

DRAFT
GLEN CANYON DAM MANAGEMENT OBJECTIVES
June 10, 1998

INTRODUCTION

Initial development of Objectives, Information Needs and Management Actions can and usually does occur by individual stakeholders. However, discussion and agreement on Management Objectives, Information Needs, and Management Actions to be included in the Adaptive Management Program must occur in an open forum of the Technical Work Group (TWG). Final approval of Management Objectives, Information Needs and Management Actions to be used in developing Grand Canyon Monitoring and Research Center (GCMRC) monitoring and research plans is by the Adaptive Management Work Group (AMWG).

PURPOSE

The purpose for developing Management Objectives is to define measurable standards of desired future resource conditions which will serve as objectives to be achieved by all stakeholders in the Glen Canyon Dam Adaptive Management process. These Management Objectives are framed within the Preferred Alternative and implemented by specific dam operating criteria and other actions taken by the Secretary to protect, mitigate adverse impacts to, and improve the values for which the Glen Canyon National Recreation Area and Grand Canyon National Park were established.

Stakeholder Information Needs define the specific scientific understanding required to obtain specified Management Objectives. These will be reviewed by the National Research Council for FY97 and FY99.

Management Objectives and Stakeholder Information Needs are the basis for development and implementation of long-term strategic and annual monitoring and research programs. Research plans are developed annually and must address specified Stakeholder Information Needs.

The GCMRC and TWG will report annually on progress related to individual Management Objectives, Information Needs, and Management Actions, and will revise Management Objectives, Information Needs and Management Actions as needed.

BACKGROUND

The Glen Canyon Dam Final Environmental Impact Statement states that an Adaptive Management Program (AMP) will be initiated following the issuance of a Record of Decision by the Secretary of the Interior. The concept of adaptive management is based on the recognized need for operational flexibility to respond to future monitoring and research findings and varying resource conditions. The AMP will monitor the effect of the operating criteria adopted by the Secretary pursuant to the Grand Canyon Protection Act of 1992 (GCPA) and determine if the anticipated results (Management Objectives) in the Preferred Alternative of the Environmental Impact Statement and the Record of Decision are being reached. If it is found that the objectives are not being reached, the AMP will develop proposals for modifying to the Glen Canyon Dam Operations, modifying the Management Objectives, and/or the exercise of other authorities under existing laws to achieve the anticipated results (Management Objectives).

Principles which guided the design of the Adaptive Management Program (AMP) include:

1. Monitoring and research programs will be designed by GCMRC in direct response to objectives and information needs of the Adaptive Management Work Group (AMWG).
2. A process is required to coordinate and communicate AMWG information needs to researchers and to develop recommendations for decision making.

The AMWG recognized the desirability of beginning the process of clarifying and consolidating the management objectives of organizations that participate in the AMP in order to clearly identify information needs to researchers. Initiating this process facilitates and expedites monitoring and research designs.

PROCESS

The procedure selected for development and approval of (Stakeholder) Management Objectives and Information Needs is as follows:

Defining Goals, Objectives and Information Needs. Defining terms were developed by Stakeholders as a guide to articulation of Goals, Objectives, Information Needs and Management Actions as follows:

<u>TERM</u>	<u>DESCRIPTORS</u>
Goals	- Directional Statement - Qualitative - Rarely Attained - Generic

- | | |
|--------------------|---|
| Objectives | <ul style="list-style-type: none"> - Defines desired Future Resource Condition - Quantifiable - Has Timelines with Target Dates - Concise - Within Legal Boundaries |
| Information Needs | <ul style="list-style-type: none"> - Uses Information Collection Process - Results in Product, Outcome, Report, Model, Data - Incorporates Data Collection, Analysis, Synthesis, etc. - Accomplishment associated with Management Objective |
| Management Actions | <ul style="list-style-type: none"> - A Management Activity: - Has Timeline and Target Completion Date - Help achieve a Management Objective
 - Within Legal Boundary |

Development of Objectives, Information Needs and Management Actions. The Management Objectives are initially designed to be in accord with the Environmental Impact Statement: these objectives do not necessarily define the ideal desired future resource condition. Rather, they describe, clarify and detail the resource objectives described in the EIS for the preferred alternative. Under the operating criteria signed by the Secretary, the GCMRC will monitor the resources and periodically inform the TWG and AMWG regarding the condition of the resources. If the operation of Glen Canyon Dam under the criteria fail to meet these objectives the AMWG will either recommend operational changes to the Secretary

The following draft Management Objectives, Information Needs and Management Actions are still in development and will be presented to the AMWG at its July 1998 meeting for approval. They are being designed to guide GCMRC program planning through the period FY1999-2003 and will be reviewed annually.

ECOSYSTEM ASSESSMENTS

MO 1: Develop a conceptual model of the Colorado River ecosystem.

IN 1.1 The conceptual model will be used to:

- (1) guide monitoring and research planning,
- (2) more clearly define critical attributes and linkages within and between resource categories,
- (3) promote improved understanding of key factors that drive changes in the systems,
- (4) make qualitative assessments of resource change resulting from alternative dam operations, and
- (5) provide information to stakeholders and managers regarding the potential impacts of alternative dam operations on Lake Powell and the Colorado River ecosystem and associated resources.

BIOLOGICAL RESOURCES

A. AQUATIC RESOURCES

Goal: To protect, restore, and enhance native fish populations in Glen and Grand Canyons, as well as recreationally-important cold water sportfish populations in Glen Canyon, and the aquatic foodbase upon which they depend.

Definition: Aquatic resources include invertebrates, algae, macrophytes, and fish, with specific concerns for Threatened and Endangered Species, and plant and animal matter contributing to the primary food base.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

A.1 - Aquatic Food Base

Definition: The aquatic food base is comprised of organisms originating from aquatic and riparian sources. It includes organisms such as *Cladophora* and other aquatic plants including macrophytes, diatoms, detritus, aquatic and terrestrial insects, and may include fish.

