camping, and by providing opportunities to analyze specimens and data in the field and thus respond with necessary modifications to studies proposed herein, or to opportunistically pursue new leads.

C. Helicopter Support. Helicopter use will be required throughout the tenure of this project to move personnel, equipment, and material to the study area, periodically resupply the base camps with necessary supplies, assist in closing out field studies by removal of equipment and personnel, and (if necessary) for emergency evacuation. This support will be provided by USBR, and coordinated by the GCES Program Manager.

III. FIELD CREWS

As described in detail below, field protocols center around basic gear types (i.e., hoop and trammel nets, traps, and seines), and manpower needed to safely operate these gear types in a variety of situations. The number of field personnel will differ among seasons (Table 1), being greatest during peak activity periods in spring-summer when chubs are spawning, intermediate during off-peak times of early spring and late summer (e.g., pre- and post-spawning), and fewest during autumn and winter when numbers of collected fish have historically been fewest and reproductive activity is not occurring.

TABLE 1. Seasonal composition of LCR field crews (numbers of individuals) and responsibilities, 1990-1994. (C=Confluence, S=Salt Trail). Support staff (one per camp) not included.

Season Camp	Net crew C/S	Trap crew C/S	Reproductive crew C/S	Total/camp C/S
Peak activity (Spring-summer, 3 months)	6/3	3/3	2/2	11/8
Off-peak activity (Summer, 3 months)	5/2	2	0	7/4
Autumn (1 month)	----5/3---		0	5/3
Winter (1 month)	----5/3---		0	5/3

During peak activity periods of spring-summer, two crews will be on the river, each crew working separately out of the confluence and Salt Trail base camps. At the Salt Trail camp, one 3-man group will be responsible for tending the traps there and above Atomizer Falls, a second 3-man group will work core nets in the LCR2 reach, while a 2-man crew will conduct spawning observations throughout the reach, and seine for juveniles. Netting and "reproductive" crews from both camps will require self-containment when on the river for periods of up to six days.

Similarly-composed net, trap, and reproductive crews will be deployed at the confluence camp to work the LCR3 reach. A separate 3-man crew will also be stationed at this camp to run trammel and hoop nets in the critically important confluence area. Thus, numbers of personnel in the two camps differ (Table 1), simply due to the prerequisite of conducting research in the confluence area. Each base camp will have a staff person during the peak activity season.

During the off-peak summer season (i.e., late in the period), crews to run traps and nets will remain at full-strength, but both reproductive crews and camp staff will be withdrawn. Trap and net crews will conduct their original duties, but at an abbreviated pace, while also seining for juvenile fishes (previously the task of the reproductive crews). Camp chores (meal preparation, etc.) will also be performed by the research crews.

Sampling during 15 to 30-day autumn and winter site visits would be handled solely by 3-man crews, one at each base camp. The trammel crew at the confluence camp will also be reduced to two individuals during this period (for a total of five researchers at the confluence camp; Table 1). Appropriate outfitting for work in cold water (e.g., dry suits, etc.) will be necessary for all crews engaged in field activity during these periods.

Personnel may be exchanged among crews during the course of study, either to provide diversity or to optimize use of available talents. Personnel will also be rotated in/out of the LCR during the lengthy, peak spawning period, to maximize enthusiasm and minimize problems associated with primitive living conditions. We fully expect that adjustments and refinements to these schedules will be appropriate (and in fact, necessary) as data are acquired and experienced gained. However, we hope to maintain basic protocols outlined below for the duration of the project. Requirements of crew members are further explained in section XII.

IV. SEASONALITY OF SAMPLING

A. Biotic and Hydrologic vs. Calendar. Sampling will be conducted according to a "standardized" protocol (outlined in USBR solicitation 0-SP-40-09110; see Fig. 2), and also opportunistically during each of four designated "seasons" (spring = March to May; summer = June-August, inclusive; autumn = September to November; winter = December to February) throughout the 14-km reach upstream from the Colorado River confluence to Atomizer Falls (Fig. 2). If movement sampling (Section V. C., below) indicates that humpback chub occupy LCR1 (the river upstream from Atomizer Falls), then the project area will be expanded upstream to include this reach.

We recognize that hydrographic "seasons" are dependent upon watershed precipitation, and that biotic "seasons" may be defined by individual species in response to a suite of environmental variables. Hydrologic and biotic "seasons" are presumably correlated, and both may vary among years.

LCR discharge at Cameron, Arizona, typically is maximum in response to convective thunderstorms during August-October, and in March-April in response to smowmelt (U.S. Geological Survey [USGS]). Runoff is intermediate during November-February, and lowest during May through July. Extended periods of no flow are common at Cameron (USGS), while discharge from and below Blue Springs remains constant during such times. Further, biotic "seasons" (e.g., pre-spawning and staging, active spawning, initial growth period of young fish, post-spawning) may also be variable within species in response to hydrology, climate, and other factors, and among species as a function of intrinsic differences in life-history features. Thus, seasonality of sampling may have to be adjusted opportunistically in response to variability in both hydrologic and biologic dynamics. In this way, a better picture can be gained of inter- and intra-annual variation in parameters and processes of interest. It is intended that sampling be attempted during all available flow conditions, within constraints imposed by practicality and safety.

V. DISTRIBUTION, ABUNDANCE, AND MOVEMENT OF HUMPBACK CHUB

Studies of distribution, abundance, and movement of humpback chub within the LCR will entail sampling large numbers of fishes with a variety of gears. We recognize that some incidental mortality to humpback chub and other species will occur during this sampling. These specimens will be prepared for future use by fleshing and drying prior to skeletonization at Arizona State University (ASU). In this way, otoliths can be obtained for use in the AZGFD aging project. Skeletons will be deposited for permanent curation at ASU. Digestive tracts of incidental mortalities will be salvaged prior to drying, and preserved in Bouin's solution so that parasite loads can be quantified. Stomachs of non-native fishes will also be retained, as required for various objectives. Specimens requested by other investigators pursuing related studies will be made available, within applicable permit limitations.

A. Distribution. Sampling gears to assess humpback chub distribution will include hoop nets, seines, and angling, in an attempt to capture all available size classes of fishes. Entanglement nets will be available for use, but deployed only if other gears fail to catch sufficient numbers of fish. Core equipment (nets, trap materials, inflatable rafts, etc.) will be transported initially to specified sites within each reach, and stored in the field after each season of sampling. Thus, field crews need only transport personal and camp support supplies, and are relieved of the necessity of repeatedly moving heavier equipment between base facilities and study reaches.

Sampling during each seasonal effort will be distributed within the diel period to assess presence-absence of fishes as a function of time-of-day. Hoop nets would typically be run at intervals of not more than 12 hours. Specific sampling locations will be determined on site, and will be consistent with applicability of gear types, to ensure coverage of available habitats throughout the LCR. We will minimally attempt to sample those habitats we recognize as distinct, such as: (1) quiet, near-shore pools (as well as those located above and below travertine dams); (2) chutes and breaches through travertine dams; (3) runs (mid-channel and near-shore); and (4) "riffles." Although the sampling regime will include "standardized" collections (i.e., from three, randomly selected, 1-km long sections within each of the two 7-km reaches), additional opportunistic sampling will be conducted each season to specifically target areas where fish are known or suspected to occur. When present, USFWS personnel studying fish habitat use will participate in location of sample sites so their data acquisition needs are accommodated.

Routine data to be recorded for each collection activity include location, date and time of day, gear type, effort, habitat (USFWS), species and numbers, total length (TL), weight, sex, health (e.g., parasites, deformities, injury, disease), reproductive condition (primary and secondary sex characters), and presence of tags or marks on individual specimens. Humpback chub will be anesthetized in a solution of MS-222 prior to examination, measurement, and tagging. Each chub will then be PIT tagged. Measurement of weight will be restricted to adults once sufficient data are obtained to produce reliable weight-length regressions for younger fish. Data will be recorded using 1600 series polycorders (Omni-Data International, Inc., Logan, UT). To the extent practicable, each unmarked/untagged native fish greater than 100 mm TL will be permanently identified with a Passive Integrated Transponder (PIT) tag; those measuring less than 100 mm TL will be temporarily marked by caudal fin clip to enable assessment of species abundances and movements (below). Fish will be rleased after treatment with antiseptic betadine to prevent infection at the site of marking. We recommend tagging fishes of this size because the potential value to be gleaned from recapturing smaller fish, to include information on residency, movements, growth, and predation, is quite high. If it becomes logistically infeasible to tag all smaller fish, minimum size for marking will be adjusted upward incrementally. PIT tag detectors will be interfaced directly with polycorders for collection of recapture data.

Implanting PIT tags into other native fishes, especially speckled dace (*Rhinichthys osculus*) and bluehead (*Pantosteus discobolus*) and flannelmouth (*Catostomus latipinnis*) suckers, is extremely important, for our data base on these fishes in the LCR is literally non-existent. Time and effort needed to tag these fishes will be minimal, for they will be captured along with humpback chub in a variety of gear types. Expense will be minimal also, for densities of these fishes (to the best of our knowledge) are relatively reduced above the confluence zone, particularly when compared to chub. Yet, recapture information on these fishes will provide an important baseline for future research. Such information would be imperative toward future development of a management plan for the LCR. Thus, subject to logistic constraints imposed by large sample sizes, all native fishes (>100 mm TL) collected at both upstream and confluence sampling areas of the LCR wil be PIT-tagged.

B. Abundance. Fish species abundance can be assessed in relative or absolute terms. Relative abundance may be in context of other species or in comparison to other data for the same species, and is typically expressed as percent composition of total catch or as catch per unit of effort. Both kinds of data will be available from catches obtained during the distributional assessment (above).

In addition, we propose to estimate absolute abundance from mark and recapture data by applying single- (Peterson-type) or multiple-census techniques (e.g., Schumacher and Eschmeyer's estimate; Ricker 1975) to available information as appropriate (see Brownie et al. 1978). Data acquired during distributional sampling will provide opportunity to also determine absolute abundance of various fish species in both time and space.

C. Movement. A central question as regards the Grand Canyon population of humpback chub is the relationship between fish in the mainstem Colorado River and those in the LCR. While available data indicate that fish move at least between the mainstem and confluence area, the integrity and independence of fish occupying upstream reaches of the LCR is unknown. One way to gain insight to this question is to assess directed movements of tagged and untagged humpback chub within the LCR, which we propose to address by use of temporary, two-way fish traps or weirs.

Fish traps will be installed at three locations: approximately 1 km above the confluence area, in the vicinity of the Salt Canyon base camp, and immediately upstream from Atomizer Falls. Traps will be constructed of fence posts driven into the substrate and fitted with a 1.52-cm mesh durethane polyethylene cloth, which is a durable, light-weight, easily manipulated alternative to typical nylon or cotton netting materials. The relatively small mesh size will enable interception and capture of most fish longer than about 125 mm. The bi-directional traps will have separate termini (holding areas) for reception of fishes moving up- and downstream. After examination and tagging, as detailed above fish will then be released so as to have an opportunity to continue movement in the same direction as when initially captured.

The fish trap located immediately above Atomizer Falls serves an additional, important purpose. If humpback chub are collected at that location, then potential exists for their occupation of the reach upstream to Blue Springs (from which humpback chubs have not been collected and are generally thought to be absent [C. O. Minckley, personal communication]). In this event, distribution, abundance, and movement sampling will be expanded to include these additional 7 km of river (LCR1; Fig. 2). If however, there are no indications that chub utilize the reach between Atomizer Falls and Blue Spring, we see little utility in expending considerable time and effort to sample that portion of the stream, except in conjunction with the USFWS habitat project.

An unique opportunity may nonetheless exist during the project period to transplant humpback chub above Atomizer Falls, and then examine establishment of residency (or abandonment of the area) by these fish. Such an experiment could provide valuable information with regard to habitat studies conducted by USFWS, and would at the very least provide guidance toward establishment of humpback chub populations in other tributaries of the Colorado River in the Grand Canyon. Additional manpower would be required to pursue this line of investigation.

Fish traps will be installed and manned for initial periods of up to 10 days during each "season," and throughout the spawning period, as practical. If data indicate that longer or shorter periods of trap sampling are necessary or appropriate to obtain reliable results, then adjustments will be made. Traps may, at certain times of year, require intensive effort to keep clean of travertine buildup and drifting materials (especially algae and macrophyte fragments during productive summer months). These devices may also capture substantial numbers of fish. Thus, although typically run twice daily, we recognize the potential for continuous monitoring at certain times. During a portion of peak activity periods, traps will be cleared of fishes more often than described above (minimally midday, midnight, and during crepuscular periods) to allow detection of any diel movement pattern. To the extent allowed by time and manpower constraints, other research activities such as seining may be pursued during periods between net clearings.

VI. REPRODUCTION

Spawning of humpback chub has never, to our collective knowledge, been observed. In fact, reports are few of spawning by any member of the diverse genus *Gila* (see Minckley 1973). We believe quantification of humpback chub spawning requirements (e.g, hydrologic conditions, temperature, water chemistry, etc.) would be incomplete without determining sites of oviposition and actual behavior(s) involved. We thus intend to focus attention specifically in this direction. This component of our proposed research will require expansion of field crews during spring to accommodate two additional biologists at each base camp (Table 1), comprising the "reproductive group," whose primary functions will be to identify and observe spawning humpback chub, as well as seine for juveniles. These individuals will be notified by radio when chub begin pre-spawning activity. They will then travel immediately to the field, and be deployed onto the LCR.

The reproductive study teams will set out in and along the river, inspecting all habitats within their respective stream reaches, in an attempt to locate spawning aggregations. Contact with net crews via radio will be an important facet of this search. When congregations are noted, biologists will encamp at that location and determine from fish behaviors whether or not spawning is actually occurring. If so, a detailed account of such activity will be recorded, including pertinent environmental information. Repeat observations will be made at the same location, to the extent afforded by opportunity. This done, collection of fertilized ova will be attempted as confirmation of successful spawning. Placement of artificial substrate within the area of question will be one mechanism to accomplish this task, as will direct observation of fish via diving in areas where congregation or staging occurs.

Results of this component of the study will determine specifically how, where, and when humpback chub spawn, and provide valuable guidance for later habitat investigations by USFWS.

VII. SURVIVORSHIP OF EARLY STAGES

This component of the proposed research is closely tied to two on-going AZGFD projects (e.g., larval drift and aging of chubs) and will rely heavily on information derived from those studies. An underlying assumption is that age and size (length) are closely correlated for juvenile humpback chub resident in the LCR, and we feel that this relationship can be satisfactorily quantified. Several mechanisms exist by which these data can be acquired, including analysis of growth rings on hard structures, and analysis of length-frequency distributions. Our approach to determining survivorship relies primarily on the latter technique, in combination with mark-recapture data (Burnham et al. 1987), and with additional information derived from short-term marking of young fish with tetracycline (Wydoski and Emery 1983).

A. Juvenile Sampling. Post-larval young-of-year humpback chub will be sampled primarily by seining, although some young fish may also be captured in hoop nets and traps. These fish will be marked by pectoral and/or pelvic fin clips (as distinct from caudal fin clips, see Section V. A., above) to identify capture method and location (reach) and thus permit assessment of any movement. If practical, fish too small to be fin-clipped will be treated by immersion with tetracycline to impart a detectable short-term mark (R. T. Muth, personal communication). Subsequently, all small fish will be examined under a black light for presence of such a mark. Thus, downstream movement versus local residency of these fish can be determined and quantified. This work will be intimately tied to studies of distribution and abundance (Section V. A. and V. B., above).

Initially, all young fish will be measured and weighed prior to release; weight determination will not be necessary once its relation to length is established. Length frequency data will then be subject to time series (e.g., week, month, season) and trend analyses in an attempt to quantify growth and survival rates (Burnham et al. 1987). Results from marking will be used to ascertain movement versus residency of young chub in the LCR, and to quantify the timing of movement, if it occurs.

B. Laboratory Studies. A second component of our approach to investigating early life survival is to examine impacts of thermal shock on larval humpback chub. To provide a baseline of information prior to *in situ* studies proposed by AZGFD, we propose experimental laboratory testing. Larvae derived from either the LCR itself (e.g., from eggs fertilized on site and removed to the laboratory) or from adults removed to hatchery facilities (the latter distinctly more desirable from perspectives of experimental control and logistics) will be utilized in these studies. Embryos fertilized/incubated/hatched at varying temperatures in the range of 10 to 25°C (Marsh 1985) will be subject to instantaneous thermal shock, at increases and decreases of 5, 10, and 15°C. These data will provide a quantitative assessment of potential adverse impacts of thermal shock on young chub moving between the Little Colorado and Colorado rivers, and set the stage for confirming field studies. If experimental material is available, potential thermal impacts on chubs through age-1 may be determined. All aspects of this portion of the research will be closely coordinated with the AZGFD larval fish project, to ensure exchange of data and optimization of effort.

VIII. BIOTIC INTERACTIONS WITH OTHER SPECIES

This component of the proposed research unquestionably poses the most difficult questions to answer, yet at the same time potentially offers the most important and needed data. Researchers on imperiled Southwestern fishes generally agree that predation by non-native fishes is the single most important factor affecting recruitment (and eventually long-term population stability) of native species (Miller 1961, Minckley 1973, 1985, Minckley and Deacon 1968, in press). Yet, attempts to quantitatively demonstrate this have been fraught with myriad difficulties, many of which defy resolution in context of present capabilities. Nonetheless, data are available for native fishes, including several of the "big river" species (Marsh and Langhorst 1988, Marsh in press, unpublished), which demonstrate that natives eclose, grow, and attain sexual maturity when reared in absence of non-native fishes. Yet, they invariably perish in great numbers at small size when alien fishes are present.

We propose several approaches to attempt to elucidate the nature and significance of the predator-prey relationship, if any, between humpback chub and non-native fishes of the LCR. In the last category, we target rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*), and channel catfish (*Ictalurus punctatus*), all of which are known or expected to co-occur with young humpback chub. Studies involving other non-native species such as red shiner (*Cyprinella lutrensis*), fathead minnow (*Pimephales promelas*), plains killifish (*Fundulus zebrinus*), and striped bass (*Morone saxatalis*) could be pursued if deemed necessary. We also recognize the value of incorporating other native fishes (speckled dace, bluehead and flannelmouth suckers), plus the potential role of humpback chub cannibalism, into this work.

A necessary first step is to combine captures and observations of non-native fishes from habitats known to be occupied in abundance by larval humpback chub. Previous study with other native fishes (Marsh and Langhorst 1988) suggests that larvae may be morphologically identifiable for only a short time after consumption. Thus, prior to field applications, we will conduct controlled laboratory experiments to determine digestion rates of larval humpback chub in guts of potential non-native predators. Trout, carp, and channel catfish will be starved for 48 hours, fed larvae, sequentially sacrificed (e.g., 10, 30, 60, 120, and 240 minutes after feeding), and examined for presence of identifiable remains. The experiment can be repeated at appropriate temperatures (e.g., 10, 15, 20, and 25°C) to obtain a suite of digestive rate curves applicable to field conditions. In this way, we can assess expectation of finding evidence of larval predation *in situ*, and obtain guidance toward additional research. This kind of investigation could conveniently be expanded to include young chubs up to a year old.

Field-collected specimens of non-native fishes will be examined microscopically for presence of the larval/young chub. In the case of larvae, we anticipate that derived data would provide only confirmation that chubs indeed were being eaten by other fishes; useful quantitative information could be wanting. It may further be possible to assess larval predation by careful observation from overhanging vantage points, snorkeling, or use of an air buoy if actual attacks could be documented. Such was possible in Lake Mohave, Arizona-Nevada, where non-native predators were observed to prey on abundant larval razorback suckers (*Xyrauchen texanus*); however, such anecdotal information similarly provides only confirmation that predation occurs. Nonetheless, if potential predators could be captured immediately after they were observed to attack other fishes, for example, by spear or bow and arrow, a possibility exists that somewhat more useful data could be obtained. We intend to examine the utility of this approach, but also suggest alternative avenues of inquiry.

Short-term predation studies will be performed in the laboratory using captive-produced humpback chub larvae and readily available predators, as identified above. Predators will be fed a "natural" diet of locally available invertebrate animals and algal material, and also offered larval chubs either alone or in combination with other foods. Thus, both vulnerability of and preference for larval humpback chub can be assessed. These studies could be expanded to include juvenile chubs up to age 1.

Finally, we intend to examine practicalities of expanding available immunoassay technology to quantification of larval native fish predation by non-native species. Recently developed radio-immunoassays and enzyme-linked immunosorbent assays require small samples, are extremely sensitive, are quantitative, and have been applied to detection of larval fish remains in predator stomachs (e.g., Theilacker et al. 1986). However, with regard to funding, manpower, and time, this research is beyond the scope of the present work, and will be addressed in a separate study by scientists at Arizona State University.

IX. COORDINATION

Coordination and cooperation with USNPS will be required to ensure successful completion of this study. USNPS has authority of issuance of permits for access to the study area (e.g., Tanner/Beamer Trail) and via commercial raft on the Colorado River mainstream), and also regulates helicopter use in the canyon (to be coordinated by GCES Program Manager, see II. C., above). Use of USNPS repeaters to provide radio communication for this project will require appropriate authorizations. These are key requirements of our study, and we intend to work closely with USNPS to ensure that all requirements are fulfilled. Park Service personnel will also be encouraged to participate in any aspect of this research in which they have interest.

There are presently at least five interrelated, ongoing, or proposed studies involving humpback chub in the Grand Canyon: (1) AZGFD larval fish studies, which are closely tied to the spring-summer spawning period; (2) USFWS habitat studies in the LCR and other tributaries; (3) USBR/Contractor research along the Colorado River, including the LCR confluence area; (4) AZGFD native fish studies; and (5) the present study of reproduction, movements, and ecology in the LCR. These are to be coordinated by the GCES/Conservation Measures Aquatic Coordination Team (GCES/ACT), and we intend to be fully responsive to direction provided by that advisory body.

AZGFD larval fish investigations will require the presence of AZGFD personnel in the LCR when larvae are present. These individuals will work out of either (or both) base camps, and will primarily be involved in capturing larvae via drift nets and seines. No conflict or overlap of research effort is seen here.

personnel with habitats and fishes of the LCR; (4) identify and "map" reaches of the river for standardized sampling regime; (5) move equipment and material to the Salt Canyon and confluence base camps, and deploy and store core gear at key locations along up- and downstream reaches; (6) develop a detailed schedule of field activities; and (7) "shake down" equipment, personnel, and facilities by making preliminary, limited-scope collections of fishes in preparation for full implementation of activity in spring-summer 1991.

TABLE 2. Time frames and schedule of seasonal activities for research on the LCR, 1990-1995. Seasons as follows: A = autumn, W = winter, S-S = spring-summer. Laboratory work will be conducted during either 1991-92 or 1992-93, depending on availability of larval fish.

	Project year and season				
Activity	1990-91 A W S-S	1991-92 A W S-S	1992-93 A W S-S	1993-94 A W S-S	1994-95 A W S-S
Reconnaissance	X X				
Field studies	X X	X X X X	X X X X	X X X X	
Laboratory studies	X X	X X X X	X X		
Annual reports	X	X	X	X	X
Final report					-----X

Intensive field activity will commence during spring-summer 1991, and proceed seasonally through summer 1994 (Table 2). Included are studies described in detail above to determine abundance, distribution, and movements of humpback chub; qualitatively and quantitatively describe spawning; and assess survivorship of early life stages from both field and laboratory studies.

Laboratory experiments on thermal shock and predator-prey relations are dependent upon availability of larval humpback chubs, and will commence immediately upon their receipt. These studies will be conducted at Arizona State University by Master-level graduate students supported by the Department of Zoology as teaching assistants. If fertilized embryos are available directly from the LCR, work could begin in spring-summer 1991. However, if adults are removed from the river to a hatchery, larval humpback chub may not be available until the following year (spring 1992). Potential predators of appropriate sizes are generally available in the Arizona State University area any time larval chubs could be obtained. Laboratory studies will be completed during project years 1 and 2 (or 2 and 3).

XI. DELIVERABLES

Quarterly written reports will summarize all activities conducted under the proposed research, with particular emphasis on significant findings, logistical or other problems encountered, and recommendations for modification or refinement of data acquisition to accommodate new information or delete unnecessary tasks. Annual written reports will be submitted at the end of each field season, no later than 30 September of each of the four project years. These will summarize all information to date and integrate results with previous and related research.

The USFWS habitat studies on the LCR will require extensive sampling of fishes for correlation with physical data. It is recommended that USFWS concentrate effort during its first year on establishment of transects and acquisition of habitat data, and that aspects of study which focus directly upon fish habitat utilization be implemented during the second year of research. In this way, our crews have ample opportunity to assess temporal and spatial distribution of humpback chub in the LCR without dilution of effort and other constraints imposed by coordination with the USFWS study. By the second year, we should be in a position to provide USFWS with necessary assistance, and be able to specifically target habitats occupied in abundance by chub of various sizes and life stages. This approach will optimize efforts of all researchers.

Presence of USBR/Contractor is expected to be relatively brief, and limited to the confluence area. To the extent allowed by responsibilities and duties to our own research, crews will be made available for assistance to the USBR/Contractor during their operations at the LCR mouth. The USBR/Contractor will be implanting humpback chubs with radio transmitters, and information on movement of these fishes into and within the LCR will be invaluable. Chemical characteristics of LCR water render signal detection unlikely under conditions of base flow and water depth exceeding about a meter (R. Williams, personal communication), but our crews may recover radio-tagged fish during routine sampling and working of fish traps. Appropriate data (e.g., tag number, location, length, etc.) will be recorded for all such captures and provided to USBR. In addition, the contractor is expected to pursue tagged chub into the LCR, if indeed such movement occurs when chub are being monitored in the mainstream Colorado River.

Native fish studies proposed by AZGFD concentrate on the Colorado River mainstream and tributary mouths. However, upstream work in tributaries will provide a valuable adjunct to that research. Studies on larval ecology and growth, for example, should make use of specimens collected by us in the LCR (as above).

Permits for scientific collection and use of endangered fishes are issued by USFWS and AZGFD. The co-investigators are presently authorized under AZGFD permits MRSH00000-15 and -23, and USFWS permit PRT-676811 for conduct of research on humpback chub and other fishes of the LCR. Applications for renewal of these authorizations will be submitted annually throughout the proposed project period.

A representative of this research team will be available for participation in all meetings of the Aquatic Coordination Team. As indicated above, we consider this advisory body invaluable in providing overall coordination among diverse studies and intend to be fully receptive toward its counsel and recommendations.

X. TIME FRAMES AND ACTIVITIES SCHEDULE

We propose to initiate research in autumn 1990 (between September and November), and proceed as outlined in Table 2 and detailed below. Study will commence with identification of field personnel and acquisition of field and laboratory equipment and materials. Brief (2-4 day) reconnaissance visits will be made to the LCR at 6- to 8-week intervals during autumn 1990 and winter (December to February) 1991. During that time we will (1) identify specific sites for the Salt Trail and confluence base camps; (2) construct and outfit these installations; (3) familiarize key project

A draft final report will be submitted for review and comment not later than 28 February of the final (fifth) contract year, and a final document will be presented within 60 days of receipt of review comments. The final report will include analyses of all project data, and integration of results with other research. All specific objectives identified in this proposal will be addressed. Copies of all raw field data will be submitted with the final report, and also made available to AZGFD as computer files, to update their native fish record for the LCR. All reports will be prepared on IBM or compatible equipment, and provided to U.S. Bureau of Reclamation for distribution to GCES Project Manager, Senior Scientist, and Aquatic Coordination Team.

XII. PROJECT PERSONNEL

This contract is to be awarded directly to Arizona State University. Drs. Michael E. Douglas, Curator of Collections (Department of Zoology), and Paul C. Marsh, Associate Research Professor (Center for Environmental Studies) will serve as co-investigators to oversee all aspects of this research (Fig. 3), including design and implementation of field and laboratory studies, data acquisition and analyses, and preparation of quarterly and final reports. Through Arizona State University, the co-investigators will be responsible for personnel matters relating to technical aspects of this research, to include coordination with the sub-contractor. Vitae of these senior research scientists are attached (Appendix 1) to demonstrate their qualifications to conduct the proposed research.

The Natural Heritage Program of the Navajo Nation (NNHP) will serve as sub-contractor on this technical proposal. Mr. Michael C. Tremble, NNHP Director, will

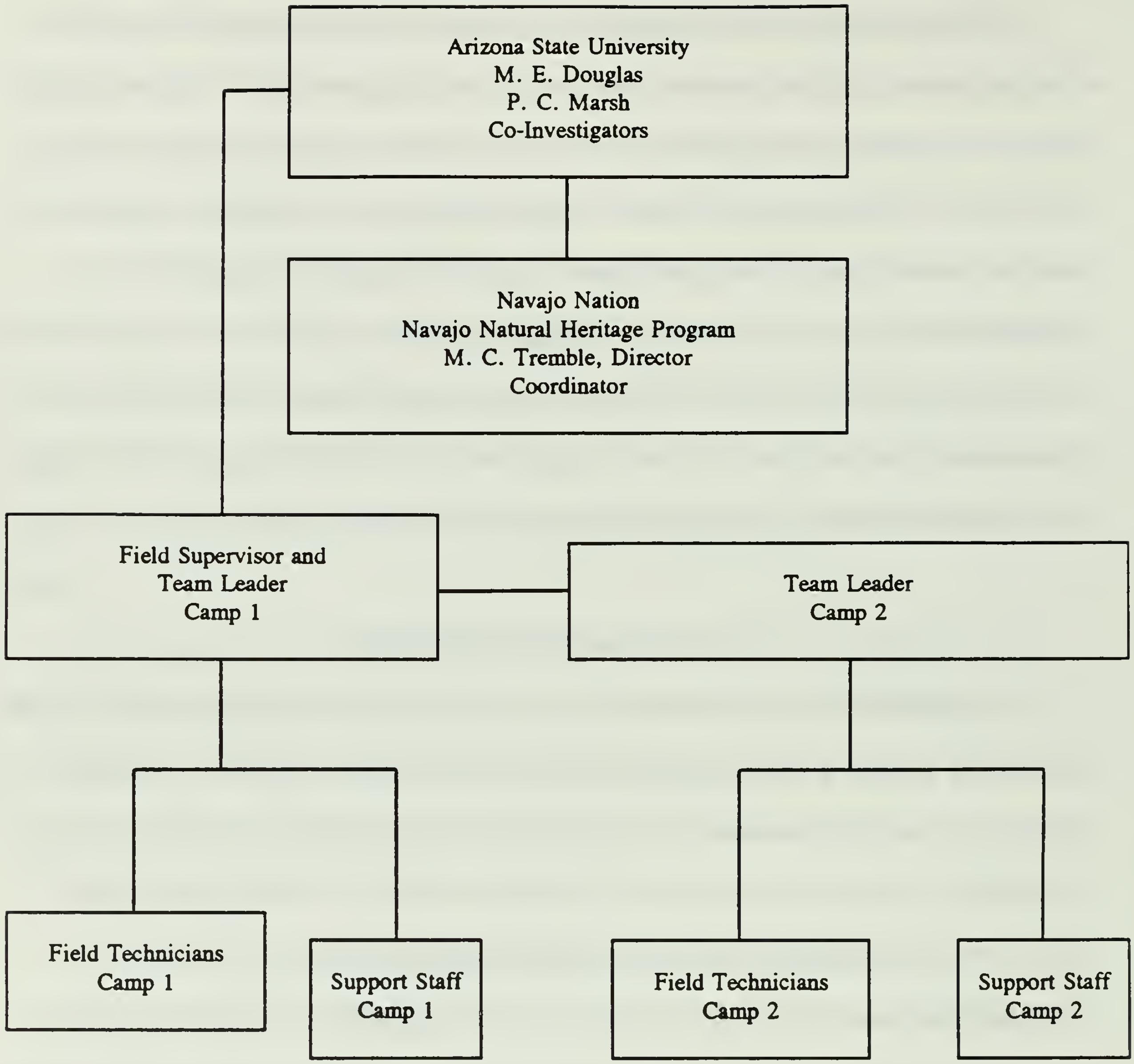


Figure 3. Table of personnel organization for Little Colorado River studies, 1990-1995. Laboratory technicians under supervision of the project co-investigators not shown.

coordinate activities on behalf of the Navajo Nation (Fig. 3), and will be directly responsible for successful integration of Navajo personnel into the proposed research endeavor. The coordinator will schedule release time so that up to four NNHP biologists can participate in sampling and research regimes, as outlined in this proposal. Each biologist will participate in the project for a total of six weeks per year. Projected time for a given biologist will be spread over all seasons, and will be subject to individual work schedules which, in turn, reflect prior commitments between NNHP and the Navajo Nation. The coordinator will arrange travel to/from the Salt Canyon trailhead for NNHP biologists, using NNHP vehicles. Biologists will be supported in the field by ASU.

Other project personnel are to include two (2) field leaders, 8-19 field technicians (depending on time of year; Table 1), 2 field support staff, and 2 laboratory technicians (Fig. 3). Field leaders will direct 8- to 11-person crews in all aspects of data collection in the LCR, and be responsible to the project co-investigators. One leader will be the overall supervisor for conduct of field operations. In recognition of the importance of the role of the overall field supervisor, a post-doctoral research associate will be sought for the position. Minimum qualifications for the other field leader include an earned Masters degree in fisheries or closely allied discipline, demonstrated competence in all applicable areas of the proposed research, and experience with Southwestern fishes and habitats in general, and preferably with humpback chub and the Grand Canyon in particular.

Field technicians will be responsible under direction of their respective field leaders for routine collection of biological data from the LCR. Field support staff under direction of the field supervisor will be responsible for all routine camp duties including meal preparation in support of activities by other field personnel. Minimum qualifications of field technicians and support staff are to be determined by the project co-investigators. NNHP biologists will provide scientific assistance to field activities (as discussed above). Technical support personnel shall include Navajos. Should these individuals initially be inexperienced, then they will be utilized on a volunteer basis during the humpback chub breeding season so they can accrue field experience, and also be evaluated by the field supervisor with regard to their potential for this project. These experienced individuals will prove useful for long-term monitoring studies of the humpback chub.

Laboratory technicians under direction of the project co-investigators will be responsible for routine conduct of laboratory experiments on larval ecology, as detailed above in Sections VII. C. and VIII., above. These persons will also be responsible for examination of predator stomach samples. Minimum qualifications of laboratory technicians include enrollment in an appropriate undergraduate program and demonstrated capability to perform all required duties of the proposed laboratory research. Specific training will be provided as necessary.,

All personnel assigned to the field must be physically capable of performing designated tasks and duties, available for continuous commitment to field operations for periods of up to six months, and be prepared to tolerate potentially uncomfortable conditions associated with fieldwork of this nature and duration. Specific training will be provided as required for all field personnel.

XIII. FACILITIES

Overall coordination of this project will be through the Center for Enviromental Studies, Arizona State University. That office has necessary support staff and equipment (e.g., administrative and secretarial personnel, computer capabilities, FAX and other telecommunication devices, and photoduplication, etc.) to perform necessary duties.

Project co-investigators occupy modern, well-equipped office and laboratory space at ASU, and have the capability to support all laboratory aspects of the proposed research. The University further provides unparalleled computer capabilities and library holdings, which are available for use on this project, plus contract administration, personnel, and payroll services. Investigators and aquatic facilities available to them are presently authorized under applicable state and federal scientific collecting permits and federal and university animal care rules and regulations to conduct research as described herein.

Field research in behalf of this contract will be conducted out of two semi-permanent (4-year) field stations to be installed at the LCR, and which are considered essential to successful completion of this research. Specifications and support capabilities of that station are detailed in Section II, above.

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ECOLOGY AND CONSERVATION BIOLOGY OF HUMPBACK CHUB,

GILA CYPHA, IN LITTLE COLORADO RIVER, ARIZONA

COST PROPOSAL

Submitted by

Arizona State University

Tempe, Arizona

to

U.S. Bureau of Reclamation

Glen Canyon Environmental Studies

Flagstaff, Arizona

30 July 1990

Gary Chaffins, Director of Sponsored Projects
AUTHORIZING UNIVERSITY OFFICIAL

July 30, 1990
Date

HUMPBACK CHUB/LITTLE COLORADO RIVER STUDIES -- EXPLANATION OF BUDGET

Attached are detailed tabulations of the budget for research on endangered humpback chub in the Little Colorado River, Arizona. The overall study is to be administered, directed, and implemented by Arizona State University (ASU), Tempe, with the Navajo Natural Heritage Program (NNHP) of the Navajo Nation, Window Rock, Arizona, as subcontractor for assistance in scientific studies. The budget is composed of costs for personnel, capital equipment, non-capital equipment, supplies, operations, per diem, and travel, plus indirect costs established by ASU. Total estimated cost is $1,398,765 for the 5-year project period (Table 1).

Salaries and wages have been computed annually on the basis of man-months required for each position (Table 2) times salary and wage rates established for 1990-1991 by ASU (Table 3); the latter have been incremented by 5% per year to reflect projected cost-of-living increases. Employee related expenses (ERE) are computed at rates of 25% (faculty), 30% (staff) and 3% (students) as established by ASU, and included in total costs for personnel (Table 4).

Costs of equipment, supplies, operations, per diem, and travel are detailed in Table 5. Capital equipment includes all items with a unit cost of $500 or more, and has a total cost of $91,550. All capital equipment is to be purchased during the first year of the project, and deployed to field sites at the Little Colorado River or stored for replacement use. Field studies incur estimated costs of $10,255 for installation and operation of base camp facilities, plus $65,023 for field activities.

Per diem to support field personnel has been computed on a basis of $4.00/person/day ($120/man-month). Travel to the field from ASU, NNHP, and Flagstaff is computed on a basis of $0.255/mile for personal vehicle use.

Laboratory equipment and supplies for use in experimental studies to be performed at ASU have a total estimated cost of $1810 (Table 5).

Indirect costs are applied at rates established for ASU (33.6% of direct costs excluding capital equipment and subcontracts exceeding $25,000), as presented in Table 1. A projected annual cost schedule (01 October to 30 September basis), including all expenditures, is presented in Table 6.

U.S. Bureau of Reclamation (USBR) will supply helicopter transportation on at least a monthly basis during each of the four, 8-month field seasons and otherwise as necessary for emergency in behalf of this project. Unavailability of this item will result in increased cost for this project; however, total costs may be reduced to the extent that other items can be made available.

TABLE 1. BUDGET SUMMARY -- ECOLOGY AND CONSERVATION BIOLOGY OF HUMPBACK CHUB, *GILA CYPHA*, IN LITTLE COLORADO RIVER, ARIZONA.

	Category	Cost
A.	Capital equipment (over $500 per unit)	$ 91,550
B.	Non-capital equipment/supplies/operations and travel	140,674
C.	Direct salaries and wages	581,926
D.	Employee related expenses	161,992
	subtotal B+C+D = $884,592	
E.	Subcontract, Navajo Natural Heritage Program	117,000
F.	ASU indirect costs (33.6% of $909,592)	305,623
G.	GRAND TOTAL	$1,398,765

File: TABLE 2
Report: LCR MAN-MONTHS

CATEGORY	POSITION	NAME	YR 1	YR 2	YR 3	YR 4	YR 5	YR
Faculty	Co-invest	M.E. Douglas	1.5	1.50	1.50	1.50	1.5	7
Faculty	Co-invest	P.C. Marsh	1.5	1.50	1.50	1.50	1.5	7
Faculty	Supervisor	to be named	4.0	12.00	12.00	12.00	8.0	48

Staff	Team Leader	to be named	14.0	16.00	16.00	16.00	0.0	62
Staff	Field Tech	to be named	72.0	82.00	82.00	82.00	0.0	318
Staff	Cook	to be named	6.0	6.00	6.00	6.00	0.0	24
Staff	Admin Asst	P.A. Chase	.5	.25	.50	.25	0.0	1
Staff	Sec	K. Lentz	0.0	.25	.25	.25	1.0	1

Student	hrly	to be named	6.0	12.00	6.00	0.00	0.0	24

File: TABLE 3
Report: MONTHLY SALARY RATE

C TEGORY	POSITION	NAME	YR 1	YR 2	YR 3	YR 4	YR 5
Faculty	Co-invest	M.E. Douglas	3159	3317	3483	3657	3840
Faculty	Co-invest	F.C. Marsh	3899	4094	4299	4514	4740
Faculty	Supervisor	to be named	1693	1778	1867	1961	2059

Staff	Team leader	to be named	1306	1371	1440	1512	0
Staff	Field Tech	to be named	866	909	954	1002	0
Staff	Cook	to be named	879	923	969	1018	0
Staff	Admin Asst	F.A. Chase	2541	2668	2801	2941	0
Staff	Sec	K. Lentz	1147	1204	1264	1327	1393

Student	hrly	to be named	754	792	832	0	0

EGORY	POSITION	NAME	YR 1	YR 2	YR 3	YR 4	YR 5	YRS 1-5
Faculty	Co-invest	Douglas	4739	4976	5225	5486	5760	26186
Faculty	Co-invest	Marsh	5849	6141	6449	6771	7110	32320
Faculty	Supervisor	to be named	6772	21336	22404	23532	16472	90516
---	---							
subtotal	Faculty		17360	32453	34078	35789	29342	149022
ERE 25%			4340	8113	8520	8947	7336	37256

Staff	Field Leade	to be named	18284	21936	23040	24192	0	87452
Staff	Field Tech	to be named	62352	74538	78228	82164	0	297282
Staff	Cook	to be named	5274	5538	5814	6108	0	22734
Staff	Admin Asst	P.A. Chase	1271	667	1401	735	0	4074
	Sec	K. Lentz	0	301	316	332	1393	2342
---								
subtotal	Staff		87181	102980	108799	113531	1393	413884
ERE 30%			26154	30894	32640	34059	418	124165

Student	hrly	to be named	4524	9504	4992	0	0	19020
ERE 3%			136	285	150	0	0	571

Subtotal	Salaries		109065	144937	147869	149320	30735	581926
Subtotal	ERE		30630	39292	41310	43006	7754	161992

Total	Sal plus ER		139695	184229	189179	192326	38489	743918

CATEGORY	LOCATION	ITEM	UNIT	NUMBER	UNIT COST	TOTAL	SUPPLIER
CAPITAL	T/N/R	scanners	ea	6	2500	17500	
CAPITAL	BASE CAMP	printer	ea	2	500	1000	ASU
CAPITAL	BASE CAMP	wall tent, canv	ea	8	600	2400	Phoenix
CAPITAL	BASE CAMP	generator, 850W	ea	2	650	1300	Honda
CAPITAL	BASE CAMP	microscope, dis	ea	2	750	1500	AO
CAPITAL	BASE CAMP	software	ea	2	1000	2000	ASU
CAPITAL	BASE CAMP	computer, lapto	ea	3	2500	7500	Zenith/A
CAPITAL	COMMUNICATIO	radio package	ea	1	30000	30000	RayCom
CAPITAL	N/R	canoe, inflatab	ea	3	1200	3600	NW River
CAPITAL	REPRO CREW	SCUBA gear	ea	1	750	750	SCUBA Sc
CAPITAL	T/N/R	polycorder	ea	8	3000	24000	Omni-dat
---							
subtotal	CAPITAL					91550	

SUPPLIES	BASE CAMP	rocket box, 25	ea	30	15	450	surplus
SUPPLIES	BASE CAMP	hose, propane	ea	2	25	50	Isley
SUPPLIES	BASE CAMP	regulator, prop	ea	2	25	50	Isley
SUPPLIES	BASE CAMP	carboy, 5-gal	ea	20	25	500	local
SUPPLIES	BASE CAMP	chairs, folding	ea	16	25	400	local
SUPPLIES	BASE CAMP	carboy, formali	5-gal	4	25	100	VWR
SUPPLIES	BASE CAMP	coleman supplie	ea	6	40	240	local
SUPPLIES	BASE CAMP	parachute cord	1200	2	50	100	
SUPPLIES	BASE CAMP	carboy, fuel	10-ga	10	50	500	local
SUPPLIES	BASE CAMP	extension cord	100 f	4	50	200	local
SUPPLIES	BASE CAMP	lights, 100W	ea	4	50	200	local
SUPPLIES	BASE CAMP	tools, fastener	ea	2	50	100	local
SUPPLIES	BASE CAMP	cot	ea	12	50	600	surplus
SUPPLIES	BASE CAMP	tarps, 20 x 30	ea	8	60	480	Nylon Ne
SUPPLIES	BASE CAMP	glassware, misc	ea	2	75	150	Bioquip/
SUPPLIES	BASE CAMP	tank, propane	5-gal	8	75	600	Isley
SUPPLIES	BASE CAMP	stove, propane	ea	2	75	150	local
SUPPLIES	BASE CAMP	table, folding	ea	4	75	300	local
SUPPLIES	BASE CAMP	rope, 1/4"	1200	2	75	150	Nylon Ne
SUPPLIES	BASE CAMP	dry box	ea	4	75	300	surplus
SUPPLIES	BASE CAMP	fire extinguish	ea	2	80	160	LabSafet
SUPPLIES	BASE CAMP	puptent (storag	ea	8	100	800	Phoenix
SUPPLIES	BASE CAMP	counters, 5-pla	ea	2	100	200	VWR
SUPPLIES	BASE CAMP	illuminator	ea	4	150	600	AO
SUPPLIES	BASE CAMP	cable	ea	2	150	300	ASU
SUPPLIES	BASE CAMP	dissecting impl	ea	2	150	300	Bioquip
SUPPLIES	BASE CAMP	tool kit	ea	2	150	300	local
SUPPLIES	BASE CAMP	first aid kit	ea	2	250	500	LabSafet
SUPPLIES	BASE CAMP	food prep, serv	ea	2	250	500	local
SUPPLIES	BASE CAMP	platform lumber	ea	2	250	500	local
SUPPLIES	BASE CAMP	formalin, bulk	55-ga	1	475	475	VWR
---							
subtotal	BASE CAMP SU					10255	

SUPPLIES	N/R	NRS straps	ea	25	4	100	NW River
SUPPLIES	N/R	carabeaners	ea	50	5	250	NW River

CATEGORY	LOCATION	ITEM	UNIT	NUMBER	UNIT COST	TOTAL	SUPPLIER
SUPPLIES	N/R	dry bag 3.8	ea	6	75	450	NW River
SUPPLIES	N/T	live bag	ea	8	10	80	Nylon Ne
SUPPLIES	N/T	dry suit	ea	6	150	900	NW River
SUPPLIES	N/T	carlin tags	1000	15	185	2775	Floy
SUPPLIES	N/T/R	freezer bags	bx-50	12	2	24	local
SUPPLIES	N/T/R	bucket	2-gal	20	4	80	Western
SUPPLIES	N/T/R	scissors	ea	10	5	50	Bioquip/
SUPPLIES	N/T/R	flagging, tags,	ea	10	5	50	Meadows
SUPPLIES	N/T/R	poly bottle	0.5-L	10	5	50	VWR
SUPPLIES	N/T/R	bucket	5-gal	20	5	100	Western
SUPPLIES	N/T/R	field books	ea	36	8	288	Meadows
SUPPLIES	N/T/R	betadine	ltr	8	20	160	
SUPPLIES	N/T/R	flashlight	ea	8	25	200	local
SUPPLIES	N/T/R	rod, reel, tack	ea	6	25	150	local
SUPPLIES	N/T/R	measure bd	ea	10	25	250	make
SUPPLIES	N/T/R	MS 222	100 g	8	32	256	Crescent
SUPPLIES	N/T/R	pisolis scales	ea	12	50	600	
SUPPLIES	N/T/R	parachute cord	1000	2	50	100	Nylon Ne
SUPPLIES	N/T/R	day pack	ea	10	50	500	REI
SUPPLIES	N/T/R	Lum-o-gram	ea	4	75	300	
SUPPLIES	N/T/R	rope, 3/8"	1000	2	90	180	Nylon Ne
SUPPLIES	NET CREW	trammels	ea	60	100	6000	Nylon Ne
SUPPLIES	NET CREW	hoop nets	ea	60	125	7500	Nylon Ne
SUPPLIES	NET CREW	gill net, expl	ea	20	150	3000	Nylon
SUPPLIES	REPRO CREW	seine brailes	pr	10	5	50	local
SUPPLIES	REPRO CREW	seines	ea	10	15	150	Nylon Ne
SUPPLIES	REPRO CREW	whirl pacs	bx-50	3	50	150	VWR
SUPPLIES	REPRO CREW	air buoy	ea	1	n/c	n/c	ASU
SUPPLIES	REPRO CREW	snorkle gear	ea	2	n/c	n/c	ASU
SUPPLIES	T/N/R	PIT tags	ea	10000	4	37500	USBR
SUPPLIES	TRAP CREW	brushes	ea	10	5	50	local
SUPPLIES	TRAP CREW	dip nets	ea	10	12	120	Nylon Ne
SUPPLIES	TRAPS	t-post	ea	60	4	240	Co-op
SUPPLIES	TRAPS	nylon ties	pkg-2	40	5	200	local
SUPPLIES	TRAPS	nylon twine	500 f	4	5	20	Nylon Ne
SUPPLIES	TRAPS	cable, ss + fas	ea	50	10	500	local
SUPPLIES	TRAPS	garden hose	50 ft	50	15	750	local
SUPPLIES	TRAPS	durethane	50 ft	18	50	900	ADFI
---							
subtotal	FIELD SUPPLI					65023	

PER DIEM	BC/N/T/R	food	man-m	404	120	48480	local
---							
subtotal	PER DIEM					48480	

TRAVEL	TRAVEL	Flag to trail	250 m	24	64	1536	local
TRAVEL	TRAVEL	WR to trail	350 m	24	90	2160	local
TRAVEL	TRAVEL	ASU to trail	550 m	8	141	1410	local
---							
subtotal	TRAVEL					5106	

CATEGORY	LOCATION	ITEM	UNIT	NUMBER	UNIT COST	TOTAL	SUPPLIER

SUPPLIES	LABORATORY	tubing, tygon	ft	50	1	50	local
SUPPLIES	LABORATORY	heat control	ea	10	10	100	local
SUPPLIES	LABORATORY	pools, 1x0.2 m	ea	10	10	100	local
SUPPLIES	LABORATORY	PVC, 4"	10 ft	4	20	80	local
SUPPLIES	LABORATORY	fish food	ea	4	24	100	local
SUPPLIES	LABORATORY	fish transport	ea	4	50	200	local
SUPPLIES	LABORATORY	predator collec	ea	4	50	200	local
SUPPLIES	LABORATORY	tank/filter rep	ea	6	60	360	local
SUPPLIES	LABORATORY	nitex, 500u	yd	2	60	120	Williams
SUPPLIES	LABORATORY	supplies, misc.	ea	2	250	500	local
SUPPLIES	LABORATORY	glassware, diss	ea	2	n/c	n/c	ASU
---							
subtotal	LABORATORY					1810	

OPERATIONS	all	maint & repair	yr	4	2500	10000	local
---							
subtotal	NON-CAPITAL					140674	

File: TABLE 6
Report: ANNUAL SUMMARY

24 JUL

ITEM	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
SALARIES AND WAGES	109065	144937	147869	149320	30735	581926
ERE	30630	39292	41310	43006	7754	161992
CAPITAL EQUIPMENT	91550	0	0	0	0	91550
BASE CAMP	10255	0	0	0	0	10255
FIELD SUPPLIES	65023	0	0	0	0	65023
PER DIEM	11040	12480	12480	12480	0	48480
TRAVEL	1488	1206	1206	1206	0	5106
LABORATORY	452	906	452	0	0	1810
MAINT & REPAIR	2500	2500	2500	2500	0	10000
SUBCONTRACT	29250	29250	29250	29250	0	117000

TOTAL DIRECT COSTS	351253	230571	235067	237762	38489	1093142

INDIRECT COSTS	79532	69744	71255	72160	12932	305623

TOTAL	430785	300315	306322	309922	51421	1398765

GLEN CANYON ENVIRONMENTAL STUDIES

EVALUATION OF THE ADULT MOVEMENT AND HABITAT RELATIONSHIPS FOR THE ENDANGERED HUMPBACK CHUB *Gila cypha* IN THE GRAND CANYON, AZ

Technical Contract Requirements

Glen Canyon Environmental Studies
U.S. Bureau of Reclamation
P.O. Box 1811
Flagstaff, AZ 86002

July 27, 1990

1983 and Maddux, 1987). From information collected from the Grand Canyon area (including the Little Colorado River) it is hypothesized that the humpback chub population in the Grand Canyon is the largest in the Colorado River. Also, because the original species description came from the Grand Canyon this population is considered to be of extreme importance genetically to the overall recovery of the species.

