ATTENDANCE ROSTER
Transition Work Group (TWG)
Meeting held on February 3-4, 1997

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THE GRAND CANY AZ TORING AND RESEARCH CENTER

LONG-TERM MONITORING AND RESEARCH STRATEGIC PLAN

Lawrence D. Garrett[1/]
Barry D. Gold
Ruth E. Lambert

EXECUTIVE SUMMARY

INTRODUCTION

This Long-Term Monitoring and Research Strategic Plan (the Strategic Plan) is designed to implement the adaptive management and ecosystem science approaches called for in the Grand Canyon Protection Act (GCPA) and Glen Canyon Dam Environmental Impact Statement (GCDEIS). The areas of monitoring, research, and information technology outlined for physical, biological, cultural and socioeconomic resources will be implemented over a five-year period. Within each of these years an annual monitoring and research plan will be developed and implemented to assure appropriate progress on critical elements of the Strategic Plan.

All elements of the Strategic Plan, and all monitoring programs, research projects and information technologies drafted into annual plans will incorporate the ecosystem

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[1]/Lawrence D. Garrett, Barry D. Gold and Ruth E. Lambert are respectively Center Chief, Biological Resources Program Manager and Cultural Resources Program Manager of the Grand Canyon Monitoring and Research Center (GCMRC).

science paradigm and be developed cooperatively with the Adaptive Management Work Group (AMWG), utilizing adaptive management procedures. All programs proposed relate to determined or potential resource impacts primarily in the Colorado River corridor between Glen Canyon Dam and Lake Mead resulting from "The effects of the Secretary's actions."[2]/

The Strategic Plan and annual monitoring and research plans will build upon the rich history of monitoring and research investigations developed by the Bureau of Reclamation (BOR) and other organizations. Although the first scientific efforts in geomorphology, biology and ethnography in the Canyon were developed by John Wesley Powell in his scientific expedition of 1869, the majority of scientific accomplishment in the corridor between Glen Canyon Dam and Lake Mead has been accomplished under the guidance of BOR since 1982. Since that time, the BOR Glen Canyon Environmental Studies Program (GCES) has initiated a significant number of research studies and monitoring activities to determine baseline conditions and associated change in many physical, biological, cultural and socioeconomic resources.

Over a period of thirteen years, the GCES developed extensive databases in many different resource areas. Further scientific analysis in many of these areas permitted identification of some of the important attributes associated with changes in critical resources. Significant opportunity now exists to conduct extensive analysis of these

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[2]/As specified in the 1992 Grand Canyon Protection Act, the GCDEIS, and the Record of Decision (ROD).

collected data and research to improve understanding of critical attributes affecting specific resources and the interrelationships of resource attributes in the riverine corridor.

Independent reviews of past research in the Colorado River corridor primarily between Glen Canyon Dam and Lake Mead have concluded that several actions need to be taken to ensure progressive future monitoring and science programs. These include:

1. Implementation of an adaptive management process to facilitate close interaction of science and management in applying potential new management criterion and evaluating impacts of those criterion in shorter time periods.
2. Development of a conceptual model of the Colorado River ecosystem primarily between Glen Canyon Dam and Lake Mead which can be used to more clearly define critical attributes within resource categories, critical attribute linkages across resource categories, and interdependencies of resource attributes.
3. An extensive synthesis of all past knowledge associated with original baseline resource conditions in the Colorado River ecosystem, riverine resource changes associated with construction of the Glen Canyon Dam, and changes associated with "The effects of the Secretary's actions."
4. Ecosystem analyses to improve understanding of the most critical attributes that drive individual resources and groups of resources, and the interdependencies of attributes within and across resources.

5. Development of predictive models of ecosystem function and interaction.

PURPOSE AND SCOPE OF GCMRC AND THE LONG-TERM PLAN

The GCPA and GCDEIS direct the Secretary of Interior, "To establish and implement long-term monitoring programs and activities that will ensure that Glen Canyon Dam is operated in a manner consistent with that of Section 1802" of the GCPA.

The mission of the Grand Canyon Monitoring and Research Center (GCMRC) and the goals of this long-term strategic plan are to determine short- and long-term ecosystem resource impacts of "The effect of the Secretary's actions" and other information needs specified by the AMWG. The GCMRC will work cooperatively with the AMWG, utilizing the adaptive management process and implementing monitoring and scientific investigations within an ecosystem science framework.

Long-term monitoring will occur in all resources of concern to determine changes in resource attributes from some desirable level. Research will be used to interpret and explain trends observed from monitoring, to determine cause and effect relationships and research associations, and to better define interrelationships among physical, biological and social processes.

In addition to monitoring and research activities, the GCMRC will develop information technologies to assure information archiving and transfer to managers and stakeholders and science organizations. Specific protocols will be developed to ensure

sensitive information such as location of endangered species and cultural resource sites are maintained in confidence.

The physical scope of the research area to be investigated by the GCMRC includes primarily the Colorado River mainstem corridor and associated riparian and terrace zones from the forebay of Glen Canyon Dam to the upper reaches of Lake Mead, normally identified as Separation Canyon, a distance of approximately 278 river miles. The research scope includes limited investigations into side tributaries such as the Little Colorado and Paria Rivers. It also includes resource impacts to inundation levels associated with a flow of 100,000 cfs from the dam.

An assessment of water quality in Lake Powell will be completed in FY97, and any future monitoring and research investigations in either Lake Powell or Lake Mead must be directly associated with impacts resulting from "The effects of the Secretary's actions." In general, resource impacts may result from "The effects of the Secretary's actions" as specified in the GCPA, GCDEIS, and the ROD, and/or identified for evaluation by the AMWG.

STAKEHOLDER INFORMATION NEEDS AND CRITICAL RESOURCE ATTRIBUTES

The Strategic Plan is by design established to respond to the general objectives and information needs of managers and stakeholders regarding the Colorado River corridor and its resources. Objectives and information needs of stakeholders are specified in nine

differing resource areas including hydropower, water, sediment, fish and aquatic, riparian vegetation, threatened and endangered species, terrestrial wildlife, cultural, and recreation.

Within each of the above resource areas specific objectives have been developed cooperatively by the BOR, and representatives of the AMWG and are reviewed in the text and specified in Appendix A. Detailed information needs for specific objectives and resource areas were then defined by representatives of the AMWG working cooperatively with the GCMRC. These are also presented in the text and Appendix A.

Objectives and information needs specified by stakeholders are the basis for development of both monitoring and research programs, and these are referenced in discussions of monitoring and research programs. Appendix A contains "resource sheets" which represent a matrix linking stakeholder objectives and information needs to potential monitoring and research statements.

ENSURING QUALITY INDEPENDENT SCIENCE

The GCMRC is established to provide high quality independent science assessments to the AMWG. To accomplish these goals, stringent protocols regarding science-planning, competition, peer-review, administration and publication have been established.

An independent Science Advisory Board will oversight scientific planning and methodologies adopted by the center. The selection of this interdisciplinary group of advisors will be based on their standing and accomplishments in the science community.

The GCMRC will solicit extensive involvement of stakeholders and scientists in defining research agendas and methods. However, it will ensure unbiased programs by independently developing needed monitoring and research projects which will be awarded through competitive science procedures.

Quality science programming and objective and unbiased research findings will be ensured through rigorous scientific peer review protocols. All proposals, data, reports, etc. will be reviewed by external anonymous scientists as well as the GCMRC science team.

PROPOSED MONITORING AND SCIENCE PROGRAMS

Monitoring and science programs proposed in the Strategic Plan include the following:

1. **Conceptual modeling and synthesis of existing knowledge.**
2. **Physical resource program.**
3. **Cultural resource program.**
4. **Biological resource program.**
5. **Socioeconomic resource program.**
6. **Information technology program.**

Each of these areas represent components of the Strategic Plan where important information will be developed to respond to objectives and information needs specified by stakeholders.

Conceptual Modeling and Synthesis of Existing Knowledge

The conceptual modeling and synthesis of existing knowledge represents two primary activities, and will be completed in the first two to three years of the Strategic Plan. The first component, will be development of a conceptual model of the Colorado River ecosystem, and the various resource attributes that respond to variable operations of Glen Canyon Dam. The second component will be a focused detailed assessment of all past research associated with the riverine corridor's resources before and after Dam construction, as well as other western riverine corridors yet undamed, and of similar character and structure to the Colorado River mainstem. These syntheses are also addressed in the individual resource program areas.

Development of a conceptual model and completion of a "state-of-the-science" synthesis is critical to understanding this riverine ecosystem and associated impacts from differing Dam operations. It will include extensive integrated data assessment and interpretation, as well as the first comprehensive transfer of information to stakeholders regarding the potential impacts of differing Dam operations on ecosystems and associated resources.

Physical Resources Program

Water and sediment are the two primary resources of concern in the physical resources area. Monitoring and research efforts will concentrate on four aspects of these physical resources as follows:

1. Dam discharges and instream flows.

2. Sediment balance and processes.

3. Interrelationship of mainstem water and sediment and side channel inflows.

4. Interaction of mainstem water and sediment and Lake Mead resources.

The Biological Resources Program

Monitoring and research activity for biological resources is intended to develop information about the structure and function of the Colorado River ecosystem as well as the impacts of differing Dam operations on the ecosystem and associated flora and fauna. The effort will provide the knowledge base required to implement ecosystem management strategies within an adaptive management framework. It is key that relationships between the biotic and abiotic components of the Colorado River ecosystem be addressed to predict impacts on critical biological resources.

Monitoring and research activities are proposed in several different areas. These include assessments of aquatic food base, native and non-native fish species, wildlife and other riparian invertebrates and vertebrates.

The Strategic Plan contains proposals to evaluate the status and trends of native fish populations in the Colorado River ecosystem and seek to collect data that can be used to assess the native and non-native fish communities response to Dam operations resulting from the Secretary's actions. Native fish species of concern are the humpback chub, razorback sucker, flannel mouth sucker, blue head sucker and speckled dase.

Monitoring of the non-native trout fisheries in the Lees Ferry reach is proposed to concentrate on growth, survivorship, and changes in population structure, including the contribution from natural reproduction over time.

Changes in the three primary riparian zones along the river is proposed to be monitored including, the old high water zone, new high water zone, and near shoreline wetland communities. Proposals to monitor faunal assemblages will be aligned to sampling of riparian vegetation habitat changes. Proposals to monitor and conduct research on terrestrial invertebrates along the riverine corridor are also included.

It is proposed that avifauna monitoring emphasize listed species such as the Bald Eagle, Southwestern willow flycatcher and Peregrine Falcon. It may also include wintering and breeding water fowl, riparian obligate species, resident non-obligate species and migrant species in a biogeographic/geomorhpic/seasonal context.

As appropriate the biological resources monitoring and research program will consider and address information needs of the biological opinion.

The Cultural Resources Program

The cultural resources program is charged with designing and implementing monitoring and research activities that assess cultural resource impacts related to dam operations. The program will accommodate both ongoing activities of the Programmatic Agreement (PA), and new programs proposed to address needs of the AMWG.

Activities necessary to the PA will be incorporated into the cultural resources program at the request of the agency and Native American tribal members of the AMWG.

Monitoring and research information needs and activities from the PA are expected to be a major component of the GCMRC's cultural resource program.

The Strategic Plan incorporates a more comprehensive perspective of cultural resources than those outlined in the PA. This perspective is derived from objectives and information needs specified by agencies, Native American tribes and other stakeholders, relating to cultural resources and their association with other resources in the Colorado River corridor.

The cultural resources program for the GCMRC will accommodate three primary components: **a core program, a tribal projects element, and a cooperative programming aspect.** Further, the program manager is responsible in coordinating with other program managers to incorporate Native American concerns within these programs.

Objectives and information needs specified by the stakeholders have been utilized to incorporate the following monitoring and research proposals in the Strategic Plan.

1. Develop data and monitoring systems to assess impacts.
2. Develop data to assess risk of damage and loss of cultural resources from varying flow regimes.
3. Develop tribal monitoring programs for evaluation of impacts to cultural resources.
4. Develop a predictive model of geomorphic processes that are related to archeological site erosion.

5. Develop mitigating strategies related to documented dam impacts to size by monitoring assessments.

6. Characterize resource values through scientific study.

The Socioeconomic Resources Program

There are many socioeconomic resources associated with the Colorado River corridor including recreation, electric power and water. Further, due to the vastness and geological distinctiveness of the Grand Canyon, the Grand Canyon National Park has acquired national and international recognition and all of the resources in the Grand Canyon are considered to be significant to the public.

