A Science Plan for WY 2000 Low Summer Steady Flows

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FINAL

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I. INTRODUCTION

The science plan for WY 2000 low steady summer flows is primarily designed to provide data concerning patterns of response by biological resources to low steady flows. Four areas of emphasis are included in this plan: (1) physical variables, (2) biotic habitat, (3) primary productivity, and (4) fish response. Two additional areas of study are proposed that address: effects on Lake Powell water quality that ultimately can affect the downstream resources of concern, and the unique opportunity to advance understanding of sediment storage and sediment budgeting. These are in addition to the hypotheses contained in Appendix 25.

Ecosystem Studies

The proposed projects are focused in scope and integrated across the four areas of emphasis identified above. Integration and the potential to detect a response necessitates a concentrated effort within a relatively small geographic area, primarily from Glen Canyon Dam to Phantom Ranch. The focused scope will result in data collection that can help direct efforts under future steady flow years. For example, patterns seen under this scenario may be tested in other areas of the river corridor in future steady flow years or may be used in future monitoring programs for resources. Patterns may be applicable across many sites or may be site specific. Resulting research involving processes and interactions can be identified and refined in this manner.

Much of the data collected during this test of low summer steady flows can be viewed as a "baseline" against which future summer seasons dominated by low flows (fluctuating or steady) can be compared. In subsequent low-volume water years, different treatments (e.g., flow regimes) may be used. Thinking about this year's test of low summer steady flows in the context of a multi-year study design is consistent with the Biological Opinion on the Operation of Glen Canyon Dam which called for experimental flow regimes in low volume years and the recommendations of the SWCA report on endangered fish flows.

This plan is designed to address the assumptions implicit in the Fish and Wildlife Service's concept of seasonally-adjusted steady flows intended to benefit native fish. They are:

1. Steady flows (i.e., 8,000 cfs) will provide consistently available low-velocity near shoreline habitats.

2. Water temperature will increase during summer steady flows both longitudinally and in and along near shoreline habitats, and 8,000 cfs flows provide greater warming than higher discharges.

3. Productivity (primary and secondary) is enhanced by steady flows and food availability is sufficient to compensate for the increased energetic demands of younger, faster growing fish.

4. Steady flows stabilize habitats used and will benefit young fish survivorship.

5. Hydrology that simulates the seasonal patterns of the natural hydrograph benefits native fish more than non-native fish.

6. Predator-prey and competitive interactions between non-native and native fish will not offset the positive effects on native fish derived from the increased availability of suitable habitat for rearing.

7. Impounding tributary mouths, primarily the LCR, retains larvae and immediate post-larvae allowing them sufficient growth to survive when they enter the mainstem in the summer and find increased suitable habitat.

8. A spike flow of 33,000 cfs for 4 days in spring will create suitable habitat and displace non-native fish, and a spike flow of 33,000 cfs for 4 days in fall will disadvantage non-native fish relative to native fish.

In the planning process used to develop this science plan these assumptions were further stepped down into a set of specific hypotheses to be tested by the scientific activities outlined below and in the attached documents. Theses hypotheses have been categorized into: (1) Physical variables, (2) Biotic habitat, (3) Aquatic foodbase, and (4) Fish response. Detailed descriptions of the specific projects that address these hypotheses are provided in the appendices that follow.

Lake Powell Studies

While not included in the hypotheses contained in Appendix 16, GCMRC proposes to measure the short- and long-term effects of both the 31,000 cfs and steady 8,000 cfs releases on the stratification and water quality of Lake Powell and the resulting implications that changes in stratification and water quality may have on the downstream resources of concern.

Sediment Storage and Budget Studies

Finally, while not included in the hypotheses contained in Appendix 15, GCMRC proposes to use the unique hydrograph proposed for WY 2000, to address critical questions concerning sediment storage and redistribution (through release of spike flows of 31,000 cfs) in the Colorado River that directly relate to physical habitat sustainability.

Organization of the Plan

The remainder of this document is organized as follows. Section II contains brief project descriptions. These include, titles, PIs, a brief project description, the hypotheses they are intended to address, and estimated cost. The individual project proposals can be found in the relevant appendix. Section III describes the recommended hydrograph. Section IV describes proposed aerial photography and topographic mapping. Section V describes survey support that will be required. Section VI describes the additional logistics support that will be provided. Section VII describes additional personnel needs driven by the added work that contained in this study plan. Section VIII describes the budget. A detailed budget breakdown is shown in Appendix 1. While Section IX contains all of the appendixes listed in this study plan.

II. PROJECT DESCRIPTIONS

A. ECOSYSTEM STUDIES

<u>1. Projects to address hypotheses concerning physical variables.</u>

a. Effect of discharge on shoreline channel and tributary velocities. P.I. - Frank Protiva, Shephard-Wesnitzer, Inc. A project description can be found in **Appendix 2.** (Estimated cost $90,000.)

The purpose of the project is to determine the extent of low velocity areas at the confluence of the LCR and mainstem as discharge increases from 8,000 cfs to 31,000 cfs. Velocities affect entrainment of small-bodied fish (young-of-the-year) and effect recruitment. Project will collect velocity and overlay these data with temperature measurements taken previously (Protiva 1996) at the mouth of the LCR and below to determine how current velocities change with discharge levels.

Hypotheses to be tested:

Ho: Current velocities for near shoreline habitats (e.g., talus, debris fans, vegetated shoreline) will not differ significantly between fluctuating and low steady flow conditions.

Low velocity habitats are assumed to be a requirement of young fish. Decreased velocities presumably accompany lower discharges. The lower velocity environments may be reflected in an elongation of a particular low velocity environment or an increase in the number of these environments.

Ho: Areal extent of low velocities does not vary for a range of steady flows.

Discharge may affect current patterns (eddies may get wider or longer), but total area of low velocity environments should remain the same. This helps determine if size of low velocity environment matters.

Ho: Current velocities will increase in tributary confluence areas under higher mainstem flows.

Valdez et al. (In prep) recommends a high spring steady flow to pond tributaries and retain young of the year, assuming that velocities will be reduced in tributary confluences. This hypothesis could be tested with flows at 17,500 cfs or higher and if flows are reduced to 14-12,000 cfs for a sustained period of time.

b. Effect of discharge and flows on temperatures in aquatic habitats. P.I. B. Vernieu GCMRC biology program. A project description can be found in **Appendix 3.** (Estimated cost $10,000, covered by existing program funds.)

The purpose of this project is to determine if warming of shoreline habitats does increase compared to mainstem temperatures. Additionally, mainstem warming rates at lower volumes (8,000 cfs) will also be measured to determine how volume affects warming downstream from the dam. We will have data for steady flows from a series of discharge volumes (8,000, 13,500, 18,000, 19,000, and 31,000 cfs) to determine the effect of volume and steady flows on temperature warming. These data will be compared with fluctuating flow data collected since 1991 at comparable volumes.

Hypotheses to be tested:

Ho: Water temperatures in the mainstem will not increase downstream greater than temperatures previously observed under other flow conditions (e.g., fluctuating, higher discharge).

We have an estimate for rate of warming in the mainstem. It would be useful to determine if steady flows affect this rate, and if discharge and steady flows affect this rate (this is particularly applicable for the temperature control device).

Ho: Near shoreline temperatures in structurally complex habitats will not differ significantly from those observed for the mainstem.

The intent of steady flows is to warm shoreline low velocity environments; if the amount of warming is negligible, then perhaps temperature along the shoreline is not a limiting factor for recruitment of native fish, but low velocities are.

c. Expanded Monitoring: Effect of test flows on suspended-sediment transport, and grain-size evolution of bed sediment along the main channel Colorado River. P.I. – Nancy Hornewer et al., USGS. Early deployment and extension of the existing, annual suspended-sediment transport monitoring program at key gage locations along the main channel of the Colorado River. A project description can be found in **Appendix 4.** (Estimated costs, $79,000)

Recent research (Topping et al., 2000a and 2000b; Rubin et al., 1998), by USGS scientists suggests that the majority of sand-sized material input annually from gaged tributaries below Glen Canyon Dam (Paria River, in particular), are transported downstream from critical reaches under Record-of-Decision Operations (ROD) within a season or two. As a result, sand inputs may not significantly accumulate in the main channel over multi-annual time scales between periods when controlled floods are implemented. Alternatively, limited-coverage bathymetric data from the Northern Arizona University sand bar monitoring program, suggest that some parts of the main channel within Marble Canyon <u>have</u> accumulated sand in the post-1996 (BHBF) period, despite relatively high ROD operations. Steady flows of 8,000 cfs during June through September, provide an excellent opportunity to more closely evaluate the degree to which new sand inputs are retained in main channel storage (storage forcing) under ROD operations at the lower flow regime. Because sand inputs are winnowed over short periods after they are input, the spring spike flow of 31,000 cfs, allows sediment-transport rates under this depleted supply condition. In addition, the proposed September spike flow of 31,000 cfs provides a chance to collect suspended-sediment transport data under the full operating range of the Glen Canyon

Dam power plant (export forcing) after the sand supply is enriched with fine sands during the summer input season.

In light of this information, the purpose of this project is to extend twice-daily monitoring of suspended-sediment loads in the main channel under steady flows and 31,000 cfs spikes in both the spring and summer, beyond that which would normally be monitored during FY 2000 (July 15 through September). Collections under steady flows of 8,000 cfs shall be made to determine whether such flows significantly advance aggradation of the river bed following tributary inputs during the summer season. Additional temporary instrumentation will be deployed to better record summer 2000, sand inputs from the Paria and Little Colorado Rivers, as well as a select number of ungaged tributaries. USGS teams shall collect about 350 additional suspended- and bed-material sediment samples at main channel (Lees Ferry, Lower Marble Canyon, Grand Canyon near Phantom Ranch and above Diamond Creek) and tributary (Paria and Little Colorado Rivers). These data shall be reported by the Arizona District, Water Resources Division, USGS, and will support efforts to develop a partitioned fine-sediment budget during Water Year 2000, under test flow conditions. As part of the normal sediment monitoring protocol, turbidity measurements will continue to be recorded at 15-minute intervals at main channel gage stations between Lees Ferry and Diamond Creek. These data will also allow scientists to correlate total suspended-sediment concentrations with light attenuation recorded in terms of both fore scatter and back scatter values (see appendices on integrated sediment studies, below). This correlation is thought to be of value to scientists studying the aquatic food base as it is governed by light attenuation conditions in the river.

Hypotheses to be tested:

Ho: Turbidity levels will remain constant during the LSSF experiment.

Turbidity does affect sight feeders like trout and affects photosynthetic activity (primary productivity). Interactions between this physical variable and the biotic components may affect growth of fish or predation rates. We are not recommending predator-prey studies at this time, but do advocate determining a relationship between flow and suspended sediment (turbidity).

Ho: Suspended sediment levels will not change under low discharge, steady flows compared to MLFF operations.

MLFF suspend sediment and carry the sediment through the system. Steady flows may or may not change the values of suspended sediment collected at the gaging stations.

2. Projects to monitor fine-sediment resources and physical-habitat hypotheses.

a. Monitoring the effect of short duration high releases and long duration low steady flows on sand storage and bar morphology within the main channel and eddy complexes. P.I. - R. Parnell, M. Kaplinski, J. Hazel, and M. Manone, Northern Arizona University. A project description can be found in **Appendix 5.** (Estimated cost $137,000.)

The purpose of this project is to conduct change-detection of sand-storage within the main channel and eddy complexes, including return-current channel storage and void volumes (available backwater habitat) under low steady flow operations. Eddy complexes are storage areas for sand along channel margins of the river corridor, and also serve as habitat for fish. Sediment deposition and erosion affects physical features that serve as aquatic habitat for fish. Sand-storage changes within eddies and throughout the main channel also relate to the potential for achieving physical habitat maintenance and restoration of sand bars that form habitats relative to controlled floods. The project will measure the gross changes in eddy complex and main channel bed topography, with special focus on return-current channels at existing sand bar monitoring sites to determine pattern of change among sandbars over time. Sites will be measured before and immediately after the spring high flow (17,000 cfs) and 31,000 cfs spike flow period (March and early June). The sand storage change data will also be used as part of the integrated effort to construct a partitioned sand budget for the period of the test flow. The terrestrial survey data collected at the monitoring study sites above the 25,000 cfs stage elevation, will also act to provide annual monitoring data for high-elevation sand storage, and campable areas.

Hypotheses to be tested:

Ho: Backwater number and total area will not differ significantly from values measured during previous fluctuating flows at equivalent stages.

Historic data regarding backwaters is associated with fluctuating flows and documented by overflights at 8,000 cfs. Antecedent conditions may not affect backwater number and areas at 8,000 cfs.

Ho: Backwater number and total area will not differ significantly throughout the period of steady flows.

Addresses sediment accumulation in return current channels and the change in backwaters over time. Do they become less available over time?

3. Projects to address productivity (primary and secondary) hypotheses.

a. Effect of steady vs. fluctuating flows on creation of "vegetated shoreline" for juvenile fish and recruitment of exotic plants into newly available habitat. P.I. -Michael Kearsley, NAU. A project description can be found in **Appendix 6**. (Estimated cost $104,000.)

The purpose of this project will be to determine which plants colonize the newly exposed sand and shoreline and the rates at which colonization takes place. Exposed fine sediments and cobbles can be colonized by clonal plants moving downslope from established populations or via seeds which emerge from the seedbank or which drift into these open habitats. The project will evaluate rates of colonization in exposed shoreline to determine contribution of seedbank on colonization, downward movement of riparian plants and exotic seedling colonization.

Hypotheses to be tested:

Ho: Germination and densities of tamarisk (*Tamarix ramosissima*), camelthorn (*Alhagi camelorum*) and other exotics will not significantly differ in years of constant flows and fluctuating flows.

Tamarisk and other exotic species may benefit from the high spring discharge and low steady flow regime which create open, disturbed habitats. This will result in the establishment of tamarisk and camelthorn seedlings and eventually encroachment along shorelines of camping beaches

Secondary hypotheses that must be examined in order to explain potential response in previous hypothesis regarding exotic species. These secondary hypotheses account for potentially confounding variables in terrestrial vegetation also responding to flows like downward expansion by wetland plants via clonal reproduction, or changes in seedbanks as a result of sediment/flood dynamics.

Ho: Creation of "vegetated shoreline" via the downslope expansion of populations of clonal wetland plants such as rushes (*Juncus* spp.), reed (*Phragmites*), and horsetail (*Equisetum)* will not differ in years of constant and fluctuating flows.

The availability of open and favorable habitat between established populations of clonal native species and the water's edge at a constant discharge may allow for a rapid colonization. This will result in the creation of a shoreline habitat type preferred by juvenile native fish.

Ho: Ho: Spike flows before and after the low steady flows will not reduce the abundance and/or diversity of seeds in the soil of wetland and low-elevation vegetated shoreline patches.

The disturbance created by even moderate flooding decreases the abundance and diversity of seeds in the soil of wetland and low-elevation channel margin areas. The spike flows on either end of the low steady flows may have the effect of decreasing the speed of regeneration in these habitats.

b.i. Effect of Low steady flows on drift and benthic mass and composition in the Lees Ferry and downstream. P.I. - D. Blinn, J. Shannon and E. Benenotti, NAU. A project description can be found in **Appendix 7.** (Estimated cost $325,000).

b.ii. Effect of Low steady flows on drift and benthic mass and composition in Lees Ferry. P.I. - B. Persons, AGFD. A project description can be found in **Appendix 8.** (Estimated cost $180,074.)

The purpose of these projects are 1) to determine if standing biomass of benthic algae, macrophytes and invertebrates vary significantly over the course of the steady flow treatment, and 2) if, possible determine how these values compare to other hydrology of either similar volume or discharge pattern. These projects will also evaluate the effects of powerplant capacity releases from GCD on the standing biomass of these same groups.

A portion of this effort will involve protocol evaluation for aquatic food base sampling. Methods used vary between researchers. Replicate samples at sites in the Lees Ferry Section will be collected by both groups. The steady flows provide an opportunity to compare methods and evaluate variability around the values collected without having flows adding another variable.

Hypotheses to be tested:

Ho: There will be no significant difference observed in the benthic or macrophytic community for biomass or composition due to spike flow treatments.

The 31,000 cfs spike has been suggested to be of sufficient magnitude to negatively affect aquatic food base biomass and composition, particularly in the fall. The effect needs to be determined.

Ho: There will be no significant difference in biomass, densities or composition observed for the benthic and macrophytic communities due to a LSSF treatment.

Low steady flows may increase water clarity and allow for increased productivity, but the area available for productivity may be decreased by discharge, and result in no significant increase or change in the benthic and macrophytic community.

Ho: The quantity and composition of drift will not significantly vary during the duration of the LSSF treatment.

Fluctuating flows are suggested to help maintain drift downstream by causing desiccation and subsequent renewed growth. If this is true, one would see a decline in quantity of drift over time under steady flows. Also the composition of the drift may change over time associated with different rates of senescence of benthos and macrophytes and tributary inputs.

Ho: The quantity and composition of drift during a LSSF treatment will not significantly vary in comparison with years of other steady or fluctuating flows.

Does magnitude of discharge matter or pattern of discharge affect drift quantity or composition? This hypothesis collects the same data as the above hypothesis, but compares it to other flows of equivalent volume.

c. Algal colonization and recolonization response rates during experimental low seasonally steady flows. P.I. - D. Blinn, NAU and M. Yard, GCMRC. A project description can be found in **Appendix 9.** (Estimated cost $5,000.)

The purpose of this project is to determine if algal colonization is independent of how long substrate has been exposed. In other words, do cladophora colonize all boulders, even those never associated with the river system, at equal rates. Information from this will help understand the effects of periodic changes in discharges that result in drying in one stage elevation and recolonization in another.

Hypotheses to be tested:

Ho: There is no lag time in the rate of colonization for *C. glomerata* and epiphytes.

Does time-since-exposure affect colonization rates of cladophora. If colonization rates are the same for similar substrate subjected to different levels of exposure, then other factors may be affecting colonization.

4. Projects to address fish response hypotheses.

a. Effect of steady flows on relative abundance and distribution of fish including young-of-year humpback chub along shoreline. P.I. - R. Valdez and S. Carothers, SWCA. A project description can be found in **Appendix 10.** (Estimated cost $300,000).

The purpose of this project is to determine if steady flows have an effect on humpback chub young-of-year abundance, distribution and growth in the mainstem, as well as other fish species. Some effort will be concentrated in the first 5 miles below the LCR because the greatest numbers of young fish are associated with the LCR. The project will collect fish along the shoreline to determine if fish numbers differ among shoreline types (sand, rocky, vegetated shoreline). As the season progresses the distribution of these young fish may also change across these shoreline types.

Hypotheses to be tested:

Ho: Relative frequencies (CPUE) of young-of-year native and non-native fish species in rearing habitats will not differ significantly during the LSSF, BHBF nor in comparison with prior fluctuating flow periods.

Steady flows are assumed to be beneficial to young-of-year fish. If stable environments foster survivorship of young fish relative frequency should increase, provided sampling effort is sufficient to capture this information. Comparisons with other hydrology may not be possible, but this effort may serve as a "baseline".

Ho: Relative frequencies (CPUE) of young-of-year native and non-native fish species will be the same in all rearing habitats during steady flows.

Does the pattern of occurrence of young-of-year fish change among shoreline habitats or are all shoreline habitats used equally by young-of-year. This may help determine if one habitat type is used disproportionately more than another.

b. Monitoring of Colorado River fish community. P.I. - Native Fish monitoring group, GCMRC, et al. A project description can be found in **Appendix 11.** (Estimated cost $90,000.)