MO 1: Maintain and enhance the aquatic food base in the Colorado River ecosystem to support desired populations of native and non-native fish. At a minimum, maintain continuously inundated areas for *Cladophora* and aquatic invertebrates at or above 5,000 cfs discharge levels from Glen Canyon Dam.

- IN 1.1 Determine status and trends in aquatic food base species composition and population structure, density and distribution and the influence of ecologically significant processes.
- IN 1.2 Determine the effects of past, present, and future dam operations under the approved operations criteria on the aquatic food base species composition, population structure, density, and distribution in the Colorado River ecosystem.
- IN 1.3 Determine the aquatic food base species composition, population structure, density, and distribution required to maintain desired populations of native and non-native fish in the Colorado River ecosystem.

(IN's 1.7 through 1.12 were moved to Appendix Biological Resources 1)

A.2 - Trout

MO 2: In the Colorado River downstream of Glen Canyon Dam to the confluence of the Paria river, sufficient ecological conditions (such as habitat, foodbase and temperature) should be maintained, which in conjunction with management by Arizona Game and Fish will produce a healthy self-sustaining population of at least 100,000 Age II+ rainbow trout that achieve 18 inches in length by Age III with a mean annual relative weight (W_r) of at least 0.90.

- IN 2.1 Determine ecosystem requirements, population character and structure to maintain naturally reproducing populations of Age II plus fish at 100,000 population levels in Glen Canyon.
- IN 2.2 Determine trends in rainbow trout population size, character and structure in Glen Canyon.
- IN 2.3 Evaluate harvested and field sampled rainbow trout to determine the contribution of naturally reproduced fish to the population in Glen Canyon.
- IN 2.4 Determine the availability and quality of spawning substrates in the Glen Canyon reach, necessary to sustain the rainbow trout fishery.
- IN 2.5 Determine the growth and condition of rainbow trout in Glen Canyon.
- IN 2.6 Define criteria (e.g., temperatures, flow regimes, contaminants, metals, nutrients) for sustaining a healthy rainbow trout population in Glen Canyon.
- IN 2.7 Determine the trophic relationship between trout and the aquatic food base including the size of the aquatic food base required to sustain the desired trout population in Glen Canyon.

A.3 - Native Fish:¹

HUMPBACK CHUB (HBC)

MO 3: Enhance the Little Colorado River population of HBC above 1987 levels determined by April/May hoop-net monitoring in the lower 1,200 meters of the Little Colorado River. (Focused

¹ Note that Critical Habitat has been designated in GC for both razorback sucker and humpback chub. As Critical Habitat for razorback sucker, GC may have a role in recovery as a reintroduction site. Such actions would need to be guided by the recovery plan (now in prep) or regional implementation plans.

at fish >200mm, and should include a fish health assessment.) Maintain or enhance levels of recruitment of HBC in the Little Colorado River.

MO 4: Maintain or enhance levels of recruitment of HBC in the mainstem as indexed by size frequency distributions and presence and strength of year-classes. (Focused at young-of-year and juvenile fish, and should include a fish health assessment.)

(IN 3/4 relates to MO's 3 & 4)

- IN 3/4.1 Determine adult HBC populations and evaluate life history schedules, population health, and reproductive success. *(Fall 97 RPM 1)*
- IN 3/4.2 Determine levels of recruitment of humpback chub in the mainstem and the LCR.
- IN 3/4.3 Develop and implement a program to evaluate effects of factors limiting overwintering survival of young-of-year HBC in the Grand Canyon (Fall 97, RPM 1). The program shall evaluate the effects of future test flows (i.e., 25,000 cfs and greater) from October through February on young-of-year HBC recruitment and over-wintering survival, habitat restrictions, predation, reduced sediment loads, and cold water temperatures. (Fall 97 Test Flow T&C 1) This is to include specific hypotheses as follows:
 - a. test flows do not significantly reduce densities of young-of-year HBC; and (Fall 97 Test Flow T&C2)
 - b. test flows do not significantly affect/alter nearshore habitats used by native fishes. (Fall 97 Test Flow T&C 2)
- IN 3/4.4 Determine and identify surrogate native or non-native fishes for evaluation of health factors for HBC and investigate trends in diseased fish.
- IN 3/4.5 Develop a habitat suitability and availability index, which may include backwaters and near shore habitat, using existing data for HBC. Determine the effects of mainstem hydrology on the number of nearshore rearing habitats, environmental conditions in these habitats, and their successful utilization by HBC. (RPM 1.C.iii)
- IN 3/4.6 Evaluate impacts of sampling methods and recreation use (e.g., habitat change, hooking mortality) on humpback chub populations.

- IN 3/4.7 Determine origins of fish food resources, energy pathways, and nutrient sources important to their production, and the effects of Glen Canyon Dam operations on these resources. (RPM 1.C.vi) Evaluate linkages between the aquatic food base and the health and sustainability of HBC populations.
- MA 4.1 Limit future test flows (i.e., 25,000 cfs and greater) from October through February until a program has been designed and implemented to evaluate and assess factors determining young-of-year HBC recruitment and overwintering survival. (*Fall 1997 RPM 1*)
- MA 4.2 Conduct BHBFs during periods that avoid concentrations of young-of-year HBC (*1996 BHBF, HBC RPM 1*)
- MA 4.3 Report the results of the monitoring, including complete and accurate records of all incidental take that occurred during the course of the 1996 BHBF to the Service the same date that a draft and final is submitted to Reclamation. Progress reports provided to Reclamation will also be provided to the Service. This report will also describe how the terms and conditions of all reasonable and prudent measures in this incidental take statement were implemented, including any deviations from the test flow and explanation for need to change. (*1996 BHBF T&C 2*)
- IN 3/4.8 Determine effects on physical habitat used by young fishes, food base, and direct effect on larval, juvenile, and adult native and non-native fishes of 1996 BHBF. Develop methods to detect changes in numbers of HBC or their habitat from 1996 BHBF. (*1996 BHBFB HBC RPM 3*)
- IN 3/4.9 Develop a method to determine the number of HBC suspected to be lost during special flows and the relationship of this loss to the Grand Canyon population. (*T&C 2*)
- IN 3/4.10 Develop a strategy to sustain notable year classes of HBC that are susceptible to being transported downstream into unfavorable habitats. (*T&C 2*)
- IN 3/4.11 Acquire an understanding of the frequency of HBC year classes in the system susceptible to being transported downstream into unfavorable habitats and impact of flows on that year class. (*T&C 2*)

