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GLEN CANYON DAM

INTERIM OPERATIONS

INTERIM FLOW MONITORING PROGRAM

FOR COOPERATING AGENCIES MEETING

APRIL 2, 1992

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INTERIM FLOW MONITORING PROGRAM
PROCESS

Development of Draft Work Plan
- October 1991 - March 1992
- Interim Flow Monitoring Work Group
  - Duncan Patten, Scenior Scientist
  - Fish & Wildlife Service
  - National Park Service
  - Arizona Game & Fish
  - Hualapai Tribe
  - Hopi Tribe
  - Navajo Nation
  - U.S. Geological Survey
  - Western Power Administration
  - Bureau of Reclamation
  - HBRS, Inc.
  - Researchers

Review of Proposals
- Distribution to Work Group, March 5, 1992
- Meeting of Work Group, March 24, 1992 at Tempe, AZ
- Recommendations of Work Group, March 27, 1992

Approval of Plan
- Cooperating Agencies, April 2, 1992, Meeting

RECOMMENDATIONS AND DIRECTION

GLEN CANYON ENVIRONMENTAL STUDIES
INTERIM FLOW MONITORING PROGRAM

RECOMMENDATIONS AND DIRECTION
March 27, 1992

I. INTRODUCTION

The Glen Canyon Environmental Studies (GCES) Interim Flow Monitoring program is developed on the basic premise that impacts of the interim flow and evaluation of use and impacts of Exception Criteria will require credible scientific data. The interim flows initiated on November 1, 1991 are designed around the set of flow recommendations proposed by the scientists of the GCES program.

The GCES Interim Flow Monitoring Program is a coordinated effort organized around the following elements: (1) Basic monitoring of key ecosystem elements; (2) Basic data collection and research to evaluate the monitoring information; and (3) Integration with the ongoing GCES Phase II program, historic GCES Phase I results and other available scientific information.

It is imperative to understand that the collection of information by itself is useless unless specific evaluation and analysis complement the data. Equally important is management and maintenance of the data. Impacts related to operations of Glen Canyon Dam can only be quantified if basic data are analyzed in reference to specific elements.

Monitoring is the use of scientific, statistically sound methodology to evaluate change over time in one or more indicators response variables (e.g. larval humpback chub survivorship in the Colorado River). Monitoring <u>requires</u> precisely worded objectives. Selection of suitable indicator response variables for monitoring must initially be the result of opinion from qualified experts in the system in question. As data are gathered, compiled and analyzed, response variables can be refined.

Monitoring, as defined in the context of the GCES Interim Flow Monitoring Program, is "the evaluation of the discharge related impacts to ecosystem and cultural resource elements based on information collected" over time. Several kinds of monitoring have been identified (MacDonald et al. 1991):

1. **Trend monitoring** generally refers to sampling at regular intervals to detect change in the response variable(s).

2. **Baseline monitoring** is a sampling program designed to describe existing conditions and variability in a component.

3. **Implementation monitoring** is used to evaluate whether the management actions were carried out as planned.

4. **Effectiveness monitoring** is used to evaluate whether a treatment (e.g. a management action) affected the response variable(s) in the predicted fashion.

5. **Validation monitoring** is used to evaluate predictions made by mathematical models.

All forms of monitoring are essential for evaluating the temporal and spatial relationships within the interim flows. In particular, trend and effectiveness monitoring are question-driven research conducted in a repeated measures statistics context and subject to the criteria that pertain to such data and analyses (Hurlbert 1984).

The temporal and spatial scales in which monitoring is conducted vary according to the type of system being monitored, the monitoring objectives, the response variables in question, and the availability of funding. Recent suggestions for monitoring ecosystem responses to environmental changes include monitoring at several ecologically relevant spatial scales (e.g. local, synoptic and system-wide scales) and at suitable temporal scales relative to the temporal patterns of driving variables (Davis 1992).

In the case of interim flows from Glen Canyon Dam, resources in the Colorado River corridor downstream have been selected through intra-agency efforts to establish priorities. The temporal scales of interim flows monitoring include daily/weekly, monthly, seasonal, between-year and between flow regime types on a multi-year scale. The first three cases involve monitoring <u>within</u> the interim flows period to determine the effects of prescribed discharge criteria and exceptions, while the latter case involves comparing interim flows effects to the 1990-1991 test flow period, the 1987-1990 normal operations period, the 1983-1986 flows, the 1965-1982 period, the pre-dam period, etc.). The spatial scales of interest include **localized**, individual recirculation zones and eddies, geomorphic **reaches**, and **system-wide** scale. Each temporal and spatial scale is important in understanding responses of the Colorado River system to this altered hydrologic regime.

The IFMP consists of work that was initiated immediately under the ongoing GCES Phase II program, basic monitoring that will be initiated under this program and basic data base gathering that will be initiated during fiscal year 1992 and 1993 to support the analysis and impact assessment of the monitoring data.

II. INTEGRATION OF THE INTERIM FLOW MONITORING PROGRAM

The GCES Interim Flow Monitoring Program is built upon the ongoing

GCES Phase II program and understanding of critical resources. The program is composed of individual monitoring study plans which are integrated to provide a coordinated approach to identifying the monitoring impacts. In this way the funding required for the support of the program are reduced and equipment, methodologies and support required are shared and costs consequently reduced. Data management and manipulation are coordinated to ensure the proper and efficient use of the resources.

The GCES Interim Flow Monitoring Plan builds upon the historical work conducted during GCES Phase I and II and serves as the stepping stone to the GCES Long-Term Monitoring program. Figure 1 depicts this linkage.

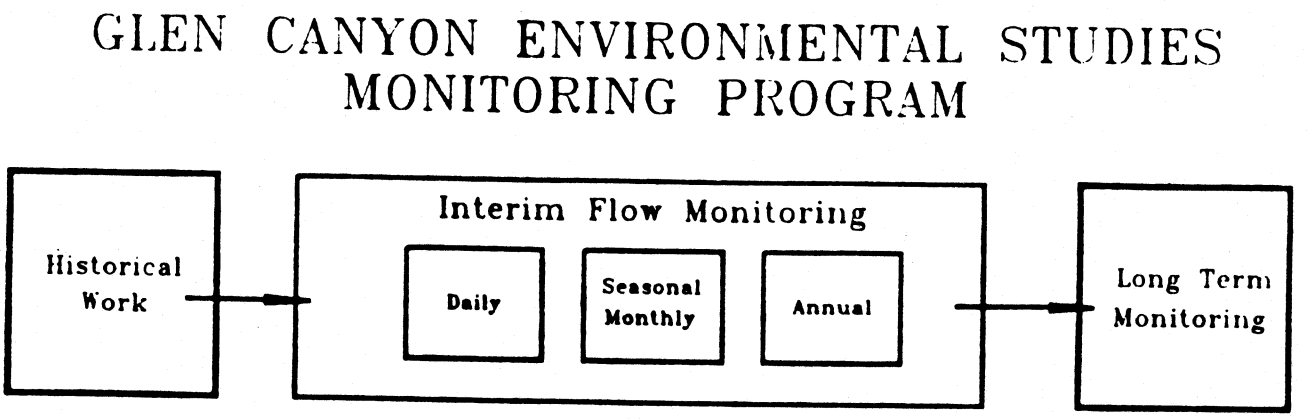


Figure 1. Linkage of the Monitoring and Research Programs

Individual monitoring study plans have been developed on three different temporal scales, **daily**, **monthly/seasonal**, and **annual**. Individual monitoring plans build and integrate with each other to supply information to evaluate short and long-term effects of interim flows and exceptions. The development of the overall monitoring plan follows the basic precepts of the GCES Phase II program integration as outlined in Figure 2. The separation of the program components are defined in Table I and reflect the interrelationship between the temporal, spatial, data base development and linkage elements.

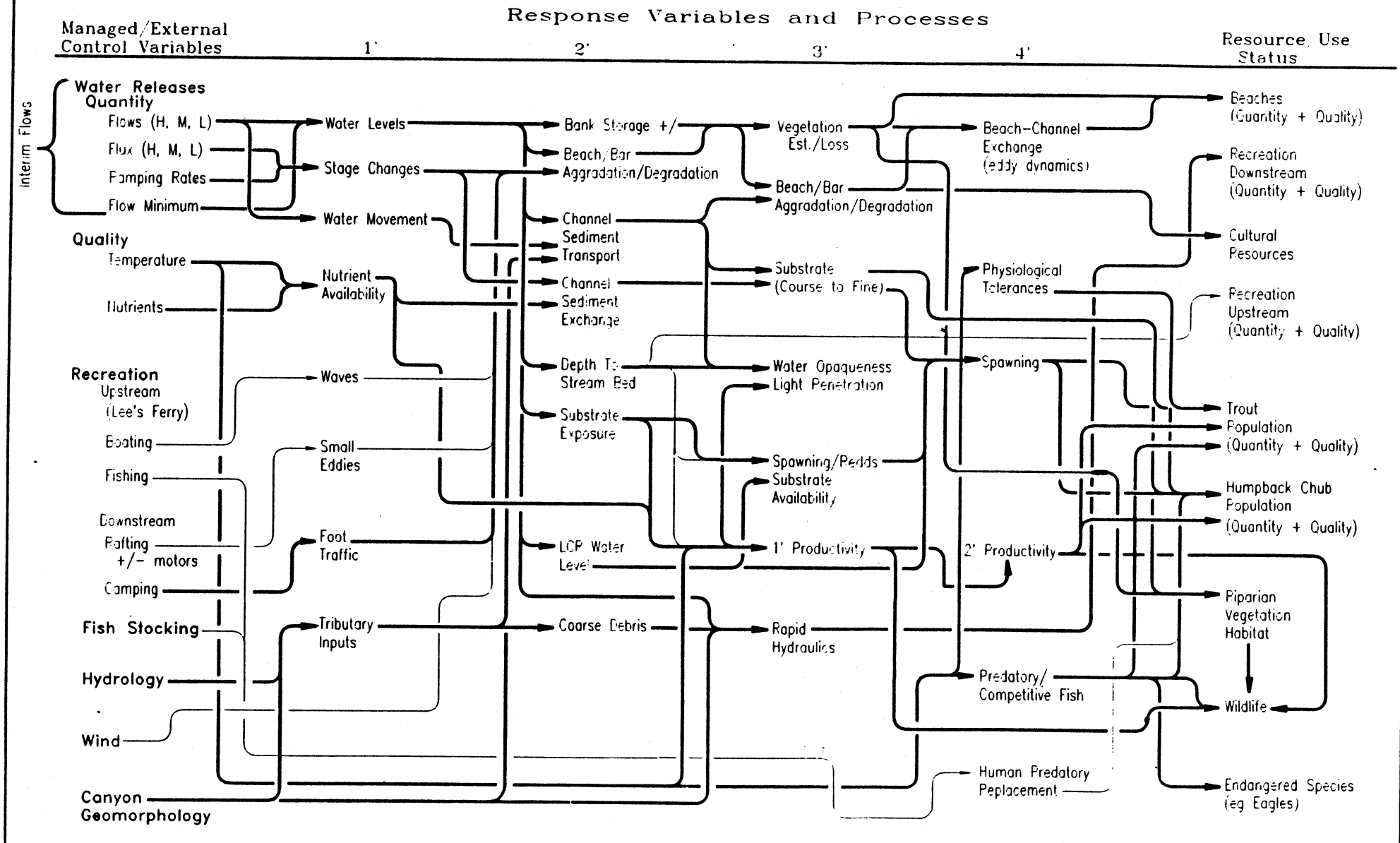
III. COMPONENTS OF THE INTERIM FLOW MONITORING PROGRAM

There are four levels that comprise the Interim Flow Monitoring Program:

(1) Ongoing implementation monitoring to assure the present interim flow release patterns are followed.

Figure 2

Interrelationships and stepwise connecting response variables and processes between controlling variables and Canyon resource and use status.



(2) Ongoing trend and effectiveness monitoring conducted under the auspices of the GCES Phase II research program.

(3) Baseline monitoring to be initiated immediately

(4) Basic research, data collection validation monitoring and technical support efforts to support the analysis and understanding of the consequences of interim flow effects (begin during fiscal year 1992 and 1993)

Each of these elements are linked together and are documented in detail in the GCES Interim Flow Monitoring Plan. The specifics of each element are as follows:

1. Monitoring Already Initiated

Ongoing elements of the GCES Phase II research program are serving a dual purpose by providing initial monitoring information until the complete GCES Interim Flow Monitoring Program can be initiated. The key elements of this program are:

A. Hydrology

1. Basic gaging station discharge records.
2. R-200 Stage recorders
3. Analysis of dam discharge data

B. Biology

1. Humpback chub monthly sampling - Bio/West
2. Vegetation - 1 trip
3. Quarterly trout population estimates at Lee's Ferry

C. Basic Data

1. Video monitoring of corridor - once per month
2. Remote cameras on selected beaches (7)
3. Development of Geographic Information System Sites

D. Cultural Resources

1. Ongoing consultation and evaluation between the Native Americans and the National Park Service

2. Immediate Monitoring Required

This effort will be implemented to collect and analyze the impacts of the interim flows. The specific are as follows:

A. Hydrology and Sediment

1. Tributary sand contributions and Transport at Gaging Stations. (USGS A8)

2. Sand Bar Stability (NPS/CPSU A2)
3. Daily Photography - original seven plus those required for cultural resources (NPS/CPSU A5)
4. Sediment Storage in Alluvial Banks and Bars (USU A9)
5. Coordination with Recreation analysis (NPS E2)

B. Cultural Resources

1. Archeological sites within GRCA and GCNRA (NPS B1)
2. Hopi Coordination with NPS (Hopi B2)

C. Aquatic Resources

1. Arizona Game & Fish (AGF C1)
2. Aquatic Food Base downstream from Glen Canyon Dam (NPS/CPSU C2)
3. Water Quality Monitoring in GCNRA (NPS C4)

D. Riparian Resources

1. Riparian Vegetation Downstream of Glen Canyon Dam (NPS/CPSU D1)
   * Integrate Fluvial Marshes identified by GCNRA (NPS D5)

2. Avifaunal Nesting Habitat Availability and Use (FWS D4)
   * Integrate with the NPS/CPSU riparian work (D1 and D5)
   * Integrate with the GCNRA work (D6)

3. Riparian Resources in Lower Grand Canyon (Hualapai D2)
   * Link with NPS methodologies

E. Recreation Resources

1. Campsite Size in GCRA (NPS D2)
2. Lower Grand Canyon Recreation Resources (Hualapai E1)
   * Limit to campsite size and distribution objective

F. Data Management and GIS Integration

1. Little Colorado River (NPS/CPSU F1)
   * Look for alternate ways to accomplish
   * Reevaluate mapping requirements
   * Review elements that may require new field data development

3. Fiscal Year 1992 Basic Data Collection Required

There are several areas of critical **baseline data** collection that needs to be collected in order to evaluate the monitoring information. This information is considered essential to a complete monitoring program but does not fit the classic definition of monitoring.

A. Sediment Resources

1. Aerial Photography - Sand Stability (NPS A6)

Explanation: The collection of aerial photography will allow for the evaluation of change over annual periods of time. There is a great deal of historic information that can assist in the evaluation of large scale changes. This information is critical in being able to evaluate changes to the sand system and will also provide important information for the measurement of other terrestrial and aquatic habitats. Several recommendations were made to this proposal:

a. Validate methodologies before initiating
b. Coordinate with A9 (sediment stability)

** Discussion should be initiated immediately and design a cooperative study plan to evaluate methods and study sites. This information provides a critical link between storage of tributary input, transport between reaches and system wide sediment balance (A5, A11, and A1).

2. Terrestrial Photography - Sand Bar Stability (NPS A5)

Explanation: Augment the existing photographic data with additional sites to assure short-term (daily) time scales of interim flow effects are being evaluated at the Beus and Stevens (A2) sites, and to assure being represent of the documented patterns. Tilt sensors are required for some sites to confirm the gravitation mechanisms of bank failure (A4).

B. Aquatic Resources

1. Lower Colorado River Fishery (Hualapai C1)

Explanation: There is limited information available on the fishery resources in the Colorado River below Diamond Creek. In order to assess impacts of interim flows basic data and information is required. Several recommendations were made to this proposal.

a. Determine if the work could be tied to existing fishery work ongoing in the Canyon.

b. Coordinate methodologies with ongoing studies.

4. <u>Fiscal Year 1993 or 1992 Basic Monitoring Research and Data Collection</u>

There were several proposals and data information gaps that will require work in fiscal year 1993 or earlier if possible. These items are basic data collection efforts and are viewed as important to the overall project but cannot be categorized under strict monitoring. Meetings will be held to consolidate as much of this effort as possible to reduce overall costs.

A. Sediment Resources

1. Monitor/Model Seepage induced erosion and deformation (USGS A4)

Explanation: This is a continuation of the work initiated under GCES Phase II. The three validation beaches (-6.5, 43, and 172 Mile) are already instrumented and are providing valuable information on the interaction of flows; including exceptions, and the movement of water in the sand beaches. Expansion to additional beaches is required to assure being representative of the initial three validation sites.

2. Debris Flow, Sediment Source, and Channel Control (USGS A12)

Explanation: This is a continuation of the ongoing work and should be done when debris flows or other significant event occur.

3. Sediment Rating Curve for Grand Canyon Gage (USGS A10)

Explanation: This effort will transfer the knowledge gained from the National Canyon gage work to the Grand Canyon gage. This will result in a more definitive model then the present rating curve from which to evaluate interim flow operations.

4. Velocity Field and Sand Bar Topography (USGS A1)

Explanation: This is new research and will provide the information on the movement of sediment from the main channel to the eddies and the resultant effect on sand bar topography under flood flows. The methods and study sites should be discussed in context of the A7 and A11 projects so as to provide baseline information before habitat building flows are conducted.

IV. COMMON COORDINATION, DATA GAPS AND CONSOLIDATION REQUIREMENTS

There were several key coordination concerns that need to be addressed and dealt with prior to the implementation of certain Interim Flow Monitoring Program elements.

A. Sediment Resources

1. Additional proposals dealing with subaqueous movement of sediment and sand need be integrated prior to implementation to reduce overlap, coordinate data gathering objectives and select study sites.
   * Subaqueous Fluvial sediment topography w/i eddies (NPS A7) integrate with movement of sand in reaches below Paria and LCR (USGS A11)
   * Integrate velocity field studies (USGS A1) with the subaqueous movement studies.

2. Additional proposals dealing with the modeling of seepage induced erosion need to be integrated prior to expanding data collection to resolve differences in approaches and data collection methods.
   * Sand Bar Stability: Seepage (UA A3)
   * Monitor/Model seepage induced Erosion and Deformation (USGS A4)

3. Additional proposals dealing with the measurement of sediment in bars need to be integrated prior to implementation to resolve issues related to location and measurement techniques
   * Sediment storage in Alluvial banks and bars (USU9)
   * Aerial photography - sand stability (NPS A6)

B. Riparian Resources

1. Historic linkage of sites within the GIS locations (NAU D3)

Explanation: The information presented in this proposal needs to be linked to the sediment studies. It will provide a historic perspective to the changes at the GIS sites and will provide the direct linkage from the interim flow monitoring to the long-term monitoring efforts.

* Coordinate with (USU A9)

C. Recreation Resources

1. Lower Canyon Resources (Hualapai E1)

Explanation: Objectives 1 & 2 dealing with use levels needs

to be coordinated in a different manner than with interim flows. It should be tied to the Hualapai recreation research program instead of monitoring.

D. Data Gaps

There are several areas of limited information that represent gaps in our information data base:

1. Riparian Resources

There is limited information being collected on the potential impacts of the interim flows on the terrestrial vertebrates and invertebrates.

Action: Evaluate what it will take to adequately assess this resource.

2. Recreation Resources

There is no information being collected on the impacts of the interim flows to the Lee's Ferry fishermen, safety levels in the Grand Canyon, and the recreation use of the 20,000 to 30,000 cfs sand bar area.

Action: Work with the National Park Service to determine how best to accomplish this work effort.

3. Aquatic Resources

There is no information presently being collected as part of the monitoring program to address the relationship of Lake Powell to the downstream water quality and productivity levels.

Action: Evaluate the present USGS, GCES and AGF work to ascertain if the information is collected or what it would take to collect it.

V. SUMMARY

The GCES Interim Flow Monitoring Program has as its primary objective the **"collection and analysis of data to evaluate the impact and relationships of the Glen Canyon Dam interim flows on the resource elements associated with the Colorado River ecosystem through the Grand Canyon"**. In order to meet this objective a series of interim flow monitoring proposals have been developed that will deal with the important resource elements. These monitoring proposals vary in spacial and temporal scales and reflect the minimal program required to adequately and credibly assess the impacts related to interim flows.

The program is organized to address immediate needs for monitoring taking into consideration that the monitoring requires a consistent data management framework (GIS) for baseline data collection and research in order to evaluate impacts related to interim flows. In summary, a scientifically credible program, that will provide the basis for the long-term monitoring program, requires that a concurrent data management and analysis system be established.

VI. LITERATURE CITED

Davis, G. The necessary ingredients for success: design elements of monitoring programs. Seminar delivered to "Improving Natural Resource Management through Monitoring: March 10-11, 1992". The College of Forestry, Oregon State University, Corvallis, OR.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. 54:187-211.

MacDonald, L.H., A. W. Smart and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. Environmental Protection Agency 910/9-91-001, Seattle, WA.

ABSTRACT OF PROPOSALS

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PROPOSALS

A. SEDIMENT RESOURCES

A1. Monitor the velocity field and changes in sand-bar topography in eddies during the interim flow period. E.D. Andrews and J.B. Graf. U.S. Geological Survey National Research Program, Denver, CO

A2. A proposal to monitor the effects of interim flows from Glen Canyon Dam on the sand bar stability in the Colorado River downstream from Glen Canyon Dam, Arizona. S.S. Beus, and L.E. Stevens. NPS/CPSU. Flagstaff, AZ

A3. Monitoring sand bar stability during interim flows: seepage erosion modeling approach. M. Budhu. Dept. of Civil Engineering and Engineering Mechanics, Univ of Arizona, Tucson, AZ

A4. Monitoring and modeling seepage-induced erosion and deformation of sand bars along the Colorado River in Grand Canyon during the interim flow period. M. Carpenter. U.S. Geological Survey WRD, Tucson, AZ

A5. A proposal to monitor sand bar stability on a daily time schedule during the interim flows using terrestrial photography. B.L. Cluer. NPS/CPSU Flagstaff, AZ

A6. A proposal to monitor sediment stability during the interim flow period using aerial photography. B.L. Cluer. NPS/CPSU Flagstaff, AZ

A7. Monitoring subaqueous fluvial sediment topography within and between eddy storage sites to determine the role of mass wasting in sand bar longevity. B.L. Cluer. NPS/CPSU Flagstaff, AZ

A8. Monitor tributary sand contributions, sand transport, flow and physical and chemical constituents at main channel gaging stations during the interim flow period. R.J. Hart. U.S. Geological Survey WRD, Flagstaff, AZ

A9. Development of monitoring program of sediment-storage in alluvial banks and bars, Colorado River, Grand Canyon. J.C. Schmidt. Dept. of Geography and Earth Sciences, Utah State University, Logan, UT

A10. Development of sediment-rating curve for the Grand Canyon gaging station at Phantom Ranch during the interim flow period. J.D. Smith and J.B. Graf. WRD National Research Program, U.S. Geological Survey, Denver, CO

A11. Monitor movement of sand in reaches below the Paria and Little Colorado Rivers during the interim flow period. J.D. Smith and J.B. Graf. WRD National Research Program. U.S. Geological Survey, Denver, CO

A12. Monitor debris-flow deposits, sediment sources, and channel control during the interim flows. R.H. Webb. U.S. Geological Survey WRD, Tucson, AZ

B. CULTURAL RESOURCES

B1. Monitoring of archeological site conditions along the Colorado River in Grand Canyon National Park. J.R. Balsom. NPS Resource Management and Planning Division. Grand Canyon, AZ

B2. Monitoring of Hopi cultural values at resource sites within Glen and Grand Canyons. M.L. Yeattes. Hopi Cultural Preservation Office. Kykotsmovi, AZ

C. AQUATIC RESOURCES

C1. Glen Canyon Environmental Studies Phase II Interim Flow monitoring proposal. Research Branch. Arizona Game and Fish Department, Phoenix, AZ

C2. A proposal to monitor the effects of interim flows from Glen Canyon Dam on the aquatic food base in the Colorado River downstream from Glen Canyon Dam, AZ. D.W. Blinn and L.E. Stevens. NPS/CPSU, Flagstaff, AZ

C3. A proposal to monitor the effects of interim flows from Glen Canyon Dam on the fishery resources of the lower Colorado River from Diamond Creek to Lake Mead. Hualapai Tribe, Peach Springs, AZ

C4. Water quality monitoring of the Colorado River, Glen Canyon Dam to Lee's Ferry, AZ. C. Pinnock and C.W. Wood. Glen Canyon National Recreation Area, National Park Service, Page, AZ

D. RIPARIAN RESOURCES

D1. A proposal to monitor the effects of interim flows from Glen Canyon Dam on riparian vegetation in the Colorado River downstream from Glen Canyon Dam, AZ. T.J. Ayers and L.E. Stevens. NPS/CPSU, Flagstaff, AZ

D2. Proposal to monitor and evaluate the impacts of Glen Canyon Dam interim flows on the riparian plant communities in the lower Grand Canyon. Hualapai Tribe, Peach Springs, AZ

D3. A proposal to monitor interim flow effects from Glen Canyon Dam on current and historical riparian vegetation trends in Grand Canyon using multitemporal remote sensing analysis of GIS sites. G.L. Waring, School of Forestry, Northern Arizona University, Flagstaff, AZ

D4. A proposal to monitor the effects of interim flows from Glen Canyon Dam on avifaunal nesting habitat availability and use. U.S. Fish & Wildlife Service, Phoenix, AZ

D5. A proposal to monitor the effects of interim flows on fluvial marshes of the Colorado River between Glen Canyon Dam and Lee's Ferry, AZ. Addendum to proposal D1. Prepared by C. Wood, National Park Service, Glen Canyon National Recreation Area, Page, AZ.

D6. Breeding bird densities, Colorado River from Glen Canyon Dam to Lee's Ferry. C.W. Wood and C. Pinnock, National Park Service, Glen Canyon National Recreation Area, Page, AZ

E. RECREATION RESOURCES

E1. A proposal to evaluate the recreational use patterns on the tribal sediment resources in the lower Grand Canyon. Hualapai Tribe, Peach Springs, AZ

E2. A proposal to monitor the effects of interim flows on campsite size in Grand Canyon. L. Kearsley. NPS/CPSU, Flagstaff, AZ

F. DATA MANAGEMENT AND GEOGRAPHIC INFORMATION SYSTEM INTEGRATION

F1. A proposal to integrate location and topographic survey data for the Glen Canyon Environmental Studies geographic information system program. L. Dexter and J. Gust. NPS/CPSU, Flagstaff, AZ

GLEN CANYON ENVIRONMENTAL STUDIES

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INTERIM FLOW MONITORING PROGRAM

PROGRAM GOALS
AND
INDIVIDUAL MONITORING PROPOSALS

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM TEST FLOW MONITORING WORK PLAN

VERSION VII

MARCH 27, 1992
FLAGSTAFF, AZ

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1. Interim Flow Criteria (Agreement between Western and Reclamation)
2. Interim Flow Report (April 10, 1991)
3. Interim Flow Monitoring Report Outline
4. GCES Integrated Research Diagram
5. Water Year 1992 Annual Operating Plan
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GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING WORK PLAN

DRAFT

I. INTRODUCTION

The Glen Canyon Environmental Studies (GCES) has been charged with developing and implementing a monitoring plan to evaluate impacts of interim flows established for the operation of Glen Canyon Dam. The Glen Canyon Dam Interim Test Flows were implemented on August 1, 1991 under the direction of the Secretary of the Interior. On November 1, 1991 the Secretary implemented Interim Flows which are to be in place through completion of the Record of Decision for the Glen Canyon Dam - Environmental Impact Statement (GCD-EIS), currently scheduled for July 1994. Periodic reviews of the Interim Flow criteria will be conducted by the GCD-EIS Cooperating Agencies (**Enclosure 1**).

The **purpose** of this document is to present the basic scientific approach necessary to measure and analyze effects of modification of flows at Glen Canyon Dam on downstream resources.

The **objective** of the monitoring of interim flows is to collect and analyze important data to determine if the resource objectives which drove development of interim flows are being met and provide information for potential refinement of interim flows. The relationship between interim dam operations and individual resources requires information and validation.

A primary assumption around which interim flows and this plan are developed is that the purpose of interim flows are to **"minimize the loss"** of natural resources in Grand and Glen Canyon until a longer term solution is defined through the GCD-EIS program. The scope of the Interim Flow Monitoring Plan and individual proposals are specific to evaluation of the short-term impacts of interim flows; however, where appropriate, long-term implications are identified.

A. Background

The interim flows were outlined in the April 10, 1991 document entitled Interim Flows for Grand Canyon (1991) and is **Enclosure 2**. The Interim Flow Monitoring Program is developed around the need to determine if prescribed interim flows are meeting their objectives. Eleven main attributes were evaluated in development of interim

flows. These articulate both representative and critical elements of the Grand Canyon riverine ecosystem and are also part of the cumulative Grand Canyon ecosystem evaluation. The individual monitoring proposals utilize the resource attributes and flow elements as controls against which change is noted. The individual attributes are listed in Table 1.

Table 1. Attributes of Evaluation for the Interim Flows

Sediment Resources (beaches, sand bars, deposits)
Native Fishes
Endangered Fishes (Humpback Chub, etc.)
Exotic Fishes
Trout
Aquatic Food Base
Riparian Vegetation
Whitewater Rafting
Fishing Success
Historical Sites
Archeological Sites

Information collected during the interim flow period will be coupled with information gathered during GCES Phase I and II through the use of data bases and a Geographic Information System (GIS). The GIS will allow for an assessment of both temporal and spatial changes.

B. Interim Flow Monitoring Plans

Interim flows address four major elements of hydrology: (1) minimum flows; (2) maximum flows; (3) daily rate of change; and, (4) ramping rates. In addition to individual components there are seasonal elements related to monthly and annual volumes of water to be released.

The interim flow monitoring plans are designed to evaluate impacts of dam operations on ecosystem components. Short-term impacts are the primary focus of monitoring plans but there are also specific elements that relate to long-term ecosystem maintenance. In all cases, interim flow monitoring proposals are designed to augment and build upon ongoing or completed GCES research.

There are three phases of the GCES Interim Flow Monitoring Program:

1. Interim Test Flow Monitoring - August 1, 1991 through November 1, 1991
2. Interim Flow Monitoring - November 1 though the end of the GCD-EIS process, currently set for July 1994
3. Long-Term Monitoring - Implemented at the completion of the GCD-EIS process

This document is to be viewed as a roadmap for overall short term GCES integrated Interim Flow Monitoring Plan. **Specific monitoring plans** have been developed and are included in the Appendix to this report.

The interim flow resource monitoring effort is designed to be integrated with the existing GCES research **and** to serve as the framework for GCES Long-Term Monitoring. Integration of the monitoring and the research minimizes time necessary to establish a separate long-term program and allows us to build upon and benefit from what we have already collected and analyzed. The definitive long-term monitoring program will be developed as part of the GCES Phase II scientific program during fiscal years 1992 and 1993. The resource agencies will be fully integrated into the program.

II. CLARIFICATION STATEMENTS

Prior to presenting the specific components of the short-term, Interim Flow Monitoring Program several clarifiers are necessary:

1. That adequate staff and dollars be provided for the implementation and analysis of the monitoring program. The monitoring program **will not take precedence** over the existing GCES responsibilities.

2. That the short-term Interim Flow Monitoring Program is not to be construed as being a substitute for the Long-Term Monitoring Program.

3. That the interim test flow and flow monitoring efforts are to be built on the ongoing GCES program.

III. REFINEMENT AND REPORTING OF THE INTERIM FLOW MONITORING PROGRAM

A. Refinement of the Interim Flow Monitoring Program

The GCES Phase II and Phase I scientific studies are serving as the basis for development of the monitoring program. Limited time and ongoing Phase II reporting dictates a conservative approach to designing the monitoring program. As additional data are collected and as GCES Phase II technical reports are completed, the Interim Flow Monitoring Program will be refined. Refinement of the Interim Flow Monitoring Program will occur twice annually, with review through the GCES Interim Flow Work Group and others identified by the Senior Scientist.

The role of the GCES research is to understand the processes that dictate how the individual ecosystem elements respond and to identify thresholds where either specific ecological processes are initiated/fail or where specific ecosystem elements are lost. The

role of the monitoring program is to collect data to evaluate whether the objectives of the interim flows are being met and to verify results being generated through the research program. Inherent in the monitoring program is an analysis and evaluation component.

B. Interim Flow Monitoring Reports

Reports on the progress of the interim flow monitoring will occur as follows:

1. Quarterly synopsis reports - presented to Cooperating agencies. Based primarily on analysis of interim flow monitoring data and specific events. The outline is **Enclosure 3**.

2. Annual summary report - presented to the Cooperating agencies and interested public. Based on analysis of interim flow monitoring data, additional data from specific research reports and any additional information from specific events.

3. Final Interim Flow Monitoring Report with recommendations for the Long-Term Monitoring Program. Based on Interim Flow Monitoring Program data, GCES technical reports, and other specific information. An analysis of both positive and negative aspects of the Interim Flow Monitoring Program will be completed.

The specific reports required for each resource category will be developed by a team of GCES researchers. GCES will take the lead in organizing and coordinating the reports and will provide the integration of the technical reports into Quarterly, Annual and Final Reports.

The Interim Flow Monitoring Program will continue until completion of the Record of Decision on the GCD-EIS. The Long-Term Monitoring Program will be developed from the Interim Flow Monitoring Program results.

IV. COMPONENTS OF THE INTERIM FLOW MONITORING PROGRAM

There are four primary evaluations of the Glen Canyon Dam interim flows. They are:

1. Characteristics of interim releases;

2. Key resource responses to interim flow elements and impacts to those selected resource components;

3. Impacts to resources related to departures from interim flow caused by enactment of the Exception Criteria; and

4. Costs associated with implementing interim flows. This includes costs associated with purchase of capacity and energy, cost of the monitoring program, and any specific financial impacts to recreation concessionaires and public.

Evaluation of the Flow Characteristics will focus on the review of **daily range of flows, maximum and minimum flows, monthly volumes, seasonal elements,** and **measurement of ramping rates** for each month.

Evaluation of impact of implementation of Exception Criteria will focus on **logging of all exceptions, stage change monitoring, collation of flow information from the dam,** and **evaluation of impacts** to resources by deviation from interim flows.

Evaluation of impacts of interim flows on natural resources is designed around three variables of interest: (1) specific resource elements, (2) processes which maintain the influence over those resource elements, and (3) identification of resource response to specific flow components.

The information collected through the Interim Flow Monitoring program will be consolidated into one primary data base and integrated into the GCES GIS. The GIS will be used for resource impact assessment and database development. The GIS is an ongoing development effort between cooperating resource agencies and GCES researchers. Specific surveying protocol and stage measurements are being developed by the GCES program.

The GCES Interim Flow Monitoring Program is composed of the following elements and processes:

1. Sediment budget and sediment deposits
2. Cultural resource impacts of selected sites and areas
3. Aquatic food base
4. Vegetation and marshes (shoreline and terrestrial habitat)
5. Economics (financial impacts)
6. Trout population dynamics
7. Native fishes - habitat and population dynamics
8. Recreation and accident rates
9. Water quality response
10. Data base development and integration of site information

V. BASELINE FOR DETERMINATION

Evaluation of the impacts of interim flows on resources of Grand Canyon requires the definition of an ecological baseline of comparison. The Interim Flow Monitoring Program is designed to collect data to evaluate the impacts to the ecosystem based on its biotic and abiotic components and interactions of the biotic communities with the abiotic environment. Determination of change as related to interim flows must be separated from the naturally occurring events and changes that reflect natural ecosystem progression.

The baseline for evaluation of the Grand Canyon ecosystem during interim flows are defined as being those environmental conditions that existed in the Grand Canyon river corridor on August 1, 1991, at cessation of GCES research flows and initiation of the Interim Test Flows. The ecological baseline varies depending ~~by~~ on the ecosystem element being evaluated.

Resource Component	August 1, 1991 Baseline Condition
Sediment	location & area transport volumes
Riparian	location, area, density, & composition
Aquatic	location & population levels
Cultural	location & stability
Economic	costs
Hydrology	volumes & levels

Ecological data collected ~~under~~ during? the interim flows will be analyzed primarily in an observational approach; ~~that is~~ this consists of making measurements on the community over a range of conditions imposed by both the operations of the dam and by nature. The primary objective of the Interim Flow Monitoring Program is to determine changes in the pattern of the ecological components rather than testing specific hypotheses. The determination of the appropriate sampling schemes and resultant analyses depends upon the identification of pattern changes and the specific resource components.

VI. METHODS FOR INTERIM FLOW MONITORING

The basic monitoring plan is built upon existing GCES research and ongoing studies. This approach will, by necessity, look a great deal like the ongoing GCES Phase II Integrated Research Program

(**Enclosure 4**). In order to assess impacts of varying the Glen Canyon Dam flow levels on specific resource variables, an understanding of the response variables and ecosystem processes is required. The logic in Interim Flow Monitoring Program approach is based on several factors:

1. Ongoing research for GCES Phase II is not yet completed and selection or focusing on selected ecosystem components is premature;

2. the research effort, while individually focused on selected resources, is designed as an integrated approach with the end goal of identifying ecosystem processes that drive responses;

3. selection of parameters to measure and monitor should be based on both short-term and long-term relationship to ecosystem processes; and

4. the GCES Long-Term Monitoring Program will build upon the Interim Flow Monitoring Program. Broad overlap will exist between the GCES Program, the Interim Flow Monitoring Program and the Long-Term Monitoring Program.

The GCES Interim Flow Monitoring Program is designed with an initial broad evaluation with the intent that every six months the Monitoring Plan will be <u>reviewed</u> and if necessary <u>refined</u> as additional GCES and other research is folded into the knowledge base. This coordination of Interim Flow Monitoring Program will provide the ability to adapt the monitoring program as new data, information, and areas of concern are developed.

An additional element to be considered in design of the monitoring program is its ability to handle not only proposed interim flows but also to address <u>natural events</u> and impacts of potential <u>exceptions</u> to interim flows, whether they are caused by emergency situations or by enactment of financial criteria.

The Long-Term Monitoring program will be developed during fiscal years 1992 and 1993 through a series of workshops and GCES scientific team meetings. Management and policy requirements of the management agencies will be included in its development.

Each of the four components listed on page 6 of the monitoring program has specific associated methodologies.

A. Flow Characteristics

Primary methodologies for measuring and assessing the effects of interim flows are dependent on the relationship between actual interim flows and monthly volumes. **Enclosure 5** reflects the anticipated 1992 Annual Operating Plan in comparison to historic

upper and lower quartiles for monthly volume releases from Glen Canyon Dam. Based on current knowledge and water predictions, there will be a variation from the "normal" operations of the dam on a monthly basis. We will use the following methodologies in the analysis of the flows:

1. Weekly evaluations of the daily range of flows, from the SCADA flow release records at Glen Canyon Dam.

2. Weekly evaluations of maximum and minimum flows, from records at Glen Canyon Dam.

3. Weekly evaluations of ramping rates, from records at Glen Canyon Dam.

4. Monthly summary of these three flow parameters using statistical programs and correlating with monthly volume released.

5. Reporting of that information quarterly to GCES scientists and Cooperating Agencies.

6. Development of a correlation between SCADA records and the U.S. Geological Survey gage located immediately below Glen Canyon Dam. Quarterly reports will be developed by USGS for the gaging station.

The official measure of releases will be the Supervisory Control and Data Acquisition (SCADA) records at Glen Canyon Dam.

B. Exception Criteria

Measurement and assessment of the effects of interim flows will be based on evaluation of the responses between flows and resources, the role and use of the Exception Criteria may be critical in the final analysis. Prediction of when Exception Criteria will be implemented may be possible and will be monitored. It is <u>imperative</u> that the GCES office, Glen Canyon Dam, and the Montrose office of Western communicate when Exception Criteria are to be implemented. In this way, specific evaluation of impacts may potentially be made.

We will be implementing the following tracking mechanisms:

1. Weekly assessment of implementation of Exception Criteria based on records from Glen Canyon Dam and communication with Montrose.

2. Monthly summary of implementation of Exception Criteria based on records from Glen Canyon Dam. Short-term impacts and potential long-term impacts to specific resources (environmental and financial) will be noted and

provided to GCES scientists and Cooperating agencies by Western Area Power Administration and the Bureau of Reclamation.

3. Quarterly reporting to the cooperating agencies will include both measured natural resource effects and financial/economic relationships.

If flows varying from interim flows can be predicted specific event related surveys will be initiated.

C. Resource Responses

The methodologies and time frame for evaluation of the response of canyon resources and cumulative effects of interim flows will vary by resource category.

Each resource category has a specific monitoring objective and a discussion of specific short-term monitoring actions. The listing includes certain GCES ongoing research elements and items specific to the interim flow monitoring. An anticipated resource monitoring timetable is included in **Enclosure 6**. During the six month reviews the resource monitoring list may be modified.

1. <u>Sediment Resources and Transport</u>

Responsibility: NPS, USGS, Hualapai, Hopi, Navajo and GCES

Monitoring Objective: To determine the annual sediment budget for Grand Canyon and to specifically identify type and scale of change in sediment deposits as related to interim flows.

a. Annually collect a set of aerial photographs to evaluate changes in sediment deposits exposed above a constant discharge of 5,000 cfs. Analysis will include:

(1) Mapping the area of gravel bars, sand bars, debris fans, backwaters, and other deposits onto 1:24,000 basemaps and incorporate these data into the GIS. Change in area from Year to year will be determined.

(2) Inventory all campsites, sand bars, and other deposits in order to assess the number and size throughout the river corridor.

b. Survey topography of a <u>minimum</u> of 20 sand deposits, including adjacent eddy return channels and determine changes in topography and volume of sediment at those sites. In return channels and at beach faces selected sediment samples will be taken to monitor changes in size composition of the sediment deposits. Annually.

c. Conduct flow and suspended load measurements at gaging stations and at the mouths of the Paria and Little Colorado Rivers such that flow and size-by-size sediment fluxes (loads) can be determined. This will allow for improvement of rating curves at gaging stations.

d. Measure sand fluxes and sand storage at five monumented sections at each of the five mainstem USGS gages. This information will be used for flow routing model calibration.

e. Collect sediment samples as part of the bi-monthly maintenance trips to each of five mainstem and five tributary USGS gages. Automatic sediment samplers will be added to the seven gage sites that presently do not have them.

f. Develop and distribute quarterly data reports for items (c), (d) and (e). An annual report summarizing the annual sediment budget for Grand Canyon will be prepared.

g. Develop and distribute quarterly reports for item (b) with an annual report developed for item (a). An annual report summarizing system-wide changes in sediment deposits will be prepared.

h. Monitor new debris flow deposits (since 1983) and any significant new deposits added, as events occur.

i. Continue detailed study of selected sediment deposits in the Grand Canyon to identify and clarify the relationship of fluctuating flows and bar stability. This will be accomplished through:

   1. Remote cameras at selected beaches
   2. Continuation of the seepage force, groundwater dewatering and bar erosion research at the 3 validation beach sites.
   3. Evaluation of the role of wave intensity and stage change.

j. Further calibrate the eddy transport model and calculate the role of beach erosion and deposition at specific sites.

k. Conduct measurements of bed topography, size composition, and sand fluxes near the Grand Canyon gage with the purpose of calibrating a flow and transport model for that site similar to the one constructed for the National Canyon site. The measurements should be conducted for the four peak flow periods.

2. <u>Cultural Resources</u>

Responsibility: NPS, Navajo, Hualapai, Havasupai, Hopi and

GCES with coordination with the State Historic Preservation Officer (SHPO).

Monitoring Objective: To determine if interim flows are providing stability needed to maintain identified cultural resource sites along the Colorado River corridor.

a. Identify 60 of the most sensitive cultural resource sites in the river corridor: 20 sites (DT) which are in danger from direct threat(s); 20 sites (IT) which are in danger from indirect threat(s); and 20 sites (NT) which are in no apparent danger from river flows. DT and IT sites will be located on unstable sediment foundations. DT sites (20 each) will be selected for their cultural significance and location from the 44 most critically endangered sites, whereas the IT and NT sites will be selected randomly from their respective pools of 179 sites and 272 sites. Remote cameras and video will be used. Evaluation will be quarterly and as significant events occur.

b. Monitor with remote cameras continuously a minimum of 6 of the most threatened sites (of the 20 DT sites).

c. Complete the cultural resource survey of the remaining 37 miles of the lower Grand Canyon from Separation Canyon to Lake Mead. Identify sensitive cultural resource sites for monitoring and integrate with sites identified under section 2a.

3. Aquatic Food Base

Responsibility: AGF, NPS, NAU, Hualapai and GCES

Monitoring Objective. To determine if the algal and invertebrate food base in the Colorado River below Glen Canyon Dam is maintaining its level or changing during the course of interim flows.

Above Lee's Ferry (build upon AGF work)

a. Evaluate colonization, standing crop, and primary productivity of periphyton (*Cladophora*/diatoms) as related to daily and seasonal interim flow levels. Measure rates of colonization (biomass accretion), standing crop, and primary productivity (benthic metabolism) as affected by different durations of exposure at varying times of day and season. Quarterly assessment.

b. Organic matter (algal and invertebrate) drift. Measure inputs of dissolved and particulate matter, including zooplankton, at Glen Canyon Dam and outputs at Lee's Ferry over 24 hour flow cycles. Analyze effects of flow range, minimum, maximum, and

ramping rates. Monthly assessment.

c. Aquatic invertebrates impact. Measure colonization rates as affected by different durations of exposure during varying time of day and season. Quarterly assessment.

Below Lee's Ferry (built upon AGF and NPS work)

d. Aquatic invertebrates. Measure colonization and mortality rates as affected by different durations or exposure during varying time of day and season. Quarterly assessment.

e. Organic matter (algal and invertebrate) drift and exposure. Measure colonization and mortality rates as affected by different durations of exposure during varying time of day and season. Quarterly assessment.

4. Riparian Areas and Wetlands

Responsibilities: NPS, FWS, AGF, Hualapai, Hopi, Navajo and GCES

Monitoring Objective: To determine community response to interim flows and assess whether the flows are impacting stability of wetlands and marshes in the Glen and Grand Canyons.

a. Marsh Areal Extent. Determine size through the use of the annual aerial photographs, video and in-field surveys. Annual aerial photography, video quarterly and in-field surveys. quarterly. The NPS, other scientists and the Native American groups will identify any specific areas to be analyzed.

b. Extent and Response of the New High Water Zone (NHWZ) and the Old High Water Zone (OHWZ). This will be based on existing vegetation quadrates established through NPS vegetation work. NHWZ work will be done during the early and late growing season and OHWZ work will be accomplished during the late growing season.

c. Insect Food Base. Monitor seasonally the aquatic food base and the near shore terrestrial insects. Seasonally.

d. Avifauna. Survey of the obligate riparian birds utilizing the NHWZ in the river corridor. A separate survey will be made of the waterfowl in the river corridor. Annually.

5. Economics

Responsibility: NPS, HBRS, FWS, Native American groups, GCES and Western and Denver Office - Reclamation

Monitoring Objective: To determine impacts of interim flows on the economics of power produced at Glen Canyon Dam.

a. Evaluate costs associated with implementation of interim flows. This should be done monthly and will include an assessment of costs incurred by purchase of non-firm and firm power, non-firm and firm capacity, and any additional costs incurred or attributed to interim flows.

b. Evaluate revenue from recreation activities. Annually.

6. <u>Trout Population Dynamics</u>

Responsibility: AGF and GCES

Monitoring Objective: To determine responses of Glen Canyon Tailwater trout fishery to the interim flows.

a. Stranding Bars. Initiate monitoring of stranding for a specific set of sites in the Lee's Ferry reach. Include known sites of stranding for alevins to adults.

b. Redds. Document and evaluate redd numbers and distribution at selected spawning bars during the spawning season (December - March)

c. Population dynamics. Sample trout population using mark-recapture techniques to ascertain changes in growth, length frequency distribution, condition, and stage of reproductive development when compared to previous years.

d. Trout access to tributaries. When feasible measure numbers of trout utilizing the Nankoweap Creek area. This work will be done in coordination with other river research trips.

e. Parasite infestation. Evaluate the degree of parasite infestation in trout and evaluate changes during interim flows.

f. Angler success. Evaluate success and quality of recreational experience among anglers in the Lee's Ferry reach.

7. <u>Native Fishes</u>

Responsibility: AGF, USFWS, Hualapai Tribe, contractors, GCES, and NPS (this will primarily be completed as part of existing research efforts)

Monitoring Objective: To determine if native fish habitats and their use by native and non-native fishes are influenced

during the course of interim flows.

a. Backwaters. Measure numbers, sizes, water temperatures, current velocities and other environmental conditions in these habitats using video, river trip surveys, and automated recording devices with data loggers. Correlate fish abundances and distributions with flow ranges, minimums and maximums, and other environmental parameters.

b. Tributary confluences. Measure changes in tributary mouth sizes, area flow hydraulics, water temperatures and other environmental parameters during downriver river trips and by video surveys. Measured tributaries will include the Paria River, Shinumo Creek, Clear Creek, Crystal Creek, the Little Colorado River, Kanab Creek, and Nankoweap Creek. Correlate fish abundances and distributions with flow ranges, minimums and maximums, and other environmental parameters.

c. Population characteristics. Determine relative abundances, length frequencies, condition factors, and other population characteristics of fishes collected during downriver sampling trips. Correlate with interim flows, habitat availability, and measured environmental parameters.

d. Initiate a monitoring study of native and non-native fishes commensurate with upstream sampling in the reach from Diamond Creek to Pierce's Ferry. Measure relative fish abundances, habitat conditions, and environmental parameters to allow comparisons with ongoing studies in the Grand Canyon.

e. Water Quality. Measure and correlate temperature and other basic water quality parameters during the above stated research efforts. This will be done at each primary mainstem, backwater and tributary site and during any observed tributary flow event.

8. <u>Recreation Use and Accident Rates</u>

Responsibility: NPS, Hualapai, Hopi, Navajo and Contractors

Monitoring Objective: To determine if recreation use in the Glen Canyon and Grand Canyon areas is responding to the interim flows as related to accidents, fishing success and use. This information will be used in sociological studies being conducted as part of the GCES non-use value economics.

a. Accident Rates. Evaluate rapids and level of difficulty under different interim flow levels. Crystal, Hance, Lava and House Rock. Relate to three interim flow volume months and visitor use levels.

b. Fishing Guides. Interview the Lee's Ferry fishing guides to

ascertain fishing success and flow levels. Evaluate fishing success, wading ability, fishermen inundation and safety issues. This would be combined with the AGF creel census. Seasonally.

c. Whitewater Rafters. Work with the Grand Canyon River Guides Association to determine impact of interim flows on boat mooring, camp inundation, camp cleanliness, stranding, accident rates, and trip itineraries. Seasonally.

d. Fishing Success. Evaluation of success and quality of the recreation experience above Lee's Ferry through ongoing AGF creel census and random surveys. Quarterly.

9. Water Quality

Responsibility: NPS, AGF, Hualapai, Hopi, Navajo, GCES and USGS

Monitoring Objective: To determine if selected water quality constituents are changing in concentration or level, loading, or form (dissolved and particulate pools) during interim flows. Constituents will include primary plant nutrients, organic matter, inorganic carbon, dissolved oxygen, water temperature, pH, and specific conductance. Where necessary for scientific evaluations, measurements will be taken in the forebay of Lake Powell and in the upper end of Lake Mead.

a. Evaluate water quality constituents in the Lake Powell forebay, releases from Glen Canyon Dam, and outflow at Lee's Ferry. Integrate measures with those of primary productivity and organic matter drift samples collected during aquatic food base studies to allow correlations with interim flows.

b. Evaluate water quality constituents in major tributaries in Grand Canyon and at adjacent mainstream sites. Integrate measures with those of sediment concentration, loading and transport to allow correlations with interim flows.

c. Evaluate bacteria, including pathogenic indicators, organic matter storage, and rates of organic matter processing at selected mainstream and tributary sites. Correlate these measures with flow hydraulics, sediment composition, and sources of organic matter substrates.

10. Data Base Development and Integration of Site Information

Responsibility: All cooperating resource agencies and groups with overall coordination and management of the data bases and Geographic Information System by the GCES Office.

Monitoring Objective: To provide for geographic integration

of sampling areas and locations in order to assess impacts and changes related to interim flows.

a. Geographic Information System. Integration of the monitoring and GCES research site information in the Little Colorado River Geographic Information System (GIS) into a consistent data base. Will require the field surveying of each of the monitoring and sampling locations through the use of standard surveying protocol and/or the use of the Global Positioning System. Procedures and protocol will then be transferable to the remainder of the monitoring sites.

b. Data Base Development. Continual integration of the monitoring and research data into common data bases and information systems will allow for the storage, analyses and archiving of the collected technical data.

D. Cost Impacts

There may be cost impacts associated with the implementation of the interim flows. In addition, the "Exception Criteria" granted for the interim flows may be enacted if the cost of power becomes too great. In order for the Cooperating Agencies to assess the relationship between interim flows, exceptions to interim flows and the costs related to those interim flows, a cost impact component will be part of the GCES Interim Flow Monitoring Program.
The economic document will be comprised of three elements:

1. Cost of the interim flows themselves. How much did the implementation of interim flows cost?

2. Costs related to the enactment of "Emergency Criteria" for the operation of Glen Canyon Dam.

3. Costs related to the enactment of the "Exception Criteria" for the operation of Glen Canyon Dam.

The GCES office will work in coordination with the Western Area Power Administration and other experts in the quarterly documentation of the costs related to the interim flows.

VII. **COMMON ELEMENTS**

There are several common elements that will be required and utilized by each of the resource categories listed above. The coordination of the needs and exchange of information between the evaluation groups will be the responsibility of the GCES office.

Common Elements	Timing
Aerial Photography	Two times per year

	(spring and fall)
Video imagery	Quarterly
Geographic Information System	Continuous
Flow Information	Continuous
Data Base Development	Continuous
Benchmarking(survey linkage)	Continuous

VIII. EXCEPTIONS AND EVENTS

If a deviation from the interim flows occurs, either due to initiation of the Exception Criteria or due to a natural flow event, then specific short-term and immediate monitoring efforts will be initiated. The amount of monitoring will be associated with the specific event (i.e. the size, duration, magnitude and timing) and the resources available.

IX. SUMMARY AND MONITORING BUDGET

The specific parameters to be measured under the GCES Interim Flow monitoring program build upon the efforts that have been initiated under the GCES Phase II Integrated Research Program. The intent of this document is to have a common set of goals and objectives. From this base, specific monitoring plans have been developed and are included in the Appendix. A summary listing of the anticipated Interim Flow Monitoring Program budget is defined in **Enclosure 7**.

The levels of evaluation are much reduced but will require significant levels of effort, **staff and budget**. There are two primary reasons for this: first, the GCES scientific program for Phase II is not completed. The monitoring program cannot make impact evaluations between the resources until existing studies and their results are completed. The intent is to build from the Interim Flow Monitoring Program the connections with the Long-Term Monitoring Program and the Geographic Information System. Secondly, we are dealing with flow changes that will have both short-term and long-term implications to the ecosystem components and processes in the Grand Canyon.

Impacts associated with the immediate changing of the flow levels will be difficult to ascertain until the system has an opportunity to respond and demonstrate its resistance and resilience to these changes. As such we have determined that it is better to collect more data than not enough, especially when the decisions facing the interim flow package are so sensitive and costly.

Providing funding is available the products to be developed over the course of the Interim Flow period will include:

1. A three month qualitative assessment of downstream resource responses for the interim test flow period.

2. An annual quantitative assessment of environment-resource

relationships identified over the preceding year as related to the interim test flows.

3. If short-term impacts occur related to operations that were not expected and if information is available, then special reports with operational recommendations will be developed.

A successful and useful monitoring program for the Grand Canyon depends upon support and action.

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PROGRAM

ENCLOSURE LIST

1. Interim Flow Criteria
2. Interim Flow Recommendations and Procedures April 10, 1991 (will be added to Cooperators Version)
3. Outline for Quarterly Reports
4. GCES Integrated Research Graphic
5. Anticipated 1992 Annual Operating Plan for Glen Canyon Dam
6. GCES Monitoring Plan Timetable (will be added to Cooperators Version)
7. GCES Monitoring Program Budget (will be added to Cooperators Version)

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PLAN

ENCLOSURE 1 - INTERIM FLOW CRITERIA

GLEN CANYON DAM INTERIM FLOWS

SUMMARY OF OPERATING CRITERIA RECOMMENDATIONS

July 30, 1991

Parameter	Historical	R/S Group	E/RM Group	USBR Option	WAPA	TEST FLOW
Max. Release (cfs)	31,500	20,000	20,000	20,000(1)(2) 22,000(3)	31,500	20,000
Min. Release (cfs)	3,000/1000	5,000	8,000	5,000(4)	3,000/ 5,000	5,000/ 8,000
Ramp Rates cfs/hr. Up	No Limit	2,000	2,000	4 hour/1 hour 8,000/4,000(4)	No Limit	4hr/1hr 8,000/ 2,500
Down	No Limit	1,000	1,000	4,800/2,000(1) 8,000/2,500(2) (3)	4,000/ 5,000	1,500
Daily Change (cfs)	30,500	5,000	5,000	8,000(1) 11,000(2) 15,000(3)	No Limit	5000(1) 6000(2) 8000(3)

R/S Group = Research /Scientific Group - Recommendations For Interim Operating Procedures For Glen Canyon Dam - April 10, 1991

E/RM Group = Ecological/Resource Managers - Letter Report - Review of Interim Flow Recommendations - March 29, 1991

USBR = Bureau of Reclamation - Presented at Cooperating Agencies meeting on June 13-14, 1991, including a phased approach which was dropped from consideration

WAPA = Western Area Power Administration - Letter and Concept of Interim Operating Criteria - May 22, 1991 - Comments on the WAPA concept was submitted by the Colorado River Energy Distribution Association and the Upper Colorado River Commission on May 29, 1991.

Notes:
(1) Low monthly volume - less than 600,000 acre-feet
(2) Medium monthly volume - 600,000 to 800,000 acre-feet
(3) High monthly volume - over 800,000 acre-feet
(4) All months

ATTACHMENT

GLEN CANYON DAM INTERIM OPERATING CRITERIA

SUMMARY OF PRELIMINARY PROPOSALS

June 25, 1991

Parameter	Historical	R/S Group	E/RM Group	USBR Option	WAPA
Max. Release (cfs)	31,500	20,000	20,000	20,000(1)(2) 22,000(3)	31,500
Min. Release (cfs)	3,000/1000	5,000	8,000	5,000(4)	3,000/ 5,000
Ramp Rates cfs/hr.				4 hour/1 hour	
Up	No Limit	2,000	2,000	8,000/4,000(4)	No Limit
Down	No Limit	1,000	1,000	4,800/2,000(1) 8,000/2,500(2) (3)	4,000/ 5,000
Daily Change (cfs)	30,500	5,000	5,000	8,000(1) 11,000(2) 15,000(3)	No Limit

R/S Group = Research /Scientific Group - Recommendations For Interim Operating Procedures For Glen Canyon Dam - April 10, 1991

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(2) Medium monthly volume - 600,000 to 800,000 acre-feet
(3) High monthly volume - over 800,000 acre-feet
(4) All months

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PLAN

ENCLOSURE 2 - INTERIM FLOW RECOMMENDATIONS - APRIL 10, 1991

INTERIM FLOWS FOR GRAND CANYON

RECOMMENDATIONS FOR INTERIM OPERATING PROCEDURES FOR GLEN CANYON DAM

Prepared for the Bureau of Reclamation and the Glen Canyon Studies Cooperating Agencies

By

The Glen Canyon Environmental Studies Senior Scientist,
The Glen Canyon Environmental Studies Program Manager
And A Small Group of Scientific Experts

Reviewed by the Glen Canyon Environmental Studies Scientific Core Group

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April 10, 1991

INTERIM FLOWS FOR GRAND CANYON

Recommendations for Interim Operating Procedures for Glen Canyon Dam

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INTERIM FLOWS FOR GRAND CANYON

Recommendations for Interim Operating Procedures for Glen Canyon Dam

I. Introduction

The Bureau of Reclamation plans on initiating Interim Operating Procedures (Interim Flows) for Glen Canyon Dam following the termination of controlled research flows under the Glen Canyon Environmental Studies (GCES). Reclamation has established an administrative procedure for developing the recommendation for Interim Flows which includes recommendations from both the scientific and power/water communities with reviews by the cooperating agencies and the public. This recommendation was initiated by a small group of scientists, called together by the GCES Senior Scientist. It has been reviewed by the GCES Scientific Core Group.

This small group of scientists was familiar with the adverse impacts of current dam operations (i.e., 1963-1991) on the downstream aquatic and riparian resources of Grand Canyon National Park and Glen Canyon National Recreation Area. The recognition of past impacts and this assessment were based on data from GCES I (Final Report and Technical Reports), GCES II (preliminary findings), the National Academy report (River and Dam Management), the open literature and their scientific experience. The flow recommendations respond to proposed federal legislation on protecting the Grand Canyon and represent their best estimate for a flow regime that will protect the resources in the short term interim period by reducing the rate of further degradation. It may not, however, provide the optimum protection for the long term. The interim period was considered to extend from the end of the research flows (July 1991) until a "Record of Decision" is implemented based on the EIS (ca. late 1993).

This report presents the initial, scientifically based recommendations and rationale for the Interim Operating Flows. It does not represent a final administrative position, and does not include integration of other water and power concerns. It is considered a conservative position to halt degradation of downstream resources.

The recommendations from this report were presented to the GCES Scientific Core Group on March 15, 1991. Additional development of the recommendations has been reviewed by the Core Group which has made some additional technical and procedural suggestions which have been incorporated into this report.

II. Development of Recommendations

The recommendations were determined by analyzing the Grand Canyon, Colorado River resource system primarily from the abiotic (sediment) and biotic (biological attributes) resource responses and secondarily from the human resource response. These represent the downstream resources that are addressed in proposed federal legislation.

The primary resources or attributes of the Canyon are natural components of the aquatic and riparian systems including beaches and other sediment (sand, silt and clay), native and endangered fish, introduced fish (trout) and other species, the aquatic food base and riparian vegetation. There are many other attributes that could have been considered in developing Interim Flow recommendations, such as other threatened or endangered species, but those used are foremost in the functioning of the Grand Canyon ecosystem and in the concerns of the public.

The secondary attributes were human oriented uses or components of the system. These included recreation (whitewater rafting and trout fishing), historical use of the area and archaeological and cultural resources along the Colorado River corridor.

The assessment process followed a Delphi approach. The group reviewed the characteristics of the attributes and their responses to components of dam operations and came to a consensus on recommendations on dam operations that would minimize adverse downstream impacts. In the process of developing the recommendations in this report, the scientists initially discussed stream flows (discharges) that would optimally minimize degradation of downstream resources. Conditions considered helpful to the system included steady daily flows, seasonal fluctuations and high spring flows. The final recommendations developed by the group recognized the need to stay within "normal" operating procedures of Glen Canyon Dam and yet offer some potential for changes in power demands. The recommendations in this report are thus compromise recommendations and are not to be considered a starting point for negotiations on interim flows.

A. Sediment Response

Large sand bars (beaches) and other sediment deposits exposed along the Colorado River corridor under normally occurring flows are one of the most important biological and recreational resources of the Colorado River through Grand Canyon National Park and Glen Canyon National Recreation Area. Since 1963, there has been progressive loss of sand from beaches and a corresponding decrease in beach area (GCES I, Schmidt and Graf 1990, Schmidt, Moore and Rubin 1989). The current regime of flow

releases accelerates erosion of beaches, and does not replenish beaches with new sand. Stability of beaches and other sediment deposits depends upon reducing the rate of erosion and increasing the rate of replenishment. Replenishment of sand beaches requires (1) a sufficient quantity of sand be maintained within channel and (2) streamflows of a magnitude and duration sufficient to deposit sand above the range of normal operating flows. It is possible to minimize the loss of existing beaches by minimizing the rate of sand loss, and providing enough deposition of sand to balance the erosion which cannot be eliminated.

1. Accelerated Erosion of Sand Bars

The current operating regime of Glen Canyon Dam has been shown to cause an increase in the erosion of the sand bars, beaches and other sediment deposits. The range of daily fluctuations in discharge, the rate of the changes in daily discharges, and the maximum and minimum daily discharge are significant factors controlling erosion rates.

a. The range of daily fluctuations in discharge increases sand bar and beach erosion in an exponential relationship to the magnitude of fluctuation. In other words, a constant daily discharge causes the least erosion and increasingly wide fluctuations in instantaneous discharge cause progressively larger rates of erosion. Erosion of beach deposits occurs primarily when the area of the recirculating zone decreases and the deposit of sand is exposed to the primary downstream current. The area of a recirculating zone is determined by local channel topography and discharges. As discharge decreases, the point at which the primary downstream current reattaches to the bank moves upstream. The zones of recirculating flow (eddies) where the sand bars are deposited decrease in size, and a portion of the channel which was previously within the recirculating zone is exposed to the much higher flow velocities of the primary downstream current. The downstream acceleration of flow along the bank can result in direct erosion of sand banks or the erosion of sand which slumps into the channel from higher elevation. Erosion of areas downstream from reattachment points was described by Schmidt and Graf (1990, fig. 20). This process likely continues until such time that nearly stagnant, nonaccelerating flow exists opposite the sandy banks.

b. The rate of the change in instantaneous discharge (ramping rate) also has been shown to influence the erosion rate of the sand bars and beaches; the steeper the ramping rate, the greater the rate of material removal. Ramping rates of 3600 cfs/hr, which are being used as the "low" ramping rate under the present regime of research flows, are producing considerable erosion. This rate is actually closer to medium to high ramping

rates under normal operations. Down ramping, or the decrease in discharge, has a much greater influence on sand bar and beach erosion than up ramping. A rapid decrease in the water surface elevation causes high positive pore pressure in the river bank material, reducing the effective material strength and promoting bank failure.

The effect of ramping rates on erosion is being studied in GCES-II through empirical and modeling approaches. Studies in other systems demonstrated that seepage-driven erosional forces are responsible for significant, rapid erosion of earthen-filled dams and banks (Finn 1967, France et al. 1971, Desai 1972). Seepage-driven erosion appears greatest when Glen Canyon Dam ramping rates are fast and ramping rates in excess of 19,000 cfs/hr occur several time per year in the Colorado River corridor (Table 1).

Because seepage forces are suspected to be a significant erosional mechanism in this system, and because data are limited, a conservative approach is recommended. Mean and median ramping rates are listed in Table 1 for low-runoff, moderate-runoff and high-runoff years, and indicate that average ramping rates fall in the 1,000 to 2,000 cfs/hr range. Up ramping rates should not exceed 2,000 cfs/hr. Because down ramping rates are more critical in seepage erosion, down ramping rates should not exceed 1,000 cfs/hr. Ramping rates of 1,000 to 2,000 cfs/hr will mean stages will change no more than about 0.5 to 1.0 ft/hr in wide and narrow reaches, respectively.

Table 1. Mean and median ramping rates for Glen Canyon Dam during low-runoff, normal and high-runoff years (Information from the Bureau of Reclamation.)

RAMPING RATE (CFS/HR)	LOW RUNOFF YEAR (1989)	NORMAL RUNOFF YEAR (1980)	HIGH RUNOFF YEAR (1986)
Median	1,000-2,000	1,000-2,000	< 1,000
Mean	2,291	2,445	1,823
Std. Deviation	1,778	2,012	1,717
Sample Size	8,760	8,784	8,760
Number of Times/yr Ramping Rates Exceeded 19,000 cfs/hr	0	5	3

c. The rate of sediment transport increases dramatically at discharges above 17,000 cfs (Figures 1 and 2). The maximum discharge determines the highest elevation exposed to sediment transport and depositional processes. The daily ebb and rise to this maximum discharge will cause erosion of yet higher sand deposits created during the very high flow years of 1983-1986. Preliminary data indicate that discharges above 20,000 cfs accelerate erosion of perched beach sand deposits, and cause lateral bank erosion (Pemberton 1988). Reconnaissance observations made in 1990 and 1991 in Grand Canyon indicate that discharges of about 20,000-22,000 cfs will begin to erode the base of the very high flow deposits (Schmidt pers. comm.). Because erosion rates appear to be rapid, a conservative ceiling to maximum discharge is merited. A maximum discharge of 20,000 cfs appropriately fits this conservative ceiling.