The purpose of this study is the continuation of the fish monitoring that has been collecting data on fish in the Colorado River since the 1980s. Summer efforts will include scheduled Little Colorado River trip to assess potential year class contribution, and mainstem efforts to determine population status of exotic predators (rainbow, brown trout, catfish, carp). The September trip that was already scheduled as a monitoring component will collect condition, distribution and relative abundance of all fish encountered in the mainstem and at the mouths of tributaries. The overwintering trip (February/March) will be used to evaluate the effect of the discharge, including the fall spike on survivorship, distribution and relative abundance of fish in the system.

Hypotheses to be tested:

Ho: Condition factor of native and non-native fish species will not change significantly during the experimental flow period.

Condition factor is a measure of food availability over time and is most likely to be reflected in older fish.

Ho: Spike flows following steady flow conditions will not actively displace non-native fish species in near shoreline nor backwater habitats for prolonged periods of time.

Spike flows of a magnitude of 31,000 cfs are recommended to remove small bodied exotics and reduce the competitive advantage these species may have incurred over the course of steady flows.

c. Coupling Hydrodynamic and Individual-Based Fish Movement Models for the Evaluation of the Effects of Flow and Temperature Releases from Glen Canyon Dam on the Accessibility of Suitable Habitat for Humpback Chub Juveniles in the Colorado River. P.I. - Josh Korman, Ecometric Research and Stephen Wiele, US Geological Survey. A project description can be found in **Appendix 12**. (Estimated cost $40,000.)

Dispersal of juvenile humpback chub from the Little Colorado River (LCR) into the mainstem Colorado River is hypothesized to be the major contributor of fish to downstream aggregations of adults (Valdez and Ryel, 1995). The relationship between sub-adult chub and mainstem habitat has been characterized by Converse et al. (1998) who found that juvenile chub preferred low-velocity shorelines near vegetation, talus, and debris fan shorelines. Recruitment of young fish reared in the mainstem may be dependent on their ability to access and remain in such habitats, and for recruitment to the LCR population, these sites need to be in proximity to the LCR confluence. This project will use data collected in Projects 1a and 4a to supplement velocity vectors and to validate the fish movement model. The results may help explain distribution pattern of humpback chub in the mainstem.

Hypotheses to be tested:

Ho: Current velocities will increase in tributary confluence areas under higher mainstem flows.

Valdez et al. (In prep) recommends a high spring steady flow to pond tributaries and retain young of the year, assuming that velocities will be reduced in tributary confluences. This hypothesis could be tested with flows at 17,500 cfs or higher and if flows are reduced to 14-12 cfs for a sustained period of time.

Ho: Current velocities for near shoreline habitats (e.g., talus, debris fans, vegetated shoreline) will not differ significantly between fluctuating and low steady flow conditions.

Low velocity habitats are assumed to be a requirement of young fish. Decreased velocities presumably accompany lower discharges. The lower velocity environments may be reflected in an elongation of a particular low velocity environment or an increase in the number of these environments.

d. Effect of LSSF on Lees Ferry trout. P.I. - B. Persons, D. Speas, AGFD. A project description can be found in **Appendix 13.** (Estimated cost $17,967.)

The purpose of this project will be to evaluate the effect of low steady flows on the Lees Ferry trout population. Project will conduct an additional electrofishing trip to determine the effect of the spring spike and steady flows on variables such as CPUE, size class structure, condition factor, and diet. Reduced habitat associated with lower volume discharges may affect the population dynamics of the trout population.

Hypotheses to be tested:

Ho: Relative frequency of young-of-year trout will not vary significantly during the entire experimental flow period inclusive of spike and LSSF.

Reduced available habitat and food resources in the Lees Ferry reach may exclude young-of-year and may result in reduced number (i.e., relative frequency) of young-of-year compared to baseline data.

B. Lake Powell Studies

Effects of low steady summer flow experiment on the stratification, composition, and hydrodynamics of Lake Powell, and the downstream effects of that limnology. P.I. - S. Hueftle and B. Vernieu, GCMRC IWQP. A project description can be found in **Appendix 14.** (Estimated cost $40,000.)

The purpose of this project is to measure short- and long-term effects of the changes in discharge patterns over the course of the LSSF experiment due to hydrodynamics, stratification and composition of Lake Powell, and the repercussions of those effects to the tailwaters. Effects of the 1996 BHBF alluded to hydrodynamic and compositional changes in the reservoir that were not adequately measured or understood; the design of the LSSF provides a further opportunity to observe and measure these effects. Alterations in the composition of the discharge have implications on tailwater primary productivity and community structure which could have significant bottom-up effects on the tailwater food web. Additionally, determining the effects of the LSSF may have implications on the operation of a TCD.

Hypothesis to be tested:

Ho: Shifts in discharge ramping rates and magnitudes will not effect Lake Powell's stratification, hydrodynamics or composition (physical, chemical, biological); nor influence tailwater quality.

Magnitude of discharge effects the dimensions of the cone of withdrawal above the dam, resulting in differential draw from various layers and across density gradients. Additionally, seiches (internal waves) can be induced by significant changes in discharge, as well as by surface winds and inflow dynamics, as was seen in the 1996 BHBF. Since the reservoir's thermocline and chemocline are consistently located near the penstocks, these effects produce significant fluctuations in discharge water quality. This can have effects on the primary productivity in the tailwaters as nutrient levels and planktonic discharge can vary significantly between the epilimnion and the hypolimnion.

C. Integrated Monitoring of Sand Storage and Budget Studies

Fine-Sediment Storage and Transport: Developing Partitioned Sand Budgets

Finally, while not included in the hypotheses contained in **Appendix 25**, the GCMRC proposes to capitalize on the uniqueness of the hydrograph proposed for WY 2000, to advance understanding of critical questions concerning fine-sediment storage and export in the main channel of the Colorado River, under ROD operations.

REMOTELY SENSED SEDIMENT DYNAMICS - Extended periods of constant discharge from Glen Canyon Dam provide optimal conditions under which new remotely sensed methods for estimating suspended-sediment concentrations can be verified and calibrated (use of backscatter collecting radiometers at main channel streamgages) at locations where intensive sediment sampling is scheduled to occur (Grand Canyon and Lower Marble Canyon streamgages). Accurate relationships developed between turbidity, total-sediment concentration and backscatter data under steady flows may allow for more efficient tracking of dam operations on downstream sediment conditions under diurnal operations in the future. The 8,000 cfs steady flow period from June through August, provides an opportunity to develop and refine such a remote method for tracking fine-sediment flux in critical reaches of the main channel. This component of the hydrograph also allows scientists an optimal chance to record and evaluate the degree to which sand inputs during the summer season can be added to channel storage under minimum operations associated with the ROD.

Recent research by the USGS, has shown that tracking the grain-size distribution of sand storage along the river bed at frequent intervals is a requirement of future long-term monitoring relative to sediment management. Evaluation of historical data show that the average grain size of sand on the bed is more of a controlling factor in suspended-sediment transport (affecting both deposition rates for bar building, and total export) than changes in discharge. Current methods for collecting such data are time consuming and labor intensive. Development of an “underwater microscope” is in development by the USGS, and promises to expedite the collection of bed grain-size data at gage sites and through the channel. Use of this prototype technology will be advanced during the field studies associated with the WY 2000 test flows, and will also support ongoing development of the use of “side-scanning sonar” to document changes in sand coverage throughout the channel bed. Such changes affect suspended-sediment transport rates, as well as influence the spatial distribution of substrates suitable as habitat for aquatic organisms of the food base.

The proposed September 2000, spike release of 33,000 cfs, also provides a unique opportunity for a more fully integrated physical science strategy to documenting the influence of peak power plant releases on the fine-sediment budget of the ecosystem (part 2, of NAU’s proposed work plan). The timing of the late-summer spike is especially important, as it will occur following summer-season inputs of fine sediment from gaged and ungaged tributaries below the dam. Development of an integrated, partitioned sand budget within Marble Canyon around a high release following low, steady summer flows, will allow scientists to test hypotheses about the effectiveness of floods in conserving fine-sediment inputs. Additionally, data on flow velocities and sand bar responses collected around the September spike release provide an additional opportunity to validate numerical simulations of sand bar evolution under controlled, steady flow operations and well documented sediment-supply conditions. This information is vital to development of highly predictive flow and sediment models under a range of conditions for the main channel.

Three projects intended to be implemented under an integrated monitoring proposal (in preparation by Schmidt et al., to be submitted to GCMRC by May 19) are described in **Appendix 15**. While the main goal of this integrated project (USU, USGS and NAU cooperators) is to determine the sand-storage and deposition/erosion dynamics under the full range of the Glen Canyon Dam power plant (as prescribed by the ROD), this effort also provides a unique chance to further develop basic long-term monitoring protocols for documenting the influx, storage change and efflux of fine sediment annually.

D. SOCIO-ECONOMIC STUDIES

1. Safety Studies

Whitewater boating safety studies below Lees Ferry. P.I.- Linda Jalbert, GCNP. A project description can be found in **Appendix 16**. (Estimated cost $ 20,500).

The purpose of this study is to ascertain the risks and potential impacts to whitewater boaters running the river at the experimental flows of 8,000cfs, compared to the “normal” daily flows for this time of year.

Hypothesis to be tested:

Ho: Whitewater safety will not significantly differ from safety during normal daily flows.

2. Economic Studies

Economic impacts to whitewater and angling concessionaires. PI – TBD. A brief project description can be found in **Appendix 17**. A more detailed project description will be developed (Estimated cost $15,000).

Economic impacts to private whitewater boaters and anglers. PI – TBD. A brief project description can be found in **Appendix 18**. A more detailed project description will be developed (Estimated cost $12,000).

The proposed hydrograph may have economic impacts to recreationalists. The high flow periods (May and September) may affect fishing opportunities in the Lees Ferry reach with economic impacts to fishermen and guides. The low flows may affect the navigability of selected rapids resulting in possible equipment damage and loss for downriver boaters. The study PIs will work cooperatively with the commercial outfitters and guides, anglers, and private boaters.

Hypotheses to be tested:

Ho: Economic impacts to whitewater and angling concessionaires will not differ significantly from economic impacts under normal daily operations.

Ho: Economic impacts to private whitewater boaters and anglers will not differ significantly from economic impacts under normal daily operations.

Economic Impacts to power customers. PI. – Clayton Palmer, WAPA. A project description is found in **Appendix 19**. (Estimated cost $ TBD).

This project will investigate the economic impacts of LSSFs to power customers.

Hypothesis to be tested:

Ho: Economic impacts to power customers will not differ significantly from economic impacts under normal daily operations

3. Recreational Use Studies

Effects on Recreational River Trip Characteristics. PI – Linda Jalbert, GCNP, Catherine Roberts, NAU. A project description is found in **Appendix 20**. (Estimated cost $14, 831).

The purpose of this study is to determine patterns and characteristics of river trips and potential impacts to camping beaches and attraction sites including archaeological and traditional cultural sites, during LSSFs compared to "normal" daily flows for the same time period.

Hypothesis to be tested:

Ho: Patterns of recreational use and their potential impacts will not differ significantly from recreational use patterns under normal daily operations

Changes in Campable Beach Areas. PI – Ruth Lambert. A project description is found in **Appendix 21**. (Project costs included in D.2.b - $ 32,000).

The availability of camping beaches is of concern to recreationalists within the Grand Canyon. The low steady flows should expose more campable areas at existing beaches and potentially provide newly exposed camping areas. This study proposes to use aerial data collected during this project to evaluate the change in campable area at recreational beaches. Data collection will occur during the aerial photography and selected locations will have topographic data generated. Following these experimental flows, these data will be analyzed and evaluated against campable areas known to exist under normal (ROD) operations. Funds for data analysis will be obtained from FY 2001 monies.

Hypothesis to be tested:

Ho: Campable beach areas will not differ significantly from campable beach areas under normal daily operations

III. SUGGESTED HYDROGRAPH

Because of the uncertainty associated with basin hydrology, reservoir filling and potentials for spills, and questions about pooling levels and spikes, we suggest the following:

1. An April hydrograph that reaches at least 17,000 cfs and does include a spike to 31,000 cfs for 4 days in early may. A May hydrograph that reaches at least steady 17,000 cfs, but that also includes a shoulder of 13,500 cfs on the descending limb for 3 days. This will allow area, velocity and temperature at tributary mouths at different discharges to be evaluated and compared.

2. Low steady flows (8,000 cfs) from June 1 - September 30.

3. A fall spike of 31,000 cfs for 4 days in September to determine if small bodied exotics are displaced and to determine the effect on the food base in Lees Ferry. The effect of exotic displacement will be evaluated on the winter fish monitoring trip, so motor use in non-motor season will not be an issue.

Under this hydrograph, data collection–beyond already planned monitoring trips–will potentially not start until approximately a week prior to the spring spike. Monitoring of fish in the LCR will be taking place in mid-April, and to some extent we can redirect efforts around this ponding event.

The ideal hydrograph would be as follows:

March 25 - April 5: steady 8,000 cfs with no generation control for aerial photography and topographic mapping. This may be shortened if the needed flights can be accomplished in a less time. If the duration is shortened, return to the release patterns immediately preceding the steady 8,000 cfs flows.

April 6: ramp up to steady 20,000 cfs releases. Maintain these releases until at least

April 25. Between May 3 and May 6, conduct a 4 day spike flow of 31,000 cfs. Following the spike, reduce to steady 19,000 cfs releases until May 27. On May 27, drop flows to steady 13,500 cfs and hold these releases for 3 days, then reduce flows to steady 8,000 cfs by May 31.

June 1 - September 4: run steady 8,000 cfs.

September 5 - 8: conduct a 4-day spike flow of 31,000 cfs.

September 8 - 30: run steady 8,000 cfs.

Note: Except as noted above, generation control will be in operation throughout this experiment, which means fluctuations in releases +/- 1,000 cfs on an hourly basis may occur.

IV. AERIAL PHOTOGRAPHY AND TOPOGRAPHIC MAPPING

1. Pre-experiment topographic base map and color infrared orthophotography (Appendix 22)

GCMRC will develop high resolution (one meter) topographic base maps and color infrared (CIR) orthophotography of the Colorado River corridor from Glen Canyon Dam to Lake Mead to establish base-line topography and pre-experiment vegetation and sand bar mapping of the Canyon corridor. The products will be:

Mapping products:

- High resolution topographic base map of the Colorado River corridor from Glen Canyon Dam to Lake Mead (mile –15 to 277) for improved resource monitoring and change detection. It is critical to develop this map at the 8,000 cfs stage in order to obtain maximum terrestrial exposure within the river corridor.

- A complete digital elevation model (DEM) of the study area with a cell resolution comparable to the average LIDAR ground point spacing.

Aerial photography and imaging products for change detection:

- Digital color infrared orthophoto mosaic of the study area for mapping vegetation type and distribution as well as sediment transport in the mainstem Colorado River.

- Digital black and white stereo imagery of the study area to provide change detection of sandbars, beaches and other geomorphic features before and after the 31,000 cfs high flow.

These products will provide a pre-experiment reference point enabling change detection of multiple physical and biological resources resulting from the proposed experimental flow conditions. The products delivered will include the first contiguous set of topographic data ever generated for the Colorado River corridor from the Glen Canyon Dam to Lake Mead at a scale useful to researchers, with appropriate georeferencing. (Estimated cost $327,000.)

2. Post-experiment color infrared and black-and-white orthophotography (Appendices 23, 24)

Post-experiment digital CIR orthophotography and black and white stereo photography has been requested for aerial interpretation of change detection of multiple physical and biological resources resulting from the proposed experimental flow condition. This will require three flights. CIR orthophotography during the peak flow of the fall 31,000 cfs spike. Black and white stereo photography immediately before and after the fall 31,000 cfs spike. (Estimated cost $406,000.)

V. SURVEY SUPPORT

Resource monitoring contractors have requested additional survey support in the areas of equipment and manpower to facilitate monitoring and research data collection efforts in support of the LSSF experiment. This will require additional survey equipment purchases and rental, travel, and per diem. (Estimated cost: $61,557.)

VI. LOGISTICS

The LSSF experiment will require logistical support of at least 13 additional trips in Grand Canyon as well as modifying trips already on the existing schedule of GCMRC research trips. In addition, it is proposed that personnel be stationed at the LCR and Grand Canyon gages for approximately 60 days during the spring spike and high flows, meaning research personnel will be added to existing trips to accomplish project objectives. Logistical costs include operations, support, and operations and maintenance costs, plus an estimate of equipment rentals and purchases required to add these trips to the existing schedule. (Estimated cost: $361,440.)

VII. PERSONNEL

Given the large number of additional trips required in the May-to-September period, GCMRC will consider adding a seasonal employee to the logistics program. Similarly, the requests for additional surveying support may require the addition of a temporary surveyor for the period May - September. Finally, given the current vacancies in the Biology Program and the added demands on the Biology Program from both the Interim Native Fish Monitoring effort and the test of Low Summer Steady Flows, GCMRC is considering detailing a fisheries biologist to GCMRC for a period of at least one year, as well as a seasonal employee to assist in data collection and analysis.

VIII. SCIENCE COORDINATION MEETING

A two-day science coordination meeting with the P.I.'s will be convened in Flagstaff from April 11-12, 2000. The purpose of the meeting is to promote dialog among the researchers and to promote collaborations to ensure that data collected can be shared and utilized to their greatest capabilities. An additional planning meeting for the fishery projects is also scheduled to take place in Phoenix from May 15-17 to coordinate data collection efforts.

