

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

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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.