2. Replenishment of Sand Bar Deposits

Erosion of sand bar deposits will occur under any flow conditions. Therefore, replenishment of sand and rebuilding sand bars is essential to maintaining this resource. Replenishment of sand bar material lost to erosion requires an available supply of sand in the river reach, and a sufficient flow to deposit sand to an elevation so that it is exposed during the normal range of dam releases.

a. The quantity of sand stored in a given reach and, thus, available for deposition on sand bars depends upon the supply of sand to the reach from the upstream channel and tributaries, and the rate at which sand is removed from the reach by transport downstream.

Randle and Pemberton (1988) and Pemberton (1988) calculated the supply of sand to reaches of the Colorado River through Grand Canyon National Park. On average, 1.1 million tons of sand annually is supplied to the reach between the Paria and the Little Colorado Rivers and 2.7 million tons of sand, on average, is supplied to the reach between the Little Colorado River and the U.S.G.S. gage just above the mouth of Bright Angel Creek (Grand Canyon gage) (Burkham 1987).

The quantity of sand transported by various discharges determined from samples collected at the Grand Canyon gage between 1983 and 1986 is shown in figure 1 with a calculated regression curve. The analysis of sand transport prepared independently for this report produced relationships similar to those found by Randle and Pemberton (1988). A steady constant flow of 11,387 cfs (8.25 million acre ft/yr) will transport approximately 200,000 tons of sand per year at the Grand Canyon gage. The same daily mean flow (11,387 cfs), but with a daily peak of 26,000 cfs for 6 hours and daily minimum of 3,000 cfs for 6 hours will transport approximately one million tons of sand per

year. The five fold increase in annual sand transport by the same mean annual flow is due to the very rapid increase in transport rate for a relatively small increase in discharge (see figure 2). Under most possible operating regimes where the mean annual flow is 8.25 million acre feet and instantaneous daily peaks are less than about 24,000 cfs, the inflow and outflow of sediment to the reach of the Colorado River between the Paria River and the LCR will be approximate in equilibrium and the reach from the LCR to the Grand Canyon gage will be aggrading (net accumulation of sediment). An operating regime of daily peak discharge of 31,500 cfs for several hours a day and daily mean discharge of 11,387 cfs, however will cause net long term deletion of sand stored in both reaches. The amount of sand calculated to be transported under any particular discharge regime assumes that sand is available for transport. If the bed is sufficiently degraded by discharges whose magnitude and duration is sufficient to transport more sediment than is typically stored on the bed, then succeeding flows will carry less sediment. Preliminary models developed by the National Park Service Water Resources Division indicate that, because there is no assurance of sediment input from the Paria during the interim period, discharges should be sufficiently low to prevent sand loss from the channel in the Paria-LCR reach (NPS 1991).

b. As long as sand is available and is being transported, sand bars will be deposited in recirculating zones at any discharge. Over time the sand bar surface will grow until it is within a foot or so of the water surface. Sand bars must be exposed a few feet or more above the range of normal operating flow in order for the bar surface to be dry and suitable for camping and as terrestrial habitat. Consequently, the sand bar must be deposited and formed by discharges somewhat greater than the normal operating range. Water surface elevation increases by roughly 1 foot for a discharge increase of 2,500 cfs between 20,000 cfs and 45,000 cfs. Thus, beach building discharges must exceed the peak of the normal operating range of the dam by about 10,000 cfs to deposit bars which will stand 4 feet above the operating range. Observation by Schmidt and Graf (1990) show that the surface of a sand bar will aggrade at a rate of a few to several inches per day.

B. Biotic Attributes

1. Native Fishes.

Native fishes include the endangered humpback chub, as well as others that are yet to be listed. Minckley (in press) reviewed ecology of fishes in the Grand Canyon region, and formed the basis of the general comments given here.

a. Humpback chub. This species has survived in the Colorado

River below the Glen Canyon Dam site for millennia, but their geographic distribution in that reach has presumably contracted since closure of the dam. Humpback Chub is a long lived fish (ca. 30 years), thus relatively minor changes in their environment over a short period, such as two years, probably will have little impact on the present population of adults. Young humpback chub may be impacted by daily fluctuating discharges as they use backwaters and creek mouths which can be greatly modified by water-level variations that influence sand bar dynamics and backwater water supply. Backwaters are progressively lost as flows decline below 8,000-10,000 cfs, although more backwaters were found to be present at 4,800 cfs than 28,000 cfs (Anderson et al. 1986). At 5,000 cfs, return channel portions of backwaters are virtually drained (Maddux et al. 1987).

b. Other Native Fishes. With the exception of speckled dace, which is short-lived, other native fishes remaining in the Canyon also are long lived. Adult populations will probably not be influenced by a two-year period. They nonetheless require backwaters and creek mouths for survival of annual recruits. Substantial daily fluctuations will negatively influence their access to creek mouths, where they spawn. Speckled dace also spawn in creeks, and young forced into the mainstem of the Colorado River by fluctuating flows are placed in greater jeopardy of predation, as well as a greater energy demand (in absence of suitable food) in the channel.

2. Introduced Fishes.

Introduced fishes include trout and other non-native fish, such as the striped bass or channel catfish.

a. Trout. Trout have been introduced to various tributaries as well as the Lee's Ferry reach. They are found throughout the Canyon and are used for sport as well as acting as a food resource for predatory birds (e.g., bald eagle). Daily fluctuations increase organic drift which might be a benefit for trout and other fish downstream (Usher and Blinn, 1990). However, daily fluctuations, especially wide ranges, are detrimental to natural reproduction of the trout. Daily fluctuations modify available aquatic habitat (Wegner 1987) and lead to the stranding of adults as well as eggs and larvae, the former is accentuated by rapid down ramping. Other mobile aquatic organisms also might not have the chance to seek refuge at high down ramping rates.

b. Other non-native fish. Constant cold water in the Colorado River is detrimental to most introduced warm water fishes. On the other hand, a lack of fluctuations between seasons (relative stability) tends to enhance survival of non-native fish. Periodic floods either eliminate or greatly reduce populations of non-native fish in smaller canyon streams

(Minckley and Meffe 1987), and presumably do so in the Colorado River mainstem. Daily fluctuations within normal operations may function more like constant flows for non-native fishes than the wide fluctuations that occurred prior to the construction of the dam.

3. Aquatic Food Base.

The aquatic food base is dependent on the stability of the sediment and biotic substrates to which it is attached. Daily fluctuations tend to erode these substrates releasing organic debris (Liebfried and Blinn 1986, Usher and Blinn 1990). This might be advantageous in the short term but the food base could be lost over the long term. Many hours of low flow, generally below 5000 cfs, has also been shown to be detrimental to Cladophora, a result of dewatering and desiccation. Cladophora provides essential cover and serves as a substratum for attached diatoms and aquatic macroinvertebrates which make up the food base for fishes. For example, spawning trout which are preyed upon at Nankoweap Creek by wintering bald eagles have a diet that consists almost entirely of Cladophora and macroinvertebrates derived from the river (Brown et al. 1989). Part of the terrestrial system is also supported by aquatic Diptera which emerge from the river. Cladophora colonizes to the typical lowest discharge stage, presently about the 3,000 cfs level and at diminishing rates above the elevation of minimum discharge, thus minimum flows regulate biological productivity in this system, particularly in the Lee's Ferry trout fishery. Exposure of more than 12 hours has been shown to result in 25-75% loss of Cladophora biomass in the laboratory (Usher and Blinn 1990). Extended losses of Cladophora have occurred in the Canyon during extended periods of low constant flow (e.g., 5,000 cfs evaluation periods during research flows). Daily fluctuations in flow from 10,000 to 20,000 cfs have negative effects on the standing crop of Cladaphora glomerata and associated epiphytes at Lee's Ferry (Pinney 1991).

4. Vegetation.

Riparian vegetation serves to stabilize banks (Grelsson 1984), contributes to soil formation, and supports a great diversity of vertebrate and invertebrate life (Brock 1985, Stevens and Waring 1988). In this system riparian vegetation is comprised of three communities, the Old High Water Zone (OHWZ), the New High Water Zone (NHWZ), and Palustrine (riverside) Marsh Zone (Carothers et al. 1979, Stevens 1984). These three communities support at least 5,000 species of plants and animals (Carothers and Aitchison 1976, Stevens 1984, Brown et al. 1987, Phillips et al. 1987) and constitute a significant benefit of impoundment to regional biodiversity. Dam operations influence all three riparian communities, but in different ways.

a. Dam operations (flood control) limits germination and growth rates of OHWZ plant species (Anderson and Ruffner 1988. The OHWZ is presently declining in areal extent and may be lost in this system (Pucherelli 1988).

b. Dam operations directly affect NHWZ vegetation by scouring and removal of vegetation (Stevens and Waring 1985). Dam operations also affect the NHWZ by accelerating soil erosion and leaching of nutrients and fine particles that enhance soil moisture retention and germination (Stevens and Waring 1988, Stevens 1989).

c. Riverside marshes have been created by settlement of tributary-derived sediments in backwaters, and are largely a function of dam operations (Schmidt et al. submitted). Because wetlands, and especially marsh habitats, are the most productive terrestrial environments and support unique flora and fauna, such habitats merit consideration in management.

C. Secondary Attributes

1. Recreation

a. Whitewater rafting. Preferable discharges for whitewater rafting are in range of 8,000 to 24,000 cfs. Constant discharges below 8,000 cfs (e.g., 5,000 cfs) have caused boat damage and logistical problems at Hance, Horn Creek and other rapids.

b. Trout fishing. Rapid ramping rates cause some problems for anglers. Approximately 25% of boats had trouble going up stream at Lee's Ferry when the water was a constant 5,000 cfs (GCES II). In addition, some anglers become stranded on sand bars during rapid up ramping. In contrast, fluctuations increase drift which may improve fishing success.

2. Historical Sites.

a. Charles Spencer boat. The Charles H. Spencer paddle wheel steamboat has been designated as a National Historic Site (Carrell 1987). The upper several feet of the hull is exposed at discharges of 5,000 cfs and is subjected to rapid wetting and drying from waves which increase the rate of decay of the wood, as well as exposure to vandalism. At discharges of 20,000 cfs to 25,000cfs the hull is susceptible to scour by sand and drifting vegetation.

3. Archaeological Sites.

Wide fluctuations in dam discharge are eroding the sediment which has acted as foundation for many near-river archaeological sites. Long periods of flooding in 1983 and resumption of

fluctuating flows uncovered many sites making them more susceptible to erosion of support material. Any dam operations which accelerate erosion of the foundation sediments will have major impacts on archaeological resources.

III. Summary of Responses.

The above discussion can be summarized in Table 2 which should be used only for general review of the various responses of Canyon attributes to different discharge rates.

Table 2. A summary of the influence of different dam discharges on attributes in the Grand Canyon.

Attribute	Discharge Conditions			
	Constant	Seasonal Flux	Daily Flux	
			High	Low
Beaches	OK	Better	Poor	OK
Native Fish	OK	Better	Poor	OK
Endangered Fish	OK	Better	Poor	?
Exotic Fish	Enhanced	Poor	?	Enhncd
Trout	Good	Good	Poor	OK
Aquatic Food Base	OK	OK	Poor	OK
Vegetation	Poor	Good	Ok-Poor	OK
Whitewater Rafting	OK (>8,000cfs)	OK	Poor	Good
Fishing Success	Poor	Good	Poor	Good
Historical Site	OK (10-20K cfs)	OK	Poor	OK
Archaeology	OK	OK	Poor	Poor

? = Uncertainty of response.

IV. Recommended Interim Operating Procedures

The following interim operating procedure recommendations are made on the assumption that the Annual Operating Plan, that is the annual and monthly releases of water from Glen Canyon Dam, will continue to be determined based on downstream water needs, but also with consideration for downstream environmental and recreational resources (Federal Register). Therefore, although there are no recommendations on seasonal discharges, they should be considered when based on additional information from GCES II. The rationale statements used to support the recommendations briefly cover the more important reasons for the recommendation. More detail can be found in the preceding text.

A. Maximum and minimum discharges.

1. Maximum discharge should be no more than 20,000 cfs.

Rationale: Discharges greater than 20,000 to 22,000 cfs erode high elevation sand deposits. The greater the discharge, the greater the amount of sand transported. The increase is logarithmic), for example, daily sand transport in tons for a daily constant discharge of 25,000 cfs equals about 8,650, for 20,000 cfs it is about 4,000 and for 15,000 cfs it is about 1,500.

2. Minimum discharge should be no lower than 5,000 cfs with the average daily discharge no lower than 8,000 cfs. There should be no extended 5,000 cfs constant flow. A constant flow of 5,000 cfs should not exceed 8 hours and should occur only between 7 pm and 6 am.

Rationale: A constant 5,000 cfs exposes much of the aquatic food base to desiccation. Spawning problems for trout and degradation of the aquatic food base progressively worsen as discharges drop from 10,000 cfs to 5,000 cfs, while discharges below 5,000 cfs increase the length of time that mass wasting takes place on the lower faces of the exposed sand bars. Backwaters are dewatered at prolonged flows of 5000 cfs or lower. Recreational impacts of discharges below 5000 cfs include reduced angler access, problems with passage of motorized rigs through rapids and logistical delays.

B. Daily fluctuation.

1. The daily fluctuation range should not exceed 5,000 cfs.

Rationale: Wide fluctuations are detrimental to nearly all canyon attributes. As the fluctuation spread increases, there is a concomitant need for steeper ramping rates. Steep ramping rates, especially steep down ramping is significantly detrimental to sediment deposits. Also, the ability of the Cladaphora glomerata to withstand flow stress is decreased.

C. Ramping rates.

1. Up ramping rate should be no greater than 2,000 cfs/hour. This change to take place over the normal 20 minute time span that an hourly change occurs.

Rationale: Greater ramping rates cause calving of beach faces. Rapid up ramping can also cause problems for anglers.

2. Down ramping rate should be no greater than 1,000 cfs/hour. This change to take place over the normal 20 minute time span.

Rationale: The down-ramping rate is most critical in beach face wasting. A rate of 1000 cfs would reduce the amount

of sand lost into the channel where it can be removed from the system by high discharges. (Monitoring of the impacts of this level of down ramping should allow possible upscaling during the second or third year of the interim flows.)

D. Beach Building Flows.

1. There should be a spring season high flow with a discharge of 31,500 cfs the maximum discharge presently obtainable through turbine operations. The high flow should be of sufficient length to permit beach building (e.g., 6 days to 2 weeks). The flows would be elevated gradually over a few day period to prevent erosion caused by the equivalent of steep ramping. The flows should be dropped more rapidly because this process tends to enhance the storage of sand deposits on elevated sand bars (Schmidt, pers. comm.). This beach or habitat building flow might be considered as a research flow with careful monitoring of the consequences of controlled high flows of this type.

Rationale: If it is possible to create a nondegradation situation for the sand deposited in the canyon system, then it would be advisable to create an occasional high flow to store the sand up on the beaches, not only for preservation of the sand reserve in the canyon but for recreational and vegetation support purposes. Any high flow beach building event should be closely monitored. High flow events should be timed to avoid enhancement of recruitment of exotic vegetation.

V. Monitoring and Research.

1. A monitoring program should be in place during the interim flow period to determine the relative levels of impact caused by the interim flows selected. The interim flow period should also be used to continue studies of the impacts of various discharge regimes from Glen Canyon Dam.

Rationale: It is possible that a selected interim flow will cause unanticipated changes in the resources downstream from Glen Canyon Dam. It is imperative that this knowledge be available before the end of the interim flow period, especially if the interim period is extended due to delays in implementation of the "Record of Decision". The interim flows may be sufficiently different from past, peak load, high fluctuating releases to warrant studies of the impacts on downstream resources that will add to the information base for final EIS decision making.

VI. Modifications.

1. Modifications in interim flows should be made if monitoring indicates impacts on downstream resources are greater than anticipated, as based on existing information.

Rationale: Establishment of interim flows will be based on the best scientific information and expertise available. New information, from future monitoring and research, or unpredicted consequences of the interim flows should be analyzed by the scientific community and used to recommend adjustments in the interim flows to better minimize degradation of downstream resources.

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Wegner, D.L. 1987. Instream flow microhabitat analysis and trends in the Glen Canyon Dam tailwater. In Glen Canyon Environmental Studies. Final Report. U.S. Deptment of Interior. Bureau of Reclamation, Upper Colorado Region,

Salt Lake City, UT, USA. NTIS No. PB88-180236.

Figure 1. Sand transported by various discharges determined at the Grand Canyon gage 1983-1986. Regression equation is ln (LD) = -14.1 + 3.53 ln (Q). R2 = 0.88.

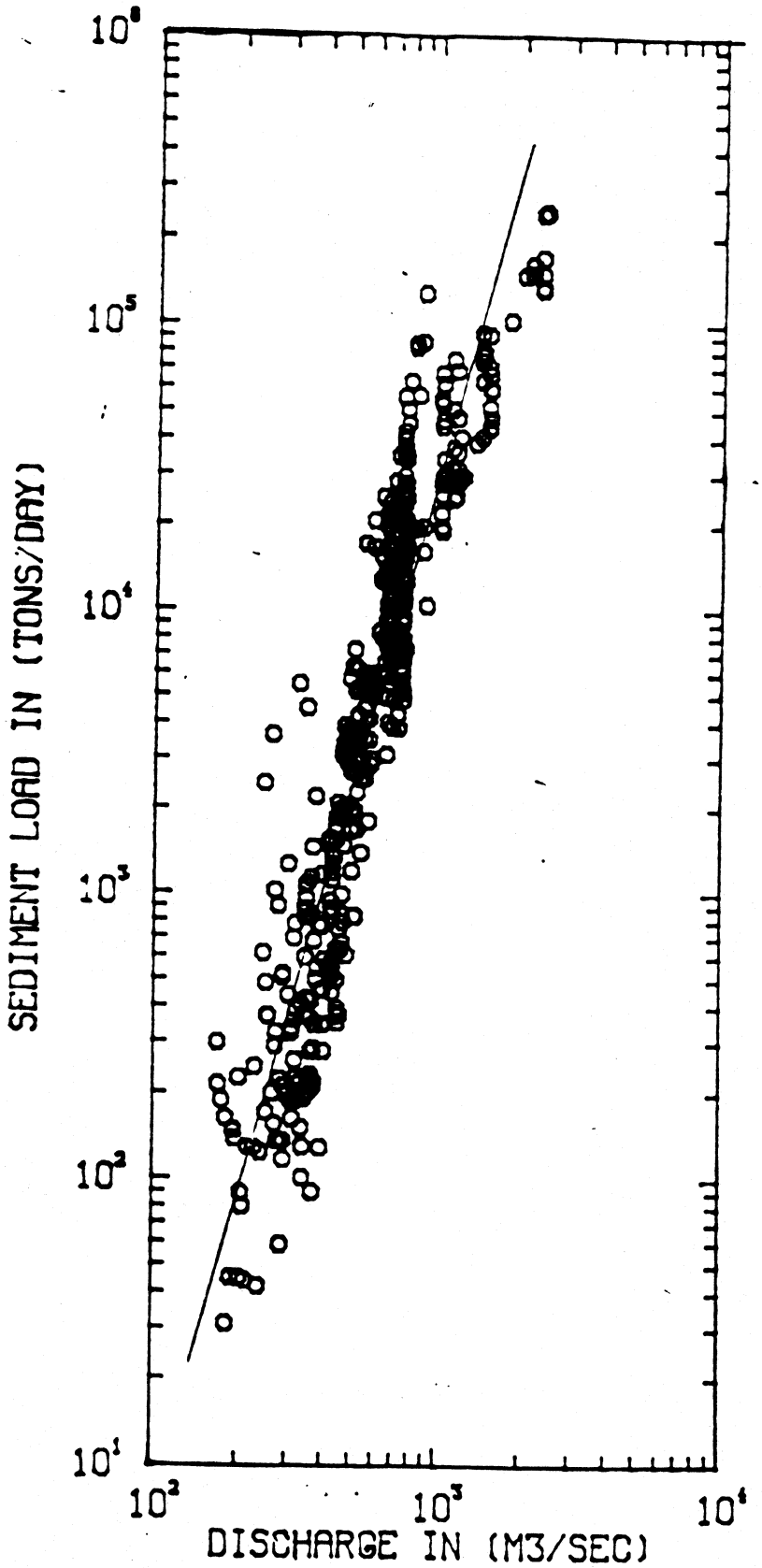
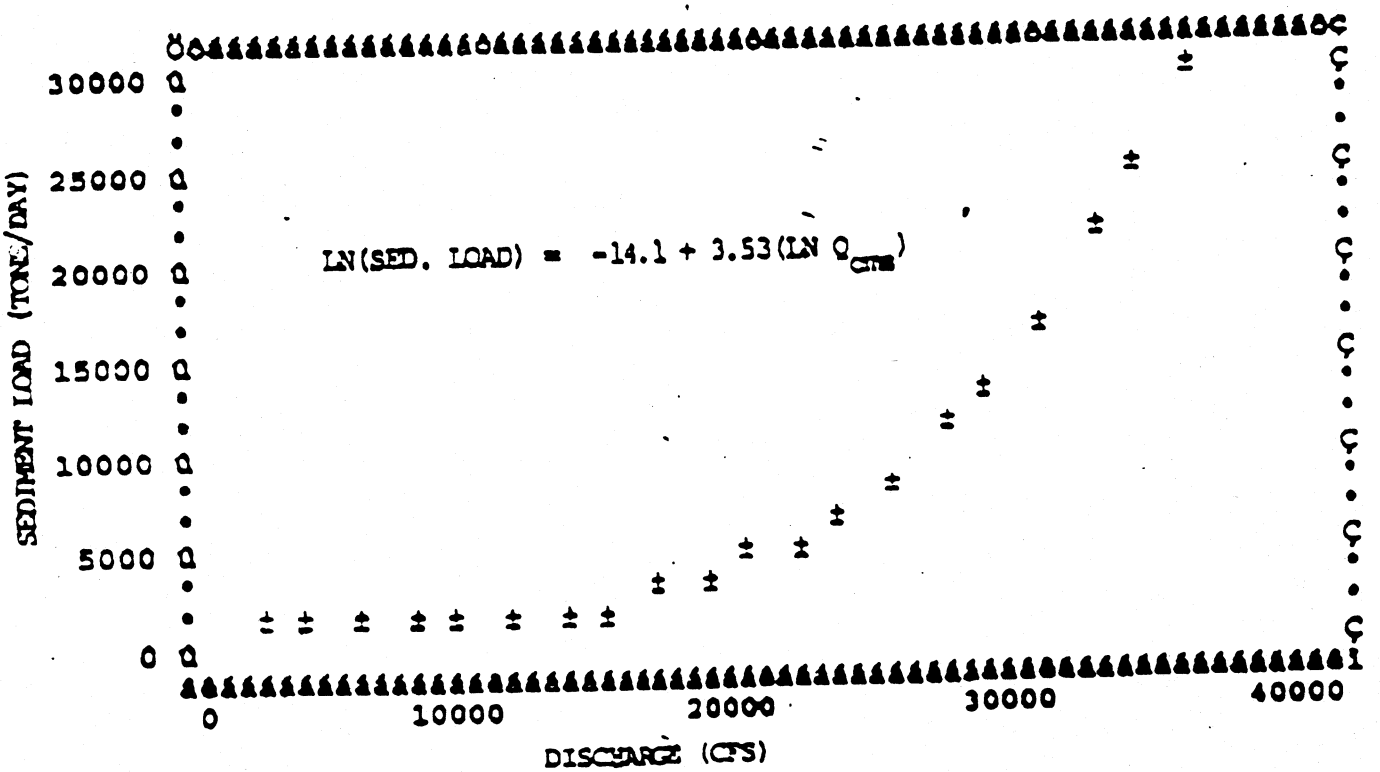


Figure 2. Sediment load transport per day as function of discharge. Data taken from regression curve calculated in figure 1.

QCMS	QCFS	SEDLOAD
50.000	1766.784	0.748
100.000	3533.569	8.640
150.000	5300.353	36.150
200.000	7067.138	99.790
250.000	8833.922	219.370
300.000	10600.707	417.530
350.000	12367.491	719.460
400.000	14134.276	1152.710
450.000	15901.060	1746.980
500.000	17667.845	2534.030
550.000	19434.629	3547.550
600.000	21201.413	4823.050
650.000	22968.198	6397.820
700.000	24734.982	8310.820
750.000	26501.767	10602.640
800.000	28268.551	13315.440
850.000	30035.336	16492.880
900.000	31802.120	20180.130
950.000	33568.905	24423.740
1000.000	35335.689	29271.690



GLEN CANYON
ENVIRONMENTAL STUDIES
P. O. BOX 1811
FLAGSTAFF, AZ 86002

ADDITIONAL INFORMATION IN SUPPORT OF THE SCIENTIFIC RECOMMENDATION FOR INTERIM OPERATIONS OF GLEN CANYON DAM

Duncan T. Patten
GCES Senior Scientist

Maximum Release of 20,000 cfs

The recommendation to limit maximum releases from Glen Canyon Dam to 20,000 cfs was based on two primary premises: (1) sand is being transported out of the system by high flows, and (2) high flows erode elevated beach deposits.

Sand Transport. The sand transport rating curve (presented in the initial scientific recommendation document) showed that the amount of sand being transported through the system increased exponentially with increasing flow velocity. Although analyses of various operational scenarios demonstrate that less sand potentially will be removed from the system above LCR than is replaced by mean inputs from Paria, there is no guarantee that the mean inputs will be achieved. In fact, sediment inputs from the Paria occur sporadically (Figure 1) and two or three year periods with little or no sediment input from the Paria are not unusual. Sand may accumulate in the channel under the various operational scenarios, but the source of this sand is, in all probability, from the elevated sand deposits (beaches).

Elevated Beach Erosion. Ongoing studies by Dr. Jack Schmidt of Middlebury College on long term changes in beach face profiles has demonstrated that high flows (i.e., flows exceeding 20,000 cfs), appear to have a greater detrimental affect on sand loss from elevated sand deposits than lower velocity flows. This phenomenon did not have the same effect universally across all beaches in the Canyon, but some effect occurred at most types of beaches to support the recommendation for limiting the maximum releases from Glen Canyon Dam. In a series of figures developed from many years of measuring beach profiles, Dr. Schmidt has been able to draw some preliminary conclusions about the action of various discharge levels. In the preliminary figures he has made available (Figs. 2-6), he notes that at each profile between 1986 and 1990 changes occurred while daily discharges occasionally, but not regularly, reached 31,500 cfs. Differences occurred at different beaches. At Grapevine Rapids (Figs 2 and 3) bank erosion occurred even at elevations higher than maximum power plant operations (31,500 cfs), presumably due to slumping, bank caving, and groundwater sapping (rill erosion). This tells us that erosion of the toe of slopes can affect areas beyond those merely wetted by daily fluctuations.

On many bars there is a well-defined break-in-slope between the eroding high-discharge deposit and lower elevation areas regularly reworked by powerplant flows. At 122 Mile Creek, that break-in-slope, was about at the 20,000 cfs discharge level (Figs. 4 and 5). This illustrates that if discharges are less than about 20,000 cfs, the base of the high-discharge deposits (i.e., high

elevation sand deposits) will be unaffected by dam operations. These high elevation deposits are often the ones that form the foundation for the sediment deposits protecting archaeological sites. In some cases, such as at a reattachment bar opposite Nineteen Mile Canyon (Fig. 6), discharges greater than 20,000 cfs were sufficient to overtop the upper platform of the bar and submerge large areas.

Daily Fluctuation of 5,000 cfs.

The daily fluctuation in discharge from Glen Canyon Dam is determined as the difference between the maximum release (in cfs) and the minimum release (in cfs) for a particular day. Thus, the daily fluctuation, at the dam is measured in cfs. At any location down the Canyon, this cfs fluctuation can be converted to stage fluctuation per day. The fluctuation in stage at any location thus is a function of the fluctuation in daily water discharge from the dam, the actual flow, the geometry of the canyon cross-section and the distance down stream from the dam (fluctuations in releases attenuate downstream). Daily fluctuation recommendations therefore can be made based on vertical fluctuations in the river (i.e., stage changes) in place of fluctuations in discharge (i.e., a cfs range). In discussing the concept of change in stage related to flow (and indirectly canyon geometry), the USGS presented data based on a stage-flow model at Grand Canyon gage. The curve presented in Figure 7a is based on a stage change limit of 3 ft (ca. 1 m). It shows that at the Grand Canyon gage a daily stage change of 3 ft is equivalent to a 5,000 cfs daily fluctuation at flows of about 10,000 cfs, and a 10,000 cfs daily fluctuation at flows of about 22,000 cfs. A similar relationship is shown for hourly fluctuations (limited to 0.7 ft/hr) in Figure 7b. The GCES Office is developing stage-flow curves for LCR and Lee's Ferry based on long term data, and preliminary curves for 43 Mile Beach to determine the relationships between daily fluctuation, river flow and stage changes in this sensitive reach of the Colorado River system below Glen Canyon Dam.

From preliminary data from 43 Mile Beach and observations at other beaches (some being closely monitored but without early preliminary data available), it is possible to develop a response curve showing the relationship between beach erosion rates and daily change in stage (Fig. 8). These data were generated in April when peak discharges from the dam were not as high as in summer months. As an example of the affects of different flow scenarios on beach erosion, changes over time of two transects surveyed on 43 Mile Beach are shown in Figure 9. These measurements were made in April 1991. On Friday (Fig. 9), the daily fluctuation was slightly over 5,000 cfs 9 (about a 1m stage change) and the ramping rates were shallow (probably tied to small daily fluctuation). On this day there was little or no beach loss from rill erosion, erosion caused by water seepage from the beach when the beach face is

exposed well below the perched water stored in the beach. On Saturday at this beach, the daily fluctuation was about 10,000 cfs (about 1.8m stage change) and the ramping rates were relatively steep. On this day, beach erosion averaged about 0.01 m, an apparently small amount until it is calculated on a yearly basis.

Based on these data and observations, the response curve (Fig. 8) shows that beach erosion dramatically increases as the daily stage change goes above one meter (ca. 3 ft.). Because this curve is based on non-high peak discharges, the approximate daily flow fluctuations (cfs) are presented for comparison. The development for stage-flow curves will more accurately present these relationships. The affects of very high stage change (e.g., 3m/day) are not as well known as for lower stage changes (i.e., 1-2m/day).

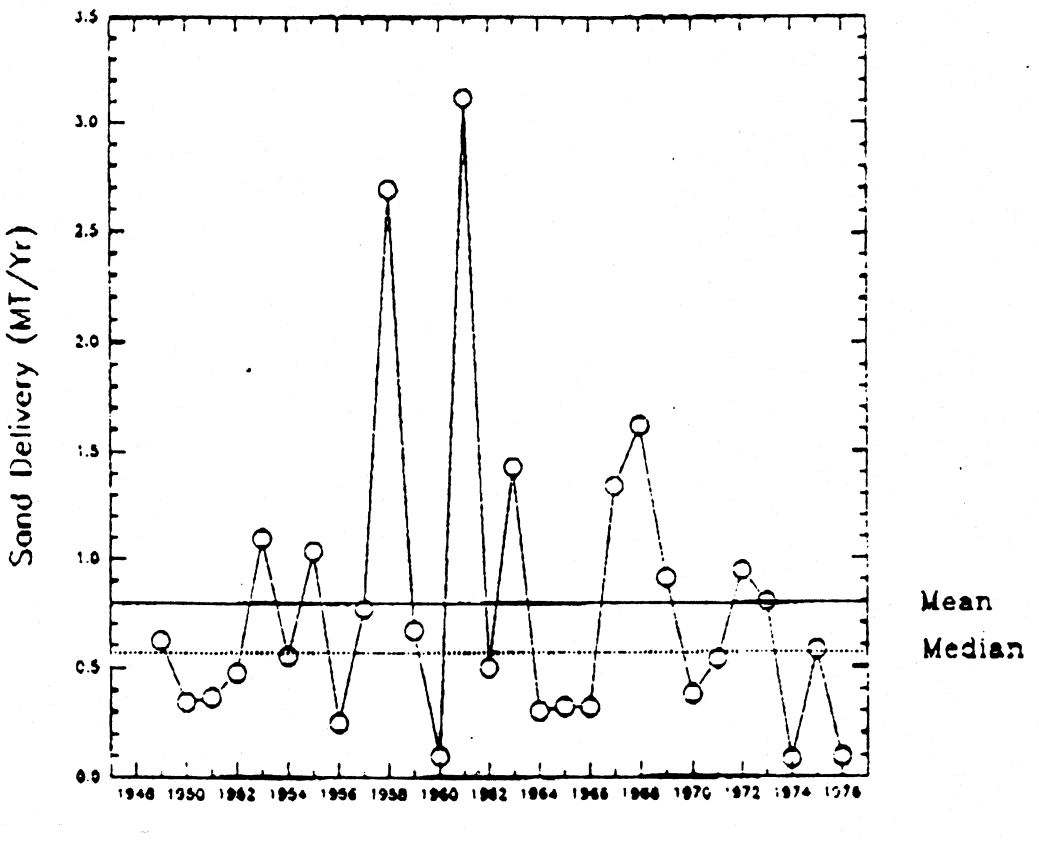
The conclusions drawn from information being analyzed from the beaches studied during research flows and normal operations is that beach face erosion (i.e., rill erosion, slumping and caving) is primarily a function of (1) the amount of water stored in the beach which is a function of recharge and down-ramp (time related factors), and (2) the vertical distance between the perched water in the beach and the lowest level of the river which is directly related to daily stage change. Information continued to be obtained from wells in the beaches and micro-surveying of beach faces should further illuminate these relationships.

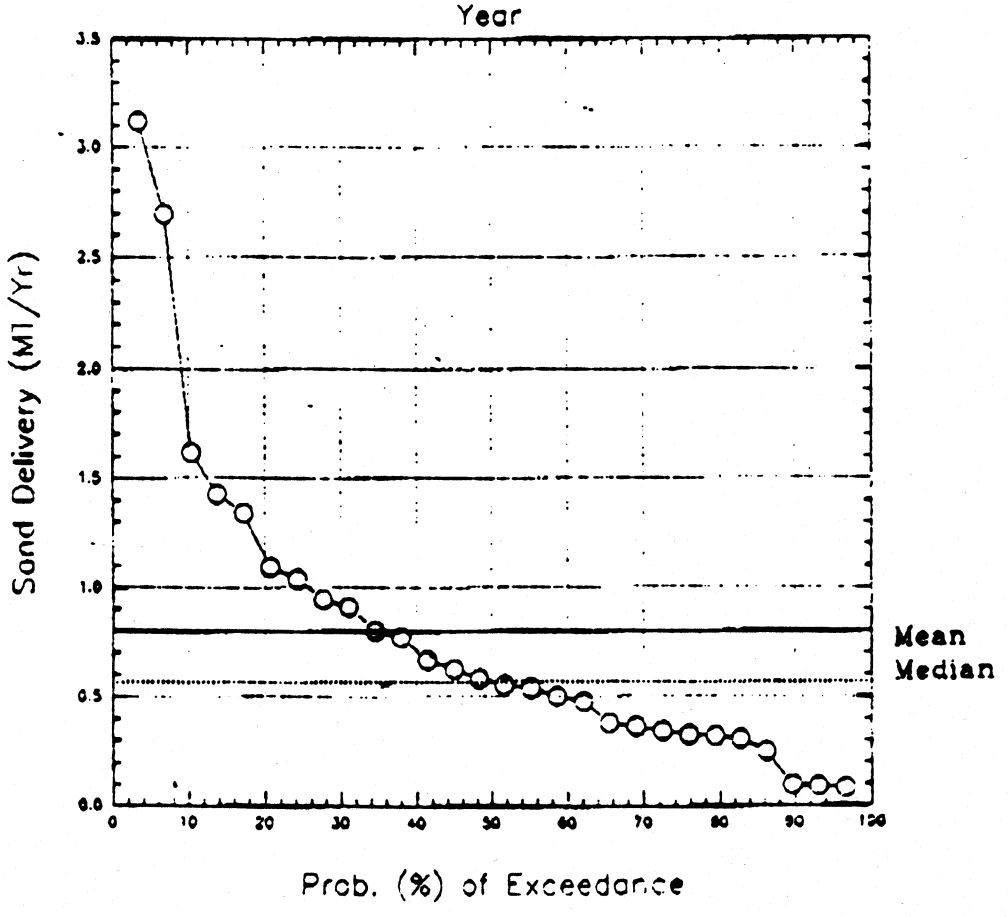
Concluding Comments.

Sediment deposits will continue to erode and be transported at some rate regardless of controls of the discharge rates from Glen Canyon Dam. High energy clear water and shear forces, alone, will erode and move particles in the system. It is thus the responsibility of those selecting flows and dam operations, whether interim or permanent, to make decisions relative to all attributes of the system. The above additional material is primarily oriented toward loss and erosion of sediments and beaches, resources that may be irreplaceable. Biological resources were addressed in the earlier recommendation report and their omission in this addendum does not indicate that they are of any lesser importance to the integrity of the Canyon ecosystem than the sediment.

FIGURE 1.

Sand Delivery (Million Tons/Year) from Paria River into the Colorado River (1948–1975)





Source: National Park Service, Water Resources Division

FIGURE 2. Above Grapevine Rapids, profile 1, 1986-1990

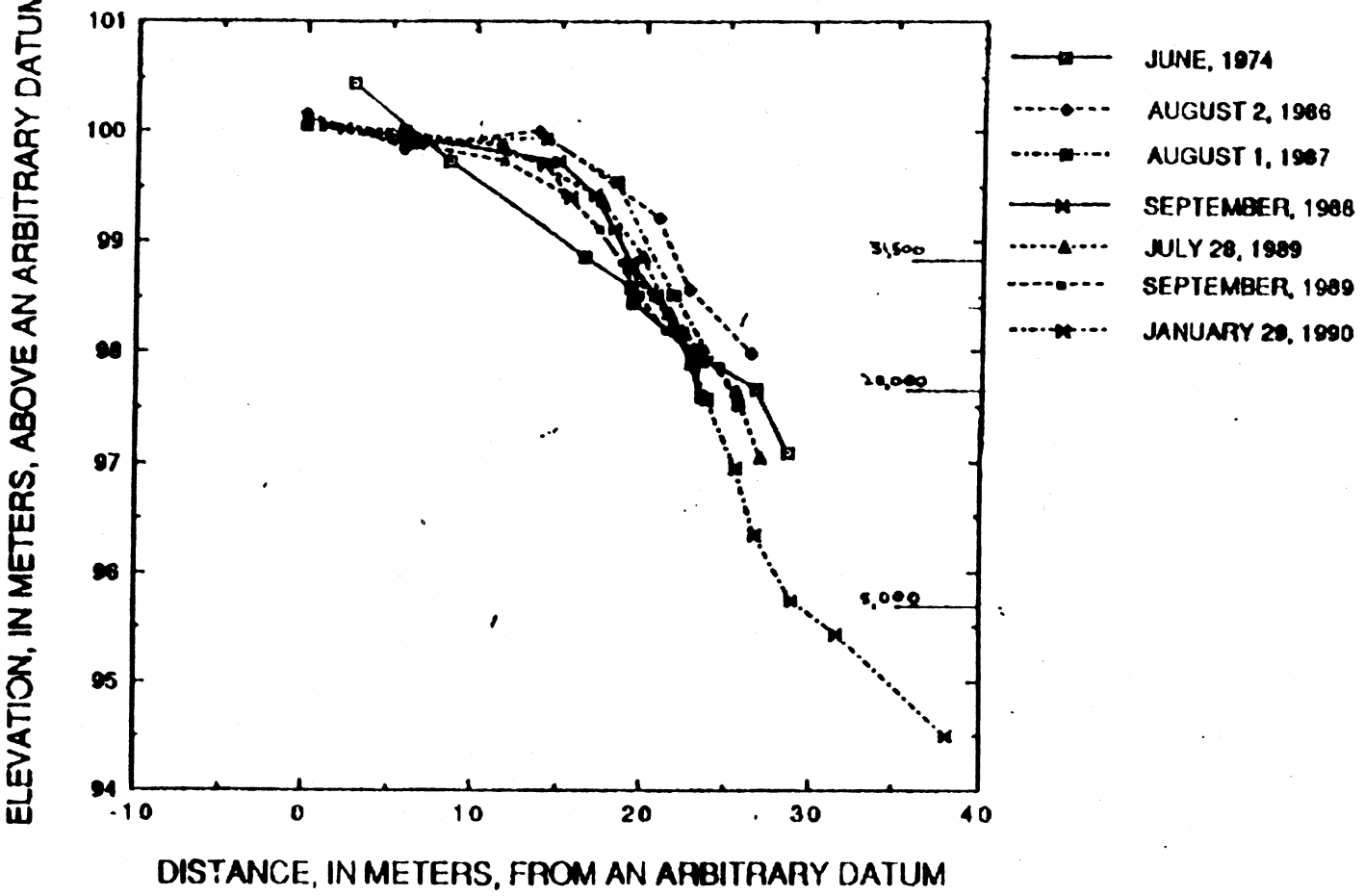


FIGURE 3. Above Grapevine Rapids, profile 2, 1986-1990

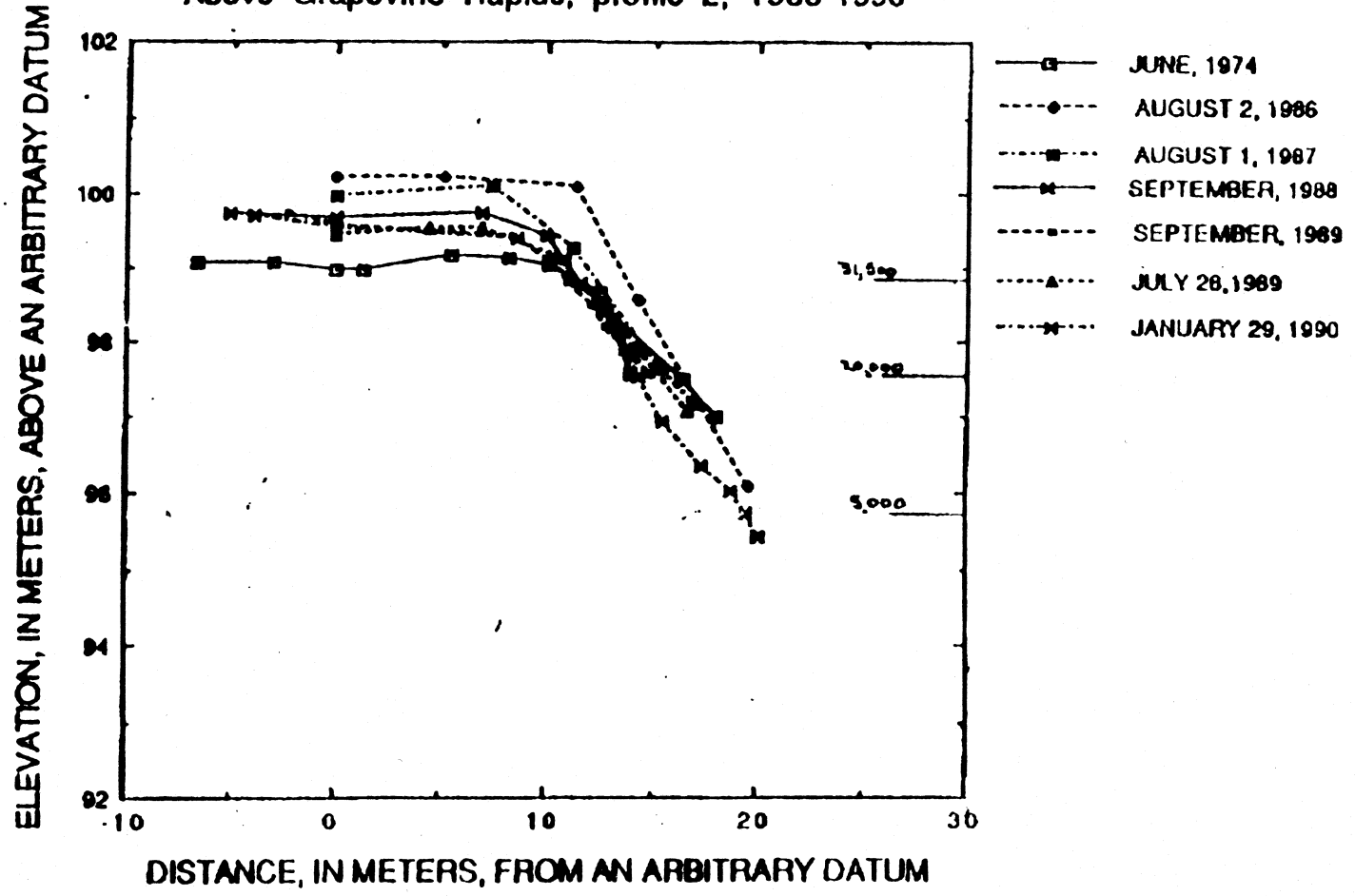


FIGURE 4. 122 MILE, CROSS SECTION 1

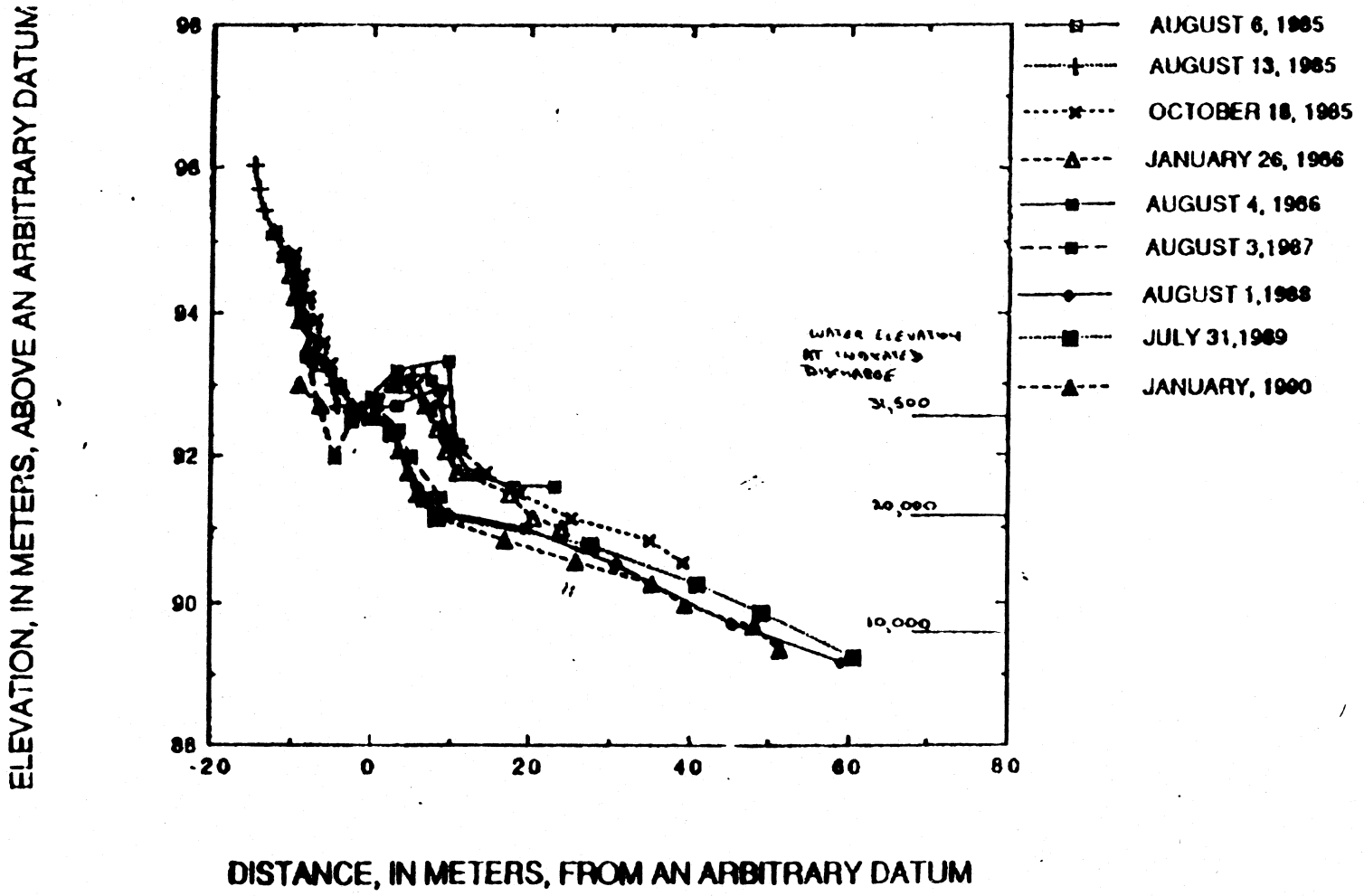


FIGURE 5. 122 MILE, CROSS SECTION 2

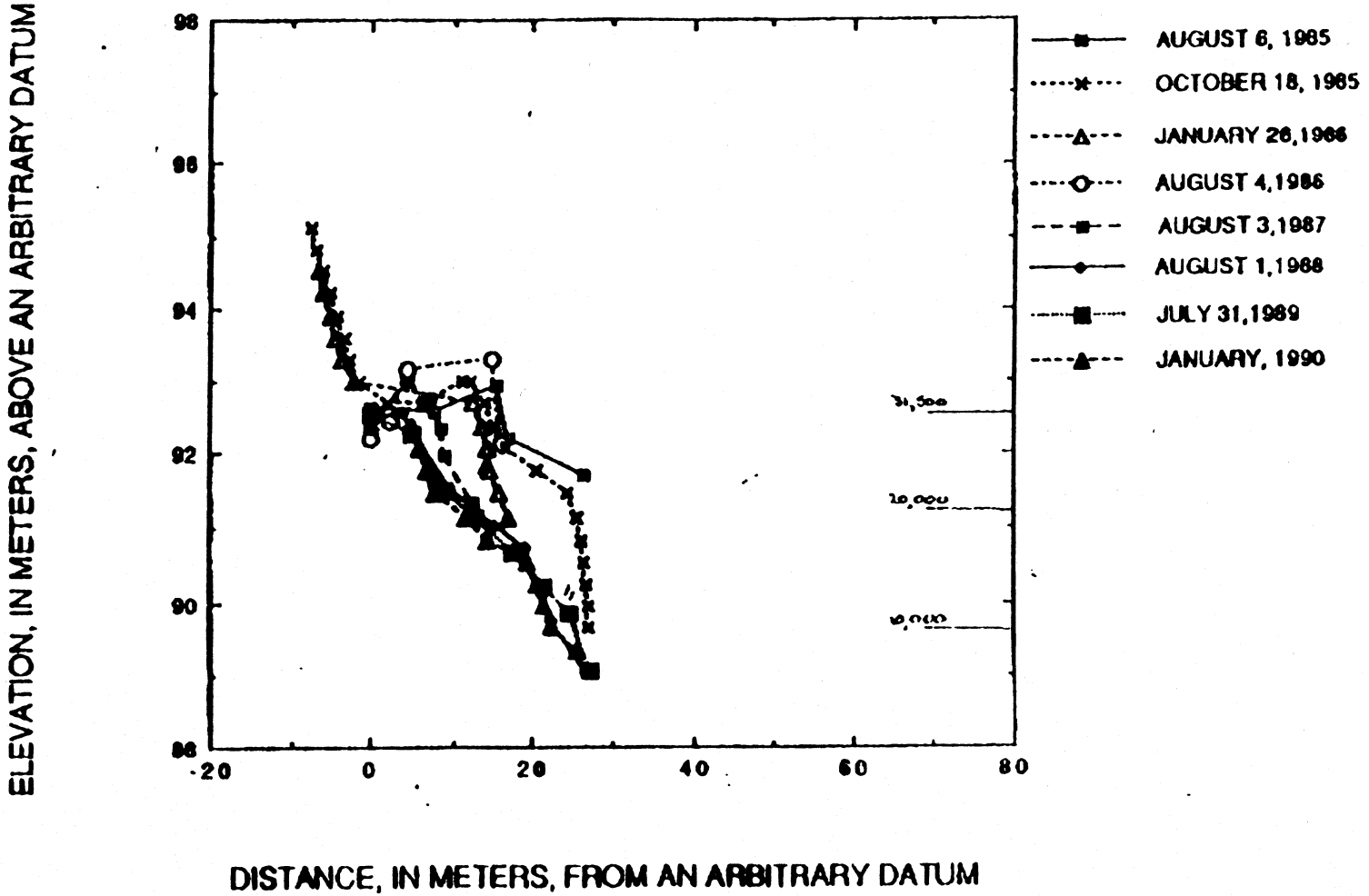


FIGURE 6. Opposite Nineteen Mile Canyon: Cross-Section 1, 1985-89

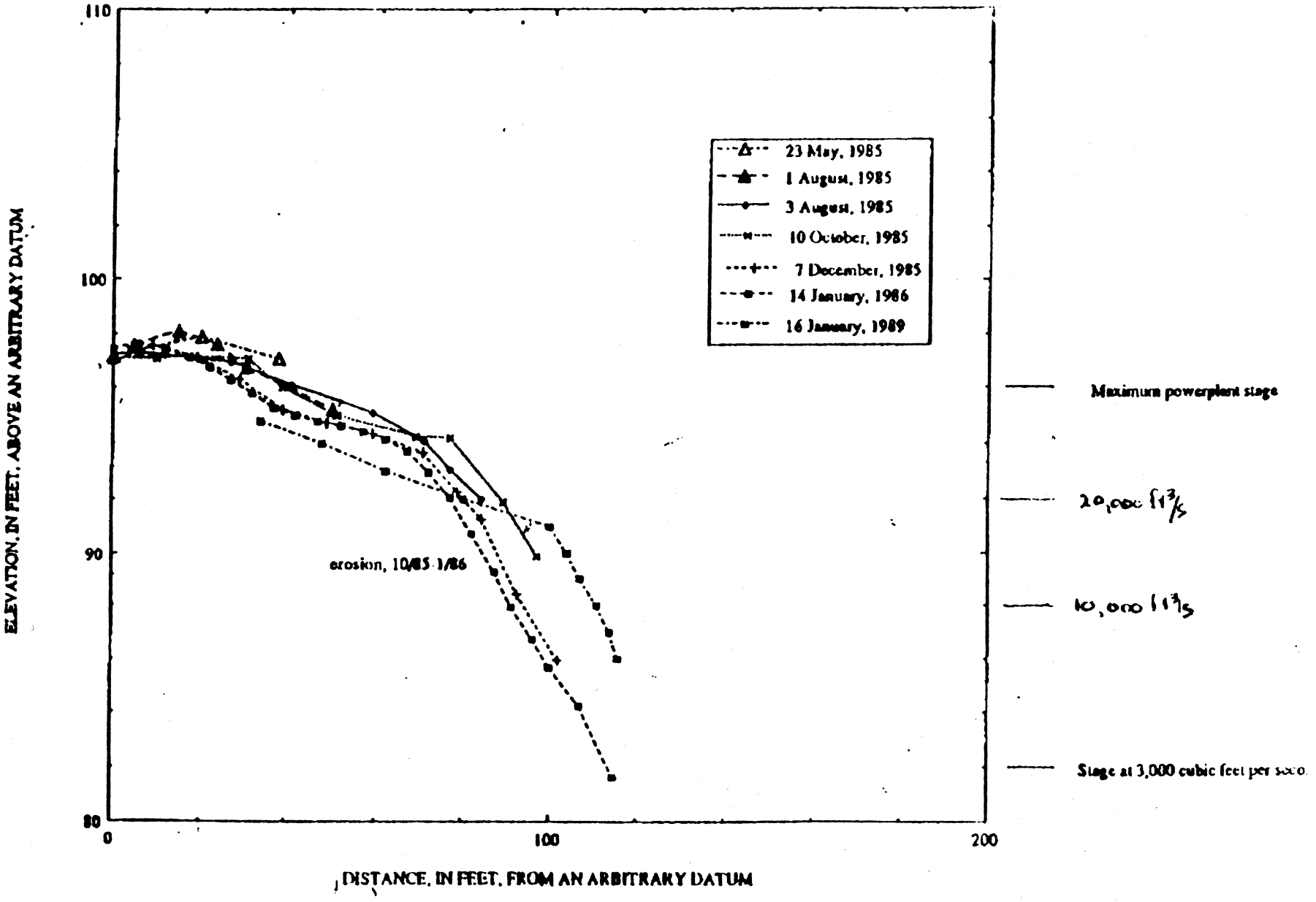
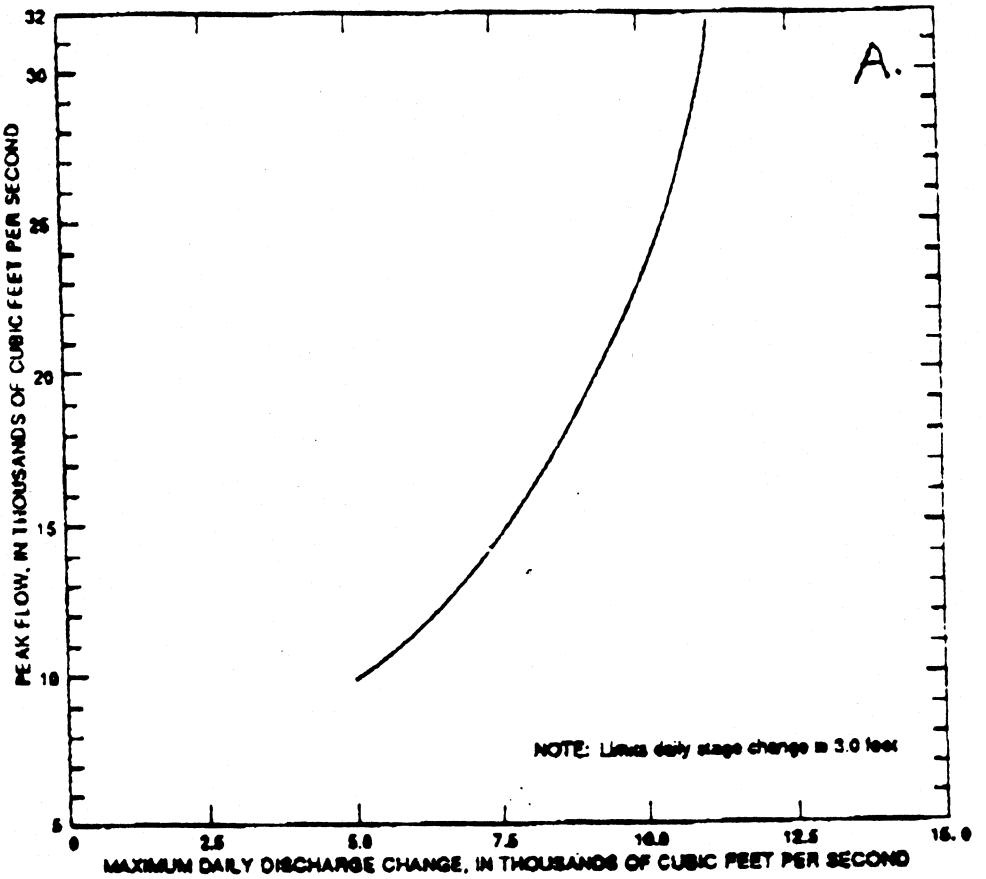


FIGURE 7.


A.
PEAK FLOW, IN THOUSANDS OF CUBIC FEET PER SECOND
32
30
25
20
15
10
5
0
2.5
5.0
7.5
10.0
12.5
15.0
MAXIMUM DAILY DISCHARGE CHANGE, IN THOUSANDS OF CUBIC FEET PER SECOND
NOTE: Limits daily stage change to 3.0 feet

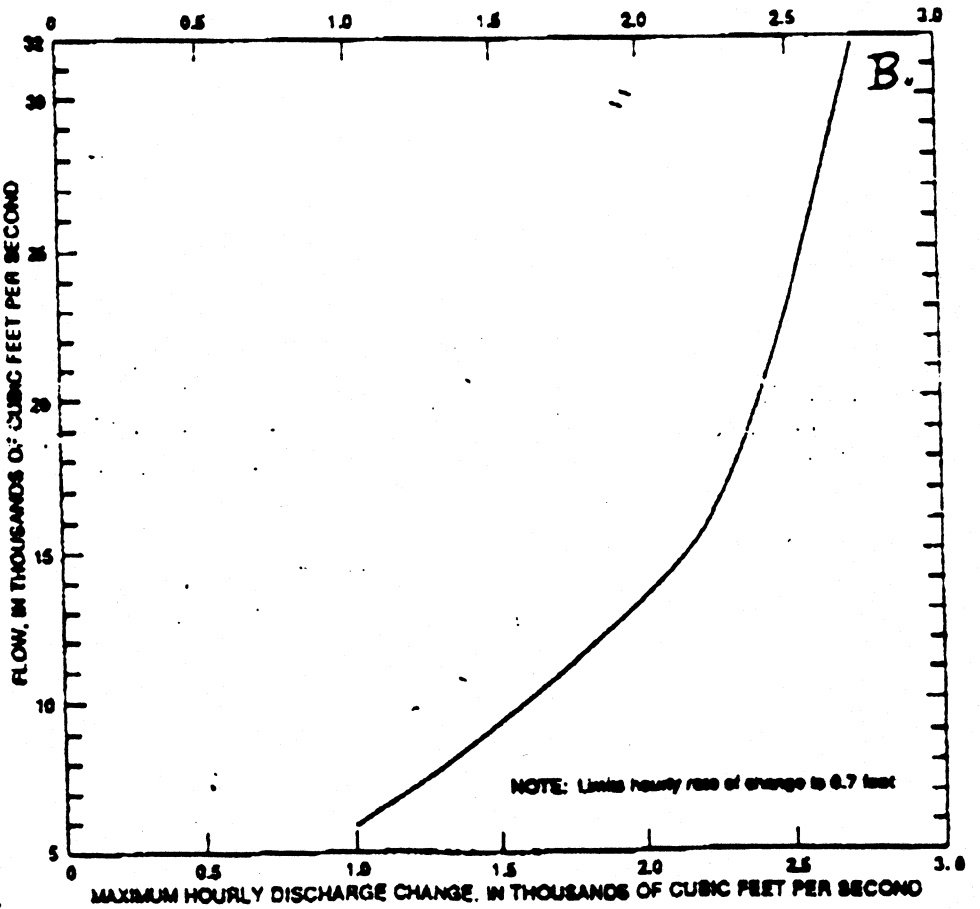

B.
FLOW, IN THOUSANDS OF CUBIC FEET PER SECOND
32
30
25
20
15
10
5
0
0.5
1.0
1.5
2.0
2.5
3.0
MAXIMUM HOURLY DISCHARGE CHANGE, IN THOUSANDS OF CUBIC FEET PER SECOND
NOTE: Limits hourly rate of change to 0.7 feet

FIGURE 8.