VII. BUDGET

See Appendix 1

Budget Table/Spreadsheet **Appendix 1**

Project ID	Project Title and PI	Project Costs	Logistics Costs	Survey Support	Total	Committed Funds	Contributed Funds	Cancel if NO 8,000 cfs steady flow	Cancel if NO 31,000 cfs fall flow
A.	**ECOSYSTEM STUDIES**								
1. a.	Effect of Discharge on Shoreline Channel and Tributary Velocities and the Effect of Thermal Inputs on Mainstem Temperatures PI: Frank Protiva, Shephard-Wesnitzer, Inc.	$90,000	$21,000	Required	$111,000	$70,000	$30,000[1]	NO	YES
1. b.	Effect of Discharge and Flows on Temperatures in Aquatic Habitats. PI: Wm. Vernieu, GCMRC	$10,000	$-0-	N/A	$10,000	$10,000	$10,000[2]	MODIFY	YES
1. c.	Monitoring Effects of the Test Flow on Suspended Sediment and Turbidity Levels in the Main Channel of the Colorado River. PI: Nancy Hornewer	$79,000	$4,800	N/A	$83,800	$83,800	$40,000[3]	NO	NO
2. a.	Monitoring Effects of Test Flows on Sand Storage in the Main Channel and Eddy Complexes PI: Rod Parnell, NAU	$137,000	$8,000	Required	$145,000	$145,000	$-0-	NO	NO
3. a.	Effect of Steady vs. Fluctuating Flows on Creation of "Vegetated Shoreline" for Juvenile Fish and Recruitment of Exotic Plants in Newly Available Habitat PI: Mike Kearsley, NAU	$104,000	$4,500	N/A	$108,500	$35,000	$30,000[4]	MODIFY	NO
3. b.i.	Effect of Low Steady Flows on Drift and Benthic Biomass and Composition in the Lees Ferry Reach and Downstream PI: Dean Blinn, NAU	$325,000	$15,240	N/A	$340,240	$100,000	$60,000[5]	MODIFY	NO
3. b.ii.	Effect of Low Steady Flows on Drift and Benthic Biomass and Composition in the Lees Ferry Reach PI: Bill Persons, AGFD	$179,872	$-0-	N/A	$179,872	$-0-	$60,000[6]	MODIFY	NO
3. c.	Algal Colonization and Recolonization Response Rates During Experimental Low Summer Steady Flows PI: Dean Blinn, NAU and Mike Yard, GCMRC	$5,000	$1,000	N/A	$6,000	$1,000	$1,000[7]	YES	NO
4. a.	Effect of Steady Flows on Relative Abundance and Distribution of Young-of-year Fish Along Shoreline Below the Little Colorado River PI: Rich Valdez, SWCA	$300,000	$125,000	N/A	$425,000	$425,000	$100,000[8]	NO	NO

Project ID	Project Title and PI	Project Costs	Logistics Costs	Survey Support	Total	Committed Funds	Contributed Funds	Cancel if NO 8,000 cfs steady flow	Cancel if NO 31,000 cfs fall flow
4. b.	Monitoring of the Colorado River Fish Community PI: Barbara Ralston, GCMRC; Bill Persons, AGFD	$90,000	$88,000	N/A	$178,000	$178,000	$100,000[9]	NO	NO
4. c.	Effects of Flow and Temperature Releases from Glen Canyon Dam on the Accessibility of Suitable Habitat for HBC Juveniles in the Colorado River PI: Steve Wiele, USGS; Josh Korman, Ecometric	$40,000	$-0-	N/A	$40,000	$-0-	$-0-	DEFER	DEFER
4. d.	Effect of Low Summer Steady Flows on Lees Ferry Trout PI: Bill Persons, AGFD	$17,967	$-0-	N/A	$17,967	$17,967	$18,000[10]	NO	NO
	SUB-TOTAL	**$1,377,839**	**$267,540**	**--**	**$1,645,379**	**$1,065,767**	**$449,000**		
B.	**LAKE POWELL STUDIES**								
1.	Effects of the Low Steady Summer Flow Experiment on the Stratification, Composition, and Hydrodynamics of Lake Powell, and the Downstream Effects of that Limnology PI: Susan Hueftle and Bill Vernieu, GCMRC	$40,000	$-0-	N/A	$40,000	$10,000	$40,000[11]	NO	YES
	SUB-TOTAL	**$40,000**	**$-0-**	**--**	**$40,000**	**$10,000**	**$40,000**		
C.	**INTEGRATED MONITORING OF SAND STORAGE AND BUDGET STUDIES**								
1.	Additional Channel-Bed Substrate Mapping PI: R. Anima, D. Rubin, D. Hoagg, P. Chavez 1.a. Bed Grain-Size Change Detection ($35,000) 1.b. 2-D Bed Substrate Change Detection $150,000)	$185,000	$20,000	Required	$205,000	$35,000	$-0-	NO NO	NO NO
2.	A Collaborative Project Before, During, and After the 31,000 cfs Fall Test Flow With Integrated and Alternative Methods to Monitor Sand Storage • Team lead & synthesis - Schmidt ($50,000) • Photogrammetry – Horizons ($132,000) • Radiometer & CIR - Chavez ($80,000) • Change-Detection of Sand Storage in the contiguous study reaches of the Main Channel and Eddy Complexes - Parnell ($160,000) • Streamflow and Sediment Modeling - Wiele ($15,000) • Intensive Fall 31,000 cfs Suspended-Sediment data collection - USGS ($11,000) • Data Analysis – Topping ($15,000)	$463,000	$-0- $16,000	Required	$479,000	$-0-	$-0-	YES	YES
	C.1 & 2 are an integrated study **SUB-TOTAL**	**$648,000**	**$ 36,000**		**$684,000**	**$35,000**	**$-0-**[12]		

Project ID	Project Title and PI	Project Costs	Logistics Costs	Survey Support	Total	Committed Funds	Contributed Funds	Cancel if NO 8,000 cfs steady flow	Cancel if NO 31,000 cfs fall flow
D.	**AERIAL PHOTOGRAPHY AND REMOTE SENSING**								
1.	Topographic Base Map	$250,000	$-0-	Required	$250,000	$250,000	$250,000[13]		
2.	1. Pre spring 31,000 cfs CIR and B&W Orthophotography	$127,000	$-0-		$533,000	$127,000		NO	NO
	2. CIR and B&W orthophotography of 1st 100 miles	$304,000							
	a. Thermal IR ($60k)							YES	YES
	b. Pre fall 31,000cfs B&W ($119k)							YES	YES
	c. Peak 31,00cfs CIR ($38k)							YES	YES
	d. Post fall 31,000 cfs B&W ($87k)							YES	YES
	3. CIR of entire CRE (annual overflight with supplement) ($102k)	$102,000				$70,000	$70,000[14]	MODIFY	NO
3.	Survey support: Equipment purchase, rental, etc.	$ -0-	$-0-	$61,557	$61,557	$58,000	$-0-	NO	NO
	SUB-TOTAL	**$783,000**	**$-0-**	**$61,557**	**$844,557**	**$505,000**	**$320,000**	**--**	**--**
E.	**SOCIO-CULTURAL WORK**								
1.	Whitewater boating safety below Lees Ferry PI: Linda Jalbert, NPS	$20,500	$-0-	$-0-	$20,500	$-0-	$-0-	YES	YES
2.	Economic impacts to concessionaires: angling & whitewater boating PI: TBD	$15,000	$-0-	$-0-	$15,000	$-0-	$15,000[15]	NO	YES
3.	Economic impacts to private whitewater boaters and private anglers PI: TBD	$12,000	$-0-	$-0-	$12,000	$-0-	$-0-	YES	YES
4.	Economic impacts to power customers PI: Clayton Palmer, WAPA	$TBD	$-0-	$-0-	$TBD	$-0-	$TBD	YES	YES
5.	Changes in whitewater boating trip characteristics PI: NPS and NAU	$14,831	$-0-	$-0-	$14,831	$-0-	$-0-	YES	YES
6.	Changes in campable beach area. (Project costs covered in D.2.b. - $32k) PI: Lambert	$-0-	$-0-	$-0-	$-0-	$-0-	$-0-	YES	NO
	SUB-TOTAL	**$62,331**	**$-0-**	**$-0-**	**$62.331**	**$-0-**	**$15,000**		

Project ID	Project Title and PI	Project Costs	Logistics Costs	Survey Support	Total	Committed Funds	Contributed Funds	Cancel if NO 8,000 cfs steady flows	Cancel if NO 31,000 cfs fall flow
F.	**LOGISTICS**								
1.	22' and 32' boat rentals ($9,600), purchase two 30 HP motors ($6,400), purchase 2 satellite phones ($5,400), purchase additional trip equipment (kitchen, stove, water purification, coolers, boxes, etc.) ($6,500). Electrofisher and motor set up ($30,000)	N/A	$57,900	N/A	$57,900	$57,900	$33,000[16]	NO	NO
	SUB-TOTAL		**$57,900**		**$57,900**	**$57,900**	**$33,000**		
G.	**INFORMATION SYNTHESIS AND DISSEMINATION**								
1.	Science Symposium	$25,000	N/A	N/A	$25,000	$-0-	$25,000[17]	MODIFY	NO
2.	Contributed Papers Volume	$20,000	N/A	N/A	$20,000	$-0-	$-0-	MODIFY	NO
3.	GCMRC Program Managers Synthesis	$50,000	N/A	N/A	$50,000	$-0-	$50,000[18]	MODIFY	NO
	SUB-TOTAL	**$95,000**			**$95,000**	**$-0-**	**$75,000**		
H.	**LSSF SCIENCE PLANNING**								
1.	Meetings / Travel, etc.	$15,000	N/A	N/A	$15,000	$15,000	$-0-	NO	NO
	SUB-TOTAL	**$15,000**			**$15,000**	**$15,000**	**$-0-**		
	TOTAL	**$3,021,170**	**$361,440**	**$61,557**	**$3,444,167**	**$1,688,667**	**$932,000**		

TOTAL REQUESTED: $3,450,038 - $932,000 = $2,518,038

Budget Table End Notes

[1] Reprogramming of funds originally budgeted for TWG requests in FY 2000.
[2] From funds to be de-obligated .
[3] From funds to be de-obligated .
[4] From deobligated funds.
[5] From deobligated funds.
[6] From deobligated funds.
[7] Reprogramming of balance of funds used to cover move related expenses of GCMRC.
[8] Reprogramming of funds for support of the HBC maintained at the Willow Beach Hatchery.
[9] Reprogramming of funds originally budgeted for unsolicited proposals in FY 2000.
[10] Reprogramming of funds carried over from FY 1999 to FY 2000.
[11] Reprogramming of funds originally budgeted for Lake Powell monitoring and research in FY 2000.
[12] If the entire LSSF hydrograph is implemented Ted Melis recommends reprogramming $300,000 from FY 2001 funds to help cover the cost of these projects. This would effect monitoring and research activities planned for FY 2001.
[13] From deobligated funds.
[14] Fund already budgeted in FY 2000 for annual aerial photography.
[15] Reprogramming of funds for socio-economic consulting in FY 2000.
[16] Reprogramming of funds carried over from FY 1999 to FY 2000 for logistics associated expenses.
[17] Reprogramming of funds originally budgeted for a science symposium in FY 2001.
[18] From funds currently budgeted for staff salaries in FY 2001.

Appendix 2

1. a. Effect of discharge on shoreline channel and tributary. P.I. - Frank Protiva, Shephard-Wesnitzer Inc. (Estimated cost $90,000).

The purpose of the project is to determine the areal extent of current velocities at the confluence of the LCR and mainstem at four discreet steady experimental flows that range from 8,000 to 31,000 cfs. It is inferred that differences in current velocities at tributary confluences may have an effect on the entrainment and survivorship of small bodied fish (young of the year) displaced into the Colorado River mainstem. The project will collect spatially referenced velocity measurements at the LCR confluence to determine how current velocities and areas may differ relative to changes in flow levels.

Study Approach / Methods:
Instream velocity data will be spatially referenced to the thermal gradient areas previously mapped at the confluence of the Colorado and Little Colorado Rivers (Protiva *et al.* 1996). Velocities below the LCR in the mainstem of the river will be collected to river mile 62. Horizontal positioning of velocity measurement nodes will be established through the use of either RTK GPS or total-station survey equipment, tied to the existing GCMRC survey control network. This data collection method is identical to the existing hydroacoustic mapping efforts currently programmed by GCMRC, using a velocity sensor instead of a depth transducer to collect the subject data.

A Sontek RiverSurveyor acoustic Doppler profiler (upgraded with shallow water performance enhancements) will be used to collect velocities in boat-accessible areas with water depths greater than 0.7m. Hand-held velocity measuring instruments (Swoffer, Global Flow Probe or equivalent) will be used to measure velocities in shallow water (<0.7m) or where boat access is not possible.

Velocity data will be collected under stable flow conditions for the following mainstem flow levels:

Flow	Data Collection Dates
8,000 cfs	Sept. 2000 (exact dates TBA)
13,500 cfs	May 28 - May 30, 2000
19,000 cfs	May 25 - May 27, 2000
31,000 cfs	Sept. 2000 (exact dates TBA)

Edited flow data will be exported to ASCII files sorted by collection epoch. These files will be input into the Terramodel software package and used to generate contours of velocity *magnitude*, which in turn will be overlaid onto the existing color-hatch plots of thermal limits generated by Protiva et. al 1996. Plots will be generated to illustrate the temperature and velocity relationships at the confluence for the mainstem flow levels listed above. All of the Protiva 1996 water temperature data was collected when the LCR was running at base flow levels. To present an accurate picture of velocity vs. temperature using the Protiva 1996 data, velocity measurements must also be taken under LCR base flow conditions.

Deliverables under this contract will include:

1) AutoCad-compatible plots of temperature (color hatched) and velocity (contours of magnitude) for the four mainstem flow levels set forth above.
2) Digital (.dwg) files of the 4 plots.
3) ASCII files of the raw and edited velocity data.
4) A summary report. The Draft report will be delivered with items 1 thru 3 above. The Final report will be delivered upon acceptance for publication in an appropriate peer-reviewed technical journal (Regulated Rivers or similar).

Hypotheses to be tested:

Ho: Current velocities for near shoreline habitats (e.g., talus, debris fans, vegetated shoreline) will not differ significantly between fluctuating and low steady flow conditions.

Low velocity habitats are assumed to be a requirement of young fish. Decreased velocities presumably accompany lower discharges. The lower velocity environments may be reflected in an elongation of a particular low velocity environment or an increase in the number of these environments.

Contours of velocity magnitude can be compared for the different mainstem flow levels to identify change in low-velocity environments under different flow levels. Color-shading of threshold velocities and/or ranges can be generated with the Terramodel software, if necessary. Areas within these ranges or above/below the identified threshold velocity can then be quantified through computer analysis.

Ho: Areal extent of low velocities does not vary for a range of steady flows.

Discharge may affect current patterns (eddies may get wider or longer), but total area of low velocity environments should remain the same. This helps determine if size of low velocity environment matters.

Color-shading of threshold velocities and/or ranges can be generated with the Terramodel software, if necessary. Areas within these ranges or above/below the identified threshold velocity can then be quantified through computer analysis.

Ho: Current velocities will not be different in tributary confluence areas under higher mainstem flows compared to lower mainstem flows.

Valdez et al. In prep recommends a high spring steady flow to pond tributaries and retain young of the year, assuming that velocities will be reduced in tributary confluences. This hypothesis could be tested with flows at 17,500 cfs or higher and if flows are reduced to 14-12 cfs for a sustained period of time.

Velocity contours overlaid onto the Protiva 1996 thermal color-hatch plots will clearly illustrate the availability of warm-water, low-velocity habitats under the four mainstem flow levels set forth above. Areas could be summed for a defined minimum temperature and maximum velocity to *quantify* this availability.

The Protiva 1996 thermal plots show the “gradient of warming” exiting from the LCR into the mainstem for three separate ranges of mainstem flow: 9200 to 9600 cfs, 12,130 to 12,809 cfs, and 17,740 to 17,798 cfs. These plots identify a short gradient “plume” around the mainstem (right) side of the island at the +/-9200 cfs flow level, increasing to a maximum “plume” length at the +/-12,000 cfs flow level. At the +/-17,000 cfs flow level, the gradient “plume” is virtually non-existent, with a well-defined warm/cold interface at the upper end of the island. Mainstem water temperatures are clearly illustrated in these plots under all three flow scenarios, with color-hatch resolution in 2 degree increments. The velocity data collected for the proposed project will be overlaid with previous thermal plots of the confluence area.

Appendix 3

I. C. Project: Effect of discharge and flows on temperatures in aquatic habitats. P.I. GCMRC biology program (Vernieu) (Estimated cost, $10,000.)

Water volume, velocity and ambient temperature influence water temperature and rates of warming, locally and cumulatively. This project will collect data along the mainstem to determine cumulative downstream warming rates from the dam at low volumes (8,000 cfs) and under steady flows. At a local scale, data will be collected to determine if there is a difference in water temperature between shoreline and the main channel and if shoreline temperatures are the same or if these temperatures differ by shoreline type.

Temperature affects swimming ability and growth of young fish. Both of these variables are important for survival, primarily to avoid predation. Low volumes and reduced water velocity in the mainstem may result in mainstem warming and increased warming along shoreline habitats used by young fish.

Hypotheses to be tested:

Ho: Water temperatures in the mainstem will not increase downstream greater than temperatures previously observed under other flow conditions (e.g., fluctuating, higher discharge).

We have an estimate for rate of warming in the mainstem. It would be useful to determine if steady flows affect this rate, and if discharge and steady flows affect this rate (this is particularly applicable for the temperature control device).

Ho: Near shoreline temperatures in structurally complex habitats will not differ significantly from those observed for the mainstem.

The intent of steady flows is to warm shoreline low velocity environments; if the amount of warming is negligible, then perhaps temperature along the shoreline is not a limiting factor for recruitment of native fish, but low velocities are.

METHODS

Water temperatures in the mainstem will not increase downstream greater than temperatures previously observed under other flow conditions (e.g., fluctuating, higher discharge).

A part of the Integrated water quality program includes data collection of water temperature in the mainstem. Mainstem temperature is recorded by hobo tempmentor that record temperature data at 15 minute intervals from the Dam to Diamond creek, an additional station will need to set-up between Diamond Creek and Pearce Ferry. The data collectors are set at distances approximately 50 miles apart. Data are downloaded every 3 months. We will have data for steady flows in the mainstem from a series of discharge volumes (8,000, 13,500, 20,000, 19,000, and 31,000 cfs) to determine the effect of volume and steady flows on temperature warming. These data will be compared with comparable fluctuating flow data collected since 1991. A rate of warming for fluctuating flows has been developed and is estimated at 1°C/30 km (Korn and Vernieu, in prep) in June. This warming rate will be compared against a rate of warming developed under LSSF operations. Higher steady flow mainstem temperatures will be recorded in the spring and fall periods and will be compared with similar seasons and average discharges under fluctuating flows.

Near shoreline temperatures in structurally complex habitats will not differ significantly from those observed for the mainstem.

Shoreline temperatures associated with fish sampling habitats will be recorded during the steady flow period. Data collection will be coordinated with YOY fish collection efforts (see **Appendix 10**). Data will be collected along the shoreline and outward toward the main channel to determine if temperatures warm incrementally shoreward for all habitats, or if shoreline habitat effect warming. Velocities along these shorelines will be collected to determine if velocity affects shoreline warming.

These data will only be collected under the LSSF period for the months of June, July, and August and September (June-September). Unlike the mainstem warming methods, temperature and velocity measurements will be taken only during the time fish sampling is taking place. While deployed, the data collectors will record data on 15-minute interval basis.

Deliverable schedule

Preliminary manuscript	January 31, 2001
Final manuscript	June 1, 2001

Appendix 4

1. c. Project: Additional Monitoring of Effects of flow on suspended sediment and turbidity levels in the main channel of the Colorado River. P.I. -- Nancy Hornewer and G. Fisk, USGS. Existing streamflow monitoring program. (Estimated cost $79,000.)

The following work plan elements are proposed in support of monitoring and research of seasonally adjusted steady flow testing between March and October, 2000. These science activities shall provide data documenting the physical effects of the steady flows on the sediment and water resources of the Colorado River ecosystem below Glen Canyon Dam. Additionally, the data shall support efforts on the part of biological scientists to link low-steady flows to physical habitat changes within the terrestrial and aquatic ecosystems.

This work shall also: 1) support ongoing research by the USGS to better define a partitioned fine-sediment budget for the upper 100 miles of the ecosystem, 2) support ongoing development of a 1-dimensional sand routing model for the main channel, 3) support and improve 2-dimensional sand-bar evolution model simulations, 4) support development of a real-time, remotely-based method (using radiometer data) for relating suspended-sediment concentration and grain-size to turbidity in the main channel, relative to dam operations, 5) provide 2-dimensional substrate maps of the channel bottom and near-shore habitats, 6) provide detailed stage and discharge data immediately below the dam (Glen Canyon streamgage), and 7) provide "event" streamflow and sediment-transport data on flash floods that may occur in ungaged tributaries of Glen and upper Marble Canyons, related to sand influx to the Colorado River ecosystem.

A. Reactivate Glen Canyon Streamgage, and conduct analyses of historical data for periods during which both the Glen Canyon and Lees Ferry sites were operated.

Total = $21,000 (for 6 months of WY 2000)

B. Additional Staff to Support Menlo Park Laboratory – (processing and analyses of additional suspended and bed material sediment samples = 0.5 additional student FTE salary).

Total = $10,000

C. Ungaged Tributary Sand Inputs in Glen and Marble Canyons – portable instrumentation deployed to capture flash-flood data

Total = $13,000 (equipment and labor)

D. Additional Sediment Sampling – main channel and gaged tributary suspended-sediment samples during April through June, 2000.