- IN 3/4.12 Determine impacts of flows on young HBC during study flows, and develop methods of detecting changes in numbers, to assist in establishing levels of incidental take. (RPM)
- IN 3/4.13 Develop biological criteria governing the implementation of special flows that will assure that the level of incidental take of HBC is not exceeded. (RPM)
- IN 3/4.14 Evaluate all test flows in RPM, using monitoring and research programs and, determine potential impacts to threatened and endangered fish.

MO 5: Remove jeopardy for the HBC in the Colorado River ecosystem (*B.O. 1994*).

- MA 5.1 Evaluate and implement, as appropriate, a selective withdrawal program for Lake Powell waters (RPM 1.B).
- IN 5.1 Determine a set of possible temperature changes in the mainstem Colorado River resulting from implementing selective withdrawal (RPM 1.B.i).
- IN 5.2 Determine the anticipated effects on HBC and other native populations which may result from installing a selective withdrawal structure for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam. Determine the range of temperatures for successful larval fish development and recruitment and the relationship between larval/juvenile growth and temperature (RPM 1.B.ii).
- IN 5.3 Determine the effects of dam operations under the approved operating criteria, including installing a selective withdrawal structure for thermal modification in the mainstem of the Colorado River downstream of Glen Canyon Dam, on:
 - a. reproductive success, growth, and survivorship of Grand Canyon fishes;
 - b. parasites and disease organisms of endangered and native fishes in the Colorado River ecosystem;
 - c. temperature induced interactions between native and non-native fish competitors and predators; and

d. the effects of temperature, including seasonality and degree, on *Cladophora* and associated diatoms, *Gammarus*, and aquatic insects. (RPM 1.B.iii, 1.B.iv, 1.C.i and 1.C.vii)

IN 5.4 Evaluate effects of withdrawing water on the heat budget of Lake Powell, effects of potentially warmer inflow into Lake Mead, and the concomitant effects on the biota within both reservoirs. Evaluate the temperature profiles along with heat budget for both reservoirs Evaluate effects of reservoir withdrawal level on fine particulate organic matter and important plant nutrients to understand the relationship between withdrawal level and reservoir and downstream resources. (RPM 1.B.v and 1.B.vi)

IN 5.5 Evaluate when to release warmer temperature water, what seasonal pattern of releases to use to avoid establishment of permanent backwater areas, and how best to use floods, to limit expansion or invasion of non-native fish species. (RPM 1B)

MA 5.2 Develop a management plan for the LCR to protect HBC spawning population and habitat.

MO 6: Establish a second spawning aggregation of HBC downstream of Glen Canyon Dam (RPM 4).

IN 6.1 Develop criteria for defining self-sustaining populations of HBC.

IN 6.2 Assess feasibility of establishing a second population of HBC downstream of Glen Canyon Dam including other current aggregations.

MA 6.1 Develop and implement, as appropriate, a plan for establishing a second population of HBC.

RAZORBACK SUCKER (RBS)

MO 7: Remove jeopardy for the Razorback Sucker in the Colorado River ecosystem.

IN 7.1 Determine opportunities to establish RBS in the Grand Canyon (e.g., possible development of spawning and rearing areas). (RPM 3)

FLANNELMOUTH SUCKER (FMS) & OTHER NATIVE FISH

MO 8: Achieve healthy, self-sustaining populations of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon based upon the capability of the habitat to support those fishes.

- IN 8.1 Determine the status of flannelmouth sucker, bluehead sucker, and speckled dace in the Colorado River ecosystem, with special emphasis on flannelmouth sucker in Glen Canyon.
- IN 8.2 Determine population dynamics, distribution, and other life history traits of native fish species.
- IN 8.3 Determine historic and current character and structure of native fish populations.
- IN 8.4 Determine historic and current ecosystem requirements (habitat, spacing, food source, interdependencies, etc.) of native fish species.
- IN 8.5 Determine and define impacts of alternative flow regimes on native fish population character and structure.
- IN 8.6 Determine requirements to maintain/enhance self-sustaining populations of native fish.

(IN's 10.1 through 10.14 were moved to Appendix Biological Resources 2)

MO 9: Attain riverine conditions, including appropriate habitat, that support all life stages of endangered and native fish species.

- IN 9.1 Design experimental flows and studies to include high steady flows in the spring and low steady flows in the summer and fall during low water years (RPM 1.A). Improve the mean for determining the definition of a "low water year" that would initiate research flows in a given year.
- IN 9.2 Quantify to the extent possible the effects of spring high steady flows and summer and fall low steady flows on endangered and native fish (RPM 1.a).
- IN 9.3 Determine relationships among tributary hydrology, reproductive success of fishes, and the abundance of fishes in mainstem rearing habitats (RPM 1.c.ii).

- IN 9.4 Assess biotic interactions between native and non-native fishes, particularly those that occur in nearshore rearing habitats affected by dam operations (RPM 1.C.iv).

A.4 - Native /Non-Native Fish Interactions

MO 10: Minimize, to the extent possible, competitive and predatory interactions between native and non-native fishes.