Although much effort has been spent in locating and describing the extent of these populations, limited information has been collected on the life history and ecology of the species and how the population is affected by the operation of the Glen Canyon Dam which controls the Colorado River environment in the Grand Canyon.

As prescribed under the Endangered Species Act P.L. 93-205 (Act), Federal agencies have the responsibility to protect and, where possible, promote the recovery of listed species. Section 7, of the act requires Federal agencies to consult with the U.S. Fish and Wildlife Service (Service) on actions that could affect the continued existence of listed species. Consultations on the operation of existing Colorado River Storage Projects were initiated in 1978 by the Service.

In 1978, the Service issued a "jeopardy opinion" on the operation of Glen Canyon Dam based on the impact Glen Canyon Dam was having on the downstream native, threatened, and endangered fish populations in the Grand Canyon. In 1982, under the directions of the Secretary, Department of Interior (DOI), the U.S. Bureau of Reclamation (Reclamation) initiated a major environmental study to determine the effects of Glen Canyon Dam operation on the resources of the Grand Canyon. Investigations conducted as part of the Glen Canyon Environmental Studies (GCES) were to include collection of information on the operational impacts of Glen Canyon Dam on the humpback chub in the Grand Canyon as conditions of the Section 7 consultation with the Fish and Wildlife Service.

At the conclusion of the first phase of the Glen Canyon Environmental Studies in 1988, it was determined that more in-depth studies were needed on the humpback chub within the Grand Canyon to determine how operation of Glen Canyon Dam affects the present population of humpback chub within the canyon. The successful conclusion and implementation of recommendations of such investigations would allow Reclamation and other federal agencies to fulfill their responsibility under the Act.

A consultation team, consisting of technical experts from Federal and state bureaus and agencies responsible for natural resource management, identified seven conservation and recovery measures that would lead to the protection and recovery of the humpback chub in the Grand Canyon. One of the measures includes the collection of biological information to understand the ecology and life history requirements of the endangered humpback chub both

SECTION C
DESCRIPTION/SPECIFICATION

C.1. INTRODUCTION

C.1.1 Purpose/Background

The native ichthyofauna of the Colorado River in the Grand Canyon once consisted of warm water cyprinids and catostomid species many of which are now officially listed as threatened or endangered by the U.S. Department of Interior, Fish and Wildlife Service. The environmental changes which occurred to the warm water reaches of the Colorado River since the closure of Glen Canyon Dam and other mainstem Colorado River Storage Project (CRSP) dams in the early 1960's eliminated much of the natural habitats and numbers of the native ichthyofauna. The change from seasonally warm conditions with an abundance of diverse habitats to cold, constantly fluctuating conditions, caused by hydropower releases from CRSP dams, has resulted in the extirpation and reduction of native fish populations and their habitat from many reaches of the Colorado River.

The humpback chub, (Gila cypha), is a large river cyprinid, endemic to the Colorado River. It is one of several forms of the genus Gila, that along with the bonytail (Gila elegans), is listed as endangered by the U.S. Fish and Wildlife Service. The humpback chub, unlike other of the large river cyprinids including Gila robusta, Gila elegans and Colorado squawfish (Ptychocheilus lucius) which have been extirpated from the Grand Canyon, still persists in the Colorado River and Little Colorado River (a tributary of the mainstem) of the Grand Canyon. Of the three native catostomids of the mainstem Colorado River, the bluehead sucker, (Catostomus discobolus), and the flannelmouth sucker, (Catastomus latipinnis), reproduce successfully in the Grand Canyon. The razorback sucker, (Xyrauchen texanus), no longer successfully reproduces in the Grand Canyon and is greatly reduced in numbers. Only one confirmed razorback sucker has been collected or observed in the last five years (Maddux 1987).

Humpback chub were first described in 1946 by R.R. Miller, from one collected specimen in the Colorado River, Grand Canyon and two other fish of unknown origin. Recent investigations have identified populations of humpback chub from Black Rocks and Westwater Canyon on the Colorado River (Kaeding,1988), Cataract Canyon of the Colorado River (Valdez, In Press.), the Yampa River and Green River (Karp and Tyus, In Press.) and Little Colorado and mainstem Colorado River of the Grand Canyon (Kaeding and Zimmerman, in the Little Colorado and mainstem Colorado Rivers.

The <u>purpose of this solicitation</u> is for the collection and analysis of biological information to test ecological and life history hypotheses developed in conjunction with the Glen Canyon Environmental Studies and conservation measure efforts. This information is necessary to describe the basic ecology and life history requirements of the juvenile and adult humpback chub in the Grand Canyon. Ecological studies shall be conducted to determine the relationship between the operations of Glen Canyon Dam and the endangered humpback chub population in Grand Canyon. It is the ultimate purpose of this investigation to obtain sufficient information on the Grand Canyon population of humpback chub to aid the Federal and state agencies in their mandated responsibilities to protect the continued existence of the humpback chub. Determining and reducing adverse operational impacts of Glen Canyon Dam, if any, would promote recovery of the humpback chub in the Grand Canyon.

C.1.2 Aquatic Coordination Team

This solicitation requires the extensive coordination of the aquatic data collection programs, the Glen Canyon Dam conservation measures and the Glen Canyon Environmental Studies program. Primary coordination efforts will be handled through an <u>Aquatic Coordination Team</u> (**ACT**) composed of technical representatives of the Bureau of Reclamation (Reclamation), the U.S. Fish & Wildlife Service (Service), the National Park Service (NPS), the Arizona Game & Fish Department (AGF), the Navajo Nation, the contractor and the Glen Canyon Environmental Studies technical office which includes the services of a Senior Scientist of the National Academy of Science.

The mission of the **ACT** is to coordinate the overall contract requirements, schedules, permits, and the other aquatic study components of the GCES program (both laboratory and field) to ensure efficient collection and utilization of the data, scientific credibility, review of study plans and modifications, data base development, analysis of data, and to ensure the aquatic studies program minimizes any adverse research impacts to the aquatic species in the Grand Canyon. The **ACT** will solicit the input of additional experts, such as population modelers and statisticians, to assist in the development and setting of definable objective criteria for the recovery of humpback chub in the Grand Canyon.

C.1.3 <u>GCES Research Flows</u>

The GCES program is scheduling special research flow releases from Glen Canyon Dam in order to collect specific flow related information required to satisfy the broad objectives of the Glen Canyon Dam - Environmental Impact Statement. It is anticipated that these special research flows will be provided during the first two years of this contract. This solicitation is primarily focused on the collection of information for the conservation measures, however the contractor will be required to tailor data collection schedules to take full advantage of the GCES research flows. Specific research shall be designed around the research flows to test for affects of flow changes on various life history aspects of the humpback chub. The GCES Research Flow schedule is provided in Section J. The ACT will coordinate with the contractor to ensure that all study programs take maximum advantage of the flow schedule.

C.1.4 Aquatic Study Components

The GCES program and the conservation measure work are a coordinated effort including federal and state resource offices and private contractors. The primary responsibilities and program components for the *Gila cypha* studies can be broadly outlined as follows:

a. Bureau of Reclamation (GCES) - primary coordination for technical, administrative, and field programs.

b. Arizona Game & Fish Department - early life history and habitat studies (up to young-of-the- year) in the Little Colorado River, annual monitoring efforts, mainstem habitat coordination, age & growth and food utilization studies of early life history stage.

c. U.S. Fish & Wildlife Service - Little Colorado River and Grand Canyon tributary habitat analysis. Coordination with contractor on data collection at the tributary confluence areas.

d. National Park Service - permit coordination and scientific assistance.

e. Navajo Nation - Little Colorado River permits and scientific assistance and technical coordination.

The ACT will work with Reclamation to ensure coordination of all aspects of the humpback chub work in the Grand Canyon.

C.1.5 Pertinent Literature

A complete listing of references and acronyms used in Section C. is included in Section J.

C.2 STUDY OBJECTIVES

Reclamation and other Federal and state agencies including the U.S. Fish and Wildlife Service (Service) and the Arizona Department of Game and Fish (AGF), are responsible for the protection of endangered species under the Endangered Species Act, however, they do not have the resources to collect information within the required time frame on the ecological needs of the humpback chub along with other resource needs of the Grand Canyon, as identified in the GCES program. The purpose of this contract is to conduct ecological studies to determine the relationship between operations of Glen Canyon Dam and the ecology and life history requirements of the endangered humpback chub population in Grand Canyon. The objectives of the investigation are as follows:

1. To the extent of information known, determine the ecological and limiting factors of all life stages of humpback chub in the Little Colorado (LCR) and mainstem Colorado River, Grand Canyon and the effects of dam operations on the humpback chub.

A. Determine resource availability and resource use (habitat and food) of humpback chub in the LCR and mainstem Colorado River.

B. Determine the reproductive capacity and success of humpback chub in the LCR and mainstem.

C. Determine the survivorship of early stages of the humpback chub in the LCR and mainstem.

D. Determine the distribution, abundance and movement of the humpback chub in the LCR, the mainstem and <u>effects of dam operations</u> on the movement and distribution of humpback chub.

E. Determine important biotic interactions with other species for all life stages of humpback chub.

2. Determine the life history schedule for the Grand Canyon humpback chub population.

A. Develop or modify an existing population model from empirical data collected during the study for use in analyses of reproductive success, recruitment and survivorship.

C.3 SCOPE OF STUDY

The Glen Canyon Environmental Studies (GCES) were initiated in 1982, by the DOI. The GCES program was intended to collect information on the effects of Glen Canyon Dam operations on various natural resources of the Grand Canyon. The GCES effort was large in scope, attempting to collect information on specific resources of the canyon that were believed to be most impacted by dam operations. These included sediment transport and beach erosion, terrestrial and aquatic resources and recreational impacts.

The aquatic information collected under the GCES effort focused primarily on trout fishery and impacts of dam operations on the tailwater reach. The GCES effort suggested that additional work was essential for better understanding the effects of dam operations on the remaining native fish, and specifically on the endangered humpback chub in the Grand Canyon. Reclamation, in cooperation with the Service, NPS, the Navajo Nation and AGF developed a series of conservation measures for the humpback chub in the Grand Canyon which included the following: 1) taxonomic status of the humpback chub, 2) maintenance of hatchery stocks, 3) protection from flood events, 4) management plan for the Little Colorado River, 5) research to identify impacts of dam operations on the humpback chub, 6) development of a long-term monitoring program for the Grand Canyon population, and (7) establishment of a second population, if possible.

The research proposed in this contract is for the collection of information to satisfy portions of Conservation Measures 5 and 7, "Conduct Research to Identify Impacts of Glen Canyon Dam Operations on the Humpback Chub in the Mainstem and Tributaries" and "Establish a Second Spawning Population of Humpback Chub in the Grand Canyon". Reclamation, in coordination with the other Federal and state agencies, through the ACT, shall collect the information to develop operational and management options for the Glen Canyon Dam. Existing information on the Grand Canyon humpback chub population is limited to basic ecological and life history information collected in 1981 and 1982 by the Service, and some distribution and abundacne information collected by AGF under the GCES effort.

It is anticipated that the new data collected under this contract on various aspects of the life history and habitat requirements of humpback chub in the Grand Canyon would be combined with information collected under other research efforts to determine impacts of dam operations on habitat availability and critical life history requirements of the chub. These data would also be used to make recommendations for the possible enhancement of environmental conditions to protect and promote the recovery of the humpback chub population in the Grand Canyon. The research proposed would also aid in future maintenance and propagation of genetically viable stocks of humpback chubs that would be used to establish a second population of chubs in the Grand Canyon if possible.

The proposed four year investigation would focus on the collection of life history needs of the humpback chub, including habitat use and availability in the mainstem reaches of the Grand Canyon. Special research emphases will be placed on sampling confluence areas and the affects of dam operation on these areas. The proposed research effort would be partitioned into two efforts. The primary effort would focus on the collection of life history information and habitat use of humpback chub within two intensive sampling site using radio telemetry and other gear types. The second effort would be comprised of a distributional survey and habitat data collection of a large reach of the mainstem Colorado

River refered to as the Granit Gorge. As part of the overall mainstem research effort during the first 14 months, the contracator will utilize scheduled research flows to determine affects of dam operation on habitat conditions in the Grand Canyon.

The contracted research effort shall focus on the collection of information on distribution, abundance and habitat use of juvenile and adult humpback chub in the mainstem Colorado River. Humpback chub shall be tracked using radio telemetry and other collection techniques to determine changes of habitat availability, habitat utilization and seasonal movement patterns of the humpback chub in the Grand Canyon. Aerial or video imagery shall be used to quantify habitat at various flows so analyses can be made on the effects of dam operations on habitat quantity, quality and availability. The information collected by the Contractor will be added to the GCES Geographic Information System for the long-term monitoring needs of the Grand Canyon.

During the first two years of investigation the contractor will work closely with and provide assistance to the **ACT** in designing and conducting research around the Phase II GCES research flows scheduled from Glen Canyon Dam (Section C.1.3). The contractor shall where possible, integrate the overall GCES research questions and hypothesis into its research design. These shall be the only scheduled flows for the four year research effort and the Contractor shall design research in concert with these scheduled releases and the needs of the GCES Phase II programs. A list of the anticipated flows is provided in Section J.

The **ACT** will solicit with the assistance of the contactor the input of population modelers and other researchers to help guide future data collection and developing recovery goals for the Grant Canyon Colorado River population of humpback chub. The intent of this effort is to develop a predictive life history model that will assist the resource agencies in developing long-term recovery strategies, goals and objectives for the native and endangered fish species in the Grand Canyon. Input from the population models will be used to guide the ACT's actions and will be included in the annual evaluation of the contracting efforts. IF the **ACT** determines that a change in data collection procedures or analysis is required, the contract shall be modified in cooperation with the contractor to reflect the appropriate changes.

C.4 STUDY SITES AND STUDY BACKGROUND

The Contractor shall conduct sampling within Grand Canyon National Park on the Colorado River. The Colorado River in the Grand Canyon fluctuates seasonally and daily with extremes ranging from 1000 cubic feet per second (CFS) to 31,500 cfs. The area of concern is approximately 464 kilometers long, dropping in elevation from 3150 feet to 1221 feet. Sampling shall be performed in flat and whitewater reaches of the canyon.

The mileage and reference points used for determining the study sites on the Colorado River in Grand Canyon have been obtained from the 1983 river guide by L. Stevens. River miles are commonly referred to as place sites and locations, however, data collection measurements taken for distance, depth, and velocity shall be performed in a metric scale. Only two points exist along the river which are accessible by land vehicles, Lee's Ferry (RM 0.0) and Diamond Creek (RM 225). Because of the limited access, remote and rugged terrain of the Canyon, conducting research is extremely difficult. An understanding of logistical problems and potential hazards of conducting fishery investigation in remote reaches of the Grand Canyon or similar riverine conditions shall be required.

Figure 1 is a map indicating the sampling areas designated for this research project. The mainriver study shall be divided into three sampling areas or sites; 1) the mainriver and confluence area of the Little Colorado River (RM 61.5), approximately 96 kilometers downstream from Lee's Ferry, (RM 0.0.), and 2) the mainstem Granit Gorge area from RM 75 to RM 156, and 3) the lower Grand Canyon reach from RM 156 to Diamond Creek.

At present we have a limited and fragmented understanding of the importance of the mainstem Colorado River to the distribution, abundance and habitat use of the humpback chub in the Grand Canyon. From previous investigations we know humpback chub seasonally enter the LCR in the spring during spawning activities (Kaeding 1983, Maddux, 1987). It is also known that backwater habitats and possibly shoreline habitats, are used by young chub. in the mainstem reaches. However, backwater habitats in the Grand Canyon are limited in number and widely distributed throughout the canyon. Backwater habitats in the Grand Canyon are also greatly affected by cold water temperatures and daily fluctuations that affect their physical and chemical characteristics. It is not known, and to what extent, other low velocity habitats offer suitable habitat for the humpback chub due their limited smampling.

Intensive sampling shall be conducted in the mainstem Colorado to determine seasonal humpback chub distribution and abundance, resource use and availability, and survivorship information on various life stages of humpback chub.

Mainstem Colorado River sampling shall be conducted seasonally in the three subreaches identified above. The selection of the two intensive radio subreaches is based on previous investigations performed by Kaeding and Zimmerman in 1983 and Maddux, 1987.

The first mainstem sampling reach (Little Colorado River, Mainstem Reach) shall extend from Kwagunt Canyon to Red Canyon, a distance of approximately 33 kilometers. Portions of this reach were sampled under earlier investigations and it is suspected that chub migrating out and staging at the LCR may reside within this reach. The use of this river reach by humpback chub and the effects of dam operations on the habitats used by chub in this reach of river are primary objectives of this contract.

The second mainstem sampling reach extends from Red Canyon (RM 76) to Havasu Canyon (RM 156) a distance of XX kilometers. While collections of humpback chub in this reach during earlier investigations were infrequent, sampling of the this area was not quanitative in nature. Sampling of various habitats in this area in a more quantative manner, may yield significant information that would help towards establishing the presence of a second population or information on the general distribution and abundance of the mainriver population of humpback chub.

The third mainstem sampling site (Lower Grand Canyon Reach) shall extend from Havasu Canyon (RM 156), to Diamond Creek (RM 225), a distance of 110 kilometers. This river reach contains a combination of flat water sections, eddies and shoreline runs, forming various shoreline low velocity habitats. This subreach of river was determined to be an important nursery or rearing area for native fish, (Maddux, 1987). Juvenile and young of the year humpback chub were collected in this reach, however, no spawning sites or larval fish were collected during the GCES investigations. Again, the identification of habitats used by the humpback chub and other native fish species and the effects of dam operation on these important habitats are the principal objectives of this research effort.

C.5 FIELD SAMPLING

Sampling of the intensive LCR radio telemetry site and the Granite Gorge site shall be conducted concurrently. The principal investigator (PI) shall be responsible for coordinating both research efforts and maintaining concurrent data bases. In addition to the PI, two separate project leaders shall be identified by the Contractor to be responsible for conducting the radio telemetry research and the Granit Gorge quantitative research effort.

C.5.1 Research Part I, Sampling the Mainsten Colorado River/Little Colorado River Confluence Area.

C.5.1.1 Sampling Sites

A. **Mainstem Colorado River/Little Colorado River Confluence Area reach (RM 56 to RM 76.5).** This 33 kilometer reach of river (Figure 1), shall be sampled extensively with the use of radio telemetry, electrofishing gear and passive experimental gill and other net types determined to effectively sample the array of habitats in the area. Habitats to be sampled include, but are not limited to: shoreline runs, eddies, ephemeral backwaters, low velocity runs, side channels, and mainriver slackwater areas. Physical and chemical habitat characteristics shall also be surveyed including, but not limited to, location (RM), depth, velocity, substrate, maximum and minimum size (length and width), and cover to describe habitats occupied or not occupied by humpback chub.

B. Granit Gorge Sampling Reach (RM 76.5 to 156). This middle mainstem sampling area will be quanitatively sampled with the use of gill and trammel nets, electrofishing equipment, seines and other gear types determined to be effective in sampling important habitats of the native fish in the area. Habitats in the Granit Gorge area consist of steep shoreline, rocky habitats typical of those that occur in the Upper Colorado River basin where humpback are known to occur. The primary purpose for sampling this area is to extend known information on the distribution, abundance by age class, habitat use and changes in habitat availability where possible. A detailed sampling program for this 79.5 mile reach shall be developed by the contractor for review by the ACT.

C. Lower Grand Canyon Reach (RM 156 to RM 225). Sampling in this lower mainstem reach shall be consistent with that conducted at the Little Colorado River, (C.5.1.1 above) reach except for the possible use of radiotelemetry. The primary sampling program shall be for the collection of information on distribution, abundance by age class, habitat use and changes in habitat availability with changes in flow discharge.

C.5.1.2 Timing and Data Collection

Life history data for all life stages of the humpback chub associated with the mainstem sampling program in the mainstem Colorado River shall be collected on a seasonal basis. This information is critical for determining habitat use by season, its availability as affected by discharge changes, and possible preference by species.

The design and scope of research planned for the first year shall be coordinated through the ACT to ensure integration with the Phase II GCES, scheduled flow releases from Glen Canyon Dam (see Section J and Section C.1.3). The ACT and the Contractor shall coordinate and schedule the logistical river trips planned for the 1990-1993 research period prior to initiation of data collection. Modification to the scheduled research trips shall be approved only by the ACT, COTR and the Reclamation GCES Flagstaff Office. The selected Contractor shall be expected to initiate the research effort by August, 1990.

The mainstem river sampling trips scheduled for the 1990-1993 research period shall require two independant data collection teams with 4 to 6 biologists and two boatmen. Each team will consist of

4 contract bioliogist, two Reclamation or other ACT respenstative biologists and two qualified Grand Canyon boatmen. If additional personnel are required the Contractor shall justify in writing the need, including the person's job description and responsibility to Reclamation. Details regarding biologists, assistants and substitutions shall be submitted for review and approval to the COTR prior to the launch of a trip.

A total of 6 trips are scheduled for conducting research in 1990. Five of the 6 trips will run 20-days in lenght begining on September 1. An additional trip will be taken in August begining on or around the 15th which will include the contractor, ACT representatives, the COTR, and the Service to discuss the overall research program and conduct preliminary radio telemetry survellence. The other trips schedule for 1990 include sampling in October 1-20, November 1-20 and December 1-20. Each trip shall be conducted for the purpose of capturing, implanting radio transmitters, tracking adult humpback and collecting habitat use information as discussed above.

Ten fish shall be captured and implanted in late July 1990, by Reclamation personnel for the purpose of initiating radio tracking and monitoring behavior by the Contractor's first scheduled research trip, August 15, 1990. A maximum of 10 humpback chub shall be implanted on each trip for a total of 40 fish in 1990. No more than 15 fish shall be available on any trip for tracking based on the average battery life of the radio tag. Radio tag implantation by the Contractor shall commence on the September 1, 1990 research trip.

Upon evaluating the effort and the resulting research data it may be determined that a particular season or critical study area may require additional or less time for sampling. Therefore, these situations shall require flexibility for re-emphasizing the scope of work, time schedule, and the study area. An intensive research effort shall be developed for the 1991, 1992, and 1993 field seasons based on the findings of the first year. Also, the findings shall determine the utility of using radio telemetry in the Lower Grand Canyon Reach. The ACT will work with the Contractor to determine any modifications that are required to insure the successfull execution of the contract while minimizing any impacts to the humpback chub population or the other native fish species. Any changes or work requirements shall be made by bilateral modification to the contract.

A total of 36 trips are scheduled between 1991, 1992 and 1993. In each year, twelve 20-day trips shall be conducted to collect life history information for all mainstem river study reaches in the Grand Canyon. Approximately 60 transmitters shall be implanted per year.

The Contractor shall employ a random sampling program, if required, for the selection and daily monitoring of implanted fish to determine habitat use. However, after implanting, no information shall be collected until the fish is determined to have recovered sufficiently to insure behavior and habitat selection are not being influenced by implanting stress or postoperative recovery (approximately 10 to 12 days). The life expectancy of most transmitters is reduced because of the fish size and the chub's laterally compressed morphology prevents the use of transmitters with longer battery life. Trips have been scheduled to ensure the most efficient use of transmitter strength and life expectancy. The specifications for the transmitters are described in C. 6.2.2.

The 20-day primary trips shall require approximately 2 days for downstream travel to the designated Little Colorado River, mainstem reach. This shall permit transportation of equipment and personnel to the initial reach where research shall be conducted for 9 to 10 days. Upon arrival at the Little Colorado mainstem sampling area the two teams will split, with one team staying at the confluence area to conduct radio telemetry studies, while the other team continues on down the river to begin sampling the Granite Gorge site. After approximately 10 to 12 days of sampling both teams shall meet at Havasu to begin sampling the lower mainstem area. All trips are scheduled to takeout at Diamond Creek (RM 225), on the 20th day.

Reclamation shall provide reconnaissance flights, if necessary, to survey the river corridor for general location, distribution, and identification of radio tagged fish. Helicopters prior to the launch of each trip shall be used to locate fish. Limitations exist for using fixed-wing aircraft in conducting radio telemetry surveillance in the Grand Canyon because of the special flight restrictions on altitude and over-flight areas. Therefore, surveillance shall be conducted by helicopter to meet FAA flight restrictions specific to the Grand Canyon.

Specific juvenile and adult habitat preference data shall be collected including water depth, velocity, and substrate for each fish located. The type of microhabitat data and how it shall be collected are described below in detail.

Reclamation shall be compiling all data into a cataloging system called Micro Image Processing System (MIPS) and a Geographic Information System (GIS). The Contractor shall provide compatible data information in three forms; 1) all text information shall be formatted with WordPerfect 5.0, 2) the original data management shall be in DataBase III Plus, and 3) photographic, videographic and cartographic information as defined by the GCES office. These data shall be transferred or optically scanned into the MIPS system by Reclamation.

C.5.1.3 Habitat Sampling

The Contractor shall sample all juvenile and adult habitat types within the three mainstem sampling reaches. Habitats to be sampled include but are not limited to: backwaters, eddies, shoreline, runs, sidechannels and mainstem slackwater or low velocity habitats. Effective sampling of these various habitat types shall require specialized netting techniques and a variety of sampling methods. Determining the method, its effectiveness and the frequency of its use, shall be dependent upon the habitat area and the life stage being sampled.

The AGF will have a concurrent backwater habitat sampling program to study the early life history habitats of the humpback chub in the mainstem Colorado River. The AGF program however, will only overlap contractor effort during the early summer months of May and June. The Contractor, through the ACT, will coordinate the mainstem habitat sampling program with the AGF to minimize over sampling of the fisery resources, and to ensure efficient, consistent, and non-overlapping collection efforts.

The Contractor shall collect physical habitat measurements to identify substrate, depth, cover, and velocity for all areas where juvenile and adult humpback chub are collected. The habitat description shall also include its location (RM), minimum and maximum size and its type. Habitat measurements shall be collected on areas where fish are located through the use of telemetry and where fish are not for comparison and analyses of habitat selection.

Fish located by radio telemetry on the Colorado River, Grand Canyon during the sampling period shall be monitored, and habitat data shall be collected using prescribed procedure. However this does not preclude the contractor from designing or initiating other telemetry sampling program to obtain information with greater ease or efficiency if the prescribed procedures do not appear to be adequate. A fish that has been identified in an area shall be monitored for 30 minutes to determine if its location is static or dynamic. Once it has been determined that the fish has remained stationary, a location point shall be identified through the process of triangulation. The fish shall be monitored for an additional 1.5 hours to insure habitat use before physical habitat measurements are taken. The contractor must keep in mind during the collection of fish movement and habitat use data that the river is changing daily due to dam operation. A sampling design to determine habitat selection in a changing environment may be different than one in which the river only affected by seasonal events. All measurements shall be taken in metric scale.

Measurements for water depth, velocity, temperature, substrate type (sand, gravel, cobble, boulders, etc.), and cover types (overhanging, lateral, etc.), shall be collected. Water quality parameters (temperature, dissolved oxygen, pH, conductivity, and turbidity) shall be collected for each site. This information shall be collected, combined with the USGS stage discharge measurements and correlated with movement patterns and habitat use of the humpback chub. Date, time, and other observations shall be recorded and documented for each habitat sampled.

The Contractor shall collect water velocity measurements using an electronic current meter. Standard multiple velocity measurements at depth intervals shall be taken as described in the methods commonly used for instream flow analysis. River bottom profiles shall be mapped using a fathometer to determine channel characteristics, depth, contour slopes, and submerged substrate. Information shall include photographic documentation and description of site, time, location point (RM), and observable reference points.

The Contractor shall construct a detailed field map using mylar overlays from aerial photographs provided by the Reclamation/GCES. These points shall be transcribed onto the base map to identify location points of fish and habitat characteristics of the study area. The Contractor shall take measurements using water quality equipment, colorimeter, secchi disks, depth rods, current meters and fathometers. This equipment shall be provided by the Contractor.
The extent and use of a random sampling program shall be determined by the Contractor and based upon time constraints, number of implants, distribution, and the logistical problems associated with the study area.

C.5.1.4 Seasonal Fish Sampling

The Contractor shall collect data on life history for juvenile and adult life stages of the humpback chub associated with the mainstem sampling program in the Colorado River on a seasonal basis. This information is critical for determining habitat availability, use, and preference.

C.5.1.5 Confluence Sampling

Within the Grand Canyon there are X tributaries. From Kwaugnut to Dimond Creek there are X tributaries of which X have historical collection of humpback chub. With in the last several years however only Havasu, Kanab, Shinamu and Bright Angel have records of humpback chub collections. The contractor shall sample the confluence area of each major tributary of the mainstem river. The contractor will record where possible the flow or stage of the river and changes in the physical habitats associated with the confluence and mainriver interface. In addition to the documentation of physical changes fish collections will be made to document fish movement activties associated with changes in stage as a result of dam operation. No more than one or two days will be spent at each tributary confluence area.

C.6 EQUIPMENT, PROCEDURES AND METHODS

C.6.1 Rafting/Boating

Reclamation, through the GCES office, shall provide the logistical support for all research river trips scheduled for the Colorado River, Grand Canyon. This shall include the primary raft support for transportation of research equipment, rafts, outboard motors, and personnel to the two research areas in the Grand Canyon. Reclamation will provide the research Contractor with logistical supplies and services necessary to conduct the research. These supplies and services shall include additional waterproof storage containers, food and preparation, primary camp locations, and additional research assistance when available. Equipment provided by Reclamation is described in Section C.10.

The Contractor shall be required to provide a minimum of 4 boats for the 20 day primary trips. The research boats shall be of size for conducting work within the three sampling areas. All of the Contractor's boats shall be disassemble and carried on the primary support rafts when they are not being used for research. The Contractor provided boats shall be a minimum length of 14 feet and shall be equipped with a motor for upstream and downstream movement in each of the study areas. The critical factors influencing a boat's performance and overall safety are horse power, hull design, size, and weight carrying capabilities. Research should not be limited by the above factors influencing the mobility of the craft to safely hydro-plane. The required horsepower ratings shall depend on the primary purpose of the craft, and shall be in the range of 30 hp to 50 hp.

Two of the Contractor provided crafts shall be equipped with electroshocking equipment that can be used frequently for sampling various types of habitat during day and night, to determine diel activity patterns of use at particular locations. The two additional crafts shall be used for radiotelemetry, setting nets, and carrying personnel and sampling gear. The electrofishing craft and secondary craft shall be powered by no less than a 30 hp outboard motor. The primary craft used for radio telemetry shall be equipped with a minimum of a 40 hp outboard motor to ensure upstream mobility to and from established work sites during the tracking and scanning phase. All boats shall have an efficient and dependable light system to navigate safely during conditions of poor visibility or night.

The Contractor provided radiotelemetry boat shall be designed with a light compact frame for equipment storage (receiver units, fathometer, current meters, etc.), and supporting whip antennas and easily disassembled extension standards. The boat shall also have the capability of transporting captured fish to and from implanting stations.

The experience of boatmen in operating boats and knowledge of sampling areas, rapids, and discharge levels in the Grand Canyon is critical for accomplishing the research objectives of this study. All boatmen operating research support boats shall be qualified by having comparable whitewater experience as listed in the Colorado River Management Plan (CRMP) and/or possess a Commercial Operating Certification.

The Contractor's biologists and personnel shall adhere to the National Park Service's, CRMP regulations regarding river safety, experience, and boating restrictions. The Contractor's research support craft shall be large enough to safely negotiate rapids in upstream travel and capable of transporting research equipment and personnel. Contractor provided inflatable rafts shall be a minimum of 14 feet and meet the equipment requirements and boat registration for their intended use. Contractor provided rafts shall meet the requirements for safe operation in the Grand Canyon as established by the National Park Service. Prior to trip departure all boats shall be inspected by the National Park Service at Lee's Ferry.

Contractor provided research biologists shall comply with the National Park Service's rules and regulations on camping and visitation. Areas prohibited to camping are from on the left side from RM 61 to RM 65 of the south east side of the Colorado River. Visitation is prohibited from RM 63 to RM 64.5, the Hopi Salt Mines. Remote sampling sites, time, distances and safety may require additional camps to be established away from the original base camp. The Contractor's biologist shall have the capabilities to transport equipment and personnel to these secondary camps to accomplish research objectives. These additional camps shall be self-contained and research personnel shall abide by the NPS regulations stated in the CRMP.

C.6.2 Radio Telemetry

Research in the upper basin has demonstrated the effective use of radio telemetry for collecting habitat use information (Valdez, 1990). Fish captured using different gear types (nets and electrofishing) can be used for implanting radio transmitters. Previous research conducted in other areas on the Green and Colorado River indicate that humpback chub may be non-migratory. The humpback chub population in the Black Rocks area of the Colorado River appear to prefer deep canyon habitat and their movements are restricted to the local area (Kaeding, In press.). The Contractor shall collect movement data on the Grand Canyon humpback chub populations' behavior or habitat requirements to determine how operations of Glen Canyon Dam affects the mainstem population. Two methods of radio telemetry shall be used to determine specific habitats used and the extent of fish movement. The Contractor shall use the <u>first method</u> to collect information as

described in C.5.1 for specific habitat use information. The Contractor shall use the <u>second method</u> to search the entire length of the river by scanning for missing frequencies not identified during the intensive or specific habitat research efforts. As a back up procedure for finding lost fish or fish that have moved long distances out of the mainstem sampling area the Contractor shall conduct surveillance flights. These flights shall be conducted prior to the launch of each research trip to establish locations of as many fish as possible. The Contractor shall provide information on the distribution and movement patterns for the Grand Canyon humpback chub population. The sampling program will be coordinated through the ACT to integrate with the GCES Research Flow program outlined in Section C.1.3.
If the use of radiotelemetry is effective in identifying other areas that are being utilized by smaller groups of humpback chub these areas shall then be sampled using the standard techniques described in Section C.7.

The Contractor shall conduct radio tracking during all research trips. However, in the interest of safety, radio tracking shall not be conducted while navigating white water rapids. Radio telemetry equipment shall be stored in dry containers but remain available and easy to assemble and disassemble for negotiating rapids. The ability to monitor with radiotelemetry equipment shall not be limited to one boat. During travel downstream from one sampling area to another tracking shall be conducted on both sides of the river from two separate boats unless all tags or radio implanted fish are accounted for during the tracking.

The Contractor shall provide radio transmitters and receivers from a manufacturer approved by Reclamation, prior to contract award, that meet the specifications and capabilities as described below. The Contractor shall use a transmitter with the highest efficiency for reception in remote location and within the riverine conditons of the Grand Canyon. The Contractor shall have available different size transmitters for surgical implants as options in utilizing the optimum transmitter, based upon the weight of the fish. Minimum weight of an implanted fish shall be no smaller than 450 grams.

The Contractor shall collect and implant approximately 200 fish radio transmitters during the course of the four year study period during the 20-day river trips. Radio tracking shall be conducted throughout the Grand Canyon, however, the study areas shall be identified from the surveillance and reconnaissance flights over the Grand Canyon.

Section C.6.2.1 Radio Telemetry Receivers

The Contractor shall provide 2 programmable-scanning receiver units, and an additional replacement receiver that must operate in the 40 MHz band, with a designated 40:600 to 40:700 frequency range. The receiver specifications are; storage memory, manual frequency selector, field programmable, add/delete features, frequency scanning, scanning rate adjuster, delta tune switch, digital display, amp meter, and jack connections for antennas and head phone sets.

The Contractor provided receiver shall be able to select for desired frequencies or scan multiple sets of programmed frequencies during normal tracking and scanning operations.
The receiver shall have the capability of adjusting scanning rates and identifying transmitters that drift off of designated frequencies.

The Contractor provided receivers shall be reduced in size for ease in transport and storage purposes, and shall be contained in secure waterproof containers. Contractor shall provide a set of stereo headphones for each receiver unit. Antennas and headphones should have a jack assembly to ensure quick assembly and disassembly. The receiver units shall have capabilities of operating with multiple headphone sets for both boat operator and biologist. The receiver shall be designed to avoid noise interference caused by the operation of other mechanical sources, and capable of distinguishing and separating out background interference from transmitter signals. The Contractor shall provide alternative systems (receiver units), power sources (replaceable battery packs, 12 v. battery) and recharging capabilities (rechargers and generators), to maintain and ensure excellent operation and performance of the radio receivers.

Section C.6.2.2 Radio Transmitters

The Contractor provided transmitters for radio telemetry shall be a pulsed implant type, consisting of two stages (battery and transmitter), with a trailing external whip-antenna. These whip antennas shall be constructed of a flexible stainless steel cable and covered with a teflon coating. Transmitters are to be encapsulated in an inert electrical epoxy and powered by lithium batteries for the advantages of higher voltage and the reduced weight for optimum life expectancy. Transmitters shall operate at maximum voltage to ensure signal strength and reception range in conductivity ranging from 800/1000 umho/cm. Transmitters shall be tolerant of a range of temperatures. The size, weight, and shape of the transmitters are critical in the surgical implant procedure. Three types of transmitters of different weights shall be used depending upon the size of the fish implanted. Table I. indicates the weight specifications of the transmitter and fish required for the surgical implant procedure.

TABLE I. Humpback chub, transmitter weight specifications.

Fish Species	Body Weight	Weight %	Transmitter Weight

Humpback chub	>450 grams	< 500 grams	2%	9 grams
Humpback chub	> 500 grams	< 650 grams	2.2%	11 grams
Humpback chub	> 650 grams		2.5%	16 grams

The Contractor shall provide specific transmitters which shall optimize the length of the monitoring period of an individual fish. Transmitters with a longer life expectancy are preferable to those of a shorter life expectancy. The availability and size of a fish shall determine the transmitter size. The Contractor shall be expected to utilize the 11 gram transmitters for most of the implants depending upon their availability. If a larger fish (> 650 g.) is captured, the Contractor shall utilize the optimum size tag. Smaller size class (>450 g.<500 g.) shall be utilized only for two purposes; 1) reduced availability of optimum fish size, and 2) for movement information during the prespawning period when remote data loggers are in operation.

Figure 3. is a representation of the desired schedule for monitoring and implanting transmitters. It indicates the transmitter size and life expectancy, implant frequency, and implant numbers during the scheduled 1990-1993 research period.

The Contractor shall develop a frequency distribution on weight and abundance for all humpback chub captured on a per trip basis to determine the probability of capturing a fish of the required size limit on a seasonal and monthly basis.

The study design and use of designated frequencies and pulse rates shall be consistent in order to avoid frequency repetition and overlap. Transmitters shall operate in the frequency range of 40:600 to 40:700 band-width. Frequencies shall not be repeated in the same year to avoid multiple transmitters operating with the same frequency. The designated frequencies shall be separated in increments of at least .002. All frequencies shall be tested by the Contractor to determine the actual frequency, and fish shall be monitored initially after surgery to identify if frequency drift has occurred. The pulse rate and width shall avoid transmitter overlap and help distinguish frequency drift.

The Contractor shall coordinate with Reclamation and the ACT to determine the initial designated frequencies for the 10 transmitters to be implanted by Reclamation personnel on the July 1990, initial implanting research trip.

Section C.6.2.3 Receiving Antennas

The Contractor shall provide two types of receiving antennas; an omni-directional antenna and a directional antenna, both tuned to the specific frequencies required for telemetry. All boats shall have the capability of using either type of antenna independently of each other. The omni-directional antennas shall be mounted on a standard extension which can be easily disassembled for navigation. A fiberglass shaft shall be used to obtain the additional height needed for the radio telemetry scanning mode. A total of 3 omnidirectional antennas and 3 directional antennas are to be provided by the Contractor. The antenna system shall be designed to optimize direction and reception without interference to navigation and safety. The antenna system shall have directional capabilities that can be used either on boat or land. The Contractor shall provide an additional directional antenna that can be mounted and operated from a helicopter. The omni-directional and directional antennas (Yagi and/or Loop antenna) shall have compatible cable connectors for the receiving units.

Section C.6.2.4 Remote Telemetry Stations

The Contractor shall provide and install two remote telemetry data logging stations to be used for scanning discrete areas. The purpose for the remote monitoring stations is to establish a continuous recording on the temporal patterns of movement of radiotagged fish. These stations shall be discretely installed in remote areas to avoid vandalism and equipment damage. The stations shall be located at two separate areas: 1) the LCR confluence area, and 2) 6 kilometers downstream of the LCR confluence. The exact monitoring locations shall be determined by field investigation. Monitors shall be installed and begin continual operation by January 1991.

The remote telemetry stations shall be engineered in such a manner that a series of directional antennas shall effectively scan a 1 km. wide spectrum of a selected site, and separate this area into distinct multiple zones.

The remote data logging stations shall have the following capabilities: receiving and distinguishing separate frequencies; a continuous scanning mode; an internal clock; a minimum one month data storage (at continuous operation); and a solar powered system and/or battery with a 1.5 month capacity at maximum load. The data logger shall be PC compatible and capable of programming and downloading either remotely and/or in the field. The data logger shall also be able to program 100 distinct frequencies within the range of 40:600 to 40:700 and shall be shock resistant, thermal tolerant (range, - 10 C.to 60 C.), and waterproof.

The Contractor shall use the multiple zone system to continuously monitor radio-tagged fish for pre-spawning and post spawning movement. The data shall provide information on fish identity,

time, direction of movement, and relative distance traveled over time.

C.7 FISH COLLECTION METHODS

C.7.1 Electrofishing Techniques

The Contractor shall use electrofishing as a standard method for sampling low velocity habitats for information on adult and juvenile fish in the three designated research areas. Comparisons on patterns of diurnal habitat use shall be conducted by replicating electroshocking efforts at distinct sampling sites. For this reason it is imperative that the electroshocking craft have the ability to up-run and navigate certain rapids for access to difficult areas within the study area. Electrofishing shall also be used for collecting chub for surgical implanting purposes.

The Contractor shall provide all electroshocking equipment and a trained operator with the working knowledge of electrical systems and its operation. The system shall have the capability of operating in relatively high conductive (800-1000 umho/cm) water and have a generator that can handle the resulting loads. The Contractor shall operate the electrical system under these specifications. The equipment used for electrofishing shall be large stainless steel spherical electrodes (20 cm.), a 220-volt generator (minimum), and a variable pulsing system, to produce an electrical field using pulsed direct current. The Contractor shall attempt to avoid potential injury to the humpback chub. The Contractor shall document the voltage, pulse frequency, pulse duration, and wave form used in the collection of fish during the electroshocking operation. To avoid down time in sampling, the Contractor shall provide backup equipment in case of equipment failure or damage.

If information becomes available or if injuries occur related to electrofishing, the Contractor shall take action to correct the problem.

The Contractor shall follow OSHA safety requirements and provide all specialized equipment such as rubber gloves, boots, lights, safety harnesses, and circuit breakers. The contractor provided boat operator and biologist shall have a working knowledge and experience in utilizing electroshocking methods on large river systems. The Contractor's electrical system shall be designed so that the equipment can be dismantled and reassembled to navigate rapids. The electrofishing boat shall be equipped with lights and other safety equipment for maneuvering while sampling in different habitat areas during both day and night.

The Contractor shall collect and compile all quantifiable data in such a manner that statistical analysis can be performed on abundance, frequency, and distribution for all species and age classes encountered. Standard CPU data and description of habitat types and use shall be collected for statistical analysis. All native fish and nonnative fish shall be recorded and lengths (standard and total), and weights taken. All humpback chub shall be tagged with a coded passive integrated transponder tag (PIT). Reclamation shall provide the PIT tags and receivers.

The Contractor shall collect additional microhabitat data on flow discharge, water quality (turbidity and conductivity), day, night, and crepuscular activity for the three mainstem sampling areas. The Contractor shall also collect information on other fish assemblages to identify and develop an understanding of the interspecific interactions, and species composition of the other fish species.

C.7.2 Netting Techniques

C.7.2.1 Passive and Active Netting

The Contractor shall set gear in various habitat types throughout the three study areas in the Grand Canyon. The Contractor shall be responsible for providing the needed hoopnet, fyke nets, gill nets, seines and trammel nets for use in mainstem sampling areas. The number, frequency, and duration of net sets shall be determined by the Contractor upon the rate of debris accumulation in the nets and the abundance of habitat types in each of the sampling locations. Gill and trammel nets shall be checked every 1 to 2 hours to avoid incidental and or excessive mortality of native species.

The size of the nets can vary according to the sampling design or methodology employed for capturing various age groups of the target species. The use of certain net types have been proven to be more effective sampling certain species, life stages, and habitats. The Contractor shall be familiar with the habitats where the target fish (species and size) would most likely be located and the method and net type and size that would insure successful capture.

The Contractor shall utilize experimental multifilament gill nets and trammel nets of various lengths for sampling shoreline habitats. The placement and selection of net types shall be determined by the Contractor for the specific habitats to be sampled. The Contractor shall be familiar with the habitat used by the target species for determining sampling method and location site.

C.7.2.2 Seining

In addition to the nets used in C.7.2.1, the Contractor shall use seines, and fine mesh kick-nets to collect juvenile and young of the year humpback chub and other native species. The net specifications shall be a minimum of 6 ft x 30 ft and 1/4 and 1/8 inch mesh. Species identification shall be performed in the field, and all fish collected shall be released unless incidental mortality occurs while employing the described collecting methods and techniques.

The Contractor shall preserve all unidentified samples and incidental mortalities in 3% to 5% formalin. Recommendations on a collecting protocol will be developed by the ACT.

C.8 FISH HANDLING

The Contractor shall provide all reasonable effort to reduce impacts associated with research on all fish species residing in the Grand Canyon National Park, especially the endangered humpback chub. All methods and procedures conducted during this study shall avoid and/or minimize those negative impacts (direct or indirect) associated with the research.

The ACT in consultation with the Contractor shall develop a protocol for handling fish to ensure recovery from the multiple processes of capture, anesthesia, measurements, implanting, and release procedures. The ACT will work with the Contractor on protocol and revise if necessary. The Contractor shall adjust or modify any handling procedure as additional information becomes available or as the ACT recommends.

If upon evaluation of the Contractor's annual report it is determined that excessive mortalities have resulted from attempts to conduct radiotelemetry on the humpback chub the ACT and the Contractor will evaluate alternative methods for collection habitat use information on the mainstem Colorado River. The Contracor shall preserve all fish mortalities for museum collections and for use in dietary studies, age and growth information and taxonomic identification.

C.8.1 Capture Techniques

Each particular gear type shall be evaluated to determine its effectiveness in collecting the target species, specific size, effort, and number of fish on a seasonal basis. Electroshocking shall be one of the methods used for collecting and implanting fish, however, alternate methods depending on season and area may work more effective in capturing humpback chub.

To avoid unnecessary stress related to the use of certain sampling methods (electrofishing, gill nets, trammel nets, etc.) as mentioned in section C. 4., the Contractor shall develop methods to minimize incidental mortality or stress caused by capture techniques, transportation, surgery, temperature, oxygen depletion, and overcrowding.

Care should be taken to minimize the stress related to the use of electrofishing methods. The Contractor shall use an electrically shielded tank for recovery of captured fish during electrofishing operation by employing the faraday shield principle. This shall maximize the rate of recovery from the initial stress associated with electrofishing, (Sharber & Carothers, 1987), and avoid the problems associated with bulky equipment, operation of mechanical pumps, and alternative sources of power. The Contractor shall develop alternative procedures for maintaining fish collected by other sampling methods.

Fish sampled shall be identified to species, measured for total and standard length (mm.), weight (g.), sex, tags and markings. The use of PIT tags for identification purposes is specific for humpback chub.

The use of anesthetizing drugs TMS 222 (Tri-caine methano sulfanate) shall be carefully administered to avoid overdoses related to overcrowding and oxygen depletion.

The standardized procedure developed by the Service's Colorado Fisheries Project (CRFP) shall be followed for photo-documenting and recording (photo I.D., date, and site) of all chub sampled. The Contractor shall be required to have the necessary photographic equipment and supplies (scaled photo-boards, camera, lenses, black & white film). Morphometric characteristics (nuchal hump, snout length, caudal length, etc.), shall be measured using the procedures that are standardized presently by the Service in the Upper Colorado Basin.

Incidental mortalities resulting from sampling methods shall be used to determine and identify food utilization through gut analysis and fecal collections. These data can also be used in determining dietary overlap and possible competition between native and nonnative species within the Grand Canyon. Stomach contents shall be stored in 10% formalin for gut analysis. Larval fish shall be preserved in alchohol to prevent later laboratory analyses. Reclamation shall be notified of all incidental mortalities at the end of each sampling trip. Reclamation will alert the ACT and AGF.

C.8.2 Implanting Procedures

Emphasis on reproductive behavior and movement patterns may necessitate implanting additional fish during the 1990-1993 research period. Approximately <u>200 fish</u> shall be implanted during the course of the radiotelemetry study. However, the number of implanted fish shall be determined by a seasonal evaluation of the data collected on abundance and availability. Frequency distribution of the different size classes of humpback chub captured in the present monitoring program shall be calculated in order to determine the feasibility of obtaining the number of fish within an acceptable size range.

The transmitter size, weight and power are critical. The acceptable transmitter weight shall be approximately 2% of overall body weight and the Contractor shall determine the type of receiving units and transmitters to used in this investigation, as described in Section C.6.2.2.

The suggested method for implanting radio transmitters shall be a slight modification of the present surgical technique commonly used for implanting radio transmitters, (Bidgood, 1980. and Tyus and McAda 1984). Reclamation reserves the right to alter or make additional changes to this method depending upon new information. Reclamation shall oversee the implanting procedures during the first field season to ensure that proper techniques are performed.

All recaptured humpback chub containing radio transmitters shall be examined and photographed for their overall condition. Fish exhibiting poor conditions or stress related to prior implant shall not be re-implanted. Those fish shall be released after the removal of the transmitter's external antenna. Recaptured fish, showing no signs of physical stress, shall be considered for the removal of the existing transmitter and re-implanted with a functional transmitter.

C.8.3 Release Procedures

To maximize recapture information, fishes shall be released in such a manner that their survival and recovery shall be ensured. The present monitoring program instituted by the AGF/FWS utilizing passive integrated transponders (PIT) shall be continued as the type tag for chub identification. The Contractor must be familiar with the implanting and operation of the PIT tag procedures. The recommended size length for PIT tag implant shall be >250 mm. Monitoring sensors are to be considered standard equipment and are to be made available and used when sampling fish at all times.

Fin markings are to be used for distinguishing recaptured fish, extent of movement, and differentiating subreaches for fish <250 mm. The Contractor shall develop a marking procedure for sampling this age/size fish.

C.9 Data Quality Assurance

The Contractor is responsible for ensuring daily data compilation, accuracy and safe keeping in the field. The success of one gear type shall be evaluated to determine the effectiveness of implementing other methodologies and gear types. The Contractor must be familiar with all of the techniques and gear types used for collecting and sampling.

A data management protocol shall be established jointly by Contractor and the ACT to ensure compatibility with the structure of the GCES endangered fish data base and the research effort being conducted by the AGF and the Service in the Little Colorado River (See Section 12.1).

The Contractor shall designate a person to coordinate the scheduling of the logistic and support aspects of the research. This appointed person shall be responsible for all communication regarding research and logistical needs and concerns. A written description shall be submitted detailing the exact study design, logistic schedule, research personnel, research equipment, storage requirements, and research equipment needs. Written notification should be received by Reclamation at least 45 days in advance of each research trip. All research personnel (Contractor biologists, assistants, volunteers, and substitutes) shall be identified with justification of work description.

ALL original data acquired by the Contractor under this solicitation will be provided to Reclamation during and at the conclusion of this contract. Reclamation will maintain all of the collected data in the GCES office and will provide AGF and other ACT associates with a copy of all of the data for inclusion into the humpback chub data base maintained in the AGF Phoenix Office. In addition to the written data base the Contractor shall provide to the ACT a photographic record for documentation of the research efforts. The photographic record shall consist of original photographs taken of methodologies employed, fish captured, habitats surveyed and procedures used to accomplish the objectives of the study.

C.9.1 Additional Studies

The Contractor will coordinate with the ACT to identify any specific laboratory or field studies that may be required to support the GCES program or the conservation measures. The ACT will determine the appropriate action to take.

The AGF, Service, NPS and Reclamation will be conducting other aquatic studies in the Grand Canyon during the time of this contract. Specifically, dietary studies, age and growth analyses, early life history and habitat studies will be carried out. The Contractor, through the ACT, will coordinate their efforts to ensure minimal impact to the humpback chub and other aquatic species and habitat. IF the Contractor identifies a data or study gap, the **ACT** will be alerted and they will recommend to the GCES office an appropriate course to take.