The objectives of long-term monitoring and research will be to determine whether recreation is enhanced and safety improved when comparing current or proposed dam operations to historical dam operations, and whether changes in recreational patterns resulting from the dam operations have any affect on the Canyon's downstream recreation resources.

In the Lees Ferry reach, monitoring methods will be established to characterize changes in sport fish recreation (trout) relative to the Secretary's actions regarding dam operations. Elements of this program will be developed with stakeholders including fishing guides and associations such as Trout Unlimited.

Continued monitoring and research is needed to assess changes in camping beach areas associated with the effects of the Secretary's actions. Monitoring changes in beach

areas will be conducted by using primarily remotely sensed data and cooperative programs with boating guides and their associations.

Hydropower supply is an integral part of the economy of the region. Changes in power operations result from changes in annual dam operations, and they affect power supply and its costs. Actual power generation will be monitored on a hourly basis to assess the consequences of changing dam operations on power economics. Power generation is also a method for estimating water discharge rates and volumes. A Cost Benefit Analysis (CBA) model is proposed, to evaluate all associated market and non-market costs and benefits, including intrinsic or existence values of key resources.

Information Technology

Extensive data and information currently exists in the GCMRC relating to resource levels, quality, and relationship to other resources. Potentially equal amounts of data and information exists within museums, universities, agencies, etc. However, much of this information has not been evaluated, to assess the interrelationship of resource attributes and differing flow regimes.

Several areas of focus will be implemented through the information technology program, including the following:

1. Development of protocols for data collection, processing and use.
2. Development of extensive databases across all resources and a database management system.

3. Development of a robust geographic information system to accommodate multiple layers associated with all resources of interest to stakeholders.

4. Development of databases associated with remotely sensed data, here to date not incorporated in the GCES database system.

5. Stakeholder direct access to selected data and information in the database management system and GIS.

6. Development of outreach programs to transport data and information to stakeholders and train stakeholders in utilization of data and models incorporated in the information technology program.

SCHEDULE AND BUDGET

The strategic plan outlined in this document addresses monitoring and research activities for a five year period: fiscal years 1998 to 2002. Each year in May, an annual operating plan will be drafted to guide implementation of specific elements of the Strategic Plan. It will be reviewed by the technical working group (TWG), and AMWG before approval by the Secretary of Interior.

This Strategic Plan is designed to guide specific monitoring and research through three fundamental phases.

1. Development of conceptual ecosystem models, synthesis of existing knowledge, and determination of key attributes associating resource impacts to dam operations.

2. Definition of integrated impact of key attributes within a resource set and across all resources.

3. Development of decision support guidelines and models to assist managers and interested stakeholders to understand resource interactions, impacts of dam operations on resources and procedures for mitigating impacts.

Phase I will require fiscal years 1997, 1998, and 1999, for completion. Fiscal years 1997 and 1998 will be utilized to develop conceptual models of the Colorado River ecosystem. Fiscal years 1998 and 1999 will involve comprehensive synthesis of past research information across all resources.

Phase II, which will be implemented in fiscal year 1998, is not expected to be completed during the first five year implementation of the Strategic Plan. This relates to the significant lack of knowledge on key driving attributes for many physical, cultural and biological resources. Significant results will be obtained for some resources, including physical and cultural resources.

Phase III of the monitoring and research program will be implemented in fiscal year 1999, primarily for predictive models in the cultural and physical resource areas. However, it is anticipated that useful operational algorithms and models in many of the biological resources areas will require most of a second five year strategic plan. Development of a comprehensive and robust decision support system (dss) is not anticipated until the end of the second five year strategic plan.

Budget for this five year strategic plan is anticipated at approximately seven million dollars per year. Of the total seven million dollar per year annual budget allocation, approximately 5.3 million will be placed into on the ground research programs. Approximately one-half million is required by the upper Colorado region of BOR to administer the adaptive management program, and approximately 1.2 million is required to operate all the center's administrative and service programming including logistics and computer support.

A3

Presentation

of the

Long-term Monitoring and Research Strategic Plan
(Working Draft #2 - 1/2/97)

to the

Transition Working Group

by

L. David Garrett
Ruth E. Lambert
Barry D. Gold

February 3, 1997
Phoenix, AZ

Long-term Monitoring and Research Strategic Plan

Outline of Presentation

I. Introduction
- Adaptive Management
  - -- Attributes
  - -- Elements
- RFPs and Peer Review
- GCMRC Peer Review Guidelines
- GCMRC Science Advisory Board
- Monitoring and Research
  - -- Definitions
  - -- Linkages
  - -- Standards and Protocols
- Geographic and Institutional Scope

II. GCMRC approach to developing the plan
- Approach adopted by GCMRC
- Review of past monitoring activities
- Conceptual Modeling

III. Individual Programs
- Resource Areas
- Physical Resources
- Cultural Resources
- Biological Resources
- Socio-economic Resources
- Information Technologies
- Budget

I. Introduction

ADAPTIVE MANAGEMENT

Attributes

Iterative process;

Treats management actions as experiments subject to modification;

Management actions/experiments used to develop an enhanced scientific understanding;

Uniqueness of adaptive management approach is the use of an explicit experimental design.

An Adaptive policy is one that is designed from the outset to test clearly formulated hypotheses about the behavior of an ecosystem being changed by human use. In most cases these hypotheses are predictions about how one or more important species will respond to management actions. **(Lee 1993)**

ADAPTIVE MANAGEMENT

Begins with stakeholders definition of management objectives;

Management actions reflect "state-of-the-science" and are implemented as "experiments";

Monitoring to see if ecosystem responds as predicted;

Research program to discern the nature of the cause and effect relationships;

Learning occurs as a result of the monitoring and research activities;

Future management actions are based on new knowledge.

Reliable knowledge comes from two procedures: controls and replication. A control matches what one is changing (the treatment) to a companion case in which that same factor is left unchanged (the control). The use of controls permits insight into whether it is the treatment that is causing the effect one sees, rather than something else such as a change in the weather. Replication is essential because if knowledge is reliable it can be shown to work more than once; real relationships between cause and effect will show up consistently. **(Lee 1993)**

RFPs AND PEER-REVIEW

GCMRC long-term monitoring and research program will be implemented through a competitive peer-reviewed process.

Following approval of the long-term monitoring and research program, a request for proposals (RFP) will be issued.

Proposals will be screened by the program managers for their responsiveness.

All qualified proposals will undergo an independent and objective scientific peer-review.

Based on the results of peer-review and GCMRC program managers review, awards will be made.

GCMRC PEER REVIEW GUIDELINES

GCMRC peer-review guidelines consistent with the "U.S. Department of Interior Guidelines for Scientific Peer Review of Research" issued by the Secretary of Interior.

GCMRC peer-review guidelines incorporate the following principles:

-- objectivity and impartiality of reviews

-- reviews will be conducted by true scientific peers, as judged by demonstrable scientific achievements

-- independence of peer reviewers

-- provision of constructive feedback to the investigators

-- anonymity of peer-reviewers, unless waived

-- periodic evaluation of the effectiveness of the peer review process

GCMRC SCIENCE ADVISORY BOARD

GCMRC proposes to establish an independent Scientific Advisory Board (SAB).

The SAB will be an advisory and not a decision-making body.

The SAB will:

-- ensure that GCMRC programs are unbiased, objective, and scientifically sound;

-- provide advice on the long-term monitoring and research program; and

-- periodically review the results of the long-term monitoring and research program.

GCMRC SCIENCE ADVISORY BOARD

The SAB will be an interdisciplinary board, composed of scientists qualified, on the basis of demonstrable scientific achievements.

Scientists will be selected for their disciplinary expertise.

Members will be selected for a three-year term, renewable for one consecutive three-year term.

Initial members will be selected for staggered one, two, and three year terms.

MONITORING AND RESEARCH

Definitions

Inventorying is the measurement of environmental attributes at a given point in time to determine what is there.

Monitoring is the measurement of environmental attributes over an extended period of time to determine status or trends in the environmental attribute being monitored.

Research is the measurement of environmental attributes to test a specific hypothesis.

An ***environmental attribute*** may be any biotic or abiotic feature of the environment which can be measured.

Linkages between monitoring and research

When properly designed, monitoring data can be analyzed as part of a research program.

Similarly, the results of a properly designed research program will suggest changes to be made in monitoring activities.

MONITORING AND RESEARCH

Standards and Protocols

Ensure compatibility of measurements over time.

Standard protocols will be established through implementation of the land-term plan.

Changes in protocols must respond to data comparability through time.

Monitoring must ensure data linkages across resources.

Monitoring must be designed with flexibility and contingency plans.

THE GEOGRAPHICAL AND INSTITUTIONAL SCOPE

Primarily the Colorado River corridor between Glen Canyon Dam and Lake Mead reservoir.

Extent of monitoring and research effort is defined by processes and conditions influenced by "the effects of the Secretary's actions".

II. GCMRC approach to developing the plan.

APPROACH TO DEVELOPING LONG-TERM PLAN

Stakeholder management objectives and information needs are the basis for the long-term plan.

Develop conceptual model to provide framework for understanding the system.

"State-of-the-science" assessments to synthesize and integrate existing knowledge.

Use the conceptual model to select initial attributes thought to be key drivers of resource change.

Ensure space and time dependence of attribute measurements.

Long-term monitoring designed to provide regular feedback for adaptive management.

REVIEW OF PAST MONITORING ACTIVITIES

Deficiencies

Reviews of past environmental monitoring have identified the following deficiencies:

-- minimal foundation in current ecological theory / knowledge

-- lack of a conceptual model

-- inadequate understanding of associations and causation

-- weak linkages between monitoring and research programs

-- inadequate time to develop a long-term monitoring program

-- weak definition of ranges of natural variability

-- inability to distinguish signal from noise in monitored attributes

-- weak linkages to stakeholder objectives and information needs

CONCEPTUAL MODELING

Why utilize a modeling approach?

Define and focus what one monitors; limits research activities to critical questions.

Models are simplifications which contain only the level of complexity needed to describe the behavior being modeled.

Process of model building permits testing assumptions and development of a shared view among scientists and managers.

Conceptual models are precise, consistent and explicit so they can be criticized and understood by anyone.

III. Individual Programs

RESOURCE AREAS FOR IDENTIFICATION

OF

STAKE HOLDER INFORMATION NEEDS

- WATER RESOURCES
- SEDIMENT RESOURCES
- CULTURAL RESOURCES
- RIPARIAN AND TERRESTRIAL VEGETATION RESOURCES
- FISH AND AQUATIC RESOURCES
- NATIVE TERRESTRIAL WILDLIFE RESOURCES
- RECREATION RESOURCES

PHYSICAL RESOURCES

IDENTIFICATION OF STAKE HOLDER INFORMATION NEEDS

PHYSICAL RESOURCES

- Monitor water quality changes with time
- Monitor water quality as compared to state and federal standards
- Measure water composition and temperature and their changes over time
- Characterize sandbar/backwater baselines and return channel structures
- Define target backwater ecosystems and associated flow regimes
- Define character and structure f all beaches and backwaters in system after 1996 test flows
- Define historical and current (character and structure) levels of river stored sediment in system and associated flow regimes
- Determine baseline conditions

PHYSICAL RESOURCES PROGRAM

Monitoring and research efforts will concentrate on four aspects of these physical resources as follows:

1. Dam discharges and instream flows.
   -- Synthesis
   -- Pilot monitoring

2. Sediment balance and process.
   -- Synthesis
   -- Pilot monitoring

3. Interrelationships of mainstem water and sediment and side channel inflows.
   -- Synthesis

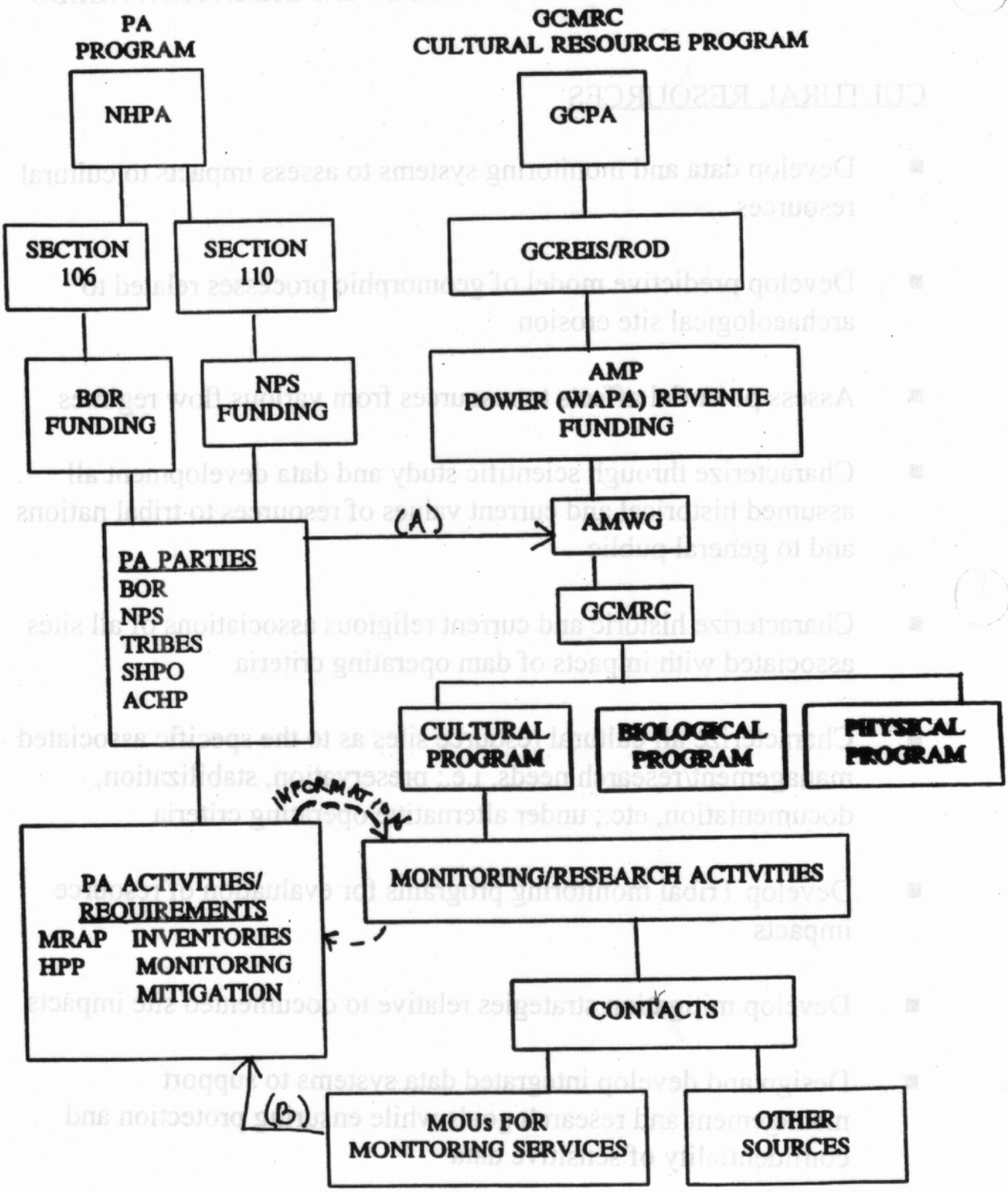
4. Interaction of mainstem water and sediment and Lake Mead Resources.
   -- Synthesis

CULTURAL RESOURCES

IDENTIFICATION OF STAKE HOLDER INFORMATION NEEDS

CULTURAL RESOURCES

- Develop data and monitoring systems to assess impacts to cultural resources
- Develop predictive model of geomorphic processes related to archaeological site erosion
- Assess potential affects to resources from various flow regimes
- Characterize through scientific study and data development all assumed historical and current values of resources to tribal nations and to general public
- Characterize historic and current religious associations of all sites associated with impacts of dam operating criteria
- Characterize all cultural resource sites as to the specific associated management/research needs, i.e.; preservation, stabilization, documentation, etc.; under alternative operating criteria
- Develop Tribal monitoring programs for evaluation of resource impacts
- Develop mitigation strategies relative to documented site impacts
- Design and develop integrated data systems to support management and research goals while ensuring protection and confidentiality of sensitive data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SECTION 110
GCREIS/ROD
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NPS FUNDING
AMP
POWER (WAPA) REVENUE FUNDING
(A)
AMWG
PA PARTIES
BOR
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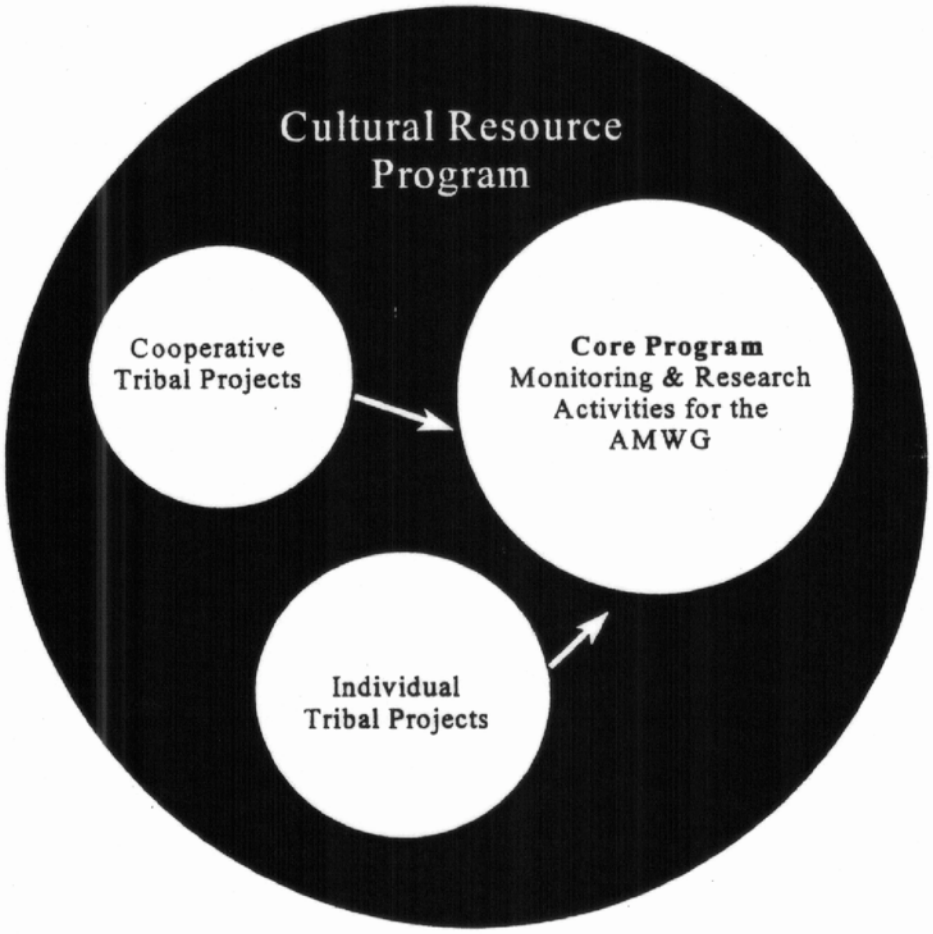
TRIBES
SHPO
ACHP
GCMRC
CULTURAL PROGRAM
BIOLOGICAL PROGRAM
PHYSICAL PROGRAM
INFORMATION
PA ACTIVITIES/ REQUIREMENTS
MRAP INVENTORIES
HPP MONITORING
MITIGATION
MONITORING/RESEARCH ACTIVITIES
CONTACTS
(B)
MOUs FOR MONITORING SERVICES
OTHER SOURCES

Primary Components of the Cultural Resources Program



PROPOSED MONITORING AND RESEARCH ACTIVITIES

1. Develop data and monitoring systems to assess impacts.

2. Develop data to assess risk of damage and loss from varying flow regimes.

3. Develop tribal monitoring programs for the evaluation of impacts to cultural resources.

4. Develop a predictive model of geomorphic processes that are related to archaeological site erosion.

5. Characterize resource values through scientific study.

6. Develop appropriate data systems and related technologies for restricted and sensitive information.

BIOLOGICAL RESOURCES

IDENTIFICATION OF STAKE HOLDER INFORMATION NEEDS

BIOLOGICAL RESOURCES (Examples)

- Define current and historic food base character and structure
- Determine adult humpback chub population levels and evaluate population level trends
- Determine levels of recruitment of humpback chub in the mainstem and Little Colorado River
- Develop criteria for self sustaining populations of humpback chub
- Determine historic and current character and structure of native species populations
- Determine ecosystem requirements, population character and structure to maintain populations of Trout
- Define criteria for healthy trout populations
- Define areas and conditions of current and future existing and potential native and non-native fish interactions
- Determine historical (pre-dam) natural composition of riparian and upland vegetation communities
- Define and specify ecology of native terrestrial wildlife resources
- Determine population changes in special status species

THE BIOLOGICAL RESOURCES PROGRAM

Program Goals

-- Address stakeholder objectives and information needs.

-- Develop information about the structure and function of the ecosystem.

-- Predict ecosystem responses.

Ecosystem degradation is not inevitable; it is simply cheaper and easier for some in the short term. Ecosystem health is also not inconsistent with economic imperatives and political realities. In fact, a healthy environment is the basis for a healthy economy. ***(Likens, G.E. 1992)***

POTENTIAL MONITORING AND RESEARCH ACTIVITIES

Fish and Aquatic Resources.

a. aquatic food base
b. reproduction, recruitment and growth of native fishes
c. reproduction, recruitment and growth of non-native warm water and cool water fishes including trout
d. habitat condition and availability
e. competition and predator-prey interactions

Riparian Vegetation.

a. area and species composition of woody riparian plants
b. area and species composition of emergent marsh plants

Wildlife and wildlife habitat.

a. area and species composition of riparian habitat for associated vertebrates and invertebrates
b. aquatic food base for wintering waterfowl

Threatened and endangered species.

a. humpback chub
b. razorback sucker
c. bald eagle
d. peregrine falcon
e. Southwestern willow flycatcher
f. belted kingfisher
g. Kanab ambersnail
h. Other federal and state species of concern

SOCIOECONOMIC

AND

RECREATION RESOURCES

IDENTIFICATION OF STAKE HOLDER INFORMATION NEEDS

SOCIOECONOMIC RESOURCES

- Maximize power resources within legal and policy guidelines

RECREATION RESOURCES

- Determine criteria and aspects that are important to or detract from wilderness experience
- Determine adequate beach quality, character and structure for camping throughout the system
- Determine if operating criteria maintain safe and adequate powercraft navigability in Glen Canyon and upper Lake Mead
- Determine flow regimes necessary to maintain fish populations of 100,000 adult Trout (age class II plus)
- Define pattern of waterfowl and other wildlife use and conflicts to other uses

PROPOSED MONITORING AND RESEARCH ACTIVITIES

SOCIOECONOMIC RESOURCES

- Develop a cost benefit analysis model for evaluating "the effects of the Secretary's actions" on environmental and socioeconomic resources

RECREATION RESOURCES

- Determine if recreation is enhanced and safety improved over impacts resulting from historical dam operations
- Determine if changes in recreational patterns resulting from selected dam operations have an effect on the Canyon's downstream resources
- Incorporate existing information on use and changes resulting from recreation at two year intervals
- Monitor beaches using aerial/video photography every other year
- Monitor recreationalists values and concerns on a five year basis or following unusual events

INFORMATION TECHNOLOGIES RESOURCES PROGRAM

Several areas of focus will be implemented in the information technology programing, including the following:

1. Development of protocols for data collection, processing and use.

2. Development of extensive databases across all resources and a database management system

3. Development of a robust geographic information system to accommodate multiple layers associated with all resources of interest to stakeholders

4. Development of databases associated with remotely sensed data, here to date not incorporated in the GCES database system.