Total = $35,000

Data Analyses and Travel Support for David Topping (to analyze sediment transport and flow data collected during the test in collaboration with researcher from USU, NAU and USGS, and to supervise additional lab analyses at Menlo Park laboratory for sediment analyses), plus student support for additional sediment analyses at Denver Federal Center laboratory.

Total = $15,500

E. Additional Side-Scanning Sonar Mapping

Additional Channel-Substrate Map Data Generated Through Capture of Side-Scanning Sonar during Seasonally Adjusted Steady Flow Testing

R. Anima, D. Rubin, D. Hoagg, and P. Chavez, USGS, Menlo Park, CA

The proposed September 2000 spike flow associated with testing of seasonally adjusted steady flows for native fishes will afford U.S.G.S. Coastal and Marine Geology scientists the opportunity to conduct side-scanning sonar surveys prior to and immediately following the 33,000 cfs spike flow to monitor changes in the distribution of sand size sediment stored in the pools between rapids at selected study reaches between Glen Canyon Dam and the Grand Canyon streamgage near Phantom Ranch. During the proposed additional cruises, USGS will conduct multi-path surveys concentrated along reaches designated by physical scientists and biologist to augment their studies. The two surveys will be coordinated with; fish biologist who are interested in river bed characteristics and bed changes; with work conducted by GCMRC on full channel bathymetry above Grand Canyon; and with researchers from Utah State University working on change detection along the river margins. The side scanning surveying will concentrate on reaches designated as primary monitoring reaches where a combination of various remote-sensing tools will be used. This will allow for a multifaceted monitoring program to ensure the most complete data set possible.

Additionally, these data will: (1) support efforts by USGS and other researchers, to better-define a partitioned fine-sediment budget for the more sand-limited reaches within 100 miles downstream of Glen Canyon Dam; and (2) support ongoing development of a 1-dimensional sand routing model for the main channel of the Colorado River ecosystem below Glen Canyon Dam. Both of these objectives are currently components of ongoing research being carried out by the USGS, Water Resources Division (Arizona District), under funding from the GCMRC.

Total cost (including overhead) for two additional map coverages and change-detection analysis between Glen Canyon Dam and Phantom Ranch

Total = $134,944

F. Additional Main Channel Sediment Sampling - The Arizona District proposes additional sampling during the remainder of FY 2000. The Glen Canyon gage was reactivated in mid-March 2000.

-<u>The Colorado River at Lees Ferry</u> will have weekly sediment samples during April 17 to May 17. Four person days will be required. Two week of QMS, QW and SS can be covered.

-The Colorado River above the Confluence with the Little Colorado River will be sampled twice daily April 17 to May 17. There will be salary and travel expenses for a GS-9 and GS-5.

-The Colorado River at Grand Canyon sampling will also require samples twice daily April 17 to May 17. There will be salary and travel expenses for a GS-9 and GS-5.

-The Colorado River at Diamond will have weekly Sediment samples April 17 to May 17. Two weeks can be covered by QM and QW. Three weeks will be required. Two teams of 7 person days, plus travel will be required.

Total = $56,000

Total (A - F) = $214,309

2. a. Effects of short duration high releases and long duration low steady flows on deposition and erosion of fine-sediment at selected eddy complexes utilizing the 34 Northern Arizona University (NAU) long-term eddy complex and sand bar study sites, plus 4 newly established channel margin monitoring sites. P.I. - R. Parnell, M. Kaplinski, J. Hazel, M. Manone, Northern Arizona University (estimated cost $137,000).

The purpose of this project is to determine the volumetric extent to which eddies fill with sediment under low steady flow operations. Eddies are a storage source for sediment in the river corridor and also serve as habitat for fish. Change detection for sediment storage versus storage potential, supply and relations to physical features, such as return-current channels that serve as aquatic habitat for fish shall be the main objective of this monitoring. Project will measure return channels at existing sandbar monitoring sights to determine pattern of change among sandbars over time. Emphasis will be placed on sand bar monitoring sites that are located between Glen Canyon Dam and Diamond Creek, with emphasis on reaches where fisheries studies are conducted. The project will also evaluate the habitat maintenance effect of the spring spike on sediment storage in eddies and channel margin deposits.

Work plan and Schedule and Budget

This project is designed to test the hypothesis that a spike flow of 31,000 ft^3/s for 4 days will deposit eddy and channel stored sand at high elevation eddy bar and channel margin locations. Between the confluence of the Little Colorado River and river mile 65, sediment-storage data within eddy complexes shall be related to areas of return current channels, known as backwaters, relative to the effects of the spring spike flow.

Backwater number and total area will not differ significantly throughout the period of steady flows.

Workplan:

Collect channel margin cross section data at four sites pre- and post-spike (spring).
Conduct topographic and hydrographic surveys at 34 long-term monitoring sites pre- and post-spike (spring).
Note: The spring vs. fall storage change detection is linked to the project described on pages 64-66 (Appendix 15, part B). Eddys will be measured between the dam and Phantom Ranch.

Schedule:

Pre-spike data collection river trip: March 18 to April 5, 2000 (this trip has already been partially funded under an existing cooperative agreement). Collecting data on return channel volumes.

Pre-spike data collection river trip: April 28 to May 15, 2000 (depends on timing of release)

Deliverables:

Updated and revised NAU Fact Sheet for March-April data (e.g., Kaplinski et al., 1999): September 30, 2000

Logistical Needs, Personnel, and Cost Estimate:

Logistical support -The pre-trip required three GCMRC motor boats including the 17 foot white knight. GCMRC survey personnel were required on the pre-trip for data collection and post trip processing. We propose to collect and process all survey data on the post trip and require no GCMRC personnel. It is expected that GCMRC total stations and the single beam hydrographic system for data collection will be provided at no additional cost.

Personnel - Field work will be accomplished by 12 persons including 3 boatmen.

Total Expected Cost (not including logistical) = **$68,000**

Appendix 6

3. a. Effects of steady vs. fluctuating flows on creation of "vegetated shoreline" for juvenile fish and exotic recruitment into newly available habitat. P.I. - Michael Kearsley, Northern Arizona University (Estimated cost $104,000.)

Objectives

The objective of this project is to determine the impact of the spring spike flow and low steady summer flows on patterns of establishment and growth of native and exotic plant species in the newly exposed sand and shoreline habitats. Exposed fine sediments and cobbles can be colonized by clonal plants moving downslope from established populations or via seeds which emerge from the seedbank or which drift into these open habitats. The project will evaluate rates of colonization in exposed shoreline to determine contribution of seedbank on colonization, downward movement of riparian plants and exotic seedling colonization.

Methods

The project involves three major areas of focus: the downslope expansion of populations of clonal native species into newly exposed habitats, the germination of exotic species, specifically tamarisk and camelthorn near the water's edge, and the impact of spike flows on exotics and other species in wetland soil seed banks. Below the methods to address each are outlined.

Downslope expansion of clonal species

We will assess the effects of the low summer steady flows on populations of clonal native species which are found in shoreline habitats with three sets of field data samples and a greenhouse experiment. The field data sets will address the following hypothesis:

Ho: Creation of "vegetated shoreline" via the downslope expansion of populations of clonal wetland plants such as rushes (*Juncus* spp.), reed (*Phragmites*), and horsetail (*Equisetum)* will not differ in years of constant and fluctuating flows.

We will test this hypothesis in three ways. First, we will repeatedly sample transects in four intensively sampled sites: Lees Ferry area, above Badger rapids, above Soap Creek rapids, and above Tanner rapids. We will measure the rate at which patches of *Equisetum*, *Juncus*, and *Phragmites* grow downslope. The Lees Ferry and Tanner transects will be coordinated with the Aquatic Foodbase Group (Blinn) and the Badger and Soap Creek sites will be coordinated with the shoreline deposit surveys of the Sandbar Dynamics Group (Parnell). Second, in the native fish reach study between the Little Colorado River and Lava Chuar rapids (per Converse et al. 1998), we will compare vegetation present in transects through three major shoreline types (debris fan, sand, and talus) early and late in the low flows. This will be coordinated with the Native Fish Group (Carothers/Valdez). Finally, to get a system-wide picture of vegetation encroachment, we will measure the change in elevation above the water's edge of the lower margin of vegetation at random points in the geomorphic reaches above Phantom Ranch between the start and end of the low steady flows.

Greenhouse data will be collected using a set of 12 rhizopods, devices in which the water level in root cylinders can be manipulated using a central reservoir (Mahoney and Rood 1991). We will create hydrographs which mimic data from the USGS Lees Ferry gage during periods of steady low flows and during low fluctuating flows (8000 - 12000 cfs). Each rhizopod will consist of six 4" or 6" diameter PVC pipes arranged in stair-step fashion so that multiple elevations can be created simultaneously. In each cylinder, small “plugs” of native vegetation will be planted. We will compare survival and growth of *Equisetum*, *Juncus*, and if technically feasible, *Phragmites* plants in the chambers.

Germination of exotic plants

We will assess the effects of the low summer steady flows on the germination of exotics species in the newly exposed near shore habitats. The data will be used to test the hypothesis:

Ho: Germination of exotic species, especially tamarisk (*Tamarix ramosissima)* and camelthorn (*Alhagi camelorum*) will not differ in years of constant and fluctuating flows.

We will test this hypothesis by collecting data on seedling presence in the transects described above. During each transect measurement in the intensive sites, native fish sites, and the upper geomorphic reaches, we will record the abundance and, where possible, identity of seedlings we encounter, and their position relative to the water’s edge. After the fall spike flow, we will make a final assessment of seedling abundance in the intensive sites to address questions about whether these flows remove potential noxious species. The data from the LSSF will be compared to data from the summer of 2001 in which fluctuations have returned to the system, assuming that fluctuations are at a similar volumetric discharge.

High flows and wetland/vegetated shoreline seed banks

The low steady summer flow hydrograph contains spike flows of 33,000 cfs during the spring ponding flow (to move sediment into high-elevation sandbars) and after the low steady flow (to flush non-native fish). We will collect data to test the following null hypothesis:

Ho: Spike flows before and after the low steady flows will not reduce the abundance and/or diversity of seeds in the soil of wetland and low-elevation vegetated shoreline patches.

Data from previous studies (Kearsley and Ayers 1999; M. Howe, unpublished) shows that intermittent flooding, even at levels within power plant capacity, has disturbed low elevation areas including wetland and vegetated shoreline habitats and reduced the abundance and diversity of the available seeds in the soils of these habitats. Inputs from large tributaries such as the Little Colorado cause seedbanks in downstream sites to diverge from those upstream, and system-wide floods, such as the 1996 controlled flood tend to homogenize them. We will sample soil seed banks in low elevation patches at 10 study sites where we have continuous data from the last 4-5 years to assess the impacts of these two spike flows on the seed-based regeneration potential of these productive and diverse habitats. We will follow direct germination methods used in previous studies (Kearsley and Ayers 1999) and will compare seed germination from samples in September 2000 and February 2001 with phenologically matched samples from the same patches in 1996 - 2000 to test for changes in species richness, total seedling abundance, and compositional dissimilarity (per Clarke 1993)

Expected Products

Data collected during this study will result in the production of two M.Sc. theses (May 2001 and May 2002), and peer-reviewed publications on vegetation dynamics and water fluctuations and the dynamics of seed banks in a regulated system. In addition, we will produce annual progress reports and a final technical report at the completion of the project (September 2002). Results from this study will be presented at annual meetings of the Ecological Society of America (Aug. 2001, Aug 2002), at a regional conference hosted by the Colorado Plateau Research Station (Oct. 2002), and at annual meetings designed to inform stakeholders of research progress (April 2001, 2002, and 2003).

Equipment Needs

No surveying beyond that planned by the Sandbar Dynamics Group and Native Fish Group will be required for this project. We will make use of fiberglass survey rods for the assessment of elevation change in the intensive and reach-based transect study. The budget includes funds for the construction of the rhizopods and an inflatable kayak for cross-river travel at the intensive sampling sites. The budget does not include logistical support from GCMRC, but we have discussed logistical needs with the GCMRC logistics coordinator.

References Cited

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Appendix 7

3. b.i. Project: Effect of Low steady flows on drift and benthic mass and composition in the Lees Ferry Reach and downstream. P.I. - D. Blinn, J. Shannon, and E. Benenati, NAU. (Estimated cost $325,000.)

Program dates June 2000 - September 2001

1) We will compare the LSFF benthic estimates to 1997 relatively steady high flow and fluctuating flow data from 1998 and 1999. Survey extent of phyto-benthic across the river channel at above and below the Paria River and above Diamond Creek. A combination of underwater photography and grab samples with SCUBA will quantify this distribution. We will compare the SLFE drift estimates to 1997 relatively steady high flow and fluctuating flow data from 1998 and 1999. This includes both coarse and fine particulate organic matter, including zooplankton, benthic macroinvertebrates and macrophyte mass estimates. These data collection efforts will also include minnow trapping on cobbles, talus and nearshore vegetated habitats to determine which habitat is preferred by small fish. This is the same protocol we used in the 1997 relatively steady high flow period and we found 11 times greater zooplankton mass in the nearshore vegetation. Juvenile and small fish were 3 times more likely to be caught in the nearshore vegetation than in cobble bars. This sampling regime allows us to quantify three trophic levels at the same time within one project. This would also include growth and distribution of near shore habitats in cooperation with Mike Kearsely's vegetation monitoring project.

Ho: There will be no significant difference observed in the benthic or macrophytic community for biomass or composition due to spike flow treatments.

Ho: There will be no significant difference in biomass, densities or composition observed for the benthic and macrophytic communities due to a LSFF treatment.

2) We will compare the LSFF drift estimates to1997 relatively steady high flow and fluctuating flow data from 1998 and 1999. This includes both coarse and fine particulate organic matter, including zooplankton. Do drift estimates change according to time of day? During fluctuating flows we have found no behavioral drift for macroinvertebrates. If the benthos increases in density similar to the 1997 steady flow period then we may begin to see behavioral drift due to crowding. Does the depth and location within the channel influence drift biomass and composition estimates during LSFF? During fluctuating flows in 1995 we addressed this question with 25 CPOM samples at 2 depths and 2 locations. No significant difference was detected between sites, indicating CPOM is evenly distributed across the channel under fluctuating flows.

Ho: The quantity and composition of drift will not significantly vary during the duration of the LSFF treatment.

Ho: The quantity and composition of drift during a LSFF treatment will not significantly vary in comparison with years of other steady or fluctuating flows.

GCMRC Protocol Evaluation Program we propose the following:
1) AGF collects at their sites on the same day NAU does their SLFE collections as a technique and site comparison, cobbles and drift (June 2000 - January 20001; n=10). The steady flows will remove one confounding variable.
2) In July 2000 paired sampling at one AGF and one NAU site, complete benthic sample processing (n=4).
3) While NAU investigates drift sampling protocol AGF does the same. This will allow use to compare drift techniques.
4) Benthic response variables in AFDM/m2
Cladophora, Oscillatoria, MAMB, detritus and total macroinvertebrates, Benthic macroinvertebrate densities in #/m2 chironomids, simullids, Gammarus, and other macroinvertebrates
Drift response variables in AFDM/m3/s
Cladophora, Oscillatoria, MAMB, detritus, aquatic diptera, Gammarus and other macroinvertebrates
Drift response variables in AFDM/m3/s
chironomids, simullids, Gammarus, and other macroinvertebrates

Data will be in an EXCEL data base following the NAU data format. AGFD is invited to bring their data sets to NAU on March 1, 2001, to analyze the data sets. At the end of the day each group will have each others data in a useable format. Each group can then add their results to their reports as they see fit.

Collecting Protocols and Sites
All of the sampling protocols have been used extensively in the past by the NAU Aquatic Food Base Project. Protocols have either been through the GCMRC peer review process and/or have been published in journals. Collection intervals, June, August, September, October, January 2001, June 2001. The August to January trips augment regular monitoring trips. Lees Ferry Protocol in June 2000.

Sites	Water Quality	Drift	Benthos	Nearshore
Glen Canyon Gage	X	X		
Lees Ferry	X	X	X	X
2 Mile Cobble Bar	X	X	X	X
60 Mile Rapid	X	X	X	X
64 Mile Tanner	X	X	X	X

138 Mile Rapid	X	X	X	X

These are established sites that bracket the major tributaries and incorporate both native and alien fish reaches.

Progress report...October 1 2000

Progress report...March 1 2001

Exchange data with AGF..March 1 2001

Final report..October 1 2001\

3. b. ii. Effect of a 31,000-cfs spike flow and low steady flows on drift and benthic mass and composition in the Lees Ferry reach (Estimated cost $179,872)

PIs: Persons, Speas Arizona Game and Fish Department

We propose collection of data to assess the status of the foodbase in the Lees Ferry reach to compare with previous years under normal Record of Decision operations. We propose to collect drift samples quarterly to compare with data collected from May 1993 to July 1994. We also propose to collect periphyton, aquatic macrophytes, and benthic invertebrates to compare with data collected from 1991-1997. We also propose to collect diatom epiphytes to compare with collections made in 1996 during the Beach Habitat Building Flow (BHBF). Quarterly samples will be used to assess impacts of the annual hydrograph including the spring spike flow and the 8,000-cfs low steady summer flow.

We will also collect and analyze periphyton, aquatic macrophytes, and benthic invertebrate samples immediately prior to and immediately after the 31,000 spring spike flow to evaluate impacts of that release on mass and composition of the Lees Ferry aquatic foodbase.

31,000 CFS SPIKE FLOW TREATMENT

Ho: There will be no significant difference observed in the benthic or macrophytic community for biomass or composition due to spike flow treatments.

The 31,000-cfs spike has been suggested to be of sufficient magnitude to negatively affect aquatic food base biomass and composition, particularly in the fall. The effect needs to be determined.

Ho: Mean mass of periphyton (predominantly *Cladophora glomerata*) will not differ between April (prior to the 31,000-cfs spike) and May (following the 31,000-cfs spike).

Ho: Mean chlorophyll *a* content in periphyton will be lower in May following the 31,000 cfs spike flow than in April.

Ho: Total diatom densities and densities of large/upright species will be lower in May following the 31,000-cfs spike flow than in April.

Ho: Abundance and distribution of submerged macrophytes will be lower in May following the 31,000-cfs spike flow than in April.

Ho: Densities of *Gammarus lacustris* will be lower in May following the 31,000 cfs spike flow than in April.

Ho: Densities of chironomid larvae, chironomid pupae, Oligochaetes, and Turbellarians will not differ between April (prior to the 31,000 cfs spike) and May (following the 31,000 cfs spike).

Periphyton and Aquatic Macrophytes

Benthic vegetation will be collected immediately prior to and immediately after the May 31,000-cfs spike flow. Samples will be collected below the 8,000-cfs flow elevation level using SCUBA gear from cobbles following methods of Angradi and Kubly (1994) and McKinney et al. (1999c) at RM -4.1 and -14.0 to determine AFDW and chlorophyll a content. We will also collect submerged macrophytes from depositional substrate (-3.5 mile) using a Hess sampler (McKinney et al. 1999c) to determine AFDW and chlorophyll a content. We will collect additional periphyton and macrophyte samples for analyses of diatom epiphytes by an appropriate contractor. We will qualitatively survey submerged macrophytes prior to and immediately following the 31,000-spring spike flow following standard methods.

If there is a fall (September) 31,000-spike flow we will repeat the sampling strategy used in the spring, sampling immediately prior to and immediately after the spike flow.

Macroinvertebrates

We will collect benthos with a Hess sampler at the same sites and times as periphyton and macrophyte samples following methods of McKinney et al. 1999c. Invertebrates will be identified, enumerated, and AFDW determined.