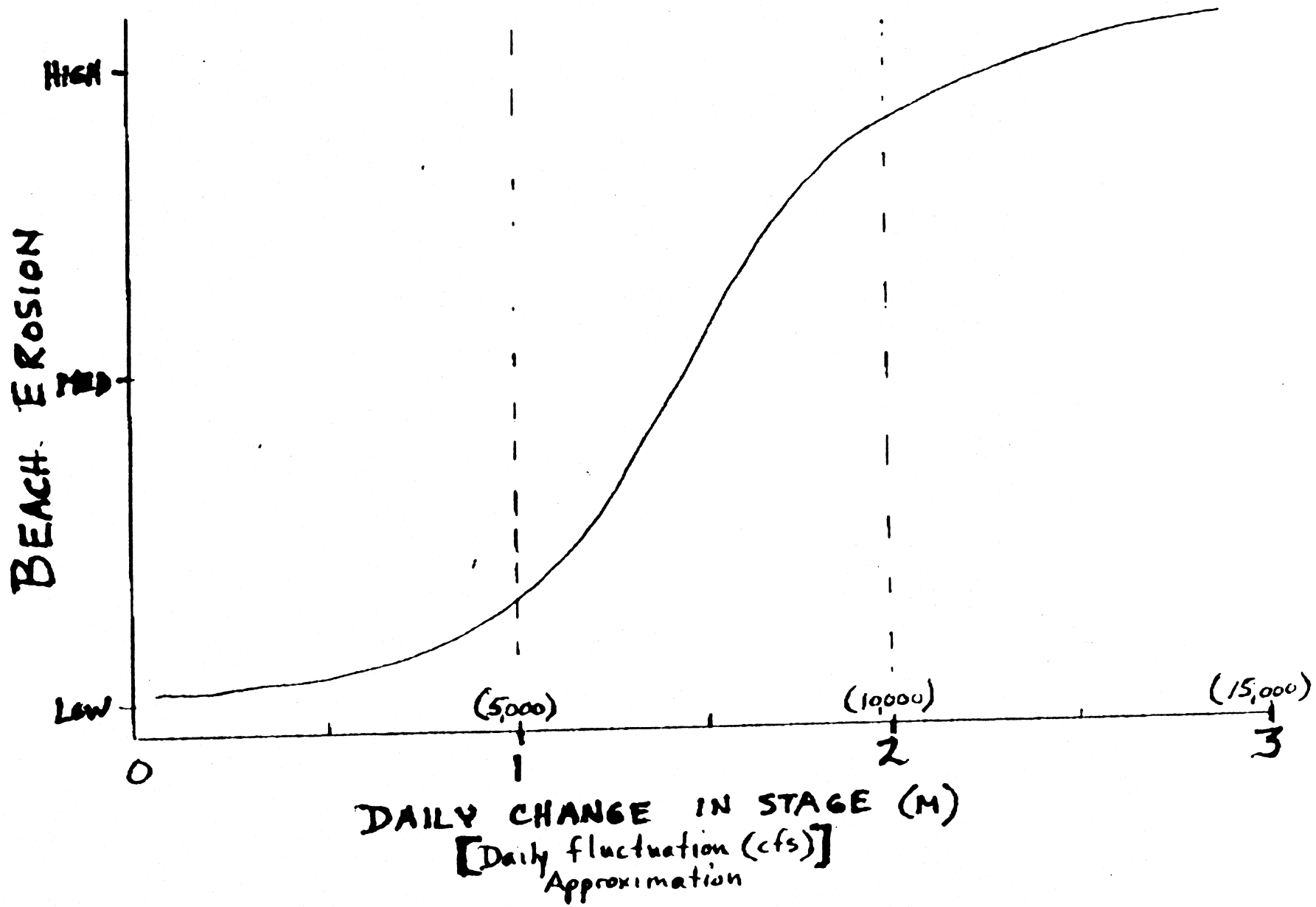
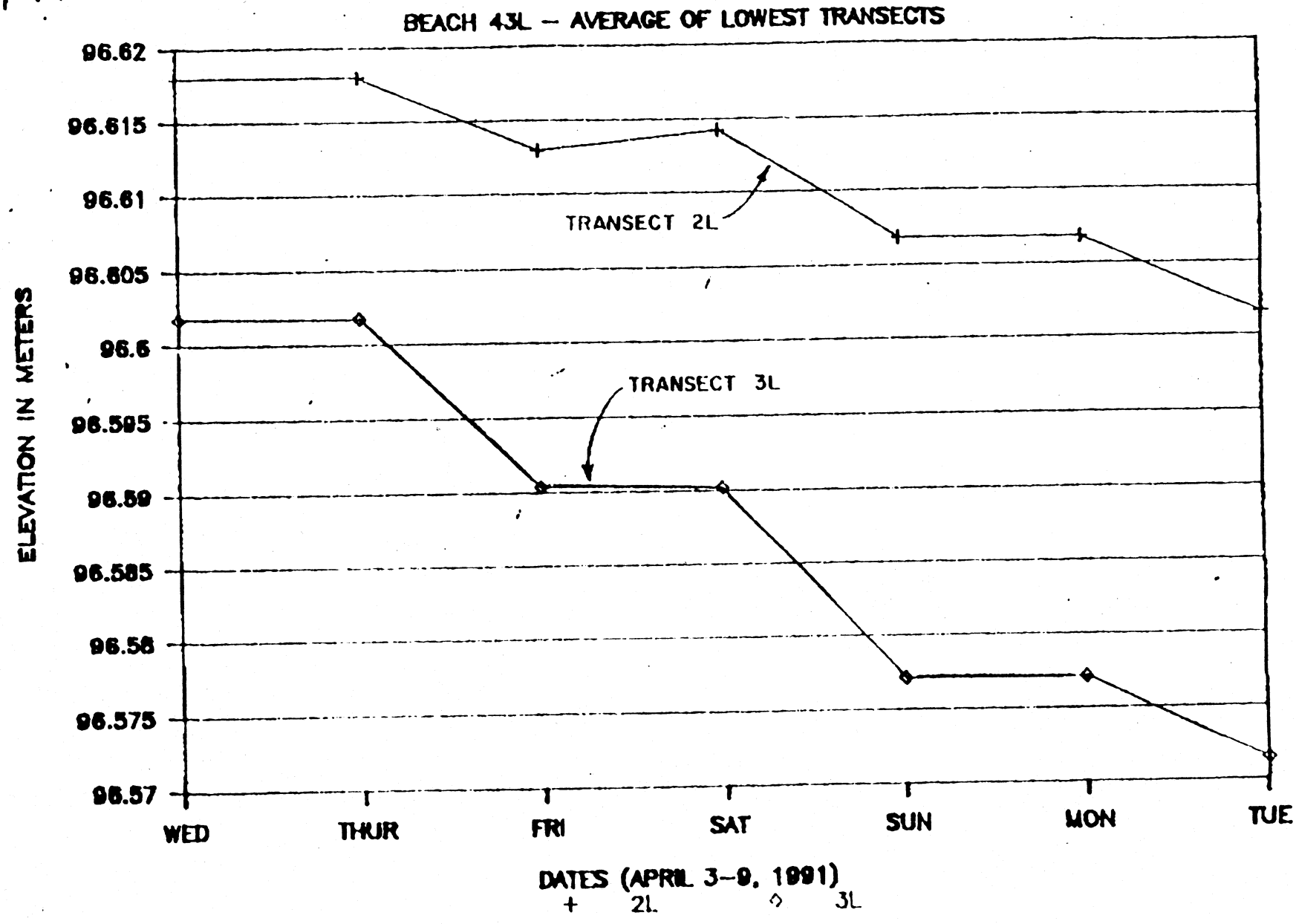

HIGH
MED
LOW
BEACH EROSION
(5,000)
(10,000)
(15,000)
0
1
2
3
DAILY CHANGE IN STAGE (M)
[Daily fluctuation (cfs)]
Approximation

FIGURE 9. GROUND ELEVATION DIFFERENTIAL GAGE



GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PLAN

ENCLOSURE 3 - OUTLINE FOR QUARTERLY REPORTS

March 27, 1992

GLEN CANYON ENVIRONMENTAL STUDIES
PROPOSED OUTLINE

QUARTERLY INTERIM FLOW MONITORING REPORT

I. Introduction

- A. Objectives
- B. Qualitative versus Quantitative

II. Interim Flow Hydrology

- A. Period Studied (outline the levels to be at)
  - 1. Annual plot with period of report highlighted
  - 2. Plot of three month period (with statistics in appendix)
  - 3. Deviations from defined flows
    - a. Emergencies
    - b. Financial
- B. Reasoning behind deviations

III. Resources Relationships and Impacts

- A. Seasonal elements (winter, summer, fall, spring)
- B. Localized perturbations (flash floods, rainfall, etc.)
- C. Short-term impacts (specifics)
  - 1. Biological
  - 2. Physical
  - 3. Financial
  - 4. Hydrology (hollow-jet tubes, spillway, etc)
- D. Long-term impacts (trends)

1. Biological
2. Physical
3. Financial
4. Hydrology (water year, reservoir levels, etc)

IV. Status of the Monitoring Program

A. Data base development

B. Integration of the ecosystem elements

C. Areas of concern

D. Areas of modification or redirection

V. Technical Recommendations

A. Monitoring program modifications

B. Refinement of interim flows

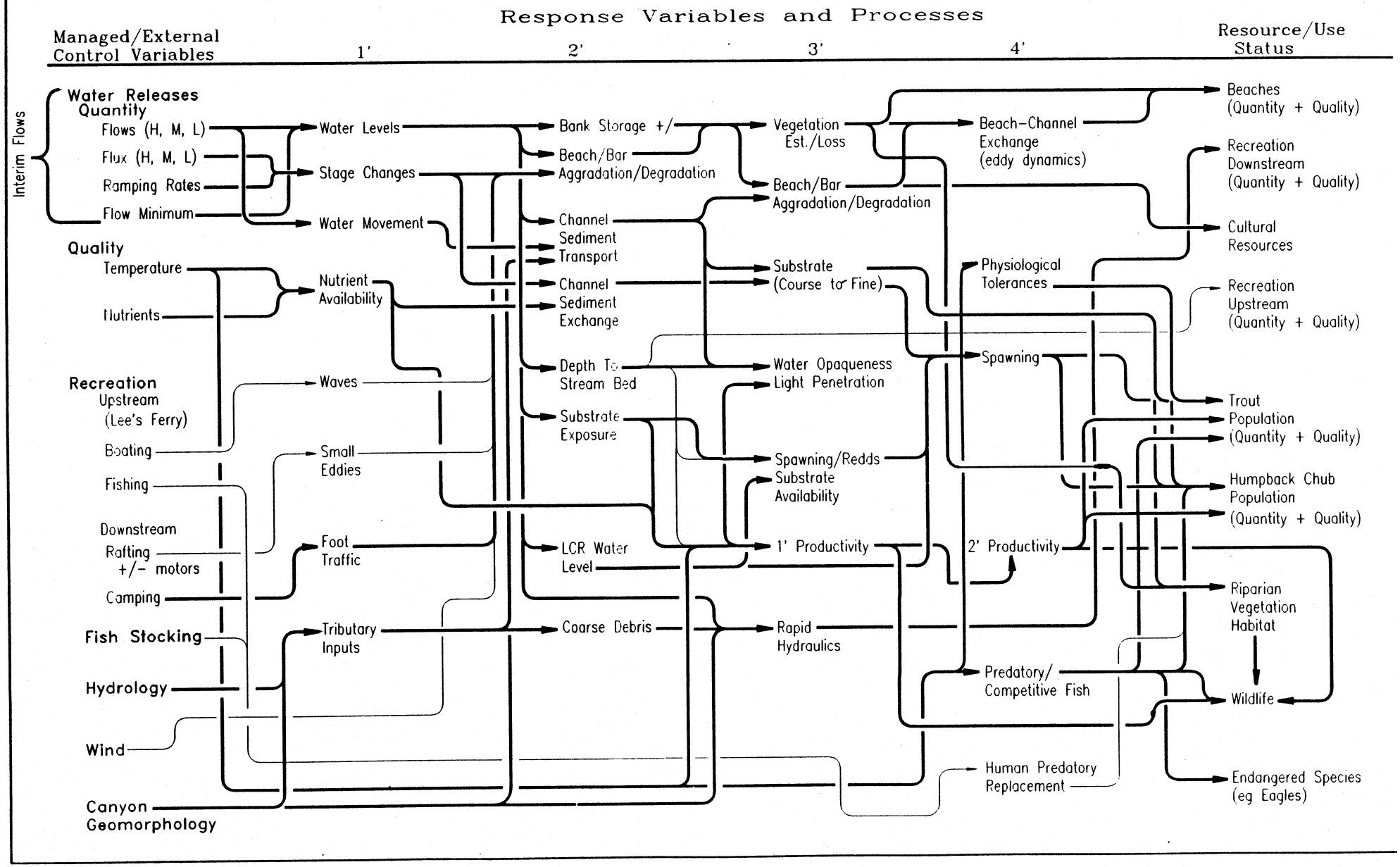
C. Coordination requirements

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PLAN

ENCLOSURE 4 - INTEGRATED RESEARCH GRAPHIC

Interrelationships and stepwise connecting response variables and processes between controlling variables and Canyon resource and use status.

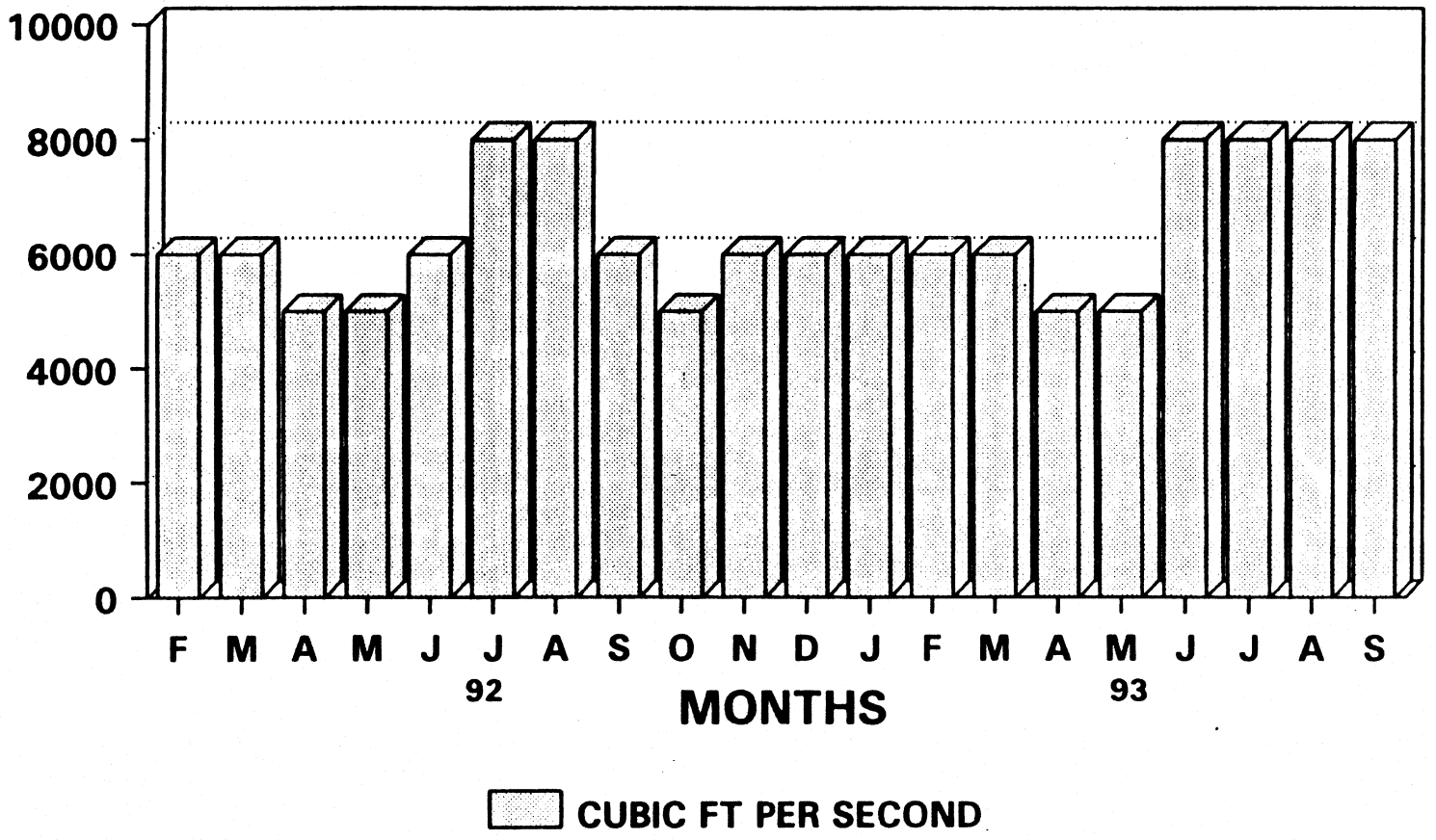


GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PLAN

ENCLOSURE 5 - ANTICIPATED 1992 ANNUAL OPERATING PLAN

GLEN CANYON DAM RELEASES
TOTAL CHANGE PER DAY IN CFS

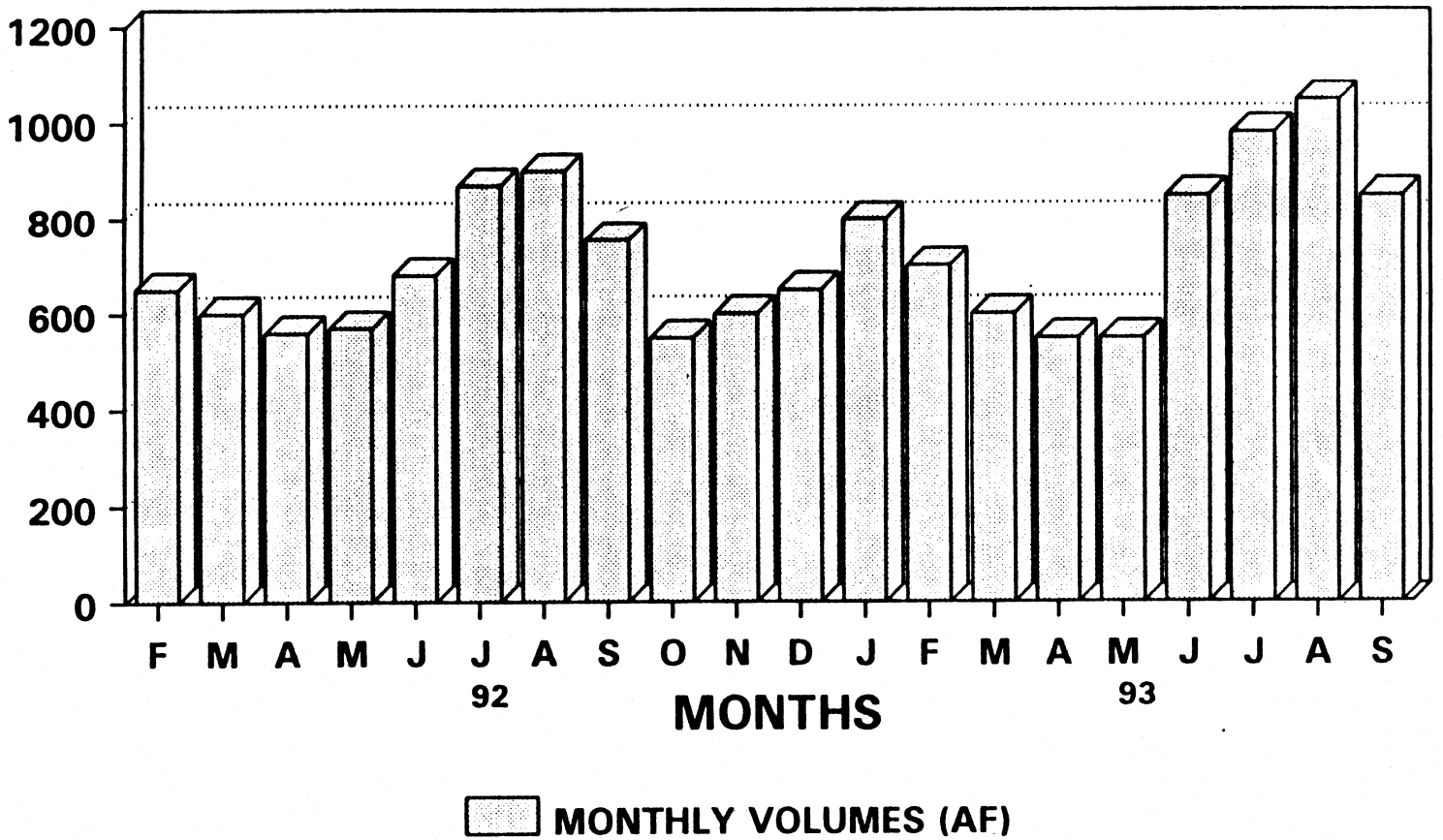


THOUSAND CFS

SUBJECT TO REVISION

2-21-92 CFS_RELS.CRT

GLEN CANYON DAM RELEASES
MONTHLY ACRE FEET



PER THOUSANDS

SUBJECT TO REVISION

2-21-92 MAF_REL6.CRT

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PLAN

ENCLOSURE 6 - GCES MONITORING PLAN TIMETABLE

WILL BE DEVELOPED AFTER AGREEMENT ON THE OVERALL PROGRAM

GLEN CANYON ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PLAN

ENCLOSURE 7 - GCES MONITORING PROGRAM BUDGET

WILL BE DISTRIBUTED AT THE COOPERATOR MEETING - MODIFICATIONS ONGOING

GLEN CANYON ENVIRONMENTAL STUDIES

DRAFT

INTERIM FLOW MONITORING PROPOSALS

SEDIMENT RESOURCES

SEDIMENT RESOURCES

SEDIMENT RESOURCES

MONITOR THE VELOCITY FIELD AND CHANGES IN SAND-BAR TOPOGRAPHY IN EDDIES DURING THE INTERIM FLOW PERIOD

A. ABSTRACT:

The effects of relatively large flows under the current interim operating regime on the erosion and deposition of sand in eddies will be characterized by combining three-dimensional velocity measurements at as many as 30 points in a single eddy with frequent resurveys of bar topography. Information from the concurrent 3-D velocity measurements will be used to verify eddy-circulation and sand-deposition models and compare the predicted and observed changes in bar topography.

B. OBJECTIVES:

During a period of sustained relatively large flow under the current interim operating regime, the objectives will be to:

1. Measure the changes in the configuration of a sand-bar deposit in an eddy.
2. To obtain a detailed description of the 3-D velocity field in an eddy to verify the eddy-circulation model.

C. JUSTIFICATION:

1. Objective 1: It is known that at higher flows sand accumulates in eddies and subsequently at lower flows these deposits are available for camping. The rate of this accumulation and the bar topography of the sand deposit below the water surface are not well known. Changes in the deposition rate and topography of the sand-bar deposit in an eddy will be determined precisely by frequent resurveying of the deposit.
2. Objective 2: Accurate prediction of the effects of flows having various magnitudes and durations on the distribution of sand in an eddy requires the simulation of the most important physical processes. Within the eddy, the three-dimensional velocity field is the principal sculptor of the sand deposits. By combining detailed measurements of the velocity field with known changes in the configuration of the sand deposits, a physically based model of an eddy system may be verified.

D. BACKGROUND INFORMATION AND EXISTING DATA:

Some information currently exists describing the configuration of sand-bar deposits in eddies, and eddy-circulation and sand-deposition models have been developed. However, the existing information is insufficient to make a thorough test of the model predictions.

E. METHODS:

A moving boat equipped with location equipment and an echo sounder have been used to make bar topography maps of eddies. This method will be used to document the changes in bed configuration over time during a period of sustained large flow. The three-dimensional velocity field will be measured with mast-mounted portable current meters, about 30, placed so as to obtain the best areal coverage of the velocity field in an eddy system. Data from the current meters and the boat-borne instruments will be recorded in the field with portable computer equipment and processed on larger computers during the analytical phase of the project.

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F. INTEGRATION WITH OTHER MONITORING EFFORTS:

Ideally, the monitoring of bar-topography changes and velocity fields in an eddy will be conducted in parallel with the stress-strain measurements being carried out on selected beaches. By combining these monitoring efforts at the same eddy, the relation of bar-topography changes resulting from erosion and deposition within the eddy and the effects of water-level fluctuation in the sub-aerial beaches can be evaluated.

If the site selected is in one of the reaches below the Paria River or the Little Colorado River, where bed changes and sand transport are being monitored under another project, information concerning the transport of sediment on each side of the eddy fence may be determined. This would permit an evaluation of the exchange of suspended sand between the main channel and the eddy.

G. PRODUCTS TO BE DEVELOPED:

1. Maps showing the evolution of bar topography in an eddy during a period of sustained relatively large flow.
2. Maps showing the three-dimensional velocity field at times corresponding to the maps of bar topography.
3. A report describing and comparing the eddy model predictions with the observed topography and velocity fields.
4. Quarterly reports on progress and data obtained in the previous quarter.

H. TIME TABLE:

This project will cover 2 fiscal years and be completed by September 30, 1993. A detailed time table will be developed once the large flows are scheduled. All equipment required to carry out this study is presently available except for the fabrication of the portable masts for deploying the current meters. This preparation process may take as long as 3 or 4 months to complete. Actual field work will take 3 to 4 weeks; 1 week for testing and evaluation of the data collection system and 2 to 3 weeks for the field measurements..

Bar-topography maps will be completed within 3 months of the experiment, and the velocity field maps will be published with the report on model evaluation.

I. BUDGET ATTACHED.

Costs include both fiscal years 1992 and 1993. Fiscal year 1992 costs are $80,600 or 56 percent of the total costs, which are $144,600.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigators E.D. Andrews, J.B. Graf Date Submitted 2/26/92
WRD National Res. Program
Department/Laboratory WRD Arizona District Organization USGS

Beginning Date 3/1/92 Completion Date 9/30/93

Project Title Monitor the velocity field and changes in sand-bar topography in eddies during the interim flow period

Budget Estimate

	Person/Mos Cal	Acad	Sumr	Total Amount
A. SENIOR PERSONNEL				$ 7,000
1. E.D. Andrews Estimated in Other Sources (K)	6			0
2. J.M. Nelson Estimated in Other Sources (K)	10			0
3. J.B. Graf	1.5			(7,000)
B. OTHER PERSONNEL				49,000
1. ( ) Post Doctoral Associates				
2. (X) Other Professional (techs.)	8			(28,000)
3. (X) Graduate Students	14			(21,000)
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical Included in Indirect Costs(I)				-------
6. ( ) Other				
C. FRINGE BENEFITS Included in Salaries A3, B2, B3				-------
D. PERMANENT EQUIPMENT				0
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				10,900
1. Domestic				
a. Principals				(7,500)
b. Others				(3,400)
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel Included in Travel E1a,b				-------
3. Subsistence Included in Travel E1a,b				-------
4. Other				

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G. OTHER DIRECT COSTS	$ 18,000
1. Materials and Supplies	(10,000)
a. Telephone Included in Indirect Costs (I)	-------
b. Other	
2. Publication Costs	(6,000)
3. Consultant Services Included in Indirect Costs (I)	-------
4. Computer Services Included in Indirect Costs (I)	-------
5. Subcontracts	
6. Other Equipment rental	(2,000)
H. TOTAL DIRECT COSTS (A through G)	84,900
I. INDIRECT COSTS	59,700
J. TOTAL DIRECT AND INDIRECT COSTS (Andrews and Nelson salaries and indirect costs)	144,600
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	126,100
L. TOTAL PROJECT AMOUNT (J + K)	$ 270,700

Itemize Capital Equipment to be Purchased in FY____

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight Charges

A2

A PROPOSAL TO MONITOR THE EFFECTS OF INTERIMFLOWS FROM GLEN CANYON DAM ON SAND BAR STABILITY IN THE COLORADO RIVER CORRIDOR, GRAND CANYON NATIONALPARK, ARIZONA

Stanley S. Beus
Department of Geology
Northern Arizona University
Flagstaff, AZ 86011

and

Lawrence E. Stevens
Resources Management and Planning Division
Grand Canyon National Park
Grand Canyon, AZ 86023

Starting Date: 15 August, 1992

Duration: 20 months

Funding Amount: $239,400

Submitted To: The National Park Service
Cooperative Studies Unit
Northern Arizona University
Flagstaff, AZ 86011

Stanley S. Beus
Co-Principal Investigator

Henry O. Hooper, PhD
Associate Vice President
for Academic Affairs,
Research and Graduate Studies

Lawrence E. Stevens
Co-Principal Investigator

GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

FEB 27 1992

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A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON SAND BAR STABILITY IN THE COLORADO RIVER DOWNSTREAM FROM GLEN CANYON DAM, ARIZONA

ABSTRACT

The objectives of this proposal are to monitor the effects of the Bureau of Reclamation's interim flows from Glen Canyon Dam on sand bar stability in the Colorado River corridor downstream from Glen Canyon Dam. Such information is necessary because sand bar stability underlies all aspects of ecosystem maintenance and development in this dam-controlled river system (Beus and Avery 1991; Water Science and Technology Board 1991). The topography and bathymetric surfaces of thirty Colorado River sand bars will be monitored on an annual basis using electronic survey technology with the methodologies employed during GCES Phase II. This study will provide continuity of data collection methods during sand bar stability during the interim flows period. We request $ 239400 to conduct this monitoring.

STATEMENT OF OBJECTIVES

The following objectives will assist the NPS evaluate the effects of interim flows on resources in the Grand Canyon.

1. Monitor subaerial and subaqueous sand bar topography on an annual basis on 30 representative sand bars in the Colorado River corridor downstream from Glen Canyon Dam during the interim flows period.

2. Compare topographic change on sand bars from July, 1991 to September 1991, October/November 1991, October, 1992 and October 1993.

3. Assist in compilation of the above data for the GCES/NPS Geographic Information System.

JUSTIFICATION

A primary objective of the interim flows criteria was to benefit sand storage and sand bar stability by reducing sediment transport, range of daily fluctuations, and ramping rates. The objectives of this study are to determine if the interim flows prescription achieved this resource objective.

1. Monitor subaerial and subaqueous sand bar topography on an annual basis on 30 representative sand bars in the Colorado River corridor downstream from Glen Canyon Dam during the interim flows period.

This monitoring objective is important because sand bars are influenced by discharge regimes from Glen Canyon Dam and are recognized by the National Park Service as a primary natural and recreational resource in Grand Canyon National Park. Colorado River sand bars are stored in the channel and in lateral bars, and sand is the foundation on which this fluvial ecosystem is structured. Rigorous topographic survey control was established on 30 study sites in GCES Phase II throughout the Grand Canyon. These sites were used to determine short-term and annual changes in bar topography and are available for monitoring studies. Interim flows criteria and implementation were undertaken in August, 1991 to reduce sand bar erosion in the Colorado River corridor and this study will evaluate the success of that management action.

2. Compare topographic change on sand bars from July, 1992 to September 1991, October/November 1991, October, 1992 and October 1993.

Discharge from Glen Canyon Dam may affect sand bar abundance, volume and distribution during the interim flows period. To evaluate the effects of interim flows, adequate baseline data must be compared with re-measured sand bar topographic data. The data of Beus and Avery (1991) provides the best such data available for this comparison. We are interested in whether or not interim flows affect sand bar stability: a negative effect may require an adjustment of existing flow criteria, while a neutral or positive response may not.

3. Assist in compilation of the above data for the GCES/NPS Geographic Information System.

This objective is important because the GCES/NPS GIS is the central data base and data base management system for GCES and Interim Flows studies, and will provide the basis for short-term and long-term monitoring and integrated management.

BACKGROUND

Interim Test Flows

The Secretary of the Interior authorized implementation of a program of reduced maximum flows and reduced fluctuation from Glen Canyon Dam beginning in August, 1990. These Interim Flows were designed to mitigate impacts of dam operations on downstream riverine resources, until a Record of Decision is reached for the Glen Canyon Dam Environmental Impact Statement. These Interim Flows consist of low-, medium-, and high-volume months, with low flows during the spring and late fall, moderate flows in May and September, and high flows during mid-summer and mid-winter.

Interim Flows have a maximum discharge of 20,000 cfs, a reduced range of daily fluctuation, and reduced up- and down-ramping rates. The Glen Canyon Environmental Studies Program is coordinating monitoring Interim Flows effects on sediments, cultural resources, the aquatic food base, riparian areas and wetlands, economics, trout, native fish, recreation and water quality, with data base management and development and development of a geographic information system GIS. The effects of flow exceptions also require monitoring under the Interim Flow discharges program.

Historical Studies on Sand Bar Stability

Regulated flow from Glen Canyon Dam influences the stability of fine-grained fluvial sediment deposits (sand bars) in lower Glen and Grand canyons (Howard and Dolan 1981; Webb et al. 1987; Rubin et al. 1990; Schmidt and Graf 1990; Beus and Avery 1991; Andrews 1991). Fine-grained sediments tend to accumulate in areas of reduced velocity in the Colorado River corridor below Glen Canyon Dam, particularly in recirculation zones formed by channel constrictions (Schmidt and Graf 1990). Geomorphology, hydrology, and sediment transport collectively interact with erosional mechanisms, including seepage forces, wave action, and tractive processes, to determine the stability of individual sandbars (Rubin et al. 1990; Schmidt and Graf 1990).

Prior to GCES-II studies, knowledge of the stability (aggradation, degradation, and rates of change) of fluvial deposits in the Colorado River downstream from Glen Canyon Dam was based on sporadic profile surveys of about 30 sandbars since 1973, and occasional aerial photography since 1965 (Howard 1975; Howard and Dolan 1981; Beus et al. 1985 et subsequ.; Zink 1989; Schmidt and Graf 1990; Schmidt 1989; Schmidt et al. in press). These studies documented slight to significant instability of sand bars under the post-dam fluctuating flow regimes, with bar building reported under the high flows of 1983-1986, and both prior and subsequent erosion. Erosional patterns are obscured by variability in reach characteristics, local channel geometry, poorly developed stage/discharge relationships, unknown antecedent conditions, and survey accuracy. Schmidt and Graf (1990) determined that sand bars typically used as campsites (and topography study sites) were an unusually stable subset of the entire population of sandbars.

Beus and Avery (1991) also studied seepage erosion, an important erosional mechanism operating in systems with rapid changes in stage (Howard and McLane 1988). Seepage-driven erosion occurs when rapid decreases in water level leave perched water tables in cohesionless sediment deposits, such as sandbars along the Colorado River. As the bankstored groundwater drains, it causes rilling and ultimately mass wasting at the water's edge. Few studies document short-term (daily, weekly) impacts of dam operations to sandbar/river-bank stability or the mechanisms of erosion in the

Colorado River corridor (Schmidt and Graf 1990, and Rubin et al. 1990 are exceptions). Here discharge from Glen Canyon Dam may vary up to an order of magnitude during a day. This fluctuating regime creates a "daily tide" from the dam to Lake Mead, Arizona. Under normal dam operations river stage typically drops faster than bank-stored groundwater can drain from the sandbars, leaving a perched water table in the bars, resulting in seepage-driven rilling and mass wasting of over-steepened banks.

Under the auspices of the GCES-II program and the Glen Canyon Dam Environmental Impact Statement, the National Park Service, Northern Arizona University and the U.S. Geological Survey undertook a study of sand bar stability in the Grand Canyon (Beus and Avery 1991). Historical data were compiled and analyzed for change during the post-dam period. The Bureau of Reclamation conducted a series of 11-day test flows in 1990-1991 to determine the impacts of specific dam operations on downstream resources. These flow tests provided an ideal opportunity to evaluate sand bar stability during specific flow regimes and model the effects of dam operations on seepage driven erosion using groundwater data from three validation sites.

We concluded the following:

1) The temporal and spatial record of sandbar change must be considered to fully interpret short term measurements of sandbar responses to flow regimes. Periods of low discharge (1966-1982 and 1987-1990) were characterized by aggradation of low elevation sandbars, while high elevation bars eroded. Between 1983 and 1986, when annual peak discharges were more than twice the low discharge periods, reattachment bars eroded but high elevation bars aggraded. Erosion rates change through time as a function of changing sediment storage: aggradation rates in 1987-1990 were equivalent to those of 1966-1982, but degradation rates were about twice as great.

2) Although only 10 of 33 ground topography sites had been analyzed at the time of reporting, several trends were suggested. Bar instability was positively correlated with distance downstream from Glen Canyon Dam. Bar instability was slightly but non-significantly positively correlated with mean discharge, increasing daily fluctuation, and increasing ramping rate.

3) Bank failure correlates with change from one flow regime to another. Fifty percent of known bank failures occurred within the first or second day of flow fluctuation following periods of low or weekend type discharge and most occurred during rising stage. Bank failures occurred at upramping rates prescribed by the test flow program of 204 and 102 cms/hr, and during interim flow prescription of 70 cms/hr. A few bank failure events also occurred during drawdown from high stage to low stage. This indicates that discharge changes destabilize sandbars. Consequently, ramping rate is suspected as the most destructive component of flow under normal

dam operations. Because up to 80% of bar areas were eroded by single bank failure events, additional research is required to develop flow restrictions to stabilize sandbars.

4) The seepage driven erosion model under development is consistent with field observations and data on bankstored groundwater movement. It appears that seepage driven erosion is affected more by the down-ramping rate and the duration of minimum flow than by the up-ramping rate. Preliminary results indicate that the model can play an important role in evaluating the effects of possible alternative dam flow regimes.Short-term and long-term discharge patterns from Glen Canyon Dam affect the stability of sand bars in the Grand Canyon (Howard and Dolan 1981; Beus et al., 1984 et subsequ.; Rubin et al. 1990; Beus and Avery 1991). Discharge effects on sand bar stability began in the Grand Canyon reach with studies by Howard (1975), and have been continued by Beus et al. (1984 et subsequ.) and Beus and Avery (1991).

Existing Data

The data base against with interim flows effects will be compared was developed by Beus et al. (1984 et subseq., 1991). This data base includes historic topographic in information as well as exhaustive data collected on each site during the GCES-II test flows. These data are presently stored in ASCII format at the Department of Geology, Northern Arizona University, and are readily available for comparison with interim flows data. The detailed photography and surveyors notes on each site will also permit us to evaluate non-riverine influences on sand bar stability that occur during the interim flows period.

METHODS

Study Site Selection

Thirty fine-grained fluvial sediment deposits (sand bars), approximately 10% of all large sand deposits between Glen Canyon Dam and Diamond Creek, were selected for repeated surveys of bar topography through the GCES-II test flow series. These sandbars were selected on the basis of: (1) distribution throughout the geomorphic reaches identified by Schmidt and Graf (1990); (2) sufficient size to guarantee persistence through the period of study; (3) geomorphic diversity within and between sites; (4) availability of historical topographic data; (5) variation in recreational use intensity and vegetation cover; and (6) access limitations downstream of Diamond Creek. Site selection, baseline surveys, and protocol development were accomplished during June and August, 1990. Sandbars studied are named on the basis of river mile (RM) and are presented in Table 1.

Topographic Surveys

Surveys of sand bars have been restricted to annual surveys in the Bureau of Reclamation Interim Flows Monitoring Plan (Wegner 1992). This restriction will not permit resolution of topographic change related to the three types of interim flows (low-volume, medium-volume and high-volume months); however, several options exist to gain this level of resolution. At the initiation of the interim flow period, survey data were collected as part of on-going studies of riparian vegetation on approximately 12 sites. These data will be compiled in a form suitable for comparison with test flow survey data and analyzed to determine the initial impacts of high (August 1991) versus low (October 1991) monthly volume interim flows. This will provide an indication of system-wide adjustment to the initiation of interim flows. If these data suggest substantial change in sand bar response to differently monthly flow types, we may suggest that NPS adopt a more frequent topographic survey schedule to clarify responses to the three montly flow volumes.

Topographic survey data will be collected on an annual basis, according to the schedule identified by the Bureau of Reclamation Interim Flows Monitoring Plan (Wegner 1992). During the annual topographic survey period, two 6-person survey teams will traverse the river corridor, re-surveying the 30 sites using at least two motor craft, or five oar-powered craft. Individual survey crews will consist of a foreman, a surveyor/instrument operator, a data entry assistant, a rodman, a depthfinder operator and a photographer/control assistant. Using Lietz SET 3 and 4C electronic total stations, data collectors and printers, each crew will surve subaerial and subaqueous topography on one-two sand bar per day. Site photographs will be re-taken at each site on each run from camera stations established during the baseline surveys.

Survey protocol will conform to the rigorous methodology prescribed by Beus et al. (1991), and will be documented according to standard practices for ground surveying. Benchmark and backsite relationships will be verified on all sites. Data will be transferred to micro-computers and edited in the field before the crew leaves its study site.

Bathymetric surveys of the subaqueous zone (water's edge to the eddy/current interface) will be conducted using state-of-the-art Hydrographics System depthfinder mounted on the raft, with a total station on shore. Sonar-derived topography will be generated with cm-level accuracy from the shore to the eddy/current interface. These data will also be downloaded after completion of the survey, transferred to a microcomputer and checked prior to leaving the site.

Preliminary maps will be made that combine ground and bathymetric surveys to detect anomalous survey points using SOKKIA/LIETZ mapping software. Edited survy data will be modeled using the

triangulated irregular network approach to produce topographic contour maps. For each beach a specific area will be defined as the "hydrologically active zone" (HAZ), the zone affected by fluctuating dam releases. Volumes and areas above a low water elevation (nominally 141.5 cms, as determined through the Beus et al. data) will be calculated within the HAZ. The following analyses will be performed on these data:

1) The percent change rate in volume will be calculated by dividing the volume difference between the present run with the volume of the previous survey (i.e. % vol. change Run X = -100*(vol.W - vol.X)/vol.W). The percent volume change between runs will be divided by the number of Julian days between runs to obtain the % volume change per day values used in the analysis. Five normal and one longitudinal cross sections that correspond to profiles staked during the field survey will be generated from the modeled surface.

2) The percent change rate in HAZ area will be calculated by dividing the area difference between the present run with that of the previous survey (i.e. % area change Run X = -100*(area W - area X)/area W). The percent area change between runs will be divided by the number of Julian days between runs to obtain the % area change per day values used in the analysis. Five normal and one longitudinal cross sections that correspond to profiles staked during the field survey will be generated from the modeled surface.

3) The percent change rate per day of at least 4 selected cross sections on each sand bar. Area beneath selected cross sections will be calculated from modeled surfaces for the hydrologically inactive zone, the upper and lower HAZ, and the bathymetric surface. These data will be analyzed using multivariate analysis of variance against the last pre-interim flow survey run data.

Integration With Other Monitoring Efforts

This project will integrate with several other interim flows monitoring efforts. This project will confirm areal change on sites that overlap with the Kearsley beach area project. This site will provide topographic validation of the sites used for fixed camera analyses and for bank failure/pool storage studies (Cluer). These data will be used to confirm vegetation effects on sand bar stability, using the GCES/NPS GIS. These data are also available for use in validating the USGS sediment transport model.

DELIVERABLES

Quarterly and annual reports will be provided to each of the following entities: the National Park Service at Grand Canyon National Park, Northern Arizona University Cooperative Parks Studies Unit, and the Regional Scientist; the Glen Canyon

Environmental Studies Office and the Senior Scientist. An initial oral report will be provided to the Grand Canyon National Park Resources Management and Planning Division staff. Draft final reports will be submitted for review to Resources Mangement and the Northern Arizona University Cooperative Parks Studies Unit in hard copy and on electronic WordPerfect disk.

PERSONNEL

NAU Staff

Dr. Stanley S. Beus has studied sand bar stability in the Colorado River downstream from Glen Canyon Dam since the early 1980's, participating extensively in GCES-II studies of this subject. Dr. Beus will contribute approximately 20% FTE for this work.

NPS Involvement

Dr. Lawrence E. Stevens coordinated the GCES-II interagency sand bar stability project and has studied the riparian ecology of the Colorado River corridor in Grand Canyon for more than two decades. He is presently employed with GRCA resources Mangement and Planning Division and is an adjunct professor at Northern Arizona University in Flagstaff. This project will require approximately 20% of his time.

This project will require four volunteers per epoch, and the NPS at GRCA will be requested to provide workman's compensation support for these volunteers. In addition, the project will require approximately 10% FTE from a technician for coordination of these volunteers. COTR involvement for this project will amount to approximately 5% FTE. In addition, the NPS may be requested to assist in a limited fashion to permitting and logistics.

Other DOI Involvement

The Bureau of Reclamation GCES Office will be requested to provide the logistics and some equipment for these annual topographic surveying efforts.

SCHEDULE

The following schedule will be followed for this project, and depends on when notification of funding has been received by Northern Arizona University.

ACTIVITY/PRODUCT	DATE
Quarterly report and initial oral presentation to NPS	1 August, 1992
Initiation of analysis of Sept. and Nov. survey data	15 August, 1992
Quarterly Report	1 October, 1992
Annual survey trip	1-20 October, 1992
Annual report	1 January, 1992
Quarterly report	1 April, 1992
Quarterly report	1 July, 1993
Quarterly report	1 October, 1993
Annual survey trip	1-20 October, 1993
Annual report	1 January, 1994
Draft final report	1 March, 1994
Final report	1 ~~June~~ July, 1994

BUDGET

The following budget does not include the cost of logistics, which will be covered and coordinated by the Bureau of Reclamation Glen Canyon Environmental Studies Office in Flagstaff, Arizona. In addition, some equipment may be purchased by the GCES and borrowed for this project. These items are marked with an asterix. This budget does not include NPS staff or travel costs, which are included in the annual NPS administrative budget associated with the GCES Program.

PERSONNEL	FY92	FY93	FY94	TOTAL
P.I.'s -- Beus	$7.0k	$7.0k	$7.0k	$21.0k
-- Stevens (NPS)	---	---	---	---
Survey crews, 1 mo/yr for two crews, 6 persons each (1 surveyor @$12/hr, 1 rodman @$10/hr, 1 sonar operator @$10/hr, 1 survey assistant @$9/hr, 2 volunteers	$0.0k	$17.0k	$17.0k	$34.0k
Data analyst, 6 mo/yr @$12/hr	$13.6k	$13.6k	$13.6k	$40.8k
ERE (10%)	$2.1k	$3.8k	$3.8k	$9.6k
Subtotal	$22.7k	$41.4k	$41.4k	$105.4k
TRAVEL				
Three trips/yr for PI's or survey staff	$2.0k	$2.0k	$2.0k	$6.0k
EQUIPMENT				
Two laptop computers, field and laboratory software	$10.0k	$2.0k	$2.0k	$14.0k
Hydrographics Survey Package* ($50.0k)	$50.0k	$3.0k	$3.0k	$56.0k
Subtotal	$60.0k	$5.0k	$5.0k	$70.0k
SUPPLIES				
Field -- pinflags, tapes, notebooks, prisms, etc.	$3.0k	$3.0k	$2.0k	$8.0k
Office -- typing, xeroxing, reprographics, publication costs	$3.0k	$4.0k	$3.0k	$10.0k
TOTAL DIRECT COSTS	$90.7k	$55.4k	$53.4k	$199.5k
INDIRECT COSTS (20%)	$18.1k	$11.1k	$10.7k	$39.9k
TOTAL COSTS	$108.8k	$66.5k	$64.1k	$239.4k

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Table 1: Sand bar study sites on which topographic survey data will be collected (Beus and Avery 1991). Distance downstream from Lees Ferry, Arizona, after Stevens (1983). Deposit types after Schmidt and Graf (1990): R - reattachment deposit, S - separation deposit, UP - upper pool deposit. Relative recreational use intensity data from interviews with 36 commercial river guides: 1 (no use) to 5 (high use). Reach (0-11) and channel width (W - wide, N - narrow) after Schmidt and Graf (1990).

RIVER MILE/SIDE (RIVER KM)	SITE NAME	DEPOSIT TYPE	REACH/ RELATIVE WIDTH	RELATIVE RECREATIONAL USE INTENSITY
**-6.5R (-10.5)	Hidden Sloughs	R	0 W	Moderate
* 2.6L (4.2)	---	R	1 W	2.4
h 8.0L (12.9)	Lower Jackass Canyon	S/R	1 W	4.2
16.4L (26.4)	Lower Hot Nana	S	2 N	3.5
* 22.0R (35.1)	---	R	2 N	1.6
30.0R (48.3)	---	R	3 N	3.3
31.2R (50.2)	Lower South Canyon	R	3 N	4.5
**43.0L (69.3)	Anasazi Bridge	R/UP	4 W	1.7
* 45.0L (71.6)	Eminence Break	S	4 W	3.6
* 47.0R (75.8)	Lower Saddle Canyon	R	4 W	4.6
50.0R (80.5)	Dino	S	4 W	3.2
* 51.0L (82.9)	---	R	4 W	1.9
* 68.0R (109.6)	Upper Tanner	S/R	5 W	3.0
h*81.1L (130.5)	Upper Grapevine	S/R	6 N	4.5
91.1R (146.6)	Upper Trinity	S	6 N	3.2
93.0L (149.6)	Upper Granite	UP	6 N	4.7
103.9R (167.2)	Upper 104 Mile	UP	6 N	3.1
119.0R (191.5)	---	R	7 N	3.6
122.1R (196.5)	---	R	7 N	3.3
122.8L (197.6)	Upper Forester	R/UP	7 N	3.1
137.0L (220.4)	Middle Ponchos	R	8 N	4.6

Table 1 (cont'd.):

139.0R (223.7)	Upper Fishtail	UP	8	N	2.8
145.0L (223.3)	---	R	9	N	2.5
*172.0L (276.9)	---	R/UP	10	W	2.0
183.5R (295.3)	---	R/UP	10	W	3.4
194.1L (312.3)	---	R/UP	10	W	3.1
202.0R (325.0)	202 Mile	S	10	W	3.4
213.0L (342.7)	Pumpkin Spring	R/UP	10	W	4.0
219.9R (353.8)	Middle 220-Mile	S/UP	11	N	4.5
225.3R (362.5)	---	R/UP	11	N	1.6

* Sites for which QA/QC data have been compiled and analyzed
** Bankstored groundwater/seepage erosion model validation sites
h Sites used in historic analyses of sandbar changes

Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator S.S. Beus and L.E. Stevens Date Submitted 26 Feb., 1992

Department/Laboratory Geology Dept., No. AZ Univ. Organization Nat'l Park Service

Beginning Date 15 August, 1992 Completion Date 15 March, 1994

Project Title The Effects of Interim Flows from Glen Canyon Dam on Sand Bar Stability

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. S.S. Beus			$21.0	$21.0k
2. L.E. Stevens (NPS)			$0.0k	$0.0k
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (10) Other Professional (techs.)			$74.8k	$74.8k
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. (1) Secretarial/Clerical				$5.0k
6. ( ) Other				
C. FRINGE BENEFITS				$9.6k
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000 2 Laptop computers w/ software				$10.0k
2. Items > $10,000 Hydrographics + accessories				$56.0k
E. TRAVEL				
1. Domestic				
a. Principals				$6.0k
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	$2.5k
b. Other	$8.0k
2. Publication Costs	$2.5k
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	$199.5k
I. INDIRECT COSTS	$39.9k
J. TOTAL DIRECT AND INDIRECT COSTS	$239.4k
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	$239.9k

Itemize Capital Equipment to be Purchased in FY 92

Description of Items > $1,000 < $10,000	Cost*
1. Two laptop computers with Leitz SDR or comparable software	$10.0k
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1. Hydrographics depthfinder and accessories	$56.0k
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

A3

MONITORING SAND BAR STABILITY DURING INTERIM FLOWS: A SEEPAGE EROSION MODELLING APPROACH

by

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A proposal submitted to GCES

February 27, 1991

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MONITORING SAND BAR STABILITY DURING INTERIM FLOWS: A SEEPAGE EROSION MODELLING APPROACH

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ABSTRACT

Extensive investigations of three instrumented sites reveal that seepage driven erosion is the primary mechanism of erosion in the Colorado River downstream of the Glen Canyon Dam. A large amount of data was collected during Phase II of the GCES program. A preliminary model ,developed as part of this program, was used to establish interim flow criteria. This model utilized the ground water, topographic surveys, geotechnical and photographic data to predict seepage erosion from fluctuating flows. The model was calibrated using only a limited set of processed data . More processed data is now becoming available for further calibration and refinement.

It is proposed in this research that the model be calibrated and refined using the additional data collected during Phase II of the GCES program. The model will then be used to make predictions of erosion for the three interim flows, monthly discharge regimes and the annual effects of the interim flows.. Comparison between predictions of the model and the measured erosion from the instrumented sand bars during the interim period, research and normal flow regimes will be conducted. This comparison will enable us to determine a set of dam discharge regimes, within the physical limits of the Glen Canyon Dam, that will decelerate the erosion of sand bars. The model will help us to understand the mechanics and the physical processes involved in fluctuating flows and the effectiveness of the countermeasures adopted under the interim flow program.

MONITORING SAND BAR STABILITY DURING INTERIM FLOWS: A SEEPAGE EROSION MODELLING APPROACH

by

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Objective

The objective of this proposal is to assess the consequences of the interim flows on sand bar stability using the preliminary seepage erosion model developed in Phase II of the GCES program.

Objective Statement

A mathematical model [1] was developed during Phase II of the GCES program. This model was used to interpret some of the data gathered at the three instrumented sand bars during the 'research flows' of Phase II of the GCES program. Results from the model established some key information regarding the operation of the Glen Canyon Dam and the erosion of the sand bars. Some of the findings include:

(1) mass wasting was found to be relatively insensitive to up ramping rates but strongly influenced by down ramping rates of dam discharge. High down ramping rates (greater than about 1500 cfs/hr) tend to accelerate sand bar instability.

(2) there is a dynamic equilibrium slope beyond which mass wasting will be negligible.

(3) the mass of beach deposits between the dynamic equilibrium slope and the maximum slope angle (angle of repose of the material) will be in a state of flux in which cycles of erosion and aggregation will occur depending on the dam discharge regime.

The findings above were made using only a limited set of field data - ground water, topographic surveys, and time lapsed photography - although a large body of valuable data was collected. However, this large body of data is still being processed. There are several questions concerning the validity of the preliminary findings of the model which need to be examined as more data become available from Phase II of

the GCES program. Some of these questions are:

(1) What dam discharge regimes are conducive to (a) sand bar aggregation and (b) sand bar erosion?

(2) What range of fluctuation, up ramping rates, down ramping rates and duration of minimum flow will minimize seepage driven erosion?

(3) Are the interim flows the best alternatives compared to the research and normal flows?

(4) Is the dynamic equilibrium slope hypothesis [1] valid for most of the sand bars? If it is, then it is possible that only minimal dam operation changes may be required to periodically rebuild eroded sand bars.

This research will provide answers to these vital questions.

JUSTIFICATION OF OBJECTIVE

The present study conducted by GCES utilizes the Colorado River downstream of the Glen Canyon Dam as a huge flume. The expense and manpower involved in monitoring this flume is substantial, though necessary. Several studies are proposed to document changes in the topography, hydraulic and ground water conditions in the sand bars during the interim flows. The data collected must be analyzed to provide an insight into the erosion process and the effectiveness of the interim flows. **The preliminary model developed in Phase II of the GCES program is, perhaps, the only tool that can synthesized the data to be collected from the interim flows. The success of the preliminary model was demonstrated by providing the necessary information (during Phase II of the GCES program) to establish the interim flows.** Thus, it is necessary to use the model to evaluate the effectiveness of the interim flows in reducing erosion. If the interim flows do not provide satisfactory sand bar stability, the model can then be used to determine a flow regime, within the physical capabilities of the dam, to retard erosion rates.

Background Information and Existing Data

The results from three sand bars, instrumented and monitored during Phase II of the GCES program [2], showed that seepage is most ubiquitous mechanism of the three interacting erosion mechanisms -seepage, traction and waves. Seepage driven erosion occurs as artesian sapping, spring sapping, rilling, tunnel scour, rivulets and mass wasting. The latter is by far the most destructive sand bar erosion process downstream of the Glen Canyon Dam.

A large body of data was accumulated from the three instrumented sites and

other sand bars during Phase II of the GCES program [2]. This data comes from topographic surveys, ground water data (including tilts and temperature), hydraulic data and time lapsed photography. Only a relatively small amount of this data has been processed (January, 1992). The model, however, requires the processed rather than the raw data for validation, calibration and refinement. It is expected that these processed data will be available shortly and certainly within the period of the interim flows. Based on the limited available processed data, the model was found [1] to play an important role in predicting erosion rates for possible alternative dam discharge regimes.

Methods

The finite element model developed by the writer [1] during Phase II of the GCES program is capable of analyzing seepage erosion, mass wasting (slope instability), deformations, stress changes and ground water variations due to river stage fluctuations either from natural occurrence or by, in this case, fluctuating dam discharge. The model can be used to forecast the erosion potential, especially mass wasting, of certain dam discharge regimes.

It is envisaged that ground water data, topographic surveys and other documentation (for examples, photography, visual examinations) made during Phase II of the GCES program will be continued for at least the three instrumented sand bars., during the interim flow period. River stage variations and the geotechnical properties of the bar deposits will be used as input data to the model.

In the initial stages of this research, the processed data from Phase II of the GCES program will be used to calibrate and refine the model. Predictions of erosion will then be made for the interim flow. A comparison will be conducted between the predictions of the model and the topographic surveys. If the interim flow induced sand bar erosion that is unsatisfactory, alternative flow regimes will be used in the model. The alternative flow regimes which will be selected for investigations will be based on the experience gained from the research and normal flows. In this way, the model provides a unique link between the Phase II GCES program and the interim flow period.

Integration with other efforts

This research will serve as the core to analyze and synthesize the data gathered from topographic surveys, ground water data (river stage data, if ground water data is unavailable) and photographic evidences. The model will use these data to facilitate a rational interpretation of the patterns and the extent of erosion due to the interim flows. It relates directly to the GCES/NPS objective of determining the potential for seepage driven erosion in the thirteen reaches.

Products to be Developed

The deliverables of this research are as follows.

(1) A refined model which is capable of predicting seepage driven erosion for different dam discharge regimes.

(2) An evaluation of the model prediction of erosion for the interim flows, research flows and normal flows with data collected during Phase II of the GCES program and during the interim flow period.

(3) Insight into vital questions regarding dam discharge rates, minimum and maximum flows, tolerable fluctuation zone of maximum and minimum flows, dynamic equilibrium slopes, magnitude and duration of minimum flows.

TIME TABLE

	1992										1993												1994		
	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Calibration and Refinement of Model Using Phase II GCES Data																									
Assessment of Erosion from Interim Flow Data																									
Assessment of Possible Dam Discharge Alternatives (if necessary)																									
Quarterly Report				↓			↓			↓			↓			↓			↓						
Draft Final Report																									
Final Report																									

↓ Quarterly Report Submitted At The End Of The Month Shown

Reference

[1] Budhu, M. (1991). Mechanisms of Erosion and a Model to Predict Seepage-Driven Erosion Due to Transient Flow. Chapter 6, in Beus, S.S. and Avery, C.C., eds., The Influence of Variable Discharge Regimes on Colorado River Sand Bars Below Glen Canyon Dam: 1991 Annual Report.

[2] Beus, S.S. and Avery, C.C. , eds. (1991). The Influence of Variable Discharge Regimes on Colorado River Sand Bars Below Glen Canyon Dam: 1991 Annual Report.

Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Dr. Muniram Budhu Date Submitted 2/27/92

Department/Laboratory Civil Engineering Organization University of Arizona

Beginning Date 4/1/92 Completion Date 9/30/92

Project Title Monitoring sand bar instability during interim flows: A seepage modelling approach.

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. M. Budhu			3.0*	$ 20,275
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (1) Other Professional (techs.)	.50			1,038
3. (1) Graduate Students		3.3	3.0	15,294
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				4,293
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	1,000
a. Telephone	
b. Other	
2. Publication Costs	1,000
3. Consultant Services	
4. Computer Services	1,000
5. Subcontracts	
6. Other Communication	400
H. TOTAL DIRECT COSTS (A through G)	44,300
I. INDIRECT COSTS 10.0%	4,430
J. TOTAL DIRECT AND INDIRECT COSTS	48,730
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	48,730

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Dr. Muniram Budhu Date Submitted 2/27/92

Department/Laboratory Civil Engineering Organization University of Arizona

Beginning Date 10/1/92 Completion Date 9/30/93

Project Title Monitoring sand bar instability during interim flows: A seepage modelling approach.

Budget Estimate

	Person/Mos Cal	Acad	Sum	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. M. Budhu			3.0	$ 21,289
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (1) Other Professional (techs.)	.50			1,089
3. (1) Graduate Students		5.5	2.0	21,083
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				4,584
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	2,000
a. Telephone	
b. Other	
2. Publication Costs	1,000
3. Consultant Services	
4. Computer Services	1,500
5. Subcontracts	
6. Other Communications	400
H. TOTAL DIRECT COSTS (A through G)	52,945
I. INDIRECT COSTS 10.0%	5,295
J. TOTAL DIRECT AND INDIRECT COSTS	58,240
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	58,240-

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Dr. Muniram Budhu Date Submitted 2/27/92

Department/Laboratory Civil Engineering Organization University of Arizona

Beginning Date 10/1/93 Completion Date 4/31/94

Project Title Monitoring sand bar instability during interim flows: A seepage modelling approach.

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. M. Budhu		1.0		$ 6,981
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (1) Other Professional (techs.)	.25			572
3. (1) Graduate Students		3.3		10,239
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				1,601
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	1,000
a. Telephone	
b. Other	
2. Publication Costs	1,000
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other Communications	400
H. TOTAL DIRECT COSTS (A through G)	21,793
I. INDIRECT COSTS 10.0%	2,179
J. TOTAL DIRECT AND INDIRECT COSTS	23,972
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	23,972-

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

PROPOSED BUDGET - NAU
04/01/92 - 09/30/92
Year 1

Direct Labor		
M. Budhu, Principal Investigator		
3.0 Months Summer		$ 20,275
Graduate Research Assistant II		
33.0% Academic Year		9,287
2.0 Months Summer		6,007
Technician		
4.0% Fiscal Year		1,038
	Total Direct Labor	36,607
Employee Related Expenses		
18.9% Faculty		$ 3,832
22.4% Staff		232
1.5% Student		229
	Total ERE	$ 4,293
Operations		
Expendable Supplies		$ 1,000
Computer		1,000
Publications		1,000
Communications		400
	Total Operations	$ 3,400
	Total Direct Costs	$ 44,300
Indirect Costs		
10.0%	Total Indirect Costs	$ 4,430
	Total Direct and Indirect Costs Year 1	**$ 48,730**
	Total Budget Year 1	**$ 48,730**

PROPOSED BUDGET - NAU
10/01/92 - 09/30/93
Year 2

Direct Labor		
M. Budhu, Principal Investigator		
3.0 Months Summer		$ 21,289
Graduate Research Assistant II		
50.0% Academic Year		14,775
2.0 Months Summer		6,308
Technician		
4.0% Fiscal Year		1,089
	Total Direct Labor	$ 43,461
Employee Related Expenses		
18.9% Faculty		$ 4,024
22.4% Staff		244
1.5% Student		316
	Total ERE	$ 4,584
Operations		
Expendable Supplies		$ 2,000
Computer		1,500
Publications		1,000
Communications		400
	Total Operations	$ 4,900
	Total Direct Costs	$ 52,945
Indirect Costs		
10.0%	Total Indirect Costs	$ 5,295
	Total Direct and Indirect Costs Year 2	**$ 58,240**
	Total Budget Year 2	**$ 58,240**

PROPOSED BUDGET - NAU
10/01/93 - 04/31/94
Year 3

Direct Labor		
M. Budhu, Principal Investigator 10.0% Academic Year		$ 6,981
Graduate Research Assistant II 33.0% Academic Year		10,239
Technician 2.0% Fiscal Year		572
	Total Direct Labor	$ 17,792
Employee Related Expenses		
18.9% Faculty		$ 1,319
22.4% Staff		128
1.5% Student		154
	Total ERE	$ 1,601
Operations		
Computer		$ 1,000
Publications		1,000
Communications		400
	Total Operations	$ 2,400
	Total Direct Costs	$ 52,945
Indirect Costs		
10.0%	Total Indirect Costs	$ 2,179
	Total Direct and Indirect Costs Year 3	**$ 23,972**
	Total Budget Year 3	**$ 23,972**
	TOTAL THREE-YEAR PROPOSED BUDGET	**$130,942**

MONITORING AND MODELING SEEPAGE-INDUCED EROSION AND DEFORMATION OF SAND BARS ALONG THE COLORADO RIVER IN GRAND CANYON DURING THE INTERIM FLOW PERIOD

A. ABSTRACT:

Seepage forces were identified in the program development stage of GCES II as an important erosion process of fluvial deposits along the Colorado River in Glen and Grand Canyons. Intensive studies at three sand bars during the test flow period proved the relation between river-stage fluctuation and seepage force development, and documented some of the effects of seepage. A mathematical model was used to define the mechanics of seepage-driven erosion and interpret the data collected at these sand bars. This model offered a comprehensive interpretation of seepage-driven erosion, mass wasting, and deformation. Instrumentation of a wide variety of additional sites is needed to characterize the full range and extent of seepage-induced erosion and deformation processes acting on other types of deposits.

It is proposed that the three instrumented sites be refurbished and maintained through the interim flow period. Additionally, it is proposed that 15 additional sites be instrumented with a small number of pressure, tilt, and temperature sensors in order to monitor the resource protection prescription on a larger sample of deposits. Further calibration of the mathematical model is necessary so that forecasts can be made with confidence.

B. OBJECTIVES:

An objective of the reduced daily range and ramping rate restrictions in the interim flow prescription was to reduce the effects of seepage erosion of fluvial-sediment deposits in Glen and Grand Canyons. The objective of this study is to determine if the interim flow prescription achieved the resource objective. The main approach will be to expand on a successful pilot program developed during the test flow period that measured seepage induced stress and consequent strain and compare seepage and its effects during the interim flow period to seepage and its effects measured during the test flow period. These results will be used to further refine the mathematical model, which will be used to predict effects for different flow regimes.

C. JUSTIFICATION:

1. Seepage erosion probably occurs on every sand bar along the Colorado River in the Grand Canyon and may be the most manageable of all processes affecting sand bars.
2. Seepage effects will accrue between sand-bar-building flows, if such flows are prescribed, and will continue to accrue on bars that are not rebuilt by such prescribed flows.
3. Seepage effects have been shown to be transporters of sand-bar materials through processes as subtle as rilling of surficial deposits and slumping, to catastrophic mass wasting of large parts of entire sand bars.
4. The three sand bars instrumented during the test flow period served admirably, but the sites are now in need of repair due to bank collapse and consequential minor sensor failures.

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5. Results from the three instrumented sites indicate that stratigraphy and topography as well as hydraulic setting affect rates of erosion and deformation. Thus, a larger variety of sand bars is needed to characterize seepage effects associated with interim fluctuating flows.

6. The model, used to interpret the data, showed excellent promise but further good-quality data are needed for calibration and refinement.

D. BACKGROUND INFORMATION AND EXISTING DATA:

Seepage forces are generated when the water level within a channel margin deposit is higher than the level of the river. This occurs on a daily basis with every flow fluctuation from Glen Canyon Dam. It also occurs on every fluvial deposit within Glen and Grand Canyons. Seepage forces were identified in the design period of GCES II as an important erosion process acting on sand bars along the Colorado River (GCES Phase II Draft I, Ft. Collins, at one site above Lees Ferry, with follow-up elaborate instrumentation of three sites by USGS-WRD, Tucson.

Three sites selected for study during the test flow period were -6.5 mile, a reattachment bar with relatively high permeability and a confining unit that dips away from the river; 43 mile, an upper pool deposit with high permeability and homogeneous stratigraphy; and 172 mile, a reattachment bar with complex stratigraphy and low permeability on the face of the sand bar. These contrasting deposit types gave a wide range of results from seepage force studies. Sensors used at each site included water-pressure sensors at various depths and positions normal to the river, tilt sensors in the face of the deposits, and temperature sensors at each tilt and pressure sensor. Pressure and temperature sensors were also installed to monitor river stage. Preliminary data from the test flow period include residual head, lag times, and tilt and temperature fluctuations associated with fluctuating river stage and water levels in the sand bars. Very high correlation exists between falling river stage and tilting within deposits, proving the connection between seepage forces and mass wasting processes.

E. METHODS:

The three instrumented sites will be refurbished to monitor the interim flow prescription and serve as baseline data sites for monitoring additional sites. A wide variety of additional sites will be instrumented with a modest array of sensors. Supplementary sites will be selected to fulfill data needs in wide versus narrow reaches, upper pool versus lower pool settings, reattachment verses separation deposits, large deposits versus small deposits, and for various stratigraphies. Fifteen additional deposits will satisfy these requirements. A team of recognized experts will be assembled to develop final site-selection criteria and suggest sites that meet those criteria.

Each site will be instrumented with proven sensors and logging equipment. Four ground-water pressure and temperature sensors, four tilt sensors, and two stage sensors with temperature sensors for calibration will be installed at each site. Automatic data-logging computers will control all instrumentation. Data will be downloaded biannually with calibration checks and maintenance of sensors and batteries.

The mathematical model will be used as an aid to determine the type, quantity, and the placement of the instrumentation. Tests will be conducted at the Geotechnical Laboratory at the University

of Arizona to characterize the soil at the selected sites. Such tests will include the shear strength and grain sizes of the various deposits. Based on the geotechnical properties of the soil and the geological setting, the model will be used to predict the occurrence and amount of seepage erosion and mass wasting. The data collected from the instrumentation will then be used to calibrate and refine the model.

F. INTEGRATION WITH OTHER MONITORING EFFORTS:

This project integrates with the daily terrestrial photogrammetry project,which will provide mass-wasting area and location data, and sand bar surveying efforts (Beus and Avery-. NAU). This project will also provide basic data for use in the mass-wasting study (Cluer-NPS).

G. PRODUCTS TO BE DEVELOPED:

This study will provide the critical elements of timing and hydraulic conditions associated with seepage-erosion processes operating during interim flows. Specific products include continuous tilt records, ground-water-head and temperature records, and river-stage and temperature records. Analyses will include monthly time-series plots of ground-water pressure head, river stage, ground-water temperature, river temperature, and sand-bar tilt. Combined plots will include associations where applicable. Further analyses will include stress-strain plots, which are derived from pressure and tilt data.and variably saturated, ground-water flow, and stress-strain models. The goal of this investigation is to develop a predictive model of beach deformation for any dam release. Interpretation and modeling of the data will be a combined effort by the USGS, NPS, and UA. Two presentations for the fall 92 AGU meeting, a "Report" in Science, and an article in Water Resources Research are planned as well as a comprehensive completion report.

H. TIME TABLE:

TASK	DATE
Go ahead, permission to allocate resources of personnel and supplies	March 1, 1992
Supplies procurement (sensors, wire, fittings)	March 15, 1992
(data loggers, storage modules, etc.)	April 15, 1992
Instrument buildup	April 25, 1992
Insrument calibration	May 10, 1992
Site refurbishing,instrument 3 additional sites	May 30, 1992
Site instrumentation trip	June 30, 1992
Downloading and recalibration I	November 30, 1992
Annual report	December 31, 1992
Downloading and recalibration II	May 30, 1993
Downloading and recalibration III	November 30, 1993
Draft final report,	
Annual report	December 31, 1993
Final report	March 31, 1994

I. BUDGET (ATTACHED):

Costs include both fiscal years 1992 and 1993. Fiscal year 1992 costs are $143,600 or 34 percent of the total costs of $422,300.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigators M.C. Carpenter Date Submitted 2/26/92

Department/Laboratory WRD Arizona District Organization USGS

Beginning Date 3/1/92 Completion Date 9/30/93

Project Title Monitoring and modeling seepage-induced erosion and deformation of sand bars along the Colorado River in Grand Canyon during the interim flow period

Budget Estimate

	Person/Mos Cal	Acad	Sumr	Total Amount
A. SENIOR PERSONNEL				$ 142,800
1. M.C. Carpenter	18			(74,200)
2. R.J. Carruth	18			(54,000)
3. S.A. Leake	3			(14,600)
B. OTHER PERSONNEL				37,900
1. ( ) Post Doctoral Associates				
2. (X) Other Professional (techs.)	7.7			(27,000)
3. ( ) Graduate Students				
4. ( ) Undergraduate Students	9			(10,900)
5. ( ) Secretarial/Clerical Included in Indirect Costs(I)				------
6. ( ) Other				
C. FRINGE BENEFITS Included in Salaries A1,2,3, and B2,4				------
D. PERMANENT EQUIPMENT All in NPS budget				0
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				14,300
1. Domestic				
a. Principals				(8,300)
b. Others				(6,000)
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel Included in Travel E1a,b				------
3. Subsistence Included in Travel E1a,b				------
4. Other				

G. OTHER DIRECT COSTS	$ 22,500
1. Materials and Supplies	(15,000)
a. Telephone Included in Indirect Costs (I)	------
b. Other	
2. Publication Costs	(7,500)
3. Consultant Services Included in Indirect Costs (I)	------
4. Computer Services Included in Indirect Costs (I)	------
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	217,500
I. INDIRECT COSTS	204,800
J. TOTAL DIRECT AND INDIRECT COSTS	422,300
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	0
L. TOTAL PROJECT AMOUNT (J + K)	$ 422,300

Itemize Capital Equipment to be Purchased in FY____

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight Charges

A5

A PROPOSAL TO MONITOR SAND BAR STABILITY ON A DAILY TIME SCALE DURING THE INTERIM FLOWS USING TERRESTRIAL PHOTOGRAMMETRY

Brian L. Cluer
Grand Canyon National Park
Resource Management Division
Flagstaff, AZ 86002
(602) 556-7363 comm
765-7363 FTS
extension 7368 FAX

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STUDIES OFFICE

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FLAGSTAFF, AZ

A PROPOSAL TO MONITOR SAND BAR STABILITY ON A DAILY TIME SCALE USING TERRESTRIAL PHOTOGRAMMETRY

Brian L. Cluer
Grand Canyon National Park
Resource Management Division

ABSTRACT

During the test flow period a technique was developed to obtain area measurements of sand bars from inexpensive fixed camera photographs. That technique has recently been enhanced by incorporating computer digitizing equipment that allows for image rectification. It was shown during the test flow program and the early part of the interim flow period that deposits change size and morphology sometimes daily in response to hydraulic interactions between the river and bank-stored water. Rapid degradation and aggradation were both documented.