C.10 GOVERNMENT FURNISHED EQUIPMENT, DATA AND PERMITS

C.10.1 Government Furnished Equipment

The primary logistical support shall be furnished by the Bureau of Reclamation through the Glen Canyon Environmental Studies logistical river support Contractor. The GCES logistical Contractor shall furnish the necessary support services that include; research equipment storage, meal preparation, location of base camps, and transport of personnel and research equipment. Reclamation shall furnish additional water quality equipment (Hydrolab Surveyor, and DataSonde II) only as a precautionary backup support to the Contractor. Also, Reclamation shall provide PIT tags, monitors, and the necessary surgical equipment for the tagging procedure.

Reclamation shall provide a backup or additional boat if needed for the radiotelemetry study. Additional waterproof storage containers shall be made available by the Reclamation for the safe keeping of research equipment and data.

C.10.2 Government Furnished Data

Reclamation shall furnish the Contractor with the hydrological data collected by the USGS on stage discharge, sediment transport, and water quality information on the mainstem of the Colorado River. Also, data shall be provided to the Contractor on the historical and present hydrology on the Little Colorado River drainage. Literature review and data analysis of the historical humpback chub information shall be provided.

C.10.3 Government Furnished Permits

Reclamation shall be responsible for securing the necessary Federal and state permits for collecting endangered fish species. Permits and applications for river research and air flight clearance shall be obtained from the FAA, and NPS, Grand Canyon, AZ. Furthermore, additional permits shall be secured for both collecting and access on the Indian reservation from the Navajo Tribe. All of the logistical scheduling shall be coordinated with Reclamation.

C.11 CONTRACTOR FURNISHED EQUIPMENT

The Contractor shall provide all of the necessary research and logistical equipment and supplies required to complete the research listed in Sections; C.5, C.6, C.7, C.8, and C.9. This shall include research equipment for; electrofishing (Generator, electrodes, voltage pulsator, etc.), radiotelemetry (receivers, transmitters, antennas, etc.), current meters, fathometers, netting (seines, hoop nets, etc.), and water quality. The logistical equipment and supplies shall include; (3) boats,outboard motors, fuel containers and fuel, sampling containers and preservatives, lights, radios, and repair kits.

The Contractor shall have at least one backup motor per motorized boat as stated in the CRMP requirements. The Contractor shall provide two rafts equipped with electroshocking equipment, and two additional boats for radio telemetry, in operational condition with additional replacement equipment. Responsibilities of the Contractor shall include the continual maintenance and repairs associated with the operation of the electrical system, telemetry system, and the equipment necessary for collecting larval and adult fish using the various netting techniques.

Also, the Contractor shall be responsible for the transport of equipment to Lee's Ferry and for pickup at Diamond Creek.

C.12 COORDINATION AND REPORTS

C.12.1 Data Collection Plan

The Contractor shall prepare a data collection, analysis and storage program (plan) prior to the implementation of any field efforts. The Contractor will provide Six copies of the Data Collection Plan to Reclamation for distribution to the ACT. This data collection plan will be reviewed by the ACT to ensure compatibility with the other components of the GCES program and the long-term data collection and data base development programs. Upon concurrence on the Data Collection Plan, the contractor will initiate the field data collection efforts. (Refer to Sections C.1, C.3, C.4, C.5, C.6, C.7, C.8, and C.9)

The Data Collection Plan Report is due two weeks after the award of the Contract.

C.12.2 Trip Report

The Contractor shall prepare a summary report for every research trip conducted, which shall be due 15 days from completion date. The trip report shall describe the effort, data collected, research schedule, research personnel, and problems encountered. Two copies of the trip report and data sheets shall be provided to Reclamation who will distribute the reports to the ACT. All attending research personnel (Contractor biologists, assistants, volunteers, and substitutes) shall be identified with justification and work description.

C.12.3 Annual Report

The Contractor shall prepare an annual report on or before January 15th of each calendar year that summarizes the research effort and the data collected in the Grand Canyon for that field season. The annual report shall include a data summary and an evaluation of gear type effectiveness. The annual summary report shall also include comparisons based on data collected from previous years. The design and utilization of radiotelemetry methods shall be evaluated in the January 1992 annual report.

The annual report shall contain the summary of the data collected to identify, if any, related effects of Glen Canyon Dam operations to the humpback chub population. The annual report shall include a summary of all data collected during the year. Information at the end of the second year of investigation will be used by the ACT and the GCES EIS team in helping assess the operational affects of Glen Canyon Dam on the humpback chub. The second year summary report shall included a summary of all sampling procedures, morphometric analysis, abundance, distribution, movement, habitat utilization, photographic record, and any other significant data collected. The report should identify any problems with logistical support, sampling design, procedures and/or methodologies. The annual report shall be prepared using software compatible with Reclamation's data base, Wordperfect 5.0 and dBaseIII, and the needs of the ACT.

The Contractor shall meet with Reclamation and the ACT and give a formal presentation of research results by January 31st of each year. The annual meeting shall allow for the review of the annual report and to determine if modifications, additional analysis, or refinement of the procedures are necessary.

Annual Report Scheduled Dates:

January 31, 1991. --------	I.	Annual Report
January 31, 1992. --------	II.	Annual Report
January 31, 1993. --------	III.	Annual Report
January 31, 1994. --------	IV.	Annual Report

C.12.4 Final Report

The Contractor shall be responsible for analyzing the data collected. The analysis shall address the specific contract objectives identified in section C.2. All necessary statistical analysis to address the objectives of the contract shall be documented and presented in the Final Report.

A complete photographic record including original photographs of all humpback chub and habitats sampled shall be provided to Reclamation by the Contractor. Reclamation will distribute the Final Report to the ACT for review and comment.

Ten copies of a draft Final Report shall be prepared by April 31, 1994. Reclamation and the ACT shall review the draft final report and meet with the Contractor 45 days after submittal of the draft. The Contractor shall have 90 days after review to complete the final report and provide Reclamation with 150 copies. Also, the Contractor shall provide all of the original data collected, statistical analysis and the documents prepared in a format approved by Reclamation (IBM compatible).

NORTHERN ARIZONA UNIVERSITY

OFFICE OF ACADEMIC AFFAIRS

GLEN CANYON ENVIRONMENTAL STUDIES OFFICE

JUL 13 1990

RECEIVED
FLAGSTAFF, AZ

July 12, 1990

Dr. David L. Wegner
Glen Canyon Environmental Studies
P.O. Box 1811
Flagstaff, Arizona 86002

Dear Dr. Wegner:

I am enclosing for your consideration a proposal written by Dr. Linn Montgomery titled "A Synthesis of Information on the Humpback Chub in the Colorado River Basin."

Please let me know if I can answer any questions you may have relevant to this proposal during Dr. Montgomery's trip to Israel. Dr. Montgomery shall return to Flagstaff in early August.

Thank you once again for your consideration of this project.

Sincerely yours,

CLConover

Carey L. Conover
Grants Administrator

CLC:jc

A SYNTHESIS OF INFORMATION ON THE HUMPBACK CHUB IN THE COLORADO RIVER BASIN

A Proposal To

Glen Canyon Environmental Studies
Bureau of Reclamation

From

W. Linn Montgomery
Associate Professor of Biology
Department of Bilogical Sciences
Northern Arizona University
Flagstaff, Arizona 86011-5640

Telephone
602-523-7505
602-523-2381

W. Linn Montgomery

W. Linn Montgomery
Associate Professor

Henry D. Hooper

Henry D. Hooper
Associate Vice President
Research and Graduate Studies

1 July 1990

INTRODUCTION:

The humpback chub *Gila cypha* is a unique minnow (Family Cyprinidae) described from Bright Angel Creek in Grand Canyon National Park (Miller 1946). It is endemic to the Colorado River basin, being found in the Colorado, Green, Yampa, White and Little Colorado Rivers (Smith, 1970, Vanicek et al., 1970, Holden and Stalnaker, 1970, 1975, Minckley 1973, Sigler and Miller 1963). Federally listed as endangered in 1967 (Anon. 1967) it has been the subject of investigations throughout its range (Archer et al., 1985, Kaeding and Zimmerman 1983, Maddux, et al., 1987, Minckley et al. 1981, Tyus et al., 1982 and others). It is also the subject of ongoing investigations in the lower Colorado River basin, where the impact of Glen Canyon dam on this species is being evaluated.

In view of the amount of research expended on this species, one would think that much of its basic biology would be well known, and the pertinent information necessary for the management of this fish would be readily available. However, this is not the case. There are various reasons for this deficiency: proper questions haven't been asked, data haven't been throughly analyzed, and results and conclusions of previous studies haven't been published in the open literature where they can be critically evaluated by the scientific community. Instead, most of the information is in the form of unpublished reports and other such "grey literature".

This proposal is designed to solve the latter problem by coalescing and evaluating all available sources of data for the humpback chub. This report will, in particular, focus upon the Little Colorado River population of humpback chub. The following objectives are proposed for this study to aid in the management of this endangered species.

OBJECTIVES:

1. To complete a through literature survey on the humpback chub in the Colorado River Basin (i.e. the states of Arizona, Colorado, New Mexico, Utah, and Wyoming).

2. To summarize available data collected on the lower basin population of this species and to analyze and evalute population dynamics, movement, reproduction, and other pertinent information. These tasks will also be performed with upper basin populations if possible.

PROCEDURES:

The literature search will be conducted by examining available publications as well as by contacting present and past investigators to make available "grey literature". It is anticipated that this will require travel to various locations (see budget justifications) to gain access to literature and data in obscure files and/or in documents present in agency files.

These data will be summarized using various statistical packages with the goal being to synthesize or all available information on this fish in the Colorado River Basin. The proposed product is not meant to be solely a summary document, but one which will be utilitarian in nature, to be used to as a blueprint for management of his species and as an aid in pointing out future research needs.

The attached outline presents some of the areas in which information is currently available. It also suggests ways in which the data may be analysed. We realize that other types of information are probably available and when encountered they will be included. Conversely, some of the material listed in the attached outline will not be available or pertinent.

SUGGESTED OUTLINE FOR THE SYNTHESIS OF INFORMATION ON HUMPBACK CHUB IN THE COLORADO RIVER BASIN.

A) Description of area
- Geological
- Hydrological
- Climate

B) Summary of distributional patterns
- Within basins
- Within tributaries
- Within habitat
  - Habitat charactized by
  - Physical parameters (i.e. depth, width, velocity, temperature)
  - Seasonally
  - By size categories
  - By sex or mature vs immature
- Seasonally
- Hydrological relationships

C) Population dynamics
- Size categories
- Sex
- Mature vs immature or reproductive vs nonreproductive
- Population estimates
  - Size categories
  - Seasonally
  - By reach
  - Length-weight relationships
    - Weekly, seasonally, yearly
  - Condition
    - Weekly, seasonally, overall

D) Age and growth
  - By length frequencies
  - Observed growth during first year
  - Available data

E) Mark-recapture data
- Type of tags

Passive
Radio tags
Number of fish tagged
Number of recaptures
By sex, size
Movement
Daily
Over an extended period i.e. week, month, year etc.
Factors affecting movement
Season, hydrology, size, location

F) Reproductive observations
Examination of larger existing collections for:
Sex
Breeding coloration
Tuberculation
Percent of ripe, immmature, spent individuals
in relation to time of year, physical parameters
Concentrations in suspected areas of reproduction
Suggested reasons for concentrations in such areas.
Physical habitat
Physical factors (temperature, light, runoff)
Hydrological data

G) Food Habits
Size categories
Seasonality
Time of day

H) Introduced fishes impact on HBC
Predation
Parasites
Behavior

I) Parasites
Ectoparasites
Endoparasite
Impacts on various life stages
Seasonality

COMMENTS ON PROCEDURES.

The literature review will be completed by 1 September 1990, and will presented as part of an interim report on that date. A list of tables and figures developed at that time will either be presented or listed in appendices. By 1 January a completed draft of the report will be provided to the GCES and other interested parties. By 1 May 1990 the report will be finalized submitted for approval.

BUDGET:

PERSONNEL:	1990-1991
Principal Investigator	0.00$
Grad. Res. Asst. (1000.00/Mo @ 11 Mo)	11,000.00$
SUPPLIES:	
Computer literature search, computer time and supplies, xeroxing, and interlibrary loans.	1,500.00$
TRAVEL:	
University, rental, or personnel vehicle 4000 miles @ 30c/mile	1,200.00$
Airfare	
Salt Lake City, Utah	339.00$
Denver, Colorado	335.00$
PER DIEM:	
Food: 25$/day X 40 days X 1 person	1000.00$
Lodging: 40$/day X 1 person X 40 days	1600.00$
TOTAL DIRECT COSTS:	17974.00$
INDIRECT COSTS (20% TOTAL)	3594.80$
TOTAL REQUEST:	21568.80$

JUSTIFICATION:

PERSONNEL:

The PI (Montgomery) will contribute at least one month of time to this project at no cost to GCES.

Support is requested for a single, research assistant, C.O. Minckley. Mr. Minckley will devote all of his time to this project.

SUPPLIES:

Computer literature searches will facilitate acquistion of references. Xerox and interlibrary loan assistance is requested because the nature of this project will require the extensive duplicaion of data and documents. Also, NAU's journal holding in aquatic biology are limited, thus necessitating loan requests from nearby universities.

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CONSERVATION MEASURE 6

ESTABLISH A LONG-TERM MONITORING PROGRAM
TO ASSESS THE RELATIONSHIP OF PROJECT
OPERATIONS TO THE HUMPBACK CHUB

Program Responsibility - Robert Williams and David L. Wegner
Estimated Time for Completion - 1993, then on-going action
Estimated Cost for Completion - Fiscal year 1991: $100,000
Funding Source - CRSP/GCES

ESTABLISH A LONG-TERM MONITORING PROGRAM
TO ASSESS THE RELATIONSHIP OF PROJECT
OPERATIONS TO THE HUMPBACK CHUB

A. Lead Role and Participants. As the lead agency responsible for insuring compliance with Endangered Species Act and providing necessary funding, Reclamation will serve as the lead in initiating research, monitoring, and recovery actions. Once work plans are developed and agreed to through involved resource agencies, Reclamation will contract necessary technical expertise to do the work, analyze the data, and prepare the appropriate reports. Involved resource agencies would continue to participate in the procurement process, review work and analysis, and critique study progress and final reports.

B. Purpose and Background. Because the operation of Glen Canyon Dam has changed the aquatic environment within the Grand Canyon and because biological responses to operational affects are difficult to identify or evaluate in the short-term, a long-term monitoring program to track population responses to operational changes is necessary to insure continued protection and recovery of the humpback chub population within the Grand Canyon.

Research conducted to date has not provided sufficient information to identify the critical habitat type or chub life stage most limiting to population growth/maintenance. Phase II of the GCES research efforts will address operational affects of the project on various life stages of project on the humpback chub and their habitats. Once the relationship of operation and potential affects on the humpback chub are better understood, then a long-term monitoring of selected biological parameters or activities can be developed.

C. Objectives and Goals. The goal of this conservation measure is to develop a long-term monitoring plan for the humpback chub in the Grand Canyon. To accomplish this goal, the following objectives have been established:

1. Annually to monitor spawning adult populations and recruitment of humpback chub in the Little Colorado River.
2. Develop a monitoring program for selected mainstem habitat conditions and fish populations based on research findings associated with the other conservation measures.

3. Develop a monitoring program for the second spawning population to determine the level of success of that effort.

D. Tasks, Study Methods, and Approach. Those on-going activities such as monitoring Little Colorado River adult fishes should be

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continued throughout the course of intensive research activities to provide long-term tag return information. These data could be incorporated into a standardized monitoring of conditions for the Little Colorado River, the mainstem Colorado River, and the new tributary population. However, no new monitoring efforts should be initiated until after the conclusion of GCES Phase II research.

During the humpback chub research efforts, a computerized data base for the storage, analysis, and use of the humpback chub data will be established. A statistically based data review program will be developed to ensure quality control on the information.

E. Timing of the Proposed Work. The initiation and the development of a monitoring plan should begin in fiscal year 1991. The monitoring plan framework should be developed with specific objectives articulated. The draft monitoring plan will be reviewed during fiscal year 1992 with implementation scheduled for fiscal year 1993.

F. Estimated Cost. Because of uncertainty in the final detail and scope of a monitoring program, only base funding has been estimated.

Fiscal Year 1993	- $50,000
Fiscal Year 1994	- $50,000
Out years	- Unknown

A monitoring program will be developed which will identify length and frequency of sampling (annual, biannual, every fives years, etc.), biological parameters to be measured, and establish criteria which will highlight significant changes in chub habitat or population status.

G. Products Expected. A draft monitoring plan will be completed during fiscal year 1992 with the final plan ready for implementation during fiscal year 1993.

CONSERVATION MEASURE 7

ESTABLISH A SECOND
SPAWNING POPULATION OF HUMPBACK CHUB
IN THE GRAND CANYON

Program Responsibility - Robert Williams and David L. Wegner
Estimated Time for Completion - Fiscal year 1992
Estimated Cost for Completion - $105,000
Funding Source - CRSP/GCES

ESTABLISH A SECOND SPAWNING POPULATION OF HUMPBACK CHUB IN THE GRAND CANYON

A. Lead Role and Participants. As the lead agency responsible for insuring compliance with the Endangered Species Act and providing the necessary funding, Reclamation will serve as the lead in initiating research, monitoring and recovery actions. Once work plans are developed and agreed to through involved resource agencies, Reclamation will contract necessary technical expertise to do the work, analyze the data and prepare the appropriate reports. Involved resource agencies would continue to participate in the procurement process, review of work and analysis, and critique of the study progress and final reports.

B. Purpose and Background. The development of a second spawning population of humpback chub would provide protection and overall enhancement of the species within the Grand Canyon. Historically, the Grand Canyon offered unique habitat for the humpback chub. Modification of the mainstream Colorado h;as reduced its range in the river as well as limited the species to tributaries such as the Little Colorado River, Bright Angel Creek, Shinumo Creek, Kanab Creek and Havasu Creek. Research conducted to date has not focused on sampling these tributaries for possible use by humpback chub other than at their confluence with the mainstem Colorado River.

Quality baseline information regarding the use of these tributaries by native species, habitat availability, and water quality and quantity characteristics are essential before attempts are undertaken to establish a second spawning population.

C. Objectives and Goals.

1. Determine any additional use of tributaries by humpback chub.

2. Determine if other tributaries within the Grand Canyon can provide suitable habitat for the humpback chub. The information necessary for determining suitability can probably be extrapolated from research conducted on the Little Colorado River and the mainstem.

3. Establish a program for augmentation or introduction of humpback chub if items 1 and 2 yield positive findings.

D. Tasks, Study Methods, and Approach.

The approach of completing this conservation measure will be based on an approach of evaluation, analysis and development of a feasibility report. The following aspects are the key components of the approach:

1. Survey, through the course of the first year of investigation, all tributaries within the Grand Canyon where humpback chub have been collected in confluence areas.

2. Collect habitat availability information seasonally to determine or track how tributary habitat changes.

3. Resurvey the tributaries during times when habitats would provide optimum spawning opportunities.

4. Develop an augmentation program or introduction and monitoring plan for any tributary where habitats are determined to be suitable for establishing a second spawning population of humpback chub.

The following tasks will be completed:

Task 1. Survey the tributaries using seines and backpack shockers. The surveys should be conducted seasonally and extend as far up the tributary as possible or where natural obstructions would preclude fish from migrating upstream.

Task 2. During the fish collection, document associated habitat availability information. This could be accomplished with the u;se of video imagery ;and ground truthing. Also, critical physical and chemical characteristics of the tributary should be collected and quantified. Stream discharge should be determined for each sampling period.

Task 3. After the first intensive collection of fish, habitat conditions would be evaluated. The tributary would then be resurveyed during the spawning season when the presence of spawning fish or evidence of spawning fish would be greatest. Also, depending on the tributary and habitats to be sampled, i.e., pool, riffle, etc., the appropriate gear type should be used.

Task 4. If a second spawning population of humpback chubs is not found in the tributary, but habitat conditions look suitable for introduction, a two year introduction and monitoring program would be implemented. The introduction of humpback chub should follow hatchery protocol established as part of Conservation Measure 2.

If a small second spawning population of humpback chub is found, then fish from the second population should be compared with the Little Colorado population for taxonomic uniqueness before an augmentation program is initiated.

E. Timing of the Proposed Work. The initial survey of the tributaries should begin in the fall or winter of Fiscal Year 1990 and run for an entire season. If it is determined that the initial survey year is not reasonably close to normal flow conditions, a second year of baseline survey may be warranted.

The second year of data collection would be limited to those times and seasons when fish would be spawning or when evidence of spawning could be collected i.e., larval or post larval fish.

From the information collected in the two or three year effort (depending on flow conditions), an evaluation of the tributaries and a proposal for either introduction or augmentation should be prepared. Depending on the course of action a monitoring program would be developed to follow the success or the effort. The monitoring effort could be developed as part of Conservation Measure 3.

If, after reasonable efforts to reintroduce the species is made, the humpback chub fails to establish itself, this conservation measure would be discontinued and a final report developed.

F. Estimated Costs.

Fiscal Year 1990 -	Baseline Survey and Collection of Habitat information	$60,000.00
Fiscal Year 1991 -	Follow up data collection, evaluation and recommendations for Tributary action	$45,000.00
Fiscal Year 1992 -	Monitoring program (costs will be included in long term program)	

G. Products Expected. A first year report will be prepared by the responsible party that will recommend future actions for Year Two. If additional baseline information is needed than a second year report will be prepared. If the second year baseline effort is not needed, then the investigator will proceed in evaluating the first year information, do selected seasonal sampling and prepare a recommendation report for either augmenting the existing spawning population or introducing fish into a selected tributary for development of a second population.

STUDY PROPOSAL -- CONDUCT AN ENDANGERED SPECIES WORKSHOP ON THE IMPACTS OF OPERATION OF GLEN CANYON DAM

Prepared by: David L. Wegner, Glen Canyon Environmental Studies Program Manager, Glen Canyon Environmental Studies, Flagstaff, AZ

I. INTRODUCTION

A concern exists among resource managers regarding the impact of the operations of Glen Canyon Dam on the endangered species that inhabit the Colorado River and the Grand Canyon. This concern has led directly to the development of a Jeopardy Biological Opinion in 1978 and recent development of conservation measures by the Glen Canyon Dam Consultation Team.

There are three areas of concern dealing with the endangered species in the Grand Canyon:

1. What are the short-term impacts of operations on the threatened and endangered species?

2. What are the long-term impacts of the operations on the threatened and endangered species?

3. What are the evaluation needs that must be met to satisfy the Glen Canyon Dam - Environmental Impact Statement alternative Review?

II. BACKGROUND

The evaluation of the information available on the endangered and threatened species in the Grand Canyon is limited. The Biological Opinion that was developed in 1978 recognized that lack of data and recommended additional data collection efforts. The Glen Canyon Environmental Studies (GCES) Phase I efforts attempted to address some of those concerns but was limited in its efforts due to the lack of fluctuating and low flows and because of the limited occurrences of the subject species.

The Upper Colorado River Basin has been collecting information on the endangered and threatened species for many years and has used periodic meetings and workshops to interpret and utilize their data. In addition, significant expertise in Southwest fishes exists in the area and could be used to augment our limited data and knowledge and help to focus the GCES research efforts.

III. OBJECTIVES

The objectives of the Endangered Species Workshop are as follows:

A. Conduct a review of the existing written and unwritten information on the endangered and threatened species in the Grand Canyon.

B. Discuss and review the impacts of Glen Canyon Dam operations on the threatened and endangered species.

C. Discuss the importance of this Grand Canyon populations to the remainder of the Colorado River system.

IV. METHODS

The methods that will be followed to effect a better information base will include:

A. Scheduling of a Threatened and Endangered Species Workshop. Establish a planning committee who will develop the list of issues to be covered.

B. Acquire the services of Experts in southwest fishes and other species and provide them with a list of issues to be addressed at the workshop.

C. Acquire the use of a facilitator to focus the discussions and address all of the issues.

D. Develop a record of the proceedings.

V. TIMETABLE

It would be most effective if this workshop occurred during the Winter of 1990/1991.

VI. DELIVERABLES

The deliverable for this effort would be in two forms:

A. Verbal dialogue with the scientists and researchers

B. Written summary of the workshop proceedings

V. BUDGET

A total budget of **$ 30,000** has been established for this workshop. This will include the costs associated with travel, time for the experts, facilitator and cost of producing and distributing the resulting document.

FINAL

THE EFFECT OF FLUCTUATING FLOWS FROM GLEN CANYON DAM ON BALD EAGLES AND RAINBOW TROUT AT NANKOWEAP CREEK IN GRAND CANYON NATIONAL PARK, ARIZONA

by

Bryan T. Brown and William C. Leibfried

A Study Plan for FY91

Proposed to

The Bureau of Reclamation

and the National Park Service

as part of the Glen Canyon Environmental Studies

30 June 1990

ABSTRACT -- This proposed study plan represents the second year of a 2-year study of the effects of fluctuating flows from Glen Canyon Dam on wintering and migrating bald eagles and spawning rainbow trout at and near the confluence of Nankoweap Creek with the Colorado River. A spectacular winter spawning run of rainbow trout has developed in Nankoweap Creek due to the operation of Glen Canyon Dam. This trout spawn provides the prey base supporting the largest concentration of wintering and migrating bald eagles in the Southwest. For 10 days in late February and March 1990 over 1000 trout were counted in Nankoweap Creek. The spawn peaked at 1500 individual trout. Up to 26 eagles were present on the peak day of the concentration in February 1990, and approximately 70 to 100 individual eagles moved through the study area during February and March 1990. Preliminary results from the 1990 field work indicate that trout stranded in isolated pools or on the rivershore by fluctuating flows provide approximately 10% of the eagles' total caloric intake; most of the 1990 data has yet to be analyzed.

The null hypothesis of this study is that fluctuating flows from Glen Canyon have no influence over either 1) bald eagle caloric intake or activity, behavior, and foraging patterns, or 2) rainbow trout abundance, distribution, and movements. An existing energetics simulation model developed for managing wintering bald eagles will be modified to determine if fluctuating flows from the dam have a <u>caloric</u> influence on the eagles via their prey base.

Experimental flows from the dam will be required during February and early March of 1991 to test several of these hypotheses.

INTRODUCTION

1. Problem Statement

This study was initiated due to concerns about the endangered bald eagles wintering in or migrating through the Colorado River corridor and congregating at or near the mouth of Nankoweap Creek. Fluctuating flows from Glen Canyon Dam are cause for the concern, in that they could influence the eagles in two ways. First, fluctuating flows could influence bald eagles directly by causing changes in their habitat that would be reflected in their activity, behavior, or foraging patterns. Second, and probably most important, fluctuating flows could indirectly influence the eagles by altering their prey base of spawning rainbow trout in Nankoweap Creek and at its confluence with the river.

The null hypothesis of this study is that fluctuating flows from Glen Canyon have no influence over either 1) bald eagle caloric intake or activity, behavior, and foraging patterns, or 2) rainbow trout abundance, distribution, and movements.

2. Objectives (tasks)

Regarding Eagles:

1. Determine abundance and length of residency of bald eagles during the peak of the eagle concentration in February and March at Nankoweap and at two control areas (Marble Canyon and Lake Powell) throughout the winter.

2. Document eagle daily activity patterns as defined by five energetically-based activities (perching, flapping flight, soaring flight, feeding, and waiting to feed).

3. Document eagle daily foraging patterns and ecology; determine if geographic foraging patterns are influenced by fluctuating flows. (Numbers 1 - 3 will require as many days free of human disturbance as possible during the peak of the eagle concentration.)

4. Determine mean daily caloric consumption and expenditure by eagles.

5. Develop bioenergetic model to calculate the caloric influence of fluctuating flows.

6. Use bioenergetic model to calculate carrying capacity of Nankoweap for winter/migrant eagles.

7. Document the influence of human activity to the eagles; calculate the caloric cost of disturbance (this will be the subject of a separate, but related, report).

Regarding Trout:

1. Determine trout abundance and the phenology of the trout spawn in Nankoweap Creek.

2. Determine if discharge from the dam can restrict or influence movement of spawning trout into the creek. Determine the minimum flow necessary to allow trout to move into the creek.

3. Determine the residence time of trout in the creek.

4. Estimate the total number of trout present in the spawning population each year.

BACKGROUND

Related Findings From the Literature

Although it is widely recognized that the construction and operation of dams and reservoirs has had a great influence on wintering and migrant bald eagles (Southern 1963, Spencer 1976, Steenhof 1978, Stalmaster 1987), virtually no quantitative information exists on these influences or on the specific effects of dam-induced fluctuating flows. In contrast to reservoir-induced destruction of riverine habitat upon which many wintering bald eagles have traditionally relied, dams and reservoirs may harbor, in some instances, new or alternative food sources. Eagles may congregate below some dams in winter to feed on fish that are killed or stunned while passing through the turbines, or to hunt in ice-free water immediately below other dams. Literature references to these occurrences are anecdotal in nature.

The literature thoroughly documents the quantitative effects of human disturbance on wintering bald eagles, both by human activities on land and by recreational boating activities (Stalmaster and Newman 1978, Knight and Knight 1984). Human disturbance adversely affects eagle behavior and distribution by displacing the eagles to areas of lower human activity. Displacement occurs when humans approach to within a mean distance of 500 m of wintering eagles. These findings concern only eagles making use of dispersed food resources and do not address the effects of human disturbance to eagles making use of a concentrated, point-source food base. The effects of human disturbance, then, may be more pronounced on the eagles making use of the trout spawn at Nankoweap Creek.

2. Previous and Related Work

Preliminary studies to determine the abundance, cause, and phenology of the eagle concentration at Nankoweap were conducted in January and February of 1988 and January of 1989 (Brown et al. 1989a). The conclusion of these preliminary studies was that wintering bald eagles had increased in numbers along the Colorado River in Marble Canyon due to a combination of regulated discharge from Glen Canyon Dam and the introduction of rainbow trout. The mouth of Nankoweap Creek had become, by 1988, a concentration point for eagle foraging activity due to the ease with which spawning trout could be obtained there. At least 18 wintering or migrant bald eagles were present at Nankoweap in February 1988 as a result of year-by-year increases in numbers beginning in the early to mid-1980s (Brown et al. 1989b).

The development of the concentration of wintering and migrant bald eagles at Nankoweap is analogous to the development of a concentration of eagles at McDonald Creek in Glacier National Park, Montana (McClelland 1973). There, the introduction of exotic kokanee salmon and their spectacular spawning runs eventually attracted hundreds of migrant bald eagles which formerly had been uncommon (McClelland et al. 1982). This became the largest concentration of bald eagles in the United States outside of Alaska.

A two-year study of the eagle concentration developing at Nankoweap was proposed to the Glen Canyon Environmental Studies in December 1989. The first season's field work, designed as a pilot study to gather enough baseline data to allow for a systematic study of the effects of fluctuating flows the following season, began in February 1990 and lasted through March 1990.

Preliminary findings from 1990 indicated that 26 bald eagles were present on the peak day (February 26) of the eagle concentration. Approximately 70 to 100 individual eagles were documented during the eagle concentration (that time when at least 10 eagles were present each day) from February 8 to March 8. A total of 890 foraging events were documented, and time-activity budgets were completed for over 300 eagle-days. Fluctuating flows were found to have an as-yet-to-be-quantified influence on the eagles: 5.4% of the trout captured by eagles were taken from isolated pools along the river near the creek mouth, pools left by fluctuating flows. An additional percentage (approximately 5%) of the trout consumed by eagles were carrion trout along the rivershore, apparently also stranded by fluctuating flows. Stranding of trout by fluctuating flows, then, contributed approximately 10% of their total caloric intake.

Preliminary analysis of the data also indicates that the creek mouth and the lowermost 30 m of the creek constitute the foraging area used most frequently by the eagles at low and moderate flows. However, this area is inundated by flows in excess of ca. 15-20,000 cfs, forcing the eagles to forage much farther upstream in the creek. This shift in foraging areas may be a benign influence of the dam, but requires further investigation. Most of the 1990 data, however, including a preliminary run of an energetics simulation model, has not been analyzed and will not be available until September 1990.

Past studies on rainbow trout in Grand Canyon have primarily concentrated on fish movements, abundance, feeding, and stranding due to fluctuating releases from Glen Canyon Dam (Carothers and Minckley 1981, Persons et al. 1985, Maddux et al. 1987, Leibfried 1988). The impacts of flow releases on the ability of trout, especially spawning individuals, to enter tributaries and spawn has not been documented.

During recent years, spawning runs of rainbow trout in excess of 500 fish have been documented in Nankoweap Creek (Maddux et al. 1987, Leibfried personal observations). These winter spawning runs occur between November and March and may have several peaks of various intensities. The 1990 spawning run at Nankoweap Creek peaked at 1500 fish in early March. Over 1000 individual trout remained in the creek for 10 days.

Dombeck et al. 1984 stressed the importance of managing fish for the benefit of piscivorous birds as well as anglers. Optimizing the spawning runs in Grand Canyon tributaries through regulating discharges from Glen Canyon Dam will accomplish both objectives.

In summary, the bald eagle concentration at Nankoweap is the largest such concentration in the southwestern United States, and eagle numbers there can be expected to increase in the future <u>provided the trout spawn remains stable</u>. The 70 to 100 individual eagles recorded during the 1990 concentration represent approximately one-fifth to one-fourth of the entire population of bald eagles wintering to the south of the Grand Canyon (in Arizona and Mexico). By making use of Nankoweap primarily as stopover feeding and resting habitat during migration, eagles are probably able to put on a substantial amount of fat that would benefit their long-term survivorship.

Human disturbance at the Nankoweap study area was extreme after approximately February 27, 1990, resulting in a loss (for scientific research purposes) of over half the 45 total research days. When boats, hikers, or fishermen approached with approximately 500 m of the mouth of the creek, the eagles would leave the area. When humans left the area, some of the eagles would return after a period of time from a half hour to several hours. Nevertheless, these frequent disturbances were enough to render the entire day useless from the point of view of trying to study the influence of fluctuating flows because mean caloric consumption as influenced by the dam could not be calculated. For this reason, the Park has been requested to restrict, and if possible, eliminate the overwhelming influence of human disturbance in late February and early March, 1991.

Trout abundance in the creek increased steadily with passing time during the study period. One trout was present in the creek on February 6, and a peak of approximately 1,500 trout were present in the lowermost 600 m of the creek by early March. Trout abundance declined sharply thereafter, but several hundred trout were still present in the creek even after eagle numbers had decreased to two or three individuals.

The timing of the trout spawn may be related to increasing water temperatures through April, when water temperatures become too high to support continued spawning behavior.

METHODS

1. Sampling Design

Regarding Eagles:

Eagle abundance, chronology, and length of stay will be determined by dawn-to-dusk direct observations using spotting scopes from an observation post 700 m from the creek mouth. Length of stay will be determined by counting the number of days that uniquely-plumaged individuals are present, as it would not be feasible or prudent to band, capture, or mark eagles. Calculation of the mean length of stay by eagles at Nankoweap will allow an estimation of the number of different individuals that pass through the study area during the study period.

A control over eagle abundance and chronology will be provided by aerial censuses of eagle abundance in two adjacent areas: 1) a helicopter survey of Marble Canyon from Glen Canyon Dam to the Little Colorado River, and 2) a fixed-wing survey of an established eagle census route over Glen Canyon National Recreation Area (Kline 1990). The surveys of both control areas will take place on the same day, three times each month from November through March. If the phenology of eagle movements into and through the Lake Powell control area is different than that observed at Nankoweap, then Nankoweap's concentrated resources may be acting as an ecological magnet to hold migrating eagles for a longer amount of time than normally-dispersed resource areas. The number of eagles at Nankoweap cannot be studied in a vacuum, but must be examined in the context of the entire regional population and its movements: if the bulk of the eagle population of Marble Canyon is located at Nankoweap during the trout spawn, then Nankoweap is a greater benefit to migrating eagles as stopover feeding and resting habitat.

Time and activity patterns will be quantified by following individual eagles within 1.5 mile of Nankoweap until they are lost from view (Craig et al. 1988), a method that provides the most reliable time budget estimates for birds observable for long periods (Bradley 1985). All activity seen from the observation post will be assumed to be a random sample of eagle activities occurring in the study area. Following Stalmaster and Gessaman (1984), the following activity (energetic) categories will be recorded: 1) perching, daytime sitting in trees or on the ground, 2) active (flapping) flight, 3) passive (soaring and gliding) flight, 4) feeding, and 5) waiting to feed, standing near other feeding birds. Determination of time and activity patters is necessary in the development of the energetics simulation model to be used in assessing the caloric effects of fluctuating flows from the dam. Foraging patterns and ecology will be documented by dawn-to-dusk observation of foraging activities in and near the creek. Location, date, time, success, and age of foraging eagle will be recorded, as well as other habitat and behavioral parameters. The number of live and carrion trout caught and consumed each day by the eagle population at Nankoweap will be documented. The research questions (hypotheses) that will be asked of the foraging data are necessary to understand the mechanics and ecology of eagle foraging behavior before any fluctuating flow analyses can be performed: do different age classes of eagles experience different foraging success rates or patterns? are eagles more successful at foraging in the river or in the creek? is this a differential success rate based on age? do geographic patterns of foraging change with changing river levels?

Once geographic foraging patterns are documented and correlated with flow patterns, we can statistically test the hypothesis that flow patterns affect foraging patterns: do higher flows prevent foraging at the creek mouth, apparently the favored foraging area, and shift the foraging arena upcreek? Is upcreek foraging success equivalent to, or less than, foraging success at the creek mouth? If so, does this effect of fluctuating flows have caloric consequences for the eagles? Is this caloric consequence of fluctuating flows influencing all age classes equally, or are younger eagles influenced more than adults?

An energetics simulation model developed in the Pacific Northwest for the purpose of managing wintering bald eagles can be directly applied to the situation at Nankoweap Creek below Glen Canyon Dam (Stalmaster 1981a, 1981b, 1983; Stalmaster and Gessaman 1984; Craig et al. 1988). The model is a prerequisite for examination of the caloric cost of fluctuating flows. This bioenergetics model takes into account both caloric intake (expressed as mean number of calories per eagle per day) and caloric expenditure (estimated based on weather and temperature costs, activity costs, and avoidance of human disturbance costs).

The caloric expenditure component of the model concerning the human disturbance costs can be easily modified to express the costs (positive or negative) of fluctuating flows. Positive costs of fluctuations might be the extra food provided to eagles via trout (alive or dead) trapped in isolated riverside pools by fluctuations; higher rates of fluctuation change might, for example, result in more stranded fish in riverside pools that would prove easy prey for the eagles. Negative costs could be those associated with being forced to forage in a less-favorable area when higher fluctuating flows inundate a preferred foraging area. In order to test this hypothesis, we will require strongly fluctuating experimental flows in February of 1991, flows that are the opposite of what the dam normally releases (low all day, high all night). These experimental flows will be required for a minimum of five days. Without these flows, we will not have the opportunity to examine this effect of fluctuations on eagle foraging. We will also require several ramping rates in late February 1991 in order to determine if ramping rates influence the number of trout stranded in isolated riverside pools.

To determine energetic costs associated with observed activities, we will use three models to compute 1) daily energy budget (total energy metabolized), 2) daily energy consumption (total food energy required), and 3) daily food requirements (total mass of prey required). Details of these models are in Stalmaster and Gessaman (1984). These models involve assessing the effects of longwave radiation, convection, conduction, evaporation, and rate of heat storage on metabolic heat production; the effect of air temperature and standard metabolic rate on existence metabolism, gross energy intake, and wet matter (prey) intake. The models require data on air temperature, wind speed, precipitation, and downward longwave radiation. The number of calories per gram of trout flesh can be obtained for Colorado River rainbow trout from several collections made at Lees Ferry and Nankoweap Creek and then processed in a bomb calorimeter.

In summary, the effects of fluctuating flows on the eagles will be assessed in several ways: 1) we will test the hypothesis that fluctuations do not result in a shift in eagle foraging areas; 2) if fluctuations do result in a shift in foraging areas, then we will test the hypothesis that these shifts have no caloric consequences for the eagles; 3) we will determine the total caloric contribution of trout stranded by fluctuating flows in riverside pools and examine the overall importance of this apparently positive influence to the eagles' daily caloric needs.

Quantitative observations on the effects of human activities on eagle behavior and abundance will be gathered, summarized, and analyzed as it relates to overall energy consumption by the eagle population. This information will be presented in a separate report.

Regarding Trout:

The number of fish in the creek will be counted at least every other day during various discharge regimes. Trout abundance will only be determined at night, to minimize daylight disturbance to the eagles.

Fish will be collected by either dip-netting or angling. All fish collected will be classified by reproductive condition. The proportion of spawning to non-spawning fish will indicate the height of spawning activity, as well as changes in spawning activity over the study period.

At the beginning of the 1991 study period, a subpopulation of trout from the river will be obtained by angling (two days of daylight activity/disturbance only). These trout will be marked with Floy tags, measured, and reproductive condition visually determined.

Trout movement into and out of the creek will be counted at the creek mouth several nights per week. Additional daytime counts will be conducted using spotting scopes at the observation point. The shallow depth of the mouth of Nankoweap Creek affords clear visibility to count incoming and outgoing trout. These movement data will be compared with flow levels to determine if flows influence movement into or out of the creek. Trout movement during low weekend flows will be compared with higher weekday flows. The different flow rates and ramping rates required by the eagle study will be sufficient for the trout movement studies.

The creek will be divided into three, 200-m reaches and a minimum of 50 fish in each reach will be marked with Floy tags. Each reach will have a different color tag code. This will take place at the beginning of the study period, as well as twice during the study period. These data will allow a determination of residence time within the creek; comparing marked populations with the unmarked fish in the creek will allow a rough determination of the total number of fish that move into the creek during the study period. A modified version of the Lincoln Index will be the technique used to determine this potential total population size. This trout population size will enable the calculation of the potential carrying capacity of the area for wintering and migrant eagles.

2. Response Curves

Response curves for eagle activity and caloric intake and for trout abundance, movement, and reproductive success will be calculated for several mean cfs levels, several flow ranges, and for several ramping rates.

3. Logistical Support Requirements

This study will require three motor rivertrips, one each in January, February, and March, to deliver the research team to the study site, resupply the team, and to take the team out at the end of the study. We will also require the use of the Bureau of Reclamation helicopter at Page, Arizona, for three surveys of Marble Canyon each month from November 1990 through March 1991. Although not technically logistics, we request that the Park restrict or prevent human activities at the Nankoweap study area during the peak of the eagle concentration from February 8 to March 8. A formal letter has been sent to the Park Superintendent to this effect. We will also require experimental releases from the dam that 1) call for five to seven days (not consecutive, but alternating with "normal" fluctuations) of low flows during the day and high flows at night, and 2) that express several ramping rates (each ramping rate, i.e. high, medium, and low rate of ramping) would need to be expresses at least twice during late February. The U. S. Geological Survey will need to provide us with hourly discharge data for both Nankoweap (estimated from flow modelling) and the Little Colorado River for the period of flow.

TASKS AND RESEARCH TIMETABLE

FY90

September 31, 1990	-	FY90 interim report completed

FY91

October 1, 1990	-	begin coordination of 1991 field work, hire field assistants
November 1990 to March 1991	-	begin helicopter surveys of Marble Canyon and Lake Powell
November 1990 to January 1991	-	periodic sampling of rainbow trout spawn at Nankoweap, in conjunction with ongoing fisheries research trips
January 24, 1991	-	launch from Lees Ferry on primary Nankoweap research effort
February 5	-	launch resupply trip to Nankoweap
March 14 (approx.)	-	launch pick-up trip to take out Nankoweap research team. All field work ends.
April through August	-	data summary, analysis, report preparation
August 31	-	draft of final project report completed; peer review
September 31	-	final project report completed

FY92

October 31	-	draft of human impact report completed; peer review
November 31	-	final human impact report completed

DELIVERABLES

Final Project Report: "The Influence of Fluctuating Flows From Glen Canyon Dam on bald eagles and rainbow trout at Nankoweap Creek, Grand Canyon, Arizona."

In addition, a separate Project Report: "The Influence of Human Disturbance on Wintering and Migrating bald eagles at Nankoweap Creek, Grand Canyon National Park, Arizona."

BUDGET

Requested For FY91 Only:

1. Personnel

Principal Investigator (B. Brown; 48 wks x $550/wk)	$ 26,400
Fisheries Biologist (W. Leibfried; 16 wks x $500/wk)	8,000
Research Assistant III (T. Yates, L. Daly, C. Hallet, M. Murov, H. Yard, P. Becker, R. Dye, B. Baldwin) 5 RAs x $ 350/wk x 40 wks total	14,000
Research Assistant I (data entry) 1 RA x $320/wk x 8 wks	2,560
(Salary Subtotal)	(50,960)

2. Field Supplies

Eagle research sampling supplies	750
Fisheries sampling supplies	700

3. Travel

15 round-trips from Flagstaff to Page (250 miles each x 0.30/mile x 15)	1,125
12 round-trips from Tucson to Flagstaff (500 miles each x 0.30/mile x 12)	1,800
GCES and NPS consultation, meetings (2,000 miles x 0.30/mile)	600

4. Analysis

Illustration Preparation	300
NAU Statistical/Computer Consultation	800
Report Preparation (xeroxing, binding, etc.)	300

5. Subcontracts

Office space for B. Brown in Tucson (FY91 only)	2,500

DIRECT COSTS TOTAL	59,835
NAU INDIRECT COSTS (20% of salary subtotal)	10,192
GRAND TOTAL	70,027

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RECREATION

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTEGRATED RESEARCH PROGRAM

RECREATION STUDIES

I. Issues

The <u>recreation</u> studies that are outlined for the Glen Canyon Environmental Studies (GCES) Phase II efforts build upon the work that was completed under the initial GCES efforts and additionally focus on the concern of beach availability and crowding.

The operations of Glen Canyon Dam impact the recreation resources in Glen and Grand Canyons in several ways. The most obvious is the level of flow. The level of flow dictates the number of beaches that are available for camping, the safety of the rapids, crowding, accessibility to fishing areas and the overall carrying capacity of the recreation ecosystem.

Additionally, the flows from Glen Canyon Dam impact the overall wilderness experience that the visitors may have and ultimately affect the natural resources that are used in the Canyon. Excessive crowding can lead to destruction of the habitat.

II. Objectives

The broad objectives of the GCES Recreation Studies are stated as follows:

A. Determination of the impact of the operations at Glen Canyon Dam on the availability of camping beaches in the Grand Canyon.

B. Determination of the recreational carrying capacity in the Lee's Ferry reach of the river.

C. Determination of the impact of the operation of Glen Canyon Dam on the recreational values of the Grand Canyon, focusing on crowding and safety.

D. Verification and integration of the recreation studies completed under GCES Phase I into the GCES Phase II program.

III. Components of the GCES Phase II Recreation Studies

The components of the GCES Phase II Recreation Studies can be separated into four areas and are depicted in Figure <u>9</u>.

A. Camping Beach Availability - evaluation of the number and quality of beaches exposed in the Colorado River corridor during specific Glen Canyon Dam releases.

B. Carrying Capacity in Lee's Ferry Area - evaluation of the carrying capacity that can be maintained in the Lee's Ferry tailwater area under varying flow regimes.

C. Crowding and Safety Studies - evaluation of the impact of various flow regimes on crowding and safety in the Grand Canyon.

D. GCES Phase I Recreation Studies - verification of the GCES Phase I studies under fluctuating flow regimes and integration of the results into the GCES Phase II program.

IV. Organization of the GCES Recreation Studies

The overall organization of the GCES Recreation Studies will be guided by the GCES Recreation Team and the GCES Scientific Core Team. The Recreation Team will be composed of representatives from the resource agencies and with contractors as required. Additional interaction will be with the GCES Economic Team.

The Recreation Team and the Scientific Core Team will be jointly responsible for the integration of the recreation studies into the overall GCES technical reports.

Representation on the Recreation Team will include but not be limited to, the following groups:

GCES - Senior Scientist (and/or designated Recreation Research Advisor)
GCES Office
Reclamation - Denver Office
National Park Service - Glen Canyon National Recreation Area
National Park Service - Grand Canyon National Park
U.S. Fish & Wildlife Service
HBRS
Contractors (as required)

Primary leadership for the Recreation Team will be with the GCES Office and the GCES Senior Scientist. The GCES Office will provide all of the coordination and logistical support.

VI. Products to be Developed

The GCES Recreation Team will be responsible for the completion of the following reports:

A. Individual Research Reports - as defined in the study plan.

B. Integrated GCES Recreation Report -synopsis of the recreation studies and identification of areas of conflict or concern.

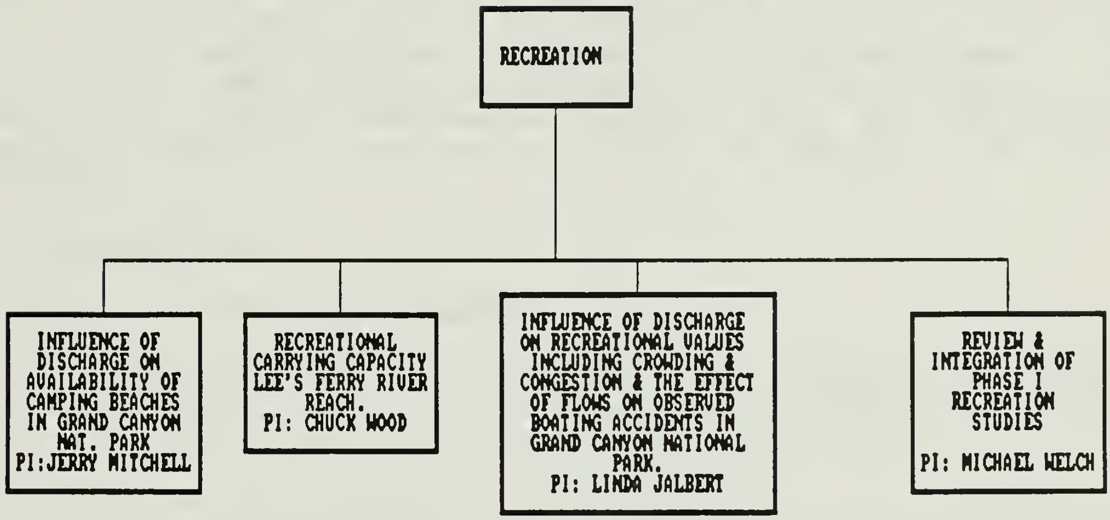

Figure 9. Glen Canyon Environmental Studies Phase II recreation Studies.

STUDY PROPOSAL--INFLUENCE OF DISCHARGE ON AVAILABILITY OF CAMPING BEACHES IN GRAND CANYON NATIONAL PARK

Jerry M. Mitchell, Resource Management Specialist, National Park Service

ABSTRACT--Proposal: study to assess camping beach availability and size along the Colorado River Corridor, as a function of discharge from Glen Canyon Dam. Much of this work can be done through repeat of past study methodologies: inventory (Brian and Thomas, 1984; Weeden, 1975); and aerial photography (or video)(Weeden, 1975). Influence on highly desireable beaches will be evaluated by segregating beaches into groups based on presence of favored attributes.

I. Introduction:

a. Specific Problem Statement

Alluvial terraces along the Colorado River through Grand Canyon form the "beaches" used by river runners for camping. Most camping beaches are sand deposits within recirculation zones.

Desirability and useability of camping beaches are influenced by several variables, including size of group accommodated; potential for inundation (from fluctuating flows from Glen Canyon Dam); accessibility; shade from heat and sun; distribution along the river, especially in critical reaches and around attraction sites; and, remoteness and isolation from other groups.

Of the 255 miles of river between Glen Canyon Dam and Lake Mead, camping is only possible in a relatively few locations along the river. Most of the shoreline is unsuitable for camping, even under extreme circumstances. An inventory of these camping beaches by Weeden et al (1975) listed about 400 campsites within the river corridor, but these were unevenly distributed in size and location. In 1984, Brian and Thomas resurveyed these beaches to assess the influence of high flows on individual beaches; these researchers had a greater understanding of the needs and desires of river runners and inventoried a greater set of camping beaches. At least 227 the these campsites were verified as inventoried in both surveys.

Physical carrying capacity of the river corridor is largely decided by campsite size and locations. Aerial extent influences the size of group that a beach has the capacity for accommodating. The location and distribution of beaches, by reach, set the absolute limits on visitor carrying capacity; i.e., the numbers of groups in a critical reach must be equal to or less than the number of campsites available in that reach.