5. Stakeholder direct access to selected data and information in the database management system and GIS.

6. Development of outreach programs to transport data and information to stakeholders.

BUDGET FOR GCMRC

Proposed FY 1998-2002

Fiscal Year

1998	1999	2000	2001	2002
7.0	7.0	8.0	7.5	7.0

Budget Allocations (000 of $)

AMP	.300
GCMRC	
Personnel	1.200
Physical resources	.800
Biological resources	1.600
Cultural resources	1.300
Socioeconomic resources	.200
Materials and service support	1.600
	7.000

4

Prospectus for an Assessment of Impacts of Glen 1 Operations on Water Quality Resources in Lake Powell and the Colorado River in Grand Canyon

W.S. Vernieu, S. Hueftle, D. Garrett
January 21, 1996

The Grand Canyon Protection Act of 1992 requires the Secretary of the Interior to evaluate the impacts of Glen Canyon Dam operations on all affected resources. Although the primary evaluation of these impacts are on resources downstream of the dam, concern has existed that certain aspects of dam operations have the potential to affect various resource attributes upstream of Glen Canyon Dam. These include, but are not limited to, physical, chemical, biological, cultural, social, economic, and public health resource attributes. During fiscal year 1997, the Grand Canyon Monitoring and Research Center will conduct an assessment of the effects of the operation of Glen Canyon Dam on the physical, chemical, and biological water quality resources in Lake Powell and the Colorado River immediately below the dam. This study will rely on data from the Bureau of Reclamation's long-term limnological monitoring program and information from other agencies and institutions. Findings of this assessment will be presented to the Adaptive Management Work Group (AMWG) in the summer of 1997. Based on these findings, the AMWG will recommend future monitoring and research programs for Lake Powell.

Introduction

The closure of Glen Canyon Dam in 1963 caused major changes to the physical, chemical and biological characteristics of the Colorado River in Grand Canyon. These changes are well documented and include the removal of sediment and the moderation of temperature, salinity and other chemical extremes. Operation of the dam for peaking power generation resulted in the removal of seasonal discharge variability and its replacement with daily discharge fluctuations.

Concurrently, changes were also made to the Colorado River as it began to form Lake Powell upstream of Glen Canyon Dam. The river was slowed and began depositing sediment in the reservoir basin. Vertical temperature and chemical gradients appeared in the reservoir body due to seasonal density variations of the inflows, climatic factors, and the mid-depth location of the powerplant penstocks. Certain aspects of dam operations over the past 33 years are hypothesized to have impacts to many of the reservoir's resources, especially water quality. Comprehensive scientific assessments have not been conducted to determine the extent of these impacts.

It is, therefore, the intent of this project to conduct an assessment of changes and/or impacts that occurred to Lake Powell water quality resources from dam operating criteria during the period of Glen Canyon Dam's operation, from 1965 to present. Impacts to other resources noted above are beyond the scope of this project and will not be addressed.

In this context, the term *water quality* is used to include the various physical, chemical, and biological attributes that characterize a body of water in terms of its hydrodynamic properties, chemical composition, and the organisms that live in it. Its use is not intended to connote any value judgements based on suitability for a given use.

Affected Resources

Many processes in Lake Powell are influenced by factors not directly related to dam operations such as inflow hydrodynamics, climatological conditions, and the existence and structure of Glen Canyon Dam. However, some water quality attributes of Lake Powell and downstream releases may be affected by certain aspects of the operation of Glen Canyon Dam. These effects can be evaluated from data developed in existing monitoring programs.

Three main interlinked resource categories may be affected by the operation of Glen Canyon Dam and other factors. **Physical and chemical** conditions in Lake Powell address evaporative water loss, temperature regime and heat budget, salinity levels, hydrodynamics and mixing patterns, nutrient and trace element concentrations, and sediment deposition. These characteristics, in turn, influence the **biological resources** of Lake Powell and the Colorado River below the dam. Affected biological components may include primary productivity, algal and zooplankton abundance and composition, and the dynamics of fish populations, water fowl, and higher species. The third affected resource category involves **social and economic components** such as power production, water delivery, cultural and historic resources, recreation and public health.

While direct linkages exist among these resource categories, identification and evaluation of effects to all these resource categories is impossible in one year under the current budget setting. The scope of this assessment will therefore be limited to the various physical, chemical, and biological water quality attributes associated with Glen Canyon Dam operations for which information has been or is currently being gathered.

Scope and Objectives of Assessment

The Grand Canyon Monitoring and Research Center (GCMRC) will undertake a one year assessment of the effects of Glen Canyon Dam operation, from 1965 to 1996, on the physical, chemical, and biological water quality characteristics of Lake Powell. This assessment will draw mainly from Reclamation's long term water quality monitoring program on Lake Powell but will also be supported by information from other studies and existing literature. It will be conducted by analysts from GCMRC in consultation with three reservoir limnologists currently not connected with the Center. Preliminary findings will be made available in late summer 1997. Final results of the assessment will be reviewed by a Science Advisory Group and presented to the Adaptive Management and Technical Work Groups at the end of fiscal year 1997.

The primary focus of this assessment will be to determine the effects of dam operations, as specified in the Glen Canyon Dam EIS and Record of Decision, on reservoir and release water quality. Primary consideration will be made to peaking power generation, operation of non-power release structures, and potential selective withdrawal. An attempt will be made to identify other factors affecting Lake Powell such as the existence and structure of Glen Canyon Dam, climatological factors, and internal hydrodynamic processes, so that these impacts are not inappropriately associated with dam operations. This assessment will not address direct impacts to fisheries, public health, recreation, or other social and economic resources other than to identify possible linkages between these resources and water quality changes. This limited scope does not assume negligible impact to these resources. Although impacts could be occurring to all these resources, the reduced scope of this assessment relates primarily to the following institutional constraints:

1. A 10-month assessment period
2. A restrictive budget
3. The availability of data for assessments from Reclamation monitoring programs that are limited primarily to physical, chemical, and biological resource attributes.

Background Information

Concurrent with historical changes in dam operations and reservoir conditions, Reclamation has maintained a water quality monitoring program on Lake Powell since 1965. By associating the monitoring effort with historical dam operations, increased understanding can be gained of effects of dam operations on reservoir resources.

Brief History of Lake Powell and Glen Canyon Dam Operations

Lake Powell has had a relatively short existence as an operating reservoir. Its history can be described in terms of three major periods in Glen Canyon Dam operations.

1963-1980. The seventeen-year period from 1963 to 1980 resulted in the eventual filling of Lake Powell to its normal pool elevation of 3700 ft. With minor exceptions, this period was characterized by constantly increasing reservoir elevations, increasing depth of the penstock withdrawal zone, and continual inundation of new areas of the reservoir basin. Stable stratification patterns in temperature and salinity developed from the constant withdrawal at the penstock level.

1980-1990. The period from 1980 to 1990 was characterized by relatively full reservoir levels. A succession of high runoff years in the early and mid 1980's brought the reservoir 8 feet above its normal pool level in July of 1983. Because of the need for increased releases from Glen Canyon Dam, the spillway structures and hollow jet bypass tubes were operated on several occasions. This allowed significant amounts of water to be released from levels above and below the penstock zone. These factors combined to cause nearly complete mixing of the reservoir in 1985,

due to the high volume of reservoir throughput and the operation of the alternative release structures. In the late 1980's, drought conditions returned to the upper basin and resulted in decreasing reservoir levels and the return of strong chemical stratification below the penstock level.

1990-1996. The period from 1990 to 1996 was marked by a series of manipulations to the operation of Glen Canyon Dam for scientific and environmental purposes. Before this time, the dam was operated primarily for peaking power generation and water delivery to the Lower Basin States.

In 1990, Phase II of the Glen Canyon Environmental Studies and the development of the Glen Canyon Dam EIS began. As part of the GCES Phase II Integrated Research Plan, a series of research flows was initiated from June 1990 to August 1991. These flows ranged widely in daily fluctuations and ramping rates, interspersed with periods of steady flow. In November 1991, following the research flow period, the Secretary of the Interior implemented the Interim Operation Criteria, which set limits on minimum and maximum discharge, daily range of discharge, and hourly ramping rates. These criteria remained in place until October 1996, when the Record of Decision for the preferred alternative of the Glen Canyon Dam EIS was signed by the Secretary of the Interior.

Of significance during this latter period was the experimental beach/habitat building flow in March and April 1996. This 7-day discharge of 45,000 cfs included a release of 15,000 cfs from the river outlet works of Glen Canyon Dam. The operation of this structure released water from 100 feet below the penstock withdrawal zone and weakened the strong chemical stratification that had previously built up below that level.

Reclamation Monitoring Program

The Bureau of Reclamation initiated a water quality monitoring program on Lake Powell in 1964 to gather information on initial water quality conditions and to observe changes as the reservoir filled and matured. This program has continued to the present. Based on sampling frequency, spatial resolution of measurements, and changes in instrumentation, four distinct phases of monitoring activity can be identified.

(1) From 1965 to 1971, monitoring activity was characterized by monthly sampling of the Glen Canyon Dam forebay and quarterly surveys of the entire reservoir for temperature and salinity. Measurements and samples were collected at 50-foot depth intervals at seven locations on the reservoir.

(2) From 1972 to 1981, the frequency of lake-wide surveys was increased to a monthly basis.

(3) From 1982 to 1990, sampling activity steadily declined to single lake-wide surveys in 1988 and 1989. Despite the decline in sampling frequency, advances in instrumentation allowed the collection of higher quality data at finer depth resolution. Continuous monitoring of temperature and salinity of the tailwater was initiated during this period.

(4) In 1990, concurrent with the implementation of GCES Phase II studies, Reclamation's Lake Powell monitoring program was restructured. Monitoring frequency was returned to a level of monthly forebay surveys and quarterly lake-wide surveys. Monthly forebay surveys were conducted by the US Geological Survey during the Phase II Research Flow period from 1990 to 1991. Resources were shifted to allow the collection of data at a finer spatial resolution while reducing the number of samples collected for chemical analysis. Sampling for nutrient chemistry and biological conditions was also initiated. The objective of this phase of monitoring activity was to establish a program of basic data collection that would balance cost with the ability to track changes in reservoir and release water quality and evaluate the effects of Glen Canyon Dam operation on these resources.

Other work has been conducted by various agencies and institutions during Lake Powell's history. Studies have been conducted by educational consortiums and federal and state agencies on subjects that include sedimentation, circulation patterns, trace element chemistry, remote sensing, and public health issues. Findings from selected analyses that relate to water quality changes associated with dam operations will be incorporated in this assessment.

Method of Assessment

The various aspects of Lake Powell water quality changes associated with dam operations will be addressed based on the existence of available information. While limited information is available from other sources, most information exists from the Reclamation long-term monitoring program regarding the physical, chemical, and biological aspects of Lake Powell water quality. Evaluation of each of these water quality components will form the basis of the assessment.

The physical aspects of hydrology and dam operations are very well documented and complete. Temperature and major ion chemistry measurements in Lake Powell cover its entire history except for sparse coverage during the 1980's. Dissolved oxygen, pH, and water clarity measurements are incomplete or questionable during certain periods. A regular program of nutrient chemistry sampling and biological measurements was not initiated until 1990, but some synoptic data from the early 1980's exist in this area. While no regular monitoring program for trace element chemistry has existed, some synoptic studies of trace element concentration in water and biota have been conducted. Biological sampling of the reservoir was begun in 1990; analysis is pending for many of these samples. The assessment will be based on the most complete data set possible.

Several tasks are required to complete this assessment. (1) Questions to be answered in the assessment will be developed, in cooperation with three independent reservoir limnologists, to assure appropriate focus to the analysis. (2) A literature review of reservoir water quality effects from dam operations will be conducted. (3) All existing Reclamation data not currently in electronic format will be incorporated into existing databases. (4) Identification, enumeration, and analysis of existing biological samples must be completed. (5) Evaluation of existing quality assurance/quality control data must be made to define levels of precision and accuracy. (6) Other tasks include minor modification of existing database structures and continued development of methods for data analysis. (7) An evaluation will then be made by the analysts and the contract limnologists regarding the effects of dam operations on the physical, chemical, and biological aspects of Lake Powell water quality. The continuation of the existing monitoring program will continue with minor modifications.

The product of this assessment will be an analysis of the effects of dam operations on Lake Powell and Colorado River water quality, an evaluation of the significance of these effects on the various affected resources, and a discussion of possible effects of future proposed structural and operational changes to Glen Canyon Dam. Recommendations for future monitoring and research activity will also be developed.