It is proposed that 33 additional automatic cameras be installed overlooking select fluvial deposits for a total of 36. With the ability to capture daily photography on a large number of sand bars during the interim flow period, a comprehensive evaluation of interim flow effects can be produced. Those effects will be compared to effects documented during the test flow and pre-test flow periods by various investigators.

OBJECTIVE STATEMENT

An objective of the interim flow criteria was to reduce erosion of fluvial deposits by reducing daily river stage fluctuations and ramping rates. The objective of this study is to determine if fluvial deposits have been stabilized by the interim flow prescription. The main approach will be to compare fluvial deposit physical stability characteristics during the interim flow period to deposit dynamics observed during the test flow and pre-test flow periods.

JUSTIFICATIONS

The physical characteristics of fluvial deposits along the Colorado River below Glen Canyon Dam have been considered to be indicators of sediment transport in the system as a whole and in specific reaches. Various techniques and equipment have been used for studies asking questions at different time scales. Land surveys have ranged from periodic annual surficial cross sections (Howard and Dolan, 1981; others) to biweekly full coverage three dimensional topography (Beus et al., 1991). Photo surveys range from centennial photo matching (Webb, in press) to daily photography (Cluer, 1991). The natural variability of fluvial deposit physical character is intrinsically linked to hydraulic activity and sediment supply.

Investigations during GCES Phase II revealed that sand bars change dramatically on various time scales. Schmidt (1991) illustrated long-term changes in sand bars relating to flood flows in the early 1980's and the ensuing degradation characteristics. On the short-term, Beus et al (1991) showed variability in sand bar area and volume for periods as short as two-weeks during the test flows that exceeded the long-term change rates, even those immediately following the 1980's floods. Cluer (1991) discovered and illustrated daily time scale changes that exceed all prior measures of sand bar variability.

The GCES Phase II sand bar stability team conclusions that sand bar size was found to be much more variable and responsive to specific dam releases than previously thought. These investigators also concluded that widely fluctuating flows cause bank-water seepage to destabilize and erode sand deposits with every fluctuation, daily (Beus et al, chapter 9, 1991). During the test flow program, degradation was often controlled by short-term events of mass wasting with sometimes catastrophic proportion. Aggradation generally followed degradation events, but at rates and locations specific to the ensuing flow characteristics. These findings were used to help justify the interim flow prescription.

This proposal describes a method of monitoring sand bar area on the daily time scale during the interim flow period. From a short-term data base, changes in sand bar area and geomorphic

characteristics can be determined on several time scales; daily, monthly, seasonally, and annually.

BACKGROUND INFORMATION AND EXISTING DATA

Daily photography proved to be both effective and inexpensive in monitoring sand bar dynamics during the test flow period (Cluer, 1991). Fixed cameras were used to resolve questions regarding very-short-term erosion rates, duration, and relationships with respect to discharge dynamics. On August 8, 1990, two automatic cameras were placed on a ledge overlooking the sand bar at River Mile (RM) 68 right. The cameras were programmed to expose and advance the film every 8 hours until 36 images were taken. The film was retrieved and processed two weeks later and the cameras were reloaded. Images from September 6, 1990 show that a large scour hole developed in the central portion of the deposit in the past 24 hours. By September 19 the scour hole had refilled, but on September 20 the downstream vegetated portion of the deposit slumped into the river channel. Encouraged by the initial results and the potential information that daily photographs might contribute to understanding short-term sand bar dynamics, preparations were made to install additional cameras.

During November and December 1990, five additional cameras were installed. The camera stations were: 1) RM 43L, an upper pool reattachment bar deposit, 2) RM 51L, a reattachment bar deposit, 3) RM 68R, a separation and reattachment bar complex, 4) RM 172L, a reattachment bar channel margin deposit, 5) RM 211L, a reattachment bar channel margin complex, and 6) RM 216R, a reattachment bar channel margin deposit. A seventh camera was installed in June 1991 at RM 81L, Grapevine camp, to monitor that dynamic reattachment bar channel margin deposit.

After the test releases ended in July 1991, when a large database of photographs had been assembled, measurements were taken from the images using a scaled magnifying loupe. Multiple cross sections were repeatedly measured by beginning each at a prominent point evident in each daily photograph. Thus the area of sand bars was measured between test flows, during each evaluation period, at constant discharge of 142 cubic meters per second (m^3/s). Daily area during test flows was then estimated based on the bracketing measurements. In most cases, daily stage can be estimated from rocks on the river bank (to about 10cm) based on water levels photographed during constant flow periods, and used to adjust deposit area measurements and estimates when discharge was not at 142 m^3/s. The units used in measuring the deposit cross sections were constant to the scaling devise, but not calibrated to actual site scale. However, since each area measurement was normalized to a percentage of the original measured area (100%), the scale units cancel as constants.

Existing data consists of daily area plots for seven sand bars in Grand Canyon for up to one year during the test flow period.

Examples of daily sand bar area are included (Fig. 1) to illustrate the type of analyses possible from daily photography in the Grand Canyon.

METHODS

Camera Installation

Additional fixed automatic cameras will be installed overlooking sand bars in Glen and Grand Canyons. The proven equipment and techniques developed during the test flow period will be relied upon. The cameras used will be Pentax 105's, housed in environmental containers. The view of each camera will be adjusted to include the area of most interest.

It is important that each camera be located in discrete settings, avoiding archaeological sites and other sensitive areas except where cooperating with other resource management specialists on those issues. The camera containers will be semi-permanently fixed to rock outcroppings using clear silicone glue. This glue has been chosen for its known inert qualities, easy removal, and durability in harsh environments. The cameras will be hidden, however no attempt will be made to anchor them. A training and education program will be presented to the professional Colorado river guide organization to encourage their cooperation.

Image Control

After the first photographs are retrieved, a survey expedition will be conducted to define the field of view and provide scaling information so that deposit areas can be scaled to real-world values.

Photographic Data Analysis

Color transparency film will record a wide variety of daily information, including local river stage, area of deposit exposed at low stage, manifestation of dominant erosion processes (ie. rills or tunnel scour and height of seepage zone, current ripples, planar scour surfaces, cut-bank inception and migration) zones of inundation, relative moisture content of surface materials, seasonal vegetation trends, relative turbidity of river, local weather conditions, and recreational use patterns. Databacks stamp the date on each image, and log books will be used to record the time each roll of film was replaced and exposure interval began. The film will be commercially processed and unmounted. Only the images to be measured will be mounted in slide mounts, by the analyst. All images will be catalogued and stored in archival containers. A fire safe should be considered for long-term storage of these images. Original images will not be released to anyone, however duplicating services and printing

may be specially arranged.

Measurements will be taken from images using one of two techniques developed during the test flow period. First, a scaled magnifying loupe served well during the test flow period to measure cross sections beginning each at a prominent point evident in each daily photograph. Secondly, a technique has been recently developed that uses a computer system to digitally trace deposit area and rectify oblique images. This technique promises to produce sand bar area values that will be directly comparable to values obtained by other investigations using vertical photography and land surveying.

The area of sand bars was measured during each evaluation period, at constant discharge of 142 cubic meters per second (m^3/s) during the test flows. Daily area during test flows was then estimated based on the bracketing measurements. Periodic flows at or near 142 m^3/s are desired for measuring deposit area during the interim flow period for continuity of area. Although the interim flows have higher average daily lows, the first four month's hydrograph records indicate that there will be opportunities to capture images at low flows about twice monthly. Those images will allow physical measurements of deposit area. Almost daily, cut bank locations will be checked. The remaining daily images will supplement those physically measured to develop daily area plots. Film will need to be replaced every 35 days. Cleaning and periodic maintenance will be part to the film changing routine.

An example of time-series area plots from the test flow period (Fig. 1) shows how sand bar area on a daily interval can facilitate evaluation of changes for various time scales or for differing flow periods. Interim flows will be plotted on a per month basis to determine the effects of adjustments to releases on that time scale.

Site Selection

Recognized experts on sediment stability along the Colorado River have been consulted in developing site selection criteria and choosing sites for camera installation. An overriding criteria is low river level during daylight hours. Presently, it seems apparent that by clustering cameras, the most information may be gained about stability within specific geomorphic settings. Sites have been chosen that represent historic study sites, test flow study sites, and sites where questions about tributary inputs and channel storage have been raised.

INTEGRATION WITH OTHER MONITORING EFFORTS

The results of this project will be compared with aerial surveys (Cluer-NPS) and land surveys (Beus and Avery-NAU) to insure

calibration of the digital rectification process at every coincident opportunity. Daily deposit dynamics are integral to the mass wasting project (Cluer-NPS), the seepage processes project (Carpenter et al.-USGS), and the seepage force modelling effort (Budhu-UofA). Additionally, the campsite monitoring project (Kearsley-NPS) is anticipating the use of certain images as is the vegetation study (Ayers-NAU). There will undoubtedly be overlap between some sand bar sites and archaeological sites that will be similarly instrumented (Balsom-NPS). In those cases, images will be shared freely for the benefit of both studies.

PRODUCTS TO BE DEVELOPED

The products from this investigation include: time-series plots of deposit area for 36 sites; perimeter plots for every low flow image; comparison plots of contiguous analyses showing aggradation and degradation areas; and catalogues and descriptions of mass wasting events. Analyses of the data will include comparisons of time-series area measurements for effects of: reach width and depth; tributary sediment inputs; seasonality; and hydraulic parameters of dam operations.

Sand bar stability will be compared with previous investigations of sediment stability conducted during the test flow and pre-test periods. The ultimate product of this investigation will be peer-reviewed journal articles on deposit dynamics and dam operations.

A video tape will be produced of the daily images to depict annual-term changes in an animated visual and narrated fashion. The tape can be widely distributed.

TIMETABLE

TASK	COMPLETION DATE
Procure cameras, containers, select sites	June 15, 1992
Install cameras	June 30, 1992
Replace film I	August 5, 1992
Replace film II	September 10, 1992
Quarterly report	September 30, 1992
Replace film III Survey locations and scale development	October 15, 1992
Replace film IV	November 20, 1992
Replace film V	December 15, 1992
Annual Report	December 31, 1992
Replace film VI	January 20, 1993
Replace film VII	February 25, 1993
Replace film VIII	March 30, 1993
Quarterly report	March 31, 1993
Replace film IX	June 10, 1993
Quarterly report	June 30, 1993
Replace film X	July 15, 1993
Replace film XI	August 20, 1993
Replace film XII	September 25, 1993
Quarterly report	September 30, 1993
Replace film XIII	October 30, 1993
Replace film XIV	December 5, 1993
Annual report and draft final	December 31, 1993
Retrieve film XV, retrieve cameras	January 10, 1993
Final report	March 31, 1994

BUDGET	YEAR 1	YEAR 2	YEAR 3
NPS Physical Scientist salary not included seperately			
Dedicated personnel			
photo analyst full time (includes benefits)	10,000	20,000	5,000
surveyor, two months	4,000	-0-	-0-
downloader 1/4 time	3,000	5,000	1,000
Other personnel			
general office support	1,000	1,000	500
Travel (PI)	-0-	-0-	1,000
Special services			
slide duplication	500	500	500
printing	500	500	500
video production	-0-	5,000	5,000
Publication costs			
photo printing	-0-	1,000	1,000
manuscript prep	-0-	-0-	1,000
TOTALS	$19,000	$33,000	$15,500
GRAND TOTAL		$67,500	

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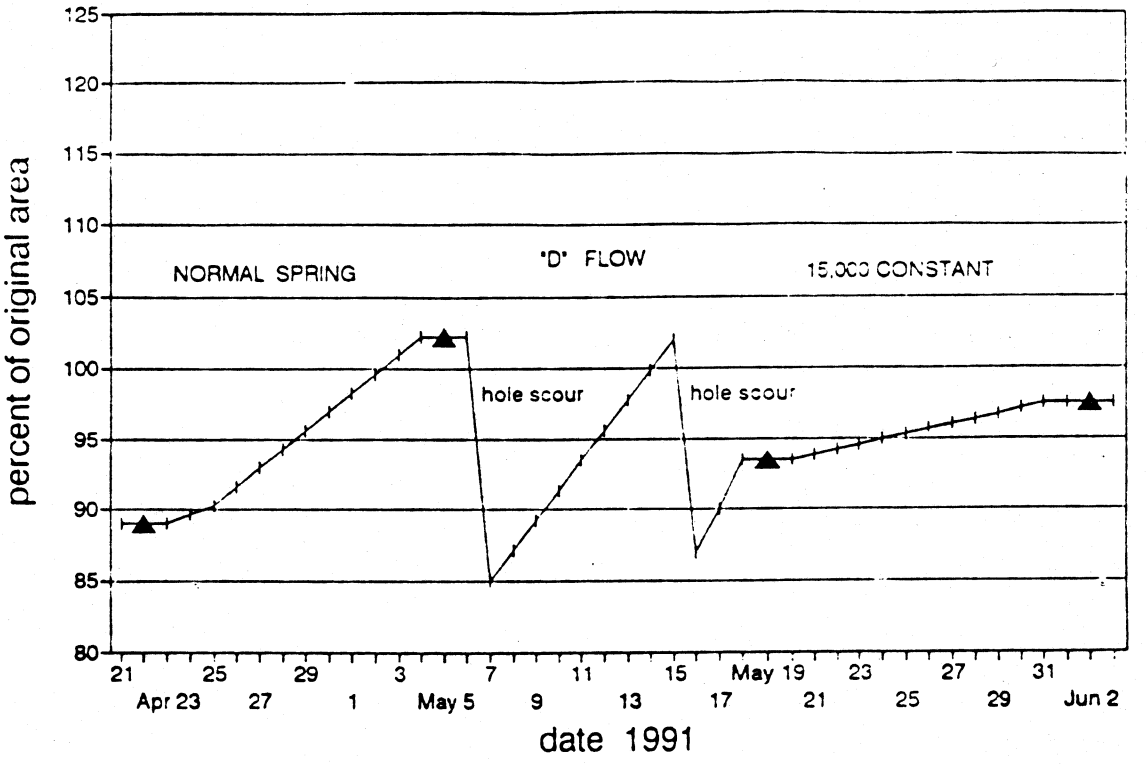
SITE 68 RIGHT



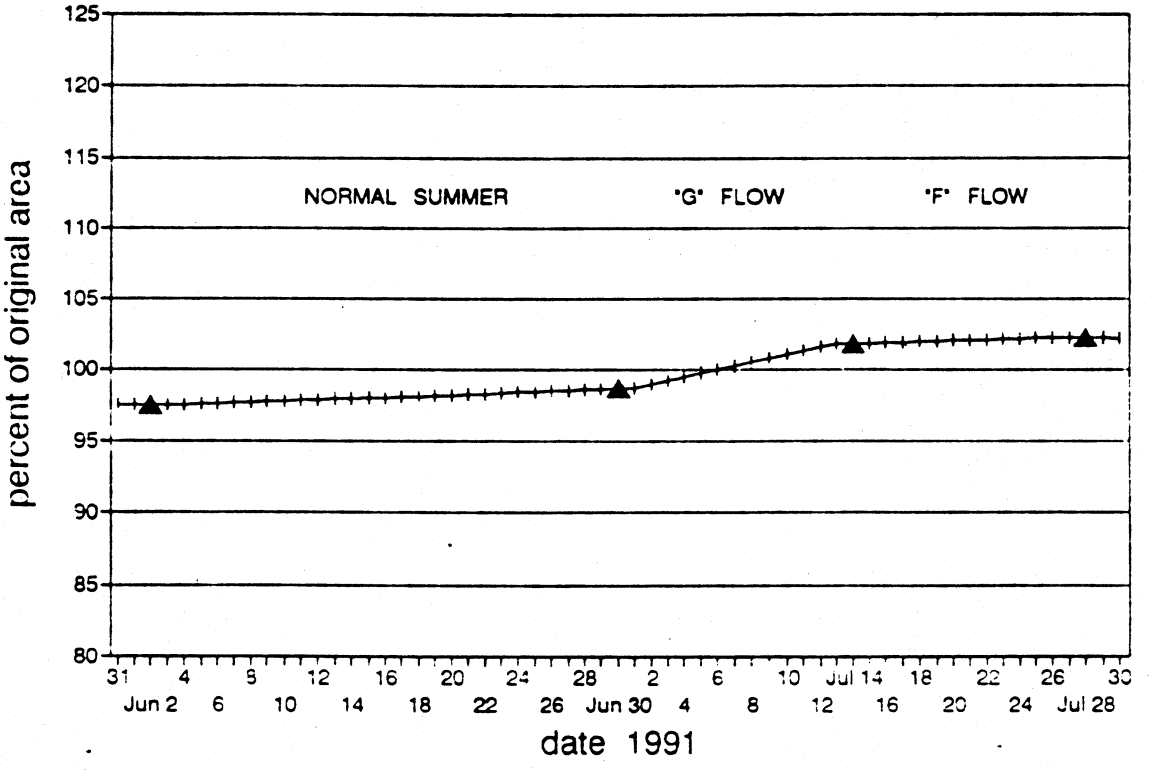


Figure 1. Example of daily sand bar area plot from terrestrial photography collected at Tanner Beach (RM 68R) during the test flow period.

:.:IOS:.Fo 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

rincipal Investigator Brian L. Cluer Date Submitted 2/26/92

epartment/Laboratory Grand Canyon National Park Organization NPS

eginning Date June 1, 1992 Completion Date May 30, 1994

roject Title Proposal to Monitor Sand Bar Stability..Daily..Interim Flows..Terrestrial Photogrammetr

udget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
. SENIOR PERSONNEL				
1. Brian L. Cluer	6			$5,500
2. photo tech, analyst	21			35,000
3. surveyor	2			4,000
downloader	6			9,000
. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. (1) Secretarial/Clerical				2,500
6. ( ) Other				
. FRINGE BENEFITS NAU %10				5,050
. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000 40 cameras, 50 boxes				12,900
2. Items > $10,000				
. TRAVEL				
1. Domestic				
a. Principals				1,000
b. Others				
2. Foreign				
. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

OTHER DIRECT COSTS	
1. Materials and Supplies film, batteries, dessicant, etc	18,648
a. Telephone	
b. Other	
2. Publication Costs	3,000
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other duplicating services, video production	13,000
TOTAL DIRECT COSTS (A through G)	109,598
INDIRECT COSTS NAU %20	14,510
TOTAL DIRECT AND INDIRECT COSTS	124,108
ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	-0-
TOTAL PROJECT AMOUNT (J + K)	124,108

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
TOTAL	

Description of Items > $10,000	
TOTAL	

*Including Freight charges

*NPS salary

A6

A PROPOSAL TO MONITOR SEDIMENT STABILITY DURING THE INTERIM FLOW PERIOD USING AERIAL PHOTOGRAPHY

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GLEN CANYON ENVIRONMENTAL
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A PROPOSAL TO MONITOR SEDIMENT STABILITY DURING THE INTERIM FLOW PERIOD USING AERIAL PHOTOGRAPHY.

Brian L. Cluer
Grand Canyon National Park
Resource Management Division

ABSTRACT

During the test flow program, 75 sand bars were aerially photographed 17 times bracketing 16 test flows. A unique technique was developed to mesh the overlapping photos into a single image, and analyze sand bars two dimensionally. Ten sites were analyzed in the development phase, resulting in promising data about deposit area, cut and fill area changes, and sediment flux associated with distinctive hydraulic parameters of individual test flows.

This proposal is two fold. First it is recommended that all sand bars photographed during the test flow program be analyzed in order to fully develop our understanding of the character of sand bar areal changes throughout Glen and Grand Canyons. Secondly, it is recommended that during the interim flow period, aerial photography be continued using the techniques and methods developed previously. With a comprehensive and robust sample to serve as benchmark data to compare subsequent area measures against, sediment stability during the interim flow monitoring period can be adequately evaluated with respect to the many local and reach-scale variables that influence each sand bar.

OBJECTIVES

One objective of the interim flow criteria was to stabilize sediment deposits by reducing the daily range in discharge ramping rates common to normal dam operations. The objective of this study is to determine if the interim flow prescription achieved the resource protection objective. The main approach will be to, 1) monitor areal change on 75 sand bars in Glen and Grand Canyon using aerial photogrammetry of the river corridor, 2) compare sand bar areas during the seasonally adjusted low, medium, and high releases in the interim flow period to, 3) a fully developed comparative database from the test flow program. An additional objective is to collect and analyze data that can be directly integrated with the NPS-GIS system.

Justifications

Understanding local perturbations to sand bar area will be necessary to interpret any sand bar stability data collected during the interim flow monitoring period. Seventy five sand bars between Glen Canyon Dam and Diamond Creek were photographed 17 times during the GCES Phase II test flow program. A large sample size is required to describe the overall effects of the test flows or interim flows, and to serve as baseline data for interim flow monitoring. If these photographs were analyzed, the data collected during the test flow program could serve to define the average effect of any given test flow. Perturbations or deviations from the norm can be identified, and possibly correlated to tributary activities or basic channel changes.

Large Sample Size-Wide Distribution The distribution of 75 sites from 5 miles below Glen Canyon Dam to river mile 225 is sufficient to adequately describe the range and mean variability of sand bars for each test flow, and to understand the range of variability in sand bar size during the interim test flow period. This knowledge is required in order to evaluate sand bar changes within the context of system variability, both for contemporary and historical studies.

Frequent Evaluations Each adjustment in seasonal flow level should be followed by an aerial evaluation to determine the effect of the previous flow type. Comparisons with effects measured during the test flow period will provide evaluations of overall as well as site specific details about interim flow prescription and its effect on the fluvial sediment resources.

Producing data that is compatible with the NPS-GIS system will minimize later adjustment and integration problems. The prevailing coordinate geometry system and scaling units will be adopted.

BACKGROUND INFORMATION AND EXISTING DATA

Two-dimensional analysis development

From August 1990, to July 1991, aerial photographs were taken of 75 sand bars in Glen and Grand Canyon dispersed between 5 miles below Glen Canyon Dam and 240 miles down river at Diamond Creek. Seventeen photo epochs were completed which bracket 16 different test flows. The photographs capture exposed sand bars at a low constant river level of 5,000 cfs.

The original intent was for the photography to be analyzed three-dimensionally, and produce topographic maps of the subject sand bars. Problems with photo geometry and image motion rendered a high percentage incapable of producing reasonable accuracy, especially in the Z dimension. A small contract for QA/QC work with the Planetary Mapping Division USGS in Flagstaff, Arizona, allowed for experimental development of two-dimensional analysis.

A technique was developed where a series of overlapping images were mechanically fitted under magnification, taking care to align water edge at the front of the sand bar and immobile rocks at the back and edges of the sand bar. The aligned overlapping images were fixed onto a stable transparency base to create a composite full coverage image. This process was repeated for each photo epoch. The composite images were then digitally surrounded along the water edge and between repeatable rocks to enclose a perimeter that defines an area. The digital perimeter was processed on a video monitor, and a program counted the number of pixels filling the perimeter and applied scaling factors to calculate the area within the perimeter in meters^2.

To compare photo epochs additional corrections were made to rectify angular variations between photographs taken at different epochs. By choosing one composite image as the base, all other photo epochs were manually adjusted on the color video monitor to align at common rock points. With common immobile points aligned, the differences in area between epochs were visually obvious, and attributable to hydraulic processes operating during the subsequent test flows. Further comparison on the color video monitor resulted in distinguishing areas of aggradation from areas of degradation between photo epochs. The results from the two-dimensional experiment are: perimeter plots of each epoch; area calculations of each epoch; comparison plots of contiguous epochs, with differently shaded areas of aggradation and degradation; and calculations of area of aggradation and degradation. The proximity of the USGS facility makes possible analysis and interpretation of comparative planimetric areas and changes between epochs on the video monitor as each epoch has a unique layer and color.

EXISTING DATA

The results from the two-dimensional analysis development are encouraging. These data are ideal for analyzing the effects of individual test flows from Glen Canyon Dam. By December 31, 1991, ten sites were fully analyzed using the two-dimensional technique described above for seventeen epochs bracketing sixteen different test flows. An example of the analysis is presented in tables 1 and 2, and figures 1, 2, and 3.

METHODS

Site Selection The sites selected for the monitoring investigation are the same as those studied during the test flow program. They are at river miles: -10, -6.5, -2.8, 1, 2.6, 4, 8, 16.4, 20, 20.5, 21.8, 29.1, 29.2, 30.4, 31.6, 33, 35.1, 37.5, 40, 43.1, 44.6, 47, 50, 51, 55, 56, 64, 66, 68, 75.6, 75.8, 76, 81, 83, 87, 91, 93, 98, 104, 108, 119, 120, 122.2 122.7, 132, 134, 137, 139, 145, 153, 157, 168, 172, 182.2, 182.4, 183.9, 194, 202, 211, 213, 220, and 225.

Completion of Test Flow Analysis The methods developed by the National Park Service and the Planetary Mapping Division of the USGS-Flagstaff (described above) will be used to complete analysis of individual test flows from Glen Canyon Dam, thereby providing a trustworthy database to compare subsequent sand bar dynamics against.

Interim Flow Monitoring Monitoring the fluvial affects of interim flows will be accomplished by repeating aerial photography of 75 sites using proven techniques, equipment, and personnel. Monitoring can be accomplished at several levels. 1) Annual aerial photography is minimally adequate. 2) The best information would come from photographing each monthly flow period. In either case, a three-day constant flow of 5,000 cfs is requested to maintain elevation control like that during the test flows. Otherwise, new relationships between area and river elevation must be developed, probably at prohibitive expense and with less comparable results.

Aerial photography will be collected and analyzed using the techniques and team developed in the test flow pilot program. Persons responsible for the development and testing of two-dimensional analysis are: Dr. Sherman S.C. Wu, US Geological Survey, Planetary Mapping Division, Flagstaff Field Office, Flagstaff, AZ; Brian L. Cluer, Grand Canyon National Park, Resource Management Division, Flagstaff, AZ. Analysis and interpretation will be conducted by NPS using color video image comparison at the USGS facilities and hard copy gray scale plots (examples included in this proposal).

Planimetric analysis of 75 sand bars will result in a robust sample from the population of all sand bars in Glen Canyon National Recreation Area and Grand Canyon National Park. With 75 of 300

(+/-) sand bars examined during 16 test flows, it is reasonable to anticipate results that will allow descriptions of the variability in the fluvial system, overall effects of test flows, localized effects such as tributary inputs or channel changes, and relative merits of alternative flows. The flow alternatives will be compared to test flows, and ranked by dynamic variables of area change. Effects of the interim flows will be compared to the baseline data obtained during the test flow period. A long-term monitoring program will be developed based on the database developed in this investigation.

INTEGRATION WITH OTHER MONITORING EFFORTS

Completion of analysis of the test flows and continued monitoring and analysis of interim flows by two-dimensional aerial photogrammetry as proposed here would integrate and support other sand bar monitoring efforts in Grand Canyon. As a stand-alone project it would produce independent reports and publications available as comparative peer-reviewed journal articles. Other studies are anticipating the availability of photographs taken during the interim flow period for; campsite evaluation (Kearsley-NPS), daily sand bar response calibrations (Cluer-NPS), the vegetation project (Ayers-NAU), and the mass wasting project (Cluer-NPS). Sediment storage ties directly to this project. This project will be integrated to the GIS system.

PRODUCTS TO BE DEVELOPED

Items that will be delivered resultant from completion of analysis of the test flow data are, for each site (75) and each epoch (17): perimeter plots; contiguous comparison plots; area calculations; and comparisons of aggradation and degradation areas. Examples of these products are shown in tables 1 and 2, and figures 1, 2 and 3. In addition, a preliminary report of sand bar response to test flows will be distributed to the EIS team and cooperators on March 31, 1992.

Interim flow monitoring reports will be prepared quarterly. Products will include perimeter plots, contiguous comparison plots, area calculations, and calculation of aggradation and degradation area for each of five epochs and 75 sites. A draft final report will be prepared by December 31, 1993, with a final report to follow by March 31, 1994. Peer-reviewed journal articles will be published from this investigation.

TIMETABLE

TASK	TARGET DATE
Preliminary report on 10 sites	March 31, 1992
Begin analysis of remaining 65 sites, test flows	June 15, 1992
Quarterly progress report	June 30, 1992
Complete analysis of test flows	August 15, 1992
Begin analysis of interim flows	August 16, 1992
Aerial photography capture I	August 31, 1992
Draft report, test flow analysis	August 31, 1992
Quarterly progress report	September 30, 1992
Aerial photography capture II	November 31, 1992
Annual report	December 31, 1992
Aerial photography capture III	March 31, 1993
Quarterly progress report	March 31, 1993
Quarterly progress report	June 30, 1993
Aerial photography capture IV	August 31, 1993
Quarterly progress report	September 30, 1993
Aerial photography capture V	November 31, 1993
Annual report	December 31, 1993
Draft Final report	December 31, 1993
Final report	March 31, 1994

Cost Estimate for Five Epochs

	YEAR 1	YEAR 2	YEAR 3
NPS Physical Scientist salary not included in cost estimate.			
A firm cost estimate has been negotiated to complete two-dimensional analysis of the remaining 65 sites for seventeen epochs, includes overhead	$50,000	-0-	-0-
Helicopter time, 5 epochs, two days each, 6 flight hours/day, @$650/hr. $7800/epoch	15,600	23,400	-0-
Camera purchase, 6x7cm rangefinder,	900	-0-	-0-
Film and processing, 20 rolls 120 format per epoch, 5 epochs @$15/roll $300/epoch	600	900	-0-
Two-dimensional analysis (sub contract to USGS) $4167/epoch	8,335	12,500	-0-
Travel	-0-	-0-	1,000
Publication	-0-	-0-	1,000
Clerical support	500	500	-0-
TOTAL	$75,935	37,300	2,000
GRAND TOTAL			$115,235

Areas of GCES Beach 172.3L

Epoch	Area(m^2)
9-30	6319.581
10-30	6242.888
12-17	6013.798
12-30	6023.905
1-12	5463.468
1-26	5178.692
2-9	4971.599
4-20	5544.125
5-5	5541.747
BASE 6-2	6171.743
6-30	5258.754
7-14	6183.634
7-27	5937 303
Horiz. .457711992 m/px	
Vert .432967311 m/px	

Table 1. Example of calculated area listing for the sand bar at river mile 172.3 left for each photo epoch during the test flow program.

AREA CHANGES FOR GOES BEACH: 172.3L

X-SCALE = 45.771 CM/PX Y-SCALE = 43.297 CM/PX

14.665	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L9-30A10-30.FLL
50.931	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L9-30A10-30.FLL
-36.266	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L9-30A10-30.FLL
72.334	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L10-30A12-17.FLL
203.723	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L10-30A12-17.FLL
-131.390	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L10-30A12-17.FLL
117.121	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L12-17A12-30.FLL
95.124	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L12-17A12-30.FLL
21.997	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L12-17A12-30.FLL
118.508	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L12-30A1-12.FLL
675.576	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L12-30A1-12.FLL
-557.068	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L12-30A1-12.FLL
106.618	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L1-12A1-26.FLL
296.865	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L1-12A1-26.FLL
-190.247	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L1-12A1-26.FLL
80.657	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L1-26A2-9.FLL
216.406	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L1-26A2-9.FLL
-135.749	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L1-26A2-9.FLL
694.007	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L2-9A4-20.FLL
253.069	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L2-9A4-20.FLL
440.938	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L2-9A4-20.FLL
53.507	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L4-20A5-5.FLL
18.232	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L4-20A5-5.FLL
35.275	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L4-20A5-5.FLL
514.659	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L5-5A6-2.FLL
39.437	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L5-5A6-2.FLL
475.222	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L5-5A6-2.FLL
133.569	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L6-2A6-30.FLL
889.605	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L6-2A6-30.FLL
-756.035	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L6-2A6-30.FLL
1189.046	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L6-30A7-14.FLL
338.085	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L6-30A7-14.FLL
850.961	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L6-30A7-14.FLL
326.393	SQUARE	METERS	OF	AREA	INCREASE	IN	G172L7-14A7-27.FLL
561.032	SQUARE	METERS	OF	AREA	DECREASE	IN	G172L7-14A7-27.FLL
-234.638	SQUARE	METERS	OF	AREA	CHANGE	IN	G172L7-14A7-27.FLL

Table 2. Example of aggradation and degradation between contiguous photo epochs for the sand bar at river mile 172.3 left for each epoch during the test flow program.

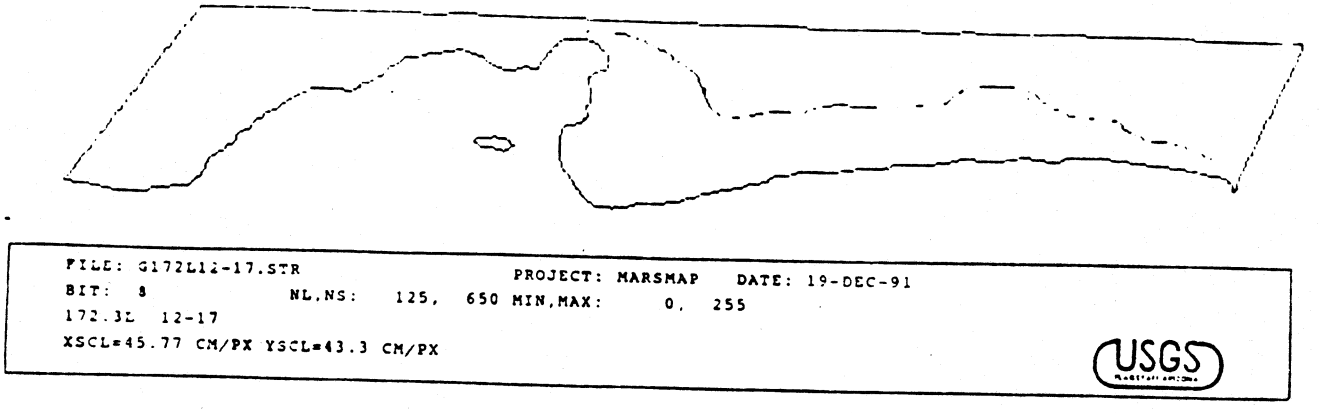

Figure 1. Example of perimeter plot for sand bar at river mile 172.3 left on December 17, 1990.

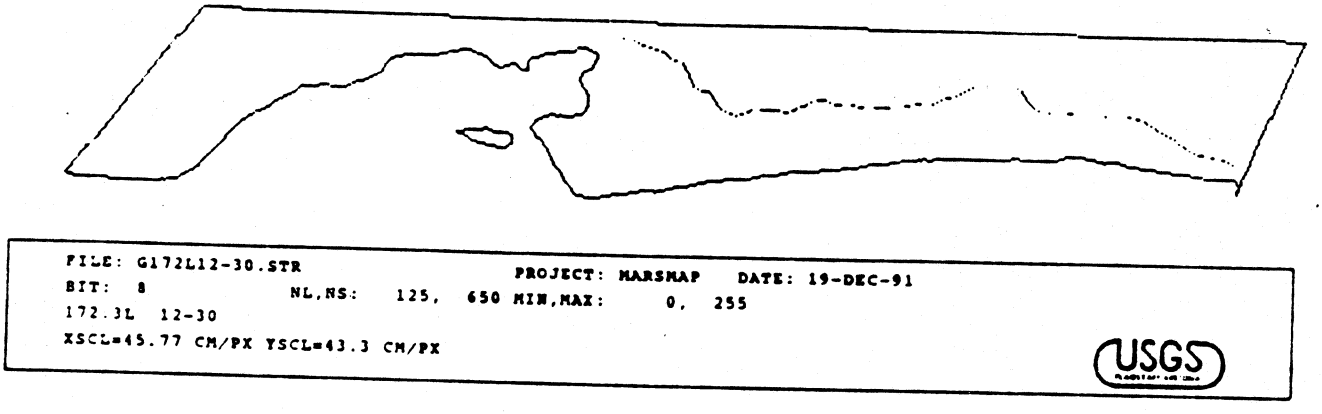

Figure 2. Example of subsequent perimeter plot for sand bar at river mile 172.3 left on December 30, 1990.

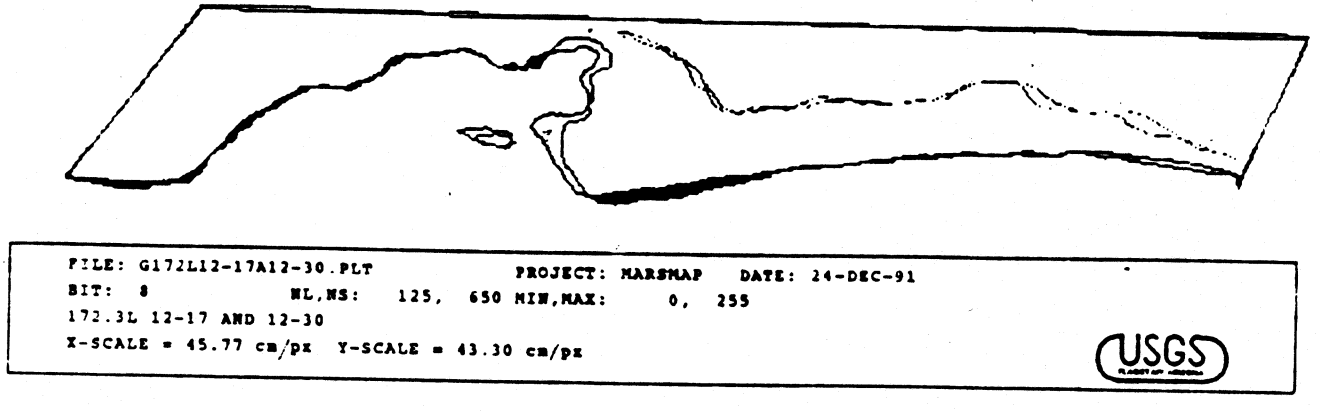

Figure 3. Example of comparison plot between two contiguous epochs at river mile 172.3 left. Comparison is of December 17 and 30, 1990. Dark shaded area was degraded, lightly shaded area was

nclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

rincipal Investigator Brian L. Cluer Date Submitted 2/26/92

epartment/Laboratory Grand Canyon National Park Organization NPS

eginning Date June 1, 1992 Completion Date May 30, 1994

roject Title A Proposal to Monitor Sediment Stability During ... Using Aerial Photography

udget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Brian L. Cluer - NPS	6			5,500
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. (1) Secretarial/Clerical				1,000
6. ( ) Other				
C. FRINGE BENEFITS				100
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				1,000
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

OTHER DIRECT COSTS	
1. Materials and Supplies film, processing, batteries, ect	1,500
a. Telephone	
b. Other camera	900
2. Publication Costs	1,000
3. Consultant Services	
4. Computer Services	
5. Subcontracts USGS Planetary Mapping Division includes overhead costs	70,835
6. Other	
. TOTAL DIRECT COSTS (A through G)	81,835
. INDIRECT COSTS	220
. TOTAL DIRECT AND INDIRECT COSTS	82,055
. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	-0-
. TOTAL PROJECT AMOUNT (J + K)	82,055*

temize Capital Equipment to be Purchased in FY___

escription of Items > $1,000 < $10,000	Cost*
.	
.	
.	
.	
OTAL	

escription of Items > $10,000	
OTAL	

Including Freight charges

*Does not include helicopter support costs, estimated at $39,000

A7

MONITORING SUBAQUEOUS FLUVIAL SEDIMENT TOPOGRAPHY WITHIN AND BETWEEN EDDY STORAGE SITES TO DETERMINE THE ROLE OF MASS WASTING IN SAND BAR LONGEVITY

Brian L. Cluer
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extension 7368 FAX

GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

FEB 27 1992

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MONITORING SUBAQUEOUS SEDIMENT TOPOGRAPHY WITHIN AND BETWEEN EDDY STORAGE SITES TO DETERMINE THE ROLE OF MASS WASTING IN SAND BAR LONGEVITY

Brian L. Cluer

ABSTRACT

Mass wasting was discovered during the test flow period to be the most destructive process of sand bar erosion along the Colorado River. As much as half of several sand bars were eroded in 24 hours or less under various flow conditions. Mass wasting continues to be an important erosion process during interim flow protection. The conditions of inception and ultimate results of this fundamental process are largely unknown. Seepage induced bank failure may explain some of the documented events, but many more are obscure in origin. An important question raised from the discovery of mass wasting events is, where does the sediment go?

This proposal explains the current state of knowledge in mass wasting of Colorado River banks, and identifies the lack of understanding of this fundamental and destructive erosion process. A two-phase approach is recommended for studying this problem. First, a pilot study will conduct repeat surveying using the hydrographic equipment and methods proposed to determine the validity of the methodology. If successful, the second-phase will repeatedly survey eddy deposit and channel geometry prior to and after mass wasting events. Erosion and deposition of sediments involved in mass wasting will be examined by continuously surveying the channel and eddies within failure zones. Comparison of topographic maps from eddies and connecting channels will result in local sediment transport analysis and short-term effects of mass wasting. Land tilt and river stage sensors will be installed at a small number of sites to determine the relationship between river stage dynamics and inception of bank failure. This will be the basis for developing long-term predictions of sand bar longevity resulting from mass wasting processes.

OBJECTIVE STATEMENT

An objective of the interim flow prescription was to reduce mass wasting of sand bars by reducing seepage induced bar deformation and slumping. This was attempted by limiting up and down ramping rates and the daily range of discharge. Mass wasting continues to erode deposits under the interim flow criteria, and sand bar rebuilding is impossible until large flows resume. The objective of this study is to monitor the rate and direction of sediment transport associated with mass wasting events, and determine if processes other that seepage activate mass wasting during the interim flow monitoring period. If so, an additional objective will be to determine if dam operations drive other mechanisms of mass wasting. The main approach will be to study the geometry and dynamic activity of eddy and channel deposits using precision hydrographic surveying equipment and techniques. Land tilt and river stage monitoring equipment will supplement the development and description of mass wasting processes. In addition, the surveying accomplished in this investigation will be integrated with the GIS database by establishing adequate prior control.

JUSTIFICATIONS

Mass wasting is an important local scale form of erosion that was studied during GCES Phase II (Cluer, 1991). Mass wasting continued to occur after the interim flow regulations began. On September 1, 1991, sand bars at river miles 81 and 172 failed, resulting in losses of 10 and 60% areas respectively. On September 7, 1991, mass wasting at river mile 211 removed 15% of that sand bar. Other sites are known to have eroded rapidly during the first 3 months of interim flows, as seen in overflights and during research river trips during the fall and winter of 1991-1992.

Determining sediment migration pathways, sites of deposition, and rates of transport following mass wasting is essential for understanding and evaluating the ceaseless processes of sand bar erosion and rebuilding. If mass wasting events simply transport the affected sediment to a lower position within the local eddy, there would be no net loss associated with events and rebuilding would be likely given large flows. Conversely, if affected sediment is transported downstream, a net loss results and no flow scenario can replace that sediment. Understanding this basic difference is imperative as mass wasting is a process that river resource managers are concerned with.

The timing of mass wasting event inception with respect to the dynamics of river stage is important in order to determine the local flow path of bank stored water. This knowledge will either support or oppose seepage as the dominant process driving mass wasting.

By initiating this project with GIS integration in mind, the data will be easily included in the database. Subsequent monitoring efforts will be able to make full use of this investigation through the GIS system.

BACKGROUND INFORMATION AND EXISTING DATA

Investigations conducted during the test flow period revealed that large losses and rebuilding of sand bars can occur rapidly. Beus et. al. (1991) indicated that many of the seemingly anomalous downward spikes in sand bar volume were probably attributable to mass wasting events. Budhu (1991) showed a conceptual model of seepage force and stage change that predicted induced bank failure during declining river stage. Carpenter and Carruth (1991) showed tilt sensor data that correlated sand bar tilting with rapid changes in hydraulic levels in the river, both up and down. They speculated that some tilt events may have been caused by "scouring" that undercut the toe of an instrumented sand bar. Cluer (1991) documented up to 50% erosion of sand bars within 24 hours or less on several occasions at numerous locations, and complete rebuilding to original size sometimes within 10 days. He suggested that additional processes yet unknown may also drive mass wasting on the Colorado River.

An important question resulting from these investigations is what processes other than seepage result in mass wasting. Other questions that originate from these investigations are: 1) does mass wasting operate in all hydraulic reaches of the river; 2) what conditions induce mass wasting processes; 3) during and immediately following a mass wasting event, where is the sediment transported to; 4) does it reside within the eddy, or is it transported downstream; and 5) what conditions must exist for rebuilding to begin?

During the test flow program, Cluer (1991) documented 23 mass wasting events at seven different sites. Those events occurred under a variety of flow conditions and had various erosive effects ranging from 2-55% of total deposit area. Approximately half of the documented events occurred within 1 or 2 days following a low flow period. These have been explained by Budhu (1991) as resulting from incipient failure developed during excessive draw-down of bank water level. The other half of events documented occurred during regular fluctuations without apparent seepage perturbation. Cluer (1991) speculated that other processes and mechanisms may drive mass wasting of channel margin deposits along the Colorado River.

METHODS

Study Site Selection

The sand bar at river mile 172 is known to have failed through mass wasting 5 times between April and September 1991. The most notable event occurred during the interim flow period on September 1, 1991. This site will be used as the initial technique and protocol development site. Other sites where mass wasting events have been documented are; 51L, 68R, 81L, 211L, 216R, and 225R. Additional sites will be studied as new mass wasting events are documented. Field studies will be coordinated around the seasonal flow adjustment time periods.

Hydrographic Surveying

Currently, investigations concerning seepage and mass wasting have documented activity in zones exposed at low flow, ie., above the 5,000 cfs river stage. All the questions raised about mass wasting concern processes below water level, in the subaerial environment. Hydrographic surveying equipment will be used to characterize eddy deposits and channel geometry in three dimensions. Rapid and accurate measurements are necessary in order to repeat surveys daily when mass wasting events are anticipated, and Cluer (1991) showed that mass wasting events occur most commonly during changes in flow regime (low flow to high, and high flow to low), and often follow a 2-3 day period of low flow.

Hydrographic surveying in this investigation refers to topographic characterization of the channel and related fluvial deposit surfaces. Generally, hydrographic surveying equipment involves a boat with a depth sounder and some form of land-based positioning system. The Global Hydrographic equipment chosen for this investigation uses a high quality sonar depth sounder with adjustable beam width and frequency control for optimizing signal to noise ratio, a modified theodolite with endless tangent screws for tracking reflective prisms mounted on the boat, an integrated communication system that automatically receives depth data from the sonar and combines with position information in the datalogging computer, a boat steering display for precisely repeating preestablished profiles, and analytical software for producing topographic maps and comparison surfaces. Crew required to operate this equipment includes: surveyor (on land station); survey leader (on boat station); assistant (on shore); and a boat operator.

This project will be conducted in two-phases. The first (pilot) phase will evaluate the equipment and methodology to determine if the objectives of this investigation can be met. The pilot evaluation will determine if topographic accuracies required to characterize the features and processes of mass wasting can be obtained with the Global Hydrographic system. If so, the second

phase will begin immediately. In order to answer the questions about sediment transport following mass wasting, surveys will be conducted in recently affected eddies, in eddies immediately downstream, and in the connecting channels. To answer the questions about rebuilding, surveys will be repeated in recently affected eddies until rebuilding begins. To determine if mass wasting operates in all reaches this project will rely heavily on data for the automatic terrestrial photogrammetry study, and will characterize eddy deposits and channel geometry in recently affected areas documented by that investigation.

Sites to be studied will first be reconnaissance surveyed to determine the size and location of bathymetric bedforms (pilot). From that information, profile spacing and point density will be determined for the remainder of surveys at that location. Surveys will be repeated daily and will continue for up to two weeks or until the deposits become stable.

Land Tilt and River Stage

Ten sites will be equipped with three tilt sensors and one river stage sensor each. These data will be used to determine the relationship between river stage fluctuation and sand bar movement. This is important in order to discriminate between seepage induced mass wasting and other processes of mass wasting.

A similar but more elaborate system was used successfully during GCES Phase II test flow investigations (Carpenter et al., 1991). The sensors will be built and calibrated by qualified personnel who instrumented sites during the test flow program. Automatic data loggers will record information every half hour. Data will be down loaded, sensors will be calibration checked, and batteries will be replaced twice yearly.

Underwater Video Documentation

An underwater video camera may be used to document erosion and deposition processes associated with mass wasting. The camera may also be used to verify and document unique or anomalous topographic features revealed in hydrographic surveying. The feasibility of this idea will be explored in the early research period.

GIS Integration

All surveying data and resulting maps will integrate directly with the NPS-GIS system. Adequate benchmark control will be established to allow reoccupation and relocation for future monitoring efforts.

INTEGRATION

This investigation will integrate with the ongoing seepage instrumentation and modeling efforts (Carpenter et al.). The ongoing and possibly upscaled terrestrial photogrammetry study (Cluer) will help in identifying sites with a history of mass wasting and will help to predict when events are most likely to occur. This investigation will provide a more specific understanding of deposit dynamics that will be eminently useful for interpreting historical and contemporary sediment stability. There may be opportunities to integrate data and concepts developed during this study with USGS investigations of sediment transportation and Colorado River system dynamics.

PRODUCTS

Comparative topographic maps of eddy and main channel deposits will be produced for the interim flow monthly flow types, and before and after mass wasting events. Analyses of these topographic maps will include comparative three dimensional changes in eddy deposits and changes in channel geometry.

Time series plots of river stage and land tilt will be produced monthly for ten sites, and will integrate with daily terrestrial photography. It is anticipated that fundamental but currently unknown channel hydraulic processes will be observed and described during the course of this study.

TIMETABLE

TASK	DATE
Phase I	
Equipment procurement Survey crew training, equipment testing	June 15, 1992
Field test, protocol development, baseline data collection, site instrumentation	June 30, 1992
End of Phase I Quarterly report	September 31, 1992
Phase II	
Field study I, high to low flow	September 25-October 15, 1992
Annual progress report	December 31, 1992
Quarterly report	March 31, 1993
Field study II, low to medium flow	May 25-June 15, 1993
Field study III, high to medium flow	August 20-September 15, 1993
Quarterly report	September 31, 1994
Annual report, Draft final report	December 31, 1993
Final Report	March 31, 1994

BUDGET	YEAR 1	YEAR 2	YEAR 3
NPS Physical Scientist salary not included in budget.			
Personnel			
instrumentation			
sensor building			
technician 2 months	$4,000	-0-	-0-
calibration tech 1 month	2,000	-0-	-0-
installation			
technicians 3, 1 month	6,000	-0-	-0-
surveying personnel			
1 surveyor 1/2 time	15,000	15,000	-0-
1 assistant 1/4 time	5,000	5,000	-0-
office support	1,000	1,000	500
Other expenses			
PI Travel	-0-	-0-	1,000
supplies, etc.	2,000	2,000	-0-
publication			1,000
video camera rental	2,000	2,000	-0-
TOTAL	$37,000	25,000	2,500
GRAND TOTAL		$64,500	

PHASE I COSTS	
Personnel	
instrument techs	$12000
surveyor	2000
assistant	1000
Other	
video rental	2000
	$17000

PHASE II COSTS	
Personnel	
surveyor	$28000
assistant	9000
office	2500
Other	
PI travel	1000
supplies	4000
publication	1000
video rental	2000
	$47500

REFERENCES CITED

Beus, S.S, Avery, C.C., Stevens, L.E., Kaplinski, M.A., and Cluer, B.L., 1991. The influence of variable discharge regimes on Colorado River sand bars below Glen Canyon Dam. Chapter 3, in Beus, S.S. and Avery, C.C., eds., The influence of variable discharge regimes on Colorado River sand bars below Glen Canyon Dam: 1991 Annual Report.

Budhu, M., 1991. A model to predict seepage driven erosion due to transient flow. Chapter 6, in Beus, S.S. and Avery, C.C., eds., The influence of variable discharge regimes on Colorado River sand bars below Glen Canyon Dam: 1991 Annual Report.

Carpenter, M.C., and Carruth, R.L., 1991. Hydrogeology of beaches 43.1L and 172.3L and the implications on flow alternatives alon the Colorado River in the Grand Canyon. Chapter 5, in Beus, S.S. and Avery, C.C., eds., The influence of variable discharge regimes on Colorado River sand bars below Glen Canyon Dam: 1991 Annual Report.

Cluer, B.L., 1991. Daily responses of Colorado River sand bars to Glen Canyon Dam test flows, Grand Canyon, Arizona. Chapter 4, in Beus, S.S. and Avery, C.C., eds., The influence of variable discharge regimes on Colorado River sand bars below Glen Canyon Dam: 1991 Annual Report.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

rincipal Investigator Brian L. Cluer Date Submitted 2/26/92

epartment/Laboratory Grand Canyon National Park Organization NPS

eginning Date June 1, 1992 Completion Date May 30, 1994

roject Title Monitoring Subaerial Sediment Topography..in Eddys..Role in Mass Wasting

udget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
SENIOR PERSONNEL				
1. Brian Cluer - NPS				21,500
2 surveyor	12			21,000
3 assistant surveyor	6			10,000
OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. (1) Secretarial/Clerical				2,500
6. (2) Other sensor tech., build-up, calibration		2months		4,000
FRINGE BENEFITS 10% of non-NPS personnel				7,500
PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				24,000
2. Items > $10,000				50,000
TRAVEL				
1. Domestic				
a. Principals				1,000
b. Others				
2. Foreign				
PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

OTHER DIRECT COSTS	
1. Materials and Supplies	4,000
a. Telephone	
b. Other	
2. Publication Costs	
3. Consultant Services	1,000
4. Computer Services	
5. Subcontracts	
6. Other Rental, video camera	4,000
TOTAL DIRECT COSTS (A through G)	150,500
INDIRECT COSTS NAU %20	15,000
TOTAL DIRECT AND INDIRECT COSTS	165,500
ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	-0-
TOTAL PROJECT AMOUNT (J + K)	165,500

mize Capital Equipment to be Purchased in FY 92

scription of Items > $1,000 < $10,000		Cost*
Campbell Scientific CR10 Measurement and control module	10	10,500
Campbell SM192 Storage Module	10	4,200
Campbell 107B Temperature Probe	40	4,000
Motorola MPX2200AS pressure sensor	10	250
DAS-30 dual axis clinometer #02794-01	30	2,150
Misc. wire, power supplies, batteries, boxes, fittings, pipe, etc.		2,300
AL		24,000

scription of items > $10,000	
Global Hydrographic Systems package	50,000
this item has been requested by Beus and Avery also	
AL	50,000

cluding Freight charges

*NPS salary

MONITOR TRIBUTARY SAND CONTRIBUTIONS, SAND TRANSPORT, FLOW, AND PHYSICAL AND CHEMICAL CONSTITUENTS AT MAIN CHANNEL GAGING STATIONS DURING THE INTERIM FLOW PERIOD

A. ABSTRACT:

Continuation of the flow and sediment monitoring effort at five main stem and tributary gages, with additional sediment data collection at the five tributary gaging stations to monitor flow, sediment transport in the main stem and tributary sediment inputs during the interim flow monitoring period. Continuation of montoring select physical and chemical constituents at six main stem and four tributary gages, in support of interim flow monitoring plan 1-c and 1-e.

B. OBJECTIVES:

1. To document flow at five main stem and five tributary gages for all monitoring efforts requiring flow information.
2. To better define the sediment transport/flow relations at all gages.
3. To document the delivery of sediment to the main stem during the interim flow period.
4. To document changes in water temperature, pH, dissolved oxygen, and specific conductance during the interim flow period.
5. To manage and maintain the hydrologic data base to make data available to all GCES entities.

C. JUSTIFICATION:

Virtually all of the interim flow monitoring elements require information on flow throughout the Canyon. All monitoring efforts involving the stability and evaluation of sand deposits need information on the effects of interim flows on the rates of sediment transport in the main channel to compare with sediment transport rates measured during the research flow periods and historical rates measured prior to the GCES program. In the short time interval of the interim flow period, it is necessary to monitor sediment inputs to the main stem from the larger tributaries in case the sediment delivery is significantly different from the long-term rates derived from the historical records for some of the major tributaries. The effects of significant departures would have to be accounted for in analyzing changes in main stem sediment transport during the interim flow period. Montoring select physical and chemical constituents during the interim flow period is necessary to those agencies responsible for the protection and well-being of native and exotic fish species in the Colorado River and it tributaries. Significant changes in water temperature, pH, dissolved oxygen, or specific conductance could occur during the interim flow period due to tributary inflow and changes in the quality of water being released from Lake Powell because of lowering or rising lake levels.

Although our October 91 budget request did not contain funding estimates for the tributary sediment monitoring and the minimonitor network, these elements are planned to be reinitiated for the interim flow periods due to input from GCES staff and other cooperating agencies as being essential for the interim flow period. The result is that network operation costs for FY92 are $342,800, of which $117,700 had been expended by January 31. The funds to be provided the Arizona District for all programs is presently estimated to be $455,000. Of this $455,000, another $283,400 will have been expended to bring all the other efforts to a conclusion and complete the EIS reports in March. Thus, of the $455,000 allocated to the Arizona District,

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only $53,900 remains to fund any program. If the hydrologic network is to continue in operation, and assuming the $53,900 is applied to that program, the additional funding needed in FY92 totals $197,300 including $26,100 for the reinstrumentation on some of the tributaries. In FY93, the cost, assuming 5 percent inflation, will be $27,400 for the interim flow monitoring component, assuming that GCES funds the monitoring network at $360,700 for a grand total of $388,100 in FY93.

D. BACKGROUND INFORMATION AND EXISTING DATA.

Long-term records of flow and sediment transport are available for two main stem stations and three of the major tributaries. Both flow and sediment-transport data are available from all stations for several periods of time in GCES I. Minimonitors are currently in place at the six main stem gaging stations and are recording continuous data of water temperature, pH, dissolved oxygen, and specific conductance. Continuous records of these constituents have been available since they were installed during the later part of 1990. Minimonitors were discontinued at the tributary stations at the beginning of fiscal year 1992 due to budgetary reductions in the GCES program.

E. METHODS:

Standard techniques for monitoring flow (stage) and collecting and processing bimonthly sediment samples will be used. Automatic samplers will be used on tributaries to capture data during infrequent runoff events. Minimonitor recorders will be used to record water temperature, pH, dissolved oxygen, and specific conductance on a continuous basis (hourly unit values) and are currently in operation on the main stem. Recorders will need to be reinstalled at the tributary gages.

F. INTEGRATION WITH OTHER MONITORING EFFORTS

This effort complements USGS and other GCES studies including sediment, flow, and fisheries related programs.

G.. PRODUCTS TO BE DEVELOPED:

All data will be processed and placed in the hydrologic data base, which is accessible and available to all entities involved in the GCES-II and interim flow monitoring programs. Flow and physical and chemical data will be entered into the data base as it is obtained through telemetry. Results of sediment-sample analyses will be entered as soon as the laboratory can analyze samples and report results (usually 3 months).

H. TIME TABLE:

This is a continuation of work carried out under GCES-II and will end in September 1994 or at the end of the interim flow monitoring period.

I. BUDGET ATTACHED.

Costs include both FY 1992 and FY 1993. Fiscal year 1992 is 88 percent of the total costs, or $197,300 of the $224,700 total..

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigators R.J. Hart Date Submitted 2/26/92

Department/Laboratory WRD Arizona District Organization USGS

Beginning Date 3/1/92 Completion Date 9/30/93

Project Title Monitor tributary sand contributions, sand transport, flow and physical and chemical constituent at main-channel gaging stations during the interim flow period

Budget Estimate

	Person/Mos Cal	Acad	Sumr	Total Amount
A. SENIOR PERSONNEL				$ 8,000
1. R.J. Hart	2			(8,000)
2.				
3.				
B. OTHER PERSONNEL Salary costs also in Stations operations (G5)				
1. ( ) Post Doctoral Associates				
2. (X) Other Professional (techs.)	2			6,000
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical Included in Indirect Costs(I)				------
6. ( ) Other				
C. FRINGE BENEFITS Included in Salaries A2, B2, and G5				------
D. PERMANENT EQUIPMENT				0
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic Most travel included in G5				2,600
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel Included in Travel E1				-------
3. Subsistence Included in Travel E1				-------
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	4,100
a. Telephone Included in Indirect Costs (I)	------
b. Other	
2. Publication Costs Included in Station Operations (G5)	------
3. Consultant Services Included in Indirect Costs (I)	------
4. Computer Services Included in Indirect Costs (I)	------
5. Subcontracts Station operations and equipment rentals	75,000
6. Other Sediment analyses	20,000
H. TOTAL DIRECT COSTS (A through G)	115,700
I. INDIRECT COSTS	108,900
J. TOTAL DIRECT AND INDIRECT COSTS	224,600
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	0
L. TOTAL PROJECT AMOUNT (J + K)	$224,600

Itemize Capital Equipment to be Purchased in FY____

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight Charges

A9

DEVELOPMENT OF A MONITORING PROGRAM OF SEDIMENT-STORAGE CHANGE IN ALLUVIAL BANKS AND BARS, COLORADO RIVER, GRAND CANYON

February 24, 1992

John C. Schmidt
Principal Investigator

M. K. Jeppesen, Director
Contracts and Grants

Derrick J. Thom, Head
Department of Geography and Earth Resources

Joseph A. Chapman, Dean
College of Natural Resources

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GLEN CANYON DAM ENVIRONMENTAL STUDIES

INTERIM FLOW MONITORING PROGRAM

Development of a Monitoring Program of Sediment-Storage Change in Alluvial Banks and Bars, Colorado River, Grand Canyon

John C. Schmidt
Department of Geography and Earth Resources
Watershed Science Unit
Utah State University

A. Abstract

This 1-yr project will (1) develop a method for monitoring change in alluvial banks and bars along five continuous reaches of the Colorado River, and (2) describe and quantify changes in these reaches during the study period. Surficial geology of the river corridor in these reaches will be mapped onto 1:2400-scale topographic base maps, based on field work and interpretation of 1992 aerial photography. Changes in alluvial banks and bars will be determined by comparing these maps with surficial geologic maps developed for the same reaches based on interpretation of historical aerial photography for the years 1965, 1973, 1980, 1984, 1985, 1987, 1988, 1989, and 1990. Interpretation of sediment-storage change will be made after all maps have been entered into a Geographic Information System. Changes in the area of different types of deposits and the characteristics of spatial change of each large deposit will be evaluated. These analyses, integrated with the results of sand-bar inventories also completed in this project and with results of topographic surveys of specific sites, will result in comprehensive evaluation of change of all types of alluvial banks and bars in Grand Canyon. Maps and computer data files developed in this project can be the basis for long-term monitoring.

B. Objective

Sediment-storage changes in alluvial bars and banks will be monitored by comparing bar area and shape in 1992 with bar area and shape at other times. Maps of sediment deposits in NPS-designated reaches 1 (vicinity of Glen Canyon Dam), 2 (-Six Mile to Cathedral), 3 (Saddle Canyon area), 4 (Nankoweap to Kwagunt), and 5 (Little Colorado River to Unkar) will be completed using base maps and 1992 air photos provided by GCES. The precent condition of these sediment deposits will be compared with the historic variability in size and shape of these bars based on interpretation of historic aerial photographs. Historic analysis of alluvial deposits for Reaches 1, 2, 3, and parts of 5 will also be completed in this project; historic analyses for Reach 4 and other parts of 5 have already been completed. Changes in the area and characteristics of all sediment deposits covered by these maps will be evaluated with the aid of Arc-Info software. An inventory of the status of all sediment deposits between Glen Canyon Dam and Diamond Creek will also be completed and compared with previous inventories.

C. Justification of Objective

The purpose of air photo mapping and inventory of sediment deposits in Grand Canyon is to comprehensively monitor change of all sediment deposits in selected reaches. Ongoing topographic surveying of selected sand bars provides detailed topographic data about

selected bars, but does not permit system-wide analysis of alluvial deposit change because of uncertainty about the representativeness of any sample set to surveying sites. Analysis of spatial changes of all deposits in continuous reaches provides an alternative strategy for assessing change. Such a strategy permits analysis of area changes that are inexact surrogates for volume changes. What is lost in topographic detail, however, is gained by comprehensive analysis of all deposits in continuous reaches. Previous studies (Schmidt and others, 1992; Clark and others, 1991) have shown that volume changes can be estimated from measurements of area.

Mapping of area changes also permit assessment of the significance of change measured for the short-term monitoring period by comparing that change with measurement determined for the same reaches for the entire period during which historical aerial photographs are available. Some study sites have been relatively stable since closure of Glen Canyon Dam, while bars in other channel expansions have changed greatly in size. The significance of any short-term measurements can only be determined when that record is placed within the context of the long-term time record and a large spatial scale.

Integration of the two approaches -- ground surveys and continuous mapping for selected reaches -- therefore provides a sound basis for evaluating system-wide changes of alluvial deposits. These results will be supplemented by a comprehensive inventory of all sediment deposits between Lees Ferry and Diamond Creek to ensure that changes throughout Grand Canyon are monitored.

D. Background Information and Existing Data

Schmidt and Graf (1990) used inventory techniques to assess alluvial-deposit change between Lees Ferry and Elves Chasm, and Zink (1990) continued this analysis downstream to Diamond Creek. Because river stage varies widely among the air photo series that were compared, a simple strategy of accounting for presence or absence of sand bars in each eddy was used. This technique is sufficient to determine gross changes in sediment storage in narrow reaches, but it is not sufficient to identify subtle erosional or aggradational changes that are likely to occur during a period of successive years of powerplant discharges as are expected for the early 1990's. Similiar strategies of sand deposit inventory using 1990 photography have been completed by the NPS in order to assess changes in campsite size (Warren and Kearsely, 1992).

A more detailed analysis of sand-bar change is being conducted by Schmidt and co-workers in those reaches of Grand Canyon where the USBR has prepared 1:2400-scale topographic base maps -- the Nankoweap reach (Reach 4) and the Little Colorado River to Unkar reach (Reach 5). In these reaches, maps of surficial geology of the river corridor are being made for each year that historical air photography is available, using a stereo zoom-transfer scope to adjust photo scales. These maps have been entered into an Arc-Info GIS data base, and the area and spatial characteristics of sand bars and other deposits are being compared. At present, one reach (RM 52-56 in the vicinity of Nankoweap Rapids; Clark, 1992) and parts of a second reach (RM 60-72) have been finished. All digital data are being sent to the USBR for inclusion into the comprehensive Grand Canyon resource GIS data base.

The preliminary results from this analysis show that changes in bars and banks can be evaluated despite differences in river discharge at the time of each historical photo (Schmidt and others, 1992). River discharge is accounted by determining a best-fit relation between river discharge at the time of each aerial photo and the area of sand exposed in that photo. Residuals from this relation are then determined to identify times when there is more of less sand exposed than would be predicted by the linear relation.

Time-series plots of these residuals illustrate bar and bank response. This strategy has been successful in Reach 4 (Clark and others, 1991). Appendix A is excerpted from Schmidt and others (1992) and describes these techniques in more detail. Because all data is entered into a GIS data base, spatial changes of individual deposits can be evaluated by comparing the characteristics of specific sites over a range of discharges and times.

In some reaches lacking topographic base maps, historical changes in sediment deposits have been evaluated by mapping surficial geology onto base maps developed from a common air photo scale (Clark and others, 1991). This type of analysis has been completed in the vicinity of Badger Creek Rapids, Nineteen Mile Canyon, Hundred Twentytwo Mile Creek, and Fern Glen Rapids and will be included in the final version of Schmidt and others (1992) due in March.