There are four sections of the river where campsite availability is a critical limitation to the physical carrying capacity of the river corridor. These are: Marble Canyon, downstream of Lees

Ferry (between River Miles 9 and 34); the Inner Gorge section of river, above and below Phantom Ranch (between RM's 76 to 117); Muav Gorge above and below Havasu (between RM's 140 to 165); and Lower Granite Gorge (between RM's 226 to 270). Some of the beaches in the Canyon are camped at nearly every night during the summer months.

Variable flows from Glen Canyon Dam directly influence camping beaches and sediment processes. Dam operations not only influence beach condition but also beach availability and useability. The rise and fall of water levels, as a result of fluctuating discharge from Glen Canyon Dam, inundates portions of these beaches, strands boats and influences "wildness". Although it is obvious that certain beaches become inundated and unavailable for camping at certain flows, past work on quantifying the relationship between levels of discharge and the number of campsites or area available for camping has been limited to a subset of camping beaches; this work has also been conducted without the certainty of knowing all discharge levels from the dam. No comprehensive assessments are available for the entire length of the river, or by reach or desireable attribute.

In addition to some beach degradation, as a result of flood level releases from the dam in 1983, from Glen Canyon Dam, new beaches were created and others aggraded, mostly in downstream and wider reaches of the river. Thomas and Bryan (1984) hypothesized that the system was not in equilibrium with respect to camping beaches and that the number, size and distribution of these beaches in Grand Canyon would continue to change in the near future. This study will be directed at answering these inquiries, while assessing also the relationship between discharge and camp availability, in the absolute sense and by reach and attribute weighting.

b. Specific objectives (hypotheses):

Objectives of the study will be to assess the influence of discharge on: camping beach availability for the entire length (H0=Discharge has no influence on the availability (number) of camping beaches); beach availability by reach (H0=There is no difference in the influence of discharge on the availability of camping beaches in narrow and wide reaches); availability of highly desireable camping beaches (H0=The availability of a camping beach, as a function of discharge, is not related to attributes of the site); and, aerial extent (H0=The area of available camping beach is not related to discharge).

While conducting this work we will also revisit the campsites inventoried by Brian and Thomas to assess any change in the availability (H0=there has been no change in camping beach distribution since 1983) and size classes (H0=there has been no change in distribution of size classes) for camping beaches.

c. Relationship to Integrated Study Plan

The testing of hypotheses related to surface area can be accomplished using a subset of camping beaches. It may be possible to use the same subset as will be evaluated in the study of the influence of discharge regimes on sediment deposits, or to select beaches from each of the river segments to be mapped for GIS. At this writing, the proposal on GIS calls for mapping 50 miles of river corridor, in 8 segments; in each of these segments, it would be desireable to map camping (surface) area in up to 3 highly desireable beaches per reach, as a function of discharge.

Testing of hypotheses related to beach availability will require a complete resurvey of the river corridor using one of several previously used methods. One method was to use aerial photography to map beach area. If aerial photographs or videos are taken during each of the constant flow periods, it would be possible to assess availability and size class through photo interpretation, with an additional amount of limited ground truthing. It might still be desirable to inventory beach availability during the periods of 33,200 cfs flow, using on-river surveyors.

For the camping beach attribute analysis, it might be possible to use the same beaches used for the sediment study. However, these beaches are likely to be chosen on the basis of criteria unrelated to desirability attributes. Camping beach attributes analysis may relate more to the recreational values studies, in as much as that study might be used to validate attribute values.

Research Flows needed to conduct studies: It is proposed that work only be conducted during the 8,000, 11,000 and 15,000 cfs, constant flow periods and the two periods of fluctuating flows to 33,200 (an additional discharge having flows to 26,000 cfs would also be desireable, but reliability of results would be leslss than for other discharges):

- -During the high, fluctuating flow periods, on-river travel and camping beach inventories will only be undertaken during periods of high flows.
- -All other comparative data on beach availability and size can be obtained during constant flow periods.

II. Background

a. Literature--previous and related work:

Most camping beaches are sand deposits within recirculation zones. These zones are areas along the margins of the river channel where part of the flow moves upstream. In a channel such as the colorado River in Grand Canyon, where the banks are typically composed of bedrock or large rock debris, recirculation zones are found where debris flows create fans that form abrupt constrictions and downstream expansions of the channel. The pattern of sand storage within recirculation zones is distinctive; sand is located at the upstream end of the zone, on the downstream-facing surface of the debris fan which forms a rapid or riffle (separation deposits). Sand is also located near the downstream end of the recirculation zone (reattachment deposits).

According to Schmidt and Graf, the number and size of recirculation zones varies along the rive corridor. Between Lees Ferry and Bright Angel Creek (River Miles 0 to 87), the number of recirculation zones varies between 2.3 and 4.5 per mile. The average size of reattachment deposits exposed at a discharge of about 6,000 cfs in 1984 between Lees Ferry and the Little Colorado River (River Miles 0 and 61) and between River Miles 118 and 160 ranged from 2,300 to 87,000 square feet. Typically, larger reattachment deposits were associated with the larger recirculation zones of wide reaches. Only those sand deposits high enough in elevation to be safe from inundation and large enough to accommodate at least a small group of people are used as campsites. All types of sand deposits are used as campsites: separation, reattachment, and channel deposits.

Past work has been directed at providing absolute inventories of the numbers of camping beaches by size and location. The first inventory was conducted in 1975 by Weeden et al. In the fall of 1983, a repeat study by Brian and Thomas (1984), using similar methodology at a discharge of 28,000 cfs, found the number of campsites to range from 0.4 to 2.6 per mile. Although the variation in number of deposits along the river differs with deposit type, the number of campsites was typically greater in wide reaches than in narrow reaches. Therefore, wide reaches of the river are characterized by a greater number and larger size of sand deposits useable as campsites.

The characteristic topography of separation and reattachment deposits affects the size of deposits available for camping at different discharges. Large parts of many separation deposits are not inundated until discharge exceeds 30,000 cfs. Reattachment deposits, in contrast, are typically broad and low in elevation and are inundated at relatively low discharges. Because of possibility of inundation, separation deposits are more attractive as campsites. For example, at nine of the separation deposits studied by Schmidt and Graf, the average area of sand inundated during an increase in discharge from about 6,000 to about 25,000 cfs is 14,000 square feet. In contrast, at six reattachment deposits an average of about 50,000 square feet in inundated over the same discharge range. The area of separation deposits is about 30 percent of the total area of each separation deposit. Most reattachment deposits are inundated at discharges within the (Glen Canyon Dam) powerplant range, whereas parts of many separation deposits are still exposed at a discharge of 45,000 cfs.

Past Camping Beach Inventories

In past work, each beach was classified by size according to the area available to camping, cooking and group use. Capacity of a site was interpreted by the relative sandy or flat rock ledge area devoid of vegetation available to a river group without undue crowding or difficulty. Weeden classified beaches giving them values according to an estimate of people capacity; the capacity estimates used were 15, 20,25, 35, and 40. Brian and Thomas used the following classes: "Small", defined as a camp area large enough to accommodate a 15-20 person group; "medium", a 21-30 person group; and, "large", a 31-40+ person group.

Weeden et al (1975)
The inventory of camping beaches conducted by Weeden formed the basis of an assessment of carrying capacity for the River Corridor through Grand Canyon (Bordon, 1976). Combining on-river inventory and interpretation of aerial photography, these works provided the following: inventories of campsites by reach and qualitative assessments of size and group size capacity for each.

Brian and Thomas (1984)
These workers had considerable experience in rafting the river and were more selective of which locations were classified as camping beaches.
Brian and Thomas inventoried camping beaches that met the following criteria:

1. The area was above 25,000-28,000 cfs level, not overgrown by vegetation, and would accommodate 15 or more people;

2. The site had a pathway from mooring location to the camp area.

Obviously, because of their using the first criterion, Brian and Thomas purposefully biased their study to inventorying those sites available at relatively high discharge from the dam.

Location of camps was identified by milage downstream from Lees Ferry, as mapped by Belkap (1969) with an accuracy of 0.1 mile and by common or topographic name when possible. Side of the river, by either left or right bank in the direction of downriver travel, was noted for each site.

Brian and Thomas prepared a comparison between the 1983 post-high water campsite inventory and Weeden's 1973 work. Various factors influenced data analysis. Campsite selection criterion and field methods differed between the studies. Bias was introduced by investigator personal experience and judgement in applying qualitative estimates. Problems also arose in matching beaches as accurate mileage designations were difficult to identify in straight sections of the river where distinguishing topographical features are lacking. Given these restraints, an analysis was made between campsites recorded both in 1973 and 1983, campsites recorded only in 1973 (lost camps), and campsites recorded only in 1983 (new camps). Comparisons of these three categories by eight 30-miles reaches are:

1. 227 campsites were identified by both surveys. Size capacity changes after 10 years showed a 34% decrease in small campsites, an 80% increase in medium campsites, and a 10%

decrease in large campsites. There was an increase in small campsites in Lower Marble Canyon and Upper Granite Gorge; an overall increase in medium campsites for all reaches; and a substantial decrease in large campsites from Lees Ferry to Kanab Creek with an accompanying increase from Kanab Creek to Granite Park. The largest group was that of sites exhibiting no discernable size change (42%), while 30% increased in size and 28% decreased in size.

2. 24 campsites were either removed by 1983 high water flows or so depleted in size as to not qualify as a small campsite. A majority of these camps were removed in Upper Marble Canyon and Upper Granite Gorge. Four camps were removed where campsite selection is critical.

3. 32 campsites were lost prior to the 1983 high water flows due to a variety of causes.

4. 77 campsites with established use prior to 1983 were not listed by the 1973 survey.

5. 86 pre-existing campsites were increased in size by 1983 high water deposition or vegetation removal. These deposits were commonly located behind dense shoreline vegetation.

6. 50 new campsites were deposited by 1983 high water where no sand deposits existed previously. Four camps (11.5R, 12.0L,133.85R, and 153.5R) have been utilized by river-runners after the high water flows.

Of the 227 campsites inventoried in both works, the re-survey following the high flows of 1983 showed a 34% decrease in small campsites, an 80% increase in medium campsites and a 10% decrease in large campsites compared to 1973. When viewed by reach, there was an increase in small campsites in Reach 2 (Lower Marble Gorge) and Reach 4 (Upper Granite Gorge), an overall increase in medium campsites for all reaches, and a substantial decrease in large campsites from Reach 1 to Reach 5 (Lees Ferry to Kanab Creek) with an accompanying increase in Reaches 6 and 7 (Kanab Creek to Granite Park).

Table 1--The following is a distribution of sizes for the 227 matched campsites, viewed by reach and showing relative numbers of size changes, for years 1973 (Weeden, et al) and 1983 (Brian and Thomas):

Reach	Small Campsites (15-20 person)		Med. Campsites (21-30 person)		Large Campsites (31-40+ person)	
	1973	1983	1973	1983	1973	1983
1. RM 0 to 31.5	4	6	2	4	8	5

2. RM 31.6 to RM 61.2	6	13	12	15	18	5
3. RM 61.3 to RM 90.0	3	0	4	12	16	11
4. RM 90.1 to 121.0	9	13	4	7	10	4
5. RM 121.1 to 143.5	3	5	3	5	22	18
6. RM 143.6 to 179.4	12	4	7	10	12	17
7. RM 179.5 to 208.8	18	2	10	18	20	29
8. RM 208.9 to 225.7	8	1	0	7	9	10

Table 2--Stevens lists the following camping beaches and estimated capacities in the his river guide (1987, Third Edition)(many are listed as available only at low water):

Reach	Small Campsites (1-10 persons comfortably)	Med. Campsites (10-25)	Large Campsites (more than 25)
1.	13	3	5
2.	18	9	13
3.	14	9	6
4.	19	5	3
5.	12	11	3
6.	10	7	5
7.	8	5	7
8.	8	7	2
9. Diamond Creek to Separation Canyon	6	0	0

III. Methods

Re-inventory of Beaches

Design: This portion of the study will essentially be a repeat of Brian and Thomas' work in 1983. Aerial photographs or video, from the 5000 cfs flow period in October 1989, would be used to make a baseline assessment of the availability and area of beaches. (Ground truthing work could be done during the June 1-4, 5000 cfs constant flow period.) Relative size class of each beach would be assessed for the entire length of the river and evaluated by reach. This work will be compared to the results of Brian and Thomas; attempt will be made to match campsites (existence only). We would expect to find greater numbers of sites at this low water.

Sample sites/size: Inventory entire population of camping beaches.

<u>**Camping Beach Availability**</u>

Design: This question will be answered with comparative data on the availability of campsites under each of several discharges; these being constant flows of 8,000, 11,000 and 15,000 cfs, and one or both of the periods of 10,000-33,000 cfs fluctuating flow (it also might be possible to estimate the beach size at 33,200 cfs by using a hand level at the stage of undisturbed vegetation development). During these discharge periods, an inventory of camp-able beaches will be conducted using aerial video and/or ground inventory; information on the camp-ability and relative size class will be noted.

Sample sites/size: Inventory entire population of camping beaches. The number of available beaches will represent a parameter at that discharge, at that point in time.

<u>**Availability by Reach**</u>

Design: To determine whether the influence of discharge on campsite availability in the narrow, "critical site availability" areas is different than in the wide, "high site availability" areas, it will be necessary to look at the data by reach. It will not be so important to focus on the lesser number of sites within these narrow areas, as it is to assess the relative change in availability by reach, as a result of flow.

Sample sites/size: Inventory entire population of camping beaches within a reach, for all reaches. The number of available beaches in a given reach, at a given discharge, will represent a parameter of that reach, for that discharge and at that point in time.

<u>**Availability by Desirability Attribute**</u>

Design: A determination of relative frequency of use, for camping beaches, will be made using existing guides survey's (Division of Resource Management, Grand Canyon National Park). A sample of highly desireable sites will be determined using this frequency data. During the site re-inventory portion of the study, the presence of certain attributes will be noted for each site. Using these "use" frequencies and attribute data, all campsites will be clustered by their attributes and then an evaluation made as to whether some clusters are more or less influenced by discharge.

Sample sites/size: 3 of the most heavily used camping beaches in each of the 8 reaches (as defined by Brian and Thomas) of the river.

Influence on Size/Aerial Extent

Design: This question will be addressed in two ways:
a) Frequency distribution, by size class, for the entire population of beaches, for each discharge; data will be evaluated for the entire length of the river and by reach, and compared to baseline (5000 cfs).

b) Twenty-four camping beaches (3 in each of the 8 GIS segments) will be selected for detailed measurements and mapping. The camp-able area of each should be initially mapped at 5000 cfs; the shoreline edge of the camp could be reexamined by video for each of the constant discharge periods (8000, 11,000 and 15,000 cfs) and defined using a handlevel at the point of vegetation disturbance for the 33,200 fluctuating discharge. If use of video is not planned for each of the discharge periods, we would adopt one of the following: measurements from a set (buried) pin, radiating out along 16 bearings to the point of intercept with the edge of the camp-able area; or use of pins or wire, placed during 5000 cfs constant flow and extending up the beach face at measured distances from the low flow shoreline. The pins nearest the shoreline could be found using a magnetic locator.

For these 24 sites, the relative influence of each flow on camping beach size will be assessed. At each study site a base size will be determined at 5,000 cfs. The difference in size at each site, as a result of each discharge, will be scaled using percentage decrease in size at each beach. Variance within and between treatments (discharges) will be evaluated using Kruskall/Wallace non-parametric ANOVA.

Sample sites/size: a) Assess size class for the entire population of camping beaches. The frequency distribution of size classes at a given discharge, will represent a parameter, for that discharge and at that point in time; b) Three camping beaches in each of the 8 segments to be mapped for GIS.

IV. Tasks and Timetable

Complete site selection	May 1990
Site preparation, 24 beach sites	June 1-4, 1990
Re-inventory of camping beaches by photo interpretation	July 1, 1990
Aerial video or on-site data collection:	
10,000-33,200 cfs fluctuating	July 30-Aug. 26, 1990

8,000 cfs constant	October 15-28, 1990
11,000 cfs constant	December 17-30, 1990
15,000 cfs constant	June 21-July 3, 1991
Draft report submission	September 30, 1991
Final report submission	December 1, 1991

V. Deliverables

-A draft and final technical report detailing the influence of discharge on availability, distribution and size of camping beaches.
-Prior to July 16 research flow, an inventory of camping beaches and their size classes, as of June 4, 1990.

VI. Budget

a. Personnel

NPS or contract, doesn't matter
It should be possible to conduct this study using existing NPS personnel and GCES-funded personnel working for the NPS.
On-river crew
Photo-interpretation personnel

b. Equipment and Services

Aerial photos or video

c. Travel

NPS or Contract
On-river trips during the June 1-4 low flows, the 10,000-33,200 fluctuating flows, others if video not planned for constant flow periods. It might be possible to put workers on trips put on the river to do other research.

VII. Literature Cited

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Brian, Nancy J. and John R. Thomas. 1984. Colorado River Beach Campsite Inventory, Grand Canyon National Park, Arizona. Unpublished National Park Service technical report. 56 pp.

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Schmidt, J.C. and J. B. Graf. 1987. Aggradation and degradation of alluvial sand deposits, 1965 to 1986, Colorado River, Grand Canyon, Arizona. U.S. Geological Survey. Open File Report. 87-555.

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STUDY PROPOSAL
GLEN CANYON ENVIRONMENTAL STUDIES

Topic: Recreational Carrying Capacity, Lee's Ferry River Reach

Investigator: National Park Service
Glen Canyon National Recreation Area

INTRODUCTION:

Hypothesis: There is no significant relationship between dam operations and the recreational carrying capacity of the Colorado River within Glen Canyon National Recreation Area. (Relates program hypotheses H8, H9 to GLCA ricer reach.).

Objectives: The objectives of the proposed study are to: (1) determine whether the hypothesis is true; and (2) to evaluate the capacity of the subject river reach to support recreational use within the management framework established for the area. (3) The method of evaluating capacity will be adaptable to predicting the effect of alternative river management scenarios if the hypothesis is rejected.

Integration with GCES research program: The proposal would be fully integrated into the GCES research package. The study would rely heavily on data generated from other GCES research for the information necessary to evaluate impacts caused by varying levels of use. Particularly important in this respect would be GCES phase I and II data on the fishery and on deterioration of beaches.

Background: The sixteen-mile reach of the Colorado River between Glen Canyon Dam and Lee's Ferry, Arizona , receives some of the most intensive recreational use in the state. Commercial day-trip rafting and fishing are the principal uses of the area, which is known throughout the state and nationally for its scenic environment, historic features, and "blue-ribbon" trout fishery. The area is managed by the National Park Service as part of Glen Canyon National Recreation Area with the objectives of preserving the recreational environment (natural and cultural resources), and preserving the trout fishery. Use by the visiting public has expanded greatly in recent years; in the process the mix of recreational uses has also changed. In 1985 there were 7546 day-use rafters. In 1989 this use had expanded to serve 28,115 visitors, with 257 boats and 5600 people traveling downstream to Lee's Ferry in the peak month of July alone. Meanwhile, fishing - the dominant use in 1985 - has grown moderately from 14,000 fishermen to 17,200 fishermen annually. Changes have also occurred in the type of fishing recreation, principally as a result of changes in regulations and management of the fishery. In 1985, when live bait was legal, bank fishing predominated and this concentrated use in the immediate vicinity of lee's Ferry. Today fishing from boats or shoreline points accessible only by boat predominates, and this has had the effect of dispersing use and making the river channel and flow regime even more important to the successful management of this recreational activity. These trends have led to a potential conflict between recreational uses that were formerly more spatially separated, and to a situation where use of the river channel may be a determinant in recreation quality for both uses. There is an immediate need to evaluate the recreational carrying capacity of this river section; and in particular, to determine what effect changes in flow management might have on this capacity.

A substantial number of carrying capacity studies have been conducted for river environments (Shelby and Heberline, 1986; Kuss, et al.), and these would serve to define the processes needed to complete a study in the instant case. A combination of measurements of direct impact to the resources being used, use levels, and visitor expectations/perceptions will be required. In the context of this proposal, carrying capacity is defined as the maximum sustainable level of use the resource can support within the management framework established for the area. The management framework for this study area includes the following key objectives:

1. Preservation of natural and cultural resources
2. Maintain a high level of public enjoyment of the area.
3. Maintain the blue-ribbon trout fishery.
4. Confine camping use to designated sites (50).

Study Plan:

A. Determine key limiting factors for physical capacity and recreational quality. The following are attributes or relationships which could be key factors in limiting use from the standpoints of physical capacity of the resource being used or the maintenance of a high level of public satisfaction.

1. <u>Fishing</u>

Number of campsites

Number of desirable fishing points

Access bottlenecks (river channel, ramp space, parking)

Catch rate, lower threshold of satisfaction

Fish quality

Competition factors (noise, crowding - other fishermen, other uses)

Safety (flow rate, ramping)

Site condition (trash, human waste)

Convenience factors (distance to fishing site, boat stranding)

Habitat preservation (trampling, San Juan "shuffle", gravel deposits, river flow impacts).

Native fish - need to preserve

2. <u>Rafting</u>

Channel space

Sight distance between rafts

Site condition

Noise Level and source

Availability of points of interest

Access bottlenecks

B. Determine relationship of key limiting factors to flows and rate of variation in flow.

C. Determine relationship of key limiting factors to recreational rates.

D. Synthesize information developed under B and C to produce management recommendations.

Methods:

Information related to the potential limiting factors will be collected from previous studies and management docuuments, then screened for prioritization as "key" factors. Key factors are recreation elements which would tend to limit capacity to the lowest level. Data needs would then be identified and acquired through field studies and visitor surveys. An inventory of physical space available for recreation will be completed; including channel area, number and size of beaches for camping, number and size of key fishing points, and major access restrictions. These attributes will be measured. Actual use levels will be measured during the study period and comparable rates obtained from records for any prior periods from which impact data is used.

Previous work and related monitoring information includes management surveys of campsite impacts from 1984; inventory of campsites; a continuous record of monitoring visitor use rates for fishing and commercial rafting; fishing pressure and harvest records; ongoing studies of flow effects on fish habitat; attribute surveys and contingent-valuation surveys of fishermen and commercial rafters in the subject river reach 1984-1985; continuous flow records; a study of boating accident rates vs flow for the subject river reach; and some information on loss rates for beach sands.

It is expected that additional information would be needed to update campsite impact information and obtain perception data from recreationists concerning their experiences. The latter category of information would need to examine the effect of crowding in terms of number of rafts or fishermen on the reach at any one time; and detect any variation in user conflicts dependent on use rates or flows.

The screening process is expected to be able to identify 3-4 key limiting factors for each recreational activity which would tend to limit use to the lowest levels if the existing management framework is maintained. The variation in these attributes with river flows can then be investigated to determine the validity of the hypothesis.

The specific methods of study and data analysis would be developed by the investigator, although any campsite impact studies would utilize methods developed to monitor river camps in

Grand Canyon. Interviews with user groups may be necessary, and these would be conducted using standard survey techniques and forms receiving OMB approval. Because of the extensive amount of existing information, ongoing monitoring and field staffing, the study would be conducted cooperatively between the NPS and a principle investigator contracted by the NPS in accord with the GCES research program. Field staff within the park would assigned to obtain certain data according to protocols designed by the principle investigator. These activities are included in the project budget.

Tasks and Timetable:

* Evaluation of existing information - July-August, 1990
* Field data collection, campsites and resources - September, 1990; May - July, 1991
* Surveys of recreationists - Fishermen October-November, 1990; July 1991; Rafters August, 1990, July, 1991. (dates are based on key use periods and may need to be changed for study purposes).
* Data analysis and synthesis - December, 1990 - September, 1991.
* Draft report due November 1, 1991.
* Final report due December 1, 1991.

Estimated cost of the project:

Personal services -- PI and assistants $33,000

NPS services for field studies	$12,000
Travel	$5,000
Materials and printing	$5,000
Total cost	$55,000

June 11, 1990 DRAFT-2/REVIEW COPY

STUDY PROPOSAL--INFLUENCE OF DISCHARGE ON RECREATIONAL VALUES INCLUDING CROWDING AND CONGESTION AND THE EFFECT OF FLOWS ON OBSERVED BOATING ACCIDENTS IN GRAND CANYON NATIONAL PARK

Prepared by Linda M. Jalbert, Resource Management Specialist, Grand Canyon National Park

ABSTRACT--Proposal: a study to assess the influence of discharge on crowding and congestion at attraction sites and during river travel, and to assess the effects of low flows on boating accidents. The river contact and attraction site monitoring programs have been implemented to determine the effects of current management in terms of launch schedules and distribution of use. Continue study on observed accidents at selected rapids during constant low flow periods.

INTRODUCTION

The revised Colorado River Management Plan (CRMP) has included Management Objectives that address the quality of the visitor experience. The establishes long-term integrated monitoring programs to assess changes in natural and cultural resources. The river contact and crowding monitoring programs look at the actual use levels at destination sites during each use period as well as contacts with other parties while travelling on the river. Previous sociological studies done at Grand Canyon indicate that density (frequency and number) of trips affects the character of the experience (Shelby, et al, 1976).

The purpose of the monitoring program is to identify current trends and conditions of present use levels and to determine if these use levels are within the limits identified in the CRMP management objectives. The monitoring program focuses on two different projects and methods. The river contact data is obtained through the use of a survey form, and the attraction site data is obtained by conducting onsite observations at specified destination sites.

During the 1989 season, the monitoring program focused on collection of actual number of contacts made on river and at attraction sites regardless of influencing environmental conditions. The proposed study will be directed at assessing the influence of discharge on contact levels at attraction sites and on river as well as recording adjustments made by river parties due to flows and associated conditions.

A study on the effects of flows on boating accidents in Grand Canyon (Brown and Hahn, 1985) examined the relationship between flow levels and the incidence of white-water boating. During the

2) to conduct onsite observations at selected attraction sites during fluctuating and constant flow periods
3) to conduct interviews with guides and noncommercial trip leaders at attraction sites to obtain information regarding the effects of various flow levels on schedule adjustments
4) to make observations at selected rapids during low flows to record potential boating accidents

METHODS

River Contact Survey: A survey form was developed to collect information on the number of contacts a river party makes while travelling on the river and at campsites. The content of the survey was based on the methodology of the 1976 River Contact Study (Shelby and Nielsen) and the 1980 River Patrol monitoring (Shelby and Harris). The form was designed to obtain accurate information with minimal effort by participants.

The survey form will be distributed to noncommercial users and commercial river guides on a random basis and nonrandom basis by the Lees Ferry Ranger and by mail during periods of fluctuating and constant flows.

Attraction Site Monitoring: NPS personnel will be stationed at the Little Colorado River, Elves Chasm, Deer Creek and Havasu to collect the data. The format for data collection was also based on the aforementioned baseline studies. Resource Management Specialists will spend seven day periods at each site during the shoulder and high density periods during varying flow regimes. The sample periods are believed to be representative of typical use patterns during each use season.

Commercial guides and noncommercial trip participants will be asked specific questions by the Park people regarding the trip itinerary and the possible influence of flows. These questions will be similar to those used in the HBRS work during Phase 1.

Observed Boating Accidents: The proposed study will utilize the methodology of the previous study. Trained volunteers will be enlisted to make observations at rapids. Logistical support would be provided by GCES and/or outfitters and NPS.

TASKS AND TIMETABLE

River Contact Survey:

Distribution during fluctuating flows:	August 1-14, 1990 June 3-27, 1991
Distribution during constant low flows:	October 1-29, 1990 July 1991

Attraction Site Observations: (Observations are made during Primary Shoulder and High Density Use Periods.)

Site	Fluctuating	Constant
Little Colorado River	May 3-9, 1990	May, 1991 (15k cfs)
	July 5-12, 1990	July, 1991
	September, 1990	September, 1991
Elves Chasm	June 13-20, 1990	June, 1991
Deer Creek	May 21-27, 1990	May, 1991
	July 5-12, 1990	July, 1991
	September, 1990	September,1991
Havasu	May 20-26, 1990	May, 1991
	June 14-21, 1990	July, 1991
	September, 1990	September, 1991

Observed Boating Accidents:

Site	Constant Low Period	Observation Period
Hance Rapids	June 1-4, 1990	June 1-4, 1990
Lava Falls	" "	June 3-6, 1990
House Rock Rapid	Oct 11-25, 1990	Oct 11-25, 1990
24 1/2 Mile Rapid	" "	" "
Hance Rapid	" "	" "
Horn Creek CRYSTAL	" "	" "
Lava Falls	" "	" "

*The number of sites and observation periods will be determined according to the number of available volunteers.

Status Report	September 30, 1990
Status Report & Draft Final	September 30, 1991
Final Report	December 31, 1991

DELIVERABLES

Draft and Final Report on attraction site contact levels and influence of discharges on crowding and congestion. This will include status report on CRMP monitoring programs. Comparative data analysis for accident observations included in final report.

BUDGET

Additional personnel will be needed for monitoring purposes. Currently two seasonal Resource Management Specialist are on duty to conduct field work portion of monitoring program. A total of four individuals will be needed to monitor attraction sites concurrently. Per diem for volunteers recording data at rapids is also needed.

2 Seasonal Park Rangers (Resource Management)--approximately 90 days x $77/day ....~$14000

Travel for additional seasonals: ~$25/day x 60 days..~$ 1500

Per diem for volunteers: 5 x $5/day x 30 days........~$ 750

River support for volunteers: 5 x $69 x 24 days......~$ 8280

Total...~$24530

REFERENCES

Brown, Curtis A., and Hahn, Martha G. 1987, "The Effect of Flows in the Colorado River on Reported and Observed Boating Accidents in Grand Canyon", U.S. Department of the Interior (BOR, NPS, FWS) Recreation Report, Glen Canyon Environmental Studies Final Report, January 1988.

Borkan, Ronald E., and Underhill A. Heaton, "Simulating the Effects of Glen Canyon Dam Releases on Grand Canyon River Trips", Environmental Management Spring 1989.

Shelby, Bo and Harris, Richard 1981. Monitoring Social Impacts of River Management in Grand Canyon: 1980 River Patrol Trips.

Shelby, Bo and Heberlein, Thomas A. 1986. Carrying Capacities in Recreation Settings Oregon State University Press, Corvallis, Oregon.

Shelby Bo, and Nielsen, Joyce M. 1976. Design and Method of the Sociological Research in the Grand Canyon. Technical Report No. 1, Colorado River Research Program Report Series, Grand Canyon National Park.

Resume

LINDA M. JALBERT
Resource Management Specialist
National Park Service
Grand Canyon National Park

PROFESSIONAL EXPERIENCE:

1988-Present	Resource Management Specialist, National Park Service, Grand Canyon National Park. Primary responsibilities: River and Backcountry monitoring, including visitor contacts, .
1987-1988	Computer Assistant--River Management, National Park Service, Grand Canyon National Park. Primary responsibilities: maintained database for permits and resource monitoring; and conduct photo-point monitoring along the Colorado River Corridor.
1986	River Ranger, Bureau of Land Management, Kemmling Resource Area. Primary Responsibilities: Patrol, and monitoring visitor activities.
1981-1986	Professional River Guide, Arkansas, Rio Grande, Green and Delores Rivers.

EDUCATION:

Associate of Science, 1975. Greenfield Community College.

Bachelor of Science, Outdoor Recreation and Natural Sciences, 1978, Southern Illinois University.

**REVIEW AND INTEGRATION
OF THE
GLEN CANYON ENVIRONMENTAL STUDIES**

**PHASE I
RECREATION STUDIES**

The study plan and contract requirements for this research is included in the Economic Studies section.

ARCHEOLOGY

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTEGRATED RESEARCH PROGRAM

ARCHEOLOGY STUDIES

I. Issues

The Glen Canyon Environmental Studies (GCES) Phase II archeology studies have been initiated due to the concern that the operation of Glen Canyon Dam is having an impact on the cultural resources in the Grand Canyon. These impacts are largely due to the direct and indirect erosion of the sediment deposits that hold and/or cover the archeological resources

With the initiation of the Glen Canyon Dam - Environmental Impact Statement, a complete survey of the cultural resource sites along the Colorado River corridor in the Glen and Grand Canyons became necessary. In order to understand why the cultural sites are eroding away, it is necessary to understand the geomorphic and geologic characteristics of the cultural resource sites themselves.

The Native American concerns have increased over the last several years due to people impacts and the impact of erosion. Native Americans involved with management of the cultural and natural resources of the Grand Canyon include the Hopi's, the Navajo's, the Havasupi's, and the Hualapi's. Coordination on all cultural resource efforts must include the Native Americans.

II. Objectives

The broad objectives of the GCES Archeology Studies are stated as follows:

A. Determine the location of the cultural resource sites along the Colorado River corridor from Glen Canyon Dam to Lake Mead.

B. Determine the level of impact associated with the operations of Glen Canyon Dam on the identified cultural resource sites and determine courses of action.

C. Integrate the Native American concerns into the overall GCES archeology studies.

III. Components of the GCES Phase II Archeology Studies

The components of the GCES Phase II archeology studies can be separated into two areas and are depicted in Figure 10.

A. Archeological Surveys - conduct and evaluate the cultural resource sites along the Colorado River corridor from Glen Canyon Dam to Lake Mead.

1. Conduct the field survey
2. Evaluate the data

B. Coordinate the Archeology studies with the Native American tribes impacted by the operation of Glen Canyon Dam.

1. Hopi
2. Navajo
3. Havasupi
4. Hualapi

IV. Organization of the GCES Archeology Studies

The overall organization of the GCES Archeology Studies will be guided by the GCES Scientific Core Team and the GCES Archeology Team. The GCES Scientific Core Group is composed of members of all the associated GCES research groups.

The Scientific Core Group and the Archeology Team will be jointly responsible for the integration of the archeology studies into the overall GCES technical reports.

Representation on the GCES Archeology Team will include, but not be limited to, the following groups:

GCES - Senior Scientist
GCES Office
National Park Service - Grand Canyon National Park
National Park Service - Glen Canyon National Recreation Area
Northern Arizona University
Navajo Nation
Hopi Tribe
Havasupi Tribe
Hualapi Tribe
State of Arizona - Historic Preservation Office
Contractors (as required)

The primary leadership for the GCES Archeology Team will be the GCES Senior Scientist and the National Park Service, Grand Canyon National Park. The GCES Office will provide the coordination and logistical support.

VI. Products to be Developed

The GCES Archeology Team and the GCES Scientific Core Group will be responsible for the completion of the following reports:

A. Individual Research Reports - as defined in the Study Plan

B. Integrated GCES Archeology Report - synopsis of the archeology studies and identification of the areas of conflict or concern.

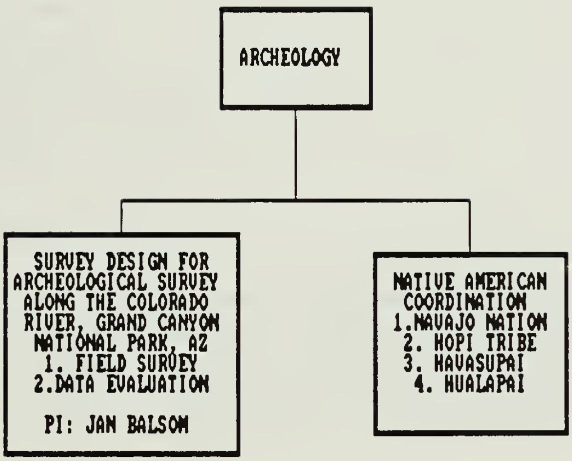


Figure 10. Glen Canyon Environmental Studies Phase II Archeology Studies.

United States Department of the Interior
NATIONAL PARK SERVICE
WESTERN REGION
450 GOLDEN GATE AVENUE, BOX 36063
SAN FRANCISCO, CALIFORNIA 94102

IN REPLY REFER TO:

H22(WR-RH)

May 29, 1990

GLEN CANYON ENVIRONMENTAL STUDIES OFFICE

JUN 29 1990

RECEIVED
FLAGSTAFF, AZ

Mr. Roland Robeson
Regional Director
Bureau of Reclamation
Upper Colorado Regional Office
P.O. Box 11568
Salt Lake City, Utah 84147

Dear Mr. Robeson:

In response to an informal suggestion from David L. Wegner (Reclamation's Glen Canyon Environmental Studies Office, Flagstaff, Arizona), we are pleased to provide two documents regarding cultural resources information for an Environmental Impact Study (EIS) addressing future operation of the Glen Canyon Dam.

These documents are: Proposed Project Budget and Project Statement which have been prepared by our archeological staff in this office and Grand Canyon National Park. Informal suggestions and opinions from the Arizona State Historic Preservation Officer and other professional sources were also considered in development of both documents.

In the design of the program of work, we have been guided by the following:

1. Full technical requirements and legal compliance with appropriate Acts of Congress (PL 96-515 as amended, Sections 110 and 106; PL 95-341, PL 100-555), Code of Federal Regulations guidance, and Proceedings of the Advisory Council for Historic Preservation.

2. Departmental directives contained in Secretary of Interior's Standards for Historic Preservation and Archeology (FR Sept. 29, 1983).

3. Park Service and Reclamation agency policy for cultural resource management as outlined in Reclamation Instructions Series 350, Part 376, Chapter 11 and NPS-28, Cultural Resource Management Guidelines.

There are critical logistic, environmental, and employee health/safety factors in the Colorado River study zone which necessitate special considerations and require greater than normal costs. The fragile and complex inter-related natural resources of the river corridor are to have maximum protection as well. We have vigorously pressed for restrictions on human impacts, including necessary research of management trips.

We realize the preparation process for the Glen Canyon EIS is a formidable task by your staff and cooperating agencies. We believe our proposal is realistic, narrow to fit the needs of an EIS and will prove scientifically sound. It will be executed effectively in a cost-efficient manner, I assure you.

Sincerely,

Stanley T. Albright
Regional Director, Western Region

Enclosures

cc:

WASO-400: Associate Director, Cultural Resources, w/c encs.
WASO-430: Consulting Department Archeologist, w/c encs.
  Attention: D. Scovill, Acting)
WASO-760: Associate Director, Planning & Developing, w/c encs.
  Attention: J. Hoogland (Environmental Quality)
Regional Director, Rocky Mountain Region, w/c encs.
  Attention: Chief, Cultural Resources, Regional Archeologist
Superintendent, Glen Canyon, w/c encs.
  Attention: Park Archeologist (L.C. Kincaid)
Superintendent, Canyonlands, w/c encs.
  Attention: Cultural Resource Specialist (C. Cartwright)
Superintendent, Grand Canyon, w/o encs.
  Attention: Resource Management Division
Regional Chief Scientist, Western Region, w/c encs.
  Attention: Charles Van Riper, NAU CPSU
Regional Environmental Specialist, Western Region, w/c encs.
Chief, Western Archeological and Conservation Center, w/c encs.
  Attention: Division of Archeology

Glen Canyon Environmental Studies Office, w/c encs.
121 East Birch Street
Room 307
Flagstaff, Arizona 86002

PROJECT STATEMENT

Colorado River Corridor Survey
for Environmental Impact Statement Preparation;
Operation of Glen Canyon Dam

Introduction

Historic and archeological resources exist in the corridor of the Colorado River between Glen Canyon Dam and Separation Canyon, a 255 river mile portion located in Northern Arizona. Included in this zone are portions of Glen Canyon National Recreation Area (GLCA), Grand Canyon National Park (GRCA), Navajo Nation Indian Reservation, Havasupai Indian Reservation, Hualapai Indian Reservation, and Lake Mead National Recreation Area. Historic and archeological resources (only partially known) relate to prehistoric major cultural traditions (Archaic, Anasazi, Cohonino), historic and continuing Native American groups (Hopi, Navajo, Paiute, Hualapai, and Havasupai) and river exploration or economic functions from non-Native Americans. The study area contains archeological and historic resources spanning several thousand years. General historical knowledge includes nationally significant events and historical individuals in the study area. For a complete description of the project area and the survey design, please refer to the attached document.

Scope

It is essential that cultural resource information be gathered for use in an Environmental Impact Statement (EIS) process which provides thorough baseline data with sufficient detail for consideration of alternatives and a variety of potential impacts, if any. The National Park Service (NPS) and Bureau of Reclamation (BOR) desire to execute an intensive examination of landforms, resources, and geomorphological settings available for long human occupancy in the study area. Data gathered shall be summarized for EIS use and will be available to support extracted reference within the environmental study and its review. Standards and procedures by which such information is gathered and interpreted exist in the form of federal legislation, regulatory guidance, agency public policy directives, and professional performance.

While gathered to provide factual materials for EIS preparation and not for direct research purposes, it is recognized that such data will continue to provide usable knowledge for future assessments, planning, monitoring and mitigation of changes as may occur. Preservation of such data will be ensured by technical reports, project archival records of several types, and a small quantity of materials collected during the field work.

Since the resources as known relate to contemporary Native American tribal communities, consultation with these communities will be essential. The project will also include discussions with the Arizona State Historic Preservation Office and interested peers who may have applicable expertise.

Legislative Directions

While not requiring federal permits due to direct National Park Service supervision and participation, this project will meet the spirit of requirements in PL 95-96 (Archeological Resources Protection Act, 1979) and 43 CFR 7.5, 7.8 and 7.9. As part of the National Environmental Protection Act (NEPA) process, consideration of historic preservation legislation includes the following:

1. Consultation with Arizona State Historic Preservation Officer pursuant to the National Historic Preservation Act as amended, particularly to federal responsibilities under Section 110 and 106 when appropriate.

2. Involvement of Native American communities who may have heritage interests in these study area, e.g., Hopi Nation Tribal Council and Cultural Resource Program, Navajo Nation Tribal Council and Cultural Resource Program, Kaibab Paiute Tribe, Hualapai Tribal Council and Havasupai Tribal Council. The project will be described to representatives of these communities for their consideration and response.

3. Consideration of the applicability of the Advisory Council on Historic Preservation Proceedings as expressed in 36 CFR Part 800 (Protection of Historic Properties). While this project is not directly related to the determination of effect or negotiated mitigation actions, information bearing on these issues will be gathered to be incorporated into recommendations as part of the formal EIS.

Departmental Directions

1. The published Secretary of Interior's Standards for Archeological Documentation (FR September 29, 1983: 44734-37) provide basic guidance, supplemented by National Park Service guidelines.

2. National Register of Historic Places instructions for nomination and eligibility review provide direct guidance

on format, topical, and technical methods of preparing nomination forms for review.

National Park Service Directions

1. The agency's Guidelines for Cultural Resource Management contain guidance on field methodology, required pre-project planning and research design, curation, and related topics.

2. The Native American Relationships Policy of the Service describes how consultations regarding Service projects will be made with neighboring or affected Native American communities with historical ties to the project location.

3. Curatorial management and collections treatment is guided by Special Directive 80-1 (Curatorial Collections Management.)

Administrative Project Reporting

At the end of each period of field work, a brief summary will be prepared on accomplishments. Since the work is critical to the preparation of the EIS, as summary data are available for areas completed, timely information needed for EIS inclusion will be forwarded, bearing in mind the legally protected sensitivity of site identifications. The project will be described in a professional technical report in the NPS-28 format. Drafts or review copies and final draft will be completed within the last quarter of Fiscal Year 1991, with a final report by the end of the calendar year.

Mandated Goals and Objectives

1. Provide summarized cultural resource information for use in preparation of an Environmental Impact Study in a timely fashion according to the schedule identified by the BOR for the Glen Canyon Dam EIS.

a). Data gathered and interpreted regarding archeological and historic resources within the described study area of the Colorado River zone, Inner Gorge of Grand Canyon National Park and a portion of Glen Canyon National Recreation Area downstream from the dam, shall meet objectives of a Class III survey (BOR) and Archeological Evaluation Studies (NPS) which primarily address collection of sufficient data for National Register of Historic Places evaluation.

b). Data gathered shall be retained and curated to meet objectives of Cultural Responsibilities (BOR) and Standards for Cultural Resources Management Activities as well as Special Directive 87-3 (NPS).

2. Execute pre-field, field work, and post field operations to meet objectives and standards outlined in the Secretary of the Interior's Standards for Archeology and Historic Preservation and appropriate public law.

a). This project shall meet objectives of Section 110 (a)(2) of PL 96-515 (December 12, 1980; Federal Register February 17, 1988), and Section 14 of PL 100-555 (October 28, 1988).

b). This project shall meet objectives of the American Indian Religious Freedom Act (PL 95-341) and the Proceedings of the Advisory Council for Historic Preservation (36 CFR 800 as revised).

GCES ARCHEOLOGICAL SURVEY BUDGET (revised 5/25/90)

Personnel Requirements

	FY 90	FY 91	FY 92	TOTAL
1. Park Archaeologist (20% time)	N/C	N/C	N/C	N/C
2. Project Archaeologist (GS-11) 45 pay periods (7/1/90 thru 4/7/92)	8,325	33,850	16,713	58,888
3. Crew Chiefs (RAII or GS-7)* 36 pay periods x 4 (8/12/90 thru 11/18/91)	14,170	103,729	17,329	135,228
4. Lab Director (RAII or GS-7)* 32 pay periods (10/1/90 thru 12/16/91)	N/C	25,933	5,267	31,200
5. Crew Members (RAI or GS-5)** 24 pay periods x 8 (8/12/90 thru 6/2/91)	21,520	105,299	N/C	126,819
6. Lab Tech/Data Entry (RAI/GS-5) 26 pay periods x 2 (10/1/90 thru 9/30/91)	N/C	36,926	N/C	36,926
7. Secretary (GS-6/1) 26 pay periods	N/C	20,591	N/C	20,591
Subtotal+	44,015	326,328	39,309	409,652
Estimated Cost of Living Increase (4.1% FY 91 & FY 92)		13,380	1,612	14,992
	44,015	**339,708**	**40,921**	**424,644**

Transportation/Equipment

	FY 90	FY 91	FY 92	TOTAL
1. Computer system (w/ laptop field computer)	5,000	10,000		15,000
2. GSA Vehicle Rental (2)	600	7,200	1,800	9,600
	5,600	**17,200**	**1,800**	**24,600**

* Wages are calculated as GS-7/5 to equal NAU RAII pay scale.
** Wages are calculated as GS-5/3 to equal NAU's RAI pay scale.
\+ Personnel costs have been calculated using FY90 wage tables and include "hidden costs" such as Sunday differential/holidays but do not include extra funds for any overtime pay.

	FY 90	FY 91	FY 92	TOTAL
<u>Supplies</u>				
1. Field & Survey supplies (includes topographic maps, aerial photos, cameras, film, pelican boxes, and related camping and survey equipment)	6,500	3,500		10,000
2. Office/Lab supplies		5,000		5,000
	6,500	**8,500**		**15,000**
<u>Miscellaneous</u>				
1. GRCA-GLCA co-ordination		3,350		3,350
1. Specialized analyses		5,000		5,000
2. Report Prep/illustration		10,000		10,000
		18,350		**18,350**
<u>Curation Costs</u> (10% of field personnel costs)			26,120	
TOTAL DIRECT COSTS (by fiscal yr.)	56115	383758	68,841	508714
INDIRECT COSTS				
(20% NAU personnel)***	7138	60894	4705	72737
River logistical support ++ 2016 person days on river (includes August and Sept. trips through OARS contract)	54294	70583		124877
Cost Breakdown for River Support:				
OARS contract costs	23184			
GRCA costs	31110	70853		
TOTAL COSTS (by fiscal year)	**117547**	**515235**	**73546**	
TOTAL PROJECT COST ESTIMATE				**706328**

*** It is assumed that NAU office rental (20 months) is included as part of the indirect NAU costs. If office space rental is not covered by the NAU indirect costs, an additional $24,000 will need to be added to the project budget:

	FY90	FY91	FY92	TOTAL
Office rent at @ $1200/month	2,400	14,400	7,200	**24,000**

++ River logistical support costs are based on using the GCES contractor for August and September, 1990, and NPS support thereafter. Savings of $14,227 will result from using NPS River Subdistrict instead of the GCES contractor.

SURVEY DESIGN FOR ARCHEOLOGICAL SURVEY ALONG THE COLORADO RIVER, GRAND CANYON NATIONAL PARK, ARIZONA

Prepared by Janet R. Balsom and Helen C. Fairley, Archeologists, Grand Canyon National Park, May 1990

Abstract

A complete archeological survey of the Colorado River corridor is proposed as part of the Environmental Impact Statement process required of the Bureau of Reclamation (BOR) for the operation of Glen Canyon Dam. The survey zone will include approximately 9775 acres along the 255 mile stretch of the Colorado River between Glen Canyon Dam and Separation Canyon. All archeological sites will be recorded and evaluated based on criteria set by Grand Canyon National Park (GRCA). The archeological information will be interfaced with the existing GRCA archeological database and Glen Canyon Environmental Studies research, particularly issues related to sedimentology and erosion. The National Park Service will take the lead role in coordinating and conducting the survey in support of BOR requirements.

Introduction

Archeological research in the Grand Canyon began with the first report of "Moqui" ruins by John Wesley Powell in 1869 (Powell 1875). Site reportings over the years and limited surveys of the rims and the inner canyon have recorded over 2600 sites. Complete archeological inventory surveys have been done in only a few locations in the canyon, so this number represents only a fraction of the sites which actually occur within the boundaries of Grand Canyon National Park (GRCA).

Inventory along the Colorado River has been sporadic, with the first professional archeological work done by Walter Taylor in 1953 (Taylor 1958). At the time, Taylor stated that "From this brief and hurried survey, it is concluded that there was very little aboriginal occupation of the near reaches of the Colorado River in the stretch between Lee's Ferry and Lake Mead" (Taylor 1958:29). While Taylor's brief reconnaissance located less than a dozen sites, subsequent work along the river has discovered over 140 additional sites (Balsom 1985). None of the ensuing survey work involved complete ground survey. The majority of the survey work was done by Robert C. Euler in the 1960's as part of the Marble Canyon Dam studies (Euler 1967). In Euler's survey work, over 200 sites were added to the site inventory, most of these at locations within the Colorado River corridor. Additional survey work was done in specific canyon areas, such as Nankoweap Canyon and Unkar Delta (Schwartz 1963; Euler and Taylor 1966; Schwartz 1965). The area specific surveys were directed toward inspections of known site areas rather than the river corridor at large. To date, no systematic survey has been done of the river corridor itself.

The portion of the Colorado River between Glen Canyon Dam and Lee's Ferry was surveyed cooperatively by the BOR and the NPS in 1980. While no final report was written, the surveyors did record a total of 24 sites and 23 isolated occurrences (Geib, in preparation).

The survey design outlined in this paper is directed toward providing an inventory of archeological sites located along the river corridor. The survey will be accomplished by examining the ground surface from the ground, rather than from the air as had been done previously (Euler 1967). Through years of monitoring and recording sites along the river, it has become apparent that site locations are often subtle, with remains visible only when the covering sands disappear. This survey will attempt to be sensitive to the subtleties of river archeology and to the changing sediment patterns.

The results of this survey will be integrated with the sedimentological research which is occurring as another phase of the GCES process. The interdisciplinary approach is necessary to fully examine the relationship between prehistoric site location, the river and the erosion of sites which is presently occurring. Integration of all facets of the environmental conditions must occur in order to understand the interrelationships and acquire adequate information to manage the resources in this unique setting.

The Colorado River environment is unique and diverse. Changes in elevation and geologic setting provide varied environmental situations from the base of Glen Canyon Dam 15 miles above Lee's Ferry to the end of the free-flowing river at Separation Canyon, 255 miles downstream. Elevation changes in the 255 mile stretch, while not extreme, encompass various vegetation zones and geologic situations between Glen Canyon Dam, at an elevation of 3107 feet above sea level, to Separation Canyon at 1240 feet above sea level.

<u>Objectives</u>

The objectives of the survey are directed toward providing an inventory of all sites located within the Colorado River corridor affected by the operation of Glen Canyon Dam. Specific objectives are as follows:

1. Provide an inventory of all sites located within the affected environment of the river corridor.

2. Evaluate site condition and impacts as they relate to the environmental situation created by Glen Canyon Dam.

3. Identify site settings which would provide information for further study as to the problems of site erosion and sedimentation.

4. Evaluate site significance and eligibility for inclusion on the National Register of Historic Places.

5. Provide management recommendations for river flow regimes for Glen Canyon Dam.

Background

Although federal law mandates that all federal lands have complete archeological inventories (E.O. 11593, 1971; NHPA as amended 1980), most land managing agencies do not have adequate funding to accomplish the task. Hence, surveys are done on an "as needed" basis, usually only in areas slated to be involved in a federal undertaking. With the directive given to the Bureau of Reclamation (BOR) to prepare an Environmental Impact Statement (EIS) for the operation of Glen Canyon Dam, evaluation of impacts to cultural resources located along the river must be completed.