- IN 10.1 Define areas and conditions of existing and potential interactions
- IN 10.2 Determine key attributes associated with competitive and predatory interactions
- IN 10.3 Determine methods for minimizing competitive and predatory interactions with or without isolation
- IN 10.4 Determine the species composition, relative abundance, and size class structure of non-native fishes in the Colorado River ecosystem and important tributaries
- IN 10.5 Identify existing and potential sources of interaction (predatory, competitive) between extant non-native fishes and native fishes of the Colorado River ecosystem and important tributaries
- IN 10.6 Evaluate the effects of various flow regimes under the approved operating criteria, including beach/habitat building flows, habitat maintenance flows, and endangered fish research flows on the distribution and abundance of native and non-native fishes in the Colorado River ecosystem and important tributaries

B. TERRESTRIAL and RIPARIAN RESOURCES

Goal: To maintain a diversity of terrestrial and riparian species, including where possible existing remnants of native communities, associated with ongoing natural evolutionary and ecological processes giving priority to native species (i.e., those occurring not directly because of man).

Definition: Terrestrial and riparian resources include, among other things: vegetation, insects, amphibians, reptiles, avifauna, and mammals. Riparian and terrestrial vegetation

includes both native and non-native plant species, and include natural species; balanced successional stages; unique plants and threatened and endangered plants.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

B.1 - General Terrestrial Resources

MO 11: Protect, restore, and enhance survival of native and special status species (federal, tribal, and state designations). Ensure that the required habitat for these species is preserved.

- IN 11.1 Define and specify ecology of native faunal components, especially threatened and endangered species; including evolutionary and environmental changes, natural range of variation, linkages, interdependencies, and requirements.
- IN 11.2 Determine species population characteristics to detect departures from natural range of variation.
- IN 11.3 Determine changes, declines in special status species and characterize ecosystem changes to benefit species.
- IN 11.4 Identify and characterize riparian wildlife habitat types along the river corridor.
- IN 11.5 Develop a comprehensive wildlife habitat map (using remote sensing and GIS) for the river corridor for high priority species (mammals, amphibians, reptiles, birds).
- IN 11.6 Evaluate/monitor leopard frog populations within Glen Canyon. Determine effects of dam operations on these populations (flooding, desiccation, loss of habitat).
- IN 11.7 Determine feasibility of establishing other populations of leopard frogs within the river corridor.
- IN 11.8 Identify and evaluate other sensitive amphibian and aquatic reptilian species, i.e., red spotted toads, Woodhouses toads, canyon tree frogs.

MO 12: Maintain a natural age-class distribution of wildlife species throughout the majority of natural range in Glen and Grand Canyons, emphasizing the need to recruit into breeding age classes.

- IN 12.1 Identify terrestrial species potentially affected by dam operations and determine effects on distribution, abundance, and population structure.
- IN 12.2 Determine species' natural ranges (pre and post dam).
- IN 12.3 Determine historic age class distribution (pre and post dam).
- IN 12.4 Assess natural range and age class disruption, changes, constraints, probable long-term viability implications to species; assess alternate habitat, ecology associations (specifically age class); and ecosystem associations.
- IN 12.5 Determine impacts of alternative operating criteria on ecosystem and ecology requirements of species.

B.1. - Avifauna

MO 13: Protect, restore, and enhance survival of native and special status avifauna.

- IN 13.1 Define and evaluate food chain associations, interdependencies, requirements, etc. for native avifauna, including the Peregrine Falcon, Southwestern Willow Flycatcher, and other special status species (e.g., Yellow-billed Cuckoo).
- IN 13.2 Determine impacts of dam operations under approved operating criteria on avifauna food chain associations.
- IN 13.3 Determine peregrine falcon breeding sites in Glen Canyon and Grand Canyon. (Conservation Recommendation 2)
- IN 13.4 Study peregrine falcon population dynamics and determine their relationship to the changing riparian ecosystem for meeting life stage requirements. (Conservation Recommendation 3)
- IN 13.5 Determine bald eagle habitat utilization and foraging patterns and their relationship to dam operations under approved operating criteria and perform additional bald eagle monitoring where deemed feasible. (Conservation Recommendation 4)

B.2 - Kanab Ambersnail

MO 14: Sustain populations of Kanab ambersnail wherever they currently exist within the Colorado River ecosystem.

- IN 14.1 Determine specific habitat characteristics required by the KAS. (T&C 3--p.41)
- IN 14.2 Determine special flow impacts on Kanab ambersnail to assure that the level of incidental take is not exceeded. (I. T. - p.40)
- IN 14.3 Complete a census of the population and characterize the habitat. Once habitat requirements are determined, other potential habitat sites within the Grand Canyon corridor will be surveyed to determine species presence and recovery potential. (Conservation Recommendation 5--p.43)
- IN 14.4 Survey KAS habitat before and after any flow greater than 25,000 cfs to determine population and its species response to disturbance and ability to recover. (T&C 4, p.42; and RPM)
- IN 14.5 Determine Kanab Ambersnail life history schedule for populations in the Colorado River ecosystem. (Conservation Recommendation 5)
- IN 14.6 Evaluate and monitor KAS populations within the Colorado River ecosystem. Determine ecological characteristics susceptible to changes in dam operations, i.e., population size, habitat needs, life history requirements.
- MA 14.1 Protect the habitat necessary for the survival of the existing population of Kanab ambersnail. (Incidental Take--p.40)
- MA 14.2 Do not allow high flows, or a controlled flood, to destroy more than 10% of the existing KAS occupied habitat in Grand Canyon. (Incidental Take--p.40)
- MA 14.3 Develop agreed upon research protocol and conduct research in such a manner as to minimize disturbance to the KAS population and habitat. (T&C 3--p.41)
- MA 14.4 Before another BHBF (45,000 cfs or greater), Reclamation will enter into informal consultation with the U.S. Fish and Wildlife Service and Arizona Game and Fish Department to:
 - MA 14.4a evaluate the test flow studies (RPM 2, 1996 BHBF);