Deliverables for Spring Spike

Trip Reports (Short summary of field activities and observations)	May 31, 2000
Draft Spring Spike Final Report	Aug 16, 2000
Final Spring Spike Final Report	Oct 16, 2000

LSSF TREATMENT

Drift

Ho: The quantity and composition of drift will not significantly vary during the duration of the LSSF treatment.

Fluctuating flows are suggested to help maintain drift downstream by causing desiccation and subsequent renewed growth. If this is true, one would see a decline in quantity of drift over time under steady flows. Also the composition of the drift may change over time associated with different rates of senescence of benthos and macrophytes and tributary inputs.

Ho: The quantity and composition of drift during a LSSF treatment will not significantly vary in comparison with years of other steady or fluctuating flows.

Does magnitude of discharge matter or pattern of discharge affect drift quantity or composition? This hypothesis collects the same data as the above hypothesis, but compares it to other flows.

Drift will be collected quarterly between March and November using a metered net (0.5 m diameter, 1 mm mesh) while traversing a transect perpendicular to direction of river flow at minimal boat speed. Samples will be depth-integrated by slowly raising and lowering the weighted net following the methods of McKinney et al. 1999b. Replicate samples will be collected for chlorophyll a content and Ash Free Dry Weight (AFDW). Samples will be collected just upstream from Lees Ferry and if possible will be compared with samples collected using the methods of Shannon et al. (1996).

<u>Periphyton, aquatic macroinvertebrates, aquatic macrophytes.</u>

Ho: There will be no significant difference in biomass, densities or composition observed for the benthic and macrophytic communities due to a LSFF treatment.

Low steady flows may increase water clarity and allow for increase productivity, but the area available for productivity may be decreased by discharge, and result in no significant increase or change in the benthic and macrophytic community.

<u>Periphyton and Aquatic Macrophytes</u>

Benthic vegetation will be collected monthly (March through September and in November) from cobbles following methods of Angradi and Kubly (1994) and McKinney et al. (1999c) at RM -4.1 and -14.0 to determine AFDW and chlorophyll a content. We will also collect submerged macrophytes from depositional substrate (-3.5 mile) using a Hess sampler (McKinney et al. 1999c) to determine AFDW and chlorophyll a content. We will collect additional periphyton and macrophyte samples for analyses of diatom epiphytes by an appropriate contractor. We will qualitatively survey submerged macrophytes during March, June, August and November following standard methods.

<u>Macroinvertebrates</u>
We will collect benthos with a Hess sampler at the same sites and times as periphyton and macrophyte samples following methods of McKinney et al. 1999c. Invertebrates will be identified, enumerated, and AFDW determined.

Deliverables for LSSF Studies

Trip Reports: Within 2-weeks of completion of field sampling
Draft Final Report: February 28, 2001
Final Report: April 30, 2001

References

Angradi, T.R., and D.M. Kubly. 1994. Concentration and transport of particulate organic matter below Glen Canyon Dam on the Colorado River, Arizona. Journal of the Arizona-Nevada Academy of Science. 28:12-22.

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3. c. Algal colonization and recolonization response rates during experimental Low Summer Steady Flows. P.I. - D. Blinn, NAU and M. Yard, GCMRC (Estimated cost $5,000.)

JUSTIFICATION:

The availability and interaction of photosynthetically active radiation, 400 to 700 nm (PAR), and its functional role in primary production in this ecosystem is essential for developing a predictive primary production model. We are in the process of developing a model for Grand Canyon Monitoring and Research Center to predict primary production and the accretion of standing biomass for *C. glomerata* in the Colorado River aquatic ecosystem (Yard and Blinn 1997). This integrative approach is designed around modular programming that incorporates existing hydrological data, predictive relationships and secondary models for sediment transport, channel morphometry, substrates, flow routing, solar insolation, optical properties, and primary production curves. Some of our preliminary results indicate that the spatio/temporal patterns for primary production derived from our model are consonant with observed changes in benthic algal standing mass.

One of the essential algal response parameters lacking for this primary production model concerns the rate of colonization and recolonization. We are at present unable to account for colonization rates. Since this model functions mechanistically, it typically overestimates algal production in the fluctuating zone. Therefore, a critical factor in completing this primary production model is understanding if there are differential rates in colonization of the phytobenthos. Assumptions have been made that temporary flow modulation on a weekly or seasonal basis can increase the total wetted area, and consequently can be periodically beneficial to benthic production. Inversely so, the effects from temporary reduction in total wetted area on benthic biomass has been demonstrated to have significant negative effects owing to desiccation. However, data is insufficient for predicting recovery rates or colonization rates following a prolonged period of low or high flows.

There are three possible mechanisms for establishment and growth of algae in the Colorado River these are: (1) fragmentation from algal filaments, (2) zoospore production, and (3) sessile hold-fast growth from prior colonization. The primary mode of propagation known for *C. glomerata* in the Colorado River is through the process of fragmentation (Blinn *et al.* 1993, Shafer 1995). Sporogenesis in the major reaches of Glen and Grand canyons has rarely been observed (Shannon *et al*. 1994). The central questions we are asking is whether or not colonization and recolonization occur almost immediately upon substrate inundation, or if there are response lags in the accretion of algal biomass? And if so, what are the antecedent or ecological factors responsible for these differential rates?

The findings from our proposed research would provide the remaining empirical relationships that are necessary for completing a primary production model for the Colorado River in Glen and Grand Canyons. The study hypotheses for the Low Summer Steady Flows (LSSF) are identified below:

HYPOTHESES

Ho1: There is no lag time in the colonization rate of *C. glomerata* and associated epiphytes.

1A Ho: *C. glomerata* colonization is instantaneous on newly submerged substrate that has never been submerged or colonized previously.

1B Ho: *C. glomerata* colonization is instantaneous for submerged substrate previously colonized, but seasonally exposed and desiccated on an annual basis.

1C Ho: *C. glomerata* colonization is instantaneous on submerged substrate previously abraded and scoured of standing biomass but never exposed to desiccation.

METHOD

Our experimental design will include a repeated sampling approach using a series of 10 sampling periods scheduled at 2 week intervals. Under the proposed unmodified Low Summer Steady Flow test, the sampling regimen would begin May 1, 2000, and extend to September 18, 2000. We would use an experimental block design with three substrate types (NC B Never colonized (>100 y), PC B Previously colonized (< 1 y), and AC - Abraded and colonized) and one control. The experimental site would be established at the Lees Ferry/Paria cobble bar (RM 0.8). Cobbles for the NC treatment are accessible at the experimental site and can be readily obtained from the quaternary channel deposits. The PC treatment cobbles can be obtained from the previous year experiments. All of these cobble substrates will be translocated to the experimental site. The remaining treatment (AC) will be collected locally and scraped clean of all biomass at the beginning of initial sampling period.

All treatment types are to be stratified by group, and each group of cobbles are to be redistributed along 10 transects at depths of 1.25 to 1.5 m from surface. For each sampling period, twenty replicate cobbles will be randomly selected with depletion from each group (treatments and control), removed and scraped using a 4 cm diameter template. The replicate sample size of twenty per group per sampling period has been selected with no assumption of normality. The algal material will be dried, weighed and ashed for AFSM determination.

Compositional samples (n =2) will also be collected for each treatment and control group to characterize composition for each sampling interval. This sampling effort will address hypotheses 1 & 2. Additional samples will be collected prior to initiating the first high-extended flow event (April 1-31) and at the end of the experimental period following the high spike flow (October 1-5). Each of these sampling periods will provide information for addressing hypothesis 3.

DISCUSSION OF EXPERIMENTAL DESIGN

If algal establishment is due solely to fragmentation or zoospore production then rates of colonization and recolonization should be equivalent for all three types of substrate treatments. However, if colonization is due to zoospore production rather than fragmentation then the distribution of algal growth on the substrate should be notably apparent. Alternately, if colonization rates are due primarily to the retention of holdfast structures, we would expect to observe a significant difference in the response rates of biomass accretion between the varying substrate treatments.

Does exposure time and desiccation influence recolonization and the rate of biomass recovery for substrate that has been seasonally exposed in comparison with substrate that has been significantly reduced due to loss from velocity, sediment abrasion or senescence from prolonged periods of light reduction? We would predict that there would be a significant difference in biomass between newly submerged substrate (NC) in comparison with prior colonized substrates (PC and AC). Based on response differences, if holdfast structures are responsible for recolonization we should be able to determine if differences in holdfast viability varies for mechanically abraded versus seasonally exposed substrate.

IMPORTANCE OF THESE FINDINGS

The results from this *in situ* experiment would provide a better understanding of how primary producers such as *C. glomerata* and other phytobenthos would respond under varying flow conditions. Using a repeated sampling approach will provide resolute data at a smaller time scale on the recovery of standing algal biomass for *C. glomerata* and its extended response to the four-month experimental period at LSSF. These results would provide response rates related to flow conditions during periods of inundation, re-inundation and light exclusion for available channel substrate. If there are differential colonization or recolonization responses these temporal rates would further improve the predictive capabilities of this primary production model.

The findings and mechanisms developed from these LSSF would apply broadly to other types of flow scenarios. Therefore, we would be able to provide better estimates for predicting the effects of multiple experimental flow treatments (duration and magnitude), inclusive of not only steady flows (low and high), but also spike flows, and low and high fluctuating flows on the aquatic food base. Lastly, using the empirical data based on the control group response we can validate the predictions derived from the primary production model by using independent comparisons.

FIELDWORK SCHEDULE

All field collection, laboratory and analytical activities will be performed as a cooperative effort using Northern Arizona University (NAU) student personnel and Grand Canyon Monitoring and Research (GCMRC) personnel. NAU will provide for the physical facilities to perform the AFSM determination and compositional identification. All logistical transportation including vehicles and boats will be provided by GCMRC. The total number of estimated hours to complete the scope of work are identified below.

ACTIVITIES		PERSONNEL	
		NAU (1.5)	GCMRC(1)
Field Collection (14 d x 10 hr per day)			
	Subtotal Hours	200	140
Laboratory			
	Subtotal Hours	150	50

Composition/Density			
	Subtotal Hours	N/A	44
Data Entry & Analyses			
	Subtotal Hours	20	20
Model Computations			
	Subtotal Hours	N/A	48
Report Writing			
	Subtotal Hours	N/A	48
	TOTAL Hr.	**370**	**400**

SCHEDULED DELIVERABLES

Draft-report	February 1, 2001
Final report	March 15, 2001

Appendix 10

4.a. .Effect of steady flows on growth, relative abundance and distribution of young-of-year fish along shoreline below the Little Colorado River. P.I. - R. Valdez and S. Carothers, SWCA. (Estimated cost $300,000.)

INTRODUCTION

This proposal describes the SWCA field sampling design for evaluating the benefits of a low steady summer flow (LSSF) experiment on native fish, particularly the endangered humpback chub (Gila cypha). This evaluation will be conducted on the Colorado River through Grand Canyon from June through September 2000. Water will be released from Glen Canyon Dam at flow rates of 17,000 cfs from April through May with an intervening 4-day spike of 31,500 cfs. Flow rates from June through October will be a steady 8,000 cfs with a 4-day spike during mid- to late September. Releases from Glen Canyon Dam before and after the LSSF will comply with modified low fluctuating flows (MLFF).

1.1 Purpose

The purpose of the low steady summer flow experiment is to implement Element 1.A of the 1995 Biological Opinion for the Environmental Impact Statement on the Operation of Glen Canyon Dam. The experiment will test the overriding hypothesis that high spring releases and low steady summer flows in low water years will benefit the endangered and other native fish species in the Colorado River through Grand Canyon.

1.2 Hypotheses

The following hypotheses are to be tested:

Ho1: There will be no mainstem reproduction by native fish as a result of the LSSF.

Ho2: There will be no significant differences in growth of young native fishes between the LSSF and MLFF.

Ho4: There will be no significant increase in catch rate of nonnative fishes during the LSSF, or between the LSSF and MLFF.

Ho5: There will be no significant difference in shoreline habitat use between LSSF and MLFF.

Ho6: There will be no significant difference in condition of native fish during the LSSF, or between the LSSF and MLFF.

Ho7: There will be no significant difference in catch rate of nonnative fishes before and after the fall spike.

Ho8: There will be no significant difference in predation on young humpback chub between the LSSF and MLFF.

Ho9: There will be no significant movement of nonnative fishes upstream from Lake Mead.

1.3 Objectives

The objectives of the LSSF experiment for the 5-month steady flow period of 8,000 cfs are to:

1. Assess mainstem reproduction of native fishes.
2. Measure growth of juvenile native fishes.
3. Estimate relative abundances of native fishes.
4. Assess survival of juvenile humpback chub.
5. Assess relative condition of native fishes.
6. Estimate relative abundance of nonnative fishes and seasonal populations of brown trout at Bright Angel and channel catfish at the LCR
7. Evaluate and assess predation on native fishes.
8. Evaluate invasion of nonnative fishes from Lake Mead.

2.0 METHODS

2.1 Study Area

The study area is the Colorado River through Marble and Grand canyons, and the major tributary inflows. Sampling will be conducted in six mainstem reaches to address the stated objectives. Within these reaches both mainstem and tributary inflows will be sampled. The six reaches are:

1. 30-Mile
2. Saddle Canyon to LCR
3. LCR Inflow to Lava/Chuar
4. Lava/Chuar to Hance Rapid
5. Bright Angel to Diamond Creek
6. Diamond Creek to Bridge Canyon

Sampling will also be conducted in six primary tributary inflows including:

1. Paria River
2. Little Colorado River (LCR)
3. Bright Angel Creek
4. Shinumo Creek
5. Kanab Creek
6. Havasu Creek.

2.2 Sample Periods

Sampling will be conducted monthly from June through September 2000, and January, 2001, according to the following schedules (see Table 1).

June-September Trips

Day 1: Drive Flagstaff to Lees Ferry, rig boats
Day 2: Launch and travel to 30-Mile to assess spawning by humpback chub
Day 3: Assess spawning by humpback chub at 30-Mile
Day 4: Travel and sample backwaters between Saddle Canyon and LCR inflow
Day 5-9: Implement intensive sampling design from LCR inflow to Lava/Chuar
Day 10: Travel and sample Bright Angel Creek area mainstem and inflow
Day 11: Travel and sample Shinumo Creek area mainstem and inflow
Day 12: Travel and sample Kanab Creek area mainstem and inflow
Day 13: Travel and sample Havasu Creek area mainstem and inflow
Day 14: Travel and sample Granite Park mainstem area
Day 15: Travel to Diamond Creek (camp above DC and sample mainstem)
Day 16: Take out at Diamond Creek and drive to Flagstaff

July-September Trips to Evaluate upstream movement from Lake Mead

Day 1: Drive Flagstaff to Diamond Creek, sample DC area.
Day 2: Launch and travel to Bridge Canyon, sample en route
Day 3: Sample Bridge Canyon area, Spencer Creek area
Day 4: Sample Spencer and Surprise Canyon areas, sample en route to Pearce Ferry area
Day 5: Take out at Pearce Ferry and drive to Flagstaff

Table 1. Purpose of sampling trips.

Sample Trips
Purpose of Trip(s)
June, July, August, September, October, November, December, January
Assess spring elevation and spawning at 30-Mile
Assess nonnative fish in backwaters from Saddle Canyon to LCR inflow
Implement intensive sampling design from LCR inflow to Lava/Chuar
Sample tributaries. Estimate relative abundance of nonnative fishes and estimate populations of channel catfish at LCR. Evaluate upstream invasion of nonnative fishes from Lake Mead
July & September
Evaluate upstream invasion of nonnative fishes from Lake Mead

The June trip will determine the sample site locations for replication during subsequent field efforts. The May spike flow will reshape near shore habitats precluding the use of past sampling sites for the LSSF experiment.

Sampling efforts will be consistent with established protocols for Grand Canyon Sampling as outlined in Valdez and Ryel (1995) and others. Electrofishing will be conducted at dawn, dusk and night with short habitat specific efforts replicated. Minnow trapping will be habitat specific with traps set in the afternoon and checked in the morning. Seining efforts will be habitat specific with area sampled and length of seine recorded to determine area sampled.

1.3 Tasks By Objective

The following tasks will be addressed for each of the stated objectives of the LSSF experiment:

Objective 1: Assess mainstem reproduction of native fishes.

Task 1a: Sample for larvae near 30-Mile Spring and in LCR inflow and mainstem..

The LSSF is hypothesized to result in warmer mainstem temperatures than MLFF, and could result in mainstem reproduction by native fishes. Shorelines will be sampled with fine mesh dip nets and small mesh seines to determine the presence or absence of larval fish.

Objective 2: Measure growth of juvenile native fishes.

Task 3a: Capture and measure juvenile native fishes monthly.

Fish will be sampled along shorelines monthly and juvenile humpback chub, flannelmouth suckers, and bluehead suckers will be measured to total and standard length. Average lengths of age groups 0, 1, and 2 will be determined monthly from June through January to determine monthly growth rate as millimeters per 30 days. This growth rate will be compared with similar data collected under MLFF during previous investigations (Valdez and Ryel 1995, Arizona Game and Fish Department 1996, Gorman 2000).

Objective 4: Estimate relative abundances of native fishes.

Task 4a: Compute monthly catch rates of native fishes under sampling design to be determined.

Average catch rates of fish that are sampled monthly along shorelines (see Task 1a) will be computed for minnow traps, electrofishing, and seines (see LCR Sampling Design). Catch rates for minnow traps will be based on pods of 5 traps and expressed as fish per 10 hours of sets. Catch rates for electrofishing will be expressed as fish per 10 hours of electrofishing. Catch rates for netting will be expressed as fish per 100 feet of net per 10 hours effort.

Objective 5: Assess survival of juvenile humpback chub.

Task 5a: Determine survival rate from average monthly catch rates of age-0 humpback chub.

Survival rate will be determined from average monthly catch rates, using a Von Bertlanfy survival model. Survival will be determined for the months of July through January. This will provide an assessment of survival of age-0 humpback chub for the 4-month low steady flow period, as well as for the overwinter period.

Objective 6: Assess relative condition of native fishes.

Task 6a: Weigh and measure all native fishes captured.

Relative condition will be computed by deriving constants from a representative population sample. Relative condition will be assessed only for native fishes greater than 200 mm TL.

Objective 7: Estimate relative abundance of nonnative fishes and population estimates of and channel catfish.

Task 7a: Sample shorelines with minnow traps, trammel nets and electrofishing

Geometric mean catch rates will be computed for minnow trap, netting, and electrofishing catches, as fish per 10 hours of trapping, fish per 100 feet of net per 10 hours effort, and fish per 10 hours of electrofishing, respectively. Catch rates will be evaluated using mean monthly catch rates in trend analysis by testing for a slope significantly different from zero. Population estimates for channel catfish will be made using closed population models (i.e., CAPTURE)

Objective 8: Evaluate and assess predation on native fishes.

Task 8a: Examine stomachs of large predatory fish.

Large predatory fishes, such as brown trout, rainbow trout, channel catfish will be captured, sacrificed, and their stomach contents examined. Stomach contents will be identified to the most resolute taxa possible, and percent of food items by percent of total and by volume will be determined.

Objective 9: Evaluate invasion of nonnative fishes from Lake Mead.

Task 10a: Sample Bright Angel to Bridge Canyon.

The Colorado River from Bright Angel to Bridge Canyon will be sampled to determine if nonnative fishes are moving upstream from Lake Mead during the LSSF. Tributaries, including Travertine and Diamond Creek will also be sampled as well as mainstem sites around primary tributaries and Granite Park.