Until recently, it was generally felt that cultural resources were not effected by the operation of the dam and the flowing of the river through Grand Canyon. In October of 1989, GRCA in conjunction with the United States Geological Survey (USGS), conducted a pilot research project to evaluate archeological site erosion at one site along the Colorado River (Balsom, Hereford and Brian 1989). Analysis of the information from the project suggests that the operation of Glen Canyon Dam may be a contributing factor to ongoing site erosion, not only at the study site but at numerous sites in the canyon. Because of the apparent connection between site erosion and the operation of the dam, a cultural sites inventory is warranted as part of the EIS process.

While the indirect impacts of the operation of Glen Canyon Dam on archeological sites was addressed in the erosion study conducted in October 1989, evidence has also been found suggesting direct impacts from the river. In recent years, a number of sites have been recorded below the historic high water zone of the river, an area previously thought to be devoid of archeological resources. For years, it has been thought that prehistoric remains would not be found below the historic high water mark for two reasons: first, the belief that prehistoric people were more cognizant of environmental conditions and would therefore build above the floodplain; and second, the assumption that any remains that were close to the river would have been washed away over the thousands of years since occupation. In many locations along the river, sites have been recorded which are within the historic high water zone and which exhibit evidence of direct river effects (Balsom 1989).

Affected Environment

For the purposes of the archeological survey, the length of the river corridor is defined as the section of river from Glen Canyon Dam (Mile +15) to Separation Canyon (Mile 240). The width of the corridor varies with the canyon topography. Because of this, no set corridor width can be specified in this design. Rather, the affected zone must encompass all riverine environments, especially those that contain river derived sediments, whether alluvial, fluvial or eolian. In the field, this zone encompasses the present beach up to and including the farthest extent of the old high water zone marked by high dunes and mesquite. All flood terraces and blown sand areas must also be included. The sand areas are often above the historic high water zone but contain sediments that were ultimately derived from the river. All areas which contain sediment originally derived from the river must be included within the boundaries of the survey.

Special attention must be given to all river corridor areas which mark access or egress points in the canyon. Many of the side canyons provide access routes from the rim to the river, or from one inner canyon area to another. Not all of these side canyons are in areas where river sediments have provided terraces.

Methodology

Fieldwork Methodology

In order to accomplish a survey of the magnitude required for this project, it is necessary to divide the river corridor into manageable units. These units can be treated as independent areas for survey, although all the information obtained from them must be compiled at the end. The survey areas have been defined based on logistical considerations, archeological erosion, and potential for study of the sedimentology and geomorphology. In all phases of the survey, primary consideration will be given to areas which hold the greatest potential for in-depth archeological and geological/sedimentological research.

Usually, a corridor survey would involve the examination of a set width along the entire length of the project. If a width of 50 meters (164 feet) on each side of the river was set for the 255 mile long corridor, a total of 10140 acres would be involved. However, as noted above, designation of a standard width corridor is impractical for this survey project because the area affected by historic river flows varies considerably along the length of the river depending on local topographic factors. In the Palisades/Tanner area, for example, historic river deposited terraces extend more than 200 meters back from the edge of the main river channel, whereas, in the Inner Gorge, the sheer canyon walls confine the river to a much narrower corridor.

For the purposes of the survey, the river has been separated into the following units (Figure 1):

1. Glen Canyon Dam to Lee's Ferry (Mile +15 - 0): Although an inventory survey was completed of this section of river in 1980, changes in the operation of the dam and the flood years of the mid-1980's warrants reexamination of this section of river. It is estimated that approximately 550 acres of land should be surveyed. Upriver travel is possible between Lee's Ferry and the dam.

2. Lee's Ferry to Badger (Mile 0 - 7): It is estimated that there are approximately 540 acres of land in this section which should be included in the survey. Support for this area can be handled with a motor boat from Lee's Ferry which would return to Lee's Ferry. The top of Badger Rapid is the extent of downriver travel with a return to Lee's Ferry.

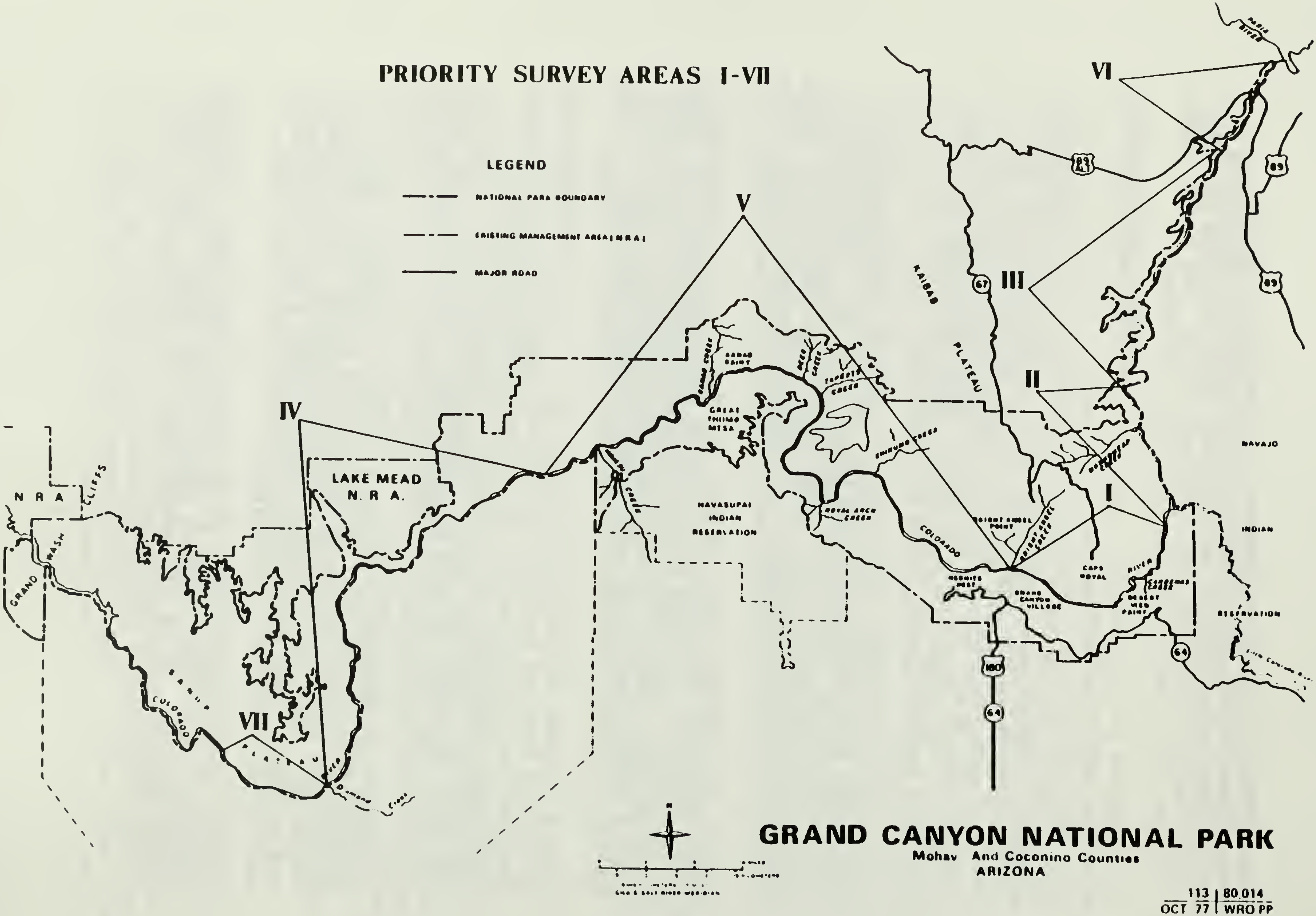
3. Badger to Triple Alcoves (Mile 7 - 46.5): It is estimated that there are 955 acres of land in this section which could be surveyed. Many small areas of river deposit are found in this section, not all showing up on topographic maps. The Marble Canyon Dam sites are located within this zone. These historic features should be recorded during the survey.

4. Triple Alcoves to Palisades (Mile 46.5 - 65.4): It is estimated that as much as 1880 acres occur in this section. Included in this area are the large deltas of Little Nankoweap, Nankoweap, and Kwagunt, along with the Tapeats ledges found near the Little Colorado confluence. One site has been recorded in this section which lies in the Tapeats ledges, below the historic high water mark.

5. Palisades to Phantom (Mile 65.4 - 87.5): This is the primary area of concern for the survey because of the documented erosion of sites which are buried within flood deposits. This area also has sites which are located below the historic high water mark. Over 1500 acres of land should be surveyed in this area.

6. Phantom to Stairway (Mile 87.5 - 170): This area contains numerous small side canyons and river terraces, but lacks large deltas. It is estimated that over 2000 acres should be surveyed within this zone.

PRIORITY SURVEY AREAS I-VII



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7. Stairway to Diamond Creek (Mile 170 - 225): This section contains numerous side canyon deltas and river terraces. It is estimated that nearly 2000 acres should be surveyed within this zone.

8. Diamond Creek to Separation (Mile 225 - 240): This section contains few side canyons and few beaches. Access routes are not generally known from the area. It is estimated that only 350 acres of land should be surveyed in this section. The Bridge Canyon Dam site is located within this zone and should be recorded as a historic site/feature.

The total number of acres thus identified is 9775 acres. It is possible that this acreage figure is high due to the inadequacy of estimating acreage from the topographic maps and the realization that field flexibility is critical.

Because of the physical limitations placed upon survey by the geological situation, it must be recognized that not all river front areas can be physically surveyed. It must also be recognized that cultural remains are often found in unusual places. Every attempt must be made to examine all likely locations, along with areas which are not so likely. The survey zone must include all areas along the river which can be physically surveyed and areas which contain river derived sediments. The areas outlined above are guidelines; finer delineation of the survey zone must be done in the field with the field supervisor and crew chiefs. Use of both topographic maps at a 1:24000 scale (7.5 minute) and aerial photographs should be used to accurately plot site locations and survey zone boundaries. The field definition of the survey area will be the final figure for acreage.

Estimates for survey time depend on intensity of field analysis, logistics, and terrain. Because the logistical constraints of working in the canyon are great, the physical demands extreme, and the complexity of archeological remains is highly variable, a general figure of 7 acres per person per day is estimated. Using this value, approximately 1440 person days will be required to complete the fieldwork portion of the project.

Although this estimate of acres per person per day may seem low, it is deemed appropriate because of the time that will be required to complete in-field analyses and cover the rugged terrain. The terrain will be extremely demanding, and the vegetation, particularly the mesquite, will be difficult to work through. However, the mesquite zone is the most critical area to survey since it seems to hold the most potential for buried sites. Also, some areas with high site densities will require considerable time to record and map. In some cases, entire delta areas will need to be mapped, with all prehistoric evidence plotted and related to features and topography.

Care must be taken to avoid unnecessary resource degradation. While the primary goal is to provide an inventory survey, human impacts caused by the survey crews themselves could potentially be more detrimental to the resources than the effects of the dam. Crew size should be kept at a minimum to avoid trampling of areas caused by too many people in a fragile environment. Also, crews must try not to create new multiple trails, destroy vegetation and cryptogamic soils, or to otherwise overly impact the environment.

To facilitate accomplishing the survey and identifying areas for in depth study, the defined survey units have been placed in a priority order, based on the considerations stated above. Primary consideration is given to those areas which are experiencing the most erosion and which hold the most promise for answering the geomorphological questions concerning archeological site erosion. The breakdown of areas is as follows as measured in river miles below Lee's Ferry:

Priority	Area/Zone
I	Palisades to Phantom (1500 acres)
II	Triple Alcoves to Palisades (1880 acres)
III	Badger to Triple Alcoves (955 acres)
IV	Stairway to Diamond Creek (2000 acres)
V	Phantom to Stairway (2000 acres)
VI	Lee's Ferry to Badger (540 acres)
VII	Diamond Creek to Separation (350 acres)
VIII	Glen Canyon Dam to Lee's Ferry (550 acres)

Three areas of the river corridor are not dependent upon taking a lengthy river trip. The fifteen miles of river corridor from Glen Canyon Dam to Lee's Ferry (Mile +15 - 0), Lee's Ferry to Badger (Mile 0 -7) and the last segment, from Diamond Creek to Separation (Mile 225 - 240) can be surveyed without a full river trip. These three areas, however, hold the least likelihood for previously unrecorded archeological remains. The segment between Palisades and Phantom can be done, in part, without river support if helicopter support or a combination river/air support is available. Survey crews can walk the segment of the river corridor between Palisades and Cardenas on the south side of the river without river assistance, although the north side cannot be done in the same manner. Other discrete sections can likewise be surveyed without requiring a complete river trip for support; However, in most areas, it would be dangerous to leave a survey crew without boat support. In fact, it would not be wise to have the boats ahead of the crew at any time in the event that surveying between points is not possible once the crew is on the ground. Often, routes that appear reasonable from a map or from examining the area from the river are not possible upon close inspection.

Although it would be desirable to proceed with the survey based upon the priority order, due to the time constraints and logistical factors, areas which can be surveyed without the coordination of a complete river trip will likely be completed before the inner canyon work proceeds. This is a function of access rather than need.

Survey Procedures

As with all complete archeological surveys, 100% coverage means that 100% of the project area will be examined. However, this does not necessarily mean that 100% of the sites will be found. Changing conditions in the field have uncovered sites in areas where no previous evidence of the site existed and eliminated cultural remains in other areas. Special attention must be paid to areas which have the potential to have sites which are not yet visible but may contain them in buried settings. Shovel testing, remote sensing, and monitoring may be initiated in these areas.

For the purposes of this survey, ground coverage will generally be accomplished by having the survey crew walk in parallel lines, spaced 10 - 15 meters apart. In some areas, it will not be possible to maintain set spacings; for example, in dune areas where the slope is great it may be necessary for the crews to walk around and over the dunes rather than through them. However, every area which is physically possible to examine will be included in the survey. Ledge areas obviously cannot be surveyed with a set crew spacing; rather, crew members taking individual levels of ledges is preferred. Each area will warrant different approaches and will be decided by the Project Supervisor and crew chiefs.

The results of this survey will provide baseline data on the physical condition and National Register eligibility of archeological sites. Since this information will be incorporated into the ongoing GRCA monitoring program, it is imperative that the recording procedures be sufficiently detailed to provide the necessary baseline information to evaluate changes in site condition over time. This includes detailed photographic documentation, detailed and accurate maps of sites in relation to topography, verbal assessments of site condition and impacts, and detailed information on the quantity, density, and variability of surface artifacts.

Once a site is located, the site will be recorded, mapped to scale, and photographed. All site locations will be plotted on both USGS 7.5 minute topographic maps and aerial photographs. A unique site number will be assigned to each site based on the GRCA site numbering system. Each site will be tagged with a metal tag identifying the site number and the date the site was recorded. The tag will be attached to a small metal stake placed on the site which will serve as site datum. Site reports will be on GRCA site recording forms and the National Park Service Cultural Sites Inventory (CSI) form and will include information on impacts/threats. Data for inclusion in the NPS and BOR/GCES Geographical Information System (GIS) will also be collected, and information concerning sedimentation will be recorded. Site maps, including a scale and north arrow indicating true north, will be drawn for each site. Both black and white prints and color slides will be taken of each site. Photographs will include a menu board and north arrow. All compass bearings will reflect proper declination set for true north.

Analysis of artifacts for the purpose of establishing temporal and cultural affiliations and interpreting site function will be undertaken at each site. In general, a policy of in-field analysis and in situ preservation will be emphasized over collection; however, when artifacts are problematical, diagnostic, or in danger of disappearing, sample collections may be taken at the discretion of the crewchief.

The in-field analysis strategy will employ a mixed judgmental-random procedure for selecting artifacts for analysis. At sites with less than 100 artifacts, all artifacts will be examined. At sites with 100 to 500 artifacts, several 4 square meter areas encompassing at least 40-50 lithics and a similar number of sherds and representing at least 1% of the site area will be judgmentally selected. At sites with more than 500 artifacts, a random selection of analysis units representing at least 1% of the site area will be employed. All ceramics and a random sample of 40-50 lithic items will be analyzed per sample unit. This sampling strategy is consistent with the 1-5% areal sample collected and analyzed from other sites in GRCA since 1983. All analysis units will be point provenienced on a scaled plan map of the site.

Analyzed ceramic attributes will include ware/type, form, and post-firing modification. For lithic debitage, information will include material type (gross categories), amount of cortex cover, and number of dorsal scars. For lithic tools, material type and technological tool type will be recorded. Standard measurements and morphological descriptions on ground stone implements will be made. A judgmental selected representative sample of the sherds and other artifacts will be photographed. These minimal in-field analysis procedures are consistent with those currently employed in other NPS inventory projects employing in-field analyses strategies such as at Bandelier National Monument (Janet Orcutt, personal communication, 1990). They will provide the minimum data required for accurate temporal and cultural-functional interpretation and will allow rough comparability with data collected from other areas of Grand Canyon National Park.

Collections will be taken only of diagnostic or exceptionally valuable artifacts (projectile points, whole vessels, etc.). Point provenienced judgmental grab samples may be taken from sites with less than 500 artifacts, while at larger sites with higher artifact densities, random collections may be substituted for in-field analysis. In the latter instances, 4 square meter units will be collected, encompassing not more than 1% of the site area; however, this procedure will only be used on sites where the density and diversity of artifacts preclude timely completion of in-field analyses. On sites with limited remains, collections will be minimal, ensuring that there would be evidence of an archeological site after the site is recorded. All collected artifacts and analysis units will be point provenienced on a scaled plan map of the site, verbally provenienced in relation to the site datum, and bagged with appropriate site and location information. Unprovenienced grab samples will not be taken.

The estimated amount of time required to record, map, and photograph the sites and conduct in-field analyses will vary considerably according to the size, complexity, and surficial visibility of the archeological remains. Presumably the time required to locate, record, map, and establish the location of analysis units will remain constant whether an in-field or laboratory analysis strategy is employed. The main difference will reflect the amount of time required to locate and analyze artifacts vs. simply collect them. For small and fairly simple sites, 45 minutes to an hour will be needed to record and map each site, with another 3/4-1 hour for analysis (mapping of the site must be more or less complete before selection of analysis areas can take place). At larger and more complex sites with numerous features, up to 1/2 day (4 hours) may be required to map and document a site; in such cases, in-field analysis could conceivably occupy the remainder of the day. Obviously, the time required for in-field analysis will vary according to the numbers and variability of the artifacts encountered, with low density/low diversity assemblages requiring considerably less time than high density/high diversity assemblages. Based on the recent experience of surveyors at Wupatki and Bandelier National Monuments, an average estimated field time increase of 100% for in-field analysis vs. simple collection seems both conservative and appropriate.

If human remains are encountered during the survey, the location will be noted on a map and the cultural context of the remains, if any, will be documented without disturbing the remains. Field crews will follow procedures outlined in the "Native American Relationships Policy (FR 52:183) and the "Guidelines for the Disposition of Human Remains, NPS-28, Technical Supplement." A new policy and revised guidelines for the disposition of human remains on NPS lands is scheduled to be drafted by June, 1990. When the new policy is finalized, the new guidelines will replace the existing one.

Time Frames and Logistical Support

In order to accomplish the quality survey required for this project, a time commitment for both the field survey and write-up phase must be identified. Assuming a 12 person survey team, approximately 165 "team days" will be required to accomplish the 9775 acre survey. Included within this total is an estimate of 40 "team days" spent in transit. Given a 20-day field session with 8-10 days off between trips, the survey team would be in the field for one session a month over an 8.3 month period. River transit time can be minimized by having crews hike in or out at Phantom Ranch, with boat support deadheading to or from Phantom.

A 12-person survey team (four three-person crews) is deemed appropriate for a variety of reasons. First, four 3-person crews can efficiently operate concurrently on both sides of the river with a single support boat. Three person crews are efficient for field recording purposes, with one person filling out the site card, one mapping, and the third person doing photographs, field analysis, and miscellaneous other tasks. More people on a survey crew, while helpful in some areas, are detractive for site recording purposes and do not constitute efficient use of people.

Consistency is critical in gathering the type of information required for the survey. Too many crews operating in different areas will not be able to produce the consistent quality data required for this project. The more crews involved, the greater the likelihood of differential data collection and inadequate survey coverage.

While the survey is important and the preservation of archeological sites legally mandated, other resource values in the canyon are also important and must be considered. It is imperative that we minimize the number of researchers trampling through the fragile desert environment. Although a smaller number of crews would be more desirable from the standpoint of minimizing environmental impacts, the use of four crews appears necessary in order to meet the project objectives within the present EIS time frame (December 1991). If the EIS time frame is extended, then modification of this plan to include a smaller number of crews (6-9 people) may be appropriate.

The bulk of the survey work survey should be confined to the off-season river months, that is, not the summer season. The inner canyon is much too hot with daily temperatures reaching well over 100 degrees during the summer months. Field crews working under harsh climatic conditions often do not produce good results because they are usually too hot to do as thorough a job as they normally would given reasonable temperatures and shade. Moreover, there are too many commercial trips on the river that would be competing with the survey crew for camps, particularly around attraction sites. The likelihood of the survey crew not being able to camp where they need to is greatly enhanced during high-use river periods. For these reasons, it would be counter-productive to send crews into the canyon in mid-summer.

River support will be the primary means for conducting the survey, although some areas could potentially be reached with air support. During the non-motor season, from October 15 through December 15, oar powered support rafts will be used. The rest of the time, support can be provided by either motor or oar powered rafts, depending on logistical needs. Additional support will be provided by GRCA in conjunction with other resource monitoring and rehabilitation work along the river.

As stated above, the survey should take place during the off-season, primarily fall and winter. Given the time necessary to complete the survey, a late August start date for the full survey crew is recommended, with full-scale field work starting during the first week of September. A orientation trip for field crew members and administrative officials (i.e., State Historic Preservation Officer and tribal representatives) will be scheduled in late August. Survey from Glen Canyon Dam to Badger will be conducted during the summer using existing personnel and summer seasonal help from both GRCA and GLCA. If the survey crews begin full-scale intensive survey in September 1990, they will be finished with the entire survey by early May, 1991.

Data analysis and preliminary report compilation can begin after the crews have begun to collect information and artifacts. Data compilation and analysis will start one months after the field work portion of the project has begun, with basic site information and artifact processing being the focus. A preliminary report detailing the sites found and initial recommendations will be available in early June, 1991. It is estimated that the remainder of the laboratory work will take an eight person staff (two data entry/analysis technicians, the project director, three crew chiefs, a laboratory director, and a secretary) 1060 person days to complete, including all of the analysis and the preparation of a publishable final report. This figure does include time required to prepare and submit National Register nomination forms for sites recorded during the survey.

Using the above figures for both the field survey and laboratory analysis portions of the project, approximately 17 months will be required to complete the survey and prepare a final report.

Analysis and Report

After each field session, the Project Archeologist will prepare a status report detailing the amount of land surveyed, the number of sites recorded, any information related to the sedimentation research, along with any problems that surfaced while in the field. Upon completion of all of the field work, all materials will be brought into the laboratory for processing, analysis, and computer data entry. All artifactual materials will be washed, labeled, bagged and analyzed using an approved system which will include cataloguing into the Automated National Catalog System (ANCS). Project specific artifact analysis will be done for all materials. All site information will be entered into the archeological data base system for both the GRCA specific information and the CSI. Locational information will be provided for the GRCA and BOR Geographical Information System (GIS) system. All locational information and site specific data will be entered into protected files since site information is not public information and is excluded from any Freedom of Information Act requests.

A survey report detailing the project findings will be prepared and will include information related to the project background, objectives, site and artifact information, cultural implications, and a management summary with recommendations. A formal outline of chapters to be included will be finalized prior to the initiation of the write-up. The final report will be published through the Cooperative Parks Studies Unit (CPSU) at Northern Arizona University (NAU), with a distribution run of 1000 copies.

Staffing

Staffing required to complete this project will be jointly managed through GRCA and the CPSU at NAU. The project will be coordinated by the GRCA Project Archaeologist who will report directly to the Park Archaeologist. A field staff including the project director, four crew chiefs, and eight crew members will carry out the field work. A Laboratory Director/ Coordinator will manage the analysis and data base operations. Two data entry technicians will be required to assist with the computer operations. Crew members will be involved with the artifact processing, cataloguing, and data analysis. Report write-up responsibilities will lie with the Project Archaeologist, Crew Chiefs, and Laboratory Director.

Conclusions

This survey design is intended to provide baseline information concerning archeological resources located along the Colorado River in Grand Canyon National Park. Those sections of the river corridor which contain river deposited sediments or lie within the historic high water zone are included in the design. A total of 9775 acres is projected at this time; however, the design is intended to allow flexibility by recognizing that changing field conditions and needs may dictate adjustments within the survey areas and priorities.

It must be understood that survey of an area does not mean that all of the sites have been found and recorded within an area. As has been discovered through the annual GRCA archeological site monitoring program, sites appear and disappear in areas where surveys have been done. Areas within the survey zone which are particularly prone to this occurrence have been documented at Tanner, Basalt, and Nankoweap, to name a few. Follow-up field monitoring and survey must be performed in areas prone to sediment changes and/or erosion. Results from the survey will identify areas which need to be closely monitored in the future and provide the baseline information critical to long-term evaluation of changing site conditions along the river corridor.

The survey results do not represent a static data set. Rather, this data base should provide the foundation for recommendations for continued work along the Colorado River. Minimally, an expanded monitoring program must be instituted which would include the additional sites located as part of this survey. This program must interface with the existing archeological site monitoring program which has been in place at GRCA since 1978. Additionally, appropriate preservation measures must be included in the survey recommendations, ranging from no action to complete data recovery. Wherever possible, the preferred form of site protection must be preservation *in situ*. All avenues of site protection must be explored, including modifications in the operation of Glen Canyon Dam.

Deliverables

1. Progress Reports: After each field session

2. Preliminary Field Report: The report will include all inventory information related to specific components of the EIS and preliminary recommendations for mitigation. Due June 1991

3. Draft Final Report: Inventory information, artifact analysis, and recommendations for mitigation actions related to the EIS. Due August 1991

4. Final Report and National Register recommendations: Complete report including inventory information, cultural history discussion, artifact analysis, and management recommendations for mitigation and river flow regimes. The final report will be published by the CPSU with a run of 1000 copies. Due December 1991.

5. All completed site survey cards, computer analysis information, catalogue information, photographs, slides, artifacts, maps, etc. associated with the survey. Due March 1992.

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GCES ARCHEOLOGICAL SURVEY BUDGET (revised 5/25/90)

Personnel Requirements

	FY 90	FY 91	FY 92	TOTAL
1. Park Archaeologist (20% time)	N/C	N/C	N/C	N/C
2. Project Archaeologist (GS-11) 45 pay periods (7/1/90 thru 4/7/92)	8,325	33,850	16,713	58,888
3. Crew Chiefs (RAII or GS-7)* 36 pay periods x 4 (8/12/90 thru 11/18/91)	14,170	103,729	17,329	135,228
4. Lab Director (RAII or GS-7)* 32 pay periods (10/1/90 thru 12/16/91)	N/C	25,933	5,267	31,200
5. Crew Members (RAI or GS-5)** 24 pay periods x 8 (8/12/90 thru 6/2/91)	21,520	105,299	N/C	126,819
6. Lab Tech/Data Entry (RAI/GS-5) 26 pay periods x 2 (10/1/90 thru 9/30/91)	N/C	36,926	N/C	36,926
7. Secretary (GS-6/1) 26 pay periods	N/C	20,591	N/C	20,591
Subtotal+	44,015	326,328	39,309	409,652
Estimated Cost of Living Increase (4.1% FY 91 & FY 92)		13,380	1,612	14,992
	44,015	**339,708**	**40,921**	**424,644**

Transportation/Equipment

	FY 90	FY 91	FY 92	TOTAL
1. Computer system (w/ laptop field computer)	5,000	10,000		15,000
2. GSA Vehicle Rental (2)	600	7,200	1,800	9,600
	5,600	**17,200**	**1,800**	**24,600**

* Wages are calculated as GS-7/5 to equal NAU RAII pay scale.

** Wages are calculated as GS-5/3 to equal NAU's RAI pay scale.

\+ Personnel costs have been calculated using FY90 wage tables and include "hidden costs" such as Sunday differential/holidays but do not include extra funds for any overtime pay.

	FY 90	FY 91	FY 92	TOTAL
<u>Supplies</u>				
1. Field & Survey supplies (includes topographic maps, aerial photos, cameras, film, pelican boxes, and related camping and survey equipment)	6,500	3,500		10,000
2. Office/Lab supplies		5,000		5,000
	6,500	**8,500**		**15,000**
<u>Miscellaneous</u>				
1. GRCA-GLCA co-ordination		3,350		3,350
1. Specialized analyses		5,000		5,000
2. Report Prep/illustration		10,000		10,000
		18,350		**18,350**
<u>Curation Costs</u> (10% of field personnel costs)			26,120	
TOTAL DIRECT COSTS (by fiscal yr.)	56115	383758	68,841	508714
INDIRECT COSTS				
(20% NAU personnel)***	7138	60894	4705	72737
River logistical support ++ 2016 person days on river (includes August and Sept. trips through OARS contract)	54294	70583		124877
Cost Breakdown for River Support:				
OARS contract costs	23184			
GRCA costs	31110	70853		
TOTAL COSTS (by fiscal year)	**117547**	**515235**	**73546**	
TOTAL PROJECT COST ESTIMATE				706328

*** It is assumed that NAU office rental (20 months) is included as part of the indirect NAU costs. If office space rental is not covered by the NAU indirect costs, an additional $24,000 will need to be added to the project budget:

	FY90	FY91	FY92	TOTAL
Office rent at @ $1200/month	2,400	14,400	7,200	24,000

++ River logistical support costs are based on using the GCES contractor for August and September, 1990, and NPS support thereafter. Savings of $14,227 will result from using NPS River Subdistrict instead of the GCES contractor.

ECONOMIC

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTEGRATED RESEARCH PROGRAM

ECONOMIC STUDIES

I. Issues

The Glen Canyon Environmental Studies (GCES) has been expanded to include the development, analysis and inclusion of economics.

II. Objectives

The objectives of the GCES Economics Program can be broadly stated as follows:

A. Identification of the primary economic program components, boundaries, and parameters of action.

B. Identification of the primary roles of the individual groups and offices in completion of the economic work, and

C. Completion of a process whereby the results of the economic program can be integrated together and tied into the technical GCES efforts.

III. Components of the GCES Phase II Economic Studies

The components of the GCES Economic Studies can be separated into three distinct areas and are depicted in Figure _12_.

A. Power Resource's Studies - evaluation of the potential economic and financial costs impact associated with modification of the flows at Glen Canyon Dam.

B. Recreation Studies - evaluation of the potential cost impacts to the recreation industry as a result of modification of the flows at Glen Canyon Dam. This includes three primary recreation types:

1. Fishing
2. Day-use rafting

3. Whitewater rafting

C. Non-Use Value or Resource Economic Studies - evaluation of the potential impact on the "worth" of the resources of the Grand Canyon as a result of flow modifications at Glen Canyon Dam.

IV. Organization of the GCES Economic Studies

The overall GCES economic studies will be guided by a coordinated technical economic group defined as the Economic Coordination Team (ECT). The ECT will be composed of representatives of the power, recreation and resource economic study groups. The ECT will be responsible for the overall integration of the individual study efforts, oversight of the economic programs and ultimately responsible for the development of the GCES Economic Report. All work of the GCES Economic Coordination Team will be integrated with the GCES Scientific Core Team.

Representation on the ECT will include, but not be limited to, the following groups:

Reclamation - Power resource leader
Reclamation - Denver office
Western Area Power - Marketing representation
Power Community
Environmental Defense Fund - ELFIN expertise
National Park Service
Fish & Wildlife Service - non-use value economics
Water community - a Seven Basin state representative
GCES contractor
GCES Office

The leadership roles for the three subteams will be as follows:

Power Resource Committee - Mike Roluti
Recreation Economics - GCES
Resource Economics - GCES

The overall leadership for the ECT will rest with GCES or a designated alternate. The GCES Senior Scientist and/or the GCES Economic Research Analyst will have the overall responsibility to integrate all of the GCES Economic Studies into the overall GCES program. Additional review entities may be brought on board to assist the Senior Scientist in his evaluation of the overall economic program.

A. Power Resource Studies

The Power Resource studies are being coordinated through the Denver Office, Bureau of Reclamation. The objectives of the power resource studies are to develop and apply methodologies for evaluating operational impacts to the cost and availability of power and energy from Glen Canyon Dam. The Power Resource studies can be separated into the following phases:

Phase I. Development of a prototype study to evaluate the relationships between three types of power modeling approaches:

1. EGEAS
2. ELFIN
3. Western Area Power

Phase II. Selection of a (or multiple) power modeling approach that will be used to assess the impacts of the operational modifications proposed during the GCD-EIS program. Specific Modeling requirements will be handled through a contract with Reclamation.

Phase III. Identification and quantification of what the changes in power revenues will have on the repayment program for the CRSP.

The overall coordination of the Power Resource Team will be Mike Roluti, Denver Office.

B. Recreation Studies

The GCES recreation studies were initiated primarily during the initial phase of the GCES program and will not require significant additions or modifications for the GCD-EIS needs. The primary areas of concern are as follows:

Phase I. Completion of the fishery resource economics as related to fluctuating flows. This is completed for the section from Lee's Ferry upstream to Glen Canyon Dam.

Phase II. Evaluate the impacts of fluctuating and constant flows on the whitewater and day-use rafting. This is primarily a verification process and should not require substantial field efforts.

Phase III. Evaluate the overall impacts of flow modifications to the recreation industry in the Grand Canyon.

The recreation studies will be coordinated through the GCES Flagstaff Office. The GCES Program Manager will be assisted in this effort by a contractor.

C. Non-Use Value and Resource Economics

A major area of concern raised by the resource bureaus of the Department of the Interior and the resource agencies of the State of Arizona has been the relationship between flow modifications and the non-use values of the Grand Canyon. This is a relatively new economic perspective that has been gaining extreme importance as decisions are being based more on the overall needs of society.

The resource economics study will occur in several phases:

Phase I. Completion of a literature review of the use and relationship of resource economics and the operations of federal and state facilities.

Phase II. Determination of the role that resource economics should play.

Phase III. Completion of surveys, studies, and analyses required.

The GCES program office will enter into a contract to provide the primary data accumulation and analyses with overall economic guidance being provided by the ECt.

V. Products to be Developed

A. Power Resource Team

1. Develop a <u>Management Plan</u> on the conduct of the power resource program efforts
2. Distribute the Prototype Power Modeling Report
3. Develop the RFP for the Power Modeling effort - full
4. Develop the CBD notice for power resource review
5. Develop the contract for EDF interaction
6. Development of a protocol for evaluation of impacts
7. Development of a process to evaluate impacts to rates and repayment

B. Recreation Economics Work Group

1. Organization of program requirements - contractor
2. Development of surveys and programs
3. Completion of program requirements

C. Resource Economics Group

1. Organization of the work group
2. Completion on literature review
3. Completion of work activities
4. Development of analyses

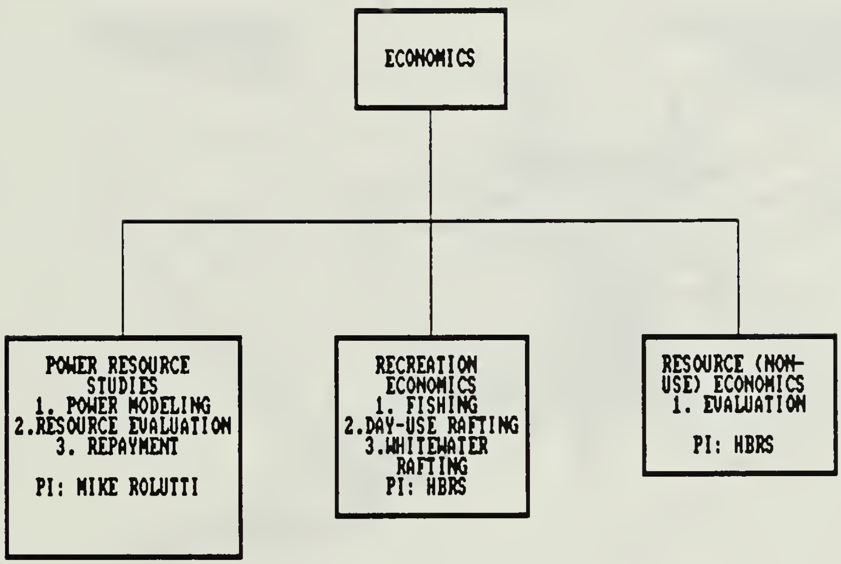
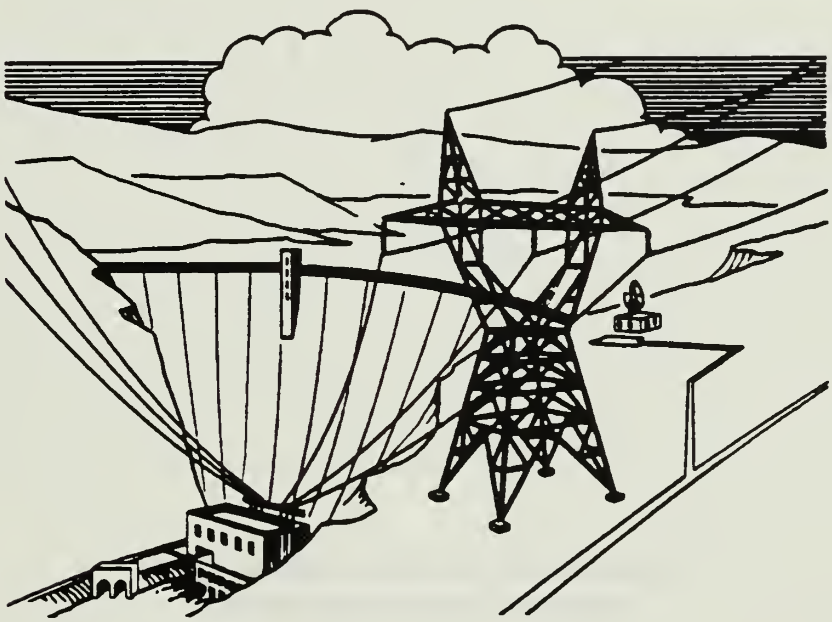


Figure 12. Glen Canyon Environmental Studies Phase II Economic Studies.

DRAFT

POWER RESOURCES MANAGEMENT PLAN



Glen Canyon Environmental Studies
Power Resources Committee

July 1990

DRAFT

POWER RESOURCES MANAGEMENT PLAN

Glen Canyon Environmental Studies
Power Resources Commitee

July 20, 1990 Draft

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SECTION 1: INTRODUCTION

Purpose of the Management Plan

The purpose of this management plan is to provide guidance to the Power Resources Committee in developing and implementing methodologies that can be used to evaluate the power resource impacts of potential changes in operations at Glen Canyon Dam. This document will also clarify the role of the Power Resources Committee within the overall context of the Glen Canyon Environmental Studies (GCES) and the Glen Canyon Dam Environmental Impact Statement (GCDEIS) process. Finally, this document will provide other members of the GCES, and interested members of the public, with a basic understanding of the efforts of the Power Resources Committee.

It should be kept in mind that this management plan has been developed to cover a wide variety of issues that have been identified through the GCES process to date. Undoubtedly, as the GCES and the GCDEIS process proceeds, additional information may arise that will require modification of this management plan. Consequently, the various updates of this management plan can provide an historical record of the development of the work effort of the Power Resources Committee.

Location and Geographic Extent

Glen Canyon Dam is located on the Colorado River near Page, Arizona (Figure 1.1). The power produced at Glen Canyon Dam is managed by Western Area Power Administration (Western) as part of the Salt Lake City Area Integrated Projects (SLCA/IP). Other hydro units producing power marketed under the SLCA/IP include the other Colorado River Storage Project units (Crystal, Flaming Gorge, Morrow Point, and Blue Mesa), the Rio Grande Project (Elephant Butte) and the Collbran project (Upper Molina and Lower Molina). The capacity of these units are shown in Table 1.1. The locations of these units are shown in Figure 1.2. Glen Canyon Dam represents roughly 80 percent of the physical capacity and roughly 80 percent of the energy marketed under SLCA/IP. Western's total SLCA/IP firm power contracts represent winter capacity of 1,291 mW and a summer capacity of 1,269 mW. The SLCA/IP seasonal energy associated with these contracts is 2,672,825 mWh in the winter and 3,028,882 mWh in the summer. Over 80 percent of the capacity and energy contained in these long-term firm contracts is sold to members of the Colorado River Energy Distributors Association (CREDA). Customers for SLCA/IP firm power are separated into a Northern Division and a Southern Division. Sales of SLCA/IP

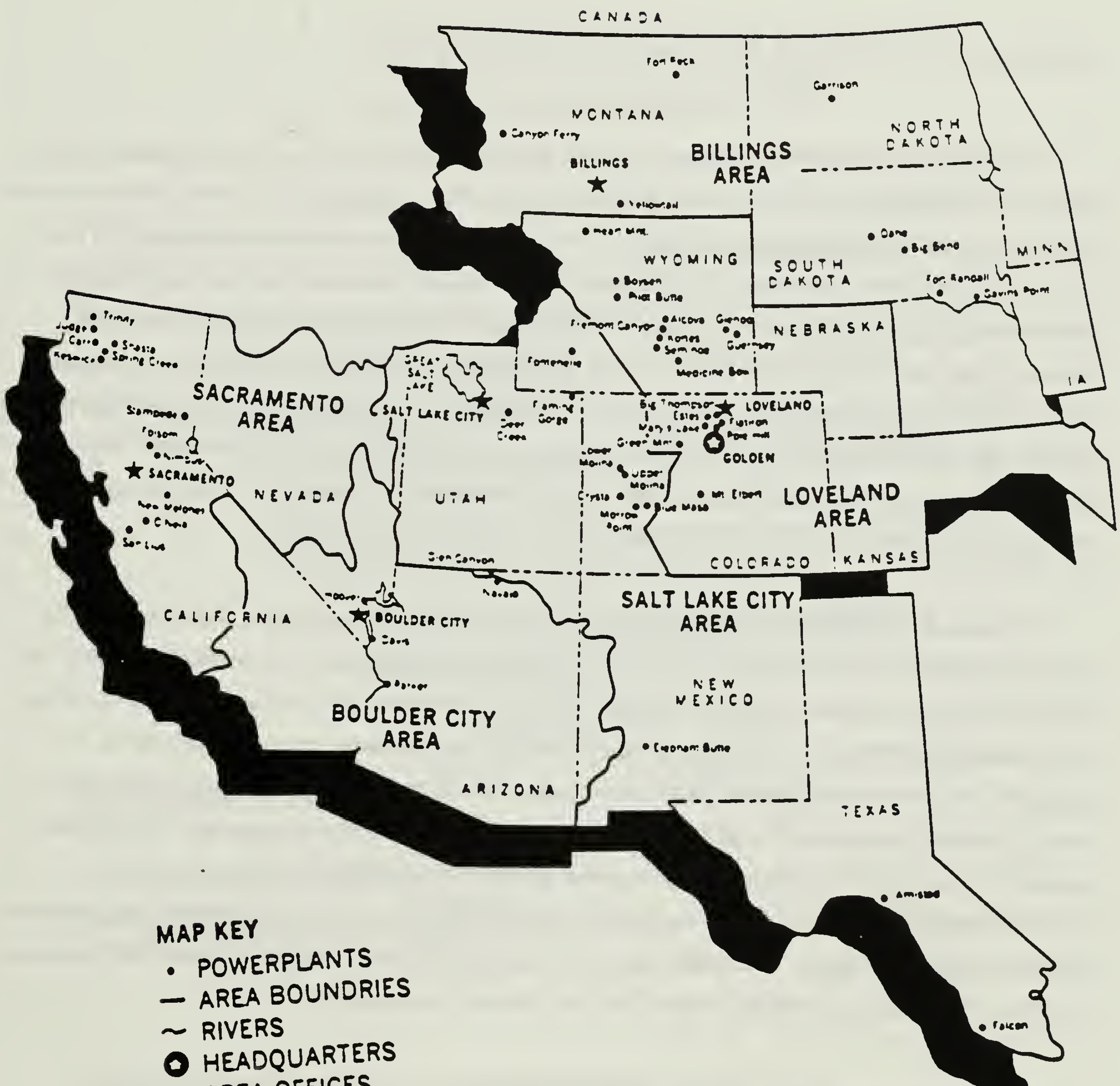
Table 1: Capacity at SLCA/IP Plants

Project	Powerplant	Number of Power Units	Water Year 1989 Total Installed Capacity	Water Year 1989 Maximum Operating Capacity	Water Year 1990 Total Installed Capacity	Water Year 1990 Maximum Operating Capacity	Water Year 1991* Total Installed Capacity	Water Year 1991* Maximum Operating Capacity	Water Year 1992* Total Installed Capacity	Water Year 1992* Maximum Operating Capacity
CRSP Storage Units										
Aspinall	Blue Mesa	2	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0
	Crystal	1	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0
	Morrow Point	2	146.0	146.0	172.0	172.0	172.0	172.0	172.0	172.0
Flaming Gorge	Flaming Gorge	3	132.0	132.0	132.0	132.0	144.0	144.0	150.0	150.0
Glen Canyon	Glen Canyon	4	1,356.0	1,300.0	1,356.0	1,300.0	1,356.0	1,300.0	1,356.0	1,300.0
Navajo	None	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRSP Total		16	1,758.0	1,702.0	1,784.0	1,728.0	1,796.0	1,740.0	1,802.0	1,746.0
Participating Projects										
Seedskedee	Fontenelle	2	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Collbran	Lower Molina	1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Upper Molina	1	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Rio Grande	Elephant Butte	1	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Participating Projects Total		5	51.0	51.0	51.0	51.0	51.0	51.0	51.0	51.0
INTEGRATED PROJECT TOTAL		21	1,809.0	1,753.0	1,835.0	1,779.0	1,847.0	1,791.0	1,853.0	1,797.0

*Projected capacity production capability.

Figure 1.1: Location of the Glen Canyon Dam

Figure 1.2: Location of the Dams in the SLCA/IP Area



nonfirm power are made throughout the marketing area, as well as California. While all of the production of SLCA/IP power occurs under the Salt Lake City Area office of Western, sales of SLCA/IP power are made through the Boulder City, Nevada, and Loveland, Colorado, offices as well as through the Salt Lake City office (Figure 1.3).

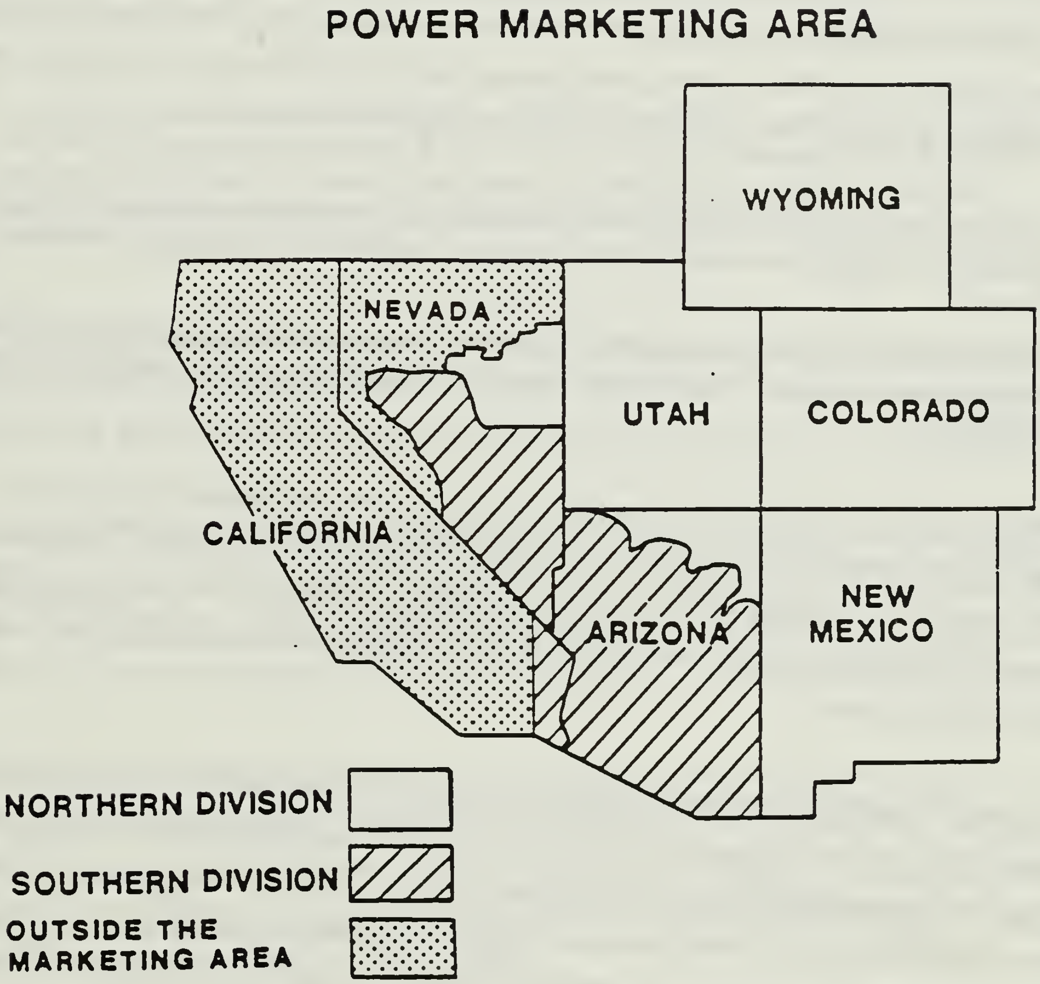
Relation of GCDEIS to the Western Marketing EIS

The GCDEIS is the result of a request from the Secretary of Interior that an environmental impact statement be prepared for the operations of Glen Canyon Dam. During the time period that Interior was making this decision, Western was involved in a lawsuit centered around issues associated with the criteria Western uses in marketing SLCA/IP power. One result of this lawsuit was an agreement by Western that they would prepare an EIS on the Salt Lake City Area Integrated Projects Post-1989 General Power Marketing and Allocation Criteria. These criteria establish the terms used to allocate capacity and energy generated by the SLCA/IP. Consequently, two separate EISs will be prepared. The GCDEIS will be prepared with the Bureau of Reclamation as the lead agency. The Western Marketing EIS will be prepared with Western as the lead agency. Since both EIS efforts are to be comprised of interagency activities, it is intended that the two documents will be compatible.

The focus of the GCDEIS is to analyze the impacts of various dam operation alternatives on the environment downstream from Glen Canyon Dam. While the alternatives to be considered during the GCDEIS have not yet been finalized, it is likely that these alternatives will include (in addition to a no-action alternative) various modifications of dam operations and perhaps structural alternatives. A complete analysis of the impacts of these alternatives will require research covering a wide range of topics, including the economic and financial consequences of the various alternatives. A complete analysis of the economic consequences for power generation will require, in turn, a thorough understanding of the production and marketing of power produced at Glen Canyon Dam and perhaps the other SLCA/IP projects. It is evident there is an obvious and clear relation between the activities of the Power Resources Committee of GCES and the Western Marketing EIS.

Western can evaluate alternative marketing criteria prior to and without knowing the specific operational changes that may be adopted for Glen Canyon Dam. Likewise, a Department of Energy (DOE) decision to change Glen Canyon water release operations can be made prior to DOE decisions on marketing criteria, recognizing certain residual effects on availability and value of peaking power (capacity and energy); therefore, it is not essential, nor necessarily desirable, that a combined single EIS or decision be issued.

Figure 1.3: SLCA/IP Marketing Area



The scoping process for the Western EIS will begin in late 1990. The schedule for completion of the Western EIS has not been determined.

Authorization

In December 1982, the Commissioner of the Bureau of Reclamation authorized the Glen Canyon Environmental Studies (GCES) to investigate how the current operations of the dam impact the riverine environment of the Colorado River between Glen Canyon Dam and Lake Mead. In his original 1982 charge to GCES, the Commissioner directed researchers to address two questions:

1. Are current operations of the dam, through control of the flows in the Colorado River, adversely affecting the existing river-related and recreational resources of Glen Canyon and Grand Canyon?

2. Are there ways to operate the dam, consistent with Colorado River Storage Project (CRSP) water delivery requirements, that would protect or enhance the environmental and recreational resources?

In cooperation with the National Park Service and the U.S. Fish and Wildlife Service, it was determined that the research to answer these two questions should focus on biology, sedimentation, and recreation. A total of 42 separate studies were completed and integrated to form the Glen Canyon Environmental Studies Final Report (see Appendix A for full citations of all documents), which was completed in January 1988.