Schmidt and others (1992) and Schmidt and Graf (1990) also showed that topographic surveys of individual study sites are not necessarily representative of the broad range of sand bars in Grand Canyon. Study sites selected by Howard (1975), Beus and others (1985), and Beus and Avery (1992) are representative of the behavior of higher elevation, more stable sites, but not of low elevation reattachment bars where most eddy sediment is stored. Thus, a sediment storage monitoring system must account for changes throughout the river corridor and not just at topographic monitoring sites. Secondly, in order to evaluate these spatial changes, short term changes must be evaluated in relation to the patterns of change detemined for the longest period of time available from historical air photography.

E. Monitoring Techniques:

For purposes of this proposal, it is assumed that 1992 air photos are provided by the Glen Canyon Environmental Studies program or by the National Park Service. It is also assumed that these photos are of a scale similiar to those previously flown by the GCES in 1984 and 1990. In Reaches 4 and 5, the area of sand bars will be directly mapped onto the existing topographic base using a stereo-zoom transfer scope.At present, USBR projects completion of topographic base maps (scale 1:2400) for reaches 1, 2, and 3 by early 1992. Surficial geology of these reaches, as well as parts of reach 5 not yet completed, will be mapped using air photos supplemented by field work. In order to compare and evaluate change, river corridor conditions in 1990, 1984, 1980, 1973, 1965, and 1952 will be mapped onto the same bases.

All maps in this project will be digitized into the same GIS data base referenced to UTM coordinates used in previous work. Digitizing and analysis of data will be completed at the Center for Remote Sensing of the College of Natural Resources.

Subsequent monitoring in these reaches will only necessitate interpretation of a new aerial photograph series. There will be more limited need for field inspection, because the types of alluvial deposits and the characteristics of their changes during the past 30 yrs will have already been completed. The projected costs of this part of the monitoring program will decrease significantly.

Elsewhere in Grand Canyon, the inventory methods of the NPS and GCES will be continued. These inventories will permit identification of the number and size of deposits that may be changing over time. Completion of such an inventory will ensure that the entire river corridor is evaluated, and large magnitude changes that may occur at sites not mapped or surveyed in the field will be identified. These sites can then be further investigated by field crews.

F. Integration with other monitoring efforts:

There will be overlap in the monitoring of approximately 6 sand bars which are regularly surveyed for topographic change (Beus and others, 1992) and which occur in one of the study reaches addressed in this proposal. This overlap will permit continuing evaluation of the representativeness of topographic monitoring sites, and will be critical if GCES is to make decisions about the number and frequency of topographic surveying throughout Grand Canyon.

Results from alluvial deposit monitoring can also be integrated with results of the U. S. Geological Survey discharge and sediment-transport monitoring program. It will also be important to integrate mapping of surficial deposits with any mapping of vegetation distribution in the same areas. Results of all mapping in this project will be made immediately available to botanists conducting the latter surveys.

G. Products:

The following will be the deliverables for this project:

1. Surficial geologic maps (scale 1:2400) for reaches 1, 2, 3, and those parts of reach 5 not already completed for historical conditions in 1952, 1965, 1973, 1980, 1984, 1990.

2. Surficial geologic maps of reaches 1, 2, 3, 4, and 5 for 1992.

3. Edited Arc-Info files of all data listed in steps 1 and 2, referenced to the UTM coordinates of each topographic base map.

4. Analysis of spatial changes in all sediment deposits mapped on each map series.

5. Results of inventories of all sediment deposits throughout Grand Canyon.

H. Timetable

The following timetable assumes an award date of May 1, 1992, and a contract period of 1 year.

June	aquire air photos; intial field reconnaissance
July - September	preliminary mapping of study reaches
October	final field checking of mapping
November - December	digitize maps
January - March	analyze data
April - May	prepare final report

References Cited

Beus, S. S., Avery, C. C., Stevens, L. E., Kaplinski, M. A., and Cluer, B. L., 1992, The influence of variable discharge regimes on Colorado River sand bars below Glen Canyon Dam: Flagstaff, report to NPS, 26 p.

Beus, S. S., Carothers, S. W., and Avery, C. C., 1985, Topographic changes in fluvial terrace deposits in Grand Canyon: Journal of the Arizona - Nevada Academy of Science, v. 20, p. 111 -120.

Clark, J. J., Kyle, E. L., and Schmidt, J. C., 1991, Mapping sediment-storage changes along the Colorado River in Grand Canyon: Eos, v. 72, p. 223.

Howard, A. D., 1975, Establishment of benchmark study sites along the Colorado River in Grand Canyon for monitoring beach erosion caused by natural forces and human impact: Univ. of Virginia Grand Canyon Technical Report No. 1, 182 p.

Schmidt, J. C., Clark, J. J., Kyle, E. L., and Grams, P. E., 1992, Historic changes in sediment deposits in Grand Canyon, 1965-90: Flagstaff, report to NPS, 62 p.

Schmidt, J. C. and Graf, J. B., 1990, Aggradation and degradation of alluvial sand deposits, Colorado River, Grand Canyon: U. S. Geological Survey Professional Paper 1493, 74 p.

GLEN CANYON DAM ENVIRONMENTAL STUDIES

PROJECT BUDGET

SUMMARY SHEET

John C. Schmidt

Department of Geography and Earth Resources

February 24, 1992

Utah State University

Beginning Date: June 1, 1992 Completion Date: May 31, 1993

Project Title: Development of a Monitoring Program for Determining Sediment Storage Changes in Five Continuous Reaches of Grand Canyon

Budget Estimate:

	Person Months			
	Calender	Academic	Summer	Total Amount
A. Senior Personnel:				
1. John C. Schmidt @$4142/mth		0.5		2071
B. Other Personnel				
1. (0) Post Doctoral Associates				
3. (1) Graduate Student @ $1000/mth		9	1	10000
C. Fringe Benefits				
1. Senior Personnel (37%)				766
3. Graduate Student (16%)				1600
D. Permanent Equipment				none
E. Travel				
1. Domestic				
a. Principals				500
b. Others				500
F. Participant Support Costs				
1. Stipends				0
2. Travel				0
3. Subsistence				0
4. Other				
G. Other Direct Costs				
1. Materials and Supplies				
a. Telephone				0
b. Other				500
2. Publication Costs				100
3. Consultant Services				0
4. Computer Services				4500
5. Subcontracts				0

H. Total Direst Costs	20537
I. Indirect Costs (37%)	7599
J. Total Direct and Indirect Costs	28136
K. Estimated Amount from Other Sources	0
L. Total Project Amount	28136*

* assumes that GCES will provide logistical support for field work in development of surficial geologic base maps for reaches 1, 2, and 3

sand deposits. Stage-to-discharge relations were developed at each study site. A detailed description of the method as applied to one study site is described in appendix A and is described fully by Kyle (1992).

CHANGES IN SEDIMENT DEPOSITS

Comprehensive Mapping of Area Changes in a Wide Reach

Figure 1 shows the surficial geology of part of the reach between river miles 55 - 56. Clark (1992) has described the characteristics and distribution of these deposits. Table 4 lists the area of those mapping units primarily comprised of sand. Because river stage affects the extent of subaerial exposure of sediment deposits, a correction for the different river stages was developed. Figure 2 shows the area of different types of sand bars in different years and the discharges at the times of those photos. This figure shows that reattachment bars comprise over half the total area of all sand deposits, and that the area of exposed sand is affected by river discharge. The equations for the linear regression lines for reattachment bars and for the total area of all sediment deposits are:

$A_t = 63363 - 29.267\ Q$, and

$A_r = 43{,}496 - 25.047\ Q$, respectively,

where A_t is total area of all sediment deposits and A_r is total area of reattachment bars, both in square meters, and Q is discharge, in cubic meters per second.

The r^2 value of these relations is 0.76 and 0.80, respectively. In contrast, the slope for regression relations for separation bars and margin deposits are nearly flat, indicating that there is essentially no relation between the exposed area of these bars and river stage. This situation exists because both of these bar types typically occur at elevations higher than the stage of any of the discharges of the aerial photos. None of the relations of figure 2 are valid for discharges greater than the range of values shown on the abscissa.

Temporal changes in area of these bars was determined by calculating the difference between predicted and actual area for each bar type for each year and plotting the time series of these residual values (figure 3). These data show that residual values of reattachment bar area and total bar area increased between 1965 - 80, declined between 1980 - 87, and then increased from 1987 - 90. The calculated value for 1989 is anomolously high and is not included in the interpolation line connecting the other data in figure 3. It is uncertain why the 1989 value is so large. It may be that bars did actually aggrade between 1987 - 89, and then degrade from 1989 - 90. Such a scenerio must be confirmed by results from mapping in other reaches before a detailed assessment of 1989 - 90 bar erosion is initiated.

The proportional change in each deposit type was estimated by dividing the residual values of figure 3 by the predicted values for each year. Figure 4 shows that reattachment

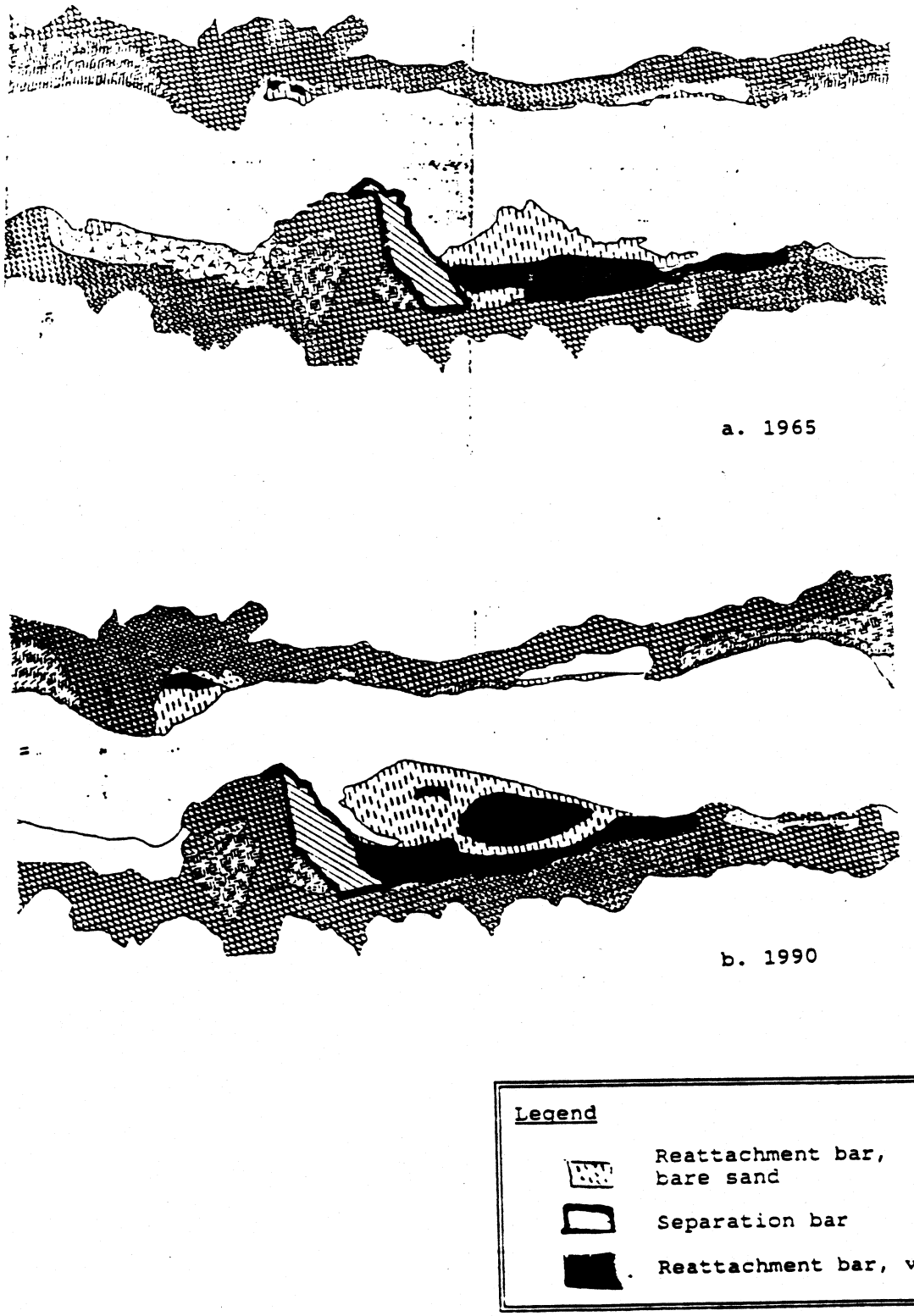


Figure 1. Example of surficial geologic map of Colorado River near 55-mile bar. River flows from left to right.
A. May 14, 1965, discharge 792 m^3/s.
B. June 3, 1990, discharge 141.5 m^3/s.

Figure 2. -- Area of sediment deposits exposed at different discharges

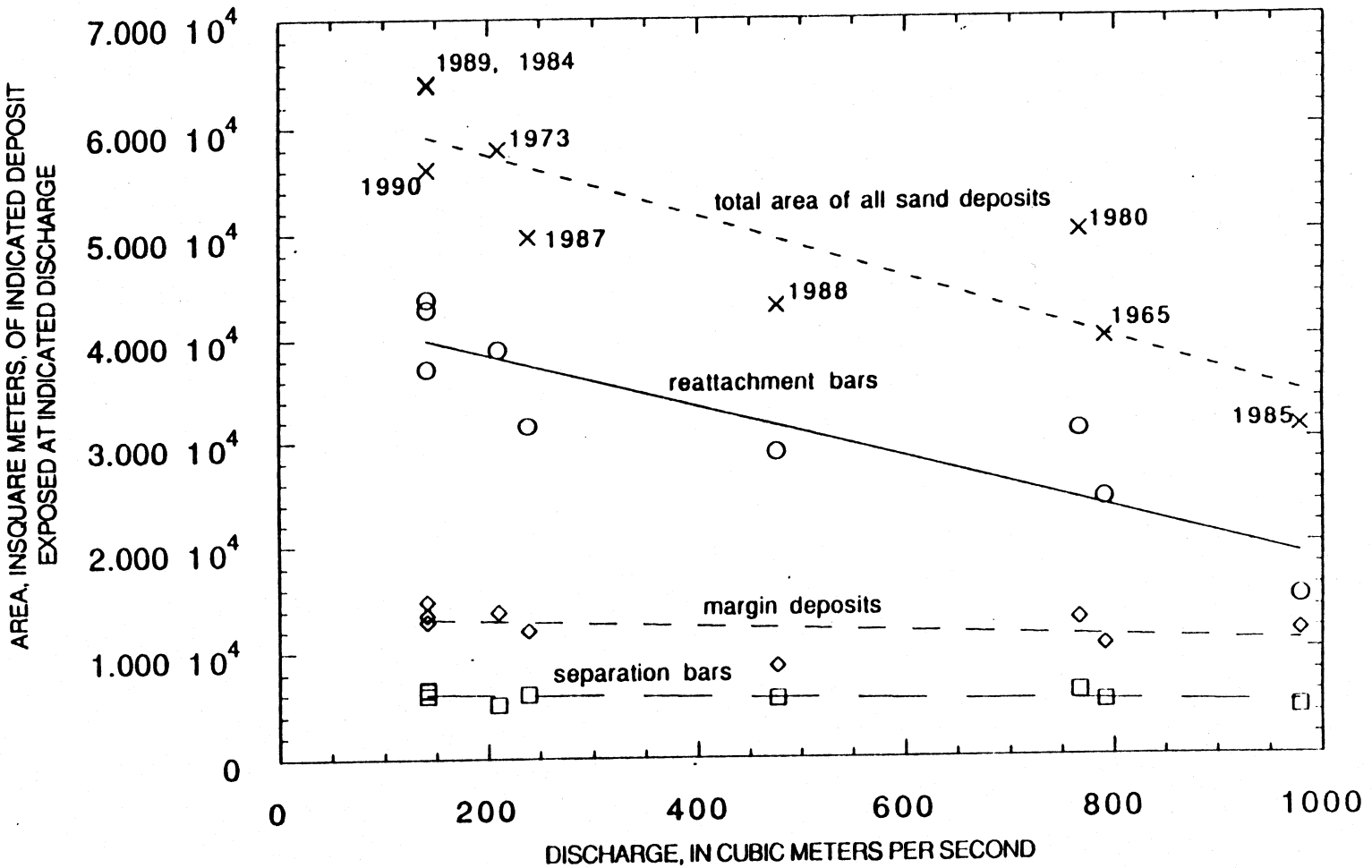
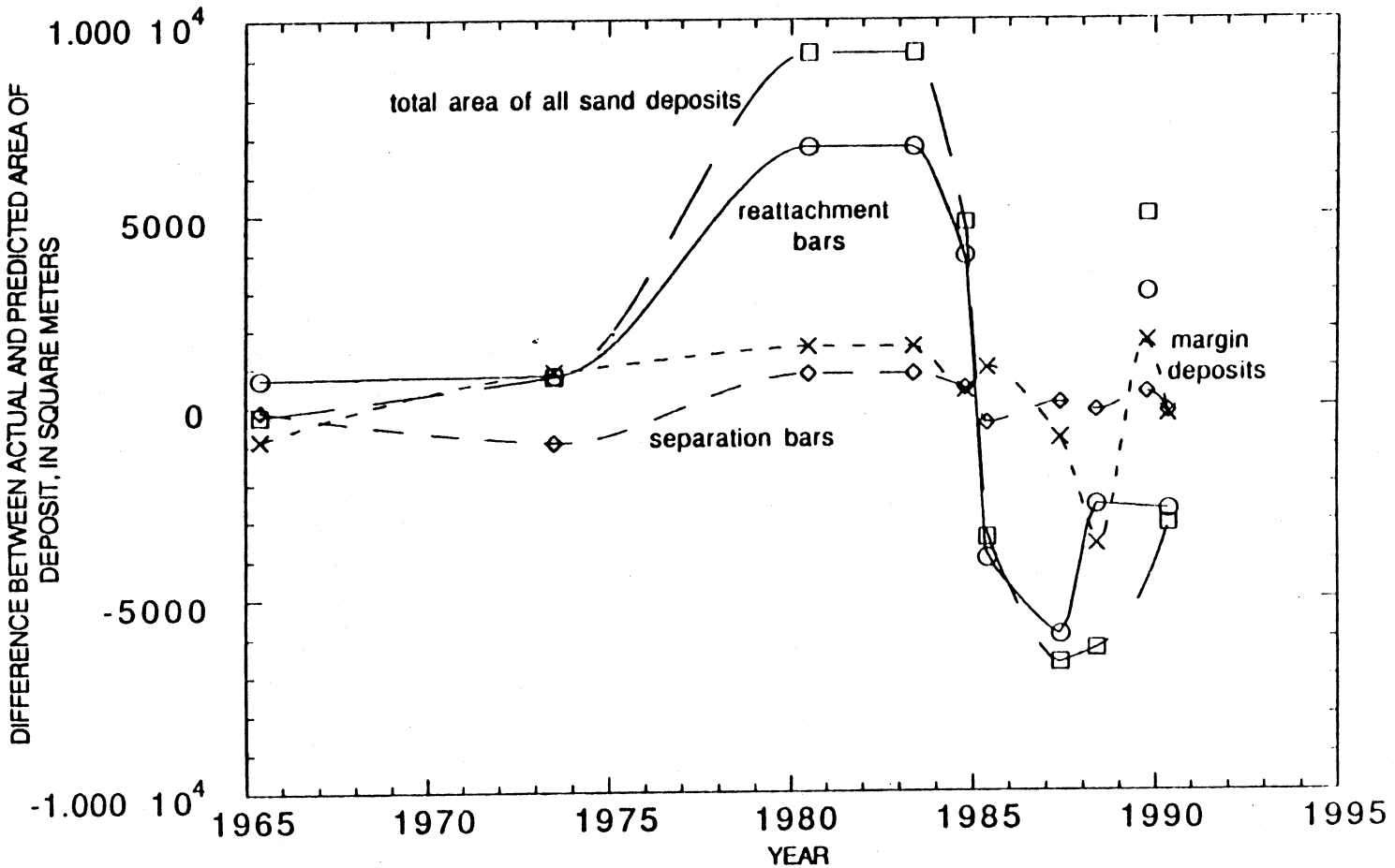
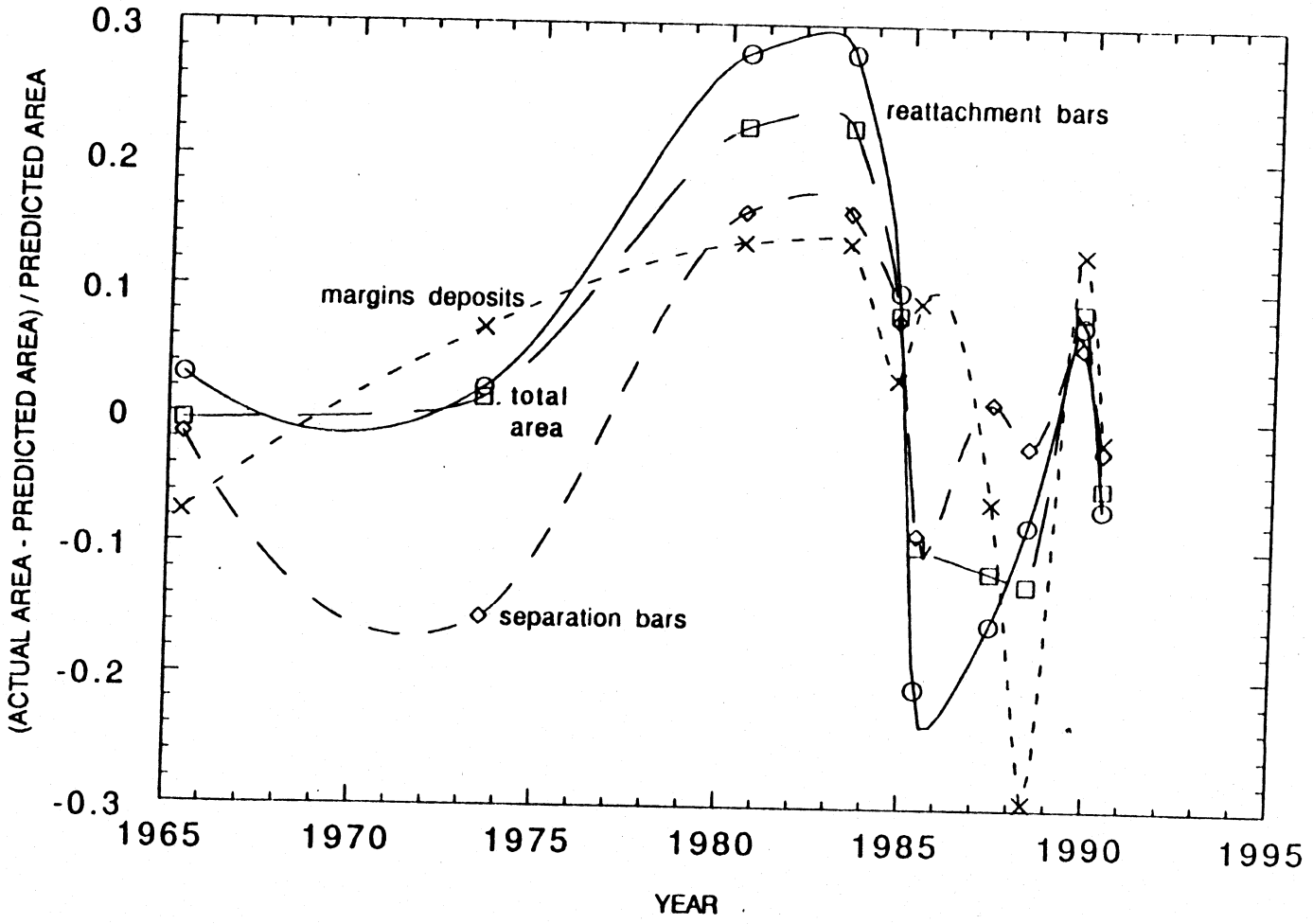


Figure 3. -- Difference between actual and predicted area of sediment deposits between river miles 55 - 56



note : Values for 1989 (reattachment bars and total area) are not connected by time-series line, although individual data points are plotted. Values for 1983 are based on field observations and not on mapping.

Figure 4. -- Proportional residual time series of deposit change between river miles 55 - 56

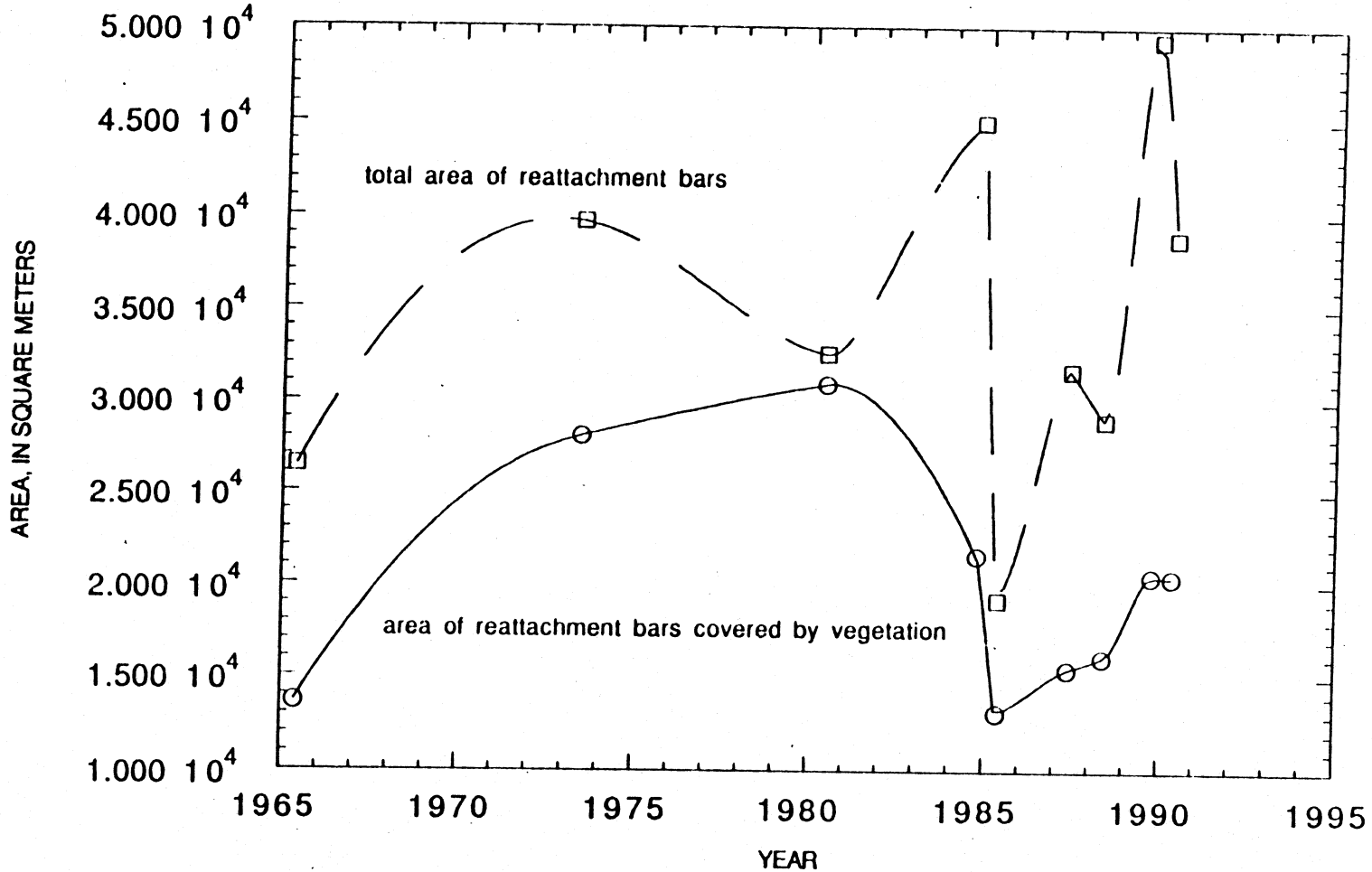


bar area in this 1.6-km reach increased by about 20 percent between 1973 - 80. Between 1983 - 86, the area of these bars decreased from +20 percent to -20 percent, a period including the high annual peak discharges of 1983 - 86. The rate of aggradation between 1987 - 90 is similiar to that of the 1973 - 80 period. The proportional change in separation-bar area is typically less than for reattachment bars, except for the 1965 - 73 period, and fails to reject the hypothesis that separation bars are more stable than reattachment bars.

Change in the area of vegetated reattachment bars is shown in figure 5. Because vegetated areas occur at elevations greater than the stage of any of the air photos, changes in vegetated area have no stage-dependent bias. Figure 5 shows that vegetation expanded its range on reattachment bars between 1965 - 80, was scoured by high discharges, and has subsequently reestablished itself in the 55 - 56 mile reach.

Collectively, these figures show that (1) reattachment bars have been subject to a greater range of aggradation and degradation than separation bars or margin deposits, (2) that all deposits increased in area from 1965 - 80, (3) that reattachment bars decreased in area during the period of high discharges from 1983 - 86, (4) that the decrease in area was greater for the period of high discharges in 1985 and 1986 than for the period of high discharges in 1983 and 1984, and (5) that the area of reattachment bars has increased since the cessation of high discharges in 1986.

Figure 5. -- Area of reattachment bars between rive mile 55 - 56, uncorrected for differences in river stage in each year



A10

DEVELOPMENT OF AN IMPROVED SEDIMENT-RATING CURVE FOR THE GRAND CANYON GAGING STATION AT PHANTOM RANCH DURING THE INTERIM FLOW PERIOD

A. ABSTRACT:

Estimation of sand budgets requires improvement of sand-rating curves by application of a physically based model to the rating-curve analysis. Monitoring of sand concentration and bed topography at the gaging station near Grand Canyon will provide the data base necessary to develop rating curves that can be used to compute meaningful transport, in support of interim flow monitoring plan item 1-k.

B OBJECTIVES:

1. Monitor bed configuration in the reach above the Grand Canyon gaging station and measure detailed velocity and sand-concentration fields at the gaged section.
2. Develop a physically based rating curve for the station.

C. JUSTIFICATION:

1. Computation of sand loss or gain in reaches between gaging stations under interim releases requires well-constrained sand-rating curves at gaging stations. Rating curves developed by purely empirical analysis from available data have an unacceptably high uncertainty. Also, rating curves developed in that way for gages downstream from the Grand Canyon gages are identical , making it impossible to use them for computation of sand budgets.
2. The long time series of discharge and sediment transport at the gaging station near Grand Canyon makes this site a critical part of a long-term monitoring program. Development of a more precise rating curve will facilitate the interpretation of historical data for comparison to interim flow conditions.

D. BACKGROUND INFORMATION AND EXISTING DATA:

Existing rating curves at the gaging stations were developed from regression analysis, and the scatter of data around the curves is typically several orders of magnitude. In 1991, an extensive suite of samples and measurements was collected at the gaging station above National Canyon to test the concept of using a local sediment transport model to generate a sand-rating curve for the site. Data included repeated surveys of bed topography at monumented cross sections in the reach above the gage and measurement of detailed velocity and suspended sand-concentration fields during research flow between January and August 1991. Analysis of data and rating-curve development are in progress for the National Canyon gage.

E. METHODS:

Methods used are those used in 1991 at the National Canyon gage. These included installation of an automatic point sampler for obtaining samples at a point at closely spaced time intervals, monitoring of bed topography at monumented cross sections in the reach above the gage, and measurement of point velocity and point suspended-sand concentration from the cableway at peak discharge of the daily hydrograph. Because interim flows will not range as widely or be as variable as the research flows, fewer sampling intervals are planned for this site than were sampled for the National Canyon gage. Methods are described in detail in the report of the National Canyon rating-curve development.

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F. INTEGRATION WITH OTHER MONITORING EFFORTS:

This work is an integral part of main channel flow and sediment monitoring. Results of this work are required for meaningful analysis of the data collected as a part of that monitoring program.

G. PRODUCTS TO BE DEVELOPED:

1. A data set suitable for current and future development of local sediment-transport models.
2. An improved suspended sand-rating curve for the Grand Canyon gaging station.
3. A long-term monitoring plan for the Grand Canyon gage.
4. Quarterly reports of progress and data acquired in the previous quarters.

H. TIME TABLE:

Bed topography and suspended-sand and velocity fields will be monitored during interim flows in the spring and early summer of 1992. Laboratory analysis and rating-curve development will be completed in fiscal year 1993.

I. BUDGET ATTACHED

Budget includes both fiscal years 1992 and 1993. Fiscal year 1992 costs are $79,700, 33 percent of the total costs, which are $245,600.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigators J.D. Smith/J.B. Graf Date Submitted 2/26/92

Department/Laboratory WRD-National Res. Program Organization USGS
WRD Arizona District

Beginning Date 3/1/92 Completion Date 9/30/93

Project Title Development of improved sediment-rating curve for the Grand Canyon Gaging station at Phantom Ranch during the interim flow period

Budget Estimate

	Person/Mos Cal	Acad	Sumr	Total Amount
A. SENIOR PERSONNEL				$ 14,000
1. J.D. Smith Estimated in Other Sources (K)	3			0
2. J.B. Graf	3			(14,000)
3.				
B. OTHER PERSONNEL				82,900
1. (X) Post Doctoral Associates	7.5			(30,000)
2. (X) Other Professional (techs.)	11.9			(41,800)
3. ( ) Graduate Students	7.4			(11,100)
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical Included in Indirect Costs(I)				-------
6. ( ) Other				
C. FRINGE BENEFITS Included in Salaries A2, B1, and B2				-------
D. PERMANENT EQUIPMENT				0
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				8,500
1. Domestic				
a. Principals				(2,000)
b. Others				(6,500)
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel Included in Travel E1				-------
3. Subsistence Included in Travel E1				-------
4. Other				

G. OTHER DIRECT COSTS	$ 34,600
1. Materials and Supplies	(9,600)
a. Telephone Included in Indirect Costs (I)	-------
b. Other	
2. Publication Costs	(8,000)
3. Consultant Services Included in Indirect Costs (I)	-------
4. Computer Services Included in Indirect Costs (I)	-------
5. Subcontracts	
6. Other Equipment rental, Sediment analyses	(17,000)
H. TOTAL DIRECT COSTS (A through G)	140,900
I. INDIRECT COSTS	105,600
J. TOTAL DIRECT AND INDIRECT COSTS (Smith salary and indirect costs)	245,600
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	23,400
L. TOTAL PROJECT AMOUNT (J + K)	$ 269,000

Itemize Capital Equipment to be Purchased in FY____

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight Charges

A11

MONITOR MOVEMENT OF SAND IN REACHES BELOW THE PARIA AND LITTLE COLORADO RIVERS DURING THE INTERIM FLOW PERIOD

A. ABSTRACT:

Monitoring of sand storage changes in reaches below the mouths of the Paria and Little Colorado Rivers and application of flow and sand flux models will allow estimation of rates and locations of deposition downstream from these major sand sources during the interim flow releases. The work is in support of interim flow monitoring plan, Item 1-d.

B. OBJECTIVE:

Document the movement of sand in reaches downstream from the Paria and Little Colorado Rivers.

C. JUSTIFICATION:

Because of the severely limited range of the interim flows, the next 2 years will be a period of substantial net deposition of sand in the Canyon. It is very important to determine how material that is added from the Paria and Little Colorado Rivers is first deposited in the main stem Colorado and how and at what rate it is moved downstream. These are difficult but very important tasks and can be accomplished only with a careful blend of data collection and fluid mechanically based analysis supplemented with the various flow and sediment transport models that are currently under development.

D. BACKGROUND:

We know from previous work that sand is deposited in patches and lenses and, in many cases, fills the spaces between the cobbles and boulders rather than smoothly increasing the elevation of the bed over large regions. Certainly, it is not uniformly distributed over the cross section. To some extent, these patches move from place to place as the sand is transported downstream; therefore, measurements of bed-surface elevation at a small number of poorly selected sites are of limited value. As a consequence of the limited range of interim flows, sand-transport rates will be small and difficult to measure accurately. Sand-accumulation rates probably will fall rapidly with distance downstream from the junctions of the two major tributaries, making deposit volume assessment difficult except near these two sand sources. Moreover, at these low discharges, ephemeral deposition and erosion of silt will cause large errors in sand-volume estimates. These problems require focusing the sand volume monitoring effort on the upstream part of the Canyon and using the data in close coordination with the accurate flow and sand flux models currently under development. In this manner the signal to be measured can be maximized, noise in the data can be filtered by comparison to the trends of data from many locations collected at a variety of times and stages, and the rates and locations of deposition at downstream sites then can be estimated using the model.

E. METHODS:

We propose to establish monumented cross sections at five points in each of five reaches downstream from the Paria and Little Colorado Rivers. This would be 25 cross sections downstream from the mouth of each river. Near the mouths of the two major sand contributing tributaries, deposition rates will be large enough that appropriate sections can be readily identified

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the best sand deposition monitoring procedure is to first determine the bed topography and roughness in relatively long segments downstream from the Paria and Little Colorado Rivers. Experience here shows that this can be done efficiently by zigzagging from bank to bank while moving upstream with a precise digital echo sounder and continuously locating the vessel with a modern laser ranging device designed specifically for this purpose. Owing to the broad spectrum of variations in bed elevation, the upstream gain on each zigzag must be no more than 0.2 times the mean river width in that reach. Once a complete bed-elevation data set has been obtained, a quasi-three-dimensional flow model can be run through this channel allowing areas of erosion and of deposition to be identified and thus permitting bed elevation monitoring sites to be located over large areas of persistent deposition. A good set of deposition monitoring sites needs to be selected and monumented by the second year of the interim flows. An intense interpretative component of this effort is essential; a completely empirical and bed elevation monitoring program in the far field will not yield useful results because of the inability to measure local bed elevation with the required precision.

Cross-section geometry will be monitored twice in fiscal years1992 and four times in fiscal year 1993. Monitoring would consist of stretching a tagline across the river at the monumented section and traversing the section under the tagline with a boat or raft equipped with an echosounder. About 10 traverses of each section would be made for each section measurement, in order to define the mean geometry in the narrow zone covered by the boat. Cross sections measured with this technique at National Canyon in 1991 were found to be reproducible to within 5 cm. The budget for 1992 provides for a 3-week raft trip to select, monument, and do the first measurement on the cross sections that can be selected immediately, a 4-week trip to make the bathymetric measurements of the longer reaches, and one additional trip to monitor the cross sections. Labor includes four people from the Arizona District. Costs for raft support and extra gasoline required for surveys are assumed to be covered under the GCES contract and so are not included in the budget.

F. INTEGRATION WITH OTHER MONITORING EFFORTS:

This effort complements the sediment-data collection at Paria River and LCR station (IFMP-1E) as this effort will yield data on sediment volumes that likely originated from flow events in the tributaries during the interim flow period.

G. PRODUCTS TO BE DEVELOPED:

1. Maps showing the bottom configuration (topography) for each survey for each reach.
2. Maps showing net change in topography between surveys for each reach.
3. Quarterly reports on progress, including data collected, processed, and reviewed in the previous quarter.
4. Report describing study and computing volume of sediment change that occurs in each reach.

H. TIME TABLE:

Surveys will begin as soon as possible, with the bathymetric survey, initial cross-section measurements, and one resurvey of cross sections in 1992. The map products will be available within three months of the survey and the final report available in December 1993.

L BUDGET ATTACHED.

Budget is for both fiscal years 1992 and 1993. Fiscal year 1992 costs are $143,900, 47 percent of the total costs, which are $305,200.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigators J.D. Smith/J.B. Graf Date Submitted 2/26/92

Department/Laboratory WRD-National Res. Program Organization USGS
WRD Arizona District

Beginning Date 3/1/92 Completion Date 9/30/93

Project Title Monitor movement of sand in reaches below the Paria and Little Colorado River during the interim flow period

Budget Estimate

	Person/Mos Cal	Acad	Sumr	Total Amount
A. SENIOR PERSONNEL				$ 14,000
1. J.D. Smith Estimated in Other Sources (K)	3			0
2. J.B. Graf	3			(14,000)
3.				
B. OTHER PERSONNEL				117,500
1. (X) Post Doctoral Associates	7.5			(30,000)
2. (X) Other Professional (techs.)	21.4			(74,800)
3. ( ) Graduate Students	8.5			(12,700)
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical Included in indirect costs(I)				-------
6. ( ) Other				
C. FRINGE BENEFITS Included in Salaries A2, B1, and B2				-------
D. PERMANENT EQUIPMENT				0
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				18,000
1. Domestic				
a. Principals				(4,000)
b. Others				(14,000)
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel Included in Travel E1				-------
3. Subsistence Included in Travel E1				-------
4. Other				

G. OTHER DIRECT COSTS	$ 21,400
1. Materials and Supplies	(9,400)
a. Telephone Included in Indirect Costs (I)	-------
b. Other	
2. Publication Costs	(8,000)
3. Consultant Services Included in Indirect Costs (I)	-------
4. Computer Services Included in Indirect Costs (I)	-------
5. Subcontracts	
6. Other Equipment rental	(4,000)
H. TOTAL DIRECT COSTS (A through G)	170,900
I. INDIRECT COSTS	134,300
J. TOTAL DIRECT AND INDIRECT COSTS (Smith salary and indirect costs)	305,200
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	23,400
L. TOTAL PROJECT AMOUNT (J + K)	$ 328,600

Itemize Capital Equipment to be Purchased in FY____

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight Charges

MONITOR DEBRIS-FLOW DEPOSITS, SEDIMENT SOURCES, AND CHANNEL CONTROL DURING THE INTERIM FLOW PERIOD

A. ABSTRACT:

The magnitude and frequency of debris flows in the Grand Canyon National Park is not known in enough detail to make accurate long-term predictions of debris-fan effects on hydraulic controls of the river and quantity of material contributed to the Colorado River. Monitoring changes in debris-fan topography and development of a model for the size and occurrence of debris flows is, therefore, a necessary aspect of main-channel flow and sediment-transport modeling. An understanding of the magnitude and frequency of debris flows is necessary for estimating sediment delivery to the main channel for ungaged tributaries, for understanding factors about beach stability that are not related directly to interim flows, and for understanding the stability and location of beaches in the Grand Canyon.

B. OBJECTIVES:

1. To determine the frequency of debris flows that have occurred in the Grand Canyon in the last century.
2. To estimate the magnitude of historical debris flows in selected tributaries.
3. To determine the effects of debris flows on rapids and beaches by direct observation of flows that occur during the interim flow period and for selected historical flows.
4. To complete development of a probabilistic models of sediment delivery from debris flows.

C. JUSTIFICATION:

1. To determine more precisely the quantity of the sediment supplied to the river and the associated sediment-accumulation rates during the interim flow period.
2. To better assess the present and future likelihood of sediment supply from debris flows.
3. To acknowledge that the opportunity to make such observations exist in the interim flow period and that their influence on sediment supply, transport, and deposition will documented.
4. To better assess the present and future likelihood of sediment supply from debris flows.

D. BACKGROUND:

Debris flows occur commonly in arid regions with flash-flood precipitation and steep topography, such as the Grand Canyon. They are rarely observed, however, because of their relative short duration and wide spatial distribution. Nevertheless, the geomorphic results of debris flows are dramatic; that is, their influence on the configuration of the channel, rapids, eddies, and associated beach deposits are significant over short and long time scales. Geomorphic phenomena are inferred from the sorts of approaches being proposed here.

E. METHODS:

A combination of field methods will be applied in this work, including study of historical photographs, dendrochronology, and radio-isotope methods.

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Historical debris flows can be evaluated using the abundant photographs that exist along the Colorado River corridor (Turner and Karpiscak, 1980). These include photographs taken by Robert Brewster Stanton in 1890 at approximately 1-mile intervals, photographs by Jack Hillers of the Powell expedition in 1872, and extensive photographs taken during a USGS expedition in 1923. Aerial photographs, which were taken as early as 1935 also record the occurrence and characteristics of debris flows. Analysis of the damage, whether direct scarring or indirect ring suppression caused by burial or root damage are additional methods for dating debris flows. Radio-carbon dating offers yet another option for aging organic materials entrained in older flows.

The magnitude of debris flows is estimated by inferring the velocities from "run-up" or super-elevation evidence in bends and the inferred velocity. Discharge is estimated from measurement of local cross-sectional areas. Magnitude can also be estimated by examination of the size of the slope failure that initiates the flow and from the amount and size of material that is mobilized from the channel.

The particle-size distribution of debris flows can be obtained from direct measurement of lateral debris-flow deposits and deposits on debris fans adjacent to the river.

The extent of changes to rapids and beaches associated wtih a recent debris flow (1989 at mile 127.5) by the interim flows will be monitored with appropriate benchmark evaluation.

F. INTEGRATION WITH OTHER MONITORING EFFORTS:

The contribution of sediment to the Colorado River is an essential input to the sediment-routing models. Debris-flow contributions and those from ungaged tributaries must be known to interpret sediment transport and potential deposition in the main channel during the interim-flow regime.

G. PRODUCTS TO BE DEVELOPED:

Reports and manuscripts for the refereed literature describing the results of this work. Quarterly reports on progress and data collected in previous quarter.

H. TIME TABLE:

One survey has just been completed (February 1992). Once a year (fall), three debris-flow deposits (post 1983) and any new ones that occur will be visited. Reports will be available within 3 months of the survey and a final report will be prepared for delivery in December 1993.

I. BUDGET (ATTACHED):

Costs included both FY92 and FY93. FY92 costs are $88,500 or 54 percent of the total cost of $164,300.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator R.H. Webb Date Submitted 2/26/92

Department/Laboratory WRD National Res. Program Organization USGS

Beginning Date 3/1/92 Completion Date 9/30/93

Project Title Monitor debris-flow deposits, sediment sources, and channel control during the interim flow period

Budget Estimate

	Person/Mos Cal	Acad	Sumr	Total Amount
A. SENIOR PERSONNEL				$ 8,400
1. R.H. Webb Estimated in Other Sources (K)	8			0
2. J.C. Schmidt			2	(8,400)
3.				
B. OTHER PERSONNEL				46,200
1. ( ) Post Doctoral Associates				
2. (X) Other Professional (techs.)	6			(21,000)
3. (X) Graduate Students	12			(18,000)
4. (X) Undergraduate Students	6			(7,200)
5. ( ) Secretarial/Clerical Included in Indirect Costs(I)				-------
6. ( ) Other				
C. FRINGE BENEFITS Included in Salaries A2, B2, B3, B4				-------
D. PERMANENT EQUIPMENT				0
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				10,000
1. Domestic				
a. Principals				(7,000)
b. Others				(3,000)
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel Included in Travel E1a,b				-------
3. Subsistence Included in Travel E1a,b				-------
4. Other				

G. OTHER DIRECT COSTS	$ 47,900
1. Materials and Supplies	(2,500)
a. Telephone Included in Indirect Costs (I)	-------
b. Other Photography	(3,000)
2. Publication Costs	(6,000)
3. Consultant Services Included in Indirect Costs (I)	-------
4. Computer Services Included in Indirect Costs (I)	-------
5. Subcontracts Analyses--sediment, radiocarbon	(36,400)
6. Other	
H. TOTAL DIRECT COSTS (A through G)	112,500
I. INDIRECT COSTS	51,800
J. TOTAL DIRECT AND INDIRECT COSTS	164,300
(Webb salary and indirect costs)	
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	63,100
L. TOTAL PROJECT AMOUNT (J + K)	$ 227,400

Itemize Capital Equipment to be Purchased in FY____

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight Charges

GLEN CANYON ENVIRONMENTAL STUDIES

DRAFT

INTERIM FLOW MONITORING PROPOSALS

CULTURAL RESOURCES

CULTURAL RESOURCES

CULTURAL RESOURCES

B1

MONITORING OF ARCHAEOLOGICAL SITE CONDITION ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK

Janet R. Balsom
Principal Investigator
Division of Resources Management
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Grand Canyon, Arizona 86023
(602)638-7758 or FTS 765-7758
FAX (602)638-7753 or FTS 765-7753

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Monitoring of Archaeological Site Condition Along the Colorado River in Grand Canyon National Park.

Principal Investigator: Janet R. Balsom, National Park Service, Grand Canyon National Park

Abstract: This study is an outgrowth of the 100% archaeological survey of the Colorado River corridor through Glen and Grand canyons conducted by the National Park Service during 1990 and 1991. A total of 475 sites were recorded during the survey, with 336 considered as impacted or potentially affected by flows from Glen Canyon Dam. The National Historic Preservation Act (as amended 1980) requires federal agencies to assess the impacts of their actions on sites which may be eligible for inclusion in the National Register of Historic Places. Of the 336 sites potentially affected, 313 have been determined eligible for the National Register, and an additional nine remain unevaluated until further information is collected. In order to fulfill compliance requirements under the Act, determination of effect must be completed and a program agreed upon by the land management agencies, State Historic Preservation Officer, Advisory Council on Historic Preservation and interested Indian tribes. This project fulfills part of the compliance requirements under Section 106 of NHPA.

Monitoring of Archaeological Site Condition Along the Colorado River in Grand Canyon National Park.

Principal Investigator: Janet R. Balsom, National Park Service, Grand Canyon National Park

Objective

The objective of this study is to develop comparative data necessary to evaluate impacts from interim flows to a specified number of archaeological sites which occur along the Colorado River corridor.

This study will conform to the monitoring stipulation required by the Programmatic Agreement between the Bureau of Reclamation, National Park Service, Advisory Council on Historic Preservation (ACHP), and the Arizona State Historic Preservation Officer (SHPO). Interested tribal organizations are concurring parties to the agreement. The monitoring program is to be in place within three months of the execution of the Programmatic Agreement.

Justification

An objective of the moderated fluctuations during the interim flow period was to reduce the erosion caused by wide daily fluctuations, thereby benefiting the sediment balance and margin deposits which contain valuable cultural resources. The study will assess site conditions in various indirect and direct impact categories during the interim flow period and compare with baseline conditions established pre-interim flow.

Background and Existing Data

An archaeological survey was completed as part of the Glen Canyon Environmental Studies, Phase II, of the entire river corridor from Glen Canyon Dam to Separation Canyon. A distance of 255 river miles was included in the survey, encompassing slightly over 10,500 acres. A total of 475 archaeological sites were recorded, and an additional 489 isolated occurrences located during the eight month survey effort. Of the 475 sites recorded, 336 were determined to be impacted, or potentially affected by flows from Glen Canyon Dam. As required by the National Historic Preservation Act (NHPA) (as amended 1980), these sites were evaluated for inclusion on the National Register of Historic Places. A total of 313 contributing properties have been identified within the area of potential effect along the river corridor. An additional nine sites remain unevaluated and will require test excavations to provide the information necessary for evaluation.

In order to evaluate site condition and impacts as they relate to

the operation of Glen Canyon Dam, it was necessary to evaluate each site based on defined criteria for impacts. The impact analysis relied upon field observations. Assumptions about potential impacts were based on our current understanding of erosion processes along the river. Four generalized categories were used to classify impacts: direct, indirect, potential and no impact. Within the four categories, additional indirect and potential impacts subcategories were identified (Fairley et al 1991:261-263). Impacts or potential impacts were noted for 70% (336) of the sites in the river corridor.

Evaluation of impacts must be considered in relation to the criteria of effect set forth in 36 CFR 800. "An undertaking shall be considered to have an effect whenever any condition of the undertaking causes or may cause any change, beneficial or adverse, in the quality of the historical, architectural, archaeological, or cultural characteristics that qualify the property to meet the criteria of the National Register (36CFR 800.3)". The Arizona State Historic Preservation Officer has evaluated the 336 sites that are considered to have direct, indirect, or potential impacts from river flows. Of the 336 sites, 313 have been determined eligible for inclusion on the National Register, 14 ineligible, and 9 sites remain unevaluated until a testing program is completed. The remaining 139 sites have not been evaluated.

Given the determinations of eligibility and the impacts defined, all sites within the affected environment of this project are considered to have an "adverse effect" determination based upon the possibility of "... destruction or alteration of all or part of the property" (36CFR 800.3b1). "An effect may be direct or indirect. Direct effects are caused by the undertaking and occur at the same time and place. Indirect effects include those caused by the undertaking that are later in time or farther removed in distance, but are still reasonably foreseeable" (36CFR 800.3a).

Federal agencies have been directed by the Advisory Council on Historic Preservation concerning treatment of archaeological properties. Preferred treatment of these properties is preservation in place. If preservation in place is not practical, appropriate mitigation measures should be developed through consultation with the State Historic Preservation Officer, the Council, and affected Indian tribes. This consultation process and the ensuing mitigation measures take the form of a Programmatic Agreement. Procedures have begun for the drafting of a Programmatic Agreement between the Bureau of Reclamation, National Park Service, ACHP and SHPO.

Methods

The methodology for monitoring will be very specific to the resources of concern and will be dictated by the agreements made in the Programmatic Agreement. In all likelihood, not all sites will be included in the monitoring program; a sample of sites

(approximately 20%) from the four major impact categories will probably be selected for interim flow monitoring. The methods to be employed in the monitoring program will likely be consistent with the initial survey documentation methods. Field inspection of sites, along with comparative photography will probably constitute the majority of the monitoring program. Remote cameras and time-lapse photography may also be employed. The details of the methodology will be established as a part of the Programmatic Agreement discussed above. A plan for monitoring the effects of the interim operating criteria governing the release schedule for Glen Canyon Dam should be in place within three months of the execution of the Programmatic. The monitoring plan will include measures by which adverse effects will be avoided or minimized.

In addition to the in-field archaeological monitoring, consultation with the affected tribes is required by NHPA and the Native American Graves and Repatriation Act (1990). This is especially important in site areas which have the potential to contain human remains (i.e. any habitation area). As the threat of erosion to these sites continues, the possibility of erosion of human remains exists.

Execution of this project will be done in cooperation with the Archaeology Laboratory at Northern Arizona University. A cooperative agreement exists between Grand Canyon National Park and the university for the needs of this project.

Integration with Other Efforts

The project described in this proposal is fully integrated with the erosion studies ongoing by USGS through Richard Hereford and Ivo Lucchitta. The information provided by the geomorphic studies is an integral component of the site monitoring program. Although the selection of sites to be monitored is contingent upon the Programmatic Agreement, it is likely that some of the sites chosen will be selected based on erosion criteria developed by Hereford and others.

This project is integrated with the other sediment studies on-going by USGS, Utah State University, and National Park Service. This integration is mainly in the form of information sharing and coordination of study sites between archaeological needs and the geomorphic studies.

Products to be Developed

The products to be developed by this project will be determined by the Programmatic Agreement. It is likely that the results of this monitoring program will be developed into a Historic Preservation Plan for the management of the sites located along the Colorado River corridor. The format for the plan will follow guidelines set forth by the Advisory Council.

Timetable

The timetable for this project is dependant upon the Programmatic Agreement. In all probability, the monitoring program will be in place within three months of the execution of the agreement. The budget attached to this proposal represents funding for Fiscal Year 1992.

References

Fairley, Helen C., and Peter W. Bungart, Christopher M. Coder, Jim Huffman, and Terry L. Samples and Janet R. Balsom
1991 "The Grand Canyon River Corridor Survey Projects: Archaeological Survey along the Colorado River between Glen Canyon Dam and Separation Canyon". Draft report on file Grand Canyon National Park, Arizona and Glen Canyon Environmental Studies, Flagstaff, Arizona.

B2

MONITORING OF HOPI CULTURAL VALUES

AT RESOURCE SITES WITHIN

GLEN AND GRAND CANYONS

Michael Yeatts
Principle Investigator
Hopi Cultural Preservation Office
P.O. Box 123
Kykotsmovi, Arizona 86004
(602) 734-2441
FAX (602) 734-2331

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Abstract

The Hopi Tribe proposes to acquire baseline data to access the degree to which interim flows are impacting Hopi cultural values in the Grand Canyon. This information is necessary for use in fully evaluating the nature and extent of impacts to cultural resources prior to developing mitigative efforts. The information obtained will be used in conjunction with that obtained by the Park Service through their archaeological site monitoring program to fulfill the requirements of cultural resources legislation. Much of the work will be coordinated with the Park Service Division of Resources Managment.

Objectives

The objectives of this study are to access to what degree Hopi cultural values within the Grand Canyon Corridor are being impacted by the interim flow regime. This will be complimentary work to that proposed by the Park Service for archaeological site monitoring, as required by the Programmatic Agreement between the Bureau of Reclamation, the National Park Service, the Advisory Council on Historic Preservation, and the Arizona State Historic Preservation Office, and will be coordinated with their study. The need for primary Hopi involvement stems from the sacred and esoteric nature of the information being sought. While the physical degradation of sites can and will be measured through the Park Service monitoring, impacts to cultural values can only be accessed by the affected cultural group.

Justification

Implementation of the interim flows was an attempt to moderate the rate of degradation to resources in the Grand Canyon. The degree of success that is being achieved can only be ascertained through monitoring of the resources. In the case of cultural resources, this is mandated through various regulations (the National Historic Preservation Act, the Archaeological Resources Protection Act, the Native American Graves Protection and Repatriation Act, the American Indian Religious Freedom Act). Several of these laws require Native American participation in order to fulfill their intent. In order for this to adequately be achieved, direct Native American involvement in the monitoring of cultural resource sites must occur, as impacts to some classes of cultural values can only be evaluated by the affected Native American group.

Background Information

The Park Service has concluded a Class III cultural resources inventory of the Colorado River corridor between Glen Canyon Dam and Separation Canyon as a portion of the Phase II Glen Canyon Environmental Studies. Of the 475 archaeological sites identified by the survey, 336 were found to have been impacted either directly or indirectly by the operations of Glen Canyon Dam and of these, 313 have been determined to be eligible for inclusion on the National Register of Historic Places (NRHP). For sites determined to be eligible for inclusion on the NRHP, the nature and extent of impacts to these resource caused by federal undertakings, and subsequent efforts needed to mitigate these impacts must be accessed. The assessment and subsequent mitigation must take into account concerns of Native Americans and this requires direct involvement by relevant tribes.

As a cooperating agency in the Glen Canyon Environmental Studies, part of the research that the Hopi Tribe has been undertaking has been to examine the concerns of the Hopi people for resources in the Grand Canyon region. This has identified the long association that the Hopi have with the Grand Canyon by virtue of it being an ancestral homeland and as focus of spiritual significance. Important resource classes have been identified, however, mitigative options for individual sites have not been determined as this will depend on the nature and extent of impacts occurring and specific cultural values present at the site. Field evaluation by relevant tribal individuals will be needed to make these assessments. Monitoring of the resources from the traditional cultural standpoint during the interim flows is an integral part in the fulfillment of cultural resources legislation.

Methods

The monitoring of cultural resource impacts during the interim flow period will be accomplished through two lines of action. First, field visitation of selected cultural resource sites will be undertaken with appropriate Hopi members. This will be done at intervals in conjunction with Park Service monitoring trips. Cultural values identified by Hopi elders will be targeted for evaluation of interim flow impacts.

The second aspect of the research will focus on evaluation of data resulting from other monitoring efforts, again with a Hopi cultural orientation. Much of this will be coordinated with the Park Service monitoring of archaeological sites, a number of which are of specific concern to the Hopi. Likewise, the results of geomorphological, hydrological, and other work related to sediment loss from cultural sites will be continuously reviewed in order to identify additional areas of potential concern that may require more in-depth monitoring and field visitation.

Integration with Other Monitoring Efforts

The work will be closely coordinated with the monitoring and mitigation work being undertaken by the Park Service. The results of the Hopi work will be tied directly into the implementation of Section 106 mitigative efforts, as required by Federal and State laws.

Products to be Developed

Periodic reports as needed will be prepared for the Park Service in order to fulfill the requirements of cultural resource legislation. The timetable and frequency of these will be determined during the development of the programmatic agreement. Bi-annual progress reports to Bureau of Reclamation will be prepared, beginning six months after signature of the contract.

Timetable

Examination of data resulting from research by other cooperating agencies will commence as soon as the data are available. Dates for field visitation to monitor sites will be contingent on Park Service selection of sites and implementation of the Programmatic Agreement.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principle Investigator Michael Yeatts Date Submitted 2-26-92

Department/Laboratory Hopi Tribe/ GCES Organization Hopi Tribe

Beginning Date 5-1-92, proposed Completion Date One year from beginning date

Project Title MONITORING OF HOPI CULTURAL VALUES AT RESOURCE SITES WITHIN GLEN AND GRAND CANYONS

Budget Estimate

	Amount
A. Senior Personnel Principle Investigator	$ 2000.00
B. Other Personnel Cultural Advisors	$ 4000.00
C. Fringe Benefits (@ 18% of P.I. salary)	$ 360.00
D. Permanent Equipment	
E. Travel Domestic (all personnel)	$ 2000.00
F. Participant Support Costs	
G. Other Direct Costs Office supplies	$ 250.00
H. Total Direct Costs	$ 8610.00
I. Indirect Costs (33.6 % of P.I. salary)	$ 672.00
J. Total Direct and Indirect Costs	$ 9282.00
K. Estimated Amount from Other Sources	
L. Total Project Amount	$ 9282.00

** note - 4 river trips to monitor sites are proposed. These will be coordinated with the Park Service monitoring trips. GCES support will be necessary for these trips.

MONITORING OF ARCHEOLOGICAL SITE CONDITION ALONG THE COLORADO RIVER IN GLEN CANYON NATIONAL RECREATION AREA

Addendum to:

MONITORING OF ARCHEOLOGICAL SITE CONDITION ALONG THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK

Chris Kincaid, Principal Investigator, Division of Resources Management

Objective

The objective of this study is to develop comparative data necessary to evaluate impacts from interim flows to a specified number of archeological sites which occur along the Colorado River corridor within the park.

This study will conform to the monitoring stipulation required by the Programmatic Agreement between the Bureau of Reclamation, National Park Service, Advisory Council on Historic Preservation (ACHP), and the Arizona State Historic Preservation Officer (SHPO). Interested tribal organizations are concurring parties to the agreement. The monitoring program is to be in place within three months of the execution of the Programmatic Agreement.

Justification

An objective of the moderated fluctuations during the interim flow period was to reduce the erosion caused by wide daily fluctuations, thereby benefiting the sediment balance and margin deposits which contain valuable cultural resources. The study will assess site conditions in various indirect and direct impact categories during the interim flow period and compare with baseline conditions established pre-iterim flow.

Background and Existing Data

The fifteen miles of river corridor located within Glen Canyon National Recreation Area were intensively surveyed by crews from Grand Canyon National Park during their intensive survey of the river corridor completed in 1991. Sites identified within GLCA were included in the evaluation and assessment processes which are ongoing with that effort.

Methods

The methodology used for monitoring will be very specific to the resources of concern and will be dictated by the agreements made in the Programmatic Agreement. In all likelihood, not all sites will be included in the monitoring program; a sample of sites will be systematically selected.

Methods will be consistent with initial documentation methods. Field inspection of sites, along with comparative photography will probably constitute the majority of the monitoring program. Remote cameras and time-lapse photography may also be employed.

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Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator: Chris Kincaid Date Submitted: 3/7/92

Department/Laboratory: Division of Resources Mgmt Organization: Glen Canyon NRA

Beginning Date: 3/15/92 Completion Date: 9/30/92

Project Title: Monitoring of Archeological Site Condition Along the Colorado River in Glen Canyon National Recreation Area

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. PI (NPS-GLCA)				no cost
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (2) Other Professional (techs.)			5 mos @	$18,000
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				
b. Others				$1000
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	$3000
b. Other (cameras, film, boat support)	
2. Publication Costs	
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	$18,000
I. INDIRECT COSTS	4,000
J. TOTAL DIRECT AND INDIRECT COSTS	$22,000
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
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3.	
4.	
5.	
TOTAL	

*Including Freight charges

GLEN CANYON ENVIRONMENTAL STUDIES

DRAFT

INTERIM FLOW MONITORING PROPOSALS

AQUATIC RESOURCES

AQUATIC RESOURCES

AQUATIC RESOURCES

C1

GLEN CANYON ENVIRONMENTAL STUDIES

PHASE II

INTERIM FLOW MONITORING PROPOSAL

Submitted By

Research Branch
Arizona Game and Fish Department
Phoenix, Arizona

To

Bureau of Reclamation
Upper Colorado Region
Glen Canyon Environmental Studies Office
Flagstaff, Arizona

February 26, 1992

ABSTRACT

Since the cessation of Glen Canyon Environmental Studies Phase II (GCES II) controlled research flows on July 31, 1991, releases of water from Glen Canyon Dam have been regulated in an attempt to diminish impacts of dam operations on downstream natural, cultural, and recreational resources. Interim operational criteria presently in force will be continued until finalization of the Glen Canyon Dam Environmental Impact Statement, now scheduled for mid-1994. Whether existing dam operations are having the desired effects on these resources is of concern to involved federal and state agencies, Native American tribes, electric utilities, and the public. In order to make these determinations, it is necessary to develop and institute a substantive and scientifically credible monitoring program. This proposal provides methods for interim flow monitoring of water chemistry (plant nutrients and organic matter) and the aquatic biota used as food resources by fishes. To provide comparisons with previous Arizona Game and Fish Department (AGFD) studies during GCES I and II, monitoring activities will be concentrated in the Lake Powell forebay, Glen Canyon Dam, and the 25 km of tailwater between the dam and Lee's Ferry.

OBJECTIVES

Water Chemistry--An objective of the interim flow criteria is to maintain or improve water quality through controls on input water temperature, dissolved oxygen, essential plant nutrients and organic matter, and through downstream effects on the rates of nutrient cycling and organic matter export from the upper tailwater. These water quality constituents are important determinants of the levels of productivity in the Colorado River. The objective of water chemistry monitoring is to determine whether the inputs and outputs of these important water quality constituents are changing during the period of interim flows and whether any changes may be attributable to dam operations.

Aquatic Food Base--An objective of the interim flow criteria is to benefit the algal and invertebrate food resources utilized by Colorado River fishes by increasing minimum flows and decreasing the daily range of flows. The objective of aquatic food base monitoring is to determine whether the interim flows achieve the desired resource maintenance and enhancement.

BACKGROUND INFORMATION AND JUSTIFICATION

Water Chemistry--The chemistry of waters released through Glen Canyon Dam is determined by several factors including: (1) chemistry of inflows to Lake Powell; (2) stratification and circulation in the reservoir; (3) sedimentation; (4) biotic productivity, (5) retention time; (6) evaporation, and; (7) elevation of the release (penstocks) in the reservoir (Potter and Drake 1989, Stanford and Ward 1990). Research on Lake Powell conducted by Merritt (1976) in which he applied a hydrodynamic model (Bohan and Grace 1969) to evaluate effects of dam withdrawal currents suggests that magnitude of the discharge from Lake Powell can also affect chemistry of the release waters. As discharge from the dam increases, thickness of the intake plume also increases resulting in the entrainment of waters at depths more removed from the penstocks.

The relationship between discharge magnitude and thickness of the intake plume is particularly important at present low reservoir elevations. As reservoir surface elevation declines, penstock depth is approaching the lower limit of the metalimnion during the extended period of stratification. Chemistry and temperature of metalimnetic waters differ from both the overlying epilimnion and the underlying hypolimnion. Of special concern is the strong gradient of increasing water temperature with decreasing depth in the metalimnion. Entrainment of these waters during the summer-early autumn period of maximum temperatures in the reservoir could have profound consequences for the downstream aquatic flora and fauna.

Aquatic Food Base--Early life stages of native Colorado River fishes and trout utilize zooplankton extensively as a food resource (Maddux et al. 1987). The relative contributions of tailwater zooplankton by passage through Glen Canyon Dam and by reproduction in the river are presently unknown. Available information suggests, however, that many of the river's zooplankton have their source in the reservoir (Haury 1986). Diel vertical migrations of zooplankton in lake and reservoir water columns are a commonly observed behavior. In typical migration patterns, zooplankton occur at depth during daylight hours and move upward during the period of darkness (Wetzel 1983, pp. 449-456). If thickness of the intake plume increases at greater dam releases as indicated in the study of Merritt (1976) and Lake Powell zooplankton undergo typical diel vertical migrations, these organisms will have a higher probability of being entrained by high mid-day releases than by lower night-time releases. Thus, the rate of delivery of zooplankton to the Glen Canyon Dam tailwater may be a function of the daily pattern of releases during interim flows. This relationship may be exaggerated during the present period of low reservoir elevation.