- MA 14.4b evaluate the establishment or discovery of a second population of Kanab ambersnail in Arizona (RPM 2, 1996 BHBF); and
- MA 14.4c evaluate incidental take. (RPM 2, 1996 BHBF)
- MA 14.5 Continue coordination with the Interagency Kanab Ambersnail Working Group to establish or discover a second population of the Kanab ambersnail in Arizona. (Fall 97 Flow T&C 4)
- MA 14.6 Monitoring of the project area and other areas that could be affected by the proposed action shall be done to ascertain take of individuals of the species and/or of its habitat that causes harm, harassment, or death to the species. This monitoring will be accomplished using the following protocol:
- MA 14.6.a "A Draft Proposal to Assess, Mitigate and Monitor the impacts of an Experimental High Flow from Glen Canyon Dam on the Endangered Kanab Ambersnail at Vaseys Paradise, Grand Canyon, Arizona" (Stevens *et al.* 1995b).
- MA 14.6.b In order to more accurately determine elevation of river stage at the range of flow that will be experienced during the test flow, and for use in developing a stage discharge relationship for future flow, the placement of a stage recorder, such as a pressure transducer coupled to a recorder should be deployed, if possible, in the mainstem at an appropriate site near the Kanab ambersnail population. The U.S. Geologic Survey should be contacted regarding the possibility of changing the location of a stage recorder to be used in test flow studies to the Kanab ambersnail site.
- MA 14.6.c SALVAGE PROTOCOL. Kanab ambersnail specimens found dead, or taken as part of research activities, shall be collected and held as specified in the AGFD and NPS permit, with final deposition in a suitable museum collection such as at Northern Arizona University (1996 BHBF KAS T&C 1)
- IN 14.7 Determine changes in populations, health, and character of Kanab ambersnail, due to dam operations(?)

MO 15: Establish or discover and ensure the continued existence of a second population of Kanab Ambersnail in Arizona.

- IN 15.1 Determine genetic similarities and differences among populations of Kanab ambersnail.
- IN 15.2 Investigate the transplant success of vegetation important to the Kanab ambersnail:
 - IN 15.2a Investigate success of temporarily removing *Mimulus*, *Nastertium*, or other appropriate vegetation into a temporary holding facility, and replanting. (1996 BHBF CM 5a)
 - IN 15.2b Investigate success of temporarily/permanently relocating *Mimulus*, *Nastertium*, or other appropriate vegetation. (1996 BHBF CM 5b)
- MA 15.1 Minimize future take and support salvage and refugia population(s) of KAS (Fall 97 Test Flow CM 1)
- MA 15.2 Provide logistical support to the Arizona Game and Fish Department's proposal to establish vegetation for the refugium population of the Kanab ambersnail at the Phoenix Zoo, and subsequent support for the transfer of ambersnails when permit and weather conditions permit. (Fall 97 Flow T&C 2)

B. 4 - Vegetation

MO 16: Maintain, enhance or restore vegetative communities made up of diverse groups of native riparian and upland species with special emphasis on preservation of unique plant communities and special status species at different stages of succession and at different elevations above the water line.

- IN 16.1 Determine distribution and abundance of native and non-native riparian and upland vegetation, including federal-, state- and tribal-listed sensitive species, old high water zone, new high water zone, and nearshore marshes.
- IN 16.2 Identify and quantify the OHWZ (above 150,000 cfs) and NHWZ (between 45,000 and 150,000 cfs) vegetation types (communities) within the Colorado River ecosystem:

- (a) Develop a comprehensive vegetation map for the Colorado River ecosystem.
- (b) Determine populations dynamics and changes due to dam operations under approved operating criteria.
- (c) Determine habitat requirements and reproductive biology of principal species.

IN 16.3 Determine change in extent or abundance of the OHWZ and NHWZ plant communities. Link monitoring to site specific studies to determine species diversity.

IN 16.4 Determine the effects of current and proposed dam operations under approved operating criteria on these communities.

IN 16.5 Determine the ecology of the principal woody species (reproduction, establishment) within the OHWZ. Quantify the effects of dam operations under approved operating criteria on this ecology.

IN 16.6 Evaluate impacts of dam operations under approved operating criteria on establishment of and impacts from exotic plant species.

CULTURAL RESOURCES

Goal: To preserve cultural resource in situ wherever possible, and develop, knowledge of the resource for future generations.

Definition: Cultural resources include prehistoric and historic archaeological sites, structures and properties of interest to all Americans. Of particular importance are traditional cultural properties, sacred sites, collection areas, and other resources that are important to Native Americans in maintaining their cultural heritage, lifeways, and practices. Cultural resources are nonrenewable and irretrievable if lost.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

MO 1: Conserve *in situ* all the downstream cultural resources and take into account Native American cultural resource concerns in the Colorado River ecosystem.

- IN 1.1 Monitor cultural sites potentially impacted by Glen Canyon Dam operations to determine present condition and rate of change to assess: types of degradation, threats; rates of degradation; define immediacy of threats to resources; protection methodologies; protection, monitoring and research costs
- IN 1.2 Develop data systems to assess variable risk of damage/loss of differing resources/sites from preferred and alternative strategies and operating criteria
- IN 1.3 Characterize all cultural resource sites as to the specific associated management/research needs, i.e.; preservation, stabilization, documentation, etc.; under alternative operating criteria
- IN 1.4 Preservation, stabilization and/or documentation of cultural resources as impacted by sediment resources associated with alternative operating criteria
- IN 1.5 Preservation, stabilization of flood terraces holding cultural resources
- IN 1.6 Evaluate flood terrace stability necessary to maintain cultural resources and terraces at pre-dam conditions
- IN 1.7 Evaluate methodology for correlating recreational sites use and cultural resource impacts.

MO 2: If *in situ* conservation is not possible, design mitigative strategies that integrate the full consideration of the values of all concerned tribes with a scientific approach.

IN 2.1 Characterize through scientific study and data development all assumed historical and current values, including scientific values, of resources to tribal nations and to general public

IN 2.2 Develop research designs and costs associated with data recovery

MO 3: Protect, and maintain physical access to and use of traditional cultural properties and other cultural resources, where such access and use may be impacted by dam operations.

IN 3.1 Characterize historic and current traditional cultural associations of all sites associated with impacts of dam operating criteria

MO 4: Maintain and integrate all appropriate cultural data recovered from monitoring, remedial, and mitigative action and incorporate these data into the evolving research designs and mitigative strategies for understanding the human occupation and use of the Colorado River ecosystem.