The research described in the final report was reviewed by a committee from the National Academy of Sciences (NAS), with particular emphasis on the process for integration (National Research Council, 1987). The NAS review identified a need for additional study and recommended, among other things, that future work "should seek to clarify the costs, benefits, and tradeoffs between power generation and recreation opportunities." A supplement to this report, dated July 1988 and attached to a letter from Dr. G. Richard Marzolf, chairman of the review committee, to Mr. David L. Wegner, program manager for GCES, elaborates on this theme:

> Recommendation 3. Perform an Economic Analysis. An operations analysis should be developed to evaluate both the costs of lost power revenues and the cost of buying additional peak period energy from alternative sources, as well as the potential benefits to other user sectors, e.g., recreation and environment. . . The committee believes that the analysis must be based on the results from a model in which the operating rule is treated as a variable that is explicit in the model (stated formally and completely in mathematical terms). The logic of the model structure should be available to the user so that sensitivity of results (frequency of spills and target release shortages) to changes in the operating rule

> can be obtained by changing the rule. The method of selecting monthly release targets as a function of current storage, snowpack, in addition to minimum flows at night, and so on, should be stated. . . .(pp. 6-7, emphasis in original).

Also submitted to the Department of the Interior, was a report of the GCES Executive Review Committee (ERC) (Glen Canyon Environmental Studies, Executive Review Committee, 1988). The ERC is a management and policy-level group representing the Bureau of Reclamation, the National Park Service, the Fish and Wildlife Service, the Office of Environmental Project Review within the Department of the Interior, and the Western Area Power Administration. The ERC concluded (p. 3) that

> "...GCES have shown that the operations of Glen Canyon Dam do affect the natural and recreational resources downstream from the dam, and that some ways of operating the dam have more negative impacts than others. The GCES also identified operational options, within existing legal and operational mandates, that could reduce impacts related to specific resources."

However, the agencies represented on the ERC failed to reach unanimous agreement that the negative impacts were sufficient to justify changes in operations at Glen Canyon Dam. Several questions were raised about the adequacy of GCES results for making decisions about dam operating criteria.

The Department of the Interior subsequently decided to continue the GCES to collect additional information to support decisions regarding potential changes in dam operations. In a letter dated June 16, 1988, the Department requested additional studies, including a detailed economic analysis of operations options to be conducted during GCES Phase II.

Subsequent to the June 16, 1988, letter, the Secretary of Interior has requested that an environmental impact statement be prepared for the operations of Glen Canyon Dam. While the GCES are distinct from the GCDEIS, the research plans developed under GCES are designed to support the preparation of the GCDEIS. The research performed by the Power Resources Committee will be designed to support the GCDEIS in a timely manner.

GCES Organization

Study Boundaries. The GCES Phase I was designed to understand the downstream impacts of the operations of Glen Canyon Dam. As such, the geographic boundaries of GCES were determined by the environment affected by the Colorado River below Glen Canyon Dam. This focus has continued for the biological and physical studies to be carried out during GCES Phase II. However, the boundaries of the economic studies are much broader. In particular, at a minimum, the boundaries for the Power Resources Committee are defined by the SLCA/IP marketing area.

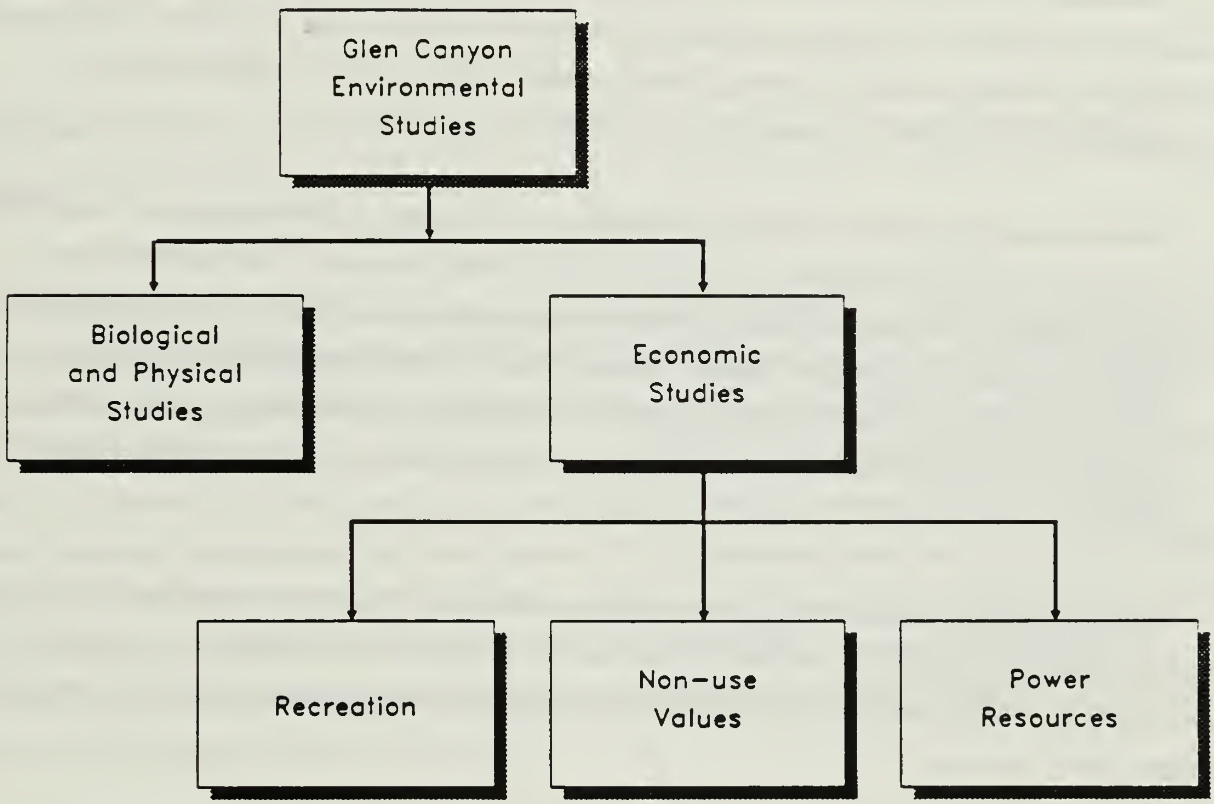
Role of the Power Resources Committee Within GCES. In understanding the role of the Power Resources Committee, it is convenient to separate the GCES Phase II studies into environmental studies and economic studies (Figure 1.4). The economic studies will be conducted under the guidance of the GCES Economic Team. The GCES Economics Team may conduct studies in three primary areas: recreation, non-use values and power resources. The purpose of all of the economic studies will be to measure the impacts of changes in operations at Glen Canyon Dam in each of the three relevant areas. Furthermore, these studies will be designed so that each of the economic studies will produce results that are comparable. In achieving this comparability all members of the GCES economic team will be guided by the economic framework described in Economic and Environmental Principles and Guidelines for Water and Related Land Resources Projects (US Water Resources Council 1983). In addition to overseeing research to address the three issues above, the economic team will produce a final report integrating the results of the research in each of the three areas.

Final Report of the Power Resources Committee. The power resources Committee will prepare a final report summarizing the economic and financial impacts of each alternative explored in the GCDEIS as well as alternatives proposed by GCES biological and physical researchers.

Participants in the Power Resources Committee

During GCES Phase II, the efforts directed toward selecting a methodology to measure the economic impacts of a change in operations at Glen Canyon Dam focused on understanding the economic, as opposed to financial, impacts. The group conducting this effort was, consequently, often referred to as the Power Economics Group. It is anticipated that the individuals serving on the Power Economics Group of GCES Phase II will be the same individuals associated with the work effort described in this management plan. However, since the present work effort involves more than a purely economic analysis, it has been suggested that this group now be referred to as the "Power Resources Committee."

Figure 1.4: Position of the Power Resources Committee Within GCES



U.S. Bureau of Reclamation. The U.S. Bureau of Reclamation (Reclamation) is a federal agency in the Department of the Interior that has been responsible for the construction of more than 500 water projects in the western United States. Reclamation operates 52 powerplants with an installed capacity of 13,500 megawatts (mW). The Western Area Power Administration and the Bonneville Power Administration market energy produced by Reclamation powerplants in excess of Reclamation project requirements.

Colorado River Energy Distributors Association. The Colorado River Energy Distributors Association (CREDA) is a nonprofit organization comprised of wholesale and retail electric utility systems or agencies providing service in Wyoming, Utah, Colorado, Arizona, Nevada, and New Mexico. A membership list is attached in Appendix B.

The retail utilities, which themselves are members or are serviced by CREDA members, range in size from fewer than 100 retail customers to more than 450,000 retail customers. Municipalities, state agencies, rural cooperatives, and utility associations are represented by CREDA. In total, approximately 1,000,000 households, or 2,850,000 persons, receive electricity through the CREDA membership. In serving these consumers, the CREDA member systems (including the retail electric utilities served by wholesale members of CREDA) cover a large portion of the six-state marketing area for the SLCA/IP electricity.

CREDA members have existing contracts for approximately 1,077 mW of summer and 1,085 mW of winter capacity from the SLCA/IP of which Glen Canyon represents the largest source. Firm electric energy to the CREDA members associated with their SLCA/IP contract is about 4,802,100 megawatt-hours (mWh) annually.

Environmental Defense Fund. The Environmental Defense Fund (EDF) is a not-for-profit organization established in 1967 and dedicated to the protection and rational use of natural resources, and to the preservation and enhancement of the human environment. EDF has offices in New York, New York; Oakland, California; Washington, D.C.; Richmond, Virginia; Raleigh, North Carolina; and Boulder, Colorado. EDF has more than 100,000 members.

Western Area Power Administration. The Western Area Power Administration (Western) was established in 1977 to market and transmit power produced at 50 federal powerplants owned by the Army Corps of Engineers, Reclamation, and the International Boundary and Water Commission.

Western serves 597 wholesale power customers in 15 western states, including electric cooperatives, municipalities, public utility districts, investor-owned utilities, federal and state agencies, irrigation districts, and Reclamation projects and facilities.

Contractors. In addition, it is anticipated that two contractors will be hired to participate in the Power Resources Committee. One of these contractors will have an extensive background in environmental and resource economics. The other contractor will have a strong background in power systems modeling.

Review and Recommendations from Previous GCES Power Resources Work

Power Evaluation Methodologies. During the first year of GCES phase II, the Power Resources Committee explored the suitability of three power valuation methodologies for measuring the economic impacts to power values caused by changes in operations at Glen Canyon Dam. The three methods included a generation expansion model (EGEAS), a production cost model (Elfin) and a version of the alternative thermal plant (ATP) method. The methodologies were implemented using (to the greatest extent possible) identical inputs, and study periods. The methodologies were evaluated in terms of their outputs, cost of implementation and their ability to address critical issues related to the operation of Glen Canyon Dam and the marketing of power from SLCA/IP. A secondary purpose of this effort of the Power Resources Committee was to establish a working relationship between representatives from the various affected agencies and interest groups.

In the executive summary for their report (Appendix C), the Power Resources Committee recommended that both the EGEAS model and the Elfin model be used to evaluate the economic impacts of changes in operations at Glen Canyon Dam. The ATP method was found to be deficient in its ability to explicitly represent important features of the power system.

Recommendations. In the course of exploring the use of power systems models for the evaluation of the economic impacts of changes in operations at Glen Canyon Dam, several related issues were addressed. These issues were not the main focus of the Power Resources Committee effort; however, it became obvious during the course of the investigation that a complete understanding of the economic impacts must address these three important issues. These issues are briefly described here and in greater detail in the scope of work section (Section 2).

Determination of the Marketable Resource. During the preparation of the report of the Power Resources Committee, the central role played by the determination of the marketable resource also became apparent. Changes in operations at Glen Canyon Dam could change the amount of capacity and/or energy that Western sells under SLCA/IP long-term firm contracts. Depending on the nature of the analysis, changes in the marketable resource may be a required input to the power system model. In addition, a change in the marketable resource can have implications for the rate that is charged under the long-term firm contracts. The report of the Power Resources Committee recommended that a methodology be devised that would show the impacts to the determination of the marketable resource of each of the proposed alternative dam operations.

Impact to Long-Term Firm Power Rates. Any change in the operations at Glen Canyon Dam may result in a change in the rate charged for long-term firm power from the SLCA/IP. While rates may not play a key role in the economic analysis of changes in operations, they are a key factor in the financial analysis (Figure 1.3). In their report, the Power Resources Committee recommended that impacts to rates be included as part of the description of the consequences of each alternative dam operation.

Small Systems Analysis. The report recognizes that power systems models have important advantages for understanding how SLCA/IP customers might change their own power production in response to changes in operations at Glen Canyon Dam. While large customers having their own power generation resources account for a significant portion of the purchased SLCA/IP power, there are a large number of very small SLCA/IP customers having no generation resources. Measuring the impacts of changes in operations at Glen Canyon Dam using a system-modeling approach is not appropriate for these small customers because they have no generation resources of their own to replace lost hydro power. To measure the impact of change on these small customers, the Power Resources Committee recommended developing a simple spreadsheet methodology. This methodology would be based on the fact that most of these small SLCA/IP customers have only a few sources from which they can purchase power if their allocation of power from the SLCA/IP is changed. There is a likelihood that the information gained from modeling the larger SLCA/IP customers can provide valuable information to be used in the small system methodology.

Other Evaluation Issues

In addition to the three important evaluation issues discussed above, five other issues related to the study process and the evaluations are mentioned here. Some of these issues arose during the evaluation of methods to measure power systems impacts and some arose during subsequent meetings and discussions.

- Responding to Public Comment. In addition to analyzing the economic and financial impacts of changes in operations at Glen Canyon Dam, the Power Resources Committee will designate a member to review all public comments made during the scoping process. This review will ensure that the Power Resources Committee's research agenda will be able to address all important issues raised during the scoping process. In addition, the Power Resources Committee will designate a member to respond to all of the comments relevant to power resources made during the period allowed for commenting on the draft EIS.

- Independent Review of Power Resource Effort. All components of the GCES are undergoing independent review to ensure the proposed research meets reasonable professional standards of experts in various research areas studied by GCES. The Power Resources Committee proposes to fulfill this function in one of two ways. Experts in the area of power evaluation may be selected by Dr. Duncan Patten to serve as part of the a panel of independent reviewers he has established to oversee GCES research. A second alternative would establish a contract with a nationally recognized expert in power evaluation to serve in the role of independent reviewer.

- Environmental Impacts at Other Sites. It is possible that the various operations alternatives might result in changes in air quality at thermal generation sites. Part of the output of the analysis of the impacts to large systems will include changes in emissions as a result of the changes in thermal generation patterns caused by changes in hydro operations. The analysis of emissions at the various thermal plants may provide insight as to whether the alternative being analyzed is likely.

- Unique Benefits of Hydropower. The evaluation of hydro power is complicated by several related features of hydro power: the ability to provide spinning reserves, the ease with which hydro power can follow load, and the ability of hydro power to quickly respond to power system emergencies. These features of hydro may be difficult to quantify. However, we propose to include descriptions of the impacts of the various operations alternatives on the ability of SLCA/IP to fill these roles for hydro power. This approach will require that the specification of the alternatives to be analyzed must include not only descriptions of minimum flows, maximum flows, and ramping rates but also descriptions of the types of deviations that would be allowed for response to adverse hydrologic conditions and/or system emergencies. If these details are provided for each set of alternative operations, the Power Resources Committee can provide a narrative description of the impacts of the alternative on these less tangible benefits of hydro power.

- Nontraditional Power Sources. In the analysis of impacts to the larger systems, a key input will be the description of the power resources that can be chosen by the power system model to replace any decrease in long-term firm energy from SLCA/IP. In recent years, increasing attention has been paid to including nontraditional power sources in the menu of choices. These nontraditional sources include conservation efforts such as demand-side management programs to reduce the overall electrical use, and time-of-use pricing designed to reduce peak demands. The nontraditional sources also include new technologies to provide power such as wind power, and solar power. As discussed in the section on measuring the impacts to large systems, an attempt will be made to include a variety of nontraditional sources in the modeling of impacts to large systems (see Section 2).

To address the issue of evaluating nontraditional resources, a literature search to identify source material that might be useful in understanding the potential for, and probable cost of, implementing various energy conservation programs was conducted as part of GCES Phase II. The literature search was performed by the Bureau of Reclamation Denver Office Library and covered the following topics: energy conservation, load management, demand-side management, least-cost planning, and electric utility environmental impact statements. Three data bases were accessed for the literature search. They were Compendex Plus, Electric Power Data Base, and Inspec. A short description of each data base is included here, followed by a table listing the number of citations for all three data bases for five areas of information about nontraditional power sources.

- The Compendex Plus data base contains approximately 2.5 million records dating from 1970 to the present. This data base is the machine-readable version of the *Engineering Index* (monthly/annual), which provides abstracted information from the world's significant engineering and technological literature. The Compendex Plus data base provides worldwide coverage of approximately 4,500 journals and selected government reports and books. Subjects covered include: civil, energy, environmental, geological, and biological engineering; electrical, electronics, and control engineering; chemical, mining, metals, and fuel engineering; mechanical, automotive, nuclear, and aerospace engineering; and computers, robotics, and industrial robots. In addition to journal literature, over 480,000 records of significant published proceedings of engineering and technical conferences formerly indexed in Ei Engineering Meetings are included.

- The Electric Power data base contains nearly 30,000 records from 1971 to the present. This data base includes references to research and development projects of interest to the electric power industry and corresponds to the printed work, *Digest of Research in the Electric Utility Industry.* The Electric Power Data base covers U.S. and Canadian research on 13 major categories related to issues in electric power including hydroelectric power, fossil fuels, nuclear power, transmission, economics, advanced power systems, and environmental assessment. The records include abstracts of project summaries for past and ongoing research projects. Such projects are conducted largely by companies under contract to EPRI or to other utilities, and by EPRI itself. Research from other corporate and utility sources is also covered.

- The Inspec data base contains nearly 3.5 million records dating from 1971 to the present. This data base corresponds to the printed *Physics Abstracts, Electrical and Electronics Abstracts, Computer and Control Abstracts*, and *IT Focus* of the *Science Abstracts*, a family of abstract journals, indexes, and title bulletins. Non-English-language source material is also included, but abstracted and indexed in English. The principal subject areas are indicated by the major headings of the classification approach used for the Inspec data base (e.g., Atomic and Molecular Physics; Computer Programming and Applications; Computer Systems and Equipment; and Elementary Particle Physics). Journal papers, conference proceedings, technical reports, books, and university theses are abstracted and indexed for inclusion in the Inspec data bases. The total number of journals scanned is approximately 3,900.

The literature search resulted in over 600 citations (see table below). The complete list of citations is available for each key word. This list will be reviewed and the Denver Office Library will obtain copies of those publications that appear to be useful to support GCES and the GCDEIS process.

Keywords Used and Number of Citations

Keyword	Number of Citations
Energy Conservation	297
Load Management	213
Demand-Side Management/Planning	78
Least-Cost Planning	24
Electric Utility Environmental Impact Statements	20

SECTION 2: SCOPE OF WORK

The scope of work section defines the four major research areas that the Power Resources Committee proposes to investigate: definition of marketable resources, the impact to long-term firm contract rates, evaluation of impacts to small utilities, and, finally, evaluation of the impacts to large utilities. The discussion in each research area covers the critical analysis issues to be considered and identifies the methodology that will be used to measure impacts. The nature of the outputs or products resulting from the analyses are discussed more completely in Section 3. The scope of work discussion is preceded by a brief discussion of the terminoloy used in this section.

Terminology. This management plan is intended to be understandable to members of GCES, members of the GCDEIS team, as well as interested members of the public. To help achieve this goal a glossary of terms has been prepared (see Appendix D). However, two terms are discussed here in more detail because they describe complex, interrelated situations are subject to misunderstanding and confusion.

Hydrology. In this document, the term hydrology will refer to the amount and timing of precipitation falling in the Colorado River basin. The hydrology to be used in this study may be both actual and simulated. First, the hydrology may be based on an historical series of actual precipitation records for the Colorado River basin. Second, the hydrology may be based on a simulated set of precipitation. The simulated hydrology would be generated in such a way that it is representative of the historical records of precipitation patterns in the Colorado River Basin.

The hydrology will serve as input to the Colorado River Simulation Model (CRSM). The CRSM will be initialized with specified reservoir levels. The output from the CRSM model will be reservoir level, inflow, outflow, capacity and energy on a monthly basis.

Marketable Resource. The capacity produced by the CRSM is the maximum instantaneous rate at which electricity can be produced. This capacity is a function of the hydraulic head during the month. The energy produced during the month is determined by the volume of water released during the month.

It is important to note that the CRSM does not address the relation between the energy available during a month and the amount of time for which generation can occur at the capacity level for a given month. Consider Glen Canyon Dam as an example. The physical capacity of Glen Canyon Dam is 1356 mW. This capacity is the output of the generators at the critical head.

When the critical head exceeds the hydraulic head, the generators will be unable to generate at the rated capacity. In any given month, the hydraulic head may differ from the critical head so that the capacity for the month is less than the rated capacity of 1356 mW. Suppose that for the next month, the CRSM indicates a capacity of 1000 mW and an energy of 400,000 mWh with a release of 800,000 acre feet. Each acre-foot of water would result in generation of .5 mWh. Given these relations there is only enough water in the monthly release to generate at capacity of 1,000 mW for 400 of the 720 hours in a 30-day month.

In determining the amount of capacity and the associated energy from a hydro project, the analyst must take account of the relation between the physical capacity of the hydro plant as determined by the hydraulic head, and the amount of time that capacity can be supported, as determined by the total volume of water available for release. The amount of energy and capacity in any given time period will vary as a result of the hydrology. After conducting a probabalistic analysis of the energy and capacity, it is possible to write contracts for long-term power. These contracts could specify at a minimum the amount of capacity and energy that is available on a long-term firm basis. Of course in any particular time period, the actual capacity and energy available may differ from the amount specified in the long-term firm contracts. If the power available exceeds the amounts in the long-term firm contracts, the excess can be sold. Depending on the hydrology, this excess power can be sold as firm or non-firm power on either a short-term or long-term basis.

In this report, the term "marketable resource" refers to all the energy and capacity that is sold. A marketable resource study merely determines the amounts that are sold as firm power under long-term contracts plus the amounts that are sold outside of the long-term firm contracts.

Determining Marketable Resources

This part of Section 2 provides a brief description of how Western determines marketable resources from the Salt Lake City Area Integrated Projects for long-term marketing purposes and for day-to-day operations purposes. The study process discussion that follows covers the scope of work and the resources required to define marketable resources for this study. A list of the work products and those responsible for delivering the products is provided at the end of this discussion.

Western's Process for Determining Marketable Resources. The long-term marketing of firm power produced at the Colorado River Storage Project facilities and other facilities of the Salt Lake City Area Integrated Projects (SLCA/IP) is accomplished by establishing marketing criteria through a public participation process. On February 7, 1986, Western published the SLCA/IP Post-1989 Marketing Criteria and Allocation Criteria in the Federal Register. In essence, the criteria provided the basis for 1) determining long-term firm marketable power, 2) the requirements for determining applicant eligibility to receive an allocation of federal power from the SLCA/IP, 3) the distribution and allocation methods to be used to determine individual allocations, and 4) general contract terms and conditions to be included in all long-term firm electric service contracts. Once total available long-term firm power has been quantified, resource pools established, pools allocated, and individual power contracts executed, the day-to-day scheduling, delivery, accounting, and monthly billing of power is accomplished through Western's Montrose District Office.

After seasonal contractual commitments of capacity and energy have been established in firm power contracts, monthly schedules consistent with the provisions of the contracts are prepared between the customers and Western's Montrose District Office. Existing contracts have several provisions that dictate the pattern of schedule and delivery of power from Western, such as the requirement of seasonal load-patterned scheduling and the 35 percent minimum schedule requirement. The actual delivery of hydro power by Western is primarily a function of the hydrologic conditions and the availability of SLCA/IP units. Based upon projections of available hydroelectric generation from SLCA/IP and the other smaller projects, and the priority of distribution of water and hydroelectric generation allocated to the period, Montrose District Office staff make day-to-day decisions regarding acquisition of additional resources to serve established contract commitments and to maintain system reliability. Actual power delivery may then be served by either hydro, thermal or a combination of hydro and thermal power, depending upon the nature of resource acquisition decisions.

Study Process for Determining Marketable Resources. The study process will be similar to Western's process for determining long-term marketable resources. Five steps are involved:

- Identify maximum seasonal long-term marketable resource (capacity and energy) commitments, using similar methodologies as previously applied by Western in the Post-1989 Marketing Criteria.
- Establish monthly power schedules by applying existing contract provisions (minimum schedule requirements, seasonal load-patterning, etc.) to seasonal contractual commitments to determine monthly distribution of commitment, similar to Western's current practices.
- Establish methodologies to assess availability of monthly and daily hydropower resources from SLCA/IP based upon Reclamation's annual operating plans and priorities of distribution of water/hydroelectric generation.
- Establish a decision process regarding auxiliary resource acquisition given assumptions for contractual load commitments and resource conditions.
- Prepare thorough documentation of all aspects of modeling: resource definition, allocation, monthly power scheduling and decision process under base case and change case conditions.

Identify the Long-Term Marketable Resource. The Bureau of Reclamation's Colorado River Simulation Model (CRSM) will be used to develop projections for future maximum monthly SLCA/IP capacity and energy under assumptions for future hydrologic conditions.

For SLCA/IP, the CRSM computes energy and capacity from the manufacturer's performance rating curves for each powerplant. The model simulates operations of the system of SLCA/IP reservoirs by arranging the optimum distribution of water in storage to satisfy downstream water release requirements. As a result, the model will be used to project maximum operable capacity and generation production for each month of each year within the specified study period.

All specific assumptions regarding hydrologic data, demand data (i.e., depletion schedule), and control data (i.e., reservoir starting conditions) will be reviewed with Reclamation prior to use in any modeling runs.

Western's probability program will establish the probability distribution of projections for maximum monthly capacity and energy from SLCA/IP. New projections for SLCA/IP will be used in establishing exceedance (cumulative frequency) curves. However, existing historic projections for the smaller projects will be retained.

Similar to the marketing criteria, the probabilities for future SLCA/IP capacity and energy for the peak load months of December, January, July, and August will be the basis for selection of appropriate marketable capacity and energy. Using the established probability distributions for the peak load months, the amount of capacity and energy currently under contract with interim marketing conditions imposed will be assessed to determine the corresponding probabilities of occurrence.

Marketable capacity and energy from the smaller projects (Rio Grande and Collbran) will be unchanged, and based upon earlier assessment of maximum (100 percent exceedance), capacity and average energy.

In the Post-1989 Marketing Criteria, Western used BOR projections of future project use requirements and the latest projection of transmission losses. In addition, reserve requirements have been calculated by Western in accordance with existing criteria for the Inland Power Pool. These assumptions will be retained, or more current assumptions, if different, will be used.

Determine Monthly Power Schedules. In distributing SLCA/IP contract commitments throughout the months of each season, the methodology used by Western to distribute the capacity and energy on a load-patterned basis, will be retained.

Determine Monthly and Hourly Available Capacity and Energy. In the CRSM, changes in powerplant constraints, such as to maximum discharge rates, generator rating, power factor, percent overload, or to unit efficiency, can be made and will affect the computation of maximum monthly generator capacity and energy production. However, the model is not sophisticated enough to consider the effects of changes in constraints such as changes to the minimum release rates or ramping rates, which affect power generation on a daily or hourly basis. A simulation model or methodology is required to distribute water releases under constraints so as to assess the variability in capacity and energy during periods with durations less than a month. The assumption made is that existing customers would modify daily power schedules to best reflect their system needs.

A "peak-shaving" methodology will be used to establish consistent priorities of distribution of monthly water as specified in Reclamation's Annual Operating Plan on an hourly basis. This methodology will reflect the differing priorities of Western and firm power customers in establishing daily power schedules: 1) from Western's perspective, the desire to maximize the value of available generation and to satisfy other contractual commitments (e.g., Salt River Exchange) within existing transmission constraints, and 2) from the collective customer perspective, the desire to influence the distribution of SLCA/IP (and Glen Canyon) generation through daily power schedules to minimize their power expenses, and make best use of available supply within existing constraints (e.g., contractual restrictions or obligations from auxiliary suppliers).

Define Resource Acquisition Decision Process. The process where hourly deficits and surpluses are assessed, and decisions made regarding source and timing of auxiliary supply will be reexamined under base case and change case conditions, and a consistent decision process established. Consideration will be given to other constraints, such as transmission limitations and other contractual obligations (e.g., Salt River Exchange).

Methodology. Spreadsheet.

Output. Determination of the capacity and energy to be marketed under the long-term firm contracts for each alternative.

Resources. The agencies and interest groups listed on the next page.

Responsibility. As a conclusion of the modeling and assessment of changes to long-term and short-term power resources, a written report or report segment will be prepared by Western. The report will include all related work, and may require preparation of an associated appendix.

The following list indicates for each task the work product to be completed and the primary agency (and secondary agency, if appropriate) responsible for completion of the task.

Task	Work Product	Responsible Agency
A.1	CRSM Modeling	BOR/Western
A.2	Probability Distribution	Western
A.3	Risk Level	Western
A.4	Adjustments	BOR/Western
B.1	Monthly Power Schedules	Western
C.1	Hourly Available Resources	Western/EDF
D.1	Resource Acquisition	Western
E.1	Prepare Report	Western

Rate Impact Analysis

After determining the change in marketable resources resulting from a change in operation, additional work will be required to assess the impact to the SLCA/IP rates. This part of Section 2 describes the power repayment study (PRS) process, the scope of work, methodology, output, resources, and responsibility for determining the rate impact of any changes in the operation of Glen Canyon Dam.

Repayment Criteria. The repayment criteria for the Colorado River Storage Project are based on Public Law 84-485 (the SLCA/IP Act) and policies established in DOE Order No. 6120.2. Public Law 84-485 provides that power revenues must pay all annual power operation, maintenance, and replacement (OM&R) costs and all annual storage unit irrigation OM&R costs except those paid by the municipal and industrial (M&I) water users. Further, the power revenues must, within 50 years, repay all power investment costs with interest, all storage unit irrigation investment costs (except those paid by the M&I water users), and all participating project irrigation investment costs in 50 years from the end of any development period, except those paid by the irrigation and M&I water users. Power revenues also must pay the salinity control construction and OM&R costs that are allocated to the Upper Colorado River Basin to comply with Public Law 93-320, as amended.

Power Repayment Study Process. PRS determines whether power revenues will be sufficient to pay all costs within the prescribed time periods. This determination is based on historical data and projected values of critical parameters for future years. Estimates of future hydrologic conditions are obtained using computer simulations of the Colorado River, taking into account predicted upstream water depletions. The estimates of future hydrologic conditions are combined with existing power plant capabilities to obtain an estimate of the power and energy that will be available in each year of the PRS.

For participating projects being built on Basin rivers where hydrologic data are unavailable, power and energy are approximated by applying average historical river conditions to anticipated powerplant capabilities. Estimated power production is reduced by reserve requirements and transmission losses. The final figures estimate the amount of energy and capacity available for sale for each future year in the PRS.

Estimated future revenues from transmission service, nonfirm energy sales, and other miscellaneous revenues, along with revenues for estimated firm power sales (using existing firm power rates) are used to determine the adequacy of the existing rates.

In each year of the power repayment study, available revenues are first used to pay annual expenses, including interest on power investment. Remaining power revenues are then applied to repay the highest interest-bearing investments first, assuring that each investment is repaid by the end of its required repayment period. If the PRS shows that the current rate will not generate sufficient revenues to pay all estimated future costs within the prescribed repayment periods, new firm rates are developed.

After the determination of marketable resources for the base case and each operational alternative for Glen Canyon Dam (defined in the marketable resources section), the impact of each alternative on the SLCA/IP rate will be determined. Western will prepare the power repayment study. An already completed, published study will be used as a base study to measure the rate impact. Depending on when this work is done, either the study to support the current rate adjustment, or the FY 91 Final PRS -- available after December 15, 1990 -- will be used. An existing study will be used so that all other assumptions in the PRS can remain the same. The only variable in these studies will be the amount and type of marketable resources.

The amount of impact on each sales category also needs to be determined. Currently in the PRS, firm contractual loads are subtracted from the marketable resources. Any remaining resources are categorized as surplus energy and/or excess capacity. If there is an annual deficit, firming-purchases are assumed. Beyond the contract period (currently 2004) loads are assumed to equal resources. Fuel replacement and economy energy sales projections are estimated and assumed to be supplied by purchased energy.

For each alternative, the Power Resources Committee will need to determine what the contractual loads are, what the level of surplus (or deficit) capacity and energy will be, and what the fuel replacement and economy energy purchases and sales – and at what rate – will be. For example, one approach will be to maintain contract commitments at current levels, but increase purchases.

Data Requirements. The data requirements are annual estimates (from FY 91 through 2090) of marketable capacity and energy, firm contractual load (which may vary with alternatives), and estimates for fuel replacement and economy energy sales. Short-term capacity and energy and firming-purchases must also be calculated.

Prices for economy energy transactions, both purchases and sales will be needed as input to the PRS. If prices are a result of some of the other efforts of the committee, those prices can probably be used. If not, determining prices for future spot market transactions could be somewhat time consuming.

Methodology. All calculations can be prepared in an electronic spreadsheet format.

Output. An estimate of the rates to be charged for power marketed under the long-term firm contracts.

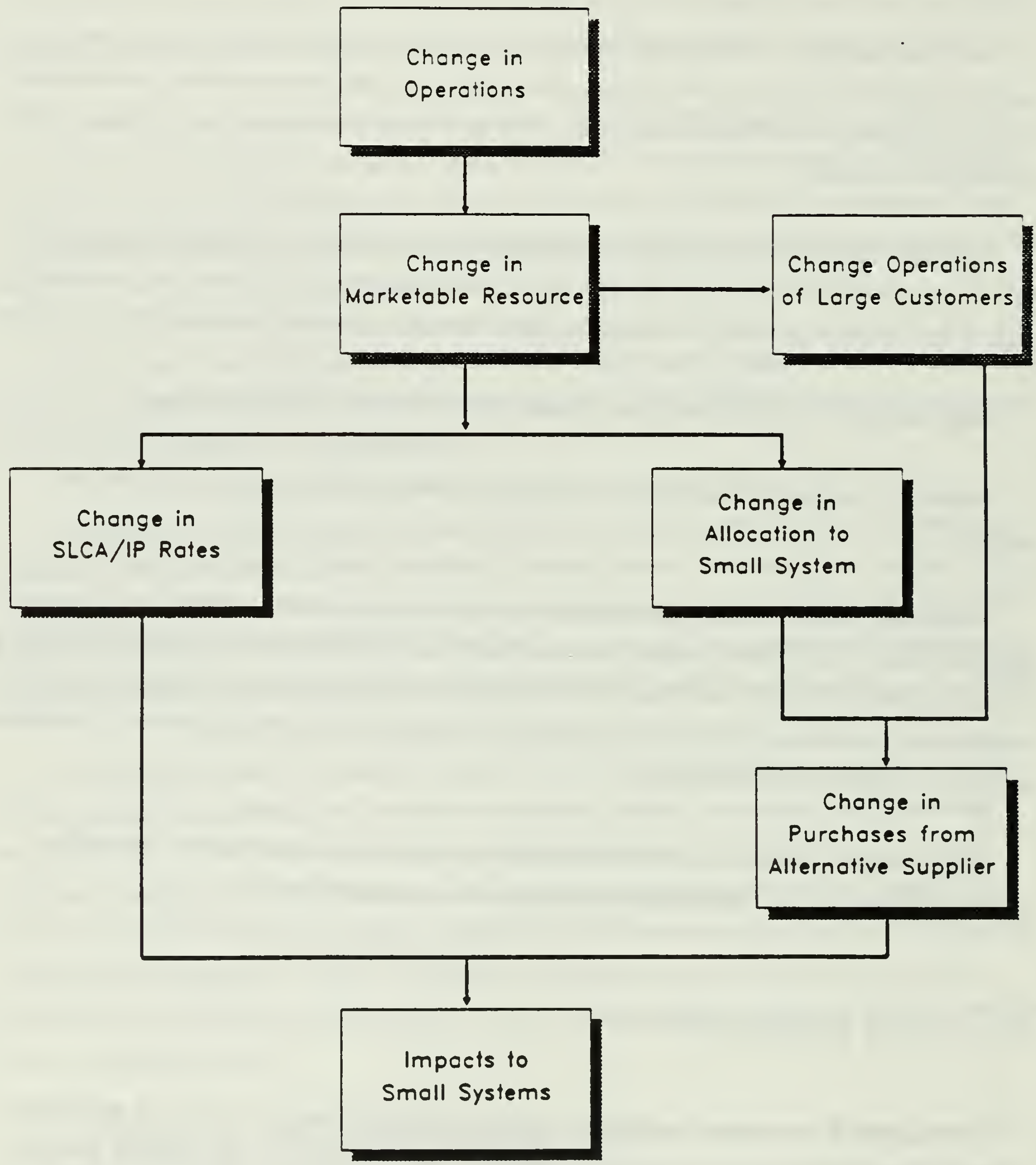
Resources. Western will provide the staff, materials and computer time needed to run the power repayment study. Given the marketable resources, the power modeling subteam will need to determine the assumptions for firm load, fuel replacement and economy energy purchases and sales. Once these estimates are determined, it should take one person one day to pull everything together in a spreadsheet as input to the power repayment study.

Responsibility. Western will be responsible for running power repayment study. The power modeling subteam will be responsible for estimating resource assumptions.

Small Utility Impact Analysis

This portion of the scope of work section discusses the methodology to determine the financial impact on small utilities receiving a SLCA/IP allocation. Once the change in the contracts (including seasonal allocation of SLCA/IP capacity and energy) and the impact to the rates are determined, the impact to small utilities can be assessed (Figure 2.1). Small utilities are defined those utilities with a SLCA/IP allocation that have no generation of their own and would not build additional capacity to replace any lost federal resources. The definition of small utility will need to be specifically determined

Figure 2.1: Assessing Impacts to Small Systems



by the Power Resources Committee. Determining the impact to small utilities will primarily be a data collection and manipulation effort. Determination of availability of replacement capacity and energy will be external to this portion of the analysis.

Process of Determining Impact to Small Utilities. The purpose of the small utility analysis is to estimate, for each utility, the additional cost of replacing federal power. The amount of replacement power needed will be determined by the impact on SLCA/IP allocation of each alternative. The financial impact to the small utilities will consist of two components: the cost of purchasing this replacement power from alternative suppliers and the increased cost of the SLCA/IP resource. (Some data have been provided by customers' submittal of data as part of the contract requirement demonstrating the benefits of federal power. These data are, however, not widely available.) The appropriate SLCA/IP rate impact will be determined by Western using the power repayment system. (See section on rate impact analysis.) Iterations may be necessary as the large system models may show that replacement power is not available, or the impacts to large systems may change the rate, which would require another iteration.

Data Requirement. Western will provide the SLCA/IP allocation for each small utility. Western will also provide the monthly load pattern for those small customers Western schedules for. Additional information, including monthly load patterns for utilities Western does not schedule, alternative power suppliers, source of the replacement power, the capacity and energy rate, and, if available, contract terms or estimates for price escalation will be collected. Western has some of this information, but most of it will need to be collected from the customers. Price escalation estimates may need to come from public sources, such as the EIA information being used in the power modeling effort.

Methodology. This analysis can be prepared on a spreadsheet. A sample of the type of analysis is attached. The sample assumes that replacement power will be priced at current alternative supplier rates. Price escalation estimates will be needed to value the replacement power over time. Estimates of future SLCA/IP rate increases will also have to be made to compare to the alternate supplier rates.

Output. A sample output is attached (See Table 2.1). After discussion with the committee, revisions to this output may be made.

Resources. Western will provide existing customer allocations, and for those customers that Western schedules for, the monthly load pattern.

The remaining work will require data collection capability, and access to a personal computer. The work is not particularly technical, but can be somewhat time-consuming.

Table 2.1: Sample Output for Small Systems

	Replacement Costs ($ per kWh per month)																			
	Winter	Summer	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Winter Peak	Summer Peak	Reduction In Winter Cap[4]	Reduction In Summer Cap[4]	Winter Replacement Cost	Summer Replacement Cost
AK-Chin	13[1]	13[1]	1,171	718	809	1,171	1,244	1,762	3,868	3,955	4,073	4,099	4,002	3,909	1,762	4,099	688	2,391	8,938	31,078
Arizona Power Pooling Association	1.33[2]	3.31[2]	11,323	11,145	12,450	12,148	11,942	11,557	19,446	21,597	25,122	26,342	26,275	23,748	12,450	26,342	9,001	12,308	11,971	40,741
Chandler Heights, ID	1.33[2]	3.31[2]	277	274	274	227	274	277	386	385	383	382	383	380	277	386	199	191	265	633
CRIR	13	13	808	660	728	712	672	651	298	361	420	426	427	426	808	427	422	236	5,487	3,065
ED3	13	13	1,306	1,144	1,208	1,368	1,561	2,643	7,756	7,643	8,336	7,909	7,814	7,101	2,643	8,336	925	4,656	12,024	60,525
ED4	1.33	3.31	1,182	1,182	1,182	1,182	1,876	3,377	3,436	3,477	4,513	4,650	4,730	3,868	3,377	4,730	1,342	2,124	1,784	7,030
ED6-Maricopa	1.33	3.31	179	179	128	122	184	214	1,200	1,230	1,230	1,221	1,200	1,217	214	1,230	221	810	293	2,018
ED6-Pinal	1.33	3.31	883	846	846	1,014	1,589	2,418	2,300	2,192	2,878	2,847	2,788	2,488	2,418	2,847	989	1,299	1,318	4,300
ED8	1.33	3.31	0	0	0	0	0	0	5,728	5,624	5,867	6,031	6,010	5,747	0	6,031	573	2,928	762	9,691
ED7	13	13	573	539	600	592	616	669	4,536	4,439	4,593	4,643	4,601	4,382	669	4,643	359	2,719	4,664	35,351
MWD	13	13	1,664	1,540	1,651	1,521	1,817	2,177	5,551	5,183	5,211	5,371	5,493	5,175	2,177	5,551	1,037	3,198	13,481	41,579
OCTOTILLO	1.33	3.31	241	236	226	228	234	250	1,082	1,098	1,102	1,098	1,101	1,122	250	1,122	250	552	332	1,826
Queen Creek, ID	1.33	3.31	0	0	0	0	0	0	1,701	1,584	1,812	1,822	1,768	1,685	0	1,822	170	867	226	2,870
Roosevelt, ID	13	13	1,577	1,376	1,603	1,243	1,316	1,618	4,241	3,376	4,453	5,022	5,064	4,706	1,618	5,064	873	2,686	11,349	34,923
Roosevelt WCD	1.33	3.31	1,483	1,410	909	985	956	1,212	1,898	2,234	2,229	2,283	2,250	2,117	1,483	2,283	885	1,111	1,177	3,878
SAFFORD	15.39[3]	15.39[3]	514	442	482	464	435	428	673	925	1,131	1,185	1,164	1,034	514	1,185	277	613	4,255	9,437
SCIP	13	13	1,516	1,496	1,688	1,676	1,574	1,554	961	1,069	1,294	1,319	1,314	1,191	1,688	1,319	950	717	12,353	9,318
SAN TAN	1.33	3.31	0	0	0	0	0	0	842	819	852	830	831	842	0	852	84	417	112	1,382
THATCHER	15.39	15.39	333	274	303	288	279	268	336	369	426	428	537	483	333	537	175	258	2,686	3,969
W-M IDD	13	13	377	368	411	383	385	342	116	123	133	136	141	134	411	141	227	78	2,946	1,017
WILLIAMS AFB	1.33	3.31	837	649	542	532	553	560	1,745	1,961	2,145	2,188	2,178	2,014	837	2,188	542	1,048	721	3,470
Yuma Proving Grounds	13	13	381	266	328	340	343	274	235	278	300	316	335	303	381	335	193	177	2,512	2,297
			26,623	24,733	26,368	26,216	27,848	32,247	68,350	69,922	78,303	80,546	80,422	74,072	34,306	81,470	18,403	45,162		

[1]Power from Arizona Public Service. Winter season rates in effect October-March.

[2]Power from Salt River Project. Winter season rates in effect October-April.

[3]Power from Graham County Electric Cooperative. Winter season rates in effect October-March.

[4]Calculated as a 10 percent reduction in monthly allocation.

Table 2.1: Sample Output for Small Systems (Continued)

	CRSP CROD Winter	CRSP CROD Summer	CRSP Demand Cost Winter	CRSP Demand Cost Winter	Total CRSP Cost	Winter Replacement Cost	Summer Replacement Cost	Total Replacement Cost	Percent Increase
AK-Chin	1,762	4,099	22,095	51,401	73,497	8,938	31,078	40,015	54.4%
Arizona Power Pooling Association	12,450	26,342	156,123	330,329	486,452	11,971	40,741	52,712	10.8%
Chandler Heights ID	277	386	3,474	4,840	8,314	265	633	898	10.8%
CRIR	808	427	10,132	5,355	15,487	5,487	3,065	8,553	55.2%
ED3	2,643	8,336	33,143	104,533	137,677	12,024	60,525	72,549	52.7%
ED4	3,377	4,730	42,348	59,314	101,662	1,784	7,030	8,814	8.7%
ED5-Maricopa	214	1,230	2,684	15,424	18,108	293	2,018	2,312	12.8%
ED5-Pinal	2,416	2,847	30,297	35,701	65,998	1,316	4,300	5,616	8.5%
ED6	0	6,031	0	75,629	75,629	762	9,691	10,453	13.8%
ED7	669	4,643	8,389	58,223	66,612	4,664	35,351	40,015	60.1%
MWD	2,177	5,551	27,300	69,610	96,909	13,481	41,579	55,060	56.8%
OCTOTILLO	250	1,122	3,135	14,070	17,205	332	1,826	2,158	12.5%
Queen Creek ID	0	1,822	0	22,848	22,848	226	2,870	3,096	13.6%
Roosevelt ID	1,616	5,064	20,265	63,503	83,767	11,349	34,923	46,272	55.2%
Roosevelt WCD	1,483	2,283	18,597	28,629	47,226	1,177	3,678	4,856	10.3%
SAFFORD	514	1,185	6,446	14,860	21,305	4,255	9,437	13,692	64.3%
SCIP	1,688	1,319	21,168	16,540	37708	12,353	9,318	21,671	57.5%
SAN TAN	0	852	0	10,684	10,684	112	1,382	1,494	14.0%
THATCHER	333	537	4,176	6,734	10,910	2,686	3,969	6,655	61.0%
W-M IDD	411	141	5,154	1,768	6,922	2,946	1,017	3,962	57.2%
WILLIAMS AFB	837	2,188	10,496	27,438	37,934	721	3,470	4,191	11.0%
Yuma Proving Grounds	381	335	4,778	4,201	8,979	2,512	2,297	4,809	53.6%

Responsibility. Western will provide information as described above. The committee will have responsibility to either prepare the work or oversee and review the work prepared by a contractor.

Large Utility Impact Analysis

Three methodologies for assessing impacts to large systems were analyzed in the 1989 prototype study conducted by the GCES Power Economics Group (now known as the Power Resources Committee): 1) an alternative thermal plant (ATP) method conducted by Western, 2) a simulation using the EGEAS model conducted by Stone & Webster Management Consultants, and 3) a simulation using the Elfin model conducted by the Environmental Defense Fund.

The Power Resources Committee found that the EGEAS and Elfin models were appropriate tools for modeling the large SLCA/IP customers who generate significant amounts of their own power. A decision was made to use both models in future evaluations 1) to insure greater reliability of the results, and 2) because the two models each have distinguishing capabilities that are particularly effective for measuring the various components of the financial and/or economic impacts of changes in operations. The GCES Power Resources Committee expects to hire a contractor to implement the Elfin and EGEAS models under its direction to perform the work described in this section.

Definition of Large Systems. The large systems to be modeled include those SLCA/IP firm power customers whose resource mix includes significant amounts of generation from their own powerplants. Some smaller utilities whose loads are combined with those of a larger utility for a centralized dispatch, will be included with the larger utility and defined as a large single-system dispatch. Under this definition, the following holders of SLCA/IP allocations would be classified as large systems:

- Salt River Project
- Tri-State Generation and Transmission
- City of Colorado Springs
- Plains Generation and Transmission
- Platte River Power Authority
- Deseret (including UAMPS)
- Colorado Ute Association (including IREA, Holy Cross, Yampa Valley)

Large System Data Bases. A data base will be created for each of the seven large systems to be modeled to serve as input to the base case and the various alternative cases. The data base will contain the following information for each of the utilities being modeled:

Load data:

- Peak demand and energy for the first year (by month, if possible);
- Load shape, hourly (8760 hours) or typical weeks (168 hrs/week); and load growth escalation factors.

Resource data:

Existing thermal plants

- Capacity
- Fuel type, price, escalation
- Loading block heat rates
- Maintenance rates
- Forced outage rates
- Minimum down times
- Fuel cost escalation rates
- Variable O&M rates, escalation
- Hydro plants (other than SLCA/IP)
- Maximum capacity
- Minimum capacity
- Available energy (by month)

Firm sales and purchases

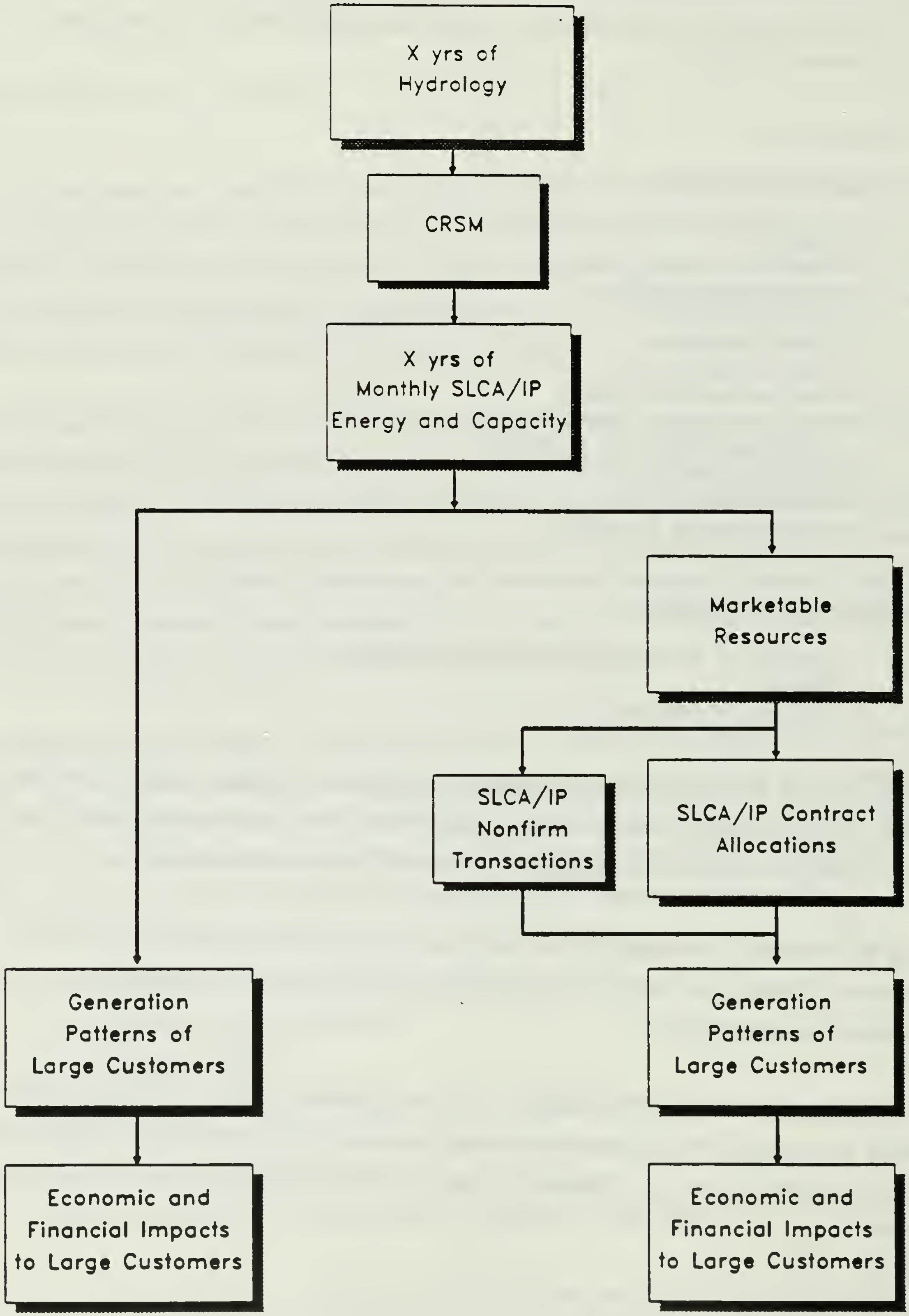
- Capacity by month (and time of day if necessary)
- Energy
- Cost per kW and per kWh

Since some of the input data will be forecasts of load growth and price escalation, sensitivity analysis may be necessary to understand the impact of those forecasts on total projected costs. The group of inputs discussed above will be used in all runs of the power systems models.