As Colorado River fishes increase in size, their food habits often shift towards larger benthic food items found both in bottom substrates and in the drift (Maddux et al. 1987). The area of benthic habitat available for production of benthic algae and invertebrates varies in accordance with the stage-discharge relationship across the range of interim flows. In like manner, current velocity, which also related to discharge, affects the extent to which benthic species are entrained and carried downstream as drift (Leibfried and Blinn 1987). Increased drift of benthic organisms potentially makes available higher numbers of food resources for fishes feeding on drift. Drift also may deplete local benthic populations, however, and short-term benefits may ultimately result in negative effects.

Dewatering and desiccation of the periphyton community, including *Cladophora glomerata* and its diatom epiphytes, in shallow, typically nearshore zones, has been demonstrated to increase algal mortality when exposure exceeds 12 hours (Usher and Blinn 1990). Available information (AGFD unpublished data) suggests that this community lacks both resistance and resilience when subjected to chronic dewatering. Interim flow operations should allow the recolonization of the periphyton community in areas where high mortality occurred during the period of controlled research flows. Present predictions are that colonization and growth rates are slow, however, and that attainment of standing crops equivalent to those in continuously inundated zones may require a year or more (AGFD unpublished data).

METHODS

Water Chemistry--Sampling for all water chemistry variables will be accomplished quarterly at all three sites. Profiles of water temperature, dissolved oxygen, pH, and specific conductance will be measured from surface to below penstock elevation in the Lake Powell forebay. Equivalent measures will be made at the dam and Lee's Ferry. Reservoir water samples for dissolved and fine particulate phases of carbon, nitrogen, phosphorus, and organic matter will be collected by diaphragm pump at a minimum of six depths. Dam samples of penstock waters will be removed from ports at the draft tubes. Lee's Ferry samples will be collected with the diaphragm pump from a boat moving normal to river flow. The pump hose will be raised and lowered through the water column in passing through the cross-section in order to provide integrated samples. Integrated coarse particulate organic matter (CPOM) samples will be collected in the same manner with paired, metered, high-speed Miller tubes.

Fine particulate fractions of nutrients and organic matter will be removed from prefiltered (750 μm) water samples by vacuum filtration on tared, ashed, and rinsed 0.7 μm glass fiber filters or by centrifugation. Fine particulate organic matter and CPOM will be determined gravimetrically as ash-free dry mass (AFDM) after drying at 105° C and burning at 550° C (APHA 1989). Chlorophyll *a* and pheophytin *a* content of these fractions will be measured by spectrometry after extraction in methanol using monochromatic equations (APHA 1989). Analyses of dissolved and particulate forms of carbon, nitrogen, and phosphorus will be conducted by a laboratory under contract to the Bureau of Reclamation in Salt Lake City.

Aquatic Food Base--Monitoring of the aquatic food base for fishes will concentrate on zooplankton and periphyton. Zooplankton will be collected quarterly in the manner described above for fine particulate matter except that filtration will be through an 80 μm mesh plankton net. Samples will be preserved in 4% buffered formalin. Zooplankton will be identified to at least the level of genus and enumerated by life stages as described by Haury (1986).

Periphyton biomass (standing crop) will be estimated quarterly from coarse substrates at three sites (upper, middle, and lower) in the Lee's Ferry reach. At each site, measurements will be made at three elevations corresponding to discharges of 4,000 cfs, 8,000 cfs, and 15,000 cfs. Duplicate samples will be removed from randomly selected rocks by methods described in Angradi et al. (in review). Periphyton will be transported from the field to the laboratory in ice chests. Biomass will be measured as AFDM, chlorophyll *a*, and pheophytin *a* using methods described above for CPOM. Taxonomic determinations will be made to at least the level of genus and relative abundances will be ranked on a scale from dominant to rare.

Colonization rates of periphyton will be measured on 225 cm^2 Navajo sandstone tiles emplaced among coarse substrates on the same transects and at the same elevations as standing crop measurements. At each elevation on a transect, three randomly selected tiles will be collected 10, 20, 30, 40, 60, and 90 days after being placed at the sites. Accumulated biomass will be removed by scraping. Chlorophyll *a* and pheophytin *a* concentrations will be determined

by spectrometry after extraction in methanol. Following these determinations, the solvent will be evaporated and the remaining organic matter will be burned at 550° C for measurement of AFDM.

Analysis of covariance will be used to test for effects of site, elevation, and time in place on biomass and pigment concentration. Least-squares regression analysis through the origin will be used to determine the rate of accretion on tiles for each level at each site. Tests for differences among slopes (rates of accretion) will be accomplished by analysis of covariance.

INTEGRATION WITH OTHER MONITORING EFFORTS

AGFD's proposed monitoring studies are naturally interrelated by virtue of the dependence of autotrophic production in the tailwater on plant nutrients delivered through Glen Canyon Dam. In like manner, trophic interactions between Colorado River fishes and their food resources dictate that integration of information concerning these ecosystem components must be accomplished for the monitoring program to be successful.

Other resource elements being monitored by AGFD biologists under present GCES funding (see Bureau of Reclamation 1990) or internal funding include the following:

- Stranding of trout during major spawning and emergence months (December-May)
- Density and distribution of trout redds during spawning (December-March)
- Relative abundance, growth, and condition of trout (Quarterly)
- Standard creel surveys of trout anglers and fishing guides (Monthly)
- Environmental conditions in native fish rearing habitats (Bimonthly)
- Relative abundance, growth, and condition of native fishes (Bimonthly)
- Distribution and abundance of *Gammarus lacustris* (Monthly)

Data from all these studies are being stored in a relational master database in order that integration of results and comparative analyses can be accommodated.

TIMETABLE FOR DELIVERABLES

Data gathered during the interim flow monitoring will be entered in the AGFD GCES Master Database to facilitate comparisons with previous data collected during Phase I and II. Quarterly and annual progress reports will be delivered to the Glen Canyon Environmental Studies office in Flagstaff, Arizona. Quarterly reports will detail the numbers and types of samples collected during the preceding period and provide tabular accounts of data gathered. Specific protocol for presentation of data will be determined with the assistance of the Glen Canyon Environmental Studies Program Manager, but every effort will be made to make the presentation of data commensurate with those for dam releases and power economics. All

available data will be analyzed for trends in the annual report and statistical analyses will be conducted where appropriate. A final report will be provided at the conclusion of the interim monitoring period. This report will summarize interim flow results and provide recommendations for the long-term monitoring program.

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GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Dennis Kubly Date Submitted 2/26/92

Department/Laboratory Research Branch Organization AGFD

Beginning Date 05/01/92 Completion Date 4/30/93[1]

Project Title Glen Canyon Environmental Studies Interim Flow Monitoring

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Dennis Kubly	1			0[2]
2. Ted Angradi	2			0
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (2) Other Professional (techs.)				36,000
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				10,800
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				2,500
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				1,000
b. Others				2,000
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				2,500
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	500
b. Other	4,000
2. Publication Costs	
3. Consultant Services	
4. Computer Services	
5. Subcontracts	10,000
6. Other	
H. TOTAL DIRECT COSTS (A through G)	69,300
I. INDIRECT COSTS	5,544
J. TOTAL DIRECT AND INDIRECT COSTS	74,844
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	15,000
L. TOTAL PROJECT AMOUNT (J + K)	89,844

Itemize Capital Equipment to be Purchased in FY 92

Description of Items > $1,000 < $10,000	Cost*
1. Hydrolab Datalogger	2,500
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

***Including Freight charges**

[1]This budget is for the first year of a monitoring study expected to continue until at least mid-1994

[2]Costs for principal investigators are already funded under GCES

C2

A PROPOSAL TO MONITOR INTERIM FLOWS EFFECTS FROM GLEN CANYON DAM ON THE AQUATIC FOOD BASE IN THE COLORADO RIVER IN GRAND CANYON NATIONAL PARK, ARIZONA

Dean W. Blinn
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Northern Arizona University
Flagstaff, AZ 86011

and

Lawrence E. Stevens
Resources Management and Planning Division
Grand Canyon National Park
Grand Canyon, AZ 86023

Starting Date: 15 June, 1992

Duration: 20 Months

Funding Amount: $293,117

Submitted to: The National Park Service
Cooperative Studies Unit
Northern Arizona University
Flagstaff, AZ 86011

Dean W. Blinn
Co-Principal Investigator

Henry O. Hooper, PhD
Associate Vice President
for Academic Affairs,
Research and Graduate
Studies

Lawrence E. Stevens
Co-Principal Investigator

GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

FEB 27 1992

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A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON THE AQUATIC FOOD BASE IN THE COLORADO RIVER DOWNSTREAM FROM GLEN CANYON DAM, ARIZONA

Dean W. Blinn and Lawrence E. Stevens

ABSTRACT

Discharge from Glen Canyon Dam strongly affects the lower trophic levels of the aquatic ecosystem in Grand Canyon National Park. The aquatic food base in the Colorado River is affected by the duration and timing of low releases from Glen Canyon Dam, as well as the range of daily fluctuations. The objectives of this proposal are to monitor the effects of discharge characteristics under the Bureau of Reclamation's interim flows from Glen Canyon Dam on the distribution and production of benthic algae and macroinvertebrates. This information is important because the lower aquatic trophic levels provide essential resources for both the aquatic and terrestrial components of the fluvial ecosystem.

This study will continue the collection of data to monitor the lower trophic level standing stock, production, and drift during the interim flows. Methods to be used include dredging and Hess sampling at five wide- and five narrow-reach sites in pools and riffles; shore and mainstream drift sampling; and size class analysis of macroinvertebrates using close-interval sampling at three sites. This proposal requests funding for FY92 in the amount of $83,196, FY93 in the amount of $156,845, and FY94 in the amount of $50,676 to meet these objectives.

STATEMENT OF OBJECTIVES

1. Monitor the effects of interim flows from Glen Canyon Dam on the standing stock of the lower trophic levels in the Colorado River between Lees Ferry and Diamond Creek.

2. Monitor the effects of low, medium and high-volume monthly interim flows on primary and secondary production in the Colorado River corridor in Grand Canyon.

3. Monitor the effects of interim flows on the re-colonization of substrata by benthic algae and macroinvertebrates in the Colorado River ecosystem.

4. Monitor the effects of interim flows on organic drift in the Colorado River corridor in Grand Canyon.

5. Prepare monitoring data for inclusion into the GCES/NPS GIS database.

JUSTIFICATION

A primary objective of the Bureau of Reclamation's Glen Canyon Dam interim flows discharge criteria was to benefit the aquatic food base of the Colorado River. These criteria established what is hoped to be an ecologically appropriate minimum release, thereby stabilizing the area available for colonization by benthic algae, decreasing loss though desiccation or freezing of benthic aquatic life, and increasing primary and secondary production. Under the interim flows, a minimum discharge of 141.5 m^3/sec may be sustained for no more than six hours between 7:00 p.m. and 7:00 a.m. Interim flow prescriptions also include reduced maximum flows and slow ramping rates which may influence scour and drift of the benthos. The objectives of this study are to determine if the interim flows prescription achieved this resource objective.

1. Monitor the effects of interim flows from Glen Canyon Dam on the standing stock of the lower trophic levels in the Colorado River between Lees Ferry and Diamond Creek.

This objective is an important monitoring issue because the interim flows criteria were designed to reduce discharge-related impacts on the benthic algae (Cladophora and associated diatoms) and macroinvertebrate (Diptera, gastropods, and Gammarus) communities of the Colorado River in Grand Canyon National Park. Results from GCES Phase II showed: 1) strong negative affects of discharge on standing crop of benthic communities, 2) differences in distribution and standing crop of benthic communities throughout the Colorado River corridor, therefore reductions in standing crop upstream may influence downstream benthic communities, 3) drift (algal, macroinvertebrate, and detritus) showed a positive correlation with discharge, and 4) under proposed interim flows, colonization would occur at 5000 cfs and above. The aquatic lower trophic levels are recognized by Grand Canyon National Park and are a management priority. Interim flow criteria were adopted to reduce impacts of fluctuating flows. This proposal will monitor the effectiveness of that management plan. The monitoring proposed here will ascertain daily, monthly, seasonal and cumulative effects of interim flows on this fluvial ecosystem.

2. Monitor the effects of interim flows on productivity in the Colorado River corridor in Grand Canyon.

This objective is an important monitoring issue because the rate of benthic production determines the ecological potential of this fluvial ecosystem. The interim flows criteria were designed to guarantee sufficient production to maintain the fisheries and terrestrial insectivore assemblages; however, fluctuating discharge may negatively affect productivity by reducing the standing crop of primary producers. GCES Phase II results showed that regulated flows significantly reduced production of standing crop of benthic communities. These data supplemented by Arizona

Game and Fish data on primary and secondary production (Az Game & Fish Draft Annual Report, 1992) will be compared with the proposed monitoring program on production. The proposal presented here will determine whether or not interim flows affect primary and secondary productivity. This study will monitor changes in production at monthly, seasonal, and annual time scales during interim flows.

3. Monitor the effects of interim flows on the re-colonization of substrata by primary producers and secondary consumers in the Colorado River.

This objective is important because it monitors the rate of re-colonization by benthic algae and macroinvertebrates following low volume monthly interim flow periods. Benthic algae and macroinvertebrates form the food base for higher trophic levels, and therefore it is important to monitor the rate of recovery of these lower aquatic trophic levels during high volume interim flows. Preliminary data from GCES Phase II showed slow recovery by primary producers (Cladophora) and relatively rapid recolonization by macroinvertebrates (within 72 hrs) at upstream sites, and relatively slow recolonization by Oscillatoria after one month at downstream sites (209 mi). The present proposal will monitor the recovery rates of the lower trophic levels during interim flow periods.

4. Determine the effects of interim flows on organic drift in the Colorado River between Lees Ferry and Diamond Creek.

This objective is an important monitoring issue because the rate and volume of organic drift determines the delivery of upstream production to downstream reaches. Allochthonous upstream organic matter appears to be the primary source of energy for downstream reaches. GCES Phase II synoptic studies suggested that drift (algae, macroinvertebrates, and detritus) is positively correlated with a range of daily discharge fluctuations. Interim flow criteria reduces stream power and promotes benthic production, therefore we predict interim flows should reduce overall drift and reduce the amplitudes in daily fluctuations in drift. The monitoring proposed here is designed to evaluate the amount and continuity of drift under the interim flow criteria, as compared to patterns of drift during synoptic research.

5. Prepare monitoring data for inclusion into the GCES/NPS GIS database.

This objective is an important monitoring issue because the aquatic food base supports not only a unique native fish fauna with several Federally listed species, but also a diverse riparian insectivore fauna. The lower aquatic trophic levels are recognized by Grand Canyon National Park as a primary component of this fluvial ecosystem. The short-term monitoring efforts

proposed here will contribute to essential baseline data for future, long-term monitoring in this system. The themes we can generate in GIS will include benthic algal and macroinvertebrate standing crop and species composition. These can be integrated with fisheries information and potentially with terrestrial fauna information. Each of the proposed Glen Canyon Dam EIS alternatives includes a long-term monitoring component, and the data collected here will be compiled in an appropriate fashion for inclusion into the GCES/NPS GIS.

BACKGROUND

Interim Test Flows

The Secretary of the Interior authorized implementation of a program of reduced maximum flows and reduced fluctuation from Glen Canyon Dam beginning in August, 1990. These interim flows were designed to mitigate impacts of dam operations on downstream riverine resources, until a Record of Decision is reached for the Glen Canyon Dam Environmental Impact Statement. These interim flows consist of low-, medium-, and high-volume months, with low flows during the spring and late fall, moderate flows in May and September, and high flows during mid-summer and mid-winter. Interim flows have a maximum discharge of 20,000 cfs, a reduced range of daily fluctuation, and reduced up- and down-ramping rates. The Glen Canyon Environmental Studies Program is coordinating the monitoring of interim flow effects on sediments, cultural resources, the aquatic food base, riparian areas and wetlands, economics, trout, native fish, recreation and water quality, with data base management and development and development of a geographic information system GIS. The effects of flow exceptions also require monitoring under the interim flow discharges program.

Historical Studies on the Aquatic Food Base

Previous studies suggest that discharge from Glen Canyon Dam, geomorphology and tributary sediment supplies strongly affect standing stock, production, drift and species composition of the lower trophic levels in the Colorado River in Grand Canyon National Park. Hofknecht (1981) reported that the distribution of benthic life forms varies on a local scale in relation to channel geometry, substratum availability, velocity and frequency of desiccation. He described the "intertidal" zone of the Colorado River, including tributary mouths, to be largely devoid of benthic life. In contrast, tributaries are diverse and densely colonized by benthic algae and macroinvertebrates.

Leibfried and Blinn (1988) reported that chironomid larvae were numerically dominant over Gammarus lacustris in the Colorado River drift, and comprised as much as 85% of the standing crop of drifting invertebrates. They also made the following observations

in macroinvertebrate drift: 1) chironomids made up more than half the standing crop of macroinvertebrates in the river; 2) chironomid drift was not associated with fluctuating discharge but was associated with the amount of Cladophora glomerata in the drift; 3) macroinvertebrate standing crop decreased below the Little Colorado River (RM 61), from summer to winter, and was low in creek mouths relative to the mainstream; and 4) macroinvertebrate standing crop was positively correlated with Cladophora glomerata standing crop spatially and seasonally.

The benthic assemblage in the Colorado River changes with distance downstream from Glen Canyon Dam (Blinn et al. 1991). The clear, cold, autochthonous tailwaters reach is dominated by Cladophora glomerata, associated periphyton (especially diatoms), Gammarus lacustris and chironomid midges, with oligochaetes, lumbricids and Physella sp. snails. Immediately below the sediment-laden Paria River near Lees Ferry, Arizona, benthic dominance shifts towards crust-forming blue-green algae (Oscillatoria spp.), simuliid gnats and a different assemblage of chironomid midges. Most of the hard substrata in the Grand Canyon is dominated by this assemblage, which appears to depend largely on allochthonous input from tributaries and the upstream Cladophora-dominated system.

Blinn and Leibfried (1988) described the algal and associated macroinvertebrate assemblage of the Cladophora community, concluding that Cladophora provided essential substrata for diatoms, which fed the macroinvertebrate assemblage. Pinney (1991) supported this conclusion by analyzing the diet of Gammarus, reporting that most food items taken were diatoms, with little Cladophora found in Gammarus guts. Blinn et al. (1991) further supported this contention by analyzing chironomid gut contents from the mainstream at Lees Ferry, again finding the vast majority of food items taken were diatoms.

Twelve-hour desiccation and rewatering cycles were shown to reduce benthic Cladophora glomerata standing stock by 50 to 60 percent over a week-long treatment, both in the laboratory and at Lees Ferry (Usher and Blinn 1990; Blinn et al. 1991). The desiccation effects are equally strong for the macroinvertebrate assemblage associated with this filamentous green alga.

Existing Data

The data base with which interim flows effects on the aquatic food base will be compared consists of two years of data gathered by Blinn et al. (1991). These data were derived from 10 sites in the Grand Canyon from Lees Ferry to Diamond Creek, and collected at two-month intervals. Most of the same study sites will be used in this proposed monitoring, and the same staff, equipment and protocol will be employed, guaranteeing continuity and comparability of data collected.

METHODS

Objective 1

The standing crop, dominance, and habitat requirements of aquatic invertebrates will be monitored seasonally at five wide-reach sites and five narrow-reach sites within the mainstem of the Colorado River (n = 4 sampling trips). Sampling sites and dates will correspond with those used by Blinn et al. (1991). Two habitat types (river pools, riffles) will be monitored at each site. Sampling will be conducted at three transects 30 meters apart in each habitat type. Petersen or Petit Ponar dredges will be used in the fine sediment and Hess substrate samplers will be utilized in tributaries and on cobble bars. Pool habitats will be sampled at five locations along the three transects; thalweg, <1,000 cfs, lower-littoral (approximately 5,000 cfs), mid-littoral (approximately 10,000 cfs), and upper littoral (28,000 cfs). Three pairs of samples will be collected for taxonomic/abundance and biomass determinations. Cobble bar collections will be taken at the lowest water flow possible with three paired samples along with mid and upper-littoral samples. Adult and pharate specimens will be collected with sweep nets, white and UV lights, spot samples, and Thienemann collections. Abiotic parameters recorded for each sample site will include: water temperature, dissolved oxygen, pH, specific conductance, substratum, microhabitat conditions, Secchi disc, water velocity or stage, depth, date, site, and time of day. Samples will be sorted into the following 10 biotic categories: Cladophora, blue-green algal crust, chironomids, Gammarus, gastropods, oligochaetes, simuliids, lumbricids, other invertebrates, and detritus. Numbers of organisms within each biotic category will be determined for abundance, and each biotic category will be oven-dried at 60°C and weighed to determine biomass. Tributaries will be monitored every other year at the same sites and with the same protocol employed above.

This protocol will monitor the aquatic food base at low-medium interim flows during spring and fall, and high interim flows during summer and winter to determine if river regulation is influencing the temporal and/or spatial abundance and biomass of lower trophic levels in the Colorado River ecosystem. We will monitor the same 10 sites (five wide- and five-narrow reaches) used in the FY90 and FY91 monitoring programs (Blinn et al. 1991). We will consider reducing the number of sites after multivariate analyses of FY91 and FY92 data, which may reduce man-days and cost during FY93 and FY94 monitoring programs.

Objective 2

During the interim flow period, we will monitor community production of the macroinvertebrate food base at low, medium, and high flow regimes at three sites including Lees Ferry, 50 m below

the confluence of the Paria River, and at the confluence of Diamond Creek. The monitoring program will focus on Gammarus lacustris because this amphipod is a major food item in the food web of the Colorado River ecosystem, especially at Lees Ferry. Twelve random samples (25 cm^2) will be taken within each of the three flow regimes (n = 72 samples for each collecting date). Collections will be taken at 3 week intervals throughout the interim flow periods. Live samples will be transported back to Northern Arizona University and processed. Gammarus will be sorted according to size class (1 mm size class intervals) and the dry weight of each size class will be determined. The size-frequency method (Benke 1984; Downing and Rigler 1984; Runck and Blinn 1990; Dehdashti and Blinn 1991) will be used to monitor the production of Gammarus within the three flow regimes during interim flow.

During the first year, preliminary collections and analyses of midge larvae will be conducted to determine the feasibility of monitoring production of midges at low, medium, and high flows during the second year of interim flows.

During FY93 we will monitor primary production of the algal food base at low, medium and high interim flows at Lees Ferry, 50 m below the confluence of the Paria River, and at the confluence of Diamond Creek. Our protocol will follow that of Arizona Game and Fish in that large in situ photosynthetic chambers will be employed.

The above sampling protocol will monitor the production of the lower trophic levels in the Colorado River ecosystem at low, medium, and high interim flows. Lees Ferry was selected because it represents the most productive reach below Glen Canyon Dam, while the Paria River is the first tributary below Glen Canyon Dam that influences primary and secondary production due to input of suspended sediment, and the Diamond Creek reach represents the collective interactions between upstream tributaries and the mainstem between Glen Canyon Dam and Lake Mead. This study will provide valuable knowledge on the influence of interim flows on the lower trophic levels in the Colorado River ecosystem.

Objective 3

Colonized rocks were removed during GCES Phase II to monitor re-colonization during interim flows. These rocks will be re-submerged and the re-colonization by benthic algae and macroinvertebrates will be monitored during interim flows at two sites in the Colorado River ecosystem. A 25 cm^2 quadrat will be harvested from each rock prior to re-submergence, and algal ash-free biomass and secondary consumer ash-free biomass will be determined. Rocks will then be placed into the Colorado River at Lees Ferry (n = 120) and below the Paria River (n = 120). Thirty rocks will be randomly selected from each site (Lees Ferry and below the Paria River) and the algal biomass and secondary

consumers will be harvested from 25 cm^2 quadrats at approximate 3-week intervals during high summer interim flows. In order to avoid disturbance within the benthic community, each submerged rock will be harvested only once (i.e, once harvested the colonized rocks will be removed). Therefore, during each sampling period, 30 new rocks will be randomly selected (i.e. each 3-week sample will consist of 30 new replicate rocks). Algal biomass and secondary consumer biomass will be separated in the laboratory. Energy equivalents for primary producers and secondary consumers will be estimated for each harvesting period for each site. A similar protocol will be conducted during winter high interim flows.

These studies will monitor the rates of re-colonization of primary producers and secondary consumers within a clear water, highly productive reach (Lees Ferry) and a turbid water reach with relatively low production (below Paria River) during summer and winter interim flow periods. We predict interim flows will result in no re-colonization in the fluctuating zone.

Objective 4

We propose to monitor drift on the rise and fall of the daily flow cycle (daily hydrograph) at ten mainstem stations in the Colorado River including: Glen Canyon gage, Lees Ferry, Vasey's Paradise, Nankoweap, upstream from the Little Colorado River, Tanner Creek, at Grand Canyon, upstream from Kanab Creek, National Canyon, and the Diamond Creek gage. At each site and at the rise and fall of the daily flow cycle we will place four drift nets in the river, two removing drift at the surface and two at the 0.6 depth from the bottom (depth of mean velocity) as near the stream center as possible. The surface net will capture drift in the area of maximum velocity. These four nets each have an orifice opening of 10 cm, length of 90 cm, and mesh openings of 250 μm. The nets are held in the river with paired metal bars. During each collection period the nets will be placed in the river for one hour. Prior to removal the river velocity in the net orifice will be measured so that the total amount of water passing through the net can be calculated.

While the four 100 mm orifice nets are in place we will make a 15 minute drift in the river in the area of rapid velocity using a net having an orifice of 0.5 m, a length of 1.6 m, and mesh openings of 250 μm. This net will be operated from the back of a boat held stationary in the current with the motor. The net will be tethered so that the top of the orifice rim is at the surface of the water. Again, velocity of the water at the net orifice will be measured for later calculation of total water passing through the net. A 15-minute time period is necessary for this net as it clogs rapidly because the large volume of water it filters.

After removal of the nets from the river the contained material

will be placed in collection jars, labeled, and preserved. Subsamples will be taken for taxonomic purposes. In the laboratory the samples will be inspected, animals removed, and algal identification made. Next the samples will be drained of moisture, dried at 105°C until all organic material has been volatilized. The final calculation will be biomass of detrital material in milligrams L^{-1}. These values will then be compared to the river discharge at the time of measurement, and to values determined in the river at the same sampling sites during the November 1990 and June 1991 synoptic experiments conducted by U.S. Geological Survey. Animals will be identified to possible taxa, and their biomass determined if sufficient numbers are present.

DELIVERABLES

Quarterly and annual reports will be provided to each of the following entities according to the schedule in Table 1: the National Park Service at Grand Canyon National Park, Northern Arizona University Cooperative Parks Studies Unit, and the Regional Scientist; the Glen Canyon Environmental Studies Office and the Senior Scientist. An initial oral report will be provided to Grand Canyon National Park Resources Management staff. Draft final reports will be submitted for review to Resources Management and the NAU CPSU.

Reports will be prepared for submission to peer-reviewed scientific journals.

SCHEDULE

The schedule outlined in Table 1 will be followed for this project, but may be adjusted pending the date of NPS notification of funding to Northern Arizona University.

Table 1: Schedule for activities and deliverables.

Project Initiation	1 June, 1992
Quarterly report and first sampling trip	1 July, 1992
Second sampling trip	15 September, 1992
Quarterly report	1 October, 1992
Draft annual report	1 December, 1992
Third sampling trip	1 January, 1993
Final 1992 annual report	1 January, 1993
Fourth sampling trip	15 March, 1993
Quarterly report	1 April, 1993
Fifth sampling trip	20 June, 1993
Quarterly report	1 July, 1993
Sixth sampling trip	15 September, 1993
Quarterly report	1 October, 1993
Draft final report	1 December, 1993
Final annual report	1 January, 1994

PERSONNEL

NAU Staff

Dr. Dean W. Blinn is Co-Principal Investigator on this project, and this project will require 25% of his time. He is fully qualified to serve as co-P.I. on this project, having studied and published widely on the aquatic and riparian ecology of this ecosystem. Dean Blinn was principal investigator on projects examining the food base for GCES Phase I and II. Hiring protocol for assistants will conform to that required by NAU Human Resources Department.

Service Involvement

Dr. Lawrence E. Stevens is Co-Principal Investigator on this project and this project will require 20% of his time. He is fully qualified to serve as co-P.I. on this project having studied and published widely on the riparian ecology of this ecosystem.

Dr. Peter Rowlands, CPSU at Northern Arizona University, will serve as the COTR on this project, requiring 0.07 FTE of his time.

The National Park Service at Grand Canyon National Park will be responsible for collection permits, logistical support in the Lees Ferry and Paria collections, and review of the study. Temporary housing may be required for laboratory analyses at Lees Ferry, and is requested from NPS-GRCA or GLCA during the summer, 1991. Permitting is required from Glen Canyon National Recreation Area for data collection in the Lees Ferry reach.

Other Agency Involvement

The Bureau of Reclamation GCES office is requested to provide river trip logistics, the loan of a depthfinder, and key river trip and laboratory equipment. Equipment will be borrowed whenever possible to avoid unnecessary purchases.

BUDGET

The following budget does not include the cost of logistics, which will be covered and coordinated by the Bureau of Reclamation Glen Canyon Environmental Studies Office in Flagstaff, Arizona. In addition, some equipment may be purchased by the GCES. This budget does not include NPS staff or travel costs, which are included in the annual NPS administrative budget associated with the GCES Program.

REFERENCES CITED

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Leibfried, W.C. and D.W. Blinn. 1988. The effects of steady versus fluctuating flows on aquatic macroinvertebrates in the Colorado River below Glen Canyon Dam, Arizona. Glen Canyon Environmental Studies Rept. No. 15, NTIS PB88-206362/AS.

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Runck, C. and D.W. Blinn. 1990. Population dyanamics and secondary production by Ranatra montezuma (Heteroptera: Nepidae). Journal of North American Benthological Society 9:262-270.

Stevens, L.E. and G.L. Waring. 1988. Effects of post-dam flooding on riparian substrates, vegetation, and invertebrate populations in the Colorado River corridor in Grand Canyon, Arizona. Glen Canyon Environmental Studies Rept. No. 19, NTIS No. PB88-183488/AS.

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Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator D.W. Blinn and L.E. Stevens Date Submitted 26 Feb., 1992

Department/Laboratory Dept. Biol. Sciences, No. AZ Uni Organization NPS-CPSU

Beginning Date 15 June, 1992 Completion Date 15 February, 1994

Project Title The Effects of Interim Flows from Glen Canyon Dam on the Aquatic Food Base

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. D.W. Blinn		4000	13,500	17,500
2. L.E. Stevens		0	0	0
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)		32000	12567	44567
3. ( ) Graduate Students		27950	6200	34150
4. ( ) Undergraduate Students		9350	2550	11900
5. ( ) Secretarial/Clerical		3000	500	3500
6. ( ) Other		26450	7840	34290
C. FRINGE BENEFITS				14022
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				22000
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				1650
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				7050
3. Subsistence				7160
4. Other				7900

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	
b. Other	16500
2. Publication Costs	3500
3. Consultant Services	5000
4. Computer Services	
5. Subcontracts	5575
6. Other	8000
H. TOTAL DIRECT COSTS (A through G)	244264
I. INDIRECT COSTS	48853
J. TOTAL DIRECT AND INDIRECT COSTS	293117
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	293117

Itemize Capital Equipment to be Purchased in FY 92

Description of Items > $1,000 < $10,000	Cost*
Hydrolab	4500
35 mm field camera (waterproof) with lenses	500
Metler Analytical Balance (electronic, 5-place)	7200
Metler Balance Weighing Table (Balance Stability)	700
Ashing Oven	900
Silver Filters (for drift)	1000
FY92 Subtotal	14800
Three Primary Production Chambers (FY93)	7200
TOTAL	22000

Description of items > $10,000	
TOTAL	

*Including Freight charges

GLEN CANYON ENVIRONMENTAL STUDIES OFFICE
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FLAGSTAFF, AZ

C3

HUALAPAI TRIBE

A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOW FROM GLEN CANYON DAM ON THE FISHERY RESOURCES OF THE LOWER COLORADO RIVER FROM DIAMOND CREEK TO LAKE MEAD

ABSTRACT

The Hualapai Tribe is proposing to monitor the effects of the Glen Canyon Dam Interim Flows by focusing on an assessment of the basic aquatic population structure, directly impacted areas of habitat, impacts related to non-native fish interactions and an evaluation on the impacts related to the food resources. The work will be accomplished utilizing the techniques defined in the previous Glen Canyon Environmental Studies (GCES) sponsored research. Efforts will be integrated with the ongoing GCES programs and will include an assessment of the aquatic resources from National Canyon to Lake Mead with special emphasis on the area from Diamond Creek to Lake Mead.

STATEMENT OF OBJECTIVES

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, abundance and behavior of native and non-native adult fish in the Lower Grand Canyon from Diamond Creek to Lake Mead, (RM226-286).

2. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, abundance, and behavior of the larval and juvenile stages of native fishes in the Lower Grand Canyon from Diamond Creek to Lake Mead, (RM226-286).

3. Monitor the effects of interim flows from Glen Canyon Dam on the reproduction, food habits and patterns of habitat use of piscivorous non-native fishes that may predate on native fishes found in the Lower Grand Canyon from Diamond Creek to Lake Mead.

4. Monitor the effects of interim flows from Glen Canyon Dam on the environmental conditions in the tributary mouths and shallow shore-line habitats in the Lower Colorado River from Diamond Creek to Lake Mead. This will include water quality and degradation and/or aggradation of sediments.

5. Monitor the effects of interim flows from Glen Canyon Dam on the food base including productivity and algal standing crops in the Lower Colorado River from Diamond Creek to Lake Mead.

GCES OFFICE COPY
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JUSTIFICATION

A primary objective of the Interim Flows discharge criteria is to minimize the effects of the operations of Glen Canyon Dam on the aquatic food base and native fish resources and habitat in the Grand Canyon. Under existing Glen Canyon Environmental Studies (GCES) mainstem aquatic resources studies, the impacts of operations are being evaluated by Arizona Game & Fish and Bio/West from Glen Canyon Dam to Diamond Creek. No monitoring or scientific research is presently ongoing below Diamond Creek.

The Hualapai Tribe along with the National Park Service, is responsible for the management of the aquatic resources in the Lower Colorado River from National Canyon to Lake Mead. The objective of this study are to determine if the interim flows are achieving the desired reduction in resource impacts to the lower Grand Canyon aquatic resources. The short-term impacts may influence and define the long-term relationships between the native and non-native fish populations. Due to limited data, additional baseline data collection is required in addition to the monitoring efforts.

All information that is collected will be consolidated and integrated into the GCES Geographic Information System (GIS). This data base which will allow for the evaluation of the long-term relationships between flows and aquatic resources.

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, abundance and behavior of the native and non-native adult fish in the Lower Grand Canyon from Diamond Creek to Lake Mead.

The fish will be potentially impacted by the changing environmental elements. In order to directly assess the impacts of the interim flows a basic understanding of the location and abundance of fish assemblages below Diamond Creek is required. Monitoring interim flow effects on the native and non-native fish populations in the Lower Grand Canyon will focus on identifying the impacts related to the monthly volumes, maximum flows, minimum flows and the ramping rates.

2. Monitor the effects of the interim flows from Glen Canyon Dam on the distribution, abundance and behavior of the larval and juvenile native fish in the Lower Grand Canyon from Diamond Creek to Lake Mead.

Monitoring interim flow effects on the native larval and juvenile fish will provide information on the impacts of the operations of Glen Canyon Dam. The larval and juvenile life stages are the most likely to be directly impacted by the short-term nature of the

interim flows and by habitat availability and its utilization by certain life stages. Specifically the population levels will be integrated with the modification of environments identified under Objective 4.

3. Monitor the effects of the interim flows from Glen Canyon Dam on the reproduction, food habits and patterns of habitat use of non-native fishes that may predate on native fishes found in the Lower Grand Canyon from Diamond Creek to Lake Mead.

Monitoring interim flow effects on the non-native fish behavioral and habitat requirements by determining their relationship to flow levels and consequently their effects on the native fish fauna. All elements of the interim flows may potentially impact the non-native fish interactions.

4. Monitor the effects of interim flows from Glen Canyon Dam on the environmental conditions in the tributary mouths and shallow shore-line habitats in the Lower Colorado River from Diamond Creek to Lake Mead.

Monitoring interim flow effects on the environmental conditions at the tributary mouths and shore-line habitats will provide a direct identification of flow impacts. Objectives 1 through 3 will be integrated with the results from this objective to determine the short-term and long-term impacts of physical and chemical habitat alteration.

5. Monitor the effects of interim flows from Glen Canyon Dam on the food base including productivity, algal standing crops, and macroinvertebrates in the Lower Colorado River from Diamond Creek to Lake Mead.

Monitoring the effects of interim flows on the food base will allow for a direct determination of the impacts related to the interim flows. Specifically the maximum flows, minimum flows and ramping rates will impact the short-term food relationships by altering the distribution, abundance and diversity of the food base available. Of specific interest will be the Cladophora, aquatic diptera, diatoms, aquatic macroinvertebrates, invertebrates and Oscillitoria present in the Lower Colorado River.

BACKGROUND

The Glen Canyon Environmental Studies

Phase I of the Glen Canyon Environmental Studies has focused primarily on the impacts of the operation of Glen Canyon Dam from the dam to Diamond Creek. Several reconnaissance level fishery surveys were conducted below Diamond Creek during Phase I but they were not consistent and were not specifically addressed to the

identification of Glen Canyon Dam operational impacts. With the initiation of the Glen Canyon Dam Environmental Impact Statement, the inclusion of the Hualapai Tribe into the impact assessment program and the continued lowering of Lake Mead, the importance and possible impacts related to the operation of Glen Canyon Dam on the lower river has increased. Baseline studies and specific impact assessments are required of the aquatic resources that may be impacted.

Limited data exists for the area below Diamond Creek (Carothers and Minckley, 1981; Maddux, 1987; U.S. Department of the Interior, 1988; Minckley, et. al., 1981). The area is influenced both by the operations of Glen Canyon Dam and by the level of Lake Mead. Limited riverine area existed in 1983 when Lake Mead was full and the Colorado River was in flood stage. Since 1987, the surface elevation of Lake Mead has been dropping and the flows in the river have been reduced. With both of these elements has come an increase in the area impacted by the operations of Glen Canyon Dam to the fish fauna. moving up the Colorado River and into the lower river segments. With limited knowledge of pre-existing native and non-native fish populations evaluation of potential impacts is restricted.
The Hualapai Tribe is interested in the impacts that interim flow operations may have on the tribal aquatic resources in the lower river corridor. Of most concern are the native species important for resource and cultural purposes and the incursion of more non-native species into the lower river.

Interim Flow Relationships

There are three levels of concern related to the interim flows:

1. Concerns related to short and long-term impacts to the native fish population both by the flows and by the expansion of the non-native fish populations.

2. Concerns related to the short-term impacts of flow alteration on the available habitats for both the native and non-native fish populations.

3. Concerns related to the short-term impacts of flow alteration on the food base for the native and non-native fish populations.

The interim flows will vary in monthly volume, maximum flows, minimum flows and stage change per day. The flow levels and characteristics will dictate the level of impacts observed downstream. Specific short-term impacts to the habitats available for the fish and to the aquatic food base will be identified immediately. The long-term impacts are related to the behavioral, distribution, abundance and habitat use in the Lower Grand Canyon.

METHODS

Study Site Selection

The location of the specific sampling locations in the Lower Colorado River will follow the procedures outlined by Maddux (1987), Carothers and Minckley, 1981, Minckley, et.al.(1981) and those identified by the Arizona Game & Fish Department in the GCES Phase II Integrated Research Plan (1990). Study sites will focus on providing information on the fishery and food base relationships for both representative and at critical tributary and backwater locations. The study sites will be selected on a reconnaissance trip in April 1992 with specific sampling beginning in June 1992. The study sites will represent focus on shallow main-channel habitats and tributary mouths.

Sampling Techniques

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution, abundance and behavior of the native and non-native adult fish in the Lower Grand Canyon from Diamond Creek to Lake Mead.

The methodology will follow those outlined in the AGF and Bio/West proposals defined in the GCES Phase II Integrated Research Plan (1990) and those identified in Maddux (1987). In summary, the adult fish will be captured in the mainstem study sites using a combination of gear types including electrofishing, trammel nets and hoop nets. Techniques may include the baiting of hoopnets for catfish. Capture techniques will complement those being used in the upper river sections. Electrofishing will be accomplished using the updated Coffelt CPS technology and nets will be checked at a minimum 12 hour intervals.

Macro and micro-habitat measurements will be made at each sampling point. Stomachs of non-native fish will be collected and evaluated seasonally in order to determine food preferences and utilization. All fish will be measured and a subsample will be used for age determination using either otoliths or pectoral spines.

2. Monitor the effects of the interim flows from Glen Canyon Dam on the distribution, abundance and behavior of the native larval and juvenile native fish in the Lower Grand Canyon from Diamond Creek to Lake Mead.

The methodology will follow those outlined in the AGF proposal outlined in the GCES Integrated Research Plan (1990). Frequency and methodology will continue unchanged from those proposed in the original study plan. Spencer Creek and Diamond Creek will be

explored separately at a minimum of three (3) times per year.

At each tributary and mainstem sampling location, habitats will be mapped and microhabitat variables will be measured. The location of the fish within the habitat matrix will be correlated with flow measurements and depths. When fish reproduction is occurring, larval drift nets will be used to study the rate and timing of the drift.

3. Monitor the effects of the interim flows from Glen Canyon Dam on the reproduction, food habits and patterns of habitat use of piscivorous non-native fishes that predate on native fishes found in the Lower Grand Canyon from Diamond Creek to Lake Mead.

The methodology will follow those outlined in the AGF and Bio/West proposals defined in the GCES Phase II Integrated Research Plan (1990) and those identified in Maddux (1987). In summary, the adult fish will be captured at the mainstem study sites using a combination of electrofishing, trammel nets and hoop nets. Techniques may include the baiting of hoopnets for catfish. Capture techniques will complement those being used in the upper river sections.

Macro and micro-habitat measurements will be made at each sampling point. Stomachs of non-native fish will be collected and evaluated seasonally in order to determine food preferences and utilization. All fish will be measured and a subsample will be used for age determination using either otoliths or pectoral spines.

4. Monitor the effects of interim flows on the environmental conditions in the tributary mouths and shallow shore-line habitats in the Lower Colorado River from Diamond Creek to Lake Mead.

The methodology will follow primarily those outlined in the AGF proposal contained in the GCES Integrated Research Plan (1990). The procedures may have to be modified for those habitats in the upper end of Lake Mead due to the large expanses of mud flats and isolated backwaters.

Shoreline habitats will be sampled at two levels of intensity. Level A will involve sampling fishes using nets in conjunction with seines and electrofishing coupled with extensive measurements of the substrates, water temperature, depth and current velocity. The site will be mapped using conventional surveying techniques and available habitat at the specific flow will be identified. Level B surveys will involve all of the Level A work plus the evaluation of change over time. Remote sensing data recorders will continuously record water chemistry information. In addition, remote cameras will be calibrated to collect information on how the surface area of the useable habitat changed over time.

5. Monitor the effects of interim flows on the food base including productivity and algal standing crops in the Lower Colorado River from Diamond Creek to Lake Mead.

The methodology will follow those outlined in the AGF proposal identified in the GCES Phase II Integrated Research Plan (1990). Specific studies will focus on the measurement of the levels of photosynthesis and productivity. Algal standing crops will be assessed by measuring levels of chlorophyll a in water samples collected from multiple sites (mainstem, tributary mouth, and backwaters) seasonally. A liquid nitrogen chamber will be used to hold the filtered samples until they can be delivered to a laboratory for analysis. Benthic metabolism chambers will be used to determine the relative contributions of planktonic and benthic organisms to system production. Levels of dissolved organic carbon, phosphorus (all forms), nitrogen (as nitrate, nitrite, and ammonia), water hardness and alkalinity will be measured at multiple locations along the mainstem Colorado, and in tributary confluence zones seasonally in order to assess system fertility.

INTEGRATION WITH OTHER GCES MONITORING EFFORTS

The monitoring efforts described in this proposal will interface directly with those ongoing in the river above Diamond Creek. There will be no overlap with other monitoring or research efforts ongoing in the Grand Canyon. The data provided from this monitoring effort will complement that already being collected by the Arizona Game & Fish Department and Bio/West and will provide all with a better understanding of the aquatic dynamics for the lower river.

The river sampling efforts will be coordinated with the AGF efforts so that one sampling trip will dovetail with the next, therefore reducing logistical and data collection costs. The habitat and population information will be integrated directly into the GCES Geographic Information System. Specific habitat locations will be surveyed in so that actual elevation changes related to flow level modifications will be determined.

All information will be integrated into the GCES long-term data bases and will serve as the baseline information for evaluation of future operational changes.

DELIVERABLES

Quarterly and annual reports will be provided to each of the following entities according to the schedule in Table 1: The Glen Canyon Environmental Studies and the National Park Service. A DRAFT Final report will be distributed for technical review as specified by the GCES and a FINAL report will be developed at the completion of the interim flow monitoring program.

Reports will be prepared for submission to peer-reviewed scientific journals.

PERSONNEL

Technical Staff

It is anticipated that the Arizona Game & Fish Department will provide the primary expertise and direction on the fishery study. Mr. Travis Magenta and Mr. Donald Bay will provide the primary leadership to this overall program with technical support provided by the GCES Office.

Other Agency Support

The GCES will provide the primary river logistics support and the coordination of the permits with the Fish & Wildlife Service, Arizona Game and Fish and the National Park Service. GCES will also provide the surveying equipment necessary to position the sites within the GIS data base and provide technical support in the development of the Map Image Processing and remote sensing sites.

SCHEDULE

The schedule outlined in Table 1 will be followed for this project, but may be adjusted pending date of the actual contract modification.

Table 1: Schedule for activities and deliverables.

Project Initiation	May 1, 1992
Quarterly report	July 1, 1992
Quarterly report	Oct. 1, 1992
Annual report #1 (DRAFT)	Dec. 1. 1992
Annual report #1 (FINAL)	Jan. 1, 1993
Quarterly report	April 1,1993
Quarterly report	July 1, 1993
Quarterly report	Oct. 1, 1993
FINAL REPORT (DRAFT)	Dec.15, 1993
FINAL REPORT (FINAL)	Feb.15, 1994

LITERATURE CITED

Carothers, S.W. and C.O Minckley. 1981. A survey of the fishes, aquatic invertebrates, and aquatic plants of the Colorado River and selected tributaries from Lee's Ferry to Separation Rapid. Final Report, U.S. Bureau of Reclamation Contract No.

7-07-30-X0026, Lower Colorado River Region, Boulder City, Nev., Museum of Northern Arizona, Flagstaff, AZ. 410p.

Minckley, C.O., S.W. Carothers, J.W. Jordan, and H.D. Usher. 1981 Observations on the humpback chub, Gila cypha, within the Colorado and Little Colorado Rivers, Grand Canyon National Park, Arizona. National Park Service Trans. Proc. Ser., Washington, DC.

Maddux, H.R., D.M. Kubly, J.C. deVos, Jr.,W.M. Persons, R. Staedicke, and R.L. Wright. 1987. Effects of varied flow regimes on aquatic resources of Glen and Grand canyons. Final Report, U.S. Bureau of Reclamation Contract 4-AG-40-01810. Arizona Game and Fish Department, Phoenix. 291p.

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Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Hualapai Wildlife - Fisheries Date Submitted 2/26/92

Department/Laboratory _____ Organization _____

Beginning Date May 1992 Completion Date December 1994

Project Title Evaluation of the Effects of the Interim Flows on the Fisheries ~~Resources of the Lower Grand Canyon~~

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Fisheries Specialist I (1)	6 month			9,250
2. Administrative Assistant	6 month			7,500
3. Fisheries Technicians (2)	6 month			16,848
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. (1) Secretarial/Clerical				6,600
6. ( ) Other Overtime				4,400
Employee Related		30%		13,379
C. FRINGE BENEFITS		19%		8,474
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				23,100
2. Items ~~> $10,000~~ less than $500				10,000
E. TRAVEL				
1. Domestic				
a. Principals				1,500
b. Others				
2. ~~Foreign~~				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				6,600
4. Other Office rental and vehicle maintenance				21,144

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	
b. Other Office	10,000
2. Publication Costs	
3. Consultant Services	
4. Computer Services	
5. Subcontracts (see table below for contracts)	9,500
6. Other	
H. TOTAL DIRECT COSTS (A through G)	148,295
I. INDIRECT COSTS 27.5%	40,781
J. TOTAL DIRECT AND INDIRECT COSTS	189,076
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	0
L. TOTAL PROJECT AMOUNT (J + K)	189,076 /year 1 (NOT

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1. Generator (2,000) + Nets -Trammel (1,000) + Current Meter (1,600)	4,600
2. Electrofishing pulsator (Coffelt CPS)	4,500
3. Computer - 386 w/printer w/software	3,000
4. Passive Integrated Transponder with Reader	6,000
5. Benthic Metabolism chambers (2)	5,000
TOTAL	23.100

~~Description of Items > $10,000~~ SUBCONTRACTS	
1. Larval Fish Identification	2,500
2. Plankton Identification	4,000
3. Date Entry and Verification	3,000
4.	
5.	
TOTAL	

*Including Freight charges

Year 1 = $189,076
Year 2 = $165,976 (less major capitalized equipment costs)
TOTAL = $355,052 (two year costs)

C4

GLEN CANYON NATIONAL RECREATION AREA
INTERIM FLOW MONITORING PROPOSAL - 1992

WATER QUALITY MONITORING OF THE COLORADO RIVER, GLEN CANYON DAM TO LEES FERRY, ARIZONA

Principal Investigators:

Clive Pinnock, National Park Service, Glen Canyon National Recreation Area
Charles W. Wood, National Park Service, Glen Canyon National Recreation Area

OBJECTIVE: The objective of this monitoring is to determine whether the "interim" water release patterns from Glen Canyon Dam have any effect on water quality at shoreline sites along the river.

JUSTIFICATION: The interim flow regime initiated in August, 1991 had the effect of reducing the magnitude of daily fluctuations in river stage and lowering the maximum water release limit by approximately 30%. Water quality within this river section is controlled by 1) the quality of water released from the dam, 2) erosion and runoff from beach and margin deposits, 3) recreational use, and 4) any contaminants entering from side drainages or accidents at upstream facilities. Factors 2 and 3 could be directly affected by interim flows because the wetting and washing of beaches would presumably be limited to a narrower band of shore, and because recreational use may be encouraged or intensified at some sites by more stable water levels. Factor 1 could also be affected by interim flows and is already being investigated by others.

The relationship between recreational use, shoreline water levels, and bacterial contamination is well established. Tunnicliff and Brickler, in a 1981 study of water quality in the Grand Canyon reported that bacterial levels were highest when discharge and turbidity were highest. They also found high levels of contamination in waters above Lees Ferry where recreational use of the shore is intense. Subsequently, the National Park Service installed permanent toilets at various campsites along the river in Glen Canyon and tightened use restrictions. Water quality then improved, although a consistent monitoring program for bacterial contamination has never been established for the river. Such a monitoring program has been established for Lake Powell, however, where it has been found that contamination is highly correlated with recreational use. In recent years, however, beach contamination on the lake worsened in a variety of locations even though recreational use has declined. One possible explanation is that lower lake levels may be reducing circulation along beaches in zones where coves or bays have become shallower. An analagous situation on the river could result from reduced fluctuation and a more stable beach-water interface, especially at eddies or backwaters. any such influence would be intensified by greater recreational use. Additionally, changes in monthly volume could result higher bacterial levels associated with increased turbidity (resuspension of sediment, etc.), at least near shore.

The National Park service is continuing to fund monitoring on Lake Powell for water quality. Staff and laboratory facilities will already be in place to collect and evaluate water samples. Due to logistical barriers additional funding for a temporary position would be needed to successfully incorporate the river into the sampling scheme. No additional funding would be needed for principals, equipment, supplies, or transportation.

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METHODS: The area of investigation encompasses all of a sixteen-mile river corridor between Glen Canyon Dam and Lees Ferry, Arizona.

Six shoreline sites representing beaches used by recreationists will be selected, emphasizing situations where current is not flowing strongly alongshore and eddies or quiet water may exist. Each site will be sampled monthly April through September. Each sample will consist of a time-series set of replicated 120-ml water collections in sterile polypropylene sample bottles. Collections will be made at 0600, 1000, 1400, and 1800 in water 1-2 feet deep near shore. Samples would be filtered and cultured for fecal coliform bacteria using the membrane filtration technique as described in Standard Methods For The Examination of Water And Wastewater. They would be processed in two batches to minimize holding time. After incubation under standard conditions for 24 hours, coliform colonies would be counted and recorded on a database program. Bacterial levels would be evaluated for trend, correlation with flow parameters and visitation level, and compared with water quality standards for human health and wildlife. Physical water quality data collected at the time of sampling would include temperature and pH. Deliverables would consist of a final report submitted December 31, 1992 containing site maps, raw data for bacterial counts, and data evaluation tables.

INTEGRATION WITH OTHER MONITORING EFFORTS: The U.S. Geological Survey measures physical and chemical water quality monthly at the Glen Canyon gage and Lees Ferry. This database would provide baseline quality information on water entering and exiting the reach under study, complementing the study proposed here. National Park Service visitor counts for the Lees Ferry subdistrict and information on water flow parameters collected by the Bureau of Reclamation would permit data analysis for any correlation of bacterial levels in water with interim flow regimes.

PRODUCTS TO BE DEVELOPED: The final report referred to above would be provided at the end of the year. Sample sites would be fixed using the GPS unit and entered into the GIS database.

GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

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GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Pinnock, Wood Date Submitted 3/2/92

Department/Laboratory National Park Service-GLCA Organization

Beginning Date April, 1992 Completion Date September, 1992

Project Title WATER QUALITY MONITORING OF THE COLORADO RIVER, GLEN CANYON DAM TO LEES FER

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Pinnock	1			NPS funded
2. Wood	.5			NPS funded
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (1) Other Professional (techs.)	6			$9,500
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	$500.
a. Telephone	
b. Other	
2. Publication Costs	
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	$10,000 - project proposal request
I. INDIRECT COSTS	
J. TOTAL DIRECT AND INDIRECT COSTS	
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	$5,500 NPS lab and PER YEAR
L. TOTAL PROJECT AMOUNT (J + K)	$ 15,500 FOR 2 YRS.

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

GLEN CANYON ENVIRONMENTAL STUDIES

DRAFT

INTERIM FLOW MONITORING PROPOSALS

RIPARIAN RESOURCES

RIPARIAN RESOURCES

RIPARIAN RESOURCES

D1

A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION IN THE COLORADO RIVER DOWNSTREAM FROM GLEN CANYON DAM, ARIZONA

Tina J. Ayers

Department of Biological Sciences
Northern Arizona University
Flagstaff, AZ 86011

and

Lawrence E. Stevens

Resources Management & Planning Division
Grand Canyon National Park
Grand Canyon, AZ 86023

Starting Date: 15 June, 1992

Duration: 20 Months

Funding Amount: $288,600

Submitted To: The National Park Service
Cooperative Studies Unit
Northern Arizona University
Flagstaff, AZ 86011

Tina J. Ayers
Co-Principal Investigator

Henry O. Hooper, PhD
Associate Vice President
for Academic Affairs,
Research and Graduate Studies

Lawrence E. Stevens
Co-Principal Investigator

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A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION IN THE COLORADO RIVER DOWNSTREAM FROM GLEN CANYON DAM, ARIZONA

ABSTRACT

Discharge patterns from Glen Canyon Dam strongly affect the riparian vegetation of the Colorado River corridor in Grand Canyon National Park. Marshes, other new high water zone and pre-dam vegetation are affected by the duration and timing of releases from Glen Canyon Dam. The objectives of this proposal are to monitor the effects of discharge characteristics under the Bureau of Reclamation's interim flows from Glen Canyon Dam on riparian vegetation in three zones using comparably collected data from the Glen Canyon Environmental Studies Phase II program. This information is important because riparian vegetation provides essential food and habitat for the diverse riparian fauna of the Colorado River corridor and may influence sand bar stability in this fluvial ecosystem.

This study will monitor riparian vegetation by providing data collected in a manner comparable with that collected during GCES-II. This proposed project is designed to monitor marsh development, shoreline vegetation in different geomorphic settings, and pre-dam vegetation during the GCES interim flows. Methods to be used include censuses of pre-established transects and study sites for species composition, germination, growth rates and tiller production, productivity, soil changes, ground cover, shrub cover, and/or litter production and decomposition rates. In addition, this project will provide data on colonization of non-native species, and will continue to evaluate the distribution of critical species in the river corridor. This proposal requests funding for FY92 - FY94 in the total amount of $280,500 to meet these objectives.

STATEMENT OF OBJECTIVES

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution and development of fluvial marshes along the Colorado River between Lees Ferry and Diamond Creek.

2. Monitor the effects of interim flows on the extent and response of other New High Water Zone (NHWZ) vegetation and the Old High Water Zone (OHWZ) vegetation in the Colorado River corridor in Grand Canyon National Park.

3. Prepare monitoring data and sites (via GPS) for inclusion into the GCES/NPS GIS database.

JUSTIFICATION

A primary objective of the Bureau of Reclamation's Glen Canyon Dam Interim Flows discharge criteria was to benefit the aquatic food base of the Colorado River. The interim flows prescription specifies a minimum discharge of 141.5 m^3/sec (5,000 cfs), reduced maximum flows, reduced range of daily fluctuation, and slow ramping rates. These criteria established what is hoped to be an ecologically appropriate discharge regime, thereby stabilizing sand bars and permitting riparian habitat development to proceed unimpeded by dam operations. The objectives of this study are to determine if the interim flows prescription achieved this resource objective.

1. Monitor the effects of interim flows from Glen Canyon Dam on the distribution and development of fluvial marshes along the Colorado River between Lees Ferry and Diamond Creek.

Monitoring interim flows effects on fluvial marshes is an important objective because fluvial marshes are diverse, biologically productive habitats that occur in low-lying areas and are subject to periodic inundation. GCES-II studies showed that 95% of the cattail/bullrush marsh vegetation at three large marshes lay between the 283 m^3/sec (10,000 cfs) and 567 m^3/sec (20,000 cfs) stage. By altering the frequency of inundation and sedimentation, interim flows may affect marsh distribution, composition, productivity, moisture stress and succession. The maintenance of fluvial marshes is important to Grand Canyon National Park because marshes play a disproportionately large role in ecosystem production and support several critical species. For these reasons, fluvial marshes should be monitored during the interim flows period.

2. Monitor responses of NHWZ and OHWZ vegetation to interim flows in the Colorado River corridor in Grand Canyon National Park.

Monitoring interim flows effects on post-dam and pre-dam vegetation is an important objective because Colorado River riparian habitat in Grand Canyon is a biologically productive habitat that is affected by discharge from Glen Canyon Dam. GCES-II studies suggested that clonal phreatophytes were rapidly colonizing the new lower NHWZ. Grand Canyon National Park has established maintenance of riparian vegetation in the Colorado River corridor as a management objective. Short-term effects of interim flows on riparian vegetation may include changes in riparian plant recruitment and survivorship, changes in species composition and moisture stress levels. The status of significant non-native riparian populations (e.g. Tamarix ramosissima, Alhagi camelorum and Erianthus ravennae) may change relatively rapidly and requires monitoring. These non-native species may alter the riparian succession towards native species observed in this system by Brian (1982), Phillips et al. (1987) and Stevens (1989). For these reasons, riparian vegetation should be monitored during the interim flows period.

3. Prepare monitoring data for inclusion into the GCES/NPS GIS database.

This is an important monitoring objective because the GCES/NPS GIS is planned to be the primary mechanism for database organization, as well as interim flows and longer-term monitoring, of Glen Canyon Dam effects on the Colorado River corridor in Grand Canyon National Park. The short-term monitoring efforts proposed here will contribute to essential baseline data for future, long-term monitoring in this system by developing themes of marsh vegetation assemblages in selected reaches, and riparian vegetation assemblages. These GIS themes can be used to monitor change associated with significant adjustment of flow regimes, such as may come about from the Record of Decision on Glen Canyon Dam oiperations. Each of the proposed Glen Canyon Dam EIS alternatives includes a long-term monitoring component, and the data collected here will be compiled in an appropriate fashion for inclusion into the GCES/NPS GIS.

BACKGROUND

The Glen Canyon Environmental Studies

Construction of Glen Canyon Dam unintentionally enhanced vegetation growth and whitewater recreation along more than 475km of the Colorado River in Grand Canyon National Park (Carothers and Aitchison 1976; Carothers et al. 1979; Turner and Karpiscak 1980; Phillips et al. 1986; Stevens 1989). Phase I of the Bureau of Reclamation's Glen Canyon Environmental Studies (GCES-I) was initiated to reveal whether Glen Canyon Dam operations had a significant impact on river resources

and whether modification of discharge criteria could ameliorate those impacts (Water and Science Technology Board 1987; U.S. Dept. Interior 1988). Although few data were available, GCES-I terrestrial studies concluded that normal (non-flooding) dam operations affected processes such as bank erosion, soil nutrient availability, and soil moisture availability. GCES Phase II was initiated to evaluate the effects of low and fluctuating flows on this system, and an Environmental Impact Statement has been requested concerning the impacts of Glen Canyon Dam operations on downstream resources.

Interim Test Flows

The Secretary of the Interior authorized implementation of a program of reduced maximum flows and reduced fluctuation from Glen Canyon Dam beginning in August, 1991. These interim flows were designed to mitigate impacts of dam operations on downstream riverine resources, until a Record of Decision is reached for the Glen Canyon Dam Environmental Impact Statement. These interim flows consist of low-, medium-, and high-volume months, with low flows during the spring and late fall, moderate flows in June, September and November, and high flows during mid-summer and mid-winter. Interim flows have a minimum flow of 5,000 cfs, a maximum discharge of 20,000 cfs, a reduced range of daily fluctuation, and reduced up- and down-ramping rates. The Glen Canyon Environmental Studies Program is coordinating monitoring interim flows effects on sediments, cultural resources, the aquatic food base, riparian areas and wetlands, economics, trout, native fish, recreation and water quality, with data base management and development of a geographic information system (GIS). The effects of flow exceptions also require monitoring under the interim flow discharges program.

Regional Importance of Riparian Vegetation

Management of riparian habitat is a major concern throughout the United States. Wetlands, including riparian habitats, are among the most biologically productive and recreationally valuable of terrestrial lands. Unfortunately, riparian habitats are poorly managed because of a lack of concern, conflicting management priorities, and inadequate information (Johnson et al. 1985). Despite the fact that riparian habitat comprises 0.04% of the Arizona landscape, it typically supports more than 50% of the species occurring there (Simcox and Zube 1985; Stevens in press). Riparian vegetation serves as an intermediary between abiotic components and higher trophic levels, and plays a significant role in both aquatic and terrestrial ecosystem dynamics, as well as providing erosion control and shade for recreationists. Management of riparian habitat requires an ability to assess changes in attributes through time, criteria which are best met by using field survey techniques and GIS.

Riparian Vegetation in the Grand Canyon

Phreatophyte distribution in the Grand Canyon was studied prior to construction of Glen Canyon Dam. Clover and Jotter (1944) described the phreatophyte distribution in the river corridor prior to impoundment, reporting little streambank vegetation along the river itself and most riparian species restricted to tributaries. Turner and Karpiscak (1980) matched pre-dam photographs and confirmed that little vegetation occurred along the pre-dam river in the annually flooded zone. Establishment of riparian vegetation began soon after closure of Glen Canyon Dam (Turner and Karpiscak 1980). Phillips et al. (1977) compiled a riparian vegetation map of the river corridor. Carothers et al. (1979) described riparian vegetation zonation of the river corridor, noting a xerophyte-dominated talus community (Zone I); a perched, pre-dam "old high water zone" (OHWZ; Zone II) community dominated by *Prosopis glandulosa* and *Acacia greggii* and lying above the approximate 3500 cms stage; a "back beach zone" with little vegetation and occupying Zone III between the approximate 1150 cms and 3500 cms stages; and

a new high water zone (NHWZ; Zone IV) below the approximate 1150 cms stage at the post-dam river edge, and dominated by exotic Tamarix ramosissima and native phreatophytes.

Several authors reported on successional development of riparian vegetation in this system. Martin (1970 unpublished) documented the widespread occurrence of exotic Tamarix ramosissima, and noted the presence of native riparian plant species. Brian (1982) examined the distribution of Salix exigua in the upper Canyon, reporting rapid, widespread expansion of this native, clonal willow into all riverside habitats. Stevens (1985) reported that low-magnitude (1400 cms) flooding in 1980 resulted in increased beach erosion and initiated a small-scale germination event. Stevens (1985) also concluded that successional replacement of T. ramosissima by native S. exigua was not induced by invertebrate herbivory. Phillips et al. (1987) also noted continuing change in post-dam riparian plant community composition in this system.

During GCES-I, Pucherelli (1988) reported a rapid increase in riparian vegetation cover in the new (post-dam) high water zone (NHWZ) between 1965 and 1982. Cover was significantly reduced in this new riparian zone in wide reaches during spillover flooding in 1983-1984. Anderson and Ruffner (1988) found that post-dam flooding had little effect on germination or growth of Prosopis or Acacia in the perched pre-dam terraces of the old high water zone (OHWZ). Brian (1988) and Stevens and Waring (1988) reported significant loss of riparian vegetation in the NHWZ as a result of spillover flooding. The latter authors noted that spillover flooding degraded substrata, decreased riparian plant cover and diversity, and stimulated germination. Subsequent studies revealed species-specific, age-related mortality and growth of dominant riparian phreatophytes under various discharge scenarios (Waring and Stevens 1988). The impacts of flooding on riparian vegetation in tributaries and along the river corridor was studied by Stevens (1989), who concluded that dam-induced substrata changes in soil texture, water availability, and nutrient status were largely responsible for the successional development of the phreatophyte community. He also reported that the river corridor was structurally more similar to the sparsely-vegetated ephemeral tributaries than to the richly-vegetated perennial tributaries. Stevens and Waring (1989) monitored post-1983 ecesis and community development of woody riparian vegetation along the Colorado River in Grand Canyon National Park from 1984 through 1988, reporting that germination of dominant riparian species was induced by flooding, and that exotic Tamarix ramosissima density appeared to have increased as a result of dam operations.

Factors Influencing Riparian Vegetation Development

The suite of factors regulating riparian plant community growth and compositional change (succession) in the Grand Canyon has only begun to be explored (Stevens 1989). Riparian vegetation develops in response to interrelated physical and biological factors, including: the flooding disturbance regime; the species pool available for colonization; differential propagule abundance; and germination and establishment requirements of constituent species (Kozlowski 1984; Reichenbacher 1984; Stevens and Waring 1988; Stevens 1989). Flooding disturbances are "killing events" (sensu Sousa 1984) that 1) decrease biological organization (i.e. diversity and complexity of trophic structure), 2) lower the "trajectory of ecological succession" by direct reduction of biomass and diversity, thereby returning the ecosystem to an earlier stage of development (Odum 1981), 3) resulting in a "perpetual succession" (Campbell and Green 1968), and 4) expose new patches of habitat and thereby promote germination of phreatophyte species (Stevens and Waring 1988; Waring and Stevens 1988; Stevens 1989). Alteration of the disturbance regime in regulated rivers may change the course of riparian succession by reducing recruitment, and by affecting biotic interactions. Post-impoundment flooding in regulated river corridors provides insight into the processes that structure phreatophyte communities (Stevens 1989).