IN 4.1 Develop evolving research designs and/or other methods including synthesis of existing available data and GIS for understanding human occupation and use.

SOCIO-ECONOMIC (HYDROPOWER)

Goal: To maximize the value of long term firm power and energy generation within the criteria and operating plans established by the Secretary under Section 1804 of the Grand Canyon Protection Act.

Definition: A product of the Glen Canyon Power plant is electrical generation. The facility contributes significant power to rural electrical associations, public municipalities, irrigation districts and Federal and State facilities in the Southwestern and Rocky Mountain areas of the United States.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

MO 1: Maximize the value of long-term power and energy generation within the criteria and operating plans established by the Secretary under Section 1804 of the Grand Canyon Protection Act².

- IN 1.1 Continue to monitor the amount of revenues collected from the generation of electrical power at the Glen Canyon Power plant.
- IN 1.2 Continue to account for the financial/economic cost of the operational changes at Glen Canyon Dam due to the ROD including rate impacts to CRSP long-term firm electrical customers.
- IN 1.3 Calculate the financial costs of research flows so that these costs can be declared “non-reimbursable” (as defined by Section 1804 of the Grand Canyon Protection Act)
- IN 1.4 Monitor any difficulties in operating an integrated electrical system, including regulating a load control area
(*Recommendation: Dave Garrett will clarify this with Clayton Palmer*)

²The data needed to measure and evaluate power production is already routinely collected by the USBR and WAPA (no data gathering is required of GCMRC).

PHYSICAL

WATER RESOURCES

Goal: To operate Glen Canyon Dam for water supply and water quality consistent with existing law and policy.

Definition: Water resources include all aspects of water quantity and quality. The “Law of the River” directs the operations of Glen Canyon Dam including monthly and annual release patterns and reservoir contents and elevations. Although of more recent concern, water quality as it relates to changes over time is of specific concern.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

MO 1: The Secretary shall Operate Glen Canyon Dam in a manner fully consistent with the Record of Decision and subject to the “Law of the River,” including but not limited to the following: Grand Canyon Protection Act of 1992, the Colorado River Compact, the Upper Colorado River Basin Compact, the Water Treaty of 1944 with Mexico, the decree of the Supreme Court in Arizona vs. California, and the provisions of the Colorado River Storage Project Act of 1956, and the Colorado River Basin Project Act of 1968 that govern allocation, appropriation, development, and exportation of the waters of the Colorado River Basin.

IN 1.1 Annually collect and report Glen Canyon Dam flow release information.

MO 2: Maintain water quality at levels appropriate to support physical, biotic, and human resource needs of various ecosystems downstream of Glen Canyon Dam as mandated by the Grand Canyon Protection Act and incorporated into the Record of Decision.

IN 2.1 Monitor water quality, composition and temperature and compare to applicable standards.

IN 2.1a Quantify current selenium levels in water discharged from Glen Canyon Dam. Determine how selenium concentrations are affected by dam operations.

IN 2.1b Determine/quantify the dynamics of major cations, anions and nitrate/phosphate ratios resulting from dam operations.

IN 2.2 Evaluate feasibility of short term or long term changes of water temperature through selective withdrawal.

SEDIMENT RESOURCES

Goal: To maintain a range of sediment deposits over the long-term, including an annually flooded bare-sediment (unvegetated) active zone, a less frequently flooded vegetated zone, terraces (within the 45,000 cfs river stage), and backwater channels. Managing sediment resources will be on a reach-scale basis. Should significant and localized adverse impacts occur, site-specific mitigation would be considered.

Definition: Sediment resources include a broad array of material, ranging from suspended fines to coarse gravels. Primary interest relates to both material in suspension, which affects benthic capability, as well as stored sediment in beaches and channel margins, which affects recreation.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

MO 1: Maintain a long-term balance of river-stored sand to support maintenance flow (in years of low reservoir storage), beach/habitat-building flow (in years of high reservoir storage), and unscheduled flood flows. Maintain system dynamics and disturbance by annually (in years which Lake Powell water storage is low) redistributing sand stored in the river channel and eddies to areas inundated by river flows between 20,000 cfs and maximum power plant capacity.

- IN 1.1 Define historical and current (character and structure) levels of river stored sediment in system and associated flow regimes
- IN 1.2 Define minimal levels of river stored sediments necessary to maintain long term sandbar, backwater, instream sediment deposits
- IN 1.3 Develop procedures to monitor and predict impacts of alternative operating criteria (flow regimes) on river stored sediment, and impacts in select reaches
- IN 1.4 Measure and model sediment contributions from all contributing sources, including tributary and high terrace sources
- IN 1.5 Evaluate the geology/geomorphology within Glen Canyon to: (1) determine historical changes in size and extent of beaches, sandbars and backwaters, (2) quantify sediment (size class and quantity) input from side channels, (3)

understand bed morphology dynamics, (4) evaluate high terrace erosion and contribution to river sediment.

MO 2: As a minimum for each reach, maintain the number and average size (area and thickness) of sandbars and backwaters between the stages associated with flows of 8,000 and 45,000 cfs that existed during the 1990/91 research flows.

IN 2.1 Characterize sandbar/backwater baselines and character and structure in 1990/91

IN 2.2 Working with various resource agencies and specialists, select most appropriate flow levels/regimes under the approved operating criteria to determine baseline for comparisons for all resources

IN 2.3 Monitor future changes in sediment and define balances (channel, banks, bars) and hydraulic processes necessary to maintain 1990/91 sandbar levels

IN 2.4 Evaluation of flow regime (under the approved operating criteria) impacts on terrace and cultural resources

IN 2.5 Evaluate historical sandbar/backwater change, and develop methods for predefining beach and sandbar change under operating criteria

IN 2.6 Determine implications of dam operating criteria on beach and sandbar and backwater character and structure, including suitability of camping beaches

IN 1.7 Quantify the extent and location of existing sandbars, beaches and backwaters along the Colorado River corridor

IN 2.8 Assess the effects and use of the spillways on bed morphology in the front of the dam and its effects on power production and biota

MO 3: Periodically increase the average size of sandbars above the 20,000 cfs river stage and number and average size of backwaters to the amounts measured during the high period of 1990/91 or the 1996 test of the beach/habitat-building flow in as many years as reservoir and downstream conditions allow.