As recommended in the report of the Power Resources Committee the impact of changes in operations on the available hydro energy and capacity will be modeled in two separate ways. These two approaches are discussed next.

Models Based on SLCA/IP Contracts. Under one approach, changes in operations will be reflected as a change in the capacity and/or energy contained in each of the larger system's contract for SLCA/IP power (Figure 2.2). Following this approach, the hydro input will be defined in the following manner:

Figure 2.2: Overview Assessing Large System Impacts



Base case hydro power input

- Maximum capacity by month as defined in existing contract
- Minimum capacity (35% of seasonal maximum)
- Energy by month as defined in existing contract

Alternative cases hydro power input

For each alternative case, SLCA/IP firm contracts may be changed, according to development of "marketable resources" as defined by the Power Resources Committee. It is likely that SLCA/IP contracts would still be modeled as a hydro resource, but amounts of capacity and energy may be different, and the 35% minimum may no longer be applicable.

Models Based on Hydrologic Conditions. Under the second approach, the hydrology input to the power system model will be based on the actual amount of hydro power that is available from the SLCA/IP in any given year (Figure 2.2). A representative 20-year hydrology will be used to model varying conditions of SLCA/IP resources. The last year in the hydrology must be an average year, so that expansion plans for each of the seven modeled utilities will be based on expected energy in the extension period. An additional hydrology may be used for a sensitivity analysis.

Base case hydro power input

- Maximum capacity by month and year as defined by reservoir level
- Minimum capacity, defined by 1000/3000 cfs and reservoir level
- Energy by month and year as defined by hydrology

Alternative cases hydro power input

- Maximum capacity, as available or as permitted
- Minimum capacity, as required
- Energy, as defined by the Annual Operation Plan (AOP) or a modified AOP
- Ramp rate restrictions, if applicable

Future Resource Additions. Over the 20-year period of study, many utilities will need to add resources to serve their loads reliably. To make future capacity plans on a least-cost basis, these resources should be chosen from a wide range of feasible options. These options should include traditional thermal plants (such as coal, combined cycle, and combustion turbine), as well as nontraditional means of generating electricity (such as thermal solar and cogeneration) and demand-side options. A comprehensive list of potential candidates for capacity expansion planning is included here and discussed in detail in the following paragraphs.

Fossil Fuel Technology

Intermediate/Peaking

- Oil
- Gas
- Combined Cycle
- Combustion Turbine
- Coal Gasification
- Internal Combustion

Base Load (will not be considered for alternative scenarios)

- Nuclear
- Coal

Renewable Energy Technology

- Conventional Hydropower (including Peaking with Hoover)
- Pumped Storage (including Spring Canyon)
- Biomass/Biofuels
- Geothermal
- Ocean Energy
- Solar Thermal Electric
- Wind Energy
- Photovoltaics
- Compressed Air Energy Storage (CAES)
- Batteries
- Thermal
- Flywheel
- Chemical
- Superconducting Magnetic Energy Storage (SMES)
- Fuel Cells

Non-Structural Alternatives

- Energy Conservation
- Load Management
- Purchase of Capability from Other Sources
- Exchange Agreement

- Interruptible Loads
- Time-of-Day Rates
- Voltage Reduction
- Brown outs/Rotating Blackouts

No-Change Alternative

Future traditional resources. Input data for future, traditional thermal plants must include the same parameters for operation as previously defined for existing thermal plants, plus those parameters relating to capital cost. These additional capital cost parameters include cost of installation per kW, fixed O&M per kW, plant life, book life, and economic carrying charge. When geography and transmission are favorable, utilities will be allowed to share new powerplants, as is the case with Navajo, Four Corners 4 and 5, Craig 1 and 2, Palo Verde, etc.

Future nontraditional resources. Meeting electricity demands with nontraditional means can be more difficult to assess. Viable nontraditional methods of generating electricity are often location-specific. Furthermore, the potential for conservation and load management depend on the nature of the use of electricity. Nevertheless, many utilities in the West have found nontraditional means to be cost-effective. The power system model should include all viable options for meeting future demand. These nontraditional options could include, but are not limited to, thermal solar, cogeneration, and demand-side management

State-of-the-art *thermal solar* has been successful in desert climates in the California. Recently built plants in the Mohave desert are competitive and may be suited to meeting the peak power needs that Glen Canyon may no longer be able to serve. Such plants can be designed to burn fossil fuels if the capacity is needed when solar power is not available. Input data for thermal solar plants is similar to traditional thermal plants, although time-varying capacities, heat rates or fuel costs must be used.

Potential sites for *cogeneration* can be included in the Elfin and EGEAS data bases as future resource options.

Identified *demand-side options* can be included in the data bases as future resource options, as well. These include both energy efficiency (reducing total demand) and load management (reducing peak demand). While costs of, and potential for, demand-side options may be difficult to estimate, they are viable ways of meeting electrical demand and should be used if they are cost-effective. Information from the utilities as well as information from the data base, discussed in Section 1, can be used as input to the model.

As a first step in evaluating demand-side potential, utilities will be requested to supply information about electricity use by type of end-use customer. End-use customers are often classified into commercial, industrial, agricultural and residential categories, but these categories can be refined further. End-use of the electricity can similarly be broken down into lighting, heating, air conditioning, etc. Furthermore, to evaluate the potential for saving capacity and energy, information for end-use by customer type should include energy, capacity (at time of system peak), technology used, etc. If this information can be obtained, the potential for saving capacity and energy by installing or retrofitting more efficient technologies can be assessed. This potential, coupled with capital cost involved, can then be modeled as a possible future resource addition, and can be weighed against other resources on an economic basis.

Utilities will also be requested to supply information as to which of their customers pay time-of-use-rates for their electricity and how those rates are structured. Peaking power is generated at Glen Canyon because electricity is worth more at those peak times. Requiring customers to pay more for electricity when it costs more to produce is a logical step to reducing peak needs.

Capacity Expansion Simulations. Two sets of simulations will be used in the analysis of the short- and long-term effects of changes in operations at Glen Canyon Dam. One set of stimulations will be based on the current power allocation methods. Under these methods, utilities would receive capacity and energy specified under contracts with Western. Contracts could vary for each case to be simulated. The other set of simulations will be based on the actual amount of available energy and capacity depending on hydrological conditions.

The first set, discussed here, will develop the capacity expansion decisions that would be made by SLCA/IP customers in a base case (current operations continue), plus those capacity expansion decisions that would be made in alternative cases (changes in operations). In this first set of simulations, capacity expansion decisions by SLCA/IP customers (in both the base case and the change cases) will be based on expected firm contracts for SLCA/IP capacity and energy, as well as expected surpluses from the SLCA/IP system. Firm contract capacity and energy will depend, of course, on Western's ability to supply firm capacity and energy, which in turn will depend on Glen Canyon Dam operating criteria. The task of determining the amount of available firm contract capacity and energy under various operating constraints will be performed by the marketable resources sub-team, in cooperation with the large systems modeling contractor.

The second set of simulations, discussed below, will represent, for each operating constraint, the year-by-year performance of the power systems under a simulated series of annually varying hydrological conditions. These hydrological conditions most likely will be based on an historical series.

This second set of simulations is necessary to completely gauge the range of power-system impacts -- in both dry years and wet years -- caused by changing operating criteria at Glen Canyon dam. These impacts include changes in baseload coal-fired generation, changes in intermediate and peaking generation, and changes in short-term capacity and economy sales and purchases, as well as concomitant changes in emissions.

The need for two separate sets of simulations is mandated by two important issues. First, capacity planning in systems with significant hydro penetration should be based on expected adverse (that is, dry-year) conditions, while expected average results should be based on the full range of conditions. Second, the method of marketing and distributing SLCA/IP resources reflects a similar distinction between firm contract amounts and nonfirm or short-term surpluses and deficits.

Study Method for Capacity Expansion Based on Contracts. The fundamental optimization criterion will be the net present value of generation and capital costs over the study period, while meeting the capacity planning constraints discussed below. The EGEAS model will be used to derive optimal expansion plans using a mix of the possible future resource additions described previously. An expansion plan will be generated for a base case (continuation of current operating criteria at Glen Canyon) and each alternative case (changed operating criteria). The optimal expansion plan in each scenario will depend, in part, on the magnitude of marketable resources in each scenario, which will be determined by the marketable resources sub-team, in cooperation with the large-systems modeling contractor.

In addition, the Elfin model will be used to derive approximately optimal expansion plans as a cross-check on the EGEAS results. The Elfin model will also be used to simulate and conduct sensitivity analyses on the expansion plans derived by EGEAS.

Systems to Be Modeled. Each of the seven large SLCA/IP customers identified above will be modeled. These utilities will either be modeled separately, or concurrently as part of a multi-area simulation. To correctly model these SLCA/IP customer utilities, it may be necessary to take account of other power users and suppliers in the Southwest Region because utilities in the Southwest Region have interconnections and frequent transactions, both firm and nonfirm. For example, other major utilities in the Southwest Region that are either alternative suppliers to SLCA/IP customers or are recipients of SLCA/IP surplus power will need to be represented in the simulations. These additional utilities will be either fully or partially simulated (that is, both loads and resources, or a portion of loads and resources, will be included in modeling runs), or they will be represented as potential power transactions (that is, an interconnected utility may be represented as a supplier or recipient of economy energy).

Study Periods. The study will be conducted over a 50-year period: a 20-year planning period followed by a 30-year extension period. The 20-year planning period is sufficiently long to reflect changes in generation resources (including the construction of new plants) that result from changes in operations at Glen Canyon Dam. The 20-year planning period will include forecasts of additional generation resources already planned by the utilities to be modeled, forecasts of load growth, forecasts of fuel, O&M, construction cost escalation, and so forth. These forecasts will be consistent with Western Systems Coordinating Council (WSCC) projections. Additional resources will be added within the 20-year planning period consistent with the capacity planning criteria discussed below.

During the 30-year extension period, generation will be held constant, while the costs of generation will rise uniformly. That is, there will not be fuel- or plant-specific escalation rates during the extension period. The extension period is necessary to capture the life-cycle costs of alternative resources constructed during the 20-year planning period.

Capacity Planning Criteria. The fundamental planning constraint will be adverse-year reserve margins consistent with WSCC practice. In addition, a loss-of-load probability (LOLP) constraint may be applied in the alternative cases. The use of an LOLP constraint may be necessary if marketable capacity for alternative cases is unchanged but the sustainability of this capacity decreases. When an LOLP constraint is used it will be consistent with the reserve margin constraint in the base case.

Glen Canyon Hydro Resource Representation. In this first set of capacity expansion simulations the Glen Canyon hydro resource will be represented as part of total SLCA/IP resources in two distinct parts. The first part will represent the firm contract magnitudes specified by the marketable resources sub-team. These magnitudes will include a seasonal capacity value, a seasonal limited-energy value, and a minimum-delivery constraint.

The second part of SLCA/IP resources will represent expected surplus energy and nonfirm capacity available from SLCA/IP. That is, the capacity optimization simulations should include, in addition to the SLCA/IP contract amounts (which do not vary from year to year), an average amount of surplus or nonfirm energy (which also will not vary from year to year in the optimization simulations). It is necessary to account for the average amount of available surplus energy in the event that firm-contract energy under some scenarios is less than expected energy. Surpluses -- if they exist -- are preferentially available to SLCA/IP customers at the customer's firm-power rate. If this surplus economy energy is not made available to the capacity expansion model, the least-cost capacity expansion plan may not be found. For example, the model may decide to build a base-load or intermediate resource to cover a projected capacity shortfall, when, in reality, the availability of economy energy would lead to the underutilization of such a resource.

Available SLCA/IP resources (both firm and nonfirm) will be allocated among the SLCA/IP customers under the various alternatives. This allocation will probably be similar to current or proposed contract allocations. Final determination of an allocation procedure will be made in conjunction with the marketable resources sub-team.

Resource Options. The resource options in the first set of capacity optimization simulations include those identified above. In order to arrive at the best capacity expansion models, certain large-unit options will be represented in the model as being available in partial-unit increments. If each utility is treated separately and joint-ownership possibilities are ignored, the capacity optimization model will be constrained in its ability to find least-cost plans. Consider, for example, a scenario in which each utility is constrained to add coal-fired capacity in 250-MW increments. Since capacity must be added in the first year of a shortfall, this could lead to surplus capacity in subsequent years. Joint ownership would allow a utility to defer adding capacity by sharing capacity with other utilities in the first year of a shortfall. Such joint-ownership possibilities may be approximately represented by allowing partial-unit increments to be constructed. In this case, for example, a baseload coal-fired unit may be represented as available in a 50-MW unit size. This hypothetical unit would have all the characteristics (heat rate, capital cost per kilowatt, etc.) of the larger, actual unit.

Intersystem Capacity and Energy Transactions. The capacity expansion simulations will also account for interutility capacity and energy transactions to the extent these are both physically and economically feasible. These transactions will include seasonal diversity exchanges (where a winter-peaking utility can sell excess capacity in the summer to a summer-peaking utility, and vice-versa) and sales of excess capacity from existing reserves (much of the Southwest Region is expected to have capacity surpluses for a number of years). In addition, economy energy transactions will also be accounted for in the capacity expansion simulations.

System Interconnections. Interconnections among the modeled utilities will be accounted for as realistically as possible in the simulations. Transmission constraints will be included.

Glen Canyon Hydro Generation Simulations. This second set of simulations will represent, for each operating constraint, the performance of the power systems under varying hydrological conditions. This set of simulations will measure power-system impacts – in both dry years and wet years – caused by changing operating criteria at Glen Canyon Dam. These impacts include changes in baseload coal-fired generation, changes in intermediate and peaking generation, and changes in short-term capacity and economy sales and purchases, as well as concomitant changes in emissions.

Study Method for Capacity Expansion Based on Hydro Generation. The hydro-generation simulations will use the optimal expansion plans for each case (continuing current operations and changed operations cases) derived by the expansion simulations described above. The performance of the power system will vary from year to year with variations in hydrologic conditions. Varying hydrologic conditions will be represented by a simulated series of Glen Canyon Dam operations data, including reservoir heights and water releases by month. This series may be based on historical data, and will be developed in conjunction with the marketable resources sub-team. It will be very important to be sure that this series is consistent with the hydrologic characteristics used by the marketable resources sub-team in developing contract capacity and energy magnitudes for the set of simulations based on SLCA/IP contracts.

In addition, because SLCA/IP contract magnitudes will be projected for each case, and because hydro generation magnitudes (different from contract magnitudes) will be projected on a monthly basis, differences between contract capacity and energy and hydro capacity and energy represent short-term or nonfirm transactions. These transactions will be accounted for in the modeling runs.

Systems to Be Modeled. The same systems included in the capacity expansion simulations will be included in the hydro-generation simulations.

Study Periods. The study periods for the hydro-generation simulations will be the same as the study periods used in the capacity expansion simulations. Since the 30-year extension period is represented by a single simulation year, care will be taken to insure that the hydro data for that year are consistent with expected average conditions.

Glen Canyon Hydro Resource Representation. Monthly Glen Canyon hydro-generation will serve as the hydro input to the power systems models. These data will be consistent with expected conditions and with data used to determine marketable resources. Hydro-generation surpluses will be allocated to utilities consistent with current practice.

Intersystem Capacity and Energy Transactions. Capacity and energy transactions within transmission constraints will be estimated. The costs and benefits of such transactions will be estimated from both a social perspective (that is, all transactions are made at cost, or with a split-the-benefits rule) and a private perspective (that is, selling utilities may make a profit on the transaction, for example, sales are made at 10% above costs).

Methodology. The analysis of large systems will be based on the EGEAS and Elfin power system simulation models.

Output. There are three principle factors in estimating total cost of changes in operations at Glen Canyon: 1) capital costs related to investments in new generating capabilities or demand-side measures, 2) production costs related to operating the system optimally with the given constraints, and 3) SLCA/IP power rate.

Change in capital costs is the difference between the investments in new resources in the alternative case compared to investment in new resources in the base case. As described above, the set of investments for each case is determined by minimizing the present value of total costs over the entire 50-year period when the hydro input is described in terms of an SLCA/IP allocation to each customer. The capital costs do not include the cost of operation with the new resources but only costs associated with acquiring the new resources.

The change in production costs is based on the difference between each alternative case and the base case in operating each system with the actual hydro operations. These costs will principally be limited to fuel and O&M.

Rate for firm SLCA/IP power is determined by cost of hydro operations and repayment obligations. Change in rate, as driven by change in marketable resource and results of power system simulations, will be determined by Western in coordination with the GCES Power Resources Committee.

Comparison of generation of electricity for simulations with SLCA/IP contract inputs and hydro operation inputs will provide net estimates of both purchases of off-peak thermal power by Western to supplement hydropower to supply firm customer's 35% minimum take requirement and nonfirm sales of surplus hydro power by Western in wet years. These estimates of power, either generated or replaced, and the associated costs, will help to determine impacts of changing operations criteria and associated marketable resource on SLCA/IP firm power rates.

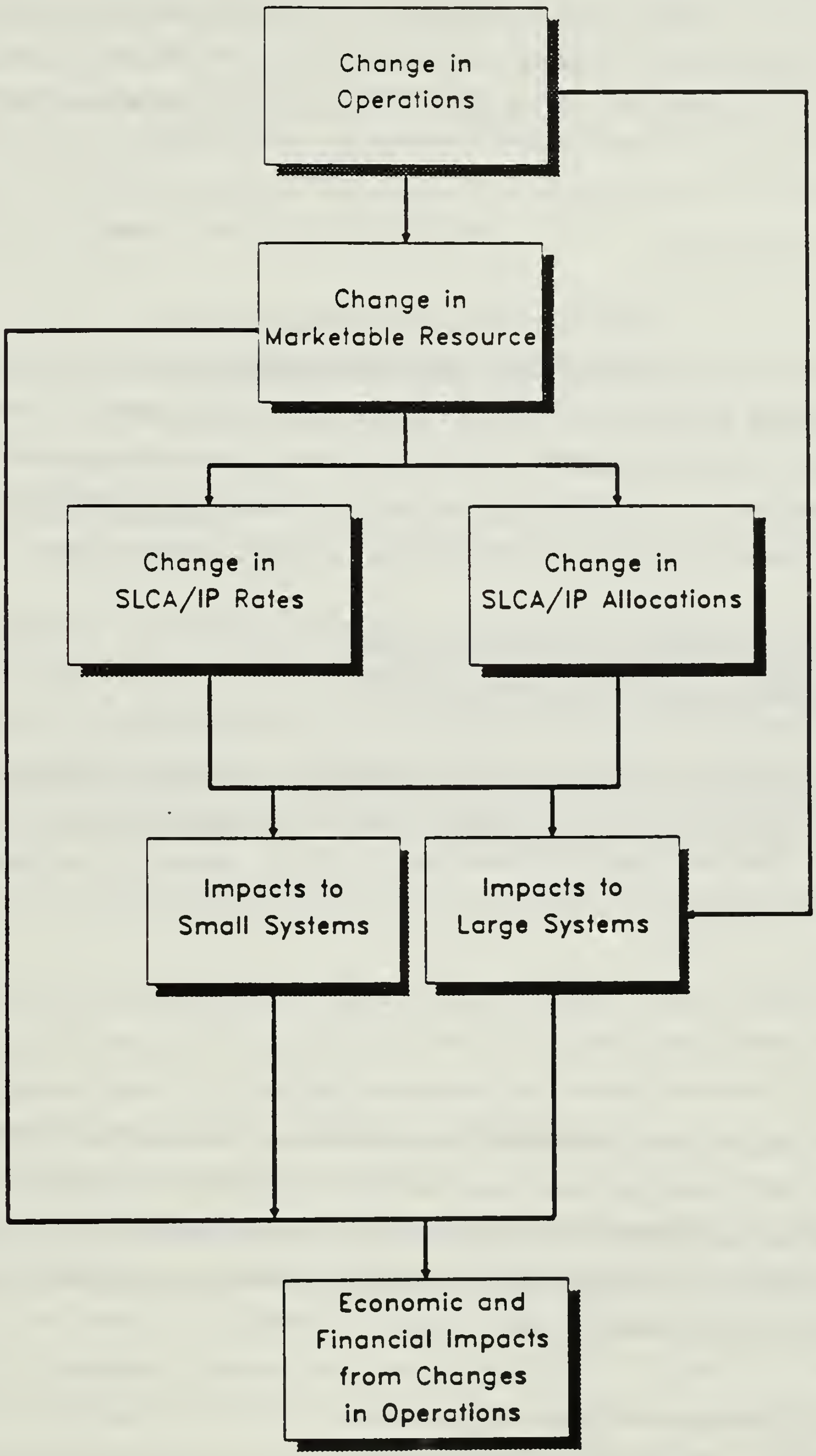
Resources. This work effort will be supported by the Power Resources Committee. In particular, it is anticipated that Western and/or Reclamation will provide the hydrologic input to the model.

Responsibility. Private contractor will take primary responsibility for collecting any additional input data and implementing the power system simulation models.

Integrating the Results

The results of these four types of analyses will be integrated in a report by the Power Resource Group. This report will describe for each alternative set of dam operations the impacts to the marketable resource, rates for SLCA/IP power, economic and financial impacts to small utilities, and the economic and financial impacts to large utilities (Figure 2.3).

Figure 2.3: Integrating Power Resource Results



SECTION 3: PRODUCTS AND TIMELINES

The nature of each deliverable was discussed in general terms in the previous section. This section draws together all of the products to be produced by the Power Resources Committee and suggests a date for each of these products. Since the measurements of impacts to the large utilities is likely to be performed by an outside contractor, the discussion of this product is more detailed than the others.

Marketable Resource

The product produced by this work effort will also be a spreadsheet that will be used to calculate the changes in marketable SLCA/IP power that would occur as a result of a change in operations. As with the small system analysis this spreadsheet will be supported by a technical document that will describe use of the spreadsheet as well as all of the assumptions embodied in the spreadsheet. The following deadlines are proposed for preparing the methodology to measure impacts to rates:

1-1-91 Draft spreadsheet and supporting document
2-1-91 Final spreadsheet and supporting document

By following this schedule the Power Resources Committee will be able to prepare a report summarizing the financial and economic impacts of changes in operations at Glen Canyon Dam for inclusion in the draft GCDEIS.

Rates

Western will take the lead in developing a spreadsheet that will be used to calculate the changes in rates for firm SLCA/IP power that would occur as a result of a change in operations. As with the small system analysis this spreadsheet will be supported by a technical document that will describe all of the assumptions embodied in the spreadsheet. The following deadlines are proposed for preparing the methodology to measure impacts to rates:

11-1-90Draft spreadsheet and supporting document
12-1-90Final spreadsheet and supporting document

Small Systems

The product to be produced from this effort will be a spreadsheet, along with a supporting technical document. This spreadsheet will allow the Power Resources Committee to calculate the impacts of changes in operations to the small SLCA/IP customers. The power resource group will designate a person to be responsible to prepare a short written report discussing the analysis of each alternative operation criteria. The following deadlines are proposed for the establishing the methodology to be used in the analysis of impacts to small SLCA/IP customers:

10-1-90	Draft spreadsheet and supporting document
11-1-90	Final spreadsheet and supporting document

Impacts to Large Systems

The major product to be delivered from this effort will be a series of reports. The first report will be a report on the benchmarking of the power systems models EGEAS and Elfin. This report should include a discussion of the data used as input to the models, including hydrology, loads, existing resources, and potential future resources. This section would be followed by a discussion of how the EGEAS and Elfin were benchmarked to verify that the models are producing reasonable results. After discussing the benchmarking process, the report should present the base case results. The base case results will summarize the present value of the least-cost plan for each of the utilities modeled.

After the initial report, the contractor will prepare a series of reports. Each of these reports will address the impacts of a new set of dam operation criteria. In preparing these reports the contractor will compare the present value of the least-cost plan under the alternative operations to the present value of the least cost-plan under the base case (present operations).

We propose that each of these reports include at least three major sections. As presented in the discussion of the scope of work for measuring impacts to the larger SLCA/IP customers, these impacts will be measured in two ways. Consequently, one section of the report will discuss the results obtained when the change in operations is reflected as a change in the SLCA/IP long-term firm power allocation. A second section will discuss the impacts when the change in operations is represented as a direct change in hydro energy available on a monthly basis to the SLCA/IP customers. The final section of each report on the alternative operations will be a discussion of the potential that small changes in the alternative dam operations might result in a significant reduction in the economic impacts. This third section can play an important role in integrating the environmental and power resources work effort conducted under GCES.

To ensure that these reports will be produced in a timely manner to support the GCDEIS, the following time schedule is proposed:

8-1-90 to 8-8-90	Commerce Business Daily Announcement Developed
8-15-90	First appearance of RFP in CBD
11-1-90	Contractor selected, work to begin
3-1-91	Data collection finished
5-1-91	Benchmarking and base case draft report due
6-1-91	Final draft of benchmarking and base case report
6-1-91 to 10-1-91	Preparation of reports on alternative dam operations.

In meeting this schedule it will be important to be sure that the alternatives to be explored as part of the GCDEIS will be available early in June of 1991. While the work of the Power Resources Committee is designed to analyze the alternatives to be considered in the GCDEIS, there exists a possibility that other GCES researchers may devise other alternatives for which it would be useful to understand the economic impacts to power. The Power Resources Committee should have a representative on the GCES Core Team to ensure that these needs are conveyed to the core team. This representative could bring back information concerning changes in the operations that would reduce the economic impacts to power. By fostering this type of give and take it increases the possibility that operational alternatives can be found that meet environmental objectives at the lowest economic impact to power. To the extent that the analysis of the impacts to the large system will require information about the impacts to the marketable resource and rates, the outputs from the efforts must be available prior to June of 1991.

Report of the Power Resources Committee

The final report of the Power Resources Committee will integrate the results from the analyses of impacts to marketable resource rates, small utilities and large utilities. The report will describe the impacts on each of these areas for each alternative set of dam operations.

Budget

The budget for this effort is unknown at this time. The actual budget required will be a function of several factors.

Benchmarking and Base Case for Large System Modeling. The cost of this effort will depend on the number of systems modeled and the level of effort required to collect data. While the number of systems to be modeled is likely to be ten or fewer, a decision by the Power Resources Committee to exclude all resources with capacities less than 5 mW would reduce the number of generating units in the model, resulting in a slight decrease in cost of data collection. This reduction, however, would not result in significant savings in the cost of actually performing the economic analysis. A second critical cost factor is whether data will be available on a voluntary and confidential basis from the system being modeled. Cooperation from the systems being modeled may reduce the contractors' cost of collecting data to implement the EGEAS and Elfin models. The Power Resources Committee will work to define "large systems" and secure the cooperation of the modeled systems to help minimize the cost of this effort.

Sensitivity Analyses of Alternatives. Unlike the costs of benchmarking and analyzing a base case, the cost of this effort will be a function of the number of alternatives to be analyzed and the number of sensitivity analyses that will be performed. Again, there will be conflict between minimizing budget expense and conducting a thorough analysis. The Power Resources Committee will consider at its meetings the need for analysis of alternatives and sensitivity analysis and make recommendations as to the number of analyses that will be required. For the purposes of planning, the Power Resources Committee suggests that four alternatives from the GCDEIS, and four alternatives arising from GCES should be considered. In addition, sensitivity analyses will be required for load growth, fuel escalation and hydrology. In determining the actual analyses to be conducted, the Power Resources Committee will weigh the value of the results against the cost of the effort.

Small Systems, Rates, and Marketing. While all of these methodologies will be developed by the Power Resources Committee, it may be desirable to ask a contractor to perform some (or all) of these analyses. If the Power Resources Committee chooses this course of action, additional work items could be added under the Power System modeling contract.

REFERENCES

GCES Power Resources Committee. 1990. Evaluation of Methods to Estimate Power System Impacts of Potential Changes in Glen Canyon Powerplant Operations.

Glen Canyon Environmental Studies, Executive Review Committee. 1988. "Final Report," May.

National Research Council, Committee to Review the Glen Canyon Environmental Studies. 1987. River and Dam Management: A Review of the Bureau of Reclamation's Glen Canyon Environmental Studies. Washington, D.C.: National Academy Press.

U.S. Department of the Interior. 1988. Glen Canyon Environmental Studies: Final Report. Salt Lake City: U.S. Bureau of Reclamation (Available from the National Technical Information Service, Access Number PB88-18334/AS).

U.S. Water Resources Council. 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. U.S. Government Printing Office.

APPENDIX A

LIST OF STUDIES COMPLETED FOR PHASE I

5 OVERALL REPORTS

Glen Canyon Environmental Studies Final Report. Department of the Interior.

Executive Review Committee Final Report. Department of the Interior, Fish and Wildlife Service, National Park Service, Bureau of Reclamation, Western Area Power Administration.

Executive Summaries of Technical Reports. Department of the Interior, Fish and Wildlife Service, National Park Service, Bureau of Reclamation, Western Area Power Administration.

Executive Summaries of Technical Reports. Department of the Interior, Fish and Wildlife Service, National Park Service, Bureau of Reclamation.

Colorado River Storage Project Constraints and Operation of Glen Canyon Dam.

Colorado River Law.

8 REPORTS ON AQUATIC LIFE

Effects of Varied Flow Regimes on Aquatic Resources of Glen and Grand Canyons. (H.R. Maddux, D.M. Kubly, J.C. deVos, Jr., W.R. Persons, R. Staedicke, and R.L. Wright).

Colorado River Water Temperature Modeling Below Glen Canyon Dam. (R. Ferrari).

Instream Flow Microhabitat Analysis and Trends in the Glen Canyon Dam Tailwater. (D.L. Wegner).

The Effects of Steady Versus Fluctuating Flows on Aquatic Macroinvertebrates in the Colorado River Below Glen Canyon Dam. (W.C. Leibfried and D.W. Blinn).

Cladophora Glomerata and its Diatom Epiphytes in the Colorado River Through Glen and Grand Canyons: Distribution and Desiccation Tolerance. (H.D. Usher, D.W. Blinn, G.G. Hardwick, and W.C. Leibfried).

Zooplankton of the Colorado River: Glen Canyon Dam to Diamond Creek. (L.R. Haury).

Exposure of Cladophora Glomerata to the Atmosphere During Regulated Flows: Exposure of Biomass and Chlorophyll A. (H.D. Usher and D.W. Blinn).

Distribution of Epiliphytic Diatoms on Cladophora Glomerata in the Colorado River Through Glen and Grand Canyons, Arizona. (G.G. Hardwich, D.W. Blinn, and H.D. Usher).

10 REPORTS ON RIVER FLOWS, BEACHES, AND SEDIMENT

Debris Flows from Tributaries of the Colorado River, Grand Canyon National Park, Arizona. (R.H.. Webb, P.T. Pringle, and G.R. Rink)

The Rapids and Waves of the Colorado River, Grand Canyon, Arizona.

Sonar Patterns of the Colorado River Bed in the Grand Canyon. (R.P. Wilson).

Recent Aggradation and Degradation of Alluvial Sand Deposits, 1965 to 1986, Colorado River, Grand Canyon National Park, Arizona. (J.C. Schmidt and J.B. Graf).

Sandy Beach Area Survey Along the Colorado River in the Grand Canyon National Park. (R. Ferrari).

Trends in Selected Hydraulic Variables for the Colorado River at Lees Ferry and Near Grand Canyon for the Period 1922 to 1984. (D.E. Burkham).

Sediment Data Collection and Analysis for Five Stations on the Colorado River from Lees Ferry to Diamond Creek. (E.L. Pemberton).

Unsteady Flow Modeling of the Releases from Glen Canyon Dam at Selected Locations in the Grand Canyon. (J. Lazenby).

Sediment Transport and River Simulation Model. (C.J. Orvis and T.J. Randle).

Results and Analysis of STARS Modeling Efforts of the Colorado River in the Grand Canyon. (T.J. Randle and E.L. Pemberton).

5 REPORTS ON VEGETATION

Evaluation of Riparian Vegetation Trends in the Grand Canyon Using Multitemporal Remote Sensing Techniques. (M.J. Pucherelli).

Effects of Post-Dam Flooding on Riparian Substrates, Vegetation, and Invertebrate Populations in the Colorado River Corridor in Grand Canyon, Arizona. (L.E. Stevens and G.L. Waring).

Aerial Photography Comparison of the 1983 High Flow Impacts to Vegetation at Eight Colorado River Beaches. (N.J. Brian).

The Effects of Recent Flooding on Riparian Plant Establishment in Grand Canyon. (G.L. Waring and L.E. Stevens).

Effects of Post-Glen Canyon Dam Flow Regime on the Old High Water Line Plant Community Along the Colorado River in Grand Canyon. (L.S. Anderson and G.A. Ruffner).

5 REPORTS ON RECREATION AND RAFTING

Glen Canyon Dam Releases and Downstream Recreation: An Analysis of User Preferences and Economic Values. (R.C. Bishop, K.J. Boyle, M.P. Welsh, R.M. Baumgartner, and P.R. Rathbun).

The Effect of Flows in the Colorado River on Reported and Observed Boating Accidents in Grand Canyon. (C.A. Brown and M.G. Hahn).

Boating Accidents at Lees Ferry: A Boater Survey and Analysis of Accident Reports. (L. Belli and R. Pilk).

An Analysis of Recorded Colorado River Boating Accidents in Glen Canyon for 1980, 1982, and 1984, and in Grand Canyon for 1981 through 1983. (A.H. Underhill, M.H. Hoffman, and R.E. Borkan).

Fluctuating Flows from Glen Canyon Dam and Their Effect on Breeding Birds of the Colorado River. (B.T. Brown and R.R. Johnson).

4 REPORTS ON BIRDS AND LIZARDS

Monitoring Bird Population Densities Along the Colorado River in Grand Canyon. (B.T. Brown).

Monitoring Bird Population Densities Along the Colorado River in Grand Canyon: 1987 Breeding Season. (B.T. Brown).

Lizards Along the Colorado River in Grand Canyon National Park: Possible Effects of Fluctuating River Flows. (P.L Warren and C.R. Schwalbe).

APPENDIX B

LIST OF CREDA MEMBERS AND ASSOCIATED SYSTEMS

CREDA MEMBERS AND ASSOCIATED SYSTEMS

<u>Northern Division</u>

- Platte River Power Authority
  - Estes Park, CO
  - Fort Collins, CO
  - Longmont, CO
  - Loveland, CO

- Tri-State Generation and Transmission Association
  - Highline Electric Association
  - K.C. Electric Association
  - Morgan County Rural Electric Association
  - Mountain Parks Electric, Inc.
  - Mountain View Electric Association, Inc.
  - Poudre Valley Rural Electric Association, Inc.
  - Union Rural Electric Association, Inc.
  - Y-W Electric Association, Inc.
  - Chimney Rock Public Power District
  - The Midwest Electric Membership Corp.
  - Northwest Rural Public Power District
  - Panhandle Rural Electric Membership Association
  - Roosevelt Public Power District
  - Wheat Belt Public Power District
  - Big Horn Rural Electric Co.
  - Carbon Power & Light, Inc.
  - Garland Light & Power Co.
  - Hot Springs Rural Electric Association, Inc.
  - Niobrara Electric Association, Inc.
  - Riverton Valley Electric Association, Inc.
  - Rural Electric Co., Inc.
  - Sheridan Johnson Rural Electrification Association
  - Wheatland Rural Electric Association, Inc.
  - Wyrulec Company

- Plains Electric Generation and Transmission Cooperative
  - Kit Carson Electric Coop.
  - Otero County Electric Coop.
  - Mora-San Miguel Electric Coop.
  - Northern Rio Arriba Electric Coop.
  - Sierra Electric Coop.
  - Springer Electric Coop.
  - Socorro Electric Coop.
  - Central New Mexico Electric Coop.
  - Continental Divide Electric Coop.
  - Columbus Electric Coop.
  - Southwestern Electric Coop.
  - Jemez Mountains Electric Coop.
  - Navapache Electric Coop.

Northern Division (continued)

- Intermountain Consumer Power Association
  - Beaver City, UT
  - Blanding, UT
  - Bountiful, UT
  - Enterprise, UT
  - Ephraim, UT
  - Fairview, UT
  - Fillmore, UT
  - Heber Light and Power
  - Holden, UT
  - Hurricane, UT
  - Hyrum, UT
  - Kanosh, UT
  - Kaysville, UT
  - Lehi, UT
  - Logan, UT
  - Meadow, UT
  - Monroe, UT
  - Morgan, UT
  - Mt. Pleasant, UT
  - Murray, UT
  - Oak City, UT
  - Page, AZ
  - Paragonah, UT
  - Parowan, UT
  - Santa Clara, UT
  - Spring City, UT
  - St. George, UT
  - Washington City, UT
  - Dixie-Escalante Rural Electric Association
  - Flowell Electric Association, Inc.
  - Garkane Power Association
  - Mt. Wheeler Power, Inc.

- Strawberry Water Users Association
  - Strawberry Electric Service District
  - Paywon, UT
  - Springville, UT

- Utah Municipal Power Agency
  - Levan, UT
  - Manti, UT
  - Nephi, UT
  - Salem, UT
  - Spanish Fork, UT

- Provo, UT

Northern Division (continued)

- Wyoming Municipal Power Agency
  - Cody, WY
  - Fort Laramie, WY
  - Guernsey, WY
  - Lingle, WY
  - Lusk, WY
  - Pine Bluffs, WY
  - Powell, WY
  - Wheatland, WY
- Truth or Consequences, NM
- Navajo Tribal Utility Authority
- Colorado Springs, CO
- Farmington, NM

Southern Division

- Arizona Municipal Power Users Association
  - San Carlos Irrigation Project
  - Safford, AZ
  - Thatcher, AZ
- Arizona Power Authority
  - Chandler Heights Citrus Irrigation District
  - Queen Creek Irrigation District
  - San Tan Irrigation District
- Irrigation and Electric Districts Association of Arizona
  - Ak-Chin Indian Community
  - Electrical District No. 3
  - Electrical District No. 4
  - Electrical District No. 5
  - Electrical District No. 6
  - Electrical District No. 7
  - Maricopa County Municipal Water Conservation District No. 1
  - Ocotillo Water Conservancy District
  - Roosevelt Irrigation District
  - Roosevelt Water Conservation District
  - Wellton-Mohawk Irrigation District
- Arizona Power Pooling Association
  - Arizona Electric Power Cooperative
    - Anza Electric Cooperative Inc.
    - Duncan Valley Electric Cooperative, Inc.
    - Graham County Electric Cooperative, Inc.
    - Mohave Electric Cooperative, Inc.
    - Sulphur Springs Valley Electric cooperative, Inc.
    - Trico Electric Cooperative, Inc.

<u>Southern Division</u> (continued)

- Arizona Power Pooling Association (continued)
  City of Mesa, AZ
  Electrical District No. 2

- Salt River Project

- Colorado River Commission of Nevada

- Silver State Power Association
  Boulder City, NV
  Lincoln County Power District No. 1
  Overton Power District No. 5
  Valley Electric Association

APPENDIX C

Executive Summary of Power Report

EXECUTIVE SUMMARY

Study Objective

- **The goal of this study was to recommend a methodology for use in estimating the economic value of impacts to power production from potential changes in operations at Glen Canyon Dam.**

Phase I of the Glen Canyon Environmental Studies (GCES) focused on the measurement of downstream impacts of dam operations. The need for studies of the impacts of changes in operations on the power production was identified in a letter dated June 16, 1988, from the Assistant Secretary for Water and Science and the Assistant Secretary for Fish, Wildlife and Parks.

The assistant secretaries stated that the lack of information on power impacts was a major impediment to making decisions about possible changes in dam operations. Evaluation of power impacts took on even more importance when Interior Secretary Lujan decided, in 1989, that Glen Canyon Dam operations should be subjected to a formal analysis under the National Environmental Policy Act (NEPA) so that an environmental impact statement could be prepared. NEPA explicitly requires that alternatives be explored and their economic implications be analyzed.

Methods

This study was designed to investigate which power valuation method would best analyze, for larger power systems, alternatives identified by ongoing GCES research and the NEPA process.

- **Three power valuation methods were compared in this study.**

  1. **A version of the alternative thermal plant method (ATP), conducted by Western Area Power Administration (Western);**

  2. **a production cost model (Elfin), conducted by the Environmental Defense Fund (EDF); and**

  3. **a generation expansion model (EGEAS), conducted by Stone & Webster Management Consultants, Inc.**

Hypothetical System

- **These three methods were evaluated by applying them to a hypothetical power system that consisted of three interconnected utilities. The three hypothetical utilities were constructed to represent a variety of attributes of Salt Lake City Area Integrated Projects (SLCA/IP) customers, including seasonal peaks, system sizes, and degree of dependence on SLCA/IP power.**

The decision to model a hypothetical system rather than attempting to model actual CRSP customers was made in the interest of simplicity. Constructing a data base using actual utilities' day-to-day operations as input was considered to be too complex. It was thought that the additional complexity of modeling an actual system was not crucial to evaluating model performance. Instead, a simplified hypothetical system which represented a variety of attributes of SLCA/IP firm power customers was constructed. To the greatest extent possible, all methodologies assumed identical assumptions and data inputs. Common assumptions and inputs included descriptions of existing thermal and hydro resources, future resources, load, fuel prices, discount rates, escalation rates, and price at which utilities would buy and sell power from each other.

Evaluation Criteria

- All three methods were evaluated for:

  1. their ability to model power system parameters (different system sizes, different utility sizes, loads, and changes in fuel costs, inflation, and interest rates);

  2. their implementation considerations (level of detail required to use the method, cost of using the method, accuracy of the method); and

  3. their flexibility in handling change cases.

Ideally, the methodology selected should be sufficiently flexible to handle impacts to utilities of various sizes, be able to handle a variety of potential restrictions on operations including minimum releases, maximum releases, and restrictions on ramp rates (the rate at which the discharge from the generators changes). In addition, the methodology should be credible in terms of both its technical merits and its acceptability to various constituent groups who will review the output from the methodology during the Glen Canyon Dam Environmental Impact Assessment process.

Description of Potential Changes in Dam Operations

- Two points of view, that changes in operations should be described in terms of changes in contract rates of delivery (CROD) or change in patterns of CRSP generation including purchases and sales, were accommodated in this study. When based on CRODs, the impact of an unspecified change in operations was arbitrarily described as a decrease of 10 percent in the CRSP capacity and energy allocation to each of the hypothetical utilities. When based on CRSP generation patterns, the change in operations was described in terms of energy and capacity under various operating rules. The operating rules considered included present operations at Glen Canyon Dam, a 5,000 cubic feet per second (ft^3/s) minimum, an 8,000 ft^3/s minimum, and a complex operating rule with hourly restrictions on minimum releases, maximum releases and ramp rates.

Implementation of these methodologies required a description of a change in operations at Glen Canyon Dam. Much of the effort during this study focused on determining the appropriate manner in which the changes in operations would be input to the various methods. Two distinct points of view developed with regard to this issue.

One point of view was that changes in the operating rules should be reflected by a contract change in the amount of SLCA/IP energy and capacity that is marketed under long-term firm power contracts. From this perspective, estimating the economic impact of the changes in dam operations requires only the estimation of the cost to SLCA/IP customers to replace the energy and capacity lost because of the changes in the contract rate of delivery.

A second point of view was that evaluations of the impacts of changes in operations ought to be based on historical SLCA/IP hydro generation patterns, and thus additionally account for non-firm purchases and sales. Non-firm power is produced and marketed under short-term contracts and sold on the regional power market. Focusing solely on long-term contracts tends to ignore the distinction between fulfillment of SLCA/IP contract obligations and SLCA/IP generation. For example, in dry years, Western must purchase power to fulfill its contracts, while in wet years, Western may have excess power to sell. Even in years in which there is just enough energy to meet the contracts, Western may meet its off-peak demand by purchasing thermal power, saving the hydro resource for sale during on-peak periods.

The distinction between delivery of energy under SLCA/IP contracts and SLCA/IP generation takes on additional importance when considering changes in dam operations. While changes in operating rule will not affect the total amount of energy produced, they may have two important impacts. First, changes in operating rules may shift energy production to periods when the energy is less needed and, therefore, the value of energy is low, reducing the overall value of the energy produced. Secondly, changes in operating rules may result in a decrease in the amount of energy sold under firm power contracts and consequently increase the amount of energy sold under non-firm power contracts. The ability to explicitly deal with these non-firm sales and purchases is central to understanding the full power impacts of changes in operations. Western's rate and repayment analysis does take these factors into account and they do effect the rates paid by the CRSP firm power customers.

Results

- **When based on changes in contracts (CRODs), the production cost model (Elfin) and the generation expansion model (EGEAS) produced results that were very similar.**

The economic impact of the 10 percent reduction in energy and capacity to all three hypothetical utilities was estimated at $126 million by Elfin and at $117 by EGEAS. These results are within 8 percent of each other. Application of the standard alternative thermal plant (ATP) method yielded an estimate of the impact of a reduction in energy and capacity of 10 percent at $12 million annually. However, because of basic inconsistencies between the modeling methods and the standard ATP method, a direct comparison between the ATP results and the modeling results is not appropriate. For example, the figures from the modeling results are the present value of a stream of 50 years of increased production costs, while the ATP method reports an annual value. Even if the ATP method results are modified to reflect the present value of a 50-year stream of annual costs, there still remain important differences. These differences prevent meaningful comparisons between the ATP method and the system simulation models.

- **When the modeling methods were applied to changes in patterns of CRSP hydro generation data, Elfin and EGEAS produced results that were within 10 percent of each other when measuring the impacts of the imposition of a 5,000 ft^3/s minimum and an 8,000 ft^3/s minimum releases.**

The ATP method was not used to evaluate changes in CRSP generation data because the method cannot efficiently deal with capacity and energy that changes on a monthly basis.

Recommendations

- **While all three methodologies have the potential for application in GCES, we feel that the power systems simulations models are superior to the ATP method.**

We base this conclusion on the ability of power systems simulation models to explicitly incorporate important features of power systems with which the ATP method has difficulty dealing. Because of this deficiency, we cannot recommend the use of the ATP method as the primary methodology for use during GCES investigations of power impacts to large systems of changes in operations at Glen Canyon Dam.

- **Because both power system simulation models have important distinguishing features and the use of two models provides greater accuracy and quality assurance, we recommend continued use of both Elfin and EGEAS in the evaluation of changes in operations at Glen Canyon Dam. To assure consistency, Elfin and EGEAS should be run by the same consultant.**

We feel that both Elfin and EGEAS possess sufficient flexibility to address the potentially large number of changes in dam operations which may develop during the course of GCES and the public involvement phase of the Glen Canyon Dam Environmental Impact Assessment. We feel that both Elfin and EGEAS can produce results that are credible, defensible, and consistent with the present state of power valuation.

Study Limitations

- **Because this study is based on a hypothetical power system, the estimated power system impacts reported in this study cannot be taken in any sense as indicative of the magnitude of power system impacts on real SLCA/IP customers that would result from a real change in Glen Canyon Dam operations. The power system impacts reported by this study, however, are sufficient to compare the results of the three methods being evaluated.**

- **Furthermore, this study only evaluates methods for estimating the power system impacts for hypothetical SLCA/IP customers having their own generating capabilities. The methods discussed in this report are not appropriate to measure the power system impacts for smaller utilities without these capabilities. The impact to these smaller utilities will be analyzed as part of GCES and the Glen Canyon NEPA process.**

- **Revenues earned by Western are used to cover project expenses and to pay back project costs. By law, rates must be set at a level adequate to repay all allocated project costs within 50 years. Any changes in dam operations resulting in a change in marketable resource and/or a change in non-firm sales and purchases will affect project revenues and, therefore, have the potential to affect rates to firm power customers. This study did not examine the effect of changes in dam operations on rates to firm power customers. Further studies by the economics team will evaluate the impacts of changes in operations to marketable resources and the resulting rates charged to firm power customers.**

- Cost estimates from power system simulation models are affected by major independent variables including the load forecast, capital and fuel costs, hydrology, interest rates, and purchased power costs. Studies of actual power system often include a sensitivity analysis in which variables are changed so that their impact on cost estimates can be analyzed. In this study, these variables were held constant. Future studies, using actual utility data, should test sensitivity to these and other variables.

- In most studies involving power system simulation models, the first step involves "benchmarking," or calibrating, the model. Benchmarking can be accomplished by using the model to estimate system costs for a recent time period for which actual system costs are known. In this study, benchmarking was impossible since the system being modeled was a hypothetical system for which no actual systems costs were known.

- For portions of this study focusing on changes in CROD, the change in marketable resource (i.e. amount of energy and capacity available for firm contracts) was arbitrarily set at a reduction of 10 percent for both energy and capacity. A satisfactory methodology to translate changes in operations to changes in the marketable resource was not developed for this component of the study.

- Transmission constraints were not included in this study.

- Environmental considerations due to changes in thermal generation were not included in this study.

APPENDIX D

GLOSSARY OF POWER TERMS

GLOSSARY OF POWER TERMS

Capacity	The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer.
Critical Head	The hydraulic head at which the full-gate output of the turbine equals the generator rated capacity (full-gate referreing to the condition where the turbine wicket gates are wide open, thus permitting maximum flow through the turbine). Below critical head, the full-gate turbine capability will be less than the generator rated capacity. Above critical head, generator rated capacity can be obtained at a discharge less than full-gate discharge. At many older plants, critical head is defined as the head at which full-gate output of the turbine equals the generator overload capacity. In recent Corpos of Engineers practice, the term critical head is used to refer only to operating projects. For planning and design purposes, the term rated head is used to describe the same head condition.
Energy	Power of doing work, looked on as one of two fundamental things in the makeup of the physical universe (the other being mass). Usually measured in kilowatt-hours.
Firm Energy	Electric energy which is intended to have assured availability to the customer to meet any or all agreed upon portion of his load requirements.
Forced Outage	The occurrence of a component failure or other condition which requires that a unit be removed from service immediately, in contrast to a planned or scheduled outage.
Generation	The process of producing electric energy by transforming other forms of energy; also, the amount of electric energy produced, expressed in kilowatt hours.
Generator	A machine that converts mechanical energy into electrical energy.
Gigawatt (gW)	1,000 megawatts
Gigawatt-Hour (gWh)	1,000 megawatt-hours
Hydroelectric Plant	A plant in which the turbine generators are driven by fallen water.
Hydroelectric Power	The harnessing of flowing water to produce mechanical or electrical energy.
Kilowatt (kW)	Unit of electric power equal to 1,000 watts, or about 1.34 horsepower.
Kilowatt-Hour (kWh)	The unit of electric energy commonly used in marketing electric power; the energy produced by 1 kilowatt acting for 1 hour.

Load	The amount of electric energy delivered at a given point.
Megawatt (mW)	1,000 kilowatts
Megawatt-Hour (mWh)	1,000 kilowatt-hours
Nonfirm Energy	Electric energy having limited or no assured availability.
Power	The rate at which energy is transferred, usually measured in watts. Also used for a measurement of capacity.
Reliability	The probability that a device will function without failure over a specified time period or amount of usage.
Turbine	A machine for generating rotary mechanical power from the energy in a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

PROPOSAL TO STUDY THE EFFECTS OF GLEN CANYON DAM ON THE RECREATION, POWER AND ENVIRONMENTAL ECONOMIC RELATIONSHIPS OF THE GRAND CANYON, AZ

Glen Canyon Environmental Studies

Flagstaff, AZ

March 28, 1990

PROPOSAL TO STUDY THE EFFECTS OF GLEN CANYON DAM ON THE RECREATION, POWER AND ENVIRONMENTAL ECONOMIC RELATIONSHIPS OF THE GRAND CANYON, AZ

A. ABSTRACT

The Glen Canyon Environmental Studies (GCES) program is supplying the information required by the Department of the Interior for the determination of the impacts associated with the operation of Glen Canyon Dam. A major portion of the understanding of impacts is that associated with economics. Three different levels of economics are evaluated: (1) Power Economics; (2) Recreation Economics; and, (3) Non-Use Value Economics.