2.4 Intensified Sampling Near LCR Inflow

Intensified sampling will be conducted for 5 days of each monthly trip near the LCR inflow to address objectives 3, 4, and 5; i.e., measure growth, abundance, and survival of native fishes, especially humpback chub. Four principal shoreline habitats will be sampled in the LCR to Lava/Chuar reach, including talus, debris fans, vegetated shorelines, and backwaters. Sand beaches

will be sampled during invasion of vegetation to assess reinvasion of vegetated habitats by juvenile humpback chub.

Four subreaches will be selected for each habitat type as repetitions (Table 2). Each will be sampled with minnow traps, boat electrofishing, seining and mini hoop nets. (Table 3).

3.0 Nonnative fish abundance and population estimates

Relative abundance and catch per unit effort estimates will be made for all nonnative fish species at all sample sites, emphasizing small bodied fishes in the LCR reach and including large fishes below Bright Angel Creek. Population estimates will be determined at the LCR in June and September for channel catfish using a variety of techniques, including electrofishing, trammel and hoop netting, angling and trot lines.

4.0 Contingency Planning

Should unanticipated short-term high flows be experienced, sampling will be continued as proposed. These flows could be the result of monsoon events causing flooding from tributaries or unanticipated emergency releases from Glen Canyon dam. Records will be kept as to timing and extent of these events and factored in when analyzing data from these periods. Depending on the extent and magnitude of these events, responses from native and nonnative fishes may be observed.

4. b. Monitoring of Colorado River fish community. P.I. Native Fish monitoring workgroup, GCMRC, et al. (Estimated cost $90,000).

Hypotheses to be tested:

Ho: Condition factor of native and non-native fish species will not change significantly during the experimental flow period.

Condition factor is a measure of food availability over time and is most likely to be reflected in older fish.

Ho: Spike flows following steady flow conditions will not actively displace non-native fish species in near shoreline nor backwater habitats for prolonged periods of time.

Spike flows of a magnitude of 31,000 cfs are recommended to remove small bodied exotics and reduce the competitive advantage these species may have incurred over the course of steady flows.

The interim monitoring plan include measuring recruitment in the LCR of native fish in the spring and mainstem trips in the winter and fall to evaluate distribution and condition prior to spring spawning and subsequent overwintering. Data collected in the LCR will be useful to understand year-class recruitment prior to entering the mainstem. These data will be important for Project 4a regarding YOY in the mainstem. The January trip and September trips will be used to address questions about condition and distribution of fish in the mainstem. In addition to the LCR work, three mainstem efforts will include sampling to determine predator population estimates (brown and rainbow trout, primarily) as well a population distributions for all fish species. Data collection in the mainstem work will be accomplished by Arizona Game and Fish Dept. The September trip takes place four days following the fall spike and will evaluate the distribution of fish collected then to historic distribution patterns. Data collected below the LCR in the mainstem (Project 4a) will be collected again on this September trip. The more intensive sampling at these sites will be used to quantify relative abundance of small bodied fish following a power plant capacity spike. The following is a summary of the interim monitoring plan.

EXECUTIVE SUMMARY
INTERIM FISH MONITORING PLAN (FY2000-2001)

INTRODUCTION

The primary purpose of this Interim Fish Monitoring Plan is to continue certain data collection activities deemed essential in monitoring the ecology and certain life history stages of fishes in Glen and Grand Canyons. An emphasis will be directed toward monitoring the status and trends of the native fish assemblage, humpback chub (*Gila cypha*), flannel mouth sucker (*Catostomus* *latipinnis*), bluehead sucker (*C. discobolus*), speckled dace (*Rhinichthys osculus*) and other non-native fishes considered as predators, competitors and pathogenic vectors.

The scope of work describe herein is to function as an interim monitoring effort until GCMRC completes the evaluation and study design essential for developing a Fish Long-term Monitoring Plan (FLMP). The interim sampling design maintains certain monitoring components from the previous and ongoing monitoring programs (AGFD 1996; Hoffnagle, *et al.* 1996; Gorman, *et al.* 1999). We intend to implement certain monitoring recommendations regarding specific gear types, sampling methods and protocols to meet specific monitoring objectives previously advised (Valdez and Cowdell 1995; Valdez and Carothers 1998).

The interim monitoring plan is based on the objectives stated below.

Little Colorado River

1. Assess abundance, distribution, growth and condition/health of native fishes in the LCR.
2. Assess reproductive capacity and success of the native fish in the LCR.
3. Assess year class strength of early life stages and recruitment of native fish in the LCR.

Colorado River Mainstem

4. Assess abundance, distribution, growth and condition/health of adult native fishes in the mainstem of Colorado River and primary tributaries.
5. Assess the relative abundance of non-native fishes in the mainstem of Colorado River and primary tributaries.
6. Assess the relative abundance, distribution and survivorship of early life stages of native fish in the tributaries and mainstem of the Colorado River.

Hypotheses to be tested:

Ho: Condition factor of native and nonnative fish species will not change significantly during the experimental flow period.

Condition factor is a measure of food availability over time and is most likely to be reflected in older fish.

Ho: Spike flows preceding and following steady flow conditions will not actively displace non-native fish species in near shoreline nor backwater habitats for prolonged periods of time.

Spike flows of a magnitude of 31,000 cfs are recommended to remove small bodied exotics and reduce the competitive advantage these species may have incurred over the course of steady flows.

STUDY AREA

Colorado River Mainstem: Six study sites have been selected in the Colorado River mainstem based on the distribution patterns of specific humpback chub aggregations (Valdez and Ryel

1995). Multiple day sampling will occur at three sites, the LCR tributary (RKM 0.0 – 15.0), LCR Inflow area (RM 59.2 – 65.2), Middle Granite Gorge (RM 126.1 – 127.5) and Havasu Creek (RM 153.5 – 159.9) sites. The other three sites 30-Mile (RM 26.5 – 35.9), Bright Angel Creek (RM 86.5 – 89.0) and Shinumo Creek (RM 107.8 – 109.8) will be sampled for only a single day.

Little Colorado River: The effective reach length of the LCR totals 15 km in distance and has been subdivided into five 3 km sections, sequentially A, B, C, D and E. Section A (0.0 to 3 km) encompasses the Little Colorado River (LCR) confluence and is associated with the coverage for GCMRC GIS Reach 5. The remaining four study sections are located in Reach 15 (RM 1.2 to RM 12) and extend upstream 15 km to a series of travertine dams that acts as a physio/chemical barrier to fish movement.

SAMPLING SCHEDULE

The sampling schedule is based on two Colorado River mainstem trips and three trips in the Little Colorado River.

Year 2000

Trip 1. Mainstem (January 11 – 27)*
Trip 2. LCR (April 1 – 10)
Trip 3. LCR (May 15 – 24)
Trip 4. LCR (July 1 – 10)
Trip 5. C.R. Mainstem (September 10 – 26)

*****three additional mainstem trips have been scheduled for this summer's work. The trips occur in June, July and August.

METHODS

Three types of macro-habitat units will be sampled these are vegetation, talus, and debris fans in accordance with the findings of Converse *et al.* (1998). The shoreline and hydraulic units are consistent with the macro-habitat descriptors implemented by Valdez and Ryel (1995) and used during the transitional monitoring program (1995 – 1999), (Hoffnagle, et al. 1996; Gorman, et al. 1999). As recommended by Valdez and Cowdell (1995) the sampling effort for each gear type will be equally distributed between these three different habitat types.

Using a purely randomized sampling approach tends to have the effect of overestimating the population variance since fish are not homogeneously distributed throughout the available habitat (Valdez and Ryel 1995; Stone 1999). Therefore, we intend on using a stratified random approach where net point locations will be selected randomly from a list of previously sampled sites (stratified) that are representative of the three shoreline habitats (debris fans, talus slopes and vegetative shorelines) and hydraulic unit (i.e., eddy complex, runs and riffles), (Valdez and Ryel 1995; Sharber and Black 1999). This type of sampling design may not be appropriate if the particular habitat types (debris fans, talus slopes and vegetative shorelines, etc.) are not representatively utilized by the non-native fish community. For this reason, we will evaluate if there is a sampling bias associated with a particular habitat type in determining abundance indices for both native and non-native fish. The FLMP group will perform this type of analysis prior to the September trip.

Gear Type Use and Justification

Trammel nets are a very effective means to capture adult fish that are not otherwise sampled using other gear types in the Colorado River mainstem. Two types of trammel nets will be used (50'x 6'x 1.5"x 12") and (50'x 6'x 1"x 12") selected based on their high CPUE from previous studies (Valdez and Ryel 1995). Trammel nets will be set for 2 hr intervals consistent with previous sampling protocols and individual nets will be periodically substituted and cleaned when fouled with debris. Five nets (2/hr set) will be set sequentially during the crepuscular periods (evening and morning). One set of five nets during the morning and two other sets of five during the evening for a total of 15 net sets/day.

GCMRC will continue to utilize electrofishing as a method for collecting data to determining relative abundance of YOY occupying near shore habitat utilizing the three macro-habitat types as suggested by Valdez and Cowdell (1995). The electrofishing boat used will be identical in design (Achilles, SU-16), electrical configuration and voltage pulsation (Coffelt, CPS) to the technical boat developed and used during the GCES Phase II research and monitoring effort. The CPS system generates a pulse train of three 240 Hz, 1.6-ms pulses every 15th of a second and is quite effective at reducing electrofishing induced injuries related to the use of this equipment (Sharber and Carothers 1988; Valdez, et al. 1991; Snyder 1992; Cowdell and Valdez 1994; Sharber and Black 1999).

Variability in capturing the smaller size class of fish has been observed to be spatially and temporally variable in the Colorado River mainstem (Valdez, et al. 1995; Hoffnagle, et al. 1996). Valdez and Ryel (1995) identified that predation was possibly limiting survivorship of YOY and juveniles dispersed into the Colorado River mainstem. It was presumed that only larger subadults dispersed or those that actively moved from the LCR were the cohort proportion that potentially maintained successful recruitment in the mainstem. Stone (1999) noted that in the LCR there were also distinct differences in habitat use by YOY and juveniles compared to adults (≥ 200 mm). Since the use of mini-hoopnets (dimensions: 50 cm diameter x 100 cm length x 0.06 cm mesh) in the mainstem have been shown to be a very effective method for capturing the larger size class of subadults that had been previously under sampled (Gorman et al. 1999), the use of this gear type will be continued in order to avoid sampling gear bias.

Seines will be used at specific downstream sites that have consistently been sampled as part of AGF monitoring program (1993-97: Hoffnagle *et al.* 1996), and partially continued by FWS (1998-99: Gorman *et al.* 1999). Utilizing seines as a method will provide for the continuation of presence/absence, relative densities and spatial distribution information for both native and non-native fishes occupying similar backwater habitats. The sampling frequency and site locations are well documented and spatially referenceable in the GCMRC Geographical Information System.

The use of passive integrated transponders (PIT) as a method for mark-recapture estimates for abundance, relative year class strength, recruitment, growth and movement in the Colorado River mainstem and associated tributaries will be continued for all native fish (>150 mm), (Burdick and Hamman 1991).

Additionally, all other non-natives (i.e., channel catfish, brown trout, rainbow trout, fat-head minnow and common carp) will continue to be monitored for relative abundance and condition at these specific sites.

Standard measures will be collected in the field, these parameters include: species identification, total and standard length (mm), weight (g), sex, recapture (Y/N), parasite presence, gear type, effort, spatial coordinates, date/time, and habitat characteristics (Brown et al., 1995).

Logistics and Technical Support

GCMRC will continue to provide all of the necessary logistical support, technical equipment and supplies inclusive of helicopter and white-water raft transport, technical sport boats (i.e., electrofishing and netting boats), sampling gear, equipment and supplies. This will enable the operational use of specialized motorized boats (GCMRC technical research boats), safe access and efficient deployment of specific gear types. GCMRC expects that the logistical support will require two large motor boats (33 ft) operated by 30 hp Honda outboards (4-stroke) owing to the amount of sampling gear, logistical and camp supplies, and trip schedule length (18 d). Two technical sport-boats will be used for conducting electrofishing and netting (16 – 17 ft) operations, powered by a 50 hp outboard (4-stroke). The operational use of these boats will follow the previously established protocols which meet all of the requirements prescribed by NPS.

SAMPLE DESIGN

The design of the interim monitoring plan emphasizes spatial and temporal consistency with past research studies (Valdez and Ryel 1995; Douglas and Marsh 1996; Gorman 1994; Hoffnagle *et al.* 1996) and other transitional monitoring programs (Valdez and Cowdell 1995; Gorman *et al.* 1999). The level of monitoring effort we propose is considered sufficient enough to maintain continuity with historical data collection activities, analyses and interpretation of past efforts that monitored the status and trends of fish populations in Glen and Grand Canyons.

It has been identified that adults of all four native species use both tributary inflows and spring habitat (Valdez and Carothers 1998; Valdez et al 1999; Douglas and Marsh 1996, 1998; Clarkson and Robinson 1993; Gorman 1994). A significant relationship exists between sub-adult densities and shoreline types (vegetation, talus, and debris fans), (Converse et al. 1998). Shoreline types were more indicative of fish densities for YOY than geomorphic characteristics (Valdez and Ryel 1995). Valdez and Carothers (1998) identified that the various life stages of the four native fish species correspond spatially and temporally to that of the focus species, humpback chub. For this reason, the sampling design will be focused around the life-history stages of humpback chub (Valdez and Carothers 1998; Valdez et al 1999).

The temporal spacing of the data collection effort will be distributed in each of the three hydrographic periods, March-May, June-September and October-February. The interim monitoring effort scheduled for FY-2000 consists of three Little Colorado River (LCR) trips (April, May/June, and July) and two Colorado River mainstem trips (January, and September). The LCR monitoring trips are specifically designed to address Monitoring Objectives (MO) 1, 2 and 3, whereas the Colorado River Monitoring Trips will address MO 4, 5 and 6. Emphasis will be placed on sampling representative tributary inflow areas because all native and some non-native fish utilize these tributaries for spawning and rearing habitat.

Monitoring, young-of-year (YOY) and juveniles, (0, I, & II) age-classes of native fish in the Colorado River mainstem will be restricted to and below the LCR and inflow area (GIS Reach 5), and at specific mainstem sites (30-Mile and Middle Granite Gorge) and tributary sites (Bright Angel Cr., Shinumo Cr., and Havasu Cr.).

The Colorado River Mainstem

Six study sites have been selected in the Colorado River based on the distribution patterns of specific humpback chub aggregations (Valdez and Ryel 1999). Multiple day sampling will occur at three sites, the LCR Inflow, Middle Granite Gorge and Havasu Creek sites. The other three sites 30-Mile, Bright Angel Creek and Shinumo Creek will be sampled for only a single day. The mainstem aggregations of interest are: 30 Mile, LCR Inflow, Bright Angel Creek, Shinumo Creek, Middle Granite Gorge and Havasu Creek aggregations.

Backwater sampling

Flow fluctuations have altered the quantity and quality of available backwaters and other near shoreline habitat used by YOY and juvenile fishes and owing to the ephemeral nature of these habitat types their actual habitat value and predictability in this system remains uncertain (Maddux, et al. 1987; Valdez and Ryel 1996 Hoffnagle, et al. 1996). The emphasis of sampling backwaters will be to assess the relative abundance, distribution and survivorship of early life stages of native fish dispersed from the tributaries throughout the Colorado River mainstem. If available, the sites that will be sampled are 44.27L, 58.68L, 60.85L, 64.27L, 66.85L, 159.93L, 166.86R, 167.83R, 186.00R, 187.53R, and 194.13L. These backwater sites have consistently been sampled as per the research and interim monitoring program instituted by Arizona Game and Fish Dept in conjunction with Bio/West (AGFD 1996; Valdez and Cowdell 1995).

Tagging methods

Alternate tagging methods other than PIT tags will be evaluated for their feasibility on marking smaller size fish using unique combinations to distinguish recapture and movement patterns. Some of the marking methods will include coded wire tags, dyes and fin clipping.

Minnow Traps

A combination of electrofishing and mini-hoop nets appears to provide adequate representation of YOY and subadults relative abundance. If minnow traps (dimensions: 23 cm diameter x 45 cm length) are continued in the mainstem they will be set and checked at 12 hr intervals (morning and evening) and repetitively run at the same locations during the entire period of deployment. Deployment periods in the Colorado River mainstem will vary depending on the sample location. A cluster or pod of five MT will be considered a single sample. The use of this pods method is described in detail by (Valdez and Cowdell 1995; Valdez and Ryel 1995). However, this gear type will continue to be used in the LCR specifically associated with the spatially blocked section (D) using cross-sectional transects.

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Appendix 12

4. c. Coupling Hydrodynamic and Individual-Based Fish Movement Models for the Evaluation of the Effects of Flow and Temperature Releases from Glen Canyon Dam on the Accessibility of Suitable Habitat for Humpback Chub Juveniles in the Colorado River.
P.I. - Josh Korman, Ecometric Research and Stephen Wiele, USGS. (Estimated cost $40,000)

Ho: Current velocities will increase in tributary confluence areas under higher mainstem flows.

Valdez et al. In prep recommends a high spring steady flow to pond tributaries and retain young of the year, assuming that velocities will be reduced in tributary confluences. This hypothesis could be tested with flows at 17,500 cfs or higher and if flows are reduced to 14-12 cfs for a sustained period of time.

Ho: Current velocities for near shoreline habitats (e.g., talus, debris fans, vegetated shoreline) will not differ significantly between fluctuating and low steady flow conditions.

Low velocity habitats are assumed to be a requirement of young fish. Decreased velocities presumably accompany lower discharges. The lower velocity environments may be reflected in an elongation of a particular low velocity environment or an increase in the number of these environments.

Dispersal of juvenile humpback chub from the Little Colorado River (LCR) into the mainstem Colorado River is hypothesized to be the major contributor of fish to downstream aggregations of adults (Valdez and Ryel, 1995). The relationship between sub-adult chub and mainstem habitat has been characterized by Converse et al. (1998) who found that juvenile chub preferred low-velocity shorelines near vegetation, talus, and debris fan shorelines. Recruitment of young fish reared in the mainstem may be dependent on their ability to access and remain in such habitats, and for recruitment to the LCR population, these sites need to be in proximity to the LCR confluence.

Operation of Glen Canyon Dam has the potential to greatly influence the ability of juvenile chub to access and remain in suitable habitats through two mechanisms. First, changes in flow affect mainstem current velocities and the ability of young chub to randomly drift into, or actively seek suitable habitats and remain there. Second, reduced water temperatures caused by the release of hypo-limnetic water behind GCD impair juvenile swimming performance (Bulkley, et al. 1982, Valdez and Ryel, 1995) and therefore potentially reduce their ability to gain access to, or remain in, suitable habitats.

Ideally, a long-term large-scale field experiment would test the effects of flow and temperature on the survival of juvenile chub in the Colorado River below GCD. Such an experiment would consist of measuring the contribution of large numbers of tagged juvenile chub to adult recruitment across years where mainstem flow and temperature conditions had been purposely manipulated. We propose that a modeling approach be taken as an interim measure until the large-scale experiment can be conducted. We propose to couple an existing multi-dimensional hydrodynamic model with an individual-based model (IBM) of juvenile fish swimming movement to examine the effects of flow and water temperature on the ability of juvenile chub to access and remain in suitable rearing habitats in the Colorado River downstream from the LCR.

The underlying assumptions of our modeling approach are: (a) accessing suitable habitat provides a survival advantage; and (b) the survival advantage results in a significant contribution to adult chub recruitment. Until such time when the large-scale experiment becomes feasible to test these assumptions, the modeling approach we describe provides the only short-term means of evaluating whether proposed GCD operation changes (e.g., installation of a temperature control device, steady low flows in summer) are even in the right ballpark.