Assessment Schedule and Budget

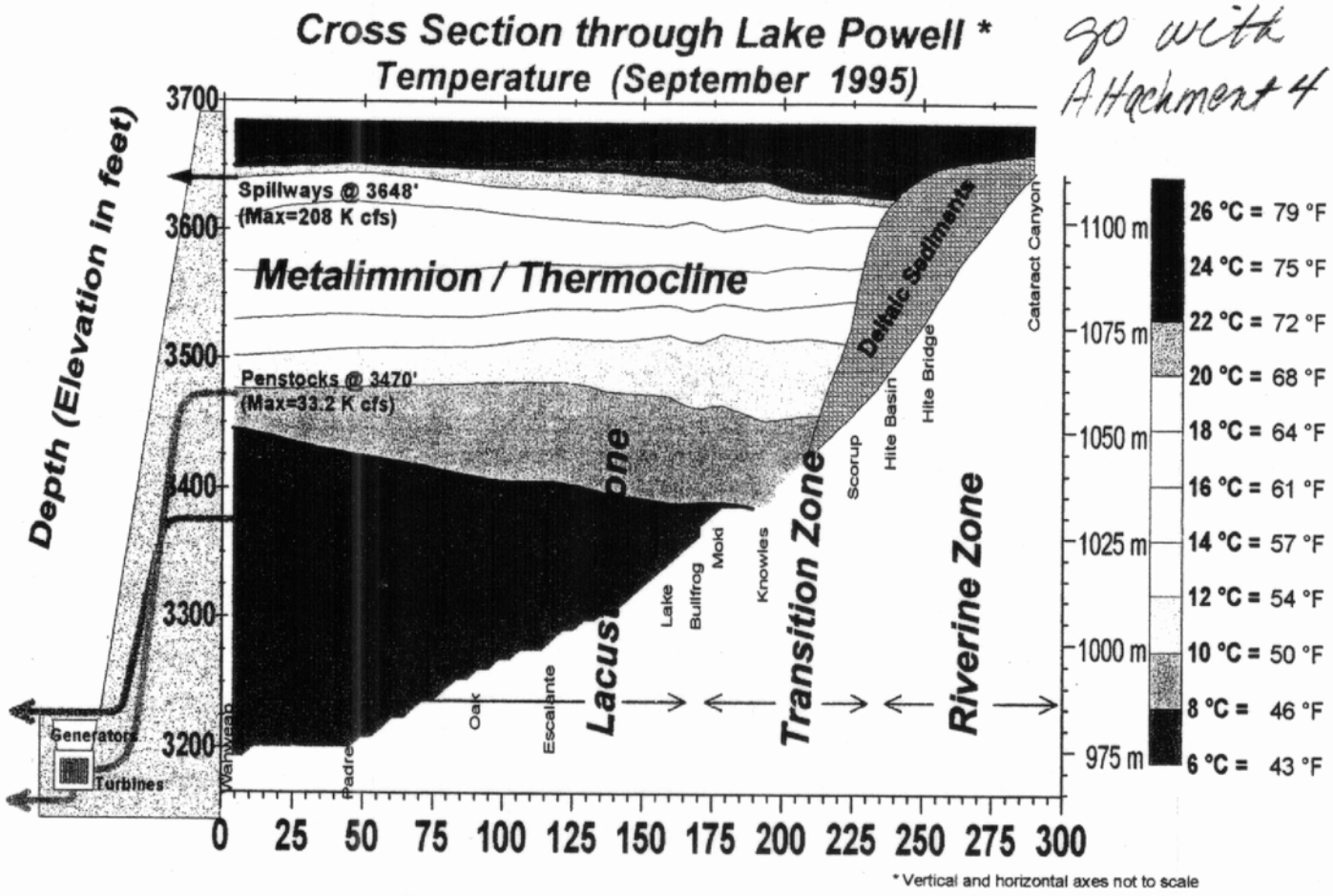
The schedule for conducting the assessment is as follows:

- January 31, 1997: Completion of study plan and implementation of study.
- February 15, 1997: Selection of three research limnologists for cooperative question formulation and interpretation of analyses.
- July 1, 1997: Completion of data analysis.
- August 1, 1997: Development of draft interpretation of assessment.
- September 1, 1997: Peer review of analysis.
- November 1997: Adaptive Management Work Group presentation of results of assessment.

Presentation to the Adaptive Management Work Group will be preceded by significant involvement of the GCMRC Planning Group (Technical Work Group) to assure appropriate response to stakeholder information needs.

It is proposed that this assessment be completed within the FY 1997 proposed monitoring budget for Lake Powell of $225,000. To meet this budget constraint, the Lake Powell monitoring program for FY 1997 may be reduced in scope and intensity.

Does this go with Attachment 4?



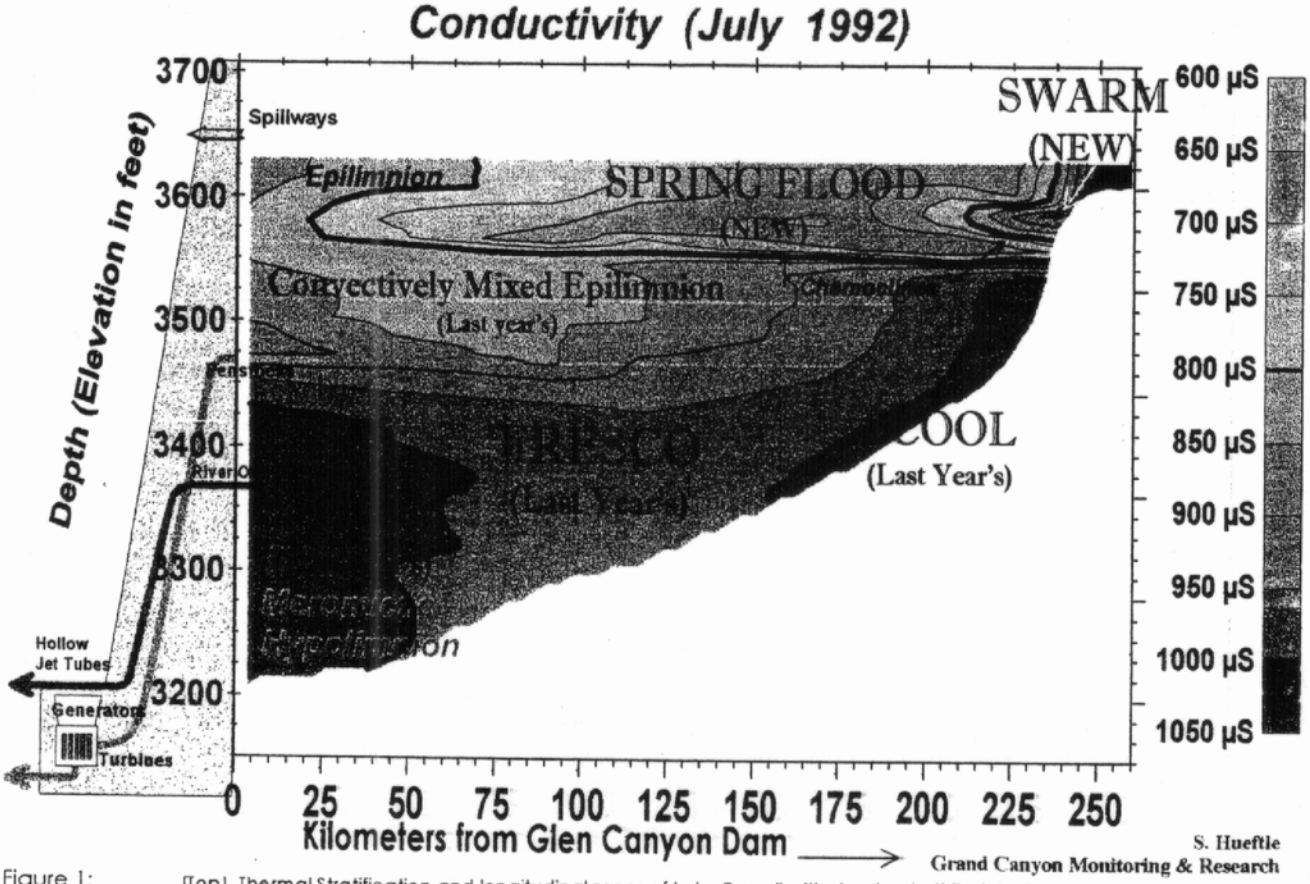


Figure 1: [Top] Thermal Stratification and longitudinal zones of Lake Powell with structural attributes of Glen Canyon Dam. [Bottom] Conductivity isopleth with Lake Powell's circulation cells present for past and present seasons

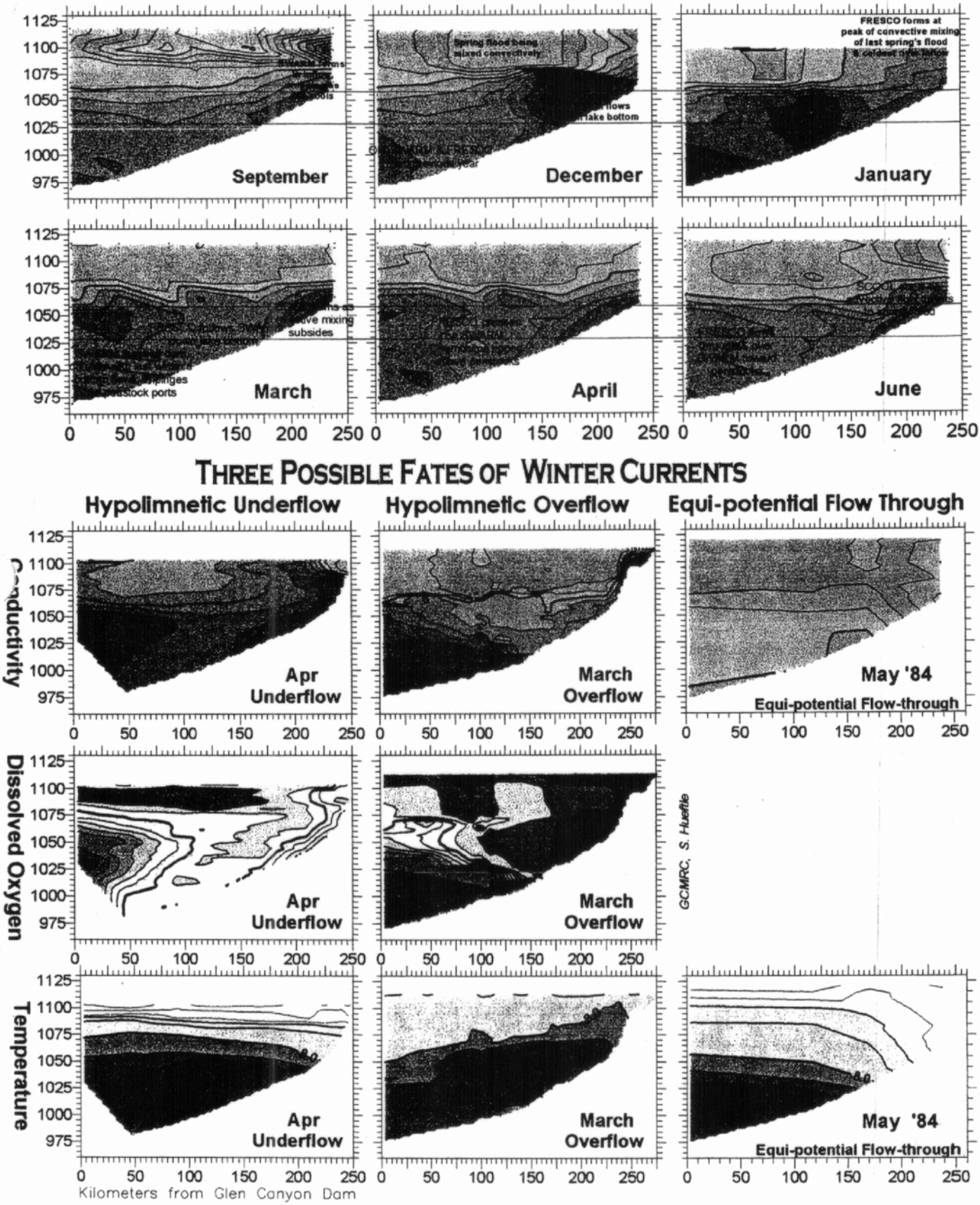


Figure 2b: [Top] Sequence of 6 conductivity isopleths demonstrate the most common annual scenario of winter interflow/overflow. [Bottom]: Example of 3 possible winter underflow currents: Underflow, Overflow & Equi-potential Flow Through for conductivity, dissolved oxygen, and temperature.