IN 3.1 Define 1996 and 1990/91 backwater ecosystems and associated flow regimes

IN 3.2 Define historical variation in backwater number and character

- IN 3.3 Define changes between 1990/91 and 1996 in sediment and backwater resources character and structure associated with dam operating criteria
- IN 3.4 Define all linkages, associations, interdependencies, etc., of physical sediment resource and backwater resources to biotic entities
- IN 3.5 Define processes necessary to maintain backwaters at 1990/91 or 1996 levels

MO 4: Maintain system dynamics and disturbance by redistributing sand stored in the river channel and eddies to areas inundated by river flows up to 45,000 cfs in as many years as possible when BHBF hydrologic and resource criteria are met.

- IN 4.1 Define character and structure of all beaches and backwaters in system after 1996 test flows
- IN 4.2 Develop methodologies to define future flow regimes under approved operating criteria to maximize benefit to sediment and backwater character and structure
- IN 4.3 Develop an assessment of dam operations under approved operating criteria impacts on range of variation in sediment and other resources within Colorado River ecosystem and the associated processes that created these ranges

Norm Henderson's Comments for Sediment Information Needs:

- IN 1. Quantify the available sediment in the river channel within the Glen Canyon reach to build beaches within Marble Canyon
- IN 2. Determine the relative importance of high terrace erosion to beach building within the Glen Canyon reach
- IN 3. Quantify the sediment inputs within the Glen Canyon reach from unregulated side channels
- IN 4. Assess the impact of current and anticipated dam operations under approved operating criteria on the high terraces within Glen Canyon. Define the relative importance of natural erosion of high terraces as compared to that experienced due to current dam operations
- IN 5. Develop an understanding of bed morphology dynamics within Glen Canyon

- IN 6. Determine the relative importance of sediment grain size within Glen Canyon compared to downstream reaches
- IN 7. Summarize the historical changes in river banks and sandbars within the Glen Canyon reach and determine long term changes in size
- IN 8. Comprehensively quantify the extent and location of existing sandbars and beaches along the river corridor

GIS

MO 1: (Management Objective to be added.)

- IN 1.1 Develop a comprehensive GIS base map for topography, geology and soils for the Colorado River ecosystem.
- IN 1.2 Develop an integrated data/GIS structure for the storage and retrieval of all GCMRC studies.

RECREATION

Goal: To provide quality recreation experiences that do not adversely affect natural or cultural resources within the river corridor.

Definition: Recreation resources include sport fishing, white water rafting, boating, hiking, sightseeing, photography, and hunting.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

MO 1: Provide quality recreation experiences consistent with other resource objectives.

IN 1.1 Determine criteria and aspects that are important to or detract from recreational experience

IN 1.2 Determine the impacts of scientific study on recreational experience

IN 1.3 Characterize procedures to mitigate those aspects of flows that detract from quality recreational experiences

IN 1.4 Determine angler satisfaction, use and harvest

IN 1.5 Determine potential impacts of increased heavy metals on sport fishing

MA 1.1 Utilize approaches for monitoring and research that are appropriate to maintain or improve the character of the recreational experience as defined in NPS management plans for those areas.

MA 1.2 Ensure water release strategies and communications systems that support and enhance the full range of river recreation experiences allowed under NPS management plans for those areas.

MO 2: Maintain flows (under approved operating criteria) and sediment processes that create an adequate quantity, distribution and variety of beaches for camping, as long as such flows are consistent with management of natural recreation and cultural resource values (other natural resource values).

IN 2.1 Determine adequate beach quantity, quality, distribution, character and structure for camping throughout system

- IN 2.2 Evaluate impacts of operating criteria on establishing and maintaining adequate beaches and distribution of other resources, quality, character and structure
- IN 2.3 Develop methodology to evaluate distribution, quantity and quality changes in all campable beaches through time
- IN 2.4 Develop systems models to predict flow regimes (under approved operating criteria) for building and maintaining beaches

MO 3: Maintain flows (under approved operating criteria) that minimize impacts to navigability by authorized water craft and for boaters, waders, and campers in the riverine corridor.

- IN 3.1 Determine if operating criteria maintains safe and adequate powercraft navigability in Glen Canyon and upper Lake Mead
- IN 3.2 Evaluate effects of operating criteria on recreation safety
- IN 3.3 Determine if operating criteria maintains whitewater raft navigation in Grand Canyon
- IN 3.4 Define ecosystem and other resource impacts of flow regimes (under approved operating criteria) required to maintain navigation
- IN 3.5 Develop methodology to evaluate potential conflicts of day rafting and other resources (e.g., bank degradation, sport fishing, bird watching, etc.)

MO 4: Maintain flows (under approved operating criteria) and habitat suitable for quality cold water fishery opportunities in Glen Canyon.

- IN 4.1 Determine flow regimes (under approved operating criteria) necessary to maintain fish populations of 100,000 adult Trout (age class II plus)

MO 5: Maintain flows (under approved operating criteria) and habitat suitable for waterfowl sport hunting and wildlife viewing opportunities in Glen Canyon.

- IN 5.1 Define pattern of waterfowl hunting use and satisfaction and other wildlife use and conflicts to other uses

LAKE POWELL

Goal: To understand impacts of Dam operations and where possible minimize these impacts, consistent with other resource objectives.

Definition: Lake Powell includes natural, biological and cultural resources impacted by operation of Glen Canyon Dam.

MANAGEMENT OBJECTIVES, STAKEHOLDER INFORMATION NEEDS, MANAGEMENT ACTIONS

The protocol for Lake Powell Management Objectives and Information Needs are related to Upstream Effects Only. (Downstream effects are included under the specific resource sections.)