The primary mode for completion of the economic studies will be a combination of contracts and interagency cooperation. Separate Requests for Proposals are being developed for the Power Economics/Power Modeling Efforts and for the Recreation and Non-Use Value Economics. Each of the resulting contracts will be fully integrated into the overall GCES research program.

The information presented in this proposal represents a definition of the primary hypotheses to be addressed, background information, the objectives of each objective, and a definition of anticipated program accomplishment. Overall program timing and budget are defined for planning purposes.

B. **INTRODUCTION**

Problem Statement

There are many social goals that may be obtained from the services provided by the Colorado River. An appropriate goal for river management might be to manage the river in such a way to achieve the largest benefits possible. Attainment of this goal requires an understanding of how the ability to promote various social objectives responds to various river management policies. Traditional uses of water resources including commercial and municipal water supply, irrigation, hydroelectric power generation and flood control have dominated water resource management debates. Recently other social goals for water resource management, such as recreation, and preservation of endangered species, have begun to be recognized as legitimate uses for water resources. In the context of GCES the social goals that appear to be most directly affected by changes in river management policies include, power production, recreation, endangered species and environmental preservation. Other uses of the Colorado River water resource such as water delivery appear to be beyond the scope of GCES and will remain so because all of the changes in operations that have been currently advanced for discussion do not involve changes in monthly or yearly release volumes. Consequently this proposal will focus on ways in which the benefits of river management policies (in terms of power benefits, recreation benefits, and benefits associated with environmental preservation can be derived and how these estimates could be integrated in the decision making process.

Economists often use the terms "use" and "non-use" benefits to characterize the benefits that society might obtain from a resource. While a complete discussion of these benefits is beyond the scope of this proposal, a brief discussion of these categories will be helpful. Use benefits can be thought of as the benefits derived from some actual use of the resource. In the context of GCES, use benefits would be associated with the use of the river for the production of electricity and the use of the river for the production of recreational experiences. Non-use benefits can be characterized as the benefits derived from the resource without any direct use of the resource taking place.

Two distinct classifications are often used in discussions of non-use values. The first (initially identified in Weisbrod 1964) is the fact that individuals may not currently have a use value for the resource, but may have a use value at some future date. Because of uncertainty regarding the nature of future demand and the uncertainty regarding future availability of the resource individuals might place some value on maintaining the option for future use. An expression of willingness to pay to ensure availability of a resource at some future date is called option price. The difference between the expected value of uncertain future use values and the option price is called the option value.

In the context of GCES an individual might be willing to pay an amount now to ensure access to a certain type of recreation in the future. While option values appear to be closely related to the risk aversion premium, it is impossible to tell under most conditions whether option value is positive or negative. Given this difficulty and the fact that theoretical arguments that suggest that option value is likely to be small compared to use benefits, very few empirical studies result in estimates option prices or option values. It is suggested that for this study option values need not be an issue.

The second major classification of non-use benefits are the benefits that might arise because an individual is better off simply because the resource exists. Existence values were first discussed by in Krutilla, (1967) and have generated a substantial literature regarding their theoretical relevance as well as the possibilities for measuring them. Existence values are often attributed to sympathy for animals and the environment, sympathy for other humans, or a sense of personal environmental responsibility. In the context of the GCES it might be argued that because the Grand Canyon is so well known, individuals might suffer a loss if dam operations cause a change in the downstream environment that is viewed as undesirable.

The distinction between these types of values is important in the context of the Glen Canyon Environmental Studies because the

Colorado River between Lake Powell and Lake Mead has the potential for generating benefits in all of these categories. Furthermore, it appears that management of the river to increase one category of benefits might result in a decrease in benefits in other categories. For example, management for increasing recreational use benefits might require changes in dam operations that would result in a decrease in the benefits derived from electricity produced at Glen Canyon Dam.

To this point, this proposal has focused on the measurement of social preferences in terms of economic benefits. It is of course possible to directly ask individuals about their preferences for the outputs of various river management policies. Such statements of direct preferences may be very useful to decision makers when an effort is being made to understand the impact of a management policy on a single attribute. For example if the only area of concern is recreation it might be sufficient to know that the majority of whitewater rafters indicate that flow pattern X is "better" than flow pattern Y. By asking individuals to evaluate many different flow patterns it is possible to determine the types of flows that maximize recreation benefits.

When a management policy must be made which has effects in several areas, direct indications of preference are less useful than economic measures of preferences. For example, what does a decision maker do if she knows that flow pattern X is preferred by recreationists over Y but that it also decreases the benefits derived from power production by $1,000,000? Two choices are then available. The first is to make a choice. The nature of the choice will reveal the decision maker's implicit tradeoff between the two goals. For example a choice of flow pattern Y by the decision maker indicates that the decision makers feels that the decrease in recreational benefits is worth less than $1,000,000. A second approach would be to use one of the economic methods described below to obtain a monetary estimate of the recreation benefits. Doing so would replace the value judgement of the decision maker with the value judgement of those affected by the choice of flow patterns. The relative impacts of flow pattern Y could then be evaluated in a common metric - dollars. In summary direct questioning about preferences can provide important information for resource managers. However when the management decision involves trade-offs between conflicting social goals, dollar based economic measures of preferences provide a common metric to be used in assessing the trade-off. In this respect hypotheses 8 and 14 really address the same issue, namely how are recreationists affected by flows from Glen Canyon Dam.

Specific Objectives

Four specific economic questions have been addressed in the overall GCES short term Research Plan. They include the following:

Objective 1. Determine the potential economic impact of changes in power operations at Glen Canyon Dam that may result from modified operations. (Hypotheses 13.1).

Objective 2. Determine the recreational values influenced by the characteristics of discharge from Glen Canyon Dam, such as discharge fluctuations, minimum discharges and rates of change of fluctuating discharges. (Hypotheses 8.1).

Objective 3. Determine the effects of Glen Canyon Dam operations on the downstream recreational activities and resulting economic benefits. (Hypotheses 14.1).

Objective 4. Determine how downstream non-use benefit values are affected by the operations of Glen Canyon Dam. (Hypotheses 15.1).

Research to address hypotheses 13.1, 14.1 and 15.1 will focus on the measurement of the economic benefits of recreation, power production and environmental preservation as they are affected by the operation of Glen Canyon Dam. The purpose of addressing these three hypotheses is to measure, in a consistent and credible manner, the impacts of Glen Canyon Dam releases on benefits from power production, recreation and the downstream environment. The recreation studies will build off of the recreation work completed under the first phase of the GCES efforts.

Process of Integration with Research Study Plan

The studies proposed here will help support the decision(s) that will be made concerning dam operation at Glen Canyon Dam. In order to fully assess all of the economic relationships, it is critical to know what environmental impacts will occur as a consequence of any particular dam operation scenario.

After the environmental and recreation impacts are ascertained, then the researchers in the environmental portion of GCES can formulate flow patterns that might achieve some specified environmental or recreational goal. The resulting specified flow pattern will then be analyzed to determine it's economic relationships in terms of power, recreation and environmental preservation.

Similarly, an understanding of the relation of between various economic benefits and flow patterns will allow the identification of flow patterns that can achieve environmental objectives with the smallest possible economic loss.

C. BACKGROUND INFORMATION ON PREVIOUS WORK

Glen Canyon Environmental Studies

The Glen Canyon Environmental Studies were initiated in 1982 with a stated objective to determine the relationship between Glen Canyon Dam operations and the <u>downstream</u> recreation resources.

There was no effort to explore or define the economic relationships except as broadly related to the recreation industry.

After the initial phase of the GCES program was completed, the Assistant Secretary for Water & Science and the Assistant Secretary for Fish, Wildlife and Parks recommended an expanded GCES effort with broader emphasis to be placed on the relationship of power economics and recreation economics. Additionally, when the Secretary of the Interior directed that the Environmental Imp[act Statement be initiated at Glen Canyon Dam, the issue of non-use value or environmental economic relationships was included.

Economic Areas of Study

Work has been accomplished on the different variables of economics. The current level of knowledge is defined for each subject area:

1. **Power Modeling**

The federal government has an interest in determining the value of hydro power. A summary of the federal perspective on the evaluation of hydropower benefits can be found in The Economic and Environmental and Principles and Guidelines for Water and Land Related Resources Implementation Studies (US Water Resources Council, 1983) and Evaluating Hydropower Benefits (US Water Resources Council 1981). These documents support the propose that hydropower benefits should be measured in economic terms.

The basic premise of power economic assessment is that a measure of willingness to pay for electricity is the appropriate measure of hydropower benefits. However, the Principles and Guidelines note that because of market imperfections typically found in power markets, an acceptable measure of hydropower benefits is "the cost of the electricity that the hydropower would have displaced".

Several methods have been developed for measuring the cost of power. These methods can be broken down into two categories, the alternative thermal plant method (ATP) and power system simulation models.

Previous and Related Work in Power Modeling: The GCES power economics team is in the process of finalizing a study of the potential of three methods for estimating the economic impacts to power production caused by changes in operations at Glen Canyon Dam. Three methods were evaluated: (1) the ATP method, (2) a production cost model, and (3) a generation expansion model. The evaluation of the models was performed by applying each of the methods to a hypothetical power system consisting of three utilities. Each method was used to evaluate the cost of imposing various types of changes in operations at Glen Canyon Dam.

The conclusions of the power prototype study is that the production cost model and the generation expansion model produced remarkably similar results. Furthermore, both models appeared to have sufficient flexibility to handle the various types of dam operation scenarios that seem likely to result from the Glen Canyon Dam EIS scoping process and the ongoing GCES environmental research. The ATP method did not produce results comparable to either of the two models and appeared to have insufficient flexibility for use in the context of GCES.

2. Recreation Economics

Publicly provided water recreation poses a different challenge in terms of estimating economic benefits. Recreation economics involves commodities that are not traded in markets. Economists have developed several methods to deal with non-market goods such as recreation(see for example Freeman 1979). One approach to making inferences about preferences and benefits is to examine transactions in some market which is linked to the resource in question. These methods are often classified as being based on weak complementarily.

The notion of weak complementarily is that access to benefits of some non-market goods can only be obtained through expenditures in other related markets. In the **travel cost method**, developed by Clawson (1957), inferences about recreational benefits are made by making observations on the expense people make to participate in the recreational activity being evaluated. An extensive body of economic theory has developed around the travel cost method and it's use to evaluate changes in the quality of a recreational experience (Maler 1974 or Freeman 1979).

A second method based on weak complementarily is the **hedonic price method.** In this method inferences about the benefits of the non-market good are made by making observations in a related market in which the benefits of the non-market good are thought to be reflected. For example, using the hedonic price method, the value of air quality might be determined by determining if real estate value systematically vary in areas of varying air quality (Brookshire et al. 1983).

A final approach to measuring economic benefits of recreational activities is the **contingent valuation method.** A summary of the application of the contingent valuation method can be found in Mitchell and Carson (1989). Rather than relying on weak complementarily, in the contingent valuation method individuals are asked how they would behave if the cost of having access to the resource were to change. Using the Lees Ferry fishery as an example, an application of the contingent valuation method might involve asking anglers if they would have come on a particular trip if their expenditures had increased by various amounts.

Previous and Related Recreation Economics Work: During GCES Phase I, an analysis was conducted of the relation between flows and recreational benefits (Bishop et al. 1987). This study focussed on three types of recreation: (1) Day use rafting between Glen

Canyon Dam and Lee's Ferry, (2) angling between Glen Canyon Dam and Lee's Ferry, and (3) whitewater rafting between Lee's Ferry and Lake Mead. Each recreational group was surveyed twice. The **first survey** involved asking the recreationists questions to determine if any of the important attributes of the recreational experience might be affected. For all three groups it was determined that there were aspects of the recreational experience that were potentially affected by flows.

The **second survey** used the contingent valuation method to study the effects of flows on recreational benefits. Based on the contingent valuation results, a simple model was developed that related flows patterns to recreational benefits. These contingent valuation surveys were conducted in 1985 and 1986. Since that time several changes have occurred. During the time of the original surveys the Lees Ferry fishery was open to anglers using bait. The Lee's Ferry fishery is now restricted to artificial flies and lures. For whitewater rafting, there is some indication that the nature of whitewater trips has changed to shorter trips. Because of these changes it is worthwhile to review the possibility that the relations between flows and recreational values need to be updated.

3. Non-Use Value Economics

The possibility that dam operations may have a significant environmental impact downstream from Glen Canyon Dam means that **existence values** could play an important role in decisions regarding dam operations. Economists have developed theoretical frameworks, for example Randall and Stoll (1983), Boyle and Bishop (1987), Smith (1987), Madariaga and McConnell (1987) and Freeman (1989), which have defined the existence values in the context of specialized issues. It is on the issue of measurability of the benefits associated with existence that economists are divided. The difficulty is that with the current state of economics, the only feasible method for estimating pure existence values is the contingent valuation method. While contingent valuation has been shown to give results comparable to the values derived from travel cost studies, hedonic price studies and values based on transactions in experimental markets (Bishop et al., 1988) there remains some skepticism that it can be successfully used to measure existence values.

Previous and Related Non-Use Value Work: An early empirical study of existence value, (Schulze et al. 1983) found substantial non-use benefits associated with preservation of air quality at the Grand Canyon. Few other studies have been done that are directly applicable to GCES.

It is beyond the scope of this proposal to review all of the arguments regarding the measurement and use of existence values, it is important to note that existence values measured using the contingent valuation (Loomis 1987) were an important piece of information in a decision regarding management of water levels in California's Mono Lake. An important goal of the GCES economic research proposals must be a review of the literature regarding existence values with a recommendation as to whether existence values are important in the context of GCES and whether these values ought to be measured as part of GCES.

D. METHODS

Sampling Design

The primary methodologies to address the economic issues outlined in this proposal are defined in Solicitation No. 0-SP-40-09080 entitled Economic Studies for the Glen Canyon Environmental Studies and the pending proposal for Power Modeling. The following information represents a reiteration of those solicitations.

Objective 1. Determine the potential economic impact of changes in power operations at Glen Canyon Dam that may result from modified operations (Hypotheses 13.1)

Power Economics

The economic impacts of changes in operations at Glen Canyon Dam can be measured, in part, by using a power system simulation model. The purpose of this model would be to estimate the present value of any increase in costs of meeting electrical demand that might be caused by a change in operations at Glen Canyon Dam. The use of such a model would allow direct estimation of the response of power benefits to various flow patterns.

While a power system simulation model will help explore the economic impacts of changes in operations at Glen Canyon Dam, other methodologies will have to be employed to measure other impacts. Two areas are of particular concern: (1) determination of the marketable resource under various operating rules and (2) the implications of changes in operation to Colorado River Storage Project repayment and electrical rates.

Western Area Power Administration has developed methodologies that it currently uses to address both of these issues. However it is necessary for GCES personnel to obtain a thorough understanding of these methodologies in order to apply them to the broad aspects of the alternative evaluation.

To implement the power system simulation model, detailed data will be needed from the CRSP customers having generation facilities on their own and the major systems with which they are interconnected. The data requirements include load data, fuel cost data, characteristics of generation facilities and contracts for power purchases and sales. The power system modeling effort will be built around the prototype power evaluations and will be contracted out.

Objective 2. Determine the recreational values influenced by the characteristics from Glen Canyon Dam, such as discharge fluctuations, minimum discharges and rates of change of fluctuating discharges (Hypotheses 8.1)

Objective 3. Determine the effects of Glen Canyon Dam operations on the downstream recreational activities and resulting economic benefits (Hypotheses 14.1)

<u>Recreational Benefits</u>

The Phase I GCES recreational benefits may need to be revised if the alternatives selected for evaluation in the EIS require an economic assessment of the impact of operational changes on recreation. The data would be collected using surveys of recreationists. These surveys could investigate preferences and benefits through both direct questions about satisfaction with various flows and the application of one of the economic methods discussed above for estimating economic benefits. Both measures of preferences could be included in the same survey. Data collected from the surveys would be used to develope response curves relating satisfaction or economic benefits to flow patterns.

The recreation assessments would be made through the use of a Contingent Valuation Survey. It is anticipated that following recreation economic efforts would be required:

1. Fishery Economics - because of fishing regulation changes, a reassessment of the economic relationships to flow should be made. This would be accomplished through the use of a contingent valuation effort. Samples would be collected from contacts made by Arizona Game & Fish creel census clerks and from fishing license information.
2. Day-Use Activities and Economics - In the GCES Phase I effort it was scientifically established that the Day-use recreation industry in Glen Canyon is no directly impacted by flows <u>except</u> during the extreme high flow releases when the trips cannot start from the dam and must begin and end at Lee's Ferry. It is not anticipated that any additional studies will be required for day-use recreation.
3. Whitewater Recreation Economics - It is recommended that a validation study be completed on the whitewater boating economics generated under GCES Phase I. This is recommended because the initial contingent valuation survey conducted on the whitewater recreationists was based largely on hypothetical flow scenarios. As a result, the information and reactions could not be verified with actual data. Samples of recreationists would be drawn from lists of individuals taking whitewater trips during the study period. This should would be stratified to include private and commercial rafting passengers, as well as motorized and non-motorized trips. The survey will be applied to people who were able to experience a wide range of flow levels.

Objective 4. Determine how downstream non-use benefit values are affected by the operations of Glen Canyon Dam.

<u>**Non-Use Value Economics**</u>

If it is decided that it is worthwhile to measure the relation between non-use benefits, such as existence value and flow patterns, data would be collected using contingent valuation surveys.

For the purpose of this study the initial sample survey will be built around a representative sample of the population of the Western United States. A contingent valuation approach will be used with this population because of the fact that the Western United States people are those most likely to be impacted by any operational change at Glen Canyon Dam. By keeping the sample population relatively small, credibility in the sample results can be increased.

D. Logistical Support Requirements

Logistical requirements for the economics efforts will come in a variety of packages:

1. Power Economic Evaluation.

Much of the data required to implement a power system model is publicly available. However, the quality of the modeling effort will be increased and the cost of the modelling effort decreased if CREDA members agree to provide some data for the modeling effort. Ideally this data would be provided under some arrangement so that it could be used for the purpose of GCES only. A second area in which logistical support is required is in the determination of the marketable resource and the impacts to rate and repayment. Integration of these impacts will require close coordination with Western Area Power Administration.

2. Recreation Economics

If surveys of whitewater rafters are conducted, it would critical to have private outfitters and the National Park Service provide trip rosters for whitewater rafting trips during specified time periods.

3. Non-Use Value Economics

Logistical support requirements are minimal. If a survey is conducted to measure non-use benefits, a sample of western households could be obtained from a commercial vendor such as Survey Sampling.

E. Tasks and Research Timetable

The following schedule is recommended for the overall recreation project with quarterly and annual reports developed for each segment of the overall effort.

A. Power Modeling Economics

1. Prototype modeling completed .... April 1990

2. Research For Proposal for expanded effort .... June 1990

3. Selection of contractor .... Dec. 1990

4. Completion of system development .... June 1991

5. Completion of initial runs .... August 1991

6. Evaluation of alternatives .... Oct. 1991

7. Quarterly Reports of Power Modeling Team ...

8. Final Report on alternatives .... Nov 1991

B. Recreation Economics

1. Fishery Economics .... June 1990

2. Selection of Recreation contractor .... June 1990

3. Development of Recreation Study Plan .... July 1990

4. Initiation of Contingent Valuation study ... Oct 1990

5. Completion of Contingent Valuation study ... March 1991

6. Draft Report .... June 1991

7. Final Report .... Sept. 1991

C. Non-Use Value Economics

1. Development of study plans .... July 1990

2. Development of Contingent Valuation study .. Sept. 1990

3. Completion of Contingent Valuation study ... March 1990

4. Draft Report .... August 1990

5. Final Report .... Oct. 1990

F. DELIVERABLES

Quarterly and annual reports will be required on each component of the economics study. In addition, draft final and final reports will be developed.

G. BUDGET

The following are estimated budgets based upon the anticipated contract and coordination costs. These are estimates only.

1. Power Valuation Studies

a.	Contract costs	$ 125,000.00
b.	Report writing costs	$ 50,000.00

2. Recreation Studies

a.	Contract Costs - fishing validation ...	$ 50,000.00
b.	Contract Costs - whitewater rafting ...	$ 110,000.00
c.	Coordination Costs	$ 25,000.00

2. Non-Use Value Studies

a.	Contract Costs	$ 50,000.00
b.	Coordination Costs	$ 15,000.00

GRAND TOTAL **$ 425,000.00**

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LONG TERM MONITORING AND DATA INTERPRETATION

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTEGRATED RESEARCH PROGRAM

LONG TERM MONITORING PROGRAM
AND
DATA INTERPRETATION

I. Issues

The long-term monitoring and data interpretation studies reflect the Glen Canyon Environmental Studies (GCES) Phase II research program commitment to develop a useable and scientifically rigorous long-term monitoring programs that will go into effect when the GCES program has been completed.

A consistent concern with the GCES effort is "how good will our recommendations be?". The value of a long-term monitoring program, centered on specific resources, allows resource managers the ability to keep track of their recommendations and identify if the initial decisions, made with limited data were correct.

The worth of a long-term monitoring program rests with its format, its timing, the components and their review. Key to the development of the long-term monitoring program for the Grand Canyon is the establishment of critical and representative monitoring sites and specific resource classes.

II. Objectives

The broad objectives of the GCES Long-Term Monitoring Studies can be stated as follows:

A. Development of a scientifically credible long-term monitoring program focused on critical and representative resources of Glen and Grand Canyons.

B. Development of a scientifically rigorous long-term data base utilizing a Geographic Information System approach.

III. Components of the GCES Phase II Long-Term Monitoring Studies

The components of the GCES Phase II Long-term Monitoring Studies can be separated into two areas and are depicted in Figure 13.

A. Long-Term Monitoring Components - determination of the parameters and components to be studied in the long-term program.

B. Geographic Information System - development of a scientifically rigorous geographic information system with natural resource class overlays.

IV. Organization of the GCES Long-Term Monitoring Studies

The overall guidance of the GCES Long-Term Monitoring Studies will be provided by the GCES Scientific Core Group. This group is composed of members from each of the associated GCES research groups and the Senior Scientist. Additional input will be sought on the Long-Term Monitoring program from the Native American Tribes.

The GCES Scientific Core Group will be responsible for the development of the Long-Term Monitoring Program and will organize a GCES Long-term Monitoring and Geographic Information System Team to develop the protocol and selection of sites required for the development of the program.

Representation on the GCES Long-Term Monitoring and GCES Geographic Information System Team will include, but not be limited to, the following:

GCES - Senior Scientist
GCES Office
Reclamation - Denver Office
National Park Service - Grand Canyon National Park
Arizona Game & Fish Department
Fish & Wildlife Service
Native American Tribes
Contractors (as required)

Primary leadership for the GCES Long-Term Monitoring and GCES Geographic Information System Team will rest with the GCES Senior Scientist or his designate.

V. Products to be Developed

The GCES Long-Term Monitoring and GCES Geographic Information System Team will be responsible for developing, in coordination with the GCES Scientific Core Group, the following products:

A. A Long-Term Monitoring Plan

B. A Geographic Information System - to be transferred to each of the interested resource offices.

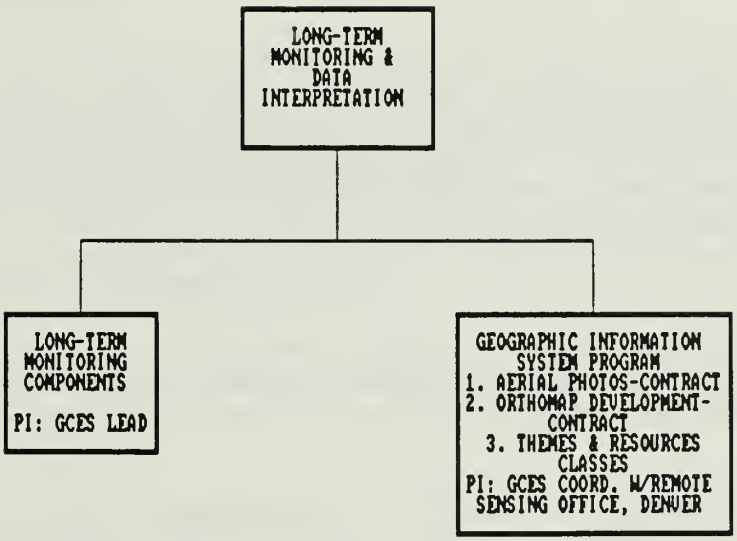

Figure 13. Glen Environmental Studies Long-Term Monitoring and Data interpretation Studies.

STUDY PROPOSAL -- DEVELOPMENT OF A LONG-TERM MONITORING PROGRAM FOR GLEN AND GRAND CANYONS BUILT AROUND THE RESULTS OF THE GLEN CANYON ENVIRONMENTAL STUDIES

Prepared by: David L. Wegner, Glen Canyon Environmental Studies, Program Manager, Glen Canyon Environmental Studies, Flagstaff, AZ

I. INTRODUCTION

The Glen Canyon Environmental Studies (GCES) Phase II research program is designed on the fact that <u>we cannot learn and understand all of the impacts of Glen Canyon Dam in the short period of time allowed for the Studies</u>. The only means available to track the results and recommendations developed from the GCES program is to develop a Long-term monitoring program that allows the resource managers to continually evaluate the original conclusions and recommendations.

The challenge that faces the resource managers is to develop a long-term monitoring program that is both scientifically rigorous and can provide data that is understandable and useable in the management setting.

The GCES <u>Long-Term Monitoring</u> study will develop a useable monitoring program that will be based on data and information collected during the GCES program, both Phase I and II, and an understanding of the specific resources of concern.

II. BACKGROUND

A major concern of the GCES program has been that there is very little background data upon which decisions can be made. A goal of the GCES program has been to initiate a <u>short-term</u> research program upon which a long-term monitoring program could be built.

An additional goal of the Long-Term Monitoring program will be to identify the additional areas of research that are needed and prioritize them for future management consideration.

The core of the GCES Long-Term Monitoring Program will be the development of a Geographic Information System.

III. OBJECTIVES

The objectives of the GCES Long-Term Monitoring Program are as follows:

A. Develop a scientifically rigorous long-term monitoring program based on data collected during GCES Phase I and other available data.

B. Develop a Geographic Information System series of maps and map overlays to serve as the basis for the long-term monitoring program.

IV. METHODS

The methodology to be used in the development of the GCES Long-Term Monitoring program will include, but not be limited to, the following:

A. Long-Term Monitoring Components - a determination of the criteria for selection and development of the long-term monitoring components will be accomplished by a multi-agency group who has resource management responsibilities in Glen and Grand Canyons. This will ensure that the long-term monitoring components will provide the initial information required.

B. Natural Resource Class Selection - Will be accomplished by the resource managers after review of the data and program goals.

C. Development of Data Bases - will be a joint effort with all resource agencies.

D. Integration with the Geographic Information System - will be accomplished concurrent with the GIS development

V. DELIVERABLES

At the completion of the GCES Phase II program, the GCES Long-Term Monitoring Program will be completed. The Long-Term Monitoring program will be implemented concurrently with the Record of Decision on the Glen Canyon Dam - Environmental Impact Statement.

Deliverables will include:

1. A written GCES Long-Term Monitoring Program with scientific logic and review process identified.

2. A timetable for each component of the Long-Term Monitoring Program.

3. A completed Geographic Information System tape for each resource office.

VI. BUDGET

The estimated budget for completion of the GCES Long-Term Monitoring program is as follows:

Fiscal Year 1991 -	$ 25,000
Fiscal Year 1992 -	$ 25,000
	$ 50,000

FLDR # 12071

ORIGINAL

United States Department of the Interior

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IN REPLY REFER TO:
D-3744

JUN 7 '90

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Memorandum

To: Regional Director, Salt Lake City UT
Attention: UC-410 (Wegner)

From: Acting Chief, Applied Sciences Branch

Subject: Proposal to Develop Geographic Information System (GIS) Data Base for Long Term Monitoring in Grand Canyon (GIS)

In response to your request, we have developed a study outline, for the development of a large GIS data base for the Glen Canyon Environmental Studies in Grand Canyon. The data base will be prepared for select river reaches in the canyon and will be comprised of existing information from previous studies, as well as aerial photographic interpretation, map transfer and digitization to be accomplished during FY90 and FY91.

The enclosed study proposal details the methods, timeframe and costs necessary to complete the data base. Any questions regarding this proposal should be addressed to Mr. Michael Pucherelli, Head, Remote Sensing Section at FTS 776-4300.

Howard A. Salman

Enclosure

IF YOU DETACH ENCLOSURES PLEASE INSERT FOLDER NO. ____

STUDY PLAN FOR GRAND CANYON DATA BASE

Background

Ongoing studies have been conducted in Grand Canyon since the inception of the Glen Canyon Environmental Studies (GCES) 1983. Studies have concluded that current operations are adversely affecting the environment in Grand Canyon. More recently, an environmental impact statement has been initiated to address these impacts. This proposal addresses a Geographic Information System (GIS) data base to be prepared by several participating bureaus and agencies under the direction of the Denver Office, Remote Sensing Section.

The GIS data base will be an interagency tool for monitoring the natural resources in the Grand Canyon. The data base will be shared among the technical personnel and decisionmakers in each participating office. The data base will be prepared in the Denver Office with coordination and input from other offices. The data base, as presented herein, will include information on 4 major themes and include 27 resource classes of information. It is believed that by updating the data base annually, trend information and resource class changes can be documented through time. This information could then be used to correlate changes in the river system with reservoir operations. Other valuable information can be acquired for individual researchers as necessary.

Study Area

An interagency group of GCES team members selected 13 study sites encompassing 65 river-miles. The sites were formally selected at a meeting of the participating agencies in Phoenix on April 2, 1990. All methods and costs for this study are outlined for the proposed 65 river-miles.

Study Sites To Be Mapped During FY 90-91

RVMILE Dam to -10.5
RVMILE -4 to 2
RVMILE 42 to 48
RVMILE 51 to 56
RVMILE 60 to 72 (includes 1 mile up the Little Colorado River)

Study Sites To Be Mapped During FY 91-92

RVMILE 93 to 99
RVMILE 120 to 123
RVMILE 133 to 138
RVMILE 143 to 145
RVMILE 179 to 181
RVMILE 207 to 210
RVMILE 225 to 230
RVMILE 273 to 276

Base Map Preparation

Photogrammetric costs have been acquired from several sources for mapping to include 2-foot contours along the river corridor. These maps would provide the base for the subsequent data themes to be input into the GIS. Control, both vertical and horizontal, must be traversed through the Grand Canyon to allow for analytical stereo plotters to be used in the mapping process. Reclamation's remote sensing office believes that these maps are necessary for the GIS efforts.

A contract has been prepared by the Remote Sensing Section, the GCES Program Office, and the Upper Colorado Regional Contract Officer, for the acquisition of base maps, surveying, and aerial photography. The surveying will be complete by mid-June for the upper sites. The photographs will be acquired at low-flows, June 1-4, for the upper sites and the subsequent base maps prepared by January 1991. These maps will form the basis of the large-scale GIS data base. During the summer of 1991, surveying and aerial photography will be initiated for the lower sites. Mapping and data base preparation will be completed for all sites during the spring of 1992.

The requirement for photogrammetric mapping was prepared by the Denver Office and presented to Gene Moody and Associates. and Horizons, Inc., the two vendors available through the USBR Upper Colorado Region's photography and mapping contract. Contract procedures usually require all work to be issued to the A vendor, Gene Moody and Associates., however since the Denver Office estimated this work to be around $300,000, it was suggested that both vendors furnish bids.

Consequently, Horizons, Inc., was selected for this work as they bid $399,000 as compared to Moody's bid of $489,000. By competing the base mapping work, Reclamation realized a net savings of $90,000.

GIS Data Base Information and Costs

1. Acquire base maps from the described photogrammetric methods

2. Prepare sediment overlays

    Beaches
    Channel configuration
    Surficial geology
    Cobble bars
    Boulders
    Gravel bars
    Sand bars
    Contours
    River-miles

Photo interpretation, MAP preparation, digitization $ 20,000

3. Terrestrial vegetation

   - Native vegetation
   - Exotic vegetation
   - Bare soil
   - Marsh
   - Wildlife transect information

Endangered species information

Interpretation/Transfer/Digitization $ 14,000

4. Aquatic biology

   - Cladaphora
   - Riffles
   - Runs
   - Pools
   - Backwaters/attributes by bank/size
   - Eddys
   - Open water

$ 10,000

Additional flows may be added for habitat comparison.

5. Recreation theme

   - Camping beaches
   - Mooring sites
   - Lunch spots
   - Trails
   - Rapids/attributes good, fair, poor
   - Attraction sites $ 4,000

Methodology

Aerial photographs will be acquired coincident with the low-flows in early June 1990. Black and white photography will be acquired for base map preparation, at a scale of 1:6000 and color infrared for resource mapping 1:4800 scale.

During the low-flow event several mapping specialists from the Denver Office will be collecting ground reference information in the canyon using historical photographs.

Upon receipt of the current aerial photographs, the above resource classes will be interpreted in the Denver Office. The photographic overlays will then be transferred to the map products prepared via the photogrammetric process.

This procedure will ensure spatial accuracy of all data themes and classes. The resultant thematic map products will be digitized using ARC/INFO software. The software is hosted by a 4325 Tektronix workstation.

Final Products

The final products from this effort will be a report summarizing the methodology and acreage results by river-mile and by site. In addition, map products will be prepared identifying the resource data by study site. Upon completion of this study, digital data, in the form of computer compatible tapes, will be transferred to each participating office.

Summary Costs

The estimated costs associated with the thematic mapping efforts are		$ 48,000
Final products will include approximately 100 thematic maps at 1:10,000 scale		$ 14,000
Any modeling costs will be determined later		
Computer time		$ 9,000
GCES meetings		$ 26,000
Field trips		$ 12,000
Other travel		$ 6,000
If the project will be accomplished with interagency personnel, the additional costs of training and coordination meetings must be included.		$ 19,600
Three year project	TOTAL	$ 134,600

FY90 COSTS

One field trip for groundtruthing Resource classes (three people)		$ 8,000
Meetings/training if necessary		$ 19,600
Begin photointerpretation		$ 10.000
	FY90	$ 37,600

FY91 COSTS

Complete mapping and data base preparation for the first five study sites	$ 23,000
GCES meeting/coordination	$ 6,000
Begin mapping for the last eight study sites	$ 16,000
Other travel	$ 6,000
FY91	$ 51,000

FY92 COSTS

Complete mapping for the last eight study sites	$ 35,000
Report and Final Map Plots	$ 8,000
Coordination Meetings	$ 3,000
FY92	$ 46,000

Upon completion of the data base preparation then the annual monitoring program from 1993 on should be funded at: $ 150,000 per year

To include trend analysis reports and transfer of data

Projected Data Base Time Frame

May 90 - Run control through the canyon

June 90 - Low flow acquire aerial photography

- Groundtruth resource classes

Jan 91 - Map products available from photogrammetry vendor

Aug 90 - Begin interpretation

Jan 91 - Transfer and begin digitizing (upper five study sites)

Jan 91 - Workstation requisition for Flagstaff

June 91 - Complete data base for the five upper sites

June 91 - Acquire low-flow aerial photographs for the lower sites

July 91 - Followup field trip for random sample quality control of photointerpretation and groundtruth the lower sites

Aug 91 - Begin interpretation of the lower study sites

Oct 91 - Transfer and digitize the lower sites

Jan 92 - Workstation delivered to Flagstaff

March 92 - Complete lower data base

May 92 - Final report

REPORT INTEGRATION PROCEDURE

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTEGRATED RESEARCH PROGRAM

GLEN CANYON ENVIRONMENTAL STUDIES

REPORT INTEGRATION PROCEDURE

I. INTRODUCTION

The Glen Canyon Environmental Studies (GCES) Phase II research program has been designed to collect, analyze and interpret the impacts of the operation of Glen Canyon Dam. Ultimately the information generated under the scientific umbrella of the GCES program will be utilized in the evaluation of alternatives being developed for the Glen Canyon Dam - Environmental Impact Statement.

The objective of the GCES **Report Integration Procedure** is to identify the process that we follow in the development of the GCES technical reports. The specific objectives are as follows:

A. Develop an integrated approach to report assimilation.

B. Develop a scientifically rigorous review process for each technical study

C. Develop the GCES technical reports in such a manner that the cumulative effects of resource integration can be followed.

It is our ultimate concern that the information provide the Glen Canyon Dam - Environmental Impact Statement process with the required information and that the technical reports can stand the test of the judicial system.

II. APPROACH

The following approach will be used by the GCES Phase II program in the development of the GCES technical reports and is defined in Figure 14 :

A. Phase I. Development of the individual technical reports as defined in the GCES Phase II Study Plan.

The specific number of reports in each study area are identified. Supporting reports for each of these studies will be included as appendices.

B. Phase II. Development of the first level of integrated resource reports. Reports will be develcped specifically for:

Sediment and Hydrology
Archeology
Hydrology and Research Flows
Biology
Recreation
Economics

Supporting reports will be included as appendices to the primary reports.

C. Phase III. Development of the GCES Final Integrated Report.

This report will include, beside the resource assessments, the following additional supporting reports:

Assessment of the Research Flows
Assessment of the Response Curves used in the Analyses
Assessment of the Glen Canyon Dam - Environmental Impact Statement Alternatives
The GCES Long-Term Monitoring Program and Geographic Information System

III. SUMMARY

By following a well defined report assimilation process we feel that the most credible products can be developed. Each report that is developed under the GCES Scientific umbrella will be subject to the GCES Review Process identified elsewhere in the GCES Study Plan.

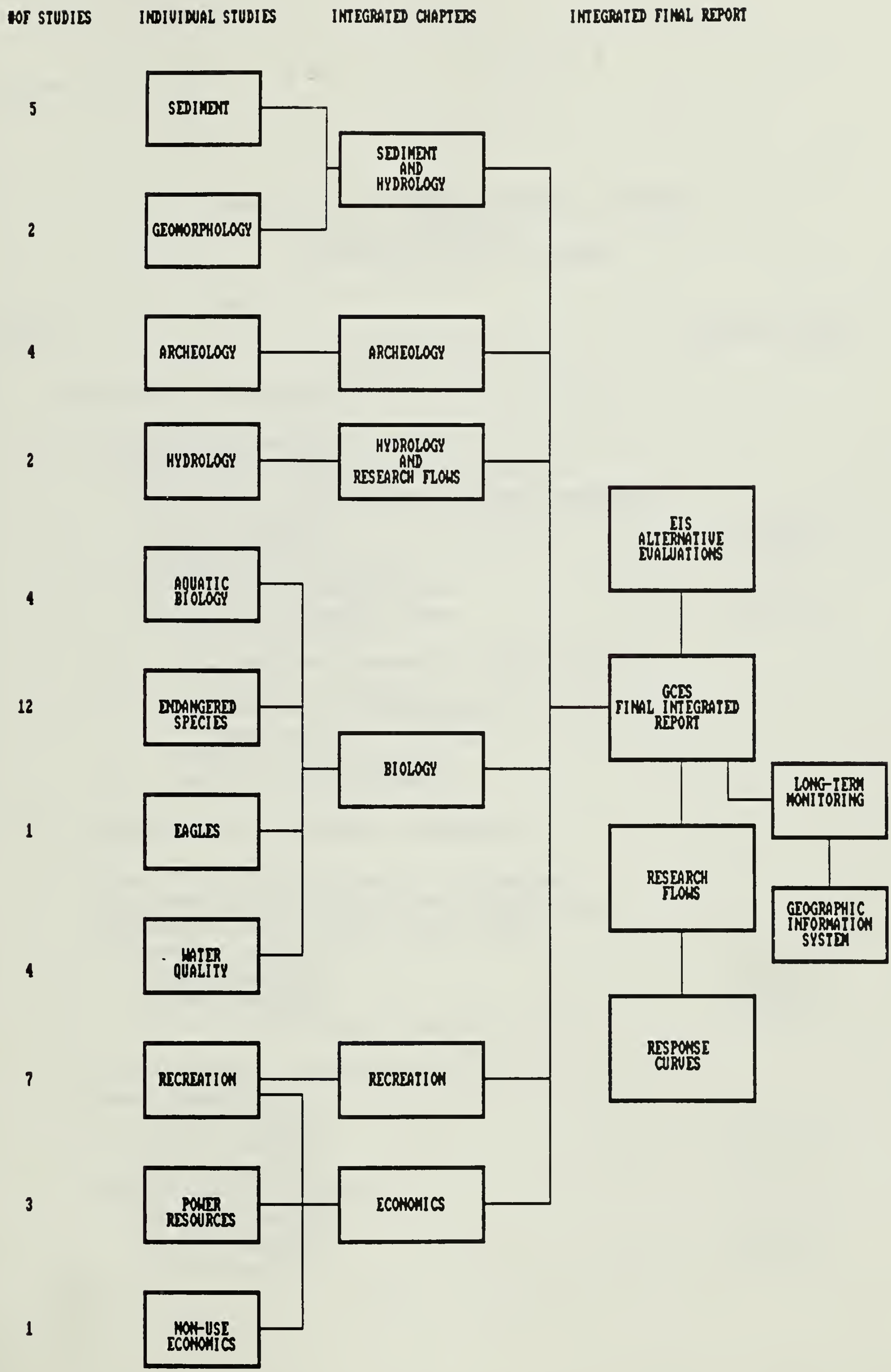

Figure 14. Glen Canyon Environmental Studies Phase II Report Integration.

August 90

GLEN CANYON ENVIRONMENTAL STUDIES
PHASE II
TECHNICAL STUDY PLANS

TITLE	REPORT DATES
I. SEDIMENT & HYDROLOGY	
A. SEDIMENT TRANSPORT	
1. Grand Canyon Sediment transport.	
PRODUCTS: Paria River flood frequency	
Draft Report:	9-30-90
Final Report:	1-31-91
INTERPRETIVE REPORTS	
All Draft Reports due:	9-30-91
All Final Reports due:	1-31-92
a. 1-D Flow Model	
b. 1-D Solute transport model (dye)	
c. 1-D Sand transport	
d. 1) Plateau Tributaries	
2) Map of Paria River	
e. Debris Flow Report	
f. Aeolian Input Report	
B. BEACHES AND SEDIMENT DEPOSITS	
1. The influence variable discharge regimes on Colorado River sediments deposits below Glen Canyon Dam.	
Annual Report:	1-31-91
Draft Report:	1-15-92
Final Report:	6-15-92
Executive Summary Report:	7-1-92
2. Grand Canyon beach evolution.	
Sand Inventory.	
Annual Report:	1-31-91
Draft Report:	9-30-91
Final Report:	1-31-92
Depositional History.	
Annual Report:	1-31-91
Draft Report:	9-30-91
Final Report:	1-31-92

Eddy Models.
Annual Report: 1-31-91
Draft Report: 9-30-91
Final Report: 1-31-92
Debris Flow Effects:
Draft Report: 9-30-91
Final Report: 1-31-92
Slope Stability.
Draft Report: 9-30-91
Final Report: 1-31-92

3. The relationships between Glen Canyon Dam operations and Colorado River paleoflood deposits in Glen and Grand Canyons, Arizona.
Draft Report: 11-15-90
Final Report: 1-1-91

4. The impacts of Glen Canyon Dam on riparian vegetation and soil stability in the Colorado River Corridor, Grand Canyon, Arizona.
Draft Report: 12-1-91
Final Report: 1-1-92

C. Hydrologic data and data-base maintenance proposal
1. USGS Development
a. Data base partitioning
b. New gages
c. Centralize data base
On-line data base : 7-1-90
Annual Data Reports: 5-1-91
5-1-92

2. Historical review of dam releases
Draft Report: 3-30-91
Final Report: 7-31-91

II. WATER QUALITY AND LIMNOLOGY

1. Limnology of Lake Powell and Lake Mead and related Releases (Historical Review).
Draft Report: 9-30-91
Final Report: 1-31-92

2. Grand Canyon water quality.
a. Colorado River water quality
Draft Reconnaissance Report: 9-30-90
Final Reconnaissnace Report: 1-31-91

Draft Initial Synoptic Experiments:	9-30-91
Final Synoptic Experiments:	1-31-92

b. Lake Powell water quality

Draft Report:	12-30-91
Final Report:	3-31-92

3. The ecology of aquatic Diptera in the Colorado River below Glen Canyon Dam.

Draft Report:	11-15-91
Final Report:	1-31-92
Monitoring Report:	4-15-92

4. AGF Water quality and Productivity
   a. Colorado River water quality
   b. Lake Powell water quality

Draft Report:	9-30-91
Final Report:	1-31-92

III. GEOMORPHIC/GEOLOGIC STUDIES OF THE COLORADO RIVER IN THE GRAND CANYON

A. Surficial geologic maps

Draft Map:	9-30-91
Final Maps:	1-31-92

B. Geomorphic/Geologic evaluation

Draft Report:	9-30-91
Final Report:	1-31-92

IV. BIOLOGICAL RESOURCE

A. Trout Studies

1. Ecosystem process and trout studies under phase II

Draft Report:	9-30-91
Final Report:	1-31-92

2. Lees Ferry Stranding Study

Draft Report:	9-30-91
Final Report:	1-31-92

3. Egg alevin survival (spawning study)

Draft Report:	9-30-91
Final Report:	1-31-92

4. Evaluation of trout strains at Lees Ferry
   - Draft Report: 9-30-91
   - Final Report: 12-30-91

B. Multiple Level Withdrawal Studies
   - Draft Report: 9-30-91
   - Final Report: 12-30-91

V. NATIVE AND ENDANGERED SPECIES

A. Native Fish Study

B. Humpback chub and other endangered fish studies.

1. Taxonomic status of the genus Gila (Conservation Measure 1)
   - Annual Reports: 12-30-90
     12-30-91
     12-30-92
     12-30-93
   - Draft Final: 12-30-94
   - Final Report: 4-30-95

2. Maintenance of hatchery stocks of Little Colorado River humpback chub. (Cons. Measure 2)
   - Draft Management Plan: 12-30-91
   - Final Management Plan: 4-30-92

3. Ensure that flood releases from Glen Canyon Dam occur with a frequency of not greater than one in twenty years. (Cons. Measure 3)
   - Draft Final Report: 9-30-91
   - Final Report: 12-30-91

4. Development of a management plan for the Little Colorado River. (Cons. Measure 4)
   a. Navajo Nation
   b. Glen Canyon Environmental Studies
      - Draft Final Report: 12-30-91
      - Final Management Plan: 3-31-92

5. Conduct research to identify impacts of Glen Canyon Dam operations on the humpback chub in the mainstem and tributaries. (Cons. Measure 5)
   a. Little Colorado and other tributaries.

b. Early life history & habitat studies

c. Adult habitat and movement.
Draft Report: 4-31-94
Final Report: 9-30-94

d. Little Colorado RIver Chub Studies. ??????

6. Establish a long-term monitoring program to assess the relationship of project operation to the humpback chub.
(Pending Completion of Research)
(Cons. Meas. 6)
Draft Monitoring Program: 3-31-92
Final Monitoring Program: 7-31-92

7. Establish a second spawning population of humpback chub in the Grand Canyon.
(Pending completion of research).
(Cons. Meas. 7)
Survey Report: 9-30-91
Draft Recommendation Report: 12-31-91
Final Recommendation Report: 3-31-92

C. Endangered species workshop
Completion: 12-31-90
Final Report: 3-31-91

D. Avian Studies

1. The effect of fluctuating flows from Glen Canyon Dam on bald eagles and rainbow trout at Nankoweap Creek in Grand Canyon National Park, Arizona.
a. Trout effects
Draft Report: 8-31-91
Final Report: 9-30-91
Human Impact Report: 11-30-91

VI. RECREATION

A. Influence of discharge on availability of camping beaches in Grand Canyon National Park
Draft Report: 9-30-91
Final Report: 12-1-91

B. Recreational Carrying Capacity, Lee's Ferry River Reach

Draft Report:	11-1-91
Final Report:	12-1-91

C. Influence of discharge on recreational values including crowding & congestion and the effect of flows on observed boating accidents in Grand Canyon National Park.

Draft Report:	9-30-91
Final Report:	12-31-91

D. Review of Phase I/Recreation Studies

Draft Report:	11-1-90
Final Report:	2-1-91

VII. ARCHEOLOGY

A. Survey design for Archeological Survey along the Colorado River, Grand Canyon National Park, AZ

1. Field Survey (NAU)

Field Report:	6-30-91

2. Data evaluation

Draft Final Report:	8-30-91
Final Report:	12-31-91

B. Native American Coordination

1. Navajo Nation
2. Hopi Tribe
3. Havasupai
4. Hualapai

Draft Reports:	8-30-91
Final Reports:	12-31-91

VIII. ECONOMICS

A. Power Resource Studies

1. Power Modeling
2. Resource evaluation
3. Repayment

Draft Final Report:	12-31-91
Final Report:	3-31-92

B. Recreation Economics

1. Fishing
2. Day-use Rafting
3. Whitewater Rafting

Draft Final Report:	9-30-91
Final Report:	12-31-91

C. Resource (non-use) Economics

1. Evaluation

Literature Review:	12-31-90
Draft Final:	12-31-91
Final Report:	3-31-92

IX. LONG-TERM MONITORING PROGRAM AND DATA INTERPRETATION

A. Long-term monitoring components

Draft Long-Term Monitoring Plan:	12-30-91
Final Long-Term Monitoring Plan:	4-31-92

B. Geographic Information System Program

1. Aerial photos-contract
2. Orthomap development-contract
3. Themes & resources classes

Aerial Photo/surveying upper site:	9-30-90
Aerial Photo/surveying lower site:	9-30-91
Completed upper sites data base:	6-30-91
Completed lower sites data base:	3-31-92
Aerial Report:	5-31-92

REVIEW PROTOCOL

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTEGRATED RESEARCH PROGRAM

GLEN CANYON ENVIRONMENTAL STUDIES

TECHNICAL AND INTEGRATED REPORTS
REVIEW PROTOCOL

I. <u>INTRODUCTION</u>

The Glen Canyon Environmental Studies (GCES) Phase II scientific effort will require a rigorous review process in order to maintain the scientific integrity necessary for the effort. To ensure the scientific credibility and to be able to move forward with the appropriate internal and external reviews, a four tiered review process will be followed:

II. <u>REVIEW PROCEDURE</u>

A. Review Tier 1

The Tier 1 level will be accomplished with the DRAFT reports and will consist of internal review of the documents by the researchers and Principle Investigators of the GCES program. This will entail a review to identify areas of inconsistency with other reports, units, and other areas of common concern. The GCES office will coordinate this initial level of review to ensure that the appropriate researchers review complementary work.

B. Review Tier 2

The Tier 2 level will be accomplished with the DRAFT reports through a network of internal review within the individual bureaus, agencies and offices. Each office has their own internal guidance on the review of research documents. No consistency is apparent between the offices and therefore it is anticipated that some internal reviews will be more strenuous than others.

The GCES office will maintain records on the extent of internal review but it will be incumbent upon each office to establish their own hierarchy for review and for ensuring that the appropriate levels of internal review are obtained.

C. Review Tier 3

The Tier 3 level will be accomplished with the FINAL DRAFT reports by a set of outside reviewers identified by either the GCES Senior Scientist and/or his Research Advisory Panel. The identified reviewers will coordinate their reviews through the Research Advisory Panel. All comments back to the individual researchers will be coordinated through the GCES office. A minimum of **three** outside reviewers will be identified for each research project.

If the requirements of Tier 2 review require outside review, the Research Advisory Panel will determine if additional review is required. The GCES office will retain all Tier 3 level review comments.

D. Review Tier 4

The initial three tiers of review will focus on the scientific integrity of the GCES research program. The Tier 4 level of review will provide for the review of the FINAL DRAFT research reports by outside, non-scientific, constituent groups who have a vested interest in the research but have limited scientific background on the research. The Tier 4 level of review will focus on the administrative and bureaucratic review level and the implications of the research. The GCES office will coordinate the distribution of the specific reports to the appropriate entities for review. The specific comments received will be reviewed by the individual scientists, the GCES Senior Scientist and the Research Advisory Panel. The Research Advisory Panel, the GCES Senior Scientist an the GCES Program Manager will determine what the appropriate course of action will be.

APPENDICES

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTEGRATED RESEARCH PROGRAM

GLEN CANYON ENVIRONMENTAL STUDIES

GENERAL TEAM COMPOSITIONS

We have assembled a listing of those people who have been actively involved in the Glen Canyon Environmental Studies (GCES) various technical teams over the last twelve months. Our intent is to identify the key personnel. We apologize if we have missed your name or identified a wrong address. Please send us a correction if one is needed.

August 1990

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