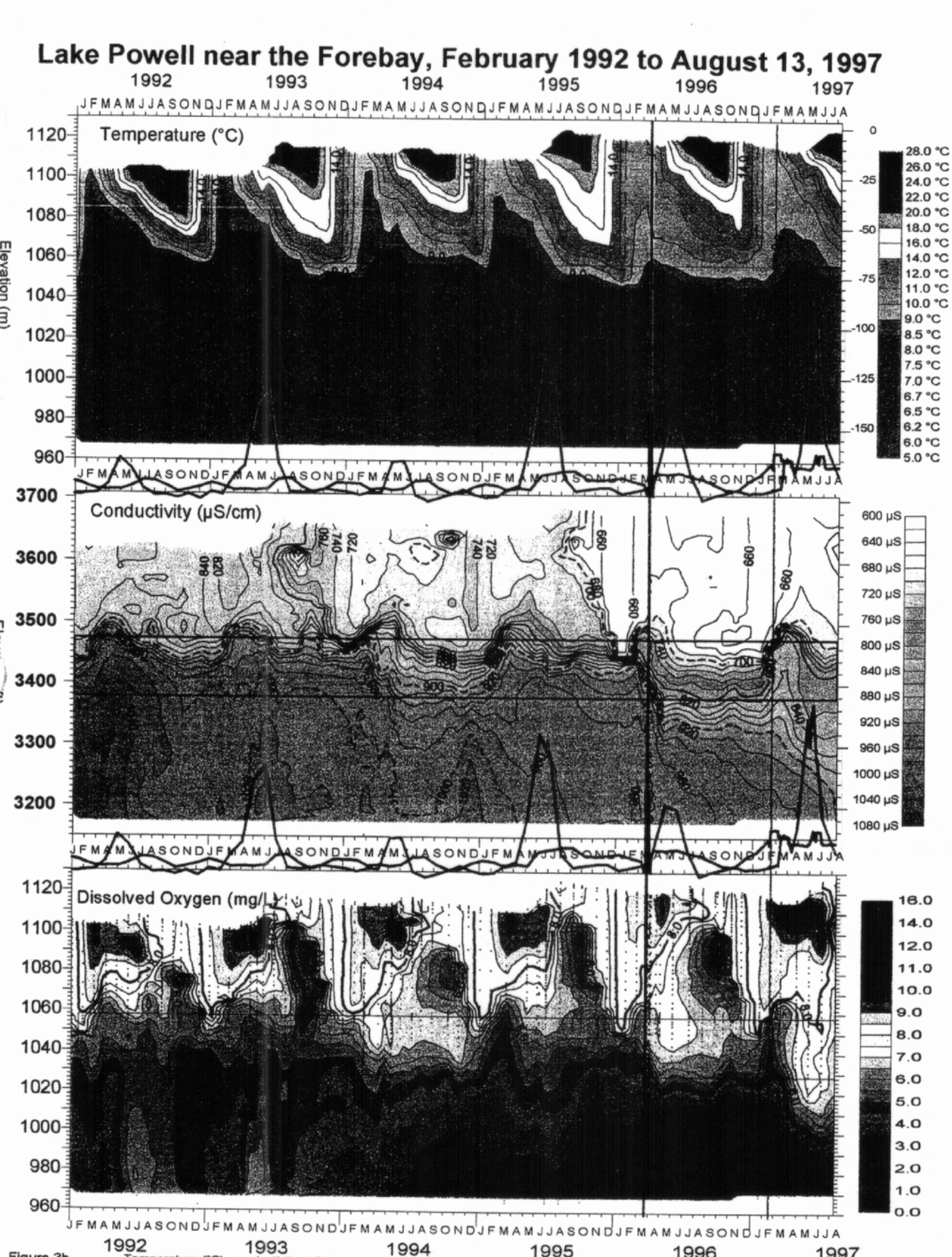


Figure 3b. Temperature (°C), conductivity (µS/cm), dissolved oxygen (mg/L) at Wahweap station in Lake Powell from February 1992 to August 13, 1997, including results from experimental flood (red line). Penstocks indicated at 1057.7 m & jet tubes at 1028.4 m. Hydrograph of inflow is indicated by red line & outflow in blue.

Grand Canyon Monitoring & Research, S. Hueftle, 08/25/97

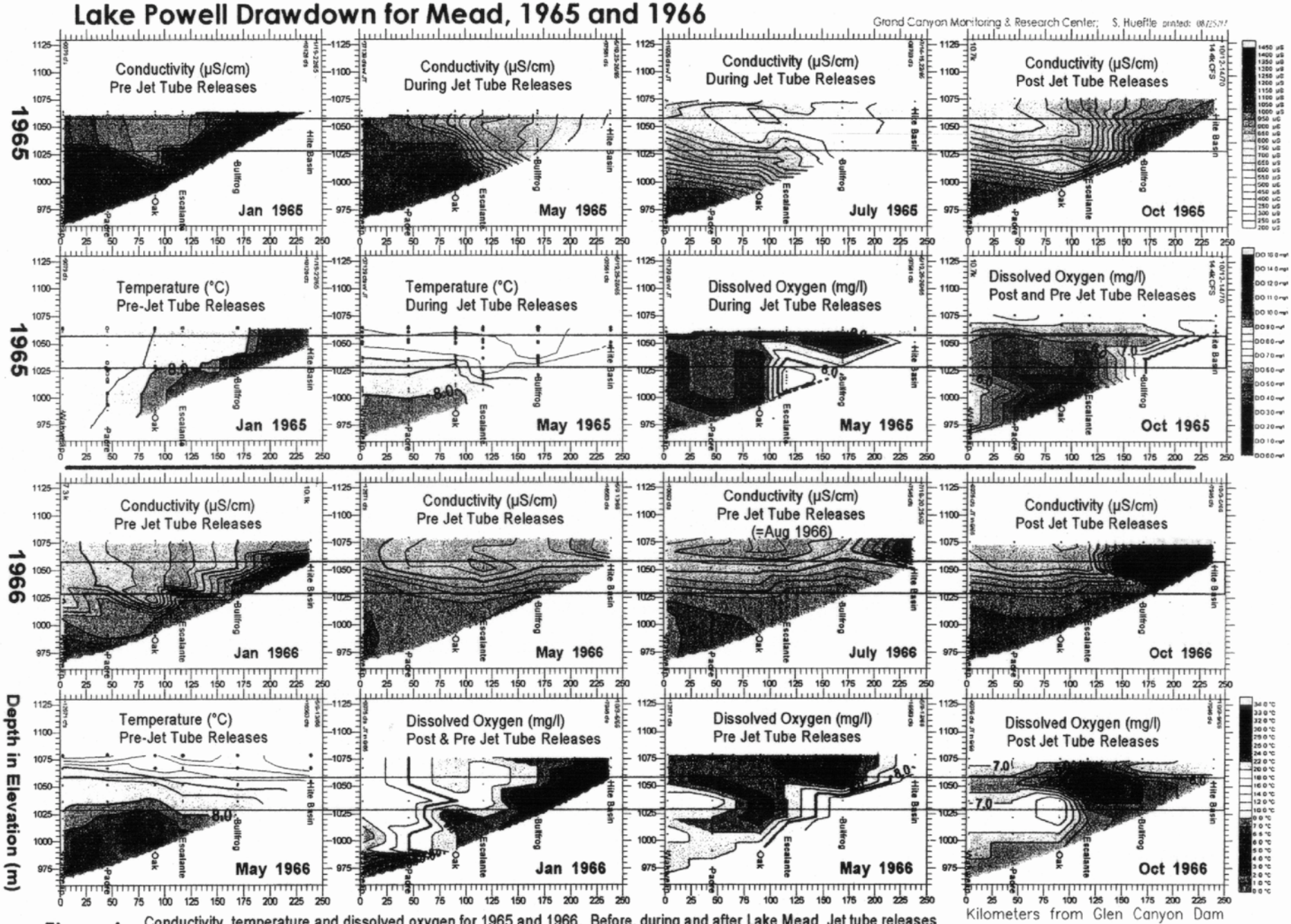


Figure 4: Conductivity, temperature and dissolved oxygen for 1965 and 1966. Before, during and after Lake Mead Jet tube releases of 2/65 to 8/65 and 8/66. Depth of penstocks (1057.7 m) and jet tubes (1028.4 m) indicated by black lines.

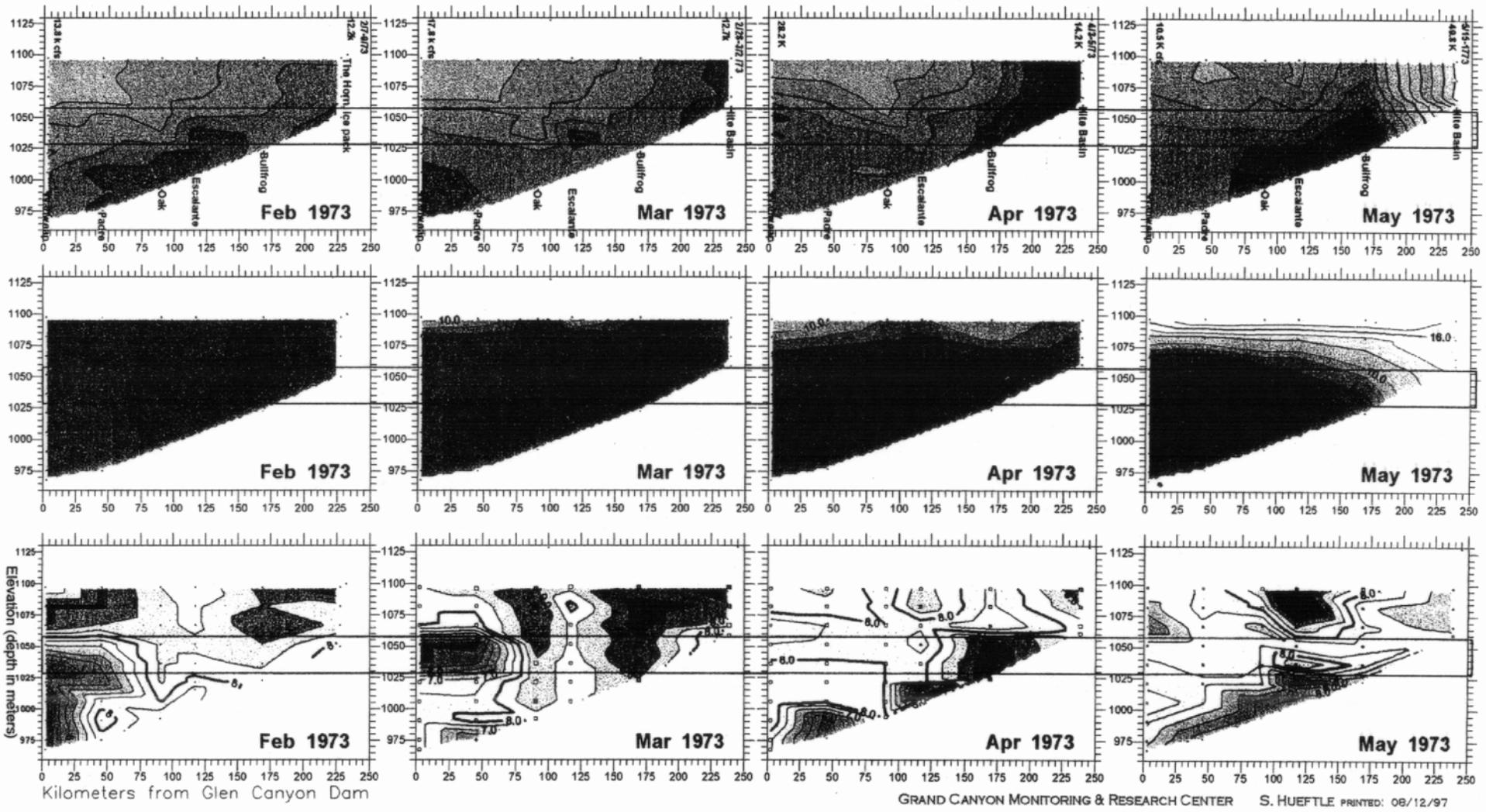
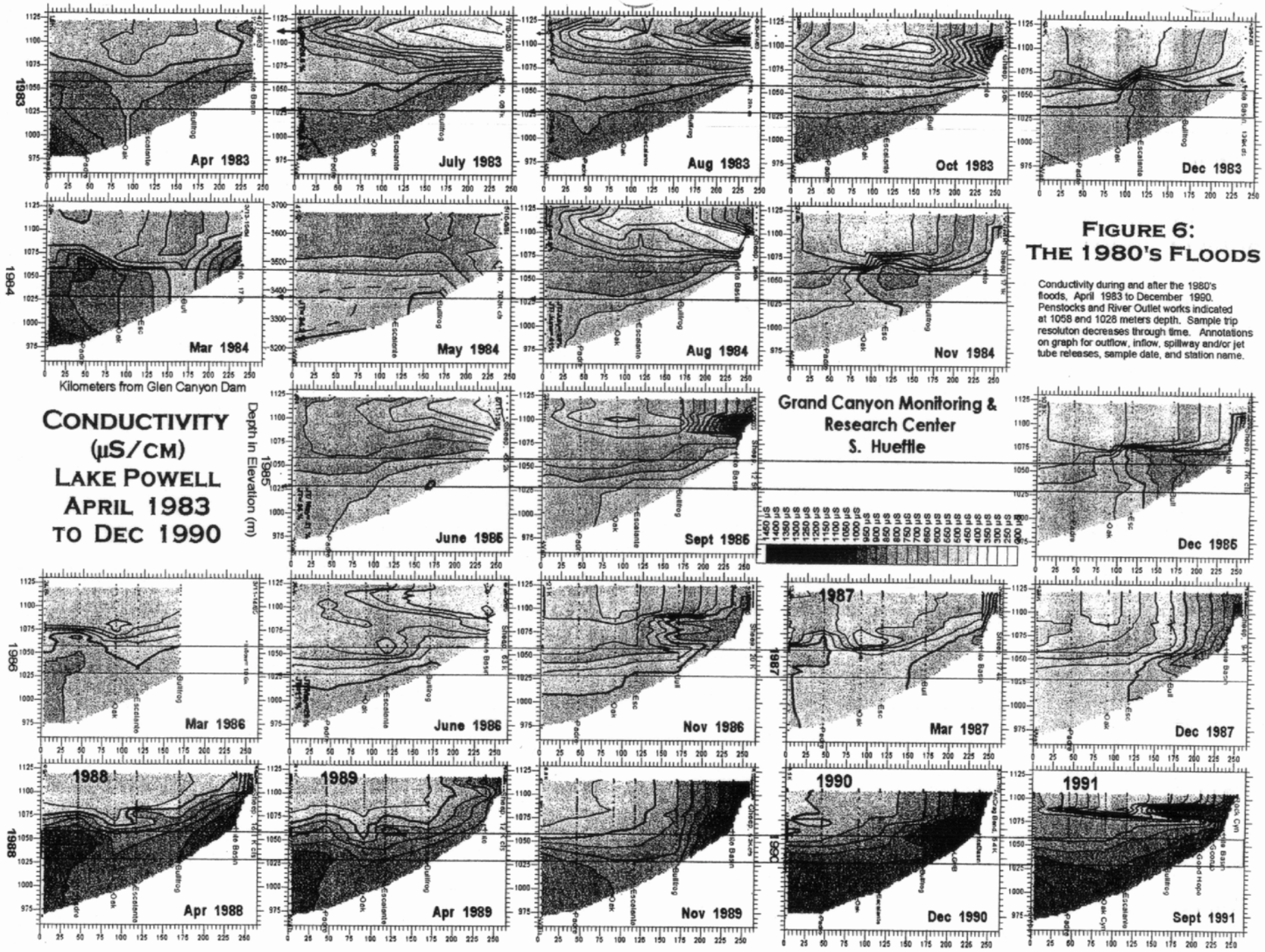