Lake Powell Water Quality

MO 1: Prevent impacts that adversely affect the water quality (physical, chemical, biological) of Lake Powell due to dam operations and ensure that fully informed AMWG decisions are possible both now and in the future.

Physical/Chemical (Limnology)

IN 1.1 Determine the effect of current dam operations (under approved operating criteria) on reservoir water quality, including but not limited to the following:

- a. Determine near-dam hydrogen sulfide levels (and other hazardous chemical constituents) within the hypolimnion occurring under current dam operating criteria.
- b. Determine the dynamics of lake stratification and advective flows and their effects on chemical constituents
- c. Determine/quantify the dynamics of major cations, anions, and nitrate/phosphate ratios resulting from dam operations
- d. Determine the effects of dam operations (under approved operating criteria) on the physical/chemical dynamics of Lake Powell side channels and embayments

- e. Quantify/model the heat budget for Lake Powell to determine near-term and long-term (monthly/weekly and annual summaries respectively) effects of a selective withdrawal system
- f. Determine the effect of current dam operations on reservoir levels of selenium.

Biological

IN 1.1 Determine the impacts of dam operations and resulting water quality on primary and secondary productivity of Lake Powell, including:

- a. algae (phytoplankton, periphyton)
- b. Macrophytes
- c. zooplankton
- d. macroinvertebrates

IN 1.2 Quantify levels of selenium and describe effects of these levels on primary and secondary productivity, fish and waterfowl, and human consumption.

Lake Powell Aquatic Ecosystem (Fishery)

Definition:

MO 2: Protect Lake Powell aquatic ecosystem from adverse impacts due to dam operations and subsequent effects, including but not limited to: temperature, reservoir surface elevations, elevated selenium levels, advective flow patterns, predator/prey relationships, and fish movements.

IN 2.1 Determine the effects of water temperature caused by dam operations

IN 2.2 Determine the effects of fluctuations in the reservoir surface elevations caused by dam operations (under approved operating criteria)

IN 2.3 Determine the effects of elevated selenium levels caused by dam operations (under approved operating criteria)

IN 2.4 Determine the effects of advective flow patterns on Lake Powell aquatic ecosystem caused by dam operations (under approved operating criteria)

IN 2.5 Determine the effects of predator/prey relationships caused by dam operations
(under approved operating criteria)

IN 2.6 Determine the effects of fish movements caused by dam operations

APPENDIX**Biological Resources 1****From Aquatic Food Base Management Objective**

- IN 1.7 Identify and characterize the available aquatic habitat of the Colorado River and significant tributaries, such as the LCR (riffle, run, pool, backwater, etc.)
- IN 1.8 Develop a comprehensive aquatic habitat map (with GIS) for the river corridor at various water levels.
- IN 1.9 Quantify and evaluate changes in river habitat caused by dam operations over time
- IN 1.10 Determine the effect of sediment exposure time on benthic community mortality
- IN 1.11 Effects of sediment removal and transport on hyporheic communities
- IN 1.12 Effects of selenium on benthic/hyporheic communities.

From Flannelmouth Sucker Management Objective

- IN 1. Establish whether Flannelmouth Suckers/native fish are actually spawning in the mainstem Colorado River within Glen Canyon under current conditions. If spawning occurs, do any eggs hatch or larvae survive? Determine the current and past (before Glen Canyon Dam) importance of mainstem Glen Canyon spawning habitat (in relationship to tributary spawning).
- IN 2. Determine the origin of adult Flannelmouth Suckers/native fish that are attempting to spawn in the mainstem Colorado River within Glen Canyon? Are the old pre-dam adults? Are the post-dam adults from the tributaries, i.e., Paria River, that find certain mainstem habitat factors preferable? Are they mainstem adults from the Grand Canyon?
- IN 3. Determine the location of all spawning beds within Glen Canyon (related to flows) and summarize the important characteristics. Determine the relative importance of Glen Canyon habitat in relationship to other mainstem habitat within Grand Canyon.
- IN 4. Specifically determine the cause(s) for mainstem spawning failure within Glen Canyon:
- a. Eggs not deposited, or if deposited not viable because of low water temperature or fluctuating flows, i.e., drying of spawning beds or removal of eggs by strong currents.
 - b. Fertile eggs deposited and hatch but larvae can't grow because of limited or no nursery habitat for food and shelter (again, due to cold temperatures and fluctuating flows).
 - c. Eggs laid and hatch and some survive and move downstream to warmer water and return much later to spawn.
- IN 5. Describe the specific role of flow levels and fluctuations on reproduction and survival of eggs, larvae, young-of-year, and adults. Specifically, determine the availability of moderate near-shore habitat that might be used by larvae, young-of-year, or adults.

- IN 6. Describe the relative importance of various tributaries to flannelmouth survival (spawning, recruitment, predation).
- IN 7. What is the food source in the mainstem now? Is there a sufficient food base for adequate growth and a healthy population in the mainstem? What was historic food source?
- IN 8. Determine the optimal habitat conditions for flannelmouth sucker. reproductions, survival, recruitment, etc., i.e., temperature, flow, food, shelter. What habitat factors in the mainstem attract adult Flannelmouth suckers to spawn? What is the attraction over tributaries, i.e., Paria River?
- IN 9. Determine the fidelity of Flannelmouth suckers to certain areas and spawning beds.
- IN 10. Determine if possible the current and historic use of Flannelmouth sucker habitat for spawning, foraging, cover, etc., within the Colorado River and Paria Rivers as well as other tributaries.
- IN 11. Develop a Flannelmouth sucker conceptual model for the Colorado River ecosystem, i.e., food, habitat, predation.
- IN 12. What habitat modifications could be made to improve Flannelmouth sucker population levels and overall health, i.e., substrate modification, nursery habitat establishment (warm backwaters), flow modification, etc.
- IN 13. Assess the influence of non-native fish on native fish species.
- IN 14. Determine the effect of current selenium levels discharged from Glen Canyon Dam on native fish species.