GCES-II Data

GCES Phase II studies on riparian vegetation were conducted by Ayers and Stevens (1991). Their preliminary data suggest several impacts of discharge on riparian vegetation:

1. Reduced flooding frequency after completion of Glen Canyon Dam in 1963 allowed fluvial marshes to form in low velocity channel margin environments in wide reaches. Marshes were scoured by spillover flooding in 1983 and have begun to redevelop since 1987. Approximately 146 wet and 954 dry fluvial marshes occur in the Colorado River corridor downstream from Lees Ferry, Arizona. Total marsh area was conservatively estimated at 25.8 ha, with 30% as wet marsh, dominated by Typha domingensis, Juncus spp. and Scirpus spp. Dry marsh dominants included Phragmites australis and Equisetum laevigatum. Riverside marshes in this system were generally small, typically less than 0.5 ha, with wet marshes significantly larger than dry marshes. Mean standing crop and estimated productivity of fluvial marshes in this system was 0.74 kg/m^2 and 147.8 g C/m^2/yr, respectively, values about 6% reported for marshes. Low productivity may be due to reduced duff accumulation and damage to vegetation (flattening and silt-coated) by high daily flows. Marsh assemblage composition and succession was related to sediment distribution and discharge, with wet marshes requiring a frequency of daily inundation between 0.4 and 0.9. More than 95% of the wet marsh vegetation in this system lies between the 283 m^3/sec (10,000 cfs) and 566 m^3/sec (20,000 cfs) stages. While fluvial marshes re-develop rather quickly after flooding events (e.g. 1983-1986), obligate marsh animal populations may not be as resilient. Willow flycatcher, which depend on marsh habitats, are believed to be nearly extirpated from this system because of habitat loss, brood parasitism by brownheaded cowbird (B.T. Brown pers. comm.).

2. Riparian seedling establishment was greatest in the New High Water Zone and was dominated by herbaceous species there. Seedling density varied as a function of particle size, and differed between plant groups (xerophytes and phreatophytes) in wide versus narrow channels. Tamarix ramosissima seedling density was low in 1991, but limited establishment suggests that this species may be capable of continuing to colonize the river corridor under fluctuating flow regimes.

3. River stage was shown to affect plant water potential for pre-dawn Salix exigua, a ubiquitous riparian phreatophyte in the Colorado River corridor. Further studies will determine whether similar patterns apply to Tamarix ramosissima and growth of both species.

4. In addition, studies of long-term vegetation quadrats, Old High Water Zone phreatophyte growth, and the status of listed, endemic and non-native species are underway. Thus far, no plants species appear to be at risk from dam operations; however, several previously unrecorded non-native species are colonizing the river corridor, including Erianthus ravennae, a large Eurasian bunchgrass. Prompt action may prevent this species from successfully invading the river corridor.

METHODS

Study Site Selection

Riparian vegetation research in GCES Phase II focused on vegetation patterns between geomorphic settings within sites (Ayers and Stevens 1991). The 20 sites to be monitored here contain 5 m x 10 m permanent quadrats in the following geomorphic settings: marsh, riparian strip, general beach (all in the New High Water Zone), debris fan, old high water zone and desert zone. The GCES-II vegetation project (Ayers and Stevens) will not be fully completed until September, 1992; however, the study sites have been established and are ready for

monitoring. These sites will be monitored during FY92 and FY93. When the Ayers and Stevens project is completed and monitoring protocol has been more fully refined, the number of sites required for evaluation of vegetation responses to discharge may be reduced, thereby increasing monitoring efficiency.

Sampling Techniques

Objective 1: *Monitor the effects of interim flows from Glen Canyon Dam on the distribution and development of fluvial marshes along the Colorado River between Lees Ferry and Diamond Creek.*

Monitoring interim flows effects on fluvial marsh distribution will require work at several temporal and spatial scales. We propose to evaluate areal change in selected reaches by re-mapping fluvial marshes onto the Bureau of Reclamation's GIS base maps (1:2400 scale). The GIS base maps were based on 1990 aerial photographs annd riparian vegetation was recognized as an important theme; however, vegetation mapping has yet to be accomplished. Selected marshes were surveyed in detail in 1991 by Ayers and Stevens, and Schmidt mapped geomorphology of selected reaches in 1991 as well. These data and maps are available and will be used to re-map fluvial marshes. Reaches to be mapped will include wide versus narrow reaches, and will include different deposit types (Schmidt and Graf 1990). This analysis will elucidate whether areal changes are occurring in fluvial marshes during the interim flows period, and whether these relate to different reach characteristics and deposit types.

To evaluate the effects of low-volume, medium-volume and high-volume monthly interim flows, we will conduct topographic surveying of inundation frequency and extent in at least ten marshes studied during GCES II by Beus and Avery (1991). Sites may include marshes at river miles (RMs) 20.0L, 43.1L, 51.5L, 56.0R, 68.2R, 71.0L, 122.8L, 144.0R, 172.1L and 194.1L, where survey control and stage/discharge relationships have been established. Standard electronic surveying protocol will be employed to provide accurate documentation of stage and area relationships at these sites. Marshes will be visited during each of the three interim flow types (low, medium and high monthly volumes), water surface elevations will be surveyed at low and high daily stage, and total area of the marsh will be remeasured, taking into account new clonal growth or dead patches. Root excavation will be conducted to confirm die back of marsh vegetation. Hypsographic relationships will be determined from this effort and reported for each fluvial marsh, and changes in topography related to aggradation or degradation will be documented.

If the (pending) results of GCES-II research on plant moisture stress (PMS) for Salix exigua and Tamarix ramosissima prove useful for evaluating discharge effects on riparian vegetation, this technique will be employed as a monitoring method. GCES-II results suggest that discharge stage and range of fluctuations significantly affect PMS levels and, potentially, growth of these two successionally interacting species. PMS will be evaluated during each of the three monthly flow regimes for Salix exigua, a species associated with fluvial marsh habitats. PMS levels will be evaluated for this "indicator species" during pre-dawn and mid-day hours during low-volume (May), medium-volume (June), and high-volume (July/August). Data collected according to standard Schollander pressure bomb techniques for a minimum of 30 tagged individual Salix exigua on each of four consecutive nights. At least one of these nights will be a week-end low flow (preferably Sunday's water), during each flow-volume type. Data will be collected at -6.5R, 43.1L and 172.1L marshes, sites where data were collected during GCES-II, and where bank stored groundwater fluctuation is being monitored by the U.S. Geological Survey.

The GCES-II 1.0 m-wide belt transects will be recensused early and late in FY92 an FY93 to monitor compositional changes during the interim flows period. Five transects will be remeasured/marsh, with data on basal area, density and species

composition measured. Changes in soil profiles relating to deposition or erosion will also be noted. All above-ground growth and litter will be collected from each of ten 0.5 m^2 plots annually in each marsh to monitor productivity. Likewise, colonization of 10 0.5 m^2 plots will be monitored to evaluate changes in marsh development rates under interim flows.

Objective 2: *Monitor the effects of interim flows on the extent and response of other NHWZ and OHWZ vegetation in the Colorado River corridor in Grand Canyon National Park.*

During GCES-II a series of 20 study sites were established, each having a 5 m x 10 m quadrat in each of six different geomorphic settings. These study sites were designed for monitoring dam discharge impacts on riparian vegetation development. During interim flows monitoring, these quadrats will be re-censused early and late in FY92 and FY93. Quadrats were divided into eight subplots for mapping purposes, and will be used to monitor species composition, germination, growth rates and tiller production, soil changes, site stability, ground cover, shrub cover, and litter production and decomposition rates. In addition, these censuses will provide trend data on colonization by non-native plant species. Spot sampling in the vicinity of these quadrats will be used to detect and monitor the distribution of critical native plant species in the river corridor.

Integration With Other Monitoring Efforts

There are few, if any, overlaps between this project and other monitoring projects planned. The data provided here may be useful for U.S. Fish & Wildlife avifaunal monitoring efforts and mapping of willow flycatcher nesting sites. We will make every effort to coordinate our activities with FWS so as not to interfere with planned studies of willow flycatcher nesting success and habitat requirements. This project may provide data to the sand bar stability project, and may provide opportunities for logistical coordination and detail on timing of erosional events to that project. This project will provide vegetational information to geomorphological maps made during GCES-II of selected reaches.

Objective 3: *Prepare monitoring data for inclusion into the GCES/NPS GIS database.*

The data collected and compiled in this project will contribute to the GCES/NPS GIS data base and mapping effort. Themes relating to marsh species composition and distribution will be developed for selected reaches, and species composition of other riparian assemblages will be developed. This will require close coordination with the GCES/NPS GIS team, and should result in deliverables that are readily included in the GIS. The data collected here will augment existing knowledge of riparian vegetation species composition and dam-related patterns of change.

DELIVERABLES

Quarterly and annual reports will be provided to each of the following entities according to the schedule in Table 2: the National Park Service at Grand Canyon National Park, Northern Arizona University Cooperative Parks Studies Unit, and the Regional Scientist; the Glen Canyon Environmental Studies Office and the Senior Scientist. An initial oral report will be provided to Grand Canyon National Park Resources Management staff. Draft final reports will be submitted for review to Resources Management and the NAU CPSU. Reports will be prepared for submission to peer-reviewed scientific journals.

PERSONNEL

NAU Staff

Dr. Tina J. Ayers (NAU Department of Biological Sciences) will serve as a Co-Principal Investigator, and this project will require 20% her time. She is fully qualified to serve as a Co-P.I. as she is intimately familiar with the system, having coordinated and conducted GCES-II studies. Hiring protocol for assistants will conform to that required by NAU Human Resources Department.

Service Involvement

Dr. Lawrence E. Stevens (Grand Canyon National Park Resource Management Division) will serve as a Co-Principal Investigator, and this project will require 30% of his time/. He is fully qualified to serve as a Co-P.I. as he is intimately familiar with the system, having coordinated and conducted GCES-II studies and published on the riparian ecology and succession taking place in this dam-regulated system.

Dr. Peter Rowlands, CPSU at Northern Arizona University, will serve as the COTR on this project, requiring 0.07 FTE of his time. The National Park Service at Grand Canyon National Park will be responsible for collection permits, occasional logistical support, and review of the study and deliverables. Temporary housing may be required at Lees Ferry when research is being conducted in that area. Permitting is required from Glen Canyon National Recreation Area for data collection in the Lees Ferry reach.

NPS Staff:	0.10 FTE COTR	$3,600
	0.30 FTE Ecologist	$10,000
	0.30 FTE BioTech	$6,000
	FICA (10%)	$2,460
	Subtotal	$22,060

Other Agency Involvement

The Bureau of Reclamation GCES office is requested to provide river trip logistics, the loan of a depthfinder, and key river trip and laboratory equipment. Equipment will be borrowed whenever possible to avoid unnecessary purchases.

SCHEDULE

The schedule outlined in Table 1 will be followed for this project, but may be adjusted pending the date of NPS notification of funding to Northern Arizona University.

Table 2: Schedule for activities and deliverables.

Project Initiation	10 June, 1992
Quarterly report and first sampling trip	15 June, 1992
Second sampling trip	15 September, 1992
Quarterly report	1 October, 1992
Draft annual report	1 December, 1992
Final 1992 annual report	1 January, 1992
Quarterly report	1 April, 1993
Third sampling trip	15 April, 1993
Quarterly report	1 July, 1993
Fourth sampling trip	15 September, 1993
Quarterly report	1 October, 1993
Draft final report	15 December, 1993
Final annual report	15 February, 1993

BUDGET

The following budget does not include the cost of logistics, which will be covered and coordinated by the Bureau of Reclamation Glen Canyon Environmental Studies Office in Flagstaff, Arizona. In addition, some equipment may be purchased by the GCES. This budget does not include NPS staff or travel costs, which are included in the annual NPS administrative budget associated with the GCES Program.

PERSONNEL	**FY92**	**FY93**	**FY94**	**TOTAL**
Principal Investigators:				
Ayers (1/6-time @$38,000/yr)	$3.8k	$7.6k	$3.8k	$15.2k
Stevens (salary by NPS)	---	---	---	---
Photo Analysis				
One full-time photo analyst @8.5/hr	$5.0k	$18.0k	$4.0k	$27.0k
Vegetation crew				
Two full-time crew leader/analysts @$12/hr	$12.6k	$50.7k	$25.3k	$88.6k
Four 1/4-time field crew @$8.5/hr	$8.9k	$17.9k	$4.5k	$31.3k
Survey Crew				
One 1/4-time surveyor(@$12/hr)	$2.5k	$6.5k	$5.0k	$14.0k
One 1/6-time rodman (@$10/hr)	$1.7k	$3.5k	$0.9k	$6.1k
ERE (10%)	$3.5k	$10.4k	$4.4k	$18.3k
Subtotal	$38.0k	$114.6k	$47.9k	$200.5k
TRAVEL				
P.I. travel & per diem (2 trips/yr)	$2.0k	$2.0k	$1.0k	$5.0k
EQUIPMENT				
Herbarium cabinet	$1.0k	$0.0k	$1.0k	$2.0k
SUPPLIES				
Field Supplies Pinflags, data sheets, surveying accessories, flagging, camera, film, video tapes, etc.	$3.0k	$2.0k	$0.0k	$5.0k
OFFICE COSTS				
Office supplies	$1.0k	$2.0k	$2.0k	$5.0k
Secretarial, xeroxing, reprographics	$3.0k	$5.0k	$2.0k	$10.0k
Subtotal	$4.0k	$7.0k	$4.0k	$15.0k

ANALYSES				
Soil and litter analyses (100 @$65 ea)	$3.0k	$5.0k	$5.0k	$13.0k
ESTIMATED TOTAL DIRECT COSTS	$51.0k	$130.6k	$58.9k	$240.5k
INDIRECT COSTS (20%)	$10.2k	$26.1k	$11.8k	$48.1k
TOTAL ESTIMATED COST	$61.2k	$156.7k	$70.7k	$288.6k

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Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator T.J. Ayers and L.E. Stevens Date Submitted 26 Feb., 1992

Department/Laboratory Dept. Biol. Sciences, No. AZ Uni Organization NPS-CPSU

Beginning Date 15 June, 1992 Completion Date 15 February, 1994

Project Title The Effects of Interim Flows from Glen Canyon Dam on Riparian Vegetation

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Ayers		3200	12000	15200
2. Stevens (salary by NPS)				0
3.				
B. OTHER PERSONNEL				
1. (2) Post Doctoral Associates		60400	28200	88600
2. (3) Other Professional (techs.)		47100		47100
3. (4) Graduate Students		31300		31300
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				7000
6. ( ) Other				
C. FRINGE BENEFITS				18300
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				2000
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				3000
b. Others				2000
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	1000
b. Other	5000
2. Publication Costs	2000
3. Consultant Services	
4. Computer Services	
5. Subcontracts	13000
6. Other	
H. TOTAL DIRECT COSTS (A through G)	240560
I. INDIRECT COSTS	48100
J. TOTAL DIRECT AND INDIRECT COSTS	288600
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	288600

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1. Two herbarium cabinets	2000
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

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HUALAPAI TRIBE

PROPOSAL TO MONITOR AND EVALUATE THE IMPACTS OF THE GLEN CANYON DAM INTERIM FLOWS ON THE RIPARIAN PLANT COMMUNITIES IN THE LOWER GRAND CANYON

ABSTRACT

The Hualapai Tribe proposes to conduct monitoring and basic data collection on the riparian ecosystem of the Colorado River on the Hualapai Indian Reservation. A description of the riparian communities that comprise this ecosystem and changes that have occurred there in response to Glen Canyon Dam interim flow operations will be identified.

STATEMENT OF OBJECTIVES

The riparian zone of the Colorado River through the Hualapai Indian Reservation in lower Grand Canyon is a complex and productive environment, and the Hualapai Tribe has strong cultural, environmental and economic ties to this portion of their reservation. The Hualapai Tribe has proposed to work with the Glen Canyon Environmental Studies program (GCES) to assess the influence of Glen Canyon Dam interim flow operations on the cultural, economic and natural resources of their lands and resources.

For centuries the riparian zone in the lower Grand Canyon has provided the Hualapai Tribe with resources used for consumption, and medicinal and religious purposes (Watahomigie et al. 1982). The Hualapai are committed to preserving this habitat that has figured so strongly in their history. Traditionally-important plants including common reed (Phragmites), Goodding's willow (Salix gooddingii), arrowweed (Tessaria sericea), cattail (Typha spp.), seep willow (Baccharis spp.) and hackberry (Celtis reticulata) still occur in the riparian zone today, while clays used for pottery construction and minerals used for medicinal and religious purposes are also found along the Colorado River corridor. There is evidence that Glen Canyon Dam operations are leading to beach erosion and may be placing these resources at risk.

The Hualapai Tribe proposes to evaluate the impacts of the interim flow operations on the development, structure and maintenance of the riparian plant and animal communities through the lower Grand Canyon. It is clear that this reach of the Grand Canyon has significant cultural and economic value to the Hualapai Tribe, as well as, the potential to provide critical habitat to many riparian plants and animals. An initial step required prior to assessment

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of the interim flow impacts is to address the riparian concerns through a baseline resource inventory. This will be accomplished through a reconnaissance survey of the riparian communities along the Colorado River on the Hualapai Reservation. Once this information is known then specific resource/monitoring efforts can be designed.

The technical efforts are designed to integrate with previous and ongoing GCES research and monitoring in the Grand Canyon. This is important for several reasons: (1) the riparian corridor extending through the Grand Canyon is itself an integrated system and must be studied as such; and (2) current and previous GCES studies, amounting to more than a decade of research, will aid us in devising specific monitoring strategies.

The reconnaissance efforts and data collection will ultimately allow the Hualapai to assess and evaluate the impacts of interacting river flows on the riparian resources of the Hualapai Tribe. The technical reports will contribute to the body of information required for making sound and balanced management decisions in the Grand Canyon.

The purpose of the Hualapai riparian monitoring program is to address two broad questions:

1. How significant are interim flow discharge fluctuations, minimum and maximum discharges and ramping to the development, maintenance or decline of the riparian community from National Canyon to Lake Mead?

2. How significant are interim flow discharge fluctuations, minimum and maximum discharges and ramping as they interact with fluctuating lake levels (Bridge Canyon to the Grand Wash Cliffs) to the development, maintenance or decline of the riparian community ?

A phased approach will be used to develop the specific elements of the Hualapai interim flow riparian monitoring plan. Phase I will provide an historical background of community structure, previous research, and a reconnaissance baseline survey of the current community complex. This will include a basic assessment of the soils, vegetation, insects, mammals, reptiles, and birds. This should be initated by June 1992 with completion a full year later. Phase II will focus on the development of specific monitoring and analysis of changes in the riparian ecosystem.

Four specific objectives are identified in this monitoring plan:

1. Review the literature and existing data on plant and animal studies of the riparian corridor throughout the Grand Canyon, as well as, in other riparian ecosystems. A reconnaissance baseline

evaluation will be made of specific areas and species of concern.

2. Monitor the change in areal extent of plant community changes in the lower Grand Canyon over the interim flows with the use of the GCES Map Imaging Processing System program (MIPS) and aerial photography.

3. Monitor the riparian communities along the lower Colorado River through the Hualapai Reservation. Combined with historical information derived from aerial photography (see # 1 above) describe the current structure of riparian communities in response to interim flow dam operations. Monitoring of selected sites will enable an assessment of the overall losses or gains in ecosystem diversity.

4. Monitor the effects of interim flow operations on plant physiology. The impact of current flow regimes and any future test flows on plant photosynthesis, a direct correlate of plant growth, will be measured in the field and provide an important index of community productivity in response to varied flows. This will address three different flow regimes that have been established under the interim flow program.

5. Integrate the riparian and natural resource results with the GCES Geographic Information System (GIS) and long-term monitoring program.

JUSTIFICATION

A primary objective of the interim flows is to reduce the level of impact on the riparian ecosystem in the Grand Canyon. The sediment and riparian resources provide the primary substrates for the insects, birds, reptiles and mammals that utilize the river corridor. The Hualapai Tribe has jurisdiction of 108 miles of the Grand Canyon from National Canyon to the boundary with the Lake Mead National Recreation Area. The Hualapai Tribe works closely with Grand Canyon National Park to ensure that the natural and cultural resources of importance are protected throughout the lower 108 miles of the Grand Canyon.

The Colorado River and the riparian zone that it supports provides the Hualapai Tribe with an economic livelihood through the development of a river recreation business and by helping to sustain a Desert Bighorn Sheep (Ovis canadensis) population. A significant number of people utilize the river corridor from National Canyon to Lake Mead. Loss of sediment resources in the river corridor may limit the number of campsites and the riparian populations.

The riparian ecosystem on the Hualapai Tribal lands represents an important resource that has been affected by the operations of Glen Canyon Dam and are likely to be affected by the Glen Canyon Dam

interim flow operations. Unfortunately, limited previous information exists on baseline riparian ecosystem levels. Historic GCES studies have typically ended at Diamond Creek and consequently the lower Hualapai riparian ecosystems have been ignored. Recently important cultural and natural resources have been identified in the lower river corridor. Marshes, springs and a Great Blue Heron (Ardea herodias) rookery are important resources that may be affected by the interim flow operations. Concurrent with the development of a specific monitoring plan is a review of the historic work that has gone on as related to these resource elements.

Objective 1. Review the literature and existing data on plant and animal studies of the riparian corridor throughout the Grand Canyon, as well as, in other riparian ecosystem. A reconnaissance baseline evaluation will be made of specific areas and species of concern.

The development of the specific interim flow monitoring plan will be preceded by an indepth analysis of the historic literature and data bases. This will provide a solid base of historic information from which specific sampling and analysis protocols can be developed. This effort is necessary due to the limited amount of historic analysis that has included specifically the lower Grand Canyon area.

Objective 2. Monitor the change in areal extent of plant community changes in the lower Grand Canyon over the interim flows with the use of the GCES Map Imaging Processing System program (MIPS) and aerial photography.

Monitoring of the areal extent of the plant community changes in the lower Grand Canyon will allow for a complete assessment of changes to the riparian ecosystem. Utilizing the MIPS methodology and aerial photography will allow for an efficient analysis of the changes on a monthly basis and will provide for a historic data base from which to build long-term monitoring programs.

Objective 3. Monitor the riparian communities along the lower Colorado River through the Hualapai Reservation. Combined with historical information derived from aerial photography (see # 1 above) describe the current structure of riparian communities in response to interim flow dam operations. Monitoring of selected sites will enable an assessment of the overall losses or gains in ecosystem diversity.

Monitoring of the riparian communities along the lower Grand Canyon will allow for the Hualapai Tribe to evaluate changes as related to overall riparian community diversity and structure. This information will be directly correlated with the interim flow levels.

Objective 4. Monitor the effects of interim flow operations on plant physiology. The impact of current flow regimes and any future test flows on plant photosynthesis, a direct correlate of plant growth, will be measured in the field and provide an important index of community productivity in response to varied flows.

Monitoring of the plant physiology through the Plant Moisture Stress evaluation, photosynthetic activity and other measures will allow for a direct assessment on the day-to-day impacts of the interim flows on the lower Grand Canyon riparian corridor.

Objective 5. Integrate the results from the riparian and natural resource monitoring into the GCES Geographic Information System and long-term monitoring program.

The integration of the technical data into the long-term monitoring and Geographic Information Systems is essential <u>if</u> management of the resources and determination of impact is a goal of the overall interim flow and monitoring program. The GCES is providing the lead in the development and utilization of the data bases.

BACKGROUND

Riparian habitat in the Southwest supports remarkably complex and productive communities of plants and animals (e.g. Knopf et al. 1988). Numerous GCES studies and others have documented a similar pattern in the riparian zone in Grand Canyon--it supports a diverse assemblage of plants and animals. Today, GCES research is being designed to address the influence of dam operations on this ecosystem (e.g. Stevens 1989, Stevens and Waring 1988, Anderson and Ruffner 1988, Brian 1988, Brown 1988, Waring and Stevens 1988, Warren and Schwalbe 1988). These studies are providing an understanding of both the initial and subsequent effects that dams have on riparian habitat in the upper Grand Canyon.

While an increasing number of studies by GCES and others are documenting dam-related changes of specific taxa within riparian communities (e.g. references above, Smith et al. 1991, Fenner et al. 1985), few have considered this relationship at the community level. With GCES, the Hualapai Tribe proposes studies designed to evaluate the effects of Glen Canyon Dam operations on the riparian communities that occur along the Colorado River on the Hualapai Reservation. These studies will benefit the Hualapai by determining what species comprise these communities, and how the communities are organized.

The riparian habitat along the Colorado River through the Hualapai Reservation, especially from Diamond Creek (river mile 225) to the edge of the Grand Canyon at Grand Wash Cliffs (mile 287), is not well-studied. Studies of riparian plants and animals there have been limited in scope and qualitative in nature (e.g. Phillips

1975, Phillips et al. 1977, Johnson and Hansen 1977, Carothers et al. 1976), leaving us with only a preliminary sense of the extent and composition of this habitat.

No studies have addressed the influence of Glen Canyon Dam operations on riparian habitat in the Grand Canyon below Diamond Creek since the mid 1970's (Turner and Karpiscak 1980; Carothers and Atkinson, 1976). Such information is essential for effective management of this reach of the Colorado River.

METHODS

Monitoring Site Selection

Interim flow monitoring sites will be selected based on an assessment of past work that has occurred in the lower Grand Canyon, the location of the GCES Geographic Information System monitoring sites, critical resource locations and representative resource locations. It is anticipated that the monitoring sites will be selected based on existing aerial photography, video coverage and past information.

Sampling and Analysis Techniques

It is proposed to describe the riparian ecosystem through the lower Grand Canyon on the Hualapai Indian Reservation and evaluate how it has been affected by Glen Canyon Dam existing and interim flow operations. The approach will involve two phases: **Phase I**, will entail a reconnaissance evaluation of the riparian community, including the beaches that support them, through the lower Grand Canyon; and **Phase II**, where specific monitoring protocols to evaluate resources and impacts identified during Phase I. Our survey work in Phase I will include searches for rare, and threatened and endangered species, and work on indicator species including exotic species. Phase II studies will include more detailed research on rare, and threatened and endangered taxa, as well as other species and issues of concern.

Objective 1. Review the literature and existing data on plant and animal studies of the riparian corridor throughout the Grand Canyon, as well as, in other riparian ecosystems. A reconnaissance baseline evaluation will be made of specific areas and species of concern.

A review of research previously conducted in the lower Grand Canyon will be used in the monitoring site selection. Species of special interest, including threatened, endangered and endemic species, will require additional search efforts, and a thorough review of previous research will provide information on distributions of many of such species. A review of previously conducted research will provide a list of plant and animal species found in this reach, as well as, site information. A reconnaissance evaluation to the

specific sites where more quantitative studies of various plant and animal groups were conducted in the 1970's (e.g. Bridge Canyon site (238 mile) and Rampart Cave (275 mile)).

Objective 2. Monitor the change in areal extent of plant community changes in the lower Grand Canyon over the interim flows with the use of the GCES Map Imaging Processing System program (MIPS) and aerial photography.

The work under Objective 2 will provide an estimation of historical and recent changes in plant cover during the last interim flows. The riparian zone along the Colorado River through the Hualapai Reservation appears to be experiencing both erosion and aggradation of beaches due to Glen Canyon Dam operations. Between National Canyon and Separation Canyon there is evidence of considerable beach loss (L. Stevens, pers. comm., M. Bravo, pers. comm.), while between Separation Canyon and Lake Mead, aggradation appears to be extensive. Correspondingly, riparian communities in the upper stretch may be at risk, while in the lower stretch, new communities are emerging at a rapid rate.

During FY92, documentation of changes in plant cover will be evaluated. The MIPS technology and evaluation of 1990 and 1992 aerial photography will be used to evaluate areal change at a selected subsample of riparian monitoring sites. GCES will supply the training and the use of technical equipment. To evaluate the correlation between interim flow dam operations and changes in plant cover, we will compare changes in plant cover at different time intervals. Determination of the actual stage changes will be accomplished by utilizing the GIS and surveying technology available through the GCES office.

By reviewing aerial photographs with MIPS and ground truthing existing conditions, it will be possible to construct a map of plant community distributions in the lower Grand Canyon. This will enable us to describe current distributions and to determine changes in stands of riparian plants that have occurred over the interim flows. A riparian vegetation map constructed for the entire Grand Canyon by Phillips et al. (1977) may prove useful in our study of the historical development of riparian plant communities in the lower Grand Canyon.

Various agencies, including the National Park Service, the Bureau of Reclamation and the USGS, are currently mapping beaches throughout the Grand Canyon. The GCES is coordinating these efforts and developing the GIS programs for long-term monitoring. The Hualapai work will integrate with these efforts.

Objective 3. Monitor the riparian communities along the lower Colorado River through the Hualapai Reservation. Combined with historical information derived from aerial photography (see # 1 above) describe the current structure of riparian communities in

response to interim flow dam operations. Monitoring of selected sites will enable an assessment of the overall losses or gains in ecosystem diversity.

Under Objective 3 permanent study plots will be established in the interim flow monitoring locations and plant communities through the lower Grand Canyon. Representative communities will include (1) cattail marshes, (2) Goodding's willow and coyote willow stands, (3) tamarisk-dominated stands, (4) tamarisk and Baccharis salicifolia stands, and (5) plant populations in tributaries. Community type maps will be constructed for the subsampled monitoring sites. Specific study sites will be selected through a statistically random procedure based on existing community types. Grids will be established within each community type to permit quantification of bird and mammal populations. Plant data will also be collected at grid points, and a minimum of 200 m^2 area will be sampled at each site. These monitoring sites will be surveyed seasonally for one year to determine what species are occurring in these communities and in what densities. Plants, insects, amphibians, reptiles, mammals and birds will be censused at each site. All points of the grid will be surveyed in using GCES protocol (GCES, 1992). This will enable the monitoring of changes in beaches that are evident in the lower Grand Canyon. By locating distance from these fixed points to the water's edge (at 5,000 cfs), a measure of the beach/riparian plant stand loss or gain over time will be possible.

Population structure (e.g. age structure) of these various species will also be estimated to determine their vigor in these communities. We will also study the distribution and population structure of exotic species, including tamarisk (Tamarix ramosissima), Russian thistle (Salsola iserica) and camelthorn (Alhagi camelorum), in an effort to evaluate their current status in the riparian ecosystem and to establish the means to observe any change in their status as related to the interim flows. By sampling animals in communities with and without tamarisk, we will be able to address the influence of this species on biodiversity in riparian communities. Maps of plant communities of the lower Grand Canyon will be generated.

Plant census data collected from the lower Grand Canyon will be compatible with that being collected by the NPS in the upper reaches of the Grand Canyon, and data will be requested from the NPS for the GCES GIS mapping effort.

Objective 4. Monitor the effects of interim flow operations on plant physiology. The impact of current flow regimes and any future test flows on plant photosynthesis, a direct correlate of plant growth, will be measured in the field and provide an important index of community productivity in response to varied flows.

Under Objective 4 an evaluation of the effects of interim flow patterns on plant physiology will be conducted. The impact of current flow regimes and any future test flows on plant photosynthesis, a direct correlate of plant growth, will be measured in the field. This work will be conducted during the summer of 1992 using methodologies outlined by Scholander, et. al. (1965), and is critical to assessing the impact of Glen Canyon Dam interim flow operations on the riparian communities of the Grand Canyon. These results will provide an index of community productivity during variable flow regimes.

INTEGRATION WITH OTHER GCES MONITORING EFFORTS

As the Hualapai Tribe joins the GCES in research, the work being proposed is designed to integrate with previous and current GCES research on plants, animals and sediments in the Grand Canyon. The riparian corridor through Grand Canyon reflects a continuum of processes from erosional to aggradational, and the proposed lower reach interim flow monitoring will help to complete an understanding of this process and its effects on associated resources. The riparian work proposed will be compatible with that ongoing in the upper Grand Canyon, and will enhance the understanding of the structure of riparian plant communities and how they are changing.

The study sites will include the five Geographic Imaging System (GIS) reaches established by the GCES in the lower Grand Canyon on the Hualapai Reservation. They are located in the vicinity of National Canyon, Lava Falls, Granite Park, Diamond Creek and Columbine Canyon. These studies will contribute essential data on plants and animals to these long-term, multifaceted research efforts. Additionally, the use of MIPS to measure area of beaches as well as, plant communities in the lower Grand Canyon will be compared with results found in the upper Grand Canyon in other GCES studies.

All surveying information gathered will be collected in the manner prescribed by the GCES so that it is directly applicable to the development of the GIS program and the long-term monitoring program.

DELIVERABLES

Quarterly and annual reports will be provided to the Glen Canyon Environmental Studies according to the schedule in Table 1. A DRAFT Final Report will be distributed for technical review as specified by the GCES and a FINAL Report will be developed at the completion of the interim flow monitoring program.

PERSONNEL

<u>Technical Staff</u>

The Principal Investigators for this work are yet to be determined. The technical assistance will be provided by the Hualapai Forestry Department and by the GCES.

Other Agency Involvement

The GCES will provide the primary river logistics support and the technical expertise and equipment for the surveying efforts. The National Park Service will provide technical scientific support and input into the design and development of the monitoring site locations. The GCES will provide the technical support and training on the MIPS efforts and the development of the GIS sites.

SCHEDULE

The schedule outlined in Table 1 will be followed for this interim flow monitoring project, but may be adjusted pending determination of the date of the actual contract initiation.

Table 1.

Project Initiation	May 1992
Quarterly Report	July 1992
Quarterly Report	October 1992
Annual Report #1 (DRAFT)	December 1992
Annual Report #1 (FINAL)	January 1993
Quarterly Report	April 1993
Quarterly Report	July 1993
Quarterly Report	October 1993
FINAL REPORT (DRAFT)	December 1993
FINAL REPORT (FINAL)	February 1994

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Enclosure 2

YEAR 1

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Hualapai Tribe Date Submitted 2/26/92

Department/Laboratory _____ Organization _____

Beginning Date May 1992 Completion Date December 1994

Project Title Monitoring of the effects of Interim Flows on the Riparian Plant Communities in the Lower Grand Canyon

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Principle Investigator	12mon			38,861
2. Technical Assistant (1)	12mon			29,511
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. ( ) Graduate Students	$10,953/each			
4. (4) Undergraduate Students FIELD	6mon*4	technicians		43,812
5. (1) Secretarial/Clerical	6 mon			8,843
6. ( ) Other				
C. FRINGE BENEFITS	19%			22,995
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				20,500
2. Items > $10,000				0
E. TRAVEL				
1. Domestic				
a. Principals				9,500
b. Others				1,000
2. Foreign				0
F. PARTICIPANT SUPPORT COSTS				0
1. Stipends				
2. Travel				
3. Subsistence				5,000
4. Other				

YEAR 1

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	3,000
b. Other Film and processing	1,000
2. Publication Costs	
3. Consultant Services	
4. Computer Services	
5. Subcontracts (see below)	11,500
6. Other	
H. TOTAL DIRECT COSTS (A through G)	195,522
I. INDIRECT COSTS 27.5%	53,769
J. TOTAL DIRECT AND INDIRECT COSTS	249,291
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	0
L. TOTAL PROJECT AMOUNT (J + K)	249,291 / year (NOTE)

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1. Reptile collection equipment - ETOH, specimen traps, etc.	1,500
2. Mammal collection equipment (2,000) Insect Collections (2,000)	4,000
3. Binoculars, field tents, camping equipment	3,500
4. Plant collection equipment	5,000
5. Computer 8M RAM, 120 M Hard Drive with printer and software	6,500
TOTAL	20,500

~~Description of Items > $10,000~~ Subcontracts	
1. Soil Analysis	3,000
2. Storing of Plant Collections	8,500
3.	
4.	
5.	
TOTAL	

*Including Freight charges
Year 1 = $249,291
Year 2 = $118,286
TOTAL = $367,577

YEAR 2

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	2,000
b. Other Film and processing	500
2. Publication Costs	3,000
3. Consultant Services	
4. Computer Services	
5. Subcontracts Museum Northern Arizona (storage)	6,000
6. Other	
H. TOTAL DIRECT COSTS (A through G)	92,773
I. INDIRECT COSTS 27.5%	25,513
J. TOTAL DIRECT AND INDIRECT COSTS	118,286
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	0
L. TOTAL PROJECT AMOUNT (J + K)	118,286 year 2

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

D3

A PROPOSAL TO STUDY CURRENT AND HISTORICAL RIPARIAN VEGETATION TRENDS IN GRAND CANYON, USING MULTITEMPORAL REMOTE SENSING ANALYSES OF GIS SITES

SUBMITTED BY

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AND

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SUBMITTED TO

GLEN CANYON ENVIRONMENTAL STUDIES PROGRAM
BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

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A. Abstract

Analysis of aerial photography offers a valuable perspective in monitoring ecosystem change. I propose the following monitoring program using aerial photography of Grand Canyon's riparian corridor to (1) evaluate the effects of interim flows on riparian vegetation cover; (2) to determine historical patterns of riparian vegetation cover from 1965 up to the initiation of interim flows; and (3) determine the influence of environmental variables, including azimuth and depositional setting on vegetation responses to interim flows. These issues will be addressed in GIS reaches to establish the ground work for monitoring these resources and to integrate this study with other GCES studies designed to assess the impact of interim flows on resources. An understanding of historical patterns of vegetation change is of fundamental importance to monitoring the GIS reaches, and the research proposed here will provide that information. The results of this monitoring project will provide a test of the ability of interim flows to minimize resource loss.

B. Specific Objectives

1. Monitor the effects of interim flows on riparian vegetation cover in the new high water zone (NHWZ) and old high water zone (OHWZ) between 1990 and 1992 in GIS reaches 1-5. This will enable a quantitative comparison of vegetation cover one year before and one year after the initiation of this flow regime.

2. Determine historical patterns of riparian vegetation cover in the NHWZ and the OHWZ from 1965 to the initiation of interim flows in the same five GIS reaches. Responses of riparian vegetation to the completion of Glen Canyon Dam, the flood years of 1983-1984 and subsequent recolonization patterns will be quantified.

3. Monitor change in vegetation cover in response to interim flows in different environmental settings, including different azimuths, depositional environments (e.g., separation bars, reattachment bars) and reaches that differ in sediment supply potential.

C. Justification for Each Objective

Objective 1. Monitor the effects of interim flows on new high water zone (NHWZ) and old high water zone (OHWZ) riparian vegetation cover between 1990 and 1992 in GIS reaches 1 to 5. This will enable a comparison of vegetation cover one year before and one year after the initiation of

this flow regime that was designed to minimize fluctuations and ramping rates of the Colorado River. Analysis of the extent of riparian vegetation cover with aerial photography will provide a test of the ability of interim flows to minimize resource loss. A finding of increased or stable vegetation cover in the NHWZ will support this assumption about of interim flows.

Photogrametric analysis will document vegetation responses to interim flows on a large-scale. The proposed analysis will measure vegetation cover along 65 km of Colorado River shoreline. Apparently, interim flow effects on riparian vegetation were discernable as early as Fall, 1991, approximately two months after the initiation of interim flows (Larry Stevens, personal communication). Specifically, clonal plants including coyote willow (Salix exigua) were extending their distributions closer to the river level.

2. Determine historical patterns of riparian vegetation cover in the NHWZ and the OHWZ from 1965 to the initiation of interim flows in the same five GIS reaches. A historical analysis of vegetation cover in GIS reaches through events such as the completion of Glen Canyon Dam and floods in 1983 and 1984 will provide an important context from which to consider interim flow effects. While a photogrametric analysis of historical vegetation change was conducted in 1988 (Pucherelli 1988; see below), nearly all of this effort was concentrated in non-GIS reaches.

3. Monitor change in vegetation cover in response to interim flows in different environmental settings, including different azimuths, depositional environments (e.g., separation bars, reattachment bars), and in reaches that differ in sediment supply potential. This will provide an understanding of possible interactions between environmental structure and interim flow effects on riparian vegetation cover. Schmidt and Graf (1988) identified four types of sediment depositional settings including separation bars, reattachment bars, upper pools and channel margins, and vegetation may colonize these environments differently during interim flows.

GIS reaches 1 to 5 encompass regions with different sediment supply potential, which will permit a test of the effect of sediment supply on vegetation cover response to interim flows: GIS reach # 1 occurs near the tailwaters of Glen Canyon Dam and lacks a sediments source; reaches 2 and 5 occur above and below tributaries that contribute high sediment loads to the Colorado River (Paria River, Little Colorado River); reaches 3 and 4 occur downstream of these sediment sources.

The interim flow regime was devised to minimize erosional loss of sediments. A determination of increase or lack of change in riparian vegetation cover through monitoring will indicate that interim flows are succeeding

in this aim. The consideration of environmental variables mentioned here will help to define the relationship between interim flows and riparian vegetation cover.

D. Background Information and Existing Data

Several studies have documented the dynamic history of riparian vegetation along the Colorado River in Grand Canyon (Turner and Karpiscak 1980, Carothers and Aitchison 1976, Martin 1971). Prior to the construction of Glen Canyon Dam, little vegetation persisted in the riparian corridor due to frequent flooding (Turner and Karpiscak 1980, Clover and Jotter 1944). Subsequent to the completion of the dam an extensive and diverse community of riparian plants and animals has become established in the NHWZ (e.g., Stevens and Waring 1988, Warren and Schwalbe 1988, Brown and Johnson 1988, Pucherelli 1986, Turner and Karpiscak 1980, Carothers and Aitchison 1976, Martin 1971). By contrast, the riparian vegetation of the OHWZ, comprised mainly of honey mesquite and catclaw acacia, appears to be in a state of decline due to limited water availability, despite high river flows during 1983 and 1984 (Anderson and Ruffner 1988, Pucherelli 1986).

Analysis of aerial photography offers a unique means of interpreting large scale phenomena in ecosystem analysis. Its application in Grand Canyon has enabled a quantification of large scale change in riparian vegetation coverage along the Colorado River over a 20 year period (1965-1985) (Pucherelli 1986). In this study, Pucherelli of the Glen Canyon Environmental Studies Phase I Program (GCES) quantified the influence of the completion of Glen Canyon Dam, and floods in 1983 and 1984 on riparian vegetation cover. Pucherelli identified a significant increase in NHWZ vegetation cover along the Colorado River from 1965 until the 1983-1984 floods. NHWZ vegetation cover decreased dramatically following these flooding events as of 1985; however, the long-term responses of vegetation to these events are not well understood.

Today, Colorado River flow patterns have entered another phase and an understanding of the impact of these interim flows on riparian vegetation is needed. An interim flow regime designed to minimize daily fluctuations in Colorado River flows has been implemented. Annual aerial photographic coverage of the river corridor is planned, and will make it possible to monitor the relationship between interim flows and riparian vegetation in Grand Canyon.

Base maps, a critical tool for photogrametric analyses, are now available for some of the GIS reaches in the riparian corridor in Grand Canyon. The availability of these maps sets the stage for monitoring resource responses to interim flows. In addition, their use eliminates potential problems of scale differences (between

photographs), photodistortion and mosaicing (Pucherelli 1986).

E. Methods (Monitoring Techniques)

1. Broad Sampling Design: Aerial photography of OHWZ and NHWZ vegetation in GIS reaches 1 through 5 will be analyzed to monitor interim flow effects on riparian vegetation cover. Six aerial photo sets dating from 1965, 1973, 1980, 1985, 1990 and 1992 will be analyzed. Approximately 65 km of riparian habitat will be studied, including both sides of the river. Details of aerial photographs will be ground-truthed during two 18-day river trips with two assistants. Vegetation polygons will be drawn onto transparent mylar sheets overlying the photographs. Density categories of 20, 40, 60, 80 or 100% will be assigned to the polygons and verified with ground-truthing. Polygon data will be transferred to Bureau of Reclamation's (BOR) GIS base maps, digitized and analyzed for change. Mapping, digitization and analysis will follow the methods of Pucherelli (1986). Mr. Pucherelli and the BOR Engineering and Research Center in Denver, Colorado, will assist with data analysis and interpretation.

Vegetation cover will be compared between 1990 and 1992 to measure change in area of cover following the initiation of interim flows in August, 1991. Historical patterns of riparian vegetation cover will be determined from 1965 to the initiation of interim flows. National Park Service staff with riparian vegetation expertise will be invited to participate in vegetation mapping at GIS reaches.

Environmental conditions, including different azimuths, depositional environments (e.g., separation bars, reattachment bars) and reaches that differ in sediment supply potential, will be determined from photos, and river maps, and through ground-truthing and consultation with other GCES scientists. These variables will be factored into analyses of interim flow effects on riparian vegetation cover.

2. Logistical Support Requirements: The Bureau of Reclamation will provide aerial photographs and technical assistance with the interpretation of GIS maps produced in the study.

The proposed study will require two 18-day raft trips during FY92-93, to ground-truth aerial photographs. Two assistants will help with this procedure.

F. Integration with GCES Research Study Plan

The GIS reaches in Grand Canyon are a major focal point for GCES research, spanning geomorphology and biology. The research proposed here will contribute to this integrated approach by providing a perspective on change in vegetation area in response to interim flows and historical events. This monitoring program will provide information on vegetation changes relevant to habitat for terrestrial fauna and flora, backwater habitat for fish, and archaeological sites.

G. Products to be Developed

Patterns of change in cover of NHWZ and OHWZ vegetation in response to current interim flow regimes and historical flow regimes will be reported through GCES to other government agencies and through peer-reviewed journals. Vegetation maps (scale 1:2400) of each reach and graphics depicting change in area of cover will be produced. Quarterly, annual and final reports will also be produced.

H. Timetable

It is expected that this project will require one year and six months for completion (Table 1).

I. Budget

See project budget summary sheet for a summary of the budget. See Table 2 for a breakdown of these expenses.

J. Literature Cited

Anderson, L.S. and G.A. Ruffner. 1988. Effects of the post-Glen Canyon Dam flow regime on the old high water zone plant community along the Colorado River in Grand Canyon. Glen Canyon Environmental Studies, Executive Summaries of Technical Reports. NTIS No. PB88-183504/AS.

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Turner, R.M. and M.M. Karpiscak. 1980. Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. U.S.A.. Prof. Paper 1132. 125 pp.

Warren, P. L. and C.R. Schwalbe. 1988. Lizards along the Colorado River in Grand Canyon National Park: possible effects of fluctuating river flows. Glen Canyon Environmental Studies, Executive Summaries of Technical Reports. NTIS No. PB88-183538/AS.

Table 1. Research schedule for aerial photogrametry project.

Coordinate methods,
obtain aerial photographs.....June, 1992

Quarterly report.....June, 1992

River trip.....July, 1992

Produce 1st set of maps .....July-Aug., 1992
(GIS site # 1)

Produce 2nd set of maps.....Sept-Oct., 1992
(GIS site # 2)

Quarterly report.....September, 1992

Produce 3rd set of maps.....Nov.-Dec., 1992
(GIS site # 4)

Annual report.....December, 1992

Produce 4th set of maps.....Jan.-Feb., 1993
(GIS site # 5)

Quarterly report.....March, 1993

Produce 5th set of maps.....Mar.-Apr., 1993
(GIS site # 3)

River trip.....Apr., 1993
(Ground-truth 1992 aerial photos)

Produce maps of all sites based on 1992
photos.....May-June, 1993

Quarterly report.....June, 1993

Map transfer.....June-July, 1993

Data analysis, report preparation.....Aug.-Sept., 1993

Final report, publication.....Nov., 1993

ENCLOSURE 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Gwendolyn L. Waring Date Submitted 26 Feb., 1992

Department/Laboratory School of Forestry Organization NAU

Beginning Date June, 1992 Completion Date November, 1993

Project Title A Proposal to Monitor the Effects of Interim Flows on Riparian Vegetation Cover in Grand Canyon Using Multitemporal Remote Sensing Techniques

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. G.L.Waring				48,000
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. (x) Graduate Students (2)				12,600
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS (10%)				6,060
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				00
2. Items > $10,000				00
E. TRAVEL				
1. Domestic				
a. Principals				6,000
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone / Office	2,500
b. Other	21,000
2. Publication Costs	1,200
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other ***	00
H. TOTAL DIRECT COSTS (A through G)	97,360
I. INDIRECT COSTS (20%)	19,472
J. TOTAL DIRECT AND INDIRECT COSTS	116,832
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	116,832

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

*** BOR costs for this project will be derived from other sources

Table 2. Breakdown of budget for aerial photogrametry project by fiscal year.

ITEM	FY92	FY93	FY94	TOTAL
Personnel (3) and fringe (10%)	17,008	43,784	5,867	66,660
Equipment/supplies	3,500	2,000	500	6,000
Photo develop.	12,000	3,000	--	15,000
Office/Phone	1,000	1,000	500	2,500
Travel	2,000	2,000	2,000	6,000
Publication	-	-	1,200	1,200
Subtotal	35,508	51,784	10,067	97,360
Indirect costs	7,101	10,356	2,013	19,472
TOTAL COSTS	42,609	62,140	12,080	116,832

Table 3. Breakdown of Bureau of Reclamation's costs for this project.

BOR scientist	6,300
Training	3,150
Digitizing	45,000
Report	1,350
Plotting (@ 1:4800)	3,500
Tabulation	1,000
Computer costs	6,500
TOTAL	71,800

D4

A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON AVIFAUNAL NESTING HABITAT AVAILABILITY AND USE

U.S. FISH AND WILDLIFE SERVICE

A. ABSTRACT

Interim flows consist of three different monthly volumes: low monthly volume (October, April, and May), medium monthly volume (November, December, February, March ,and June), and high monthly volume (January, July, August, and September). With this range of flows combined with releases due to exception criteria allowances, we may expect to see differences in avian habitat utilization and availability between months. Census data will be used to evaluate breeding bird use of available habitat patterns during the three different monthly flow volumes that comprise interim flows.

B. OBJECTIVES

The following objective will assist the U.S. Fish and Wildlife Service (FWS) in monitoring the effects of interim flows on ground and low-nesting avian species by evaluating nesting habitat utilization and availability:

> Monitor the effect of actual interim flow releases on the nesting zone of ground and low-nesting avian species to include the following indicator species: Mallard, Spotted Sandpiper, Common Yellowthroat, Yellow Warbler, Bell's Vireo, Blue Grosbeak, Southwestern Willow Flycatcher, and Yellow-breasted Chat.

The following two objectives were considered but have been eliminated due to the following factors:

1. Monitoring of migrant, wintering, and breeding bird populations along the Colorado River ecosystem corridor downstream of Glen Canyon Dam in Glen and Grand Canyons and determine effects of interim flows. Emphasis would be placed on population density and diversity of riparian nesting species, waterfowl, and rare species.

   REASONS FOR ELIMINATION: At this time, the FWS cannot develop a monitoring methodology that would quantitatively evaluate and isolate the effects of interim flow releases separate from outside influences. Attenuation of flows downstream of Glen Canyon Dam and other outside influences make it difficult to evaluate direct effects on population changes (both in density and diversity) the more miles downstream flows get from the dam. However, the FWS strongly suggests that this monitoring be carried out in the Glen Canyon reach above Lee's Ferry. The Glen Canyon reach will be most directly affected by

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interim flows due to its proximity to the dam and a lowered attenuation of flows in this reach as compared to other reaches of the river corridor.

2. Monitoring interim flow effects on important terrestrial invertebrates as avifaunal food chain components that are dependent for their production on maintenance of marsh and low riparian habitats.

   REASONS FOR ELIMINATION: At this time, with the available baseline data, it is impossible to quantify the appropriateness of which terrestrial invertebrates to select as indicator species without stomach analysis of insectivorous birds. The FWS does not feel that it is possible, in the short amount of time given for interim flows monitoring, to develop a comprehensive protocol that would isolate impacts of interim flows on terrestrial invertebrates and the effects any changes would have in the food base. It is difficult to determine the significance of interim flows on the density and diversity of terrestrial invertebrates in such a short period of monitoring. Because of the lack of baseline data, the rapidness of generation turn-over rates, and changes in the chronology of invertebrate species present between months, the best we would able to do in the interim is to possibly monitor gross changes in invertebrate populations. A methodology is needed in association with research that provides a method to monitor specific insect or other important ecosystem components that occur within the emergent marsh and lower riparian zones along the river which would support determination of presence or absence of affects from interim flow releases.

If, GCES and the Senior Scientist support the necessary research work needed to accomplish the above objectives, the FWS will assist in development of the protocol and provide field assistance.

C. JUSTIFICATION

It is important to monitor the effects of interim flows on nesting habitat availability and utilization by ground or low-nesting birds, such as waterfowl, shorebirds, and songbirds. Interim flow releases may have an affect on successful utilization and availability of nesting habitats. Monitoring effects of interim flows on habitat availability and utilization will allow us to compare historic avian and vegetation data with contemporary interim flow data.

Monitoring these nesting habitats will permit evaluation of interim flow releases and the resultant effects on breeding birds. This, then, will be used to advise the Bureau of Reclamation of any adverse impacts of interim flows.

GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

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D. BACKGROUND INFORMATION AND EXISTING DATA

The Glen Canyon Environmental Studies (GCES) Scientific Core Team drafted an interim flow monitoring program from spring, 1992 through 1993 (Glen Canyon Environmental Studies 1992). This proposal addresses monitoring the effects of interim flows from Glen Canyon Dam on avifaunal nesting habitat availability and utilization and evaluation of impacts to breeding birds along the Colorado River in Grand Canyon National Park, Arizona. Monitoring of breeding bird habitat and impacts of interim flows will be undertaken using the methodologies employed during GCES Phase I and, where applicable, Phase II. This effort will assist various management agencies and entities, FWS, and Department of the Interior to evaluate the impact of interim flows on downstream resources prior to a record of decision on the Glen Canyon Dam Environmental Impact Statement by the Secretary of the Interior.

Existing data on the avian communities of the Glen and Grand Canyons and impacts of construction and operation of Glen Canyon Dam on habitats, food base components, and avian populations are summarized in the Draft 1992 Fish and Wildlife Coordination Act Report, Review of Avian Communities and Impacts of Glen Canyon Dam in the Grand Canyon. Additional information on waterfowl, semi-aquatic, and riparian avian species during GCES Phase II, is compiled in Stevens and Kline (1991). Historical avian density data from ten sites in the river corridor during GCES Phase I, are presented in Brown (1988) and in Brown's field notes (Brown, pers. comm.). Carothers and Sharber (1976) presented data on avian density and distribution in the Colorado River corridor, with detailed studies at Nankoweap Creek, Cardenas Creek, and Granite Park. Other essential studies that historical data can be drawn upon are presented in Table 2.

E. METHODS

The following methods will be used to meet the proposed objective and evaluate interim flow effects on a monthly, seasonal, and annual time scale. To accomplish the objective, a series of annual river trips are planned (see Section H). These trips will help the FWS to evaluate effects of interim flows on ground or low-nesting avian species along the Colorado River in the Grand Canyon. All monitoring will be carried out during the avian breeding season in the Grand Canyon (April through July, depending upon species and nesting chronology).

On an initial trip, nine permanent study sites will be established (Table 1). These monitoring sites will be surveyed to obtain all vegetation data using the methodologies of the vegetation studies in GCES Phase II (Stevens and Ayers 1991). This work will be subcontracted to skilled vegetation surveyors by the FWS. In all but two cases, these sites are included in the GCES GIS map (the two sites not in the GIS system will have maps made using aerial photographs, GPS, and MIPS). All sites are characterized by having

historical data and sufficient riparian vegetation to support avifauna.

GIS maps of each site will be overlaid with a grid 800 meters long and the width required to include five meters in elevation (from normal flow levels). Each site will be sampled on one morning of every month to obtain data on any active nest sites within the study site using the Emlen's Transect Method. Location of active nests will be recorded during the breeding season and vegetation type at and around the nests, distance from water, and height above the ground will also be documented for each nest found (methods of Brown, 1988). All nests found will also be photographed and documented on the GIS maps.

GIS maps will have vegetation data that will be used to compile nest site utilization by ground or low-nesting avian species. Vegetation data collected will include species composition, density, and size class within each vegetation zone of each study site. Plant assemblage information will be compiled using the techniques employed by Stevens and Ayers (1991) and physical site characteristics will be measured. Nest site habitat utilization of each avian species encountered within the study site will be documented and compiled. A synopsis of available data on susceptibility of habitats to interim flow effects will be detailed. Data on habitat changes will be coordinated with on-going research involving interim flow effects on riparian vegetation.

In one area of each study site, monitoring stakes will be set up every 0.5 meters (m) until a minimum of 5 m in elevation (from normal flows) is included. Each monitoring stake (Figure 1) will be constructed out of PVC pipe, have one-third cut out from one side, and the inside will be painted with a water soluble paint. These monitoring stakes will allow the FWS to evaluate habitat inundation under the various stages of interim flows. As the stage rises, the water will wash away any paint on the stake which is inundated. Elevation of inundation will be correlated with flows (as documented by Glen Canyon Dam Flow Release Reports). Using this information, we will be able to correlate flow releases with levels of inundation at each study site, and this data will be used to correlate elevation with the different vegetational types on each study site. In this way, the FWS can obtain information on vegetational inundation and correlate it to known nesting site elevation and vegetation without continual disturbance to active nests.

After the initial and follow-up trips, trips will be done at two week intervals. The first trip of each month will survey for active nests, gather data on the monitoring stakes, and replace monitoring stakes with newly painted stakes. The second trip of each month will only replace all monitoring stakes with freshly painted stakes and obtain data from stakes.

Travel will be done on afternoons between sites.

Because the intent is to monitor from baseline data, trips will monitor habitat and locations between Lee's Ferry and Phantom Ranch. However, if GCES and the Senior Scientist believe it is necessary, these trips can be extended to survey suitable habitat sites below Phantom Ranch, including the Hualapai Indian Reservation.

F. INTEGRATION WITH OTHER MONITORING EFFORTS

Avian nesting habitat utilization and preference will be integrated with the riparian vegetation studies (GCES-II, Stevens and Ayers).

Avian monitoring will be integrated with the Fish and Wildlife Coordination Act Report on Avian Communities in the Grand Canyon (GCES-II) and all historical data to evaluate avian habitat utilization and availability trends (Table 2). Monitoring information will be incorporated into the development of the Glen Canyon Dam Environmental Impact Statement as appropriate.

G. PRODUCTS TO BE DEVELOPED

A seasonal report will be delivered to the FWS Regional Office and GCES for review. Reports will be presented in the form used in Fish and Wildlife Coordination Act Reports. A final report will be developed at the end of the interim flows monitoring period.

H. TIMETABLE

Schedule of annual monitoring trips.

TRIP DATES	CREW	PURPOSE OF TRIP
April 1-14	2 Biologists	Initial trip to set up study sites, search for active nests and put monitoring stakes in place.
April 17-30	2 Biologists	Follow-up trip to review each study site, search for active nests and replace monitoring stakes.
May 5-18	2 Biologists	First regular trip; search for active nests, replace monitoring stakes.
May 20-27	1 Biologist	Short trip to replace monitoring stakes.
June 5-19	2 Biologists	Search for active nests, replace monitoring stakes.
June 23-30	1 Biologist	Replace monitoring stakes.
July 6-20	2 Biologists	Search for active nests, replace monitoring stakes.
July 27-Aug 2	1 Biologist	Take out all monitoring stakes.

Crew: Two trained avian biologists and one boatman (possibly the biologists will help swamp, to avoid extra cost of another crew member).

Vegetation Surveys will be subcontracted (not shown on timetable).

I. BUDGET

The following budget does not include logistics. Logistics will involve: One boatman per trip, one motor snout rig, food for number of people and days specified in Section H, and travel to and from launch and take-out sites. The FWS assumes that GCES will take responsibility for logistics.

There is a Budget Summary Form for 1992 and 1993 seperately.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Gilbert Metz Date Submitted 03/01/92

Department/Laboratory _____ Organization USFWS

Beginning Date Mar. 1992 Completion Date Dec. 1992

Project Title BREEDING BIRD MONITORING

Estimated Budget

	Person/Mos Cal	Acad	Sumr	Total Amount
A. SENIOR PERSONNEL				
1. PI (BIRDS) (15% FTE)				$8.0 K
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (2) Other Professional				$50.0K
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. (2) Secretarial/Clerical (10% FTE)				$7.0 K
6. ( ) Other				
C. FRINGE BENEFITS				$20.0K
D. PERMANENT EQUIPMENT				
1. Items > $ 1K < $ 10K				$4.0 K
2. Items > $ 10K				
E. TRAVEL				
1. Domestic				
a. Principals				$7.0 K
b. Others				
2. Foreign				

	TOTAL AMOUNT
G. OTHER DIRECT COSTS	
1. Materials and Supplies	$0.5 K
a. Telephone	$1.0 K
b. Other	$0.5 K
2. Publication Costs (if FWS is responsible)	
3. Consultant Services	
4. Computer Services	$15.0 K
5. Subcontracts (Vegetation Surveys)	
6. Other	
H. TOTAL DIRECT COSTS (A THROUGH G)	$43.0 K
I. INDIRECT COSTS	
J. TOTAL DIRECT AND INDIRECT COSTS	
K. ESTIMATED AMOUNT FROM OTHER SOURCES	$156.0 K
L. TOTAL PROJECT AMOUNT (J + K)	
Itemize Capital Equipment to be purchased in FY92	
Description of Items > $ 1K < $ 10K	Cost*
1. 1" diameter PVC pipe	$0.65 K
2. Water soluble paint	$0.35 K
3. Rebar for monitoring stake stablization	$0.10 K
4. Paint brushes, saw, wire, etc.	$0.5 K
5. Laptop computer, printer, and software	$2.4 K
TOTAL	$4.0 K
Description of Items > $ 10K	
1.	
2.	
3.	
4.	
5.	
TOTAL	

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Gilbert Metz Date Submitted 03/01/92

Department/Laboratory _____ Organization USFWS

Beginning Date Mar. 1993 Completion Date Dec. 1993

Project Title BREEDING BIRD MONITORING

Estimated Budget

A. SENIOR PERSONNEL	Person/Mos Cal	Acad	Sumr	Total Amount
1. PI (BIRDS) (15% FTE)				$8.0 K
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (2) Other Professional				$50.0K
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. (2) Secretarial/Clerical (10% FTE)				$7.0 K
6. ( ) Other				
C. FRINGE BENEFITS				$20.0K
D. PERMANENT EQUIPMENT				
1. Items > $ 1K < $ 10K				$0.7 K
2. Items > $ 10K				
E. TRAVEL				
1. Domestic				
a. Principals				
b. Others				$7.0 K
2. Foreign				

G. OTHER DIRECT COSTS	TOTAL AMOUNT
1. Materials and Supplies	
a. Telephone	$0.5 K
b. Other	$1.0 K
2. Publication Costs (if FWS is responsible)	$0.5 K
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A THROUGH G)	
I. INDIRECT COSTS	$36.0 K
J. TOTAL DIRECT AND INDIRECT COSTS	
K. ESTIMATED AMOUNT FROM OTHER SOURCES	
L. TOTAL PROJECT AMOUNT (J + K)	$130.0 K
Itemize Capital Equipment to be purchased in FY92	
Description of Items > $ 1K < $ 10K	Cost*
1. General material replacement (brushes, etc.)	$0.35 K
2. Water soluble paint	$0.35 K
3.	
4.	
5.	
TOTAL	$0.7 K
Description of Items > $ 10K	
1.	
2.	
3.	
4.	
5.	
TOTAL	

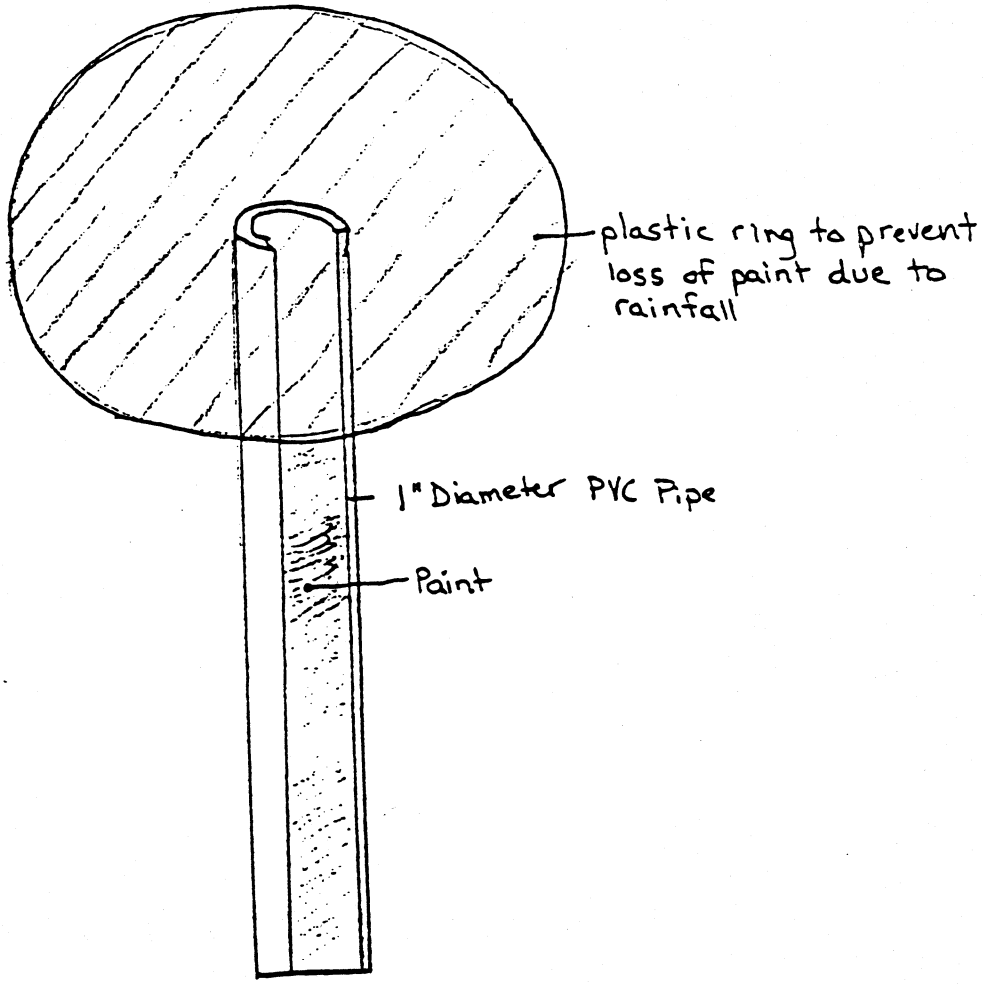

Figure 1. Diagram of Monitoring Stake.

Table 1: Study sites planned for detailed avian censuses, with tributary sites will be employed as controls. Mileages are downstream from Lees Ferry, Arizona (and reflect river side).

PERMANENT SITES
Hidden Slough Canyon (-6.5R)
Lees Ferry (0.0R)
Saddle Canyon (47.1R)
Nankoweap Creek (53.0R)
Cardenas Creek (71.0L)
Forester Canyon (122.8L)
Near Parashant Wash* (198.0R)
Granite Park (209.0L)
220 Mile Canyon* (220.0R)

* Not mapped on the GCES GIS

Table 2: Existing data and other historical references to be used for integration with avian monitoring.

Behle, W.H. and H.G. Higgins. 1959. The Birds of Glen Canyon. Pages 107-133 C.E. Dibble, ed. Ecological Studies of the flora and fauna in Glen Canyon. Anthropological Papers No. 40; University of Utah Press, Salt Lake City.

Brown, B.T. 1991. Status of nesting Willow Flycatchers along the Colorado River from Glen Canyon Dam to Cardenas Creek, Arizona. Final Report to U.S. Fish and Wildlife Service, U.S. Department of Interior, Phoenix, AZ. 33pp.

_____ 1988. Monitoring bird population densities along the Colorado River in Grand Canyon. Final report to the Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, AZ. 26pp.

_____, S.W. Carothers, L.T. Haight, R.R. Johnson, and M.M. Riffey. 1985. Birds of the Grand Canyon Region: An Annotated Checklist. 2nd Ed. Grand Canyon Natural History Association; Monograph 1. (Appendix)

_____, S.W. Carothers, and R.R. Johnson. 1983. Breeding range expansion of Bell's vireo in Grand Canyon, Arizona. Condor 85: 499-500.

_____ and R.R. Johnson. 1984. Effects of Colorado River flooding on riparian nesting birds studied. Park Science 4(2): 12-14.

_____ and R.R. Johnson. 1987. Fluctuating flows from Glen Canyon Dam and their effect on breeding birds of the Colorado River. Final report to the Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, Az. 87pp.

_____, R. Mesta, L.E. Stevens, and J. Weisheit. 1989. Changes in winter distribution of Bald Eagles along the Colorado River in Grand Canyon, Arizona. J. Raptor Res. 23(3): 110-113.

_____ and M.W. Trosset. 1989. Nesting-habitat relationships of riparian birds along the Colorado River in Grand Canyon, Arizona. The Southwestern Naturalist 34(2): 260-270.