Figure 5: Longitudinal profiles of Lake Powell for February, March, April and May, 1973. Drawdown of Lake Powell in anticipation of large spring flood and concerns for inundation of Rainbow Bridge. Penstock discharges were elevated from March 22, 1973 to May 1, 1973. Discharges during elevated releases averaged 27 K cfs, accounting for 2.29 MAF (million acre-feet) or 22.6% of water year 1973's total discharge. Penstocks and river outlet structures (not used) are indicated 1057.7 m and 1028.4 m, respectively. Average monthly discharge and exact sample date are indicated at top of conductivity plots.



CONDUCTIVITY (µS/CM) LAKE POWELL APRIL 1983 TO DEC 1990

FIGURE 6: THE 1980'S FLOODS

Conductivity during and after the 1980's floods, April 1983 to December 1990. Penstocks and River Outlet works indicated at 1058 and 1028 meters depth. Sample trip resoluton decreases through time. Annotations on graph for outflow, inflow, spillway and/or jet tube releases, sample date, and station name.

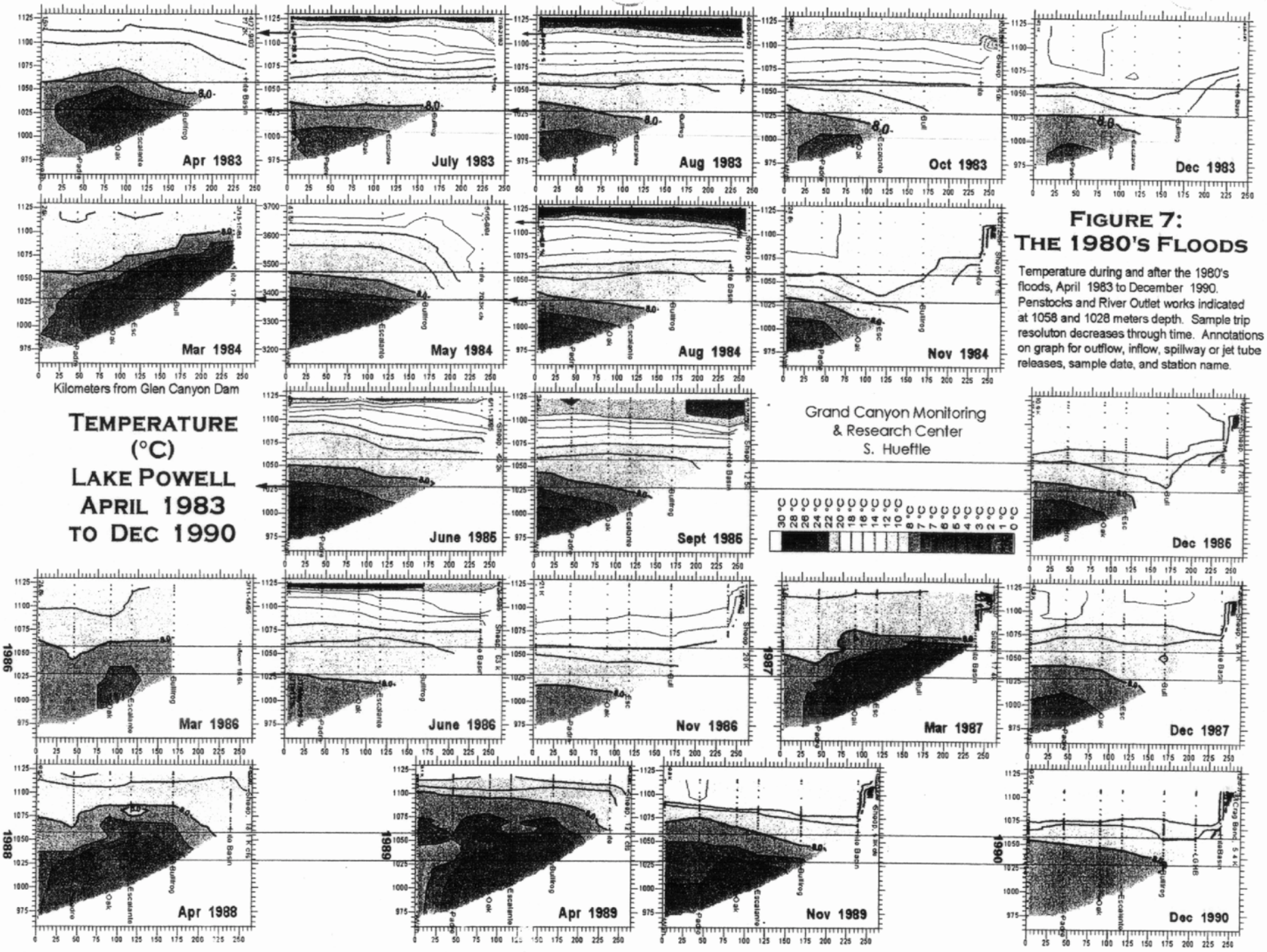


FIGURE 7: THE 1980'S FLOODS

Temperature during and after the 1980's floods, April 1983 to December 1990. Penstocks and River Outlet works indicated at 1058 and 1028 meters depth. Sample trip resoluton decreases through time. Annotations on graph for outflow, inflow, spillway or jet tube releases, sample date, and station name.

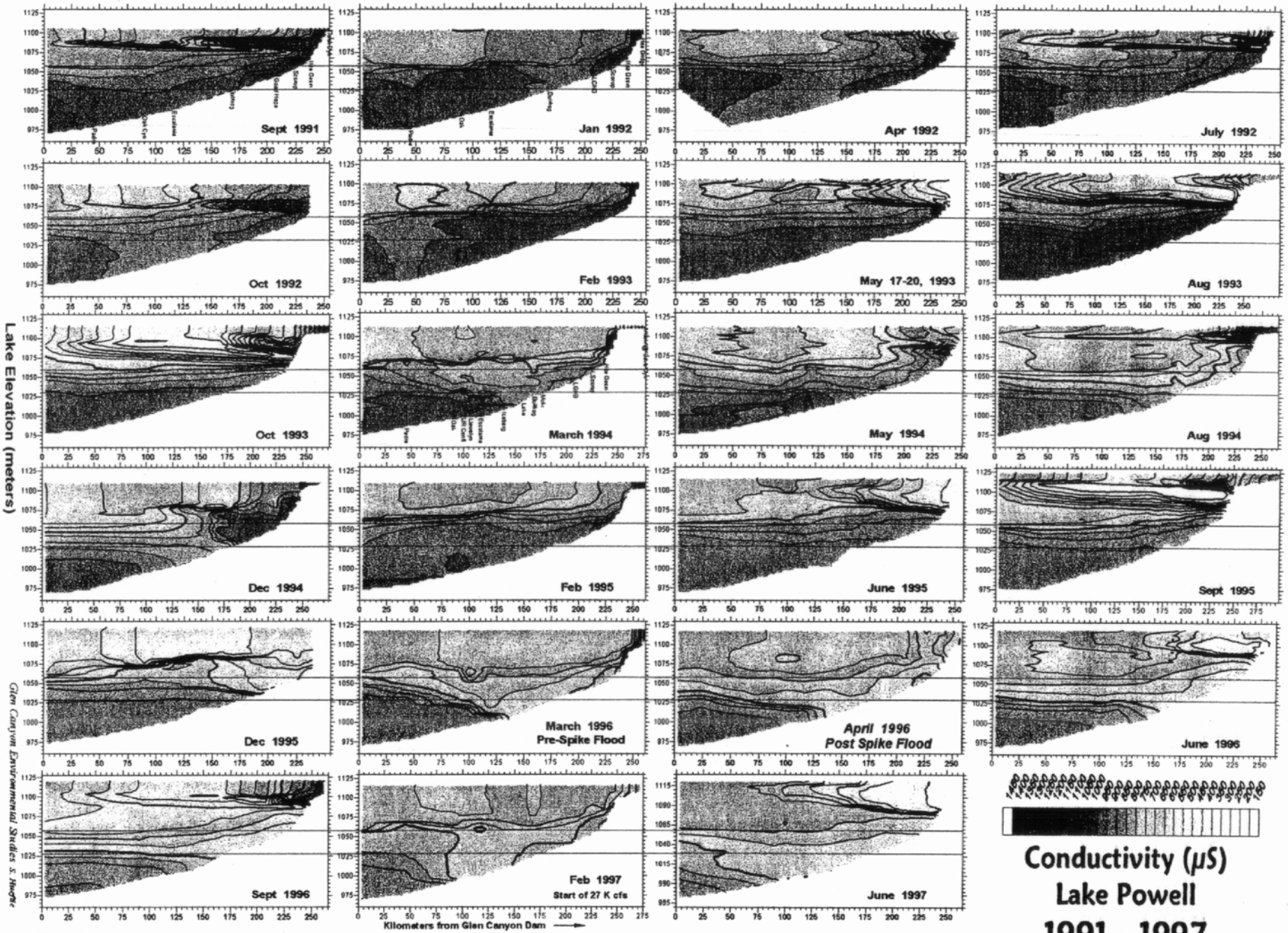


Figure 8: Lake-wide conductivity for the 1990's, Sept. 1991 to March 1997, during Spike Flow and Spring 1997 high steady discharge. Penstocks and River Outlet Works indicated at 1058 and 1028 meters depth. (8/25/97)