Model development

The hydrodynamic component of the model simulates a two-dimensional steady flow field as a function of bathymetry and flow. The IBM simulates the movement of individual fish as effected by current velocities (predicted from the hydrodynamic model) and different assumptions of swimming behavior (speed and direction). At the start of the simulation, a finite number of 'fish' would be distributed across the grid cells at the upstream end of the modeled grid. As the simulation proceeds, the fish paths would be calculated based on current velocities predicted by the hydrodynamic model, as well as assumptions about their active swimming behavior (Figure 1). The model would keep track of the percentage of fish from the start of the simulation that reached the shoreline or a suitable low velocity environment (based on criteria from Valdez and Ryel 1995, p. 7-26). Information on shoreline substrate type and vegetation recently compiled by L. Stevens (unpublished data, Grand Canyon and Monitoring Center) will be overlaid on the modeled area to provide an index of habitat quality (from data in Converse et al., 1998) for fish retained in the area (i.e., not drifting downstream). The 'percentage retained' and suitability statistics provide a surrogate for juvenile chub survival under specific flow and temperature conditions, subject to the assumptions described above. The simulations would be repeated across a range of discharges (which affect the flow field) and water temperatures (which affect swimming speed) to quantify the effects of historic changes in these variables (pre-dam vs. post-dam) and potential changes under likely future experimental scenarios (e.g., steady summer low flows, installation of a Temperature Control Device).

To model swimming behavior, each individual particle would be randomly assigned a swimming velocity and one of four different swimming behaviors: (a) passive (drifting particle, no active movement); (b) random movement (swimming, but in a random direction); (c) 'geotactic' - swimming in a cross-stream direction towards the nearest bank; or (d) 'rheotactic' - swimming in the direction of the slowest moving water. To simulate the effects of reduced water temperatures due to GCD releases (or enhanced temperatures from a TCD), standardized swimming speeds will be modified based on the temperature effects measured by Bulkley, et al. (1982).

The areas that we can simulate will be limited to locations where detailed bathymetry data have been collected. We have data for at least 9 mainstem sites ranging from ½ to 1 km long, between the LCR (river mile 61.3) and Unkar (river mile 72.5). It is unlikely that juvenile chub have the swimming ability to disperse upstream of the LCR when they enter the mainstem Colorado, making the LCR confluence a reasonable upstream boundary for the study reach. The calculation of flow fields in the study sites will be accomplished with a model that has been developed and applied to the study of erosion and deposition in kilometer scale reaches in the Colorado River in the Grand Canyon (Wiele et al., 1996; Wiele, 1998; Wiele et al., 1999). The model has shown good accuracy in its predictions of locations and rates of erosion and deposition, processes that are extremely sensitive to the flow field. For this project, only the flow component of the model will be used. The flow is calculated as a vertically averaged, two-dimensional flow field.

Summary of Proposed Tasks

1. assemble and process bathymetry for modeling
2. development of IBM and modification of flow model
3. field experiment to test hydrodynamic component of flow model, may use fish capture data (project 4a) for validation.
4. tabulation and analysis of modeling results
5. writing of manuscript describing results

Expected Results/Products

An interpretive report describing modeling results and analysis will be submitted to the GCMRC at the end of the contract period.

Project Duration

We would plan to complete the work described herein within one calendar year after award of the contract.

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4. d. Effect of LSSF on Lees Ferry trout. P.I. - B. Persons and D. Speas, Arizona Game and Fish Department. (Estimated cost $17,967.)

We propose to address the following hypotheses using our standardized monitoring with the addition of one sampling trip at the initiation of the LSSF hydrograph.

Ho1: Catch per unit effort of all size classes of rainbow trout will not differ from that observed during 1991-1999.

The original hypothesis in the planning document was:

Ho: Relative frequency of young-of-year trout will not vary significantly during the entire experimental flow period inclusive of spike and LSSF.

Detection of the loss of a year-class of rainbow trout may take a year to detect in the fishery depending on the mechanism that affects loss of a cohort. Therefore we will examine catch rates of all size classes of fish. If there is a year-class failure that occurs after implementation of the experimental flow period our monitoring program should be able to detect it.

Ho2: Relative condition factor (Kn) of rainbow trout will not differ from that observed during 1999.

Decreases in relative condition factor (Kn) might indicate increased competitive interactions.

Ho3: Growth rate of rainbow trout will not differ from that observed during 1991-1999.

Decreases in growth rate might indicate increased competitive interactions.

Ho4: Proportional Stock Density (PSD) or size structure of the population will not differ from that observed during 1991-1999.

Changes in PSD would indicate shifts in the size composition of the fishery and might signal loss of a year class or cohort.

Ho5: Relative gut volume (RGV) of major food taxa will not differ from that observed during 1991-1999.

RGV can be used to determine changes in diet during the LSSF experiment compared to previous years of fluctuating flows.

We propose to sample the trout fishery by electrofishing following standard monitoring procedures (McKinney et al., 1999a) to assess changes in catch-per-unit-effort indices, size class structure, and condition factor. Our current sampling strategy calls for three sampling trips in 2000 during April, August, and November. We will move our normal April sample to March and to add a June sample to increase our ability to detect responses to the Low Summer Steady Flow test. We will not be able to separate effects of 31,000 cfs spike flows from the 8,000 cfs steady flows under this approach, but instead will assess the overall effect of the annual flow regime on the fishery. These data collection efforts will record similar data for any flannelmouth suckers encountered during sampling efforts.

Deliverables

Trip Reports:	Within 2-weeks of completion of field sampling
Draft Final Report:	November 30, 2000
Final Report:	January 30, 2001

Budget Information (AGFD):

Budget Information Summary (AGFD)	
Personnel	$ 9,792
Fringe benefits	$ 3,264
Travel and vehicle mileage	$ 3,580
Supplies	
Equipment	
Total direct costs	$16,636
Indirect costs	$ 1,331
Total costs	$17,967

Appendix 14

B. LAKE POWELL STUDIES: Effects of low summer steady flow experiment on the stratification, composition, and hydrodynamics of Lake Powell, and the downstream effects of that limnology. P.I. - S. Hueftle and B. Vernieu, GCMRC. (Estimated cost $40,000.)

Hypothesis to be tested:

Ho: Shifts in discharge ramping rates and magnitudes will not effect Lake Powell's stratification, hydrodynamics or composition (physical, chemical, biological); nor influence tailwater quality.

Areas of study:

1) Discharge related seiche effects on stratification or hydrodynamics of Lake Powell.
2) The withdrawal zone dimensions effected by changes in discharge rates.

Justification:

Seiches (internal waves) induced by significant changes in discharge can be measured, in terms of both magnitude and periodicity, by tracking fluctuations of the thermocline of Lake Powell. A thermistor string at the Wahweap forebay station as well as one or two stations uplake (Oak @ 90 km, Escalante @ 117 km) will track the wave and it's effects upstream. This effort would be focussed at the upramp and downramp phases of the ** block and spike flows in March-April and September. It would be left in place over the summer and potentially longer to separate background effects of wind-induced seiches. The thermistor string will also be used, in conjunction with the existing Hydrolab probes continuously monitoring in the dam, to extrapolate the withdrawal plume's dimensions. This effort will be augmented by periodic profiling on the lake to define effects to parameters other than temperature.

Cost: 7-12 thermistors per station with duplication to account for losses

30-40 thermistors	$100 x 40	$4,000
Hardware for deployment		$500
Person Hours for calibration, deployment, maintenance, download, data processing and analysis.		$20,000

Maintenance through summer:
Decommissioning:

Logistic support: Boat availability on lake for monthly downloads, possibly available in-house
Buoy's at each station would be required for deployment-this would require cooperation with GCNRA.
Some maintenance may be achieved with cooperative agreement with GCNRA.

3) The composition (physical, chemical, and biological) of Lake Powell may be affected by the altered discharge regime.
4) Tailwater quality will be affected by the LSSF.

Justification:

Effects of discharge spikes and LSSF may have long-term effects on the physical, chemical, and biological makeup of the reservoir in addition to short-term effects on the stratification and hydrodynamics. The tailwaters will experience short-term water quality effects which may influence metabolic shifts of primary productivity. Increased frequency and greater replication of the normal sampling regime would detect most of these changes.

Cost: Each additional forebay-tailwater sampling: $5000/trip. Estimate 3 additional trips.

Effort: Added person hours
May require cooperation from GCNRA for boats and personnel. or rental of equipment.

B. Additional mainstem profiling bracketing major shifts in dam operations.

Justification:

Definition of lake-wide stratification patterns requires understanding of baseline conditions. While continuous tailwater monitoring provides information about instantaneous conditions, predictive capabilities depend on understand upstream dynamics and conditions. This trip would be used to download and reset thermistor strings at uplake stations.

Cost: $500-1000 /trip. Estimate 1 additional trips. Utilizes existing equipment and personnel.
Effort: Added person-hours: 2 people x 3 days x 9 hours = 54 person-hours
May require cooperation from GCNRA for boats and personnel or boat rentals.

Trip schedule:

March 31- forebay/ tailwater
*April ~6 – forebay/ tailwater
*April ~30 – forebay/tailwater
*May ~26 – forebay/tailwater
June 3-8 – lakewide quarterly
July 6 –forebay/ tailwater
*July – mainstem profile only
August 3 – forebay/tailwater
Aug 22-28 – lakewide quarterly
*Sept 9 – forebay/tailwater

* Addition to normal sampling schedule.

Downstream:

A. Maintain and possibly replicate Recorder® deployments inside GCD and at Lees Ferry.

Justification:

Tracking shifts (magnitude, duration, periodicity) in discharge from Lake Powell in conjunction with shifts in dam operations is efficiently detected through physical monitoring of temperature, specific conductivity, dissolved oxygen, pH and turbidity. This instrumentation is part of the existing program.

Cost: Minor additional costs, some equipment augmentation may be required.

Effort: May require added effort to reinforce and backup existing program.

COSTS:

Equipment and supplies:	$9,000
Travel:	$2,000
Logistics:	$21,000
Personnel:	**$8,000**
Total:	$40,000

Deliverables:

Progress Report	October 2000
Final Report	March 2001

C. SEDIMENT STORAGE AND SEDIMENT BUDGET STUDIES

a. Additional Radiometer, QTC and CIR research

Remote sensing component to investigate change detection of suspended sediment concentration, turbidity, and river-bottom cover type. Pat Chavez, Stuart Sides, and Miguel Velasco, USGS. (Estimated cost $119,600)

We are proposing to do research into the mapping and change detection of suspended sediment concentration, turbidity, and river-bottom cover type using three different remotely sensed data types. The three data types to be investigated in this research are those collected by field spectral radiometers, acoustic QTC data, and CIR photography. The application of each of the three data sets are as follows:

1. **Spectral Radiometer Investigation**

We have been collecting spectral radiometer data near the gauge station at the bottom of the Grand Canyon every 30 minutes since mid August, 1999. The data collected at this site, along with spectral radiometer data collected and used in a previous project in the San Francisco Bay, indicate that suspended sediment concentration and turbidity can be mapped and monitored using this field based instrument. The spectral data are correlated to water sample results and then used to monitor the water with a high temporal resolution. The radiometer at the bottom of the Grand Canyon was scheduled to be removed in May when phase two of the current project ends. We are proposing to leave this instrument installed at it's current location and continue collecting data until the end of October, 2000, plus install a second radiometer just above the mouth of the LCR near the WRD gauge station. This will allow us to take advantage of the water sampling that will occur at these two sites so that we can monitor suspended sediment concentration and turbidity with a temporal resolution of 30 minutes. We will not be able to install the second spectral radiometer until July 2000, which will put it in place well before the second planned spiked flood.

Budget:

Salaries plus Benefits	
Pat Chavez	$17,500
Stuart Sides	$ 8,400
Miguel Velasco	$ 2,000
Travel	$ 2,000
Data Logger Equipment	$ 7,000
Project Level Cost	$36,900
USGS Assessments	$11,100

TASK 1 TOTAL $48,000

2. QTC Acoustics Data Investigation

Besides mapping and detecting change in the water column another critical requirement within the Colorado River Ecosystem is the mapping of cover types on the river bottom and detecting a change in those cover types. A relatively new instrument that is currently available for mapping cover types on in-land and coastal waters is an acoustic system called QTC. It is a profiling system that collects acoustic data at a user specified frequency and has the potential for allowing under water cover type mapping to be done in an efficient manner. We are proposing to use the QTC system along three reaches for cover type mapping and change detection. We will use the QTC system in May during the USGS sidescanning sonar trip; the same reaches will be extensively covered by both systems so that their results can be compared. We will then use the QTC system again during river trips in the fall before and after the second planned spiked flood. These data will be collected during the joint USGS/NAU planned river trips. Once the data have been collected they will be rasterized into an image format and used to both generate cover type digital image maps and to apply some of the digital image change detection procedures we have developed with satellite and digital aerial photography.

Budget:

Salaries and Benefits	
Pat Chavez	$16,500
Stuart Sides	$ 8,800
Miguel Velasco	$ 3,200
Travel	$ 2,000

QTC System Lease
It is assumed that the GCMRC will handle the lease arrangement, cost, and getting the system to the river and help in the mounting of the system.

Project Level Cost	$30,500
USGS Assessments	$ 9,100

TASK 2 TOTAL $39,600

3. Aerial CIR Investigation

Field instruments, such as the spectral radiometers discussed in task 1, have the capability to collect high temporal resolution data but their spatial resolution is generally quite poor. On the other hand, airborne imaging systems collect images/photos with very good spatial resolution and coverage, but their temporal resolution are usually poor for operational type monitoring. In this task we are proposing to make use of both data sets to complement each other and generate digital image maps showing the spatial distribution of suspended sediment concentration. Depending on the analysis done on the water samples collected we may also be able to generate turbidity image maps using the same data. We are proposing to use the digital camera CIR photography collected during September 1999 and calibrate the data from several reaches to the spectral radiometer data collected during the same time period. Our preliminary look at the September 1999 CIR photographs supports our request for their collection last summer; the initial analysis of some of these data look very promising for mapping suspended sediment concentration and their spatial distribution along the river. The digital CIR photograph will be used to generate suspended sediment concentration image maps and an attempt will be made to compute the total suspended sediment load from these images for the reaches covered by the data. We then propose that new digital camera CIR photographs be collected for the reaches being studied in the late summer/early fall during the planned spiked flood and before or after the flood. These data will also be converted to spectral radiometer type data and used to generate digital image maps of suspended sediment concentration, and turbidity if the water samples collected are analyzed for this water parameter. The resulting digital image maps will then be used as input to our change detection procedure to generate digital change image maps.

Budget:

Salaries and Benefits	
Pat Chavez	$13,500
Miguel Velasco	$ 8,600
Misc. Supplies/Printer	<u>$ 2,500</u>

CIR Photographs
It is assumed that GCMRC will handle the collection of the new digital camera CIR photographs and the cost involved with their collection.

Project Level Cost	$24,600
USGS Assessments	<u>$ 7,400</u>

TASK 3 TOTAL $32,000

SUMMARY:

TASK 1	$ 45,400
TASK 2	$ 37,050
TASK 3	<u>$ 29,900</u>

TOTAL $119,600 (Chavez, Rubin and Anima)

b. Additional Streamflow and Sediment Modeling

Additional Sediment and Streamflow Modeling Along the Colorado River Ecosystem Between Glen Canyon Dam and Phantom Ranch in Support of Low Summer Steady Flow Testing. PI - S. Wiele and M. Franseen, USGS, Denver, CO. (Estimated cost $15,000.)

The 33k cfs high flow scheduled for September 2000 provides an opportunity to make field measurements that can be used to test and refine ongoing developments in physical resources research. A recent synthesis of suspended sand transport measurements and sand deposit surveys has led to new understanding of the locations of stored sand in Marble Canyon that is available for redistribution by Beach/Habitat-Building Flows (Hazel and others, in review). Hazel and others (in review) concluded that most of the sand in transport in Marble Canyon during the 1996 test flow derived from deposits located at the lower elevations of eddies. The timing of the 33k cfs release to coincide with likely sand-supplying flows on the Paria River provides an opportunity to measure the response of these storage sites to the relatively high discharge and sand influx.

The location of redistributable sand at the lower elevations of eddies has important implications for the design of future BHBFs and for the prediction of sand supply and the response of sand deposits to dam operation. The entrainment from or deposition in these locations is a crucial process that must be accurately represented in a predictive model. A 1-dimensional model under development (Wiele and Franseen, 1999) routes sand through Marble Canyon based on reach-averaged channel geometry. Side-channel environments that are secluded from the main flow, such as recirculation zones, are included in the 1-dimensional model by results tabulated from the application of a 2.5-dimensional model (Wiele, et al., 1996; Wiele, et al., 1999) run for a range of flow and sand supply conditions. The original purpose in the use of 2.5 d results in the 1d model was to account for sand losses to recirculation zones during high discharges. With the discovery that lower elevation deposits play an important role in sand storage, the deposition and evacuation of sand form these locations will also be represented in the 1d model with 2.5d results. Measurements of bathymetry changes and associated flow fields in the study reaches will more precisely quantify topographic response of these deposits and aid in the development of predictive methods.

Proposed field work:
1. Before and after surveys in X reaches.
2. Repeat bathymetric surveys during the 33k cfs release in 1 reach.
3. Velocity measurements during the 33k cfs release in the same reach as (2).

Total Budget: $15,000

c. A collaborative research project before, during, and after the 33,000 ft^3/s fall test flow with integrated and alternative methods to monitor sand storage. P.I.- R. Parnell, NAU; J. Schmidt, Utah State U., D. Topping and S. Wiele, U.S. Geological Survey. (Estimated cost $175,000)

Workplan and Schedule and Budget

In this project we propose to develop a cooperative research approach among Northern Arizona University, Utah State University, and the U.S. Geological Survey. The objective of this joint research effort is to determine the total change in sediment storage in three reaches of Marble Canyon for the period that includes the September spike flow. The four reaches will be: (1) between Paria Riffle and Cathedral Wash, (2) near the Marble Canyon Dam site, (3) near Eminence Break camp, and (4) between Sixtymile Rapid and the lower Marble Canyon gage. In these reaches, we will measure the change in storage on the bed using multibeam mapping techniques repeated before and after the flood, field surveys of eddy sand bars and channel-margin deposits before and after the flow, recovery of some scour chains and analysis of some new sand deposits, and interpretation of air photos.

The 33,000 ft^3/s fall test flow provides an opportunity to make field measurements that can be used to test and refine ongoing developments in physical resources research. A recent synthesis of suspended sand transport measurements, sediment grain-size distributions, and sand deposit surveys has led to new understanding of the locations of stored sand in Marble Canyon that is available for redistribution by high releases (i.e., Beach/Habitat Building Flows) intended to rebuild eroded sand bars (Hazel and others, in review). Hazel and others (in review) and Schmidt (1999) concluded that most of the sand in transport in Marble Canyon during the 1996 controlled flood was derived from deposits located at the lower elevations within eddies. The timing of the 33,000 ft^3/s fall test flow to coincide with possible sand-supplying flows on the Paria River in August and September provides an opportunity to measure the response of eddy and main channel storage sites to the relatively high discharge and sand influx and allow more accurate budgeting of the sand supply in the Grand Canyon ecosystem

The entrainment from or deposition in these reaches is a crucial process that must be accurately represented in a predictive model . A 1-dimensional model under development (Wiele and Franseen, 1999) routes sand through Marble Canyon based on reach-averaged channel geometry. Side-channel environments that are secluded from the main flow, such as recirculation zones, are included in the 1-dimensional model by results tabulated from the application of a 2.5-dimensional model (Wiele and others, 1996; Wiele and others, 1999) run for a range of flow and sand supply conditions. The original purpose in the use of 2.5 d results in the 1d model was to account for sand losses to recirculation zones during high discharges. With the discovery that lower elevation deposits play a more important role than previously believed in sand storage, the deposition and evacuation of sand from these locations will also be represented in the 1d model with 2.5d results. Measurements of bathymetry changes and associated flow fields in the study reaches will more precisely quantify topographic response of these deposits and aid in the development of predictive methods.

The location of redistributable sand at the lower elevations of eddies has important implications for the design of future BHBFs and for the prediction of sand supply and the response of sand deposits to dam operation. We propose to refine the sediment budget for the reach between the Paria River and Phantom Ranch, 27 miles downstream from the Little Colorado River, by utilizing reach-integrated change-detection from detailed topographic measurements, large scale spatial data acquired from the LIDAR and photographic overflights, and collection of sediment grain-size distributions.

Workplan:

Collect eddy, main channel, and channel margin data at a combination of NAU study sites, newly established channel margin, eddy, and main channel pool monitoring sites, and at four 2-3 km contiguous reaches. These data will be collected pre- and post-spike. At each site the bed will be sampled with a pipe dredge for sediment grain-size distributions. Similar data will be collected during the spike at one or two selected eddies to document rates of main channel and eddy sand transfer and predictive model development. The LIDAR and overflight data will be utilized to calculate areas of eddy inundation and for large scale temporal change detection.

Schedule:

Pre-spike data collection river trip: August 22 to September 2, 2000
During-spike data collection: September 3 to September 10?
Post-spike data collection river trip: September 9 to September 20, 2000

Deliverables:

Draft final report...March 1, 2001
Final report...September 30, 2001

Responsibilities of Research Groups:

Multibeam data collection before and after the flood will be collected by the staff of the GCMRC and NAU. Ground surveys will be made by personnel of Northern Arizona University and Utah State University. The relative responsibility between these two universities concerning preparation of surveying data and analysis of change will be negotiated at a later date. It is anticipated that NAU will analyze change at their long-term study sites, that Utah State will develop data bases for new sites, and that these data will be later combined into one reach length compendium.

Utah State will analyze air photos taken before and after the flood and develop maps of the areas of significant deposition and erosion that will be compared to the detailed ground surveys. USU will explore expanded use of Imagine software and analysis of LIDAR data to supplement the field effort

The two universities will work together to develop quantitative data on the change in sand storage among the bed, bars, and banks in each reach. These data will be analyzed in conjunction with USGS sediment data collection and bar sediment analysis to develop an interpretative report that describes how the bed, bars, and banks change in the different study reaches.

Logistical Needs, Personnel, and Cost Estimate:
Logistical support -The pre-trip required three GCMRC motor boats including the 17 foot white knight. One to two GCMRC survey personnel will be required on the pre- and post-trip for multibeam data collection but not for post trip processing. The during-spike work will not require GCMRC personnel but will require the singlebeam hydrographic system with geodimeter. It is expected that GCMRC total stations and the single beam hydrographic system for data collection will be provided at no additional cost.

Personnel - Field work will be accomplished by 12 persons including 3 boatmen.

Expected costs:

*Field data collection and processing (NAU)	= $115,000
-Sediment sampling and processing (NAU)	= $10,000
**Photographic analyses (USU)	= $50,000
***Model development (USGS)	= ($15,000)

Total Expected Cost (with overhead, but not incl. logistical) = **$175,000**

*includes $15,000 for the Hypack software package required to process hydrographic data.
**The current agreement with USU will be increased through a modification by this amount.
***This amount is currently included in the cost estimate for additional FY 2000 work by the AZ District.

Appendix 16

Whitewater boating safety studies below Lees Ferry. P.I.- Linda Jalbert, GCNP (Estimated cost $ 20,500).

Hypothesis to be tested:

Ho: Whitewater safety will not significantly differ from safety during normal daily flows.

Purpose

The purpose of this study is to ascertain the risks and potential impacts to whitewater boaters running the Colorado River at the experimental flows of 8,000 cfs, compared to the "normal" daily flows for this time of year.

It is known that flows from Glen Canyon Dam have an affect on Colorado River boaters. These effects can be both positive and negative, and contribute to defining experience quality. Results from previous studies have shown that certain accident variables, including hitting rocks and equipment damage, are directly related to low flows (5,000 – 8000 cfs). Furthermore, low flows impact motorized trips, which carry approximately 75% of the recreational boater population. Since this experimental flow is a management action supported through a public process, and may continue at some time in the future, it is important for river managers (NPS and BOR) to ascertain the risks involved. Direct observation, systematic analysis of data, and input of professionals and experienced boaters, will provide a basis from which future management actions can be determined.

The proposed study will be a continuation of the recreation studies conducted during the Glen Canyon Environmental Studies (1985-1992) and the Glen Canyon Dam Beach/Habitat-Building Flow (1996). Investigators have collected and analyzed several kinds of data addressing the relative hazards associated with running rapids at different flow levels. Individual studies included surveys of boaters (Bishop, 1986; Jalbert 1992), analysis of NPS records of boating accidents (Underhill, 1986; Jalbert 1992 and 1996), and observations of boats running rapids (Brown and Hahn, 1987; Jalbert 1992 and 1996). The proposed study adopts the methods used in previous studies for data collection and analysis.

Objectives

The primary objectives are to assess the effects of the LSSF on boating safety, and how safety affects the recreational experience for boaters on the Colorado River through Grand Canyon National Park.

1) Observe and record boating incidents at six rapids. Incidents include: accidents or actions taken to avoid accidents, such as lining or walking around rapids.

2) Review NPS case incident files on boating related accidents to determine correlation between flows and accident rate. Case files include: reports based on response from NPS such as emergency helicopter evacuations, and incident reports filed by trip leaders as required by the NPS is associated costs exceed $500.
3) Combine the new data with baseline data sets, and carry out an analysis of the relationship between flows and incidents.

Design and Methodology

The proposed study will utilize the methodology of the baseline research developed for the Glen Canyon Environmental Studies Phase I and II, and the Glen Canyon Dam Beach/Habitat-Building Flow. Data collection methods and locations are consistent with previous studies and will serve as the basis of comparison for various flow levels.

The study period will include the LSSF and "spike" flow period in September. The study period will consist of two sampling periods. The first sampling period will be in June 2000 during the LSSF, the second sampling period will be in September to include the LSSF spike flow period. Data will be collected during each sampling period for a minimum of seven days. Data collection locations will be four of six major rapids above Diamond Creek and one site below Diamond Creek in consultation with the Hualapai Nation.

<u>Observations</u>:

Trained observers will use a structured checklist to record the characteristics and outcome of the run for each boat. Observers record the time of arrival, time spent scouting, description of runs, whether passengers walked, if boats were lined or portaged, and any type of "incident" that is observed, such as person overboard, flips, hit rocks, etc. Observers are equipped with binoculars are can ascertain whether or not equipment damage has occurred, such as broken oars or motors.

<u>Reports</u>:

National Park Service files will be investigated for river related accidents for a calendar year that ends at the conclusion of the LSSF experimental period. The standard NPS Case Incident Reports are filed whenever a medical evaluation is performed by NPS rangers, an evacuation of an injured person occurs, or an accident resulting in $500 damage is reported. Commercial and noncommercial trip leaders are required to file a River Incident Report based on the same criteria. Other sources of information which will be utilized include: computerized data on daily launches, hourly dam releases for each day of the study period, and daily flow routing information for USGS gauges along the river. Analysis includes comparison of the incident report data with various flows within the calendar year.

Deliverables and Schedule

Final Report on results of observed and reported whitewater boating accidents. Comparative data analysis for accident rates will be included.

May 5, 2000	Study Plan due to GCMRC
May 20, 2000	Finalize sampling plan and river trip logistics
June 1- Sept 15, 2000	Field work/data collection
December 31, 2000	Draft Report
March 1, 2001	Final Report

References

Bishop, Richard C., K.J. Boyle, M.P. Walsh, R.M. Baumgartner, and P. Rathbun (HBRS). 1986. “Glen Canyon Dam Releases and Downstream Recreation.” Final Report on file, U.S. Bureau of Reclamation, Salt Lake City, UT.

Brown, Curtis, and M.G. Hahn. 1987. “The Effects of flows in the Colorado River on Reported and Observed Accidents in Grand Canyon.” Final Report on file, U.S. Bureau of Reclamation, Salt Lake City, UT.

Jalbert, Linda M. and J.M. Mitchell. 1992. “The Influence of Discharge on Recreational Values including Crowding and Congestion and Safety on the Colorado River in Grand Canyon National Park.” Final Report on file, Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, AZ.

Jalbert, Linda M. 1997. “The Effects of the 1996 Beach/Habitat-Building Flow on Observed and Reported boating accidents on the Colorado River in Grand Canyon National Park.” Final Report on file, Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, AZ.

Underhill, A.H., M.H. Hoffman, and R.E. Borkan. 1987. “An Analysis of Recorded Colorado River Boating Accidents n Grand Canyon for 1981 through 1983.” Final Report on file, U.S. Bureau of Reclamation, Salt Lake City, UT.

Budget for LSSF Study -- **Whitewater Boating Safety**

Linda Jalbert, NPS and Jeffrey Behan, Consultant/Field Coordinator
May 2000 - March 1, 2001

	Requested	In-kind support from NPS
Personnel		
A. Senior Personnel		
Linda Jalbert, PI NPS		5000
Jeff Behan, Field Coordinator	6000	
B. Field Staff		
Observers, 4 VIPs @ $25/day* 80 days	8000	
Hualapai staff	2000	
Observer, 30 days		2400
Data Input		1200
Travel		
Various trips for VIPs incl mileage to GCNP, LFY, DIA, Lake, etc	3000	500
Administrative		
Data Analysis & Report	1000	2000
Misc Supplies	500	500
Clerical for travel, etc.		1000
TOTAL	20,500	12,600

* Meals & incidental expenses while at observation locations

Appendix 17

Economic impacts to whitewater and angling concessionaires. PI – TBD. A more detailed project description will be developed (Estimated cost $15,000).

Hypotheses to be tested:

Ho: Economic impacts to whitewater and angling concessionaires will not differ significantly from economic impacts under normal daily operations.

Economic Impacts to angling will be studied using existing records supplemented with direct interview to compare and contrast the number of guided fishing trips during the LSSF period and comparable previous periods. Using this information, estimates of the incremental loss of income to commercial fishing guides and the local community will be developed.

Impacts to whitewater boating will be studied to determine if there are increases in incidences of motor, equipment and raft damage during the LSSF period and the potential economic impacts of these incidences. In addition, the reductions in water releases will affect river travel times with possible economic impacts to day rafting and downriver whitewater boating. Economic impacts to rafting operations launching at Diamond Creek where possible and feasible similar data will be obtained through direct interview. Using the available data, estimate the incremental loss of income to concessionaires.

Appendix 18

Economic impacts to private whitewater boaters and anglers. PI – TBD A more detailed project description will be developed (Estimated cost $12,000).

Hypotheses to be tested:

Ho: Economic impacts to private whitewater boaters and anglers will not differ significantly from economic impacts under normal daily operations.

There may be economic impacts to private whitewater boaters through increased incidence of motor, equipment and raft damage during the LSSF period and slower river travel times. In addition there may be increased incidences of motor and equipment damage sustained by private anglers during the LSSF period resulting in financial losses. Using available information, questionnaires and other data sources, evaluate the economic impacts to these groups.

Economic Impacts to power customers. PI. – Clayton Palmer, WAPA (Estimated cost $ TBD).

This project will investigate the economic impacts of LSSFs to power customers. A detailed project description will be developed.

Hypothesis to be tested:

Ho: Economic impacts to power customers will not differ significantly from economic impacts under normal daily operations

Appendix 20

Effects on Recreational River Trip Characteristics. PI – Linda Jalbert, GCNP, Catherine Roberts, NAU. (Estimated cost $ 14, 831).

Hypothesis to be tested:

Ho: Patterns of recreational use and their potential impacts will not differ significantly from recreational use patterns under normal daily operations

Purpose

The purpose of the study is to determine patterns and characteristics of Colorado River trips and potential impacts to camping beaches and attraction sites including archeological sites, during experimental flows of 8,000 cfs compared to "normal" daily flows for the same time period.

Recreation research conducted during the Glen Canyon Environmental Studies (1985 – 1992) concluded that the value of the whitewater boating experience is sensitive to the volume of water released by Glen Canyon Dam. The attribute and contingent value survey concluded that higher (32,000+ cfs) and lower (less than 10,000 cfs) flows reduce the enjoyment of the Grand Canyon boating experience. Specific attributes of a quality experience include safety, time for off-river activities, and the quality and availability of campsites (Bishop, 1986). Different flow regimes also have an affect on use patterns, and use levels at attraction sites and camping beaches vary accordingly (Jalbert, 1992).

Objectives

The primary objective is to collect detailed information on river trip patterns and characteristics during the LSSF and compare this to similar data collected during "normal" daily flow periods.

Through an existing cooperative agreement between Northern Arizona University (NAU) and Grand Canyon National Park (CA #8210-99-002), this research would involve the following:

1) Collect river trip data recorded by commercial and noncommercial trip leaders. Information is recorded on a trip report which is a comprehensive diary that lists camp and activity sites along the river corridor. Trip leaders complete the report by making the time in and out for every stop.
2) Analyze and compare the data sets from the 1998 and 1999 season to the LSSF. The 1998/1999 database includes approximately 500 records (trip reports).
3) Analyze and compare NPS monitoring data (1995-1999) to determine if LSSF river trip patterns impact camping beaches and attractions sites differently than at "normal" flows.

Design and Methodology

The study period will include the LSSF period through September. Trip reports will be distributed to a sample of the commercial trips (~500) and all of the noncommercial trips (120). The commercial sample will be based on trip length and type and is estimated to be approximately 200 trips. Distribution and collection of trip reports will be done in the same manner as in the past two years. Outfitters will distribute directly to trip leaders, and additional commercial trip distribution and noncommercial trip distribution will occur at the launch ramp. Trip leaders are also provided with a stamped return envelope.

The LSSF data will be entered into an existing database that includes over 500 records of trips in 1998 and 1999. The database includes all camps and activity sites (i.e., attraction sites such as the Vasey's, Nankoweap, LCR, Havasu, etc.). Most campsites are categorized by sized based on data from previous studies (Kearsley, 1992 and 1996, and GCRG, 1996). Analysis will include travel rate, time spent at sites versus time on river and campsite selection. This will be compared to trips conducted under the normal daily flows in the previous two years.

An additional benefit of this research is related to the Grand Canyon River Trip Simulator (GCRTSim). This computer model of river traffic on the Colorado River has been the primary focus of the cooperative agreement referenced above. It consists of an extensive database as well as an integrated statistical and artificial intelligence-based computer simulation that models complex human-environment interactions on the river.

The goal of the GCRTSim is to simulate a realistic river environment that can be used to test alternative launch schedules. River managers can use it to understand the effect of launch schedule changes and impacts to various resources.

Collection of trip data for the LSSF will enable the GCRTSim to extend its capacity to run simulated launch scenarios on two distinct flow regimes. The data collected from the trip reports will serve the dual purpose of contributing to these efforts.

Deliverables and Schedule

Final Report on results of river trip characteristics and resource impacts. Comparative data analysis will be included.

May 5, 2000	Study Plan due to GCMRC
May 20, 2000	Finalize sampling plan
June 1 – Sept 15, 2000	Data collection
December 31, 2000	Draft Report
May 1, 2001	Final Report

References

Bishop, Richard C., K.J. Boyle, M.P. Walsh, R.M. Baumgartner, and P. Rathbun (HBRS). 1986. "Glen Canyon Dam Releases and Downstream Recreation." Final Report on file, U.S. Bureau of Reclamation, Salt Lake City, UT.

Cipra, B. 1999. "Mathematicians Offer Answers to Everyday Conundrums: Shooting the Virtual Rapids." Science 283:925.

Jalbert, Linda M. and J.M. Mitchell. 1992. "The Influence of Discharge on Recreational Values including Crowding and Congestion and Safety on the Colorado River in Grand Canyon National Park." Final Report on file, Glen Canyon Environmental Studies, U.S. Bureau of Reclamation, Flagstaff, AZ.

Roberts, Catherine A. and H.R. Gimblett. 1999. "Computer Simulation for Rafting Traffic on the Colorado River." Unpublished.

For update information about this and other modeling projects, visit the web site for the Modeling and Simulation Lab at NAU: http://odin.math.nau.edu/msl

Budget for LSSF Study -- **River Trip**

Catherine A. Roberts, NAU Modeling & Simulation Lab
June 1, 2000 - May 31, 2001

	Requested	In-kind Support from NAU	In-kind from NPS
Personnel			
A. Senior Personnel			
Catherine Roberts			
27 weeks * 10 hrs/wk* 33.44/hr	4514	4514	
Linda Jalbert			2400
B. Other Personnel			
Trip Report Distribution			2000
Data Entry (undergraduate)			
30 weeks * 10 hrs/wk * $6.50/hr	1950		
Data Analyst (undergraduate)			
20 weeks * 10 hrs/wk * $10/hr	2000		
C. Employee Related Expenses			
Catherine Roberts (26%)	1174	1174	
Data Entry (1%)	20		
Data Analyst (1%)	20		

D. **Total Personnel & ERE**	9,678	5,688	4,400
Other Direct Costs			
E. Travel	225		
F. Supplies & Materials			
Print Trip Reports			2000
Use of Modeling & Simulation Lab	1000	3000	
Printing, postage, misc	1500		
G. Consulting			
S. Cherry - train data entry worker			
2 days @ $15/hr (16 hrs)	240		
travel	254		
H. Database structure & baseline data			30,000
TOTAL DIRECT COSTS	12,897	8,688	36,400
Indirect costs:			
15% NPS coop agreement	1934		
48.3% NAU contribution		915	
TOTAL PROJECT	14,831	9,603	36,400

Changes in Campable Beach Areas. PI – Ruth Lambert. (Project costs included in D.2.b - $32,000).

Hypothesis to be tested:

Ho: Campable beach areas will not differ significantly from campable beach areas under normal daily operations

Purpose

The availability of camping beaches is of concern to recreationalists within the Grand Canyon. In certain areas, camping beaches are limited due to the geomorphology. These have been termed "critical reaches" (Kearsley, L.; Quartaroli, R.; Kearsley, M. 1999). The low steady flows should expose more campable areas at existing beaches and potentially provide newly exposed camping areas.

Objectives

1. This study proposes to evaluate the change in campable recreational beaches under LSSFs using aerial data collected during the project.

2. Campable beaches under LSSFs conditions will be compared to available recreational beaches under normal daily operations.

Methodology

Data collection for this project will occur during aerial photography overflights that are currently scheduled. Approximately 20 recreational beaches primarily in critical reaches will be selected for analysis. Aerial data from these locations will undergo orthorectification to produce topographic data. In addition, these locations will be photographed by NPS personnel during a resources monitoring trip at the beginning of the low flow period with follow up photographic monitoring by river guides under the Adopt-a-Beach program throughout the experiment. Analysis of remote sensing data and beach photographs will occur after LSSF experiment.

Deliverables and Schedule

Aerial data will be collected before and after the fall spike flow. Orthorectification and production of topographic data of selected beaches will occur following the experiment. Data analysis will occur during FY 2001. A final report describing the changes in recreational beaches under LSSFs as compared to normal daily operations will be completed in FY 2001.

Budget

Costs for aerial data collection and orthorectification at 20 recreational beach locations are included within the