Carothers, and B.T. Brown. 1991. The Colorado River Through Grand Canyon: Natural History and Human Change. The University of Arizona Press, Tucson, Az.

Table 2: Existing data and other historical references to be used for integration with avian monitoring (continued).

_____ and R.R. Johnson. 1976. Recent observations on the status and distribution of some birds of the Grand Canyon region. Grand Canyon National Park, Colorado River Research Series, Contribution No. 11. (Appendix)

_____ and R.R. Johnson. 1981. Status of the Colorado River ecosystem in Grand Canyon National Park and Glen Canyon National Recreation Area. Chap. 10 in V.D. Adams and V.A. Lamarra (eds). Proceedings of the 1981 Symposium on the Aquatic Resources Management of the Colorado River Ecosystem.

_____ and N. J. Sharber. 1976. Birds of the Colorado River. Chap. VI in Carothers, S.W. and S.W. Aitchison (eds). An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. Grand Canyon National Park. pp. 109-122. (See Appendix)

Glen Canyon Environmental Studies. 1992. Draft Interim Test Flow Monitoring Workplan. Version 6. Glen Canyon Environmental Studies.

Glinski, R.L. and R.D. Ohmart. 1984. Factors of Reproduction and Population Densities in the Apache Cicada (*Diceroprocta apache*). Southwestern Naturalist 29 (1): 73-79.

Gosse, J.C. 1981. Preliminary investigations of microhabitat requirements for plants, macroinvertebrates and fish in the Colorado River below Glen Canyon Dam with regard to peaking power proposals. U.S. Fish and Wildlife Service, Phoenix, AZ. 23pp.

Grater, R.K. 1936. Bird Banding from October 15, 1934 to October 15, 1935. Pages 1-4 McKee, ed. Natural History Bulletin No. 4. Grand Canyon Natural History Association. (Appendix)

Harris, J.H. 1991. Effects of brood parasitism by brown-headed cowbirds on willow flycatcher nesting success along the Kern River, California. Western Birds 22: 13-26.

Johnson, R.R. 1991. Historic changes in vegetation along the Colorado River in the Grand Canyon. Chap. 8 National Academy Press, Proceedings of the Symposium on Colorado River Ecology and Dam Management, 178-206.

Table 2: Existing data and other historical references to be used for integration with avian monitoring (continued).

Karpiscak, M.M. 1976. Vegetational changes along the Colorado River. Chap. 1 Carothers, S.W. and S.W. Aitchison (eds.). An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. Grand Canyon. 1-39.

Lee, M.H. 1920. Notes on a few birds of the Grand Canyon, Arizona. The Condor 22: 171-172. (Appendix)

McKee, E.D. 1930. Preliminary checklist of birds, Grand Canyon. Report to U.S. Department of Interior, National Park Service, Grand Canyon National Park. (Appendix)

_____ 1936. Bird Observations in Grand Canyon National Park from October 1, 1934 to October 1, 1935. Pages 9-17 McKee, ed. Natural History Bulletin No. 4. Grand Canyon Natural History Association. (Appendix)

Stevens, L.E. 1976a. An insect inventory of Grand Canyon. Chap. VII Carothers, S.W. and S.W. Aitchison (eds). An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. Grand Canyon. 141-145.

_____. 1976b. Insect production on native and introduced dominant plant species. Chap. VIII Carothers, S.W. and S.W. Aitchison (eds.). An ecological survey of the riparian zone of the Colorado River between Lees Ferry and the Grand Wash Cliffs, AZ. Colorado River Research Tech. Rept. No. 10. Grand Canyon. 146-154.

_____. 1985. Invertebrate herbivore community dynamics on *Tamarix chinensis* Loueiro and *Salix exigua* Nuttail in the Grand Canyon, Arizona. Northern Arizona University MS Thesis, Flagstaff. 161pp.

_____, B.T. Brown, J.M. Simpson, and R.R. Johnson. 1977. The importance of riparian habitat to migrating birds. Pages 156-164 in R.R. Johnson and D.A. Jones, tech. coords. *Importance, preservation and management of riparian habitat: a symposium*. U.S. For. Ser. Gen. Tech. Rep. RM-43.

_____ and T.J. Ayers. 1992. Draft Report on the Impacts of Glen Canyon Dam on Riparian Vegetation and soil stability in the Colorado River corridor, Grand Canyon, Arizona. Submitted to the National Park Service and Glen Canyon Environmental Studies (Phase II).

Table 2: Existing data and other historical references to be used for integration with avian monitoring (continued).

_____ and N. Kline. 1992. Draft Report on the Results of a Winter Waterfowl Survey on the Colorado River in Arizona, 1990/1991. Submitted to the National Park Service and Glen Canyon Environmental Studies (Phase II).

_____ and G.L. Waring. 1985. The effects of prolonged flooding on the riparian plant community in Grand Canyon. Pp. 81-86 Johnson, R.R. et al. (eds.). Riparian ecosystems and their management: reconciling conflicting uses. U.S.D.A. Forest Serv. Tech. Rept. RM-120. Tucson. 523pp.

_____ and G.L. Waring. 1986. Effects of post-dam flooding on riparian substrates, vegetation and invertebrate populations in the Colorado River corridor in Grand Canyon, Arizona. Final Report to the Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, AZ. 166pp.

Turner, R.M. and M.M. Karpiscak. 1980. Recent vegetation changes along the Colorado River between Glen Canyon Dam and Lake Mead, Arizona. United States Gov. Printing Office, Washington.

U.S. Fish and Wildlife Service. 1992. Review of Avian Communities and Impacts of Glen Canyon Dam in the Grand Canyon. Draft 1992 Fish and Coordination Act Planning Aid Report.

Waring, G.L. and L.E. Stevens. 1986. The effects of recent flooding on riparian plant establishment in Grand Canyon. Final Report to the Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, AZ. 79pp.

Willson, M.F. and S.W. Carothers. 1979. Avifauna of habitat islands in the Grand Canyon. The Southwestern Naturalist 24(4): 563-576.

Woodbury, A.M., S. Flowers, D.W. Lindsay, S.D. Durrant, N.K. Dean, A.W. Grundman, J.R. Crook, W.H. Behle, H.G. Higgins, G.R. Smitt, G.G. Musser, and D.B. McDonald. 1959. Ecological Studies of the flora and fauna in Glen Canyon. University of Utah Anthropological Papers 40: 149-229.

D5

GLEN CANYON NATIONAL RECREATION AREA
INTERIM FLOW MONITORING PROPOSAL - 1992

A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS ON FLUVIAL MARSHES OF THE COLORADO RIVER BETWEEN GLEN CANYON DAM AND LEES FERRY, ARIZONA

THIS PROPOSAL IS AN ADDENDUM TO: " A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS FROM GLEN CANYON DAM ON RIPARIAN VEGETATION IN THE COLORADO RIVER DOWNSTREAM FROM GLEN CANYON DAM, ARIZONA"

Principal Investigators: Tina J. Ayers, Department of Biological Sciences, Northern Arizona University; Lawrence E. Stevens, National Park Service, Grand Canyon National Park

Statement of Purpose: This proposal is intended to extend the Ayers-Stevens study of fluvial marshes into Glen Canyon, where several significant wetlands exist that are subject to the greatest of flow-related impacts by virtue of proximity to the dam. This circumstance makes the reach of considerable importance in interpreting data gathered elsewhere, and maximizes the opportunity for monitoring a worst-case situation (or a best-case situation if interim flows are promoting growth and recovery).

Concurrent with this project would be a program of waterfowl monitoring which has been carried out by the NPS in Glen Canyon for the past year. Waterfowl numbers are high throughout the Glen Canyon river reach during winter, particularly in the marsh and wetland areas, which are used for cover and feeding. While 14 species were recorded in mid-winter, only five species are still present in Summer. However, these five species breed in the wetlands along the reach, and it constitutes critical habitat for these birds. Breeding waterfowl in the study area include mallard, gadwall, common merganser, and American coot. Several other species present in the wetlands during breeding season for which nesting has not yet been confirmed include redhead, ring-necked duck, American widgeon, ruddy duck, and blue-winged teal.

Additional related studies and proposals include those related to trout and the aquatic foodbase study; both conitinuing from GCES II and proposed for interim flow monitoring.

Proposal: The monitoring methods proposed by Ayers-Stevens for fluvial marshes (referenced proposal, page 6) would remain the same. However, three wetland sites in Glen Canyon (6-mile and two others to be determined during a March site selection visit) would be added to the study. The 6-mile site has already been surveyed and has established transects from work conducted in GCES II.

Deliverables and personnel would be the same as outlined in Ayers-Stevens. Additional time would be required to complete the added sites.

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Enclosure 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Ayers-Stevens, GLCA addendum Date Submitted 3/3/92

Department/Laboratory _____ Organization _____

Beginning Date 6/10/92 Completion Date 2/15/93

Project Title A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS ON FLUVIAL MARSHES OF THE COLORADO RIVER BETWEEN GLEN CANYON DAM AND LEES FERRY, ARIZONA

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Principal Investigators				$1,000
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (x) Other Professional (techs.)	.8			$3,000
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	
b. Other	
2. Publication Costs	
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	
I. INDIRECT COSTS	
J. TOTAL DIRECT AND INDIRECT COSTS	
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	$4,000 PER YEAR FOR 2 YEARS

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

D6

GLEN CANYON NATIONAL RECREATION AREA
INTERIM FLOW MONITORING PROPOSAL - 1992

BREEDING BIRD DENSITIES, COLORADO RIVER FROM THE DAM TO LEES FERRY

Principal Investigators:

Charles W. Wood, National Park Service, Glen Canyon National Recreation Area
Clive Pinnock, National Park Service, Glen Canyon National Recreation Area

OBJECTIVE: The objective of this monitoring is to document the status of breeding bird populations in the area of investigation to allow detection of any trends or immediate impacts resulting from changes in river management, particularly reduction of the intensity of fluctuating flows and frequency of high flows during the "interim flow" period.

JUSTIFICATION: Interim flows are temporary modified releases of water from Glen Canyon Dam designed to moderate flow variation in the Colorado River during a Department-level policy assessment on dam operations. The modified flows were initiated in August, 1991 and are expected to continue through at least the Fall of 1994. The new flow regime reduced the magnitude of high flows during Summer up to 30% and reduced daily fluctuation of river stage approximately 50% during the breeding season for birds.

Birds living along the river between Glen Canyon Dam and Lees Ferry may be affected by altered river flow regimes through direct or indirect processes.

Direct effects may occur when changes in flow increase or decrease damage to nesting habitat. Floods may directly reduce nesting habitat for some riparian species, affecting areas nearest the river most strongly. Alternatively, a reduction in floods or high flows may permit increased stability of habitat in the near-shore zone, perhaps influencing the mix of species and populations of breeding birds. In the present case, additional direct effects on birds may result from adjustments to flucuating flows, which are believed responsible for erosion of beach and margin deposits that support vegetation used as bird habitat. It may be hypothesised that reduced erosion would reduce the rate at which habitat is eliminated.

Indirect effects of flow adjustments on bird populations may occur from changes in food supply, predators, vegetation, or other factors.

The influence of river management on riparian bird populations is potentially strongest in Glen Canyon where the magnitude of fluctuations is greatest (fluctuations attenuate downriver), making this an essential reach for monitoring direct impacts and trends.

An objective of this study is to use quantitative methodology capable of assessing the significance of any variation observed. It is believed that variation in populations caused by river management considerations - if any - would be small on a short-term basis (though possibly significant over a long period) in comparison with natural variability in bird numbers along the river corridor.

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BACKGROUND INFORMATION AND EXISTING DATA: Background studies include research on breeding birds in Grand Canyon conducted during GCES Phase I, during which it was discovered that obligate riparian species were strongly affected by high flood flows. Recent work by Linder documented differences in bird species between NHWZ and OHWZ along the river. In Glen Canyon waterfowl diversity and peregrine falcon populations have been monitored for several years, but there are no prior studies of riparian bird populations in the river reach above Lees Ferry.

METHODS: The area of investigation encompasses all of a sixteen-mile river corridor between Glen Canyon Dam and Lees Ferry, Arizona.

Shoreline monitoring will be accomplished using modified Emlen transects (variable-strip census) and recording data on the accompanying form (attachment 1.). The form will be modified slightly to convert the distance bands to meters.

Sampling will be done monthly April through September covering the period of breeding, fledging, and dispersal for most species; and also encompassing planned variation in monthly water volumes. In the succeeding fiscal year, the sample would be repeated during two winter months.

Eight permanent transects 200M long will be established along the shoreline; four transects on each bank. Beach and margin deposits would be represented equally. Each transect will be sampled by a single observer trained in the method and familiar with bird identification by sight and sound. A sample will consist of one census daily for three consecutive days, using the variable strip method on the interior side of the transect line only. This modification (walking the shore near water) is necessary to maximize observability of birds along the edge, or margin, most heavily influenced by fluctuating flows; and to avoid the adverse effects of "brush beating" through the extremely dense tamarisk thicket. Generally, the habitat within the strips will be homogeneous, or nearly so, on the one side of transect line being sampled. All censuses will be accomplished between sunrise and four hours after sunrise. Two individuals will be required to accomplish one sample, dividing the transects equally. Both the observer and start times will rotate among transects from sample to sample, but the same two individuals will always do the census.

Following completion of the third transect "run" during each sample period, a nest search would be conducted on all eight transects, using the observations just completed as a guide. For each nest located, the following information would be recorded: location on the transect, species, number of eggs or young and estimated age, type of plant or vegetation the nest is in, distance from the river, discharge on the day of measurement, height of nest above ground, estimated cover, notes on unusual conditions. Once a nest is recorded it would only be observed from a distance on repeat visits to observe the chronology of life stages or other conditions.

A second method of monitoring will be necessary in this situation to ensure detection of trends in different habitats and guilds; and to help remove variables in data interpretation that are not related to fluctuating flows. Each month a set of ten randomly located transects running perpendicular to the river axis will be censused. Locations will alternate regularly between river banks, making this a stratified random sample. The length of the transects will be variable, always extending from the shore to the cliff. This length will be

measured as accurately as possible using step distance. Along each transect all birds will be censused on both sides of the transect line using the variable distance bands shown on the form, except for birds flying overhead - these will be recorded only within the maximum distance band (0-120M). Nest searches will not be conducted on these transects. Note: randomly located variable-radius circular plots were considered for this sample set, but it was decided that the transects would best detect variation due to habitat bands with the least amount of sampling.

For all transects vegetation data will be recorded qualitatively. On the transects perpendicular to the river the distance where community type appears to change will be noted (these changes are usually abrupt, especially between Shore and New High Water Zone, and NHWZ and Old High Water Zone. Also present would be transitions to grassland-shrub habitats and rock).

For each sample, relative density and relative frequency will be computed by species. The data will be evaluated for trend and for correlation with season, habitat types and flow characteristics (using parameters such as monthly mean discharge, median discharge, mean monthly fluctuation, and maximum stage for the month. The statistical significance of any correlations found will be computed.

This monitoring will require a minimum of two years to achieve a sufficient data set.

INTEGRATION WITH OTHER MONITORING EFFORTS: Similar monitoring is expected to take place in Grand Canyon; data from the two areas will be compared and correlated. Related projects in Glen and Grand Canyons include erosion studies, insect and vegetation studies in riparian habitats, and the monitoring of falcons and waterfowl.

PRODUCTS TO BE DEVELOPED:

Type 1 transect locations will be located using a GPS unit and incorporated into the GIS system.

An annual report and final report will be prepared containing data summaries, and the analysis and interpretation of the data. All original data sheets will be maintained in a permanent file.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator WOOD, et.al. Date Submitted 2/24/92

Department/Laboratory _____ Organization NPS/GLCA;USFWS

Beginning Date April, 1992 Completion Date December, 1993-1994

Project Title BREEDING BIRD DENSITIES, COLORADO RIVER FROM THE DAM TO LEES FERRY

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT ANNUAL COSTS
A. SENIOR PERSONNEL				
1. Pinnock	1.0			$1540
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other seasonal Biologist	6.0			$10140
C. FRINGE BENEFITS				
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				
1. Domestic Field supervision and research team mtgs.				$1,600
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	
b. Other photographs	$150
2. Publication Costs	
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	$13,430
I. INDIRECT COSTS	
J. TOTAL DIRECT AND INDIRECT COSTS	
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars) existing principal support	$5,050
L. TOTAL PROJECT AMOUNT (J + K)	$18,480 PER YEAR FOR 2 YRS

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

FIELD DATA SHEET - STRIP CENSUS

Project _____ File No. _____

Sheet No. _____ of _____

Transect # _____ Vegetation Type _____ Sample Period _____

Date _____ Time (24 hour) _____ Temperature (°C) at Start _____

Wind (Beaufort Code #) _____ Sky Condition Code # _____ Observer _____

Comments: _____

Species	Code	Number Observed per Strip						Fly Over
		0-10'	10-25'	25-50'	50-100'	100-200'	200-400'	

INSTRUCTIONS

1. Fill out the top of the form prior to commencing the census. The Beaufort wind code and sky condition codes are given in the manual under item .41 1. c. (2) (c) for the Cooperative Breeding Bird Survey of North America.

2. All birds either heard or seen are recorded on the form in the appropriate column, depending on the perpendicular distance of the bird from the central line of the transect. Birds may be tallied, or marked, in the appropriate column by the use of dots or other marks, and by species.

3. The observer walks slowly along the central transect line, noting all birds detected until he reaches the end of the transect. If possible, an aerial photograph should be carried and the exact location plotted for each bird observed. Special landmarks or different characteristic of the vegetation that can be seen on the photograph will make the bir mapping easier. Actual distances to the observed birds can be measure later from the aerial photograph, if desired.

4. After completing the transect route, the observer then determines how many birds were detected in each of the different parallel strips. He then determines the strip that contained the basal plateau and then computes a projected number of birds for the entire transect width. Calculations are provided in the manual under Illustration 8 .

GLEN CANYON ENVIRONMENTAL STUDIES

DRAFT

INTERIM FLOW MONITORING PROPOSALS

RECREATION RESOURCES

RECREATION RESOURCES

RECREATION RESOURCES

GLEN CANYON ENVIRONMENTAL STUDIES OFFICE
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E1

HUALAPAI TRIBE

A PROPOSAL TO EVALUATE THE RECREATIONAL USE PATTERNS ON THE TRIBAL SEDIMENT RESOURCES IN THE LOWER GRAND CANYON

ABSTRACT

The Hualapai Tribe proposes to monitor year-round recreational use patterns, volume of use and sediment deposit availability on the Hualapai reservation. This information will be used to determine the impact of the Glen Canyon Dam interim flow operations and possible exception criteria on the recreation resources of the Hualapai Tribe. All of the information will serve as the basis for the development of the Glen Canyon Environmental Studies long-term monitoring data bases with the sediment resource information being integrated into the Geographic Information System. Three primary areas of monitoring are addressed with a focus on the historical and ongoing impacts.

STATEMENT OF OBJECTIVES

The Hualapai Tribal boundaries extend for the lower 108 miles of the Grand Canyon from National Canyon to the boundary with the Lake Mead National Recreation Area. The primary area of recreational concern for the Hualapai Tribe exists in the Lower Gorge and in the upper end of Lake Mead. The specific area of concern extends from National Canyon (RM 166.5 L) to Pearce's Ferry. The Hualapai Tribe will coordinate their recreation studies with the National Park Service for all areas but with special emphasis on those areas below Diamond Creek.

The National Park Service (Kearsley and Warren, 1991) has conducted and completed a recreational survey of the recreational use areas from Lee's Ferry to Diamond Creek. During a 1991 Glen Canyon Environmental Studies (GCES) and Hualapai Tribe reconnaissance river trip in the lower Grand Canyon, it was found that 6 out of 9 sediment deposits previously used by the Hualapai Tribe recreation are currently not of an adequate size to be functionally used by the Hualapai River recreation operations. The small number of camps in this reach (approximately one per four miles) limit the size and quantity of commercial river trips that the Hualapai Tribe can run in the lower Grand Canyon. Further loss will be a detriment to recreation potential and of great loss to the Hualapai Tribe economically.

The purpose of this interim flow monitoring program is stated in three specific objectives:

1. Monitor the impact that the interim flows and exception

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criteria from Glen Canyon Dam are having on the patterns and level of recreation use of the sediment resources in the lower Grand Canyon from National Canyon to Lake Mead.

2. Monitor the value of the current recreation industry for the Hualapai Tribe and how that is being impacted by the interim flows and exception criteria.

3. Monitor the physical location and total area of the sediment deposits that are used by the Hualapai Tribal river operations in the Lower Grand Canyon and integrate that information into the long-term GCES monitoring program.

JUSTIFICATION

A primary objective of the Interim Flows is to reduce the level of impact to the sediment resources throughout the Grand Canyon. The sediment resources provide substrate for the riparian corridor, habitat for aquatic species and substrate for recreation use. A primary business for the Hualapai Tribe is the use of the lower Grand Canyon for river running and recreation. The Hualapai Tribe has identified that since 1986 the number and useability of the beaches in the lower Grand Canyon have been reduced (Bay, 1992). The Hualapai Tribe finds it crucial that the number of beaches in the lower Grand Canyon not be reduced further and therefore is concerned that the Interim Flows achieve their objective of reducing the loss of the remaining sediment resources. It is imperative that a complete analysis of the recreational resources as related to the sediment resources of the Hualapai Tribe be completed as part of the Interim Flow monitoring effort.

The Hualapai Tribe has jurisdiction over the lower 108 miles of the Grand Canyon from National Canyon to Lake Mead. The overall objective of this monitoring effort is to ensure that those resources are protected and evaluated as related to the interim flows for both the short-term and long-term impacts.

All information collected during the interim flow monitoring period will be integrated into the GCES Geographic Information System (GIS) and the data bases which will form the basis for the long-term monitoring program. The GCES Map Image Processing System (MIPS) and aerial photography will be used for the immediate analysis of the sediment resource locations and area.

The Hualapai Interim Flow monitoring program will emphasize a phased approach. The objectives of Phase I will develop a historical background of recreational use and volume in the lower Grand Canyon. The data will be gathered from the Park Service and Tribal records. The objectives of Phase II will be to evaluate the physical location data and determine the impacts of the interim

flows and exception criteria.

Phase I.

Objective 1. Monitor the impact that the interim flows from Glen Canyon Dam are having on the recreation use of the beach resources in the lower Grand Canyon from Diamond Creek to Lake Mead.

Monitoring interim flow effects on the recreation use of the sediment resources of the lower Grand Canyon requires that an initial analysis be conducted on the general use levels so that a comparison can be made of the impacts related to interim flows. An evaluation will be made of the past use levels and the 1992, 1993 and 1994 levels to ascertain if a change is occurring and determine if this is due to changing use levels due to reduced sediment areas.

Objective 2. Monitor the value of the current recreation industry for the Hualapai Tribe and how that is being impacted by the interim flows and exception criteria.

Monitoring the interim flows impact on the Hualapai Tribe's river recreation industry will allow for an economic assessment of the changes in value. This will include an assessment of the historic and the existing river use levels.

Phase II.

Objective 3. Monitor the physical location and total area of the sediment deposits that are used by the Hualapai Tribal river operations in the Lower Grand Canyon and integrate that information into the long-term GCES monitoring program.

Monitoring the interim flows impact on the sediment resources in the lower Grand Canyon will allow for an identification of how the interim flows are affecting the stability and useability of the deposits. By understanding the levels of impact we can ascertain the requirements of the long-term monitoring program and the relationships to the alternative operations.

BACKGROUND

The Lower Grand Canyon area extends from National Canyon to (Rm 166.5) to Pearce's Ferry. Many of the commercial and private river trips end at Diamond Creek. However many continue and/or initiate trips at Diamond Creek and boat through the lower Gorge to Pearce's Ferry or other take out locations on Lake Mead. Trips that carry passengers through the Lower Gorge spend one or two nights in the 54 mile stretch to Lake Mead. The Hualapai Tribe operates a river recreation operation in the Lower Grand Canyon providing guided service to Pearce's Ferry. In addition, several of the Grand

Canyon concessionaires continue their trips below Diamond Creek and take out either at Pearce's Ferry or in the Virgin River. Jet boats shuttle most passengers from about RM 240 out to Pearce's Ferry across the flat water of Lake Mead.

Prior to the 1983 floods, the Hualapai Tribe River Running Enterprise conducted primarily two day trips. Since the flood fewer two day trips are taken due to limited camping beaches. No studies to our knowledge have been done in the past on recreational issues from Diamond Creek down to the Lake Mead. Information on the effects of the operations of Glen Canyon Dam and the interim flows are essential for effective management of this reach of the Colorado River by the Hualapai Tribe.

METHODS

Study Site Selection

The sites to be monitored will be selected based on an evaluation of the aerial photography and videos collected by the GCES. A listing of the sediment deposits used by the Hualapai River Concession and by the other Grand Canyon concessionaires will be developed from interviews with Hualapai Tribal guides and from discussions with Grand Canyon River Guides. Sites will be selected based on existing use and area in the lower Grand Canyon.

Sampling and Analysis Techniques

The Hualapai Tribe will work with the Grand Canyon National Park River SubDistrict to determine actual launches from Lee's Ferry from 1980 to present for trend and comparison purposes. Secondly, the Hualapai Tribe will document launches from Diamond Creek using Tribal records which were not listed on the Park Service permits. A complete listing of trip records will be made from the combined number of Tribal issued permits, Grand Canyon National Park trip permits and private permits. This will provide a basis of actual use levels and will be used for quantifying the value of the recreation resource.

To assess the impacts related to the interim flow and the exceptions, the Diamond Creek launch and take-out area will be monitored during the monitoring period by a Hualapai Recreation staff person. A sign post register will also be tried for a period of time to see if it is more cost efficient. The purpose of this effort will be to discuss with the river guides their trip schedules and proposed camping sites along the river corridor. A site list will be developed and used for quantification of use levels. Methodologies established by Kearsley and Warren, 1991, will be utilized for the identification of user levels.

Information will be compiled from these sources and will include

date and season of launch, take-out date, take-out point, number of boats, number of passengers. From this data, the number of days spent in the Lower Grand Canyon will be calculated. In addition, the dollars collected from the Hualapai permitting program will be totalled. This baseline information will be used to evaluate impacts during interim flows and exceptions.

Physical site location and area location will be collected utilizing the methodologies outlined in Kearsley and Warren, 1991. All information collected will be entered into the GCES GIS data base for use in the long-term monitoring program. During the interim period an assessment of the sediment resource areas will be made utilizing the GCES MIPS program, aerial photography and the video tapes collected monthly during the interim flow period. Specific surveying needs and actual elevation requirements for the GIS system will be collected utilizing the defined GCES surveying protocol and the GCES surveyors and GPS equipment. Remote cameras will be established at selected sediment resource sites based on the methodology established by the National Park Service (Cluer, 1991).

INTEGRATION WITH OTHER GCES MONITORING EFFORTS

As the Hualapai Tribe continues to work with GCES all research will be integrated with the GCES GIS database. They will draw from past Park Service research on recreation from National Canyon to Diamond Creek. Since minimal research on recreation has been attempted from Diamond Creek to the reservation's western boundary, this study is invaluable to G.C.E.S. and to identifying impacts of EIS alternatives on the resources of the Hualapai Tribe. The information will be used by the Hualapai to allow for the development of specific management criteria for the Lower Grand Canyon. Coordination with the National Park Service will be made.

DELIVERABLES

Quarterly and annual reports will be provided to the Glen Canyon Environmental Studies according to the schedule in Table 1. A DRAFT Final Report will be distributed for technical review as specified by the GCES and a FINAL Report will be developed at the completion of the interim flow monitoring program.

PERSONNEL

Technical Staff

Ms. Tamera Ross and Mr. Mario Bravo will be the Principal Investigators for this work with coordination provided by the GCES

office in Flagstaff and the National Park Service through Grand Canyon National Park.

Other Agency Involvement

The GCES will provide the primary river logistics support required and the coordination of all reports and reviews. The National Park Service will assist the Hualapai Tribe in the collection of historic records of river use. The GCES will provide technical support in the use of the MIPS and the GIS programs, technical surveying information and the collection of actual Global Positioning System information. This will allow for consistency in the data collection program.

SCHEDULE

The schedule outlined in Table 1 will be followed for this interim flow monitoring project, but may be adjusted pending date of the actual contract initiation.

Table 1.

Project Initiation	May 1992
Quarterly Report	July 1992
Quarterly Report	October 1992
Annual Report #1 (DRAFT).....	December 1992
Annual Report #1 (FINAL).....	January 1993
Quarterly Report.....	April 1993
Quarterly Report.....	July 1993
Quarterly Report.....	October 1993
FINAL REPORT (DRAFT).....	December 1993
FINAL REPORT (FINAL).....	February 1994

LITERATURE CITED

Bay, Donald. 1992. Personal communication

Cluer, B. 1991. Daily Responses of Colorado River Sand Bars to Glen Canyon Dam Test Flows, Grand Canyon, AZ. GCES DRAFT EIS Report. December 1991.

Kearsley and Warren, 1991. River Campsites in Grand Canyon National Park: Inventory and Effects of Discharge on Campsite Size and Availability. GCES DRAFT EIS Report. December 1991.

Exhibit 2

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator HUALAPAI TRIBE - Tamera Ross Date Submitted 2/26/92

Department/Laboratory HUALAPAI TRIBE Organization

Beginning Date May 1992 Completion Date December 1994

Project Title Evaluation of the Recreational Use Patterns on the Tribal Sediment Resources in the Lower Grand Canyon

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Principal Investigator - Tamera Ross	1/2 yr			12,923
2. Technician	1/2 yr			7,410
3. Technician	1/2 yr			7,410
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. ( ) Other Professional (techs.)				
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS			19%	5,271
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				2,000
2. Items > $10,000				
E. TRAVEL				
1. Domestic				
a. Principals				1,000
b. Others				
2. ~~Foreign~~ Per Diem				4,000
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

G. OTHER DIRECT COSTS		
1. Materials and Supplies		
a. Telephone		
b. Other	Gasoline	500
2. Publication Costs		
3. Consultant Services		
4. Computer Services		
5. Subcontracts		
6. Other		
H. TOTAL DIRECT COSTS (A through G)		40,514
I. INDIRECT COSTS	27.5%	11,141
J. TOTAL DIRECT AND INDIRECT COSTS		51,655 per year
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)		0
L. TOTAL PROJECT AMOUNT (J + K)		51,655/yr

Itemize Capital Equipment to be Purchased in FY___

Description of Items > $1,000 < $10,000	Cost*
1. Maps	500
2. Cameras	500
3. Computer software	1,000
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

Year 1 = $51,655 Year 2 = $51,655 * 12.7% COLA = $58,215
TOTAL PROJECT (2 years) = $109,870

E2

A PROPOSAL TO MONITOR THE EFFECTS OF INTERIM FLOWS ON CAMPSITE SIZE IN GRAND CANYON

Lisa Kearsley
Division of Resource Management
National Park Service
Grand Canyon, Arizona

GCES Office, FTS 765-7363, Fax 765-7368

ABSTRACT

Campsites in the Colorado River corridor in Grand Canyon National Park have dramatically decreased in both number and size in the past 20 years, while the number of campsite users has increased. Consequently, use in certain reaches of the river is at or near its physical carrying capacity. A monitoring study on the effects of interim flows on campsite size is critical to determine how interim flows from Glen Canyon Dam affect carrying capacity within the Grand Canyon. As part of Glen Canyon Environmental Studies (GCES) Phase II program, a study was conducted in 1991 which inventoried all campsites within the Colorado River corridor in Grand Canyon and measured the area of these campsites under different river discharges (Kearsley and Warren in prep.). That study provides baseline information which can be used to assess the impacts of interim flows on campsite size.

The proposed study will determine the effects of interim flows on campsite size. We will remeasure a representative number of the campsites to monitor area changes between 1991 and 1992. We will measure campsites twice during the interim flow period so that we can also compare changes occurring within this period. Campsites will be measured using the same methods as those used in 1991: campable area will be delineated on a photograph while ground truthing the site, and the area will be measured using a Map and Image Processing System. All campsite data collected during the interim flow period will be prepared for inclusion in the Geographic Information System (GIS) stationed at the GCES office. Cost will consist of two river trips, one person working 2/3 time on the project for 1 1/2 years and one field assistant for the river trips.

OBJECTIVES STATEMENT

The following objectives are proposed:

1. Determine change in campable area since 1991 as a function of changes in beach size and morphology resulting from interim flows.

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2. Determine how different flow volume months in the interim flow period affect campsite area.

3. Prepare all campsite area data for inclusion into the Glen Canyon Environmental Studies GIS.

JUSTIFICATION FOR EACH OBJECTIVE

An objective of the reduced fluctuations of interim flow criteria was to decrease erosion of sediment deposits. The objective of this study is to determine how interim flows are affecting beach size and morphology, and consequently camping area.

1. A comparison of pre-interim flow campsite area with interim flow campsite area is crucial to our understanding of how interim flows are affecting campable space. The number and size of campsites in certain reaches of the river are quite limiting. Further reduction in the number or size of campsites would worsen crowding, which is already at or near its maximum carrying capacity.

2. Comparisons of campsite area changes between different volume months will provide information on how low/medium and high volume months affect campsite size. Detailed mapping of several key campsites will allow us to quantitatively assess areas deemed non-campable and to note changes in non-campable areas after high volume months and low/medium volume months. These maps will also provide detailed information with which to compare the impact of future flows on campable area of sites.

3. Inclusion of campsite area into GIS will enable us to make rapid assessments of changes in campsite area in the future. It will also enable us to interrelate campsite size information with information collected from other studies, such as flow elevation, deposit type, vegetation type, etc.

BACKGROUND INFORMATION AND EXISTING DATA

Sediment deposits along the Colorado River in the Grand Canyon serve as campsites for river runners and as habitat for vegetation and wildlife, and represent sand storage in the system. While use of the river has increased in the past 20 years to approximately 22,000 people per year, the number and size of campsites has markedly decreased. (Kearsley and Warren, in prep.). As a result, campsites in certain stretches of the river are extremely limited, causing severe competition and excessive use. For example, Grapevine Camp (river mile 81) was used for camping by a total of 68 separate trips during 93 recorded days between June 13-Sept. 13, 1991. On ten percent of

the days (9/93 days), two trips were double camped at Grapevine Camp (Cluer, pers comm. 1992a).

Three campsite inventories conducted between Lees Ferry and Diamond Creek show a decrease in the number of campsites between 1973 and 1991. The first inventory, in 1973, documented 333 campsites above the new high water zone (25,000-28,000 cfs) (Weeden 1975). The second inventory was conducted in 1983 after flood level flows were discharged from the Glen Canyon Dam; it documented 438 campsites. The increased number of campsites since 1973 were primarily attributed to the previous year's flood releases (Brian and Thomas 1984). The most recent survey, which was not preceded by flood conditions, was conducted in 1991. This inventory documented 218 campsites, a 35% reduction in campsite number since 1973, and a 50% reduction since 1983 (Kearsley and Warren, in prep.).

A comparison of the three inventories also shows an overall decrease in size of campsites. Size class comparison of 134 campsites documented in all three inventories shows that 40% of the campsites have decreased in size between 1973 and 1991, while only 8% have increased in size. The reduction in size between 1983 and 1991 is more marked, with 48% decreasing and 3% increasing in size.

Certain reaches of the river are limited in the number of available campsites, and competition for sites in these "critical reaches" is greater than for sites on other stretches of the river (Kearsley and Warren in prep.). Because of their importance to the overall carrying capacity of the river, campsites in critical reaches received primary focus in the 1991 study.

Data collection of measured campsites consisted of the following: in March and May 1991, 84% (84/100) of the campsites in critical reaches were measured, and 25% (41/161) of the campsites in non-critical reaches were measured. Maps were drawn of all measured sites, and areas suitable for camping were measured in m^2 at 5,000 cfs, 8,000 cfs, 15,000 cfs, and the new high water line (25,000-28,000 cfs).

Measured areas of campsites provided baseline information for monitoring studies and showed trends in the effects of river discharge on available campsite area. Measurements provided information on campable area of each campsite and the average area for each reach and each designated size class (small, medium, or large) at each discharge. Calculations showed a substantial increase in area available for camping, when river discharge decreased from 25-28,000 cfs to 5,000 cfs, an average of 35% increased area.

METHODS

Data collection will consist of two river trips during which we will measure 62 campsites. One river trip will be in the fall of 1992, following high volume months, and one will be in the spring of 1993, following medium and low volume months. We conducted a power test to determine the required sample size and estimate 62 sites are required for a one-way analysis of variance (Zar 1984: p 110). To determine change in campable area as a function of interim flows, areas measured in the fall of 1992 will be compared to those measured in 1991, before the interim flow period began. To determine change in campable area as a function of different flow months during interim flows, areas measured in the spring of 1993 will be compared to those measured in the fall of 1992.

The methods for measuring campable area include the following: 1) Printouts of aerial videos taken during the proposed early October 1992 5,000 cfs flows will be used for campsite mapping. 2) While visiting each campsite, useable area will be assessed and outlined on the video printout of the campsite. Useable area includes any area that is relatively flat (less than 8 degree slope), non-cobbled, and non-vegetated. 3) The location of the new high water line (25-28,000 cfs) will also be marked on each photo by using the 1991 new high water line as a reference. The new high water line was assessed in 1991 by an experienced boatman by observing drift, cut banks, and vegetation lines. 4) The Map and Image Processing System (MIPS) software will be used to measure campable area in m^2 using the aerial video images of October 1992 along with the marked campsite perimeters.

Detailed maps of campable area will be made of ten campsites for in depth monitoring. Campsites to be monitored are River Mile (RM) 8L, RM 31.6R, RM 61.7R, RM 76.5L, RM 107.8L, RM 119R, RM 133.5R, RM 136L, RM 153.6R, and RM 212.9L. Campsite area will be mapped on copies of small scale aerial photographs taken in 1992 for the proposed sediment stability monitoring study (Cluer 1992b). Maps of these campsites will delineate campable and non-campable area more accurately than other maps in this study. Also, area not suitable for camping will be measured, and the reason for its non-campable designation will be noted. Whenever possible, the factors causing non-campable designation will be measured. These include measuring degree of slope if the slope was designated too steep for camping or density of vegetation if the area was designated too vegetated for camping. Campable and non-campable area, and the measured factors causing non-campable designation, will serve as baseline data which can be compared with data collected during future flows.

Data will be analyzed as follows: change in campable area will be analyzed separately for critical and non-critical reaches.

Percent changes in campable area will be arcsine square root transformed and analyzed with a repeated measure analysis of variance (Sokal and Rohlf 1981). Differences in area will be tested between campsites measured in 1991 and in fall 1992, and between campsites measured in fall 1992 and in spring 1993. Lisa Kearsley will conduct data collection and analysis. One field assistant will help with data collection. Since Lisa Kearsley measured all campsites in the field and on the MIPS system in 1991, data collection techniques will be identical to those in the 1991 study.

INTEGRATION WITH OTHER MONITORING EFFORTS

In depth monitoring of ten campsites will depend upon aerial photography taken for the proposed sediment stability monitoring study (Cluer 1992b). Changes in area of campsites can be compared to beach erosion and sediment storage data. All information collected on campsite location, and the locations of campable space in 1991 and 1992 will be included in the GIS at the Glen Canyon Environmental Studies office.

PRODUCTS TO BE DEVELOPED

Products will include quarterly and annual reports. A draft final report will be submitted once data collection and analysis is completed, as well as a publication in a peer-reviewed scientific journal.

TIMETABLE

Task	Date
Videos made of 5,000 cfs discharges	Early October 1992
First campsite monitoring river trip	Fall 1992
Quarterly Report	December 31 1992
Campsite areas measured on MIPS	Winter 1992
Analysis of data from first river trip	Winter 1992/1993
Quarterly Report	March 31 1993
Second campsite monitoring river trip	Spring 1993
Analysis of data from second river trip	Summer 1993
Quarterly Report	June 30 1993
Quarterly Report	September 30 1993
Data analysis completed	October 31 1993
Quarterly Report	December 31 1993
Annual Report and Final Report	March 31, 1994

LITERATURE CITED

Brian, N.J. & J.R. Thomas. 1984. 1983 Colorado River beach campsite inventory. USDI, NPS, Div. of Res. Mgmt., Grand Canyon N.P., Grand Canyon.

Cluer, B.L. 1992a. Physical Scientist, Division of Resource Management, National Park Service, Grand Canyon. AZ. Daily evening photographs of sand bars.

Cluer, B.L. 1992b. A proposal to Monitor Sediment Stability During the Interim Flow Period Using Aerial Photography. Division of Resource Management, National Park Service, Grand Canyon, AZ. Submitted with this proposal.

Kearsley, L.H. & K. Warren. in preparation. River Campsites in Grand Canyon National Park: Inventory and effects of Discharge on Campsite Size and Availability. USDI, NPS, Div. of Res. Mgmt., Grand Canyon N.P., Grand Canyon.

Weeden, H.A., et al. 1975. Grand Canyon National Park campsite inventory. Progress Report #3 in accordance with Contract #CX 001-3-0061 with the National Park Service. Pennsylvania State University, University Park, PA.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

Principal Investigator Lisa Kearsley Date Submitted 2-27-92

Department/Laboratory Resource Management Organization NPS

Beginning Date September 1, 1992 Completion Date March 31, 1994

Project Title A Proposal to Monitor the Effects of Interim Flows on Campsite Size in GC

Budget Estimate

	Person/Mos Cal	Acad	Sumr	TOTAL AMOUNT
A. SENIOR PERSONNEL				
1. Lisa Kearsley	12			$21,000
2.				
3.				
B. OTHER PERSONNEL				
1. ( ) Post Doctoral Associates				
2. (X) Other Professional (techs.)	1.5			$2,500
3. ( ) Graduate Students				
4. ( ) Undergraduate Students				
5. ( ) Secretarial/Clerical				
6. ( ) Other				
C. FRINGE BENEFITS				
D. PERMANENT EQUIPMENT				
1. Items > $1,000 < $10,000				
2. Items > $10,000				
E. TRAVEL				(1)
1. Domestic				$400
a. Principals				
b. Others				
2. Foreign				
F. PARTICIPANT SUPPORT COSTS				
1. Stipends				
2. Travel				
3. Subsistence				
4. Other				

(1) River logistic costs will be supplied by GCES - 2 trips planned

G. OTHER DIRECT COSTS	
1. Materials and Supplies computer discs for MIPS	$400
a. Telephone	
b. Other office supplies for data collection & analysis	$500
2. Publication Costs	$1,000
3. Consultant Services	
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	$25,800
I. INDIRECT COSTS NAU overhead	$960
J. TOTAL DIRECT AND INDIRECT COSTS	$26,760
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	0
L. TOTAL PROJECT AMOUNT (J + K) FY 92 - $1,980 FY 93 - $16,080 FY 94 - $8,700	$26,760

Itemize Capital Equipment to be Purchased in FY____

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

GLEN CANYON ENVIRONMENTAL STUDIES

DRAFT

INTERIM FLOW MONITORING PROPOSALS

DATA MANAGEMENT AND GIS INTEGRATION

DATA MANAGEMENT AND GIS INTEGRATION

DATA MANAGEMENT AND GIS INTEGRATION

F1

TITLE: A PROPOSAL TO INTEGRATE LOCATION AND TOPOGRAPHIC SURVEY DATA FOR THE GLEN CANYON ENVIRONMENTAL STUDIES GEOGRAPHIC INFORMATION SYSTEM PROGRAM

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AND

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SUBMITTED TO:

U.S. Department of the Interior
National Park Service
Cooperative Park Studies Unit
Northern Arizona University

LELAND DEXTER, PHD
Co-Principal Investigator

HENRY O. HOOPER,
Associate Vice President
for Academic Affairs, Research
and Graduate Studies

JOSEPH GUST, PE, LS, PHD
Co-Principal Investigator

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GLEN CANYON ENVIRONMENTAL
STUDIES OFFICE

FEB 27 1992

RECEIVED
FLAGSTAFF, AZ

A PROPOSAL TO INTEGRATE LOCATION AND TOPOGRAPHIC SURVEY DATA FOR THE GLEN CANYON ENVIRONMENTAL STUDIES GEOGRAPHIC INFORMATION SYSTEM PROGRAM

A. ABSTRACT

The Bureau of Reclamation's (BR) Glen Canyon Environmental Studies (GCES) program has initially identified 22 projects that require integration into the GCES Geographic Information System (GIS) program and Map Image Processing System (MIPS) through location and topographic surveying (Wegner 1991). The projects requiring interrelation include beach surveys, tributary mouths, GCES Phase I studies (hydraulic maps, debris flow maps), archeological sites, endangered fish study sites including the Little Colorado River, the 13 GIS reaches, historic photographic points, backwaters and marshes, trout spawning bars and recreation sites in Glen Canyon National Recreation Area and Grand Canyon National Park (Wegner 1991). We propose to integrate the existing, but heretofore uncorrelated, fixed surveying points associated with each of these projects, and to incorporate these and related data into the GCES/NPS GIS and MIPS. The GIS will serve as the primary tool in the development and implementation of the Colorado River corridor interim flow monitoring and long-term monitoring programs.

B. OBJECTIVES

This study is separated into two phases. Phase 1 will serve as the pilot study, achieving the following objectives in the Little Colorado River Reach (Area 5), with Phase 2 being implemented upon the successful completion of Phase 1. The objective of both phases is to develope the necessary location data for incorporating the study sites listed below into the GCES GIS and interim-flow monitoring program. (Wegner 1991: 1-2):

High Priority

1. Tie all NPS beaches, both land surveys (A) and photogrammetric sites(B), into the Global Positioning System Control Network that the GCES has already established in the Grand Canyon, where possible.

2. Tie in all historic beaches into the GCES GPS efforts. This will include the Schmidt and Graf beaches, the Howard and Dolan beaches, and the Beus beaches, where possible.

3. Tie all Sue Kieffer's hydraulic maps into the GIS, where possible.

4. Tie all important archeological and cultural resource sites into the GIS, where possible: first level - high priority sites; second level - second priority sites.

5. Tie all R-200 and gaging station locations into the GIS.

6. Tie all of the endangered fish stage recorders into the GIS.

7. Survey the LCR below Blue Springs vicinity for inclusion into the GIS.

8. Develope detailed bathymetric maps of the endangered fish habitat sites.

9. Coordinate with the MIPS program in the enhancement of the MIPS for beach mapping with the video technology.

10. Survey the trout spawning bars in the Lees Ferry area and tie them into the GIS.

11. Integrate the GIS/MIPS in the long-term monitoring program for the GCES.

12. Tie-in all terrestrial habitat sites (soil, vegetation, invertebrates, vertebrates).

Second Priority

The following items will be accomplished **as time permits**:

13. Develop definitive topographic maps for each tributary mouth.

14. Tie the USGS sedimentary/geologic maps into the GIS (Hereford et al. maps).

15. Tie all debris flow areas into the GIS.

16. Tie all other USGS sites into the GIS.

17. Develop detailed site maps of the archeological sites in the Grand Canyon in conjunction with the GRCA archeologist.

18. Develop detailed map locations for the springs in the LCR.

19. Assist in the development and implementation of the GIS program in Flagstaff and the implementation of the long-term monitoring program.

20. Develop maps for selected backwaters and marshes in the Grand Canyon and the upper end of Lake Mead, with level of detail dependent on GCES needs.

Third Priority

The following items will be accomplished **as time permits:**

21. Complete the remainder of the internal GIS sites between the existing thirteen sites.

22. Establish and tie in the historic photo points to the GIS.

Upon successful completion of phase 1, phase 2 will be implemented to bring the 12 remaining BR study reaches into the GIS, incorporating as many of the studies from the above list as possible. This will assist the interim flows program with integration of fixed points associated with the aforementioned studies . **This proposal only addresses the task descriptions and costs associated with phase 1.** Phase 2 costs and task descriptions will be set forth in a separate proposal, using the phase 1 results as a guide. Because of the "pilot study" nature of phase 1, it is anticipated that the phase 2 unit costs will decrease significantly, since proven procedures from phase 1 can be employed. It is therefore not appropriate to use unit cost projections from this proposal to determine the total costs for tying-in all 13 BR study reaches.

C. JUSTIFICATION for OBJECTIVES

This project is **essential** to GCES/NPS interim flow and long-term monitoring programs. The GCES/NPS GIS is the vehicle for database organization and analysis. This proposal will achieve the level of integration requested by the National Academy of Sciences: "the descriptive data collection program supporting an ecosystem study should have a common organizational basis across all ecosystem components. For example, physical, chemical, and biological studies should be coordinated in time and space because the ultimate aim is to use these data sets in relation to each other (1987: 119-120)." This study is necessary for the verification of experimental GPS techniques that will be used to orient data in the GIS.

Benefits to the National Park Service and the Bureau of Reclamation include integration of GCES Phase I and Interim Flow study sites and data in the GIS, and the establishment of permanent benchmarks that can be relocated for future long-term monitoring efforts. This research will provide critical monitoring data needed for Goal 1 of Grand Canyon National Park's 1989 Colorado River Management Plan (Grand Canyon National Park 1989), "to preserve the natural resources and environmental processes of the Colorado River corridor (p. 9)," and Management Objective 3, to "advocate and support operational objectives for the Glen Canyon Dam which are

most compatible with protection of the intrinsic resources of the Colorado River within Grand Canyon National Park (p. 10)".

Interim Test Flows

The secretary of the Interior authorized implementation of a program of reduced maximum flows and reduced fluctuation from Glen Canyon Dam beginning in August, 1991. These Interim Flows were designed to mitigate impacts of dam operations on downstream riverine resources, until a Record of Decision is reached for the Glen Canyon Dam Environmental Impact Statement. These Interim Flows consist of low-, medium-, and high-volume months, with low flows during the spring and late fall, moderate flows in June, September and November, and high flows during mid-summer and mid-winter. Interim Flows have a minimum flow of 5,000 cfs, and maximum discharge of 20,000 cfs, a reduced range of daily fluctuation, and reduced up- and down-ramping rates. The Glen Canyon Environmental Studies Program is coordinating monitoring Interim Flows' effects on sediments, cultural resources, the aquatic food base, riparian area and wetlands, economics, trout, native fish, recreation and water quality, with database management and development and development of a Geographic Information System (GIS). The effects of flow execptions also require monitoring under the Interim Flow discharges program. Thus, this project will contribute substantially to integrated data management for past, ongoing and future studies and monitoring of this system. To be of use to GRCA and GLCA resource managers, the aforementioned surveys must be conducted within the boundaries of those management units. A consistent, rigorous GIS effort is required for a useful monitoring program. In order to achieve a useable GIS, specific survey requirements must be completed and integrated together.

D. BACKGROUND INFORMATION

Glen Canyon Environmental Studies Interim Flows monitoring plan was developed as an integrated research program to determine the impacts of Glen Canyon Dam operations on resources in the Colorado River corridor in Glen and Grand Canyons, Arizona for a Department of Interior Environmental Impact Statement. The integrated research plan presented by Patten (1990) outlined 45 studies. Although the level of integration of these studies was noteworthy, the studies take place at numerous sites that have not been integrated into the BR Geographic Information System base map. The GCES Phase I was criticized by the National Academy of Sciences (1987) for not integrating existing data into a single data base. A comprehensive GIS can provide this integration provided that fixed points associated with study sites are linked with GPS, and these and related data are included into the existing GIS. This proposal is designed to provide that integration to GCES.

Benefits to Northern Arizona University:

This proposal will benefit both students and faculty as well as the reputation of Northern Arizona University. As a cooperator in this project, Northern Arizona University faculty will benefit through authorship on subjects of national significance in both pure and applied resource management. This program will increase faculty and staff exposure to several federal agency staffs and programs that may serve as sources of funding for future research. This project will provide an opportunity for multi-disciplinary, inter-departmental interaction within NAU. The project will also benefit NAU and the federal agencies by providing the opportunity to develop an integrated, inter-departmental/inter-agency resource management program for effective ecosystem management. Direct educational benefits will extend to the graduate and undergraduate students to be involved in field research, data reduction, computer-assisted analysis and report preparation in this project. Many opportunities will exist for tutorials and special research projects overseen by faculty and other professionals. The financial support provided by this project will assist students in completing their academic programs, and students will benefit from exposure to agencies with which they may seek future employment. The University will directly benefit from this project through overhead costs and from the national exposure this project will provide as the university expands its expertise in GIS and the use of remote sensing in land management and environmental science. For these reasons Northern Arizona University will greatly benefit from this research project.

E. METHODS

The GCES GIS Project

GIS data integration will be accomplished under the direction of the Bureau of Reclamation GCES GIS staff, the National Park Service, Northern Arizona University P.I.'s and an independent geomorphology advisor (Dr. John C. Schmidt, Utah State University at Logan). Project personnel will be responsible for quality control of data entered into this "constellation" style GIS, and these staff will receive specific training by the BR for these tasks. This Arc/Info GIS is based on a State Plane coordinate system, and will have a minimum mapping unit of approximately 3m x 3m, and will consist of approximately 50 layers initially. Projection criteria will be determined by the National Geodetic Survey. Eventually the GCES GIS will include the full Colorado River corridor; however, the tasks enumerated in phases 1 and 2 here pertain initially to the 13 reaches mapped by the BR during the Interim Flow monitoring program. The level of accuracy desired for an analysis will be dependent on the scale of the individual inquiry. Thus the format of the GIS will be supplied by the BR-Denver, while quality control/quality assurance of all data will be

the responsibility of the GCES/NPS/NAU GIS staff. Funding for additional consultation and training required by this staff is included in the budget.

This proposal will consist of a pilot study for the Little Colorado River Reach (Area 5) to develop techniques and trouble-shoot for problems with GIS preparation. The National Geodetic Survey has expressed an interest in assisting with the pre-survey planning and analysis of results for this task. Completion criteria will be established for each of the above tasks, and will be followed before additional tasks are undertaken. This will ensure completion of each task in order of its priority.

Integration of MIPS with GIS data is underway by the BR-Denver. If successful, this integration will be conducted under the direct supervision of BR staff associated with the MIPS approach.

Standard surveying protocol established through the GCES program and NAJ has been developed for all aspects of this project, including equipment calibration and maintenance, survey control, field topographic surveying, and data reduction. A consistent, rigorous surveying protocol must be followed to guarantee the reliability of survey data. Project needs will require adjustment of surveying protocol; however the proposed protocol found in Appendix A will be employed, where appropriate, for equipment maintenance and calibration, control survey specification, topographic survey protocol, and quality assurance/quality control of data and analyses.

Personnel will be directed to the objectives listed in the objectives section (above) according to Table 1.

Table 1: Personnel time requirements in each of the objectives. Several items require detailed coordination with GCES and NPS and are to be decided (TBD) on initiation of the project.

OBJECTIVE NUMBER	FIELD TIME (PERSON/DAYS)	PRE-PLANNING AND DATA REDUCTION TIME (PERSON/DAYS)	TOTAL (PERSON/DAYS)
1 & 2	39	117	156
4	50	90	140
5	9	27	36
8	72	150	222
12	12	36	48
13	3	9	12
15	3	9	12
16	12	36	48
22	36	100	136
TOTAL	236	574	810

Service Contribution and Participation

The National Park Service will coordinate this project. Dr. Peter Rowlands of the NAU CPSU will serve as the COTR. An NPS Physical Scientist and a biotechnician (both GRCA-Resources Management Division) will oversee day-to-day logistics and progress of this project on a 1/5 time basis each. Ircluded within this 20% time commitment, these individuals will also contribute to report preparation, editing and distribution, and will provide daily coordination with the GCES Program Manager. An NPS Ecologist (project coordinator), will monitor progress on a 1/8 time basis.

Personnel

Dr. Leland Dexter, PhD is an assistant professor in the Department of Geography at Northern Arizona University. He has a strong background in GIS and geography and will provide considerable expertise to this project. Joseph Gust, PE, LS is an associate faculty member in the NAU College of Engineering and Technology, and has extensive experience in all surveying topics. Dr. John C. Schmidt, Utah State University at Logan, is preeminently qualified

to advise and coordinate GIS related mapping of this system. He has a decade of experience in sediment transport, detailed mapping, and integration of geomorphological data in this system. He is presently involved in historical mapping of all sediment deposits in the GCES GIS reaches, and these data are essential for developing a long-term understanding of sediment and geomorphological processes in the Colorado River corridor. Curriculum vitae are provided for both Principal Investigators and Dr. Schmidt. Qualified NAU staff surveyors or surveyors hired through the fair employment practices of NAU, as well as graduate and/or undergraduate students will be employed according to the needs of the various component projects.

F. INTEGRATION with OTHER MONITORING EFFORTS

The integration with other monitoring efforts is the objective of this study. Accordingly, please refer to the "Methods" section above for specific integration activities.

G. PRODUCTS TO BE DEVELOPED

Deliverables will be supplied to the NPS according to the schedule outlined in Table 2 below. Deliverables will include initial, annual and final oral reports to the NPS. Quarterly progress reports, and annual and final written reports will consist of both management and technical components, the latter with technical recommendations for the NPS and improved management of the system. Copies of all reports will be delivered to the Resources Management Chief at GRCA, the Unit Leader of the NAU CPSU, and the NPS Regional Chief Scientist of the Southwest Regional Office. The PI's will provide the CPSU Unit Leader at NAU with an electronic media copy, written in WordPerfect version 5.1, of the annual and final reports. These reports will be reviewed through the established protocol for GCES, and will be prepared for publication in appropriate peer-reviewed scientific journals.

In addition, the following items will be delivered with the final technical and administrative report:

1) Baseline Control Network for all GIS data found in the pilot study area.

2) All individual study sites within the pilot study area will be rotated and translated into the baseline control network.

3) Written recommendations shall be provided regarding the accuracy and efficiency of future GIS compilation techniques.

4) A written protocol shall be assembled (in standard report form) to address both the needs of individual study participants, as well as the minimum requirements necessary to incorporate individual study sites into the GIS.

5) Written recommendations shall be provided regarding the level of detail necessary for GIS evaluation of long-term monitoring activities.

G. TIMETABLE

Table 2: Schedule of completion of proposed work.

Initial oral report	Within one month of project initiation
Quarterly report	1 October, 1992
Annual technical and administrative report	1 January, 1993
Quarterly report	1 April, 1993
Quarterly report	1 July, 1993
Quarterly report	1 October, 1993
Quarterly report	1 November, 1993
Submit draft final report	1 January, 1993
Submit final technical and admin. report	1 April, 1994

H. BUDGET

Please refer to the attached Project Budget Summary Sheet.

LITERATURE CITED

Beus, S.S., F. Lojko, et al. 1984-1990. Colorado River investigations, Vol. I-IX. Grand Canyon National Park, Grand Canyon, AZ.

Howard, A. and R. Dolan. 1981. Geomorphology of the Colorado River in Grand Canyon. J. Geol. 89: 269-298.

Patten, D. 1990. Glen Canyon Environmental Studies Phase II draft integrated research plan. Bureau of Reclamation, Salt Lake City, UT.

Schmidt, J. C. and J. B. Graf. 1990. Aggradation and degradation of alluvial sand deposits, 1965 to 1986, Grand Canyon National Park, Arizona. U.S. Geol. Surv. Prof. Pap. 1286.

Water Science and Technology Board. 1987. River and dam management. National Academy Press, Washington, DC.Wegner,D.1991.GCES GIS surveying and integration projects. Memorandum issued to all GCES researchers and cooperating agencies. Flagstaff, AZ.

GLEN CANYON ENVIRONMENTAL STUDIES
PROJECT BUDGET
SUMMARY SHEET

rincipal Investigator Leland Dexter/ Joseph Gust Date Submitted _____

epartment/Laboratory Geography / Engineering Organization No. Az. Univ.

eginning Date 5-1-92 Completion Date 1½ yrs. from actual start date

roject Title A Proposal to Integrate Location and Topographic Survey Data for the Glen Canyon Environmental Studies' GIS and Monitoring Program

udget Estimate

	Person/Mos Cal		Acad	Sumr		TOTAL AMOUNT
. SENIOR PERSONNEL	FY 92	FY 93		FY 92	FY 93	
1. Leland Dexter, Ph.D.				3	2	18,924
2. Joseph Gust, MS, PE				2	2	19,108
3.						
. OTHER PERSONNEL						
1. ( ) Post Doctoral Associates						
2. (3) Other Professional (techs.)	20	7				93,960
3. ( ) Graduate Students						
4. ( ) Undergraduate Students						
5. (1) Secretarial/Clerical	5	5				11,038
6. (1) Other (Surveyor Assistant)	2.5	0.8				8,000
FRINGE BENEFITS						34,396
PERMANENT EQUIPMENT (Using existing and/or borrowed)						0
1. Items > $1,000 < $10,000						
2. Items > $10,000						
TRAVEL						
1. Domestic						
a. Principals						1,000
b. Others						5,200
2. Foreign						
PARTICIPANT SUPPORT COSTS						
1. Stipends						
2. Travel						
3. Subsistence						3,160
4. Other (5 days GPS Training @$600/day)						3,000

G. OTHER DIRECT COSTS	
1. Materials and Supplies	
a. Telephone	
b. Other	
2. Publication Costs	5,500
3. Consultant Services	29,000
4. Computer Services	
5. Subcontracts	
6. Other	
H. TOTAL DIRECT COSTS (A through G)	232,286
I. INDIRECT COSTS	46,457
J. TOTAL DIRECT AND INDIRECT COSTS	278,743
K. ESTIMATED AMOUNT FROM OTHER SOURCES (In real dollars)	
L. TOTAL PROJECT AMOUNT (J + K)	278,743

Itemize Capital Equipment to be Purchased in FY__

Description of Items > $1,000 < $10,000	Cost*
1.	
2.	
3.	
4.	
5.	
TOTAL	

Description of items > $10,000	
1.	
2.	
3.	
4.	
5.	
TOTAL	

*Including Freight charges

APPENDIX A
PROPOSED PROTOCOL

Equipment Maintenance and Calibration Protocol

A. Total Station

1. Tribrach and optical plummet are checked and adjusted according to procedure specified in owners manual.

2. Two sets of angles, including direct and reverse, are turned from a backsight to a foresight. The first set are backsight with zero and the second set are backsight with a random angle. This procedure will determine that the level, plate, and reticle culmination are all in proper adjustment.

3. Two angles are turned to "close the horizon" to verify that the horizontal circle is in proper adjustment.

4. The vertical circle is manually indexed and checked by the addition of the direct and reverse vertical angles = 360 degrees. 5. Electronic Distance Measurement (EDM) device distance measurements are checked on an established baseline. Distances are measured in meters and in feet. Distance measurements to backsights in the field are checked and compared to previous surveys. Prism constants, PPM calibrations, and power supplies are also checked and adjusted according to baseline specifications in the owners manual.

6. If the Total Station does not preform to the acceptable specifications of the owners manual after all of the above tests are preformed, the instrument will be sent for repair and\or adjustment by the manufacturer or an authorized dealer.

B. Field Equipment

1. The level bubble on prism poles (jacob staff) are checked and adjusted with a plumb bob and verified with a hand level. All other hand levels are checked with an adjusted prism pole.

2. Tripods are tightened and lubricated. Stability of legs, lock down clamps, and all moving parts are checked and adjusted.

3. Data collectors are run through a self-test routine before each survey trip. All survey data from previous trip is downloaded on to a disc, batteries replaced, and all configurations and parameters are checked and/or reset. The designated surveyor on each survey is responsible to make sure that all of the above procedures for equipment maintenance have been followed. The surveyor will also document all checks and adjustments with the applicable maintenance forms.

Control Survey Specification and Protocol

A. Recording data

1. All notes and information will be recorded in a bound field book with pencil. Notes will never be erased for any reason. If an error is made a single line will be drawn through the error.

2. The following information will be recorded for every control survey:

a. Identification of site, mile marker, left or right of river, (looking downstream)and a sketch map with a north arrow orientation.

b. Date, time, and weather conditions such as precipitation, wind, overcast, and visibility.

c. Names and duties of all personnel on the survey. d. Serial numbers and description of

all instruments. e. Physical descriptions of all benchmarks, backsights, occupied points, located points and set or staked points. Also include a measurement and description of monuments or points and their relationship above, below, or equal to natural ground elevation.

f. Measurements of instrument height, target height, and any time they change during the survey. These measurements will be measured in meters and in feet. g. Temperature and barometric pressure.

h. Prism constants may also be recorded.

3. Photo documentation is to be maintained on all benchmarks, backsights, and any other control point that needs to be relocated.

B. Angular measurements

1. Horizontal angles shall be repeated direct and reverse for as many sets as needed to achieve the desired accuracy established for the survey.

2. Vertical angles shall be turned direct and reverse and checked by their sum totaling 360 degrees.

C. Distance Measurements

1. EDM distance measurements shall be taken in meters and in feet. Repeat measurements shall be taken as needed to achieve the desired accuracy established for the survey.

Topographic Survey Protocol

A. Total station set-up procedure

1. Secure tripod before mounting the instrument.

2. Instrument should be carefully leveled and centered on the benchmark.
3. Set vertical index circle as per manual. (Do not use automatic indexing feature.)

4. The following information shall be hand written on hard copy as well as recorded in data collector:

a. Height of instrument in meters and feet. b. Height of rod and extensions in meters and feet. c. Vertical angles taken from vertical index verification. d. Personnel and their duties, job no.,time and date. e. Temperature, barometric pressure, and calculated PPM. f. Horizontal angle, vertical angle, and slope distance of Backsight 1 and Backsight 2 (BS1, BS2).

5. The following information will also be recorded in data collector:

a. Coordinates, elevation, and description of total station benchmark (BM) as per control survey data. b. Azimuth direction or coordinates of BS1 or available BS as per control survey data.

6. BS1 and at least one other BS will be measured. Horizontal distance and elevation of both BS's must correlate with control survey data. Horizontal angle from BS1 to second BS must correlate with control survey data. If these constants do not check, repeat all the above set-up measurements and make sure correct BM and BS's are being used.

7. Check BS1 (re-zero) at least every 50 measurements, or as often as conditions may require.

8. When the survey is completed, measure both BS's to make sure all measurements have remained constant.

9. To assure agreement with the Banner surveying protocol and to integrate GPS data into the GCES GIS, GPS receivers, software and hardware will be purchased.

B. Bathymetric Surveys

1. Bathymetric surveys will be conducted using a Lowrance X-16 Depthfinder, unless individual projects require and supply an alternate depthfinder.

2. Depthfinders will be calibrated daily, or more often if needed, using a drop pan to a depth equal to or greater than that encountered in the survey.

3. Data will recorded in hard copy in the field.

C. The following information and protocol is subject to modifications and improvements based on previous survey data. These changes will be updated at Surveyor-Crew Leader meetings

1. Acceptable error on BS elevation and distance measurements. 2. Acceptable angular error when re-zeroing BS1.

3. Rodman's procedure in selection of points to record effective topographic data.

4. Codes used in data collector to identify features located on sites.

Data Analysis and QA/QC Protocol

A. Data Recovery

1. Topographic and bathymetric data will be returned to the laboratory and downloaded from data collectors and/or hand-entered, depending on the types of data collected.

B. QA/QC

1. Data will be transferred into an appropriate data base, copies made on separate disks and stored at NAU.

2. Ten percent of the hand-entered data for large data sets will be randomly checked for accuracy. If substantial errors are found then the entire data set will be rechecked in detail. Small data sets will be rechecked in their entirety.

3. Topographic data sets will be edited by creating maps to detect anomalous points.

C. Data Analysis

1. Data will be transferred to the appropriate software for reduction into topographic maps, area analyses, or volumetric analyses. Cross sectional data will be developed from the appropriate data base system.

2. Further hard copy assistance and analyses will be performed as requested by individual project leaders, and

the results will be provided to the project leader(s).

3. Data will be transferred to the GCES for inclusion into the GIS system.

APPENDIX B
SALARY SCHEDULE

*This project requires the full-time involvement of the surveyors, which places their hourly workload above that allowed for the "Full-Time Temporary" position classification. Accordingly, their position classification must be "Limited Term", which requires full benefits as part of the compensation package. A factor of 0.26 was used to determine this benefit amount.

Surveyors' salary = 8 hrs/day @ $14.50/hr.

Surveyor Assistant's salary = 8 hrs/day @ $10.00/hr. Surveyor Assistant shall only be used for field work (80 days) and for equipment preparation (20 days).

Clerical staff shall be chosen from existing part-time department staff, if possilble. If existing department staff is unavailable, every effort will be made to employ a person with knowledge of the NAU billing system.