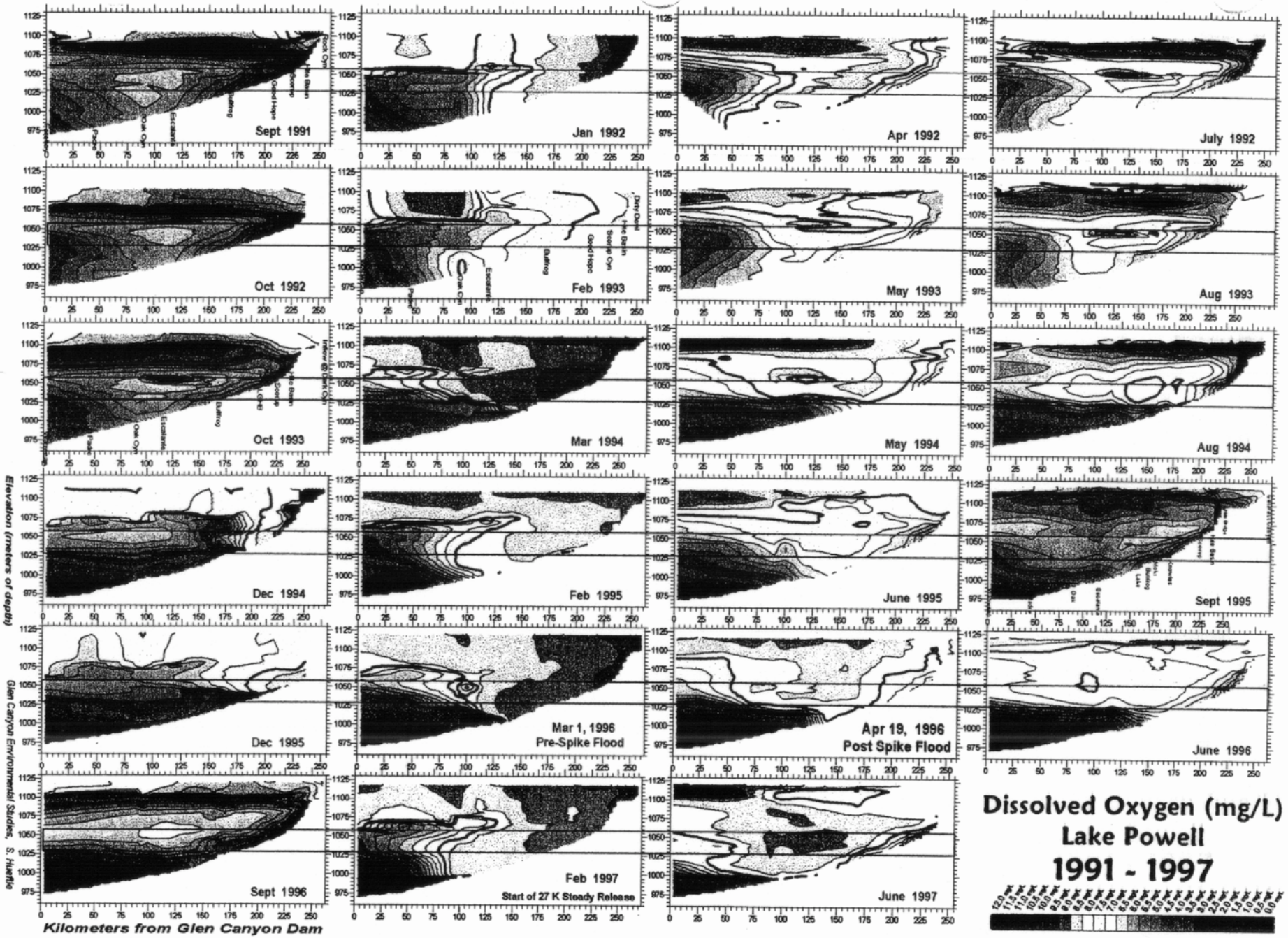


Figure 9: Lake-wide dissolved oxygen for the 1990's, Sept. 1991 to March 1997, during Spike Flow and Spring 1997 high steady discharge. Penstocks and River Outlet works indicated at 1058 and 1028 meters depth. Sept. 1991 out of sequence at end of plot. (8/25/97)

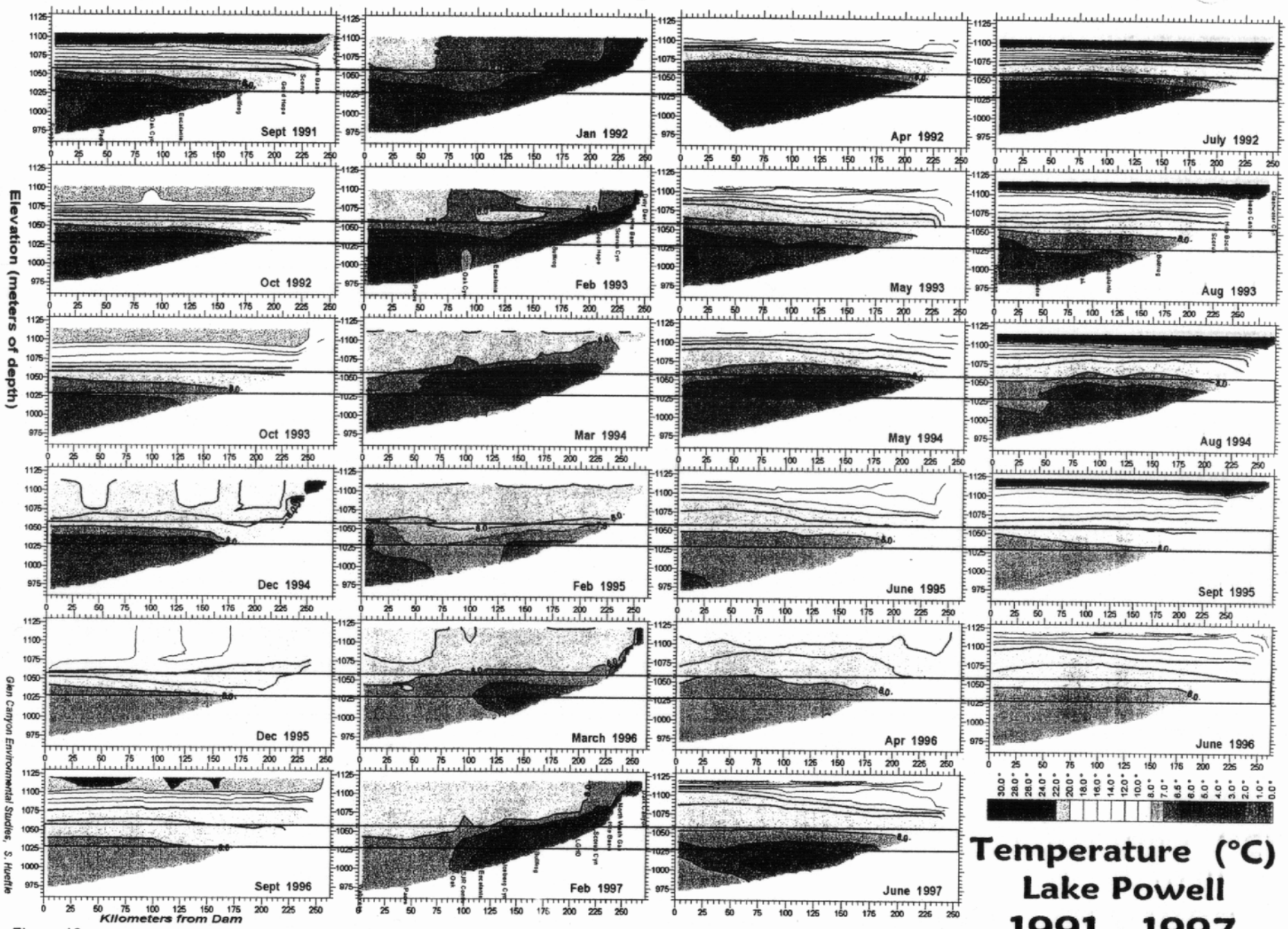


Figure 10: Lake-wide Temperature for the 1990's, Sept. 1991 to March 1997, during Spike Flow and Spring 1997 high steady discharge. Penstocks and River Outlet works indicated at 1058 and 1028 meters depth. Sept. 1991 out of sequence at end of plot.

(08/24/97)

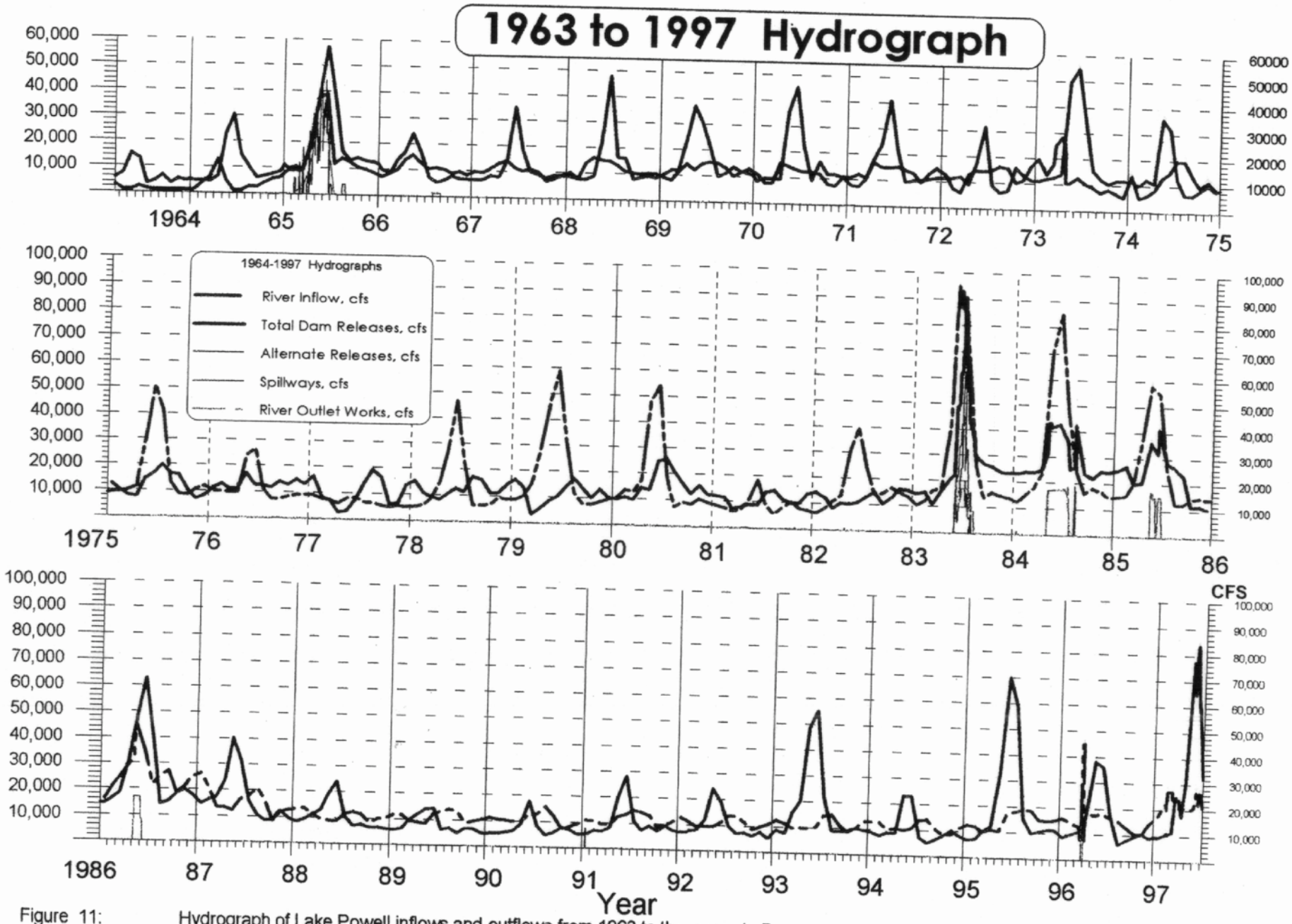


Figure 11: Hydrograph of Lake Powell inflows and outflows from 1963 to the present. Dam releases are subdivided into spillway releases (elevation 1111.9 m / 3648 feet), river outlet works or hollow jet tubes (elevation 1028.4 m / 3374 feet), alternate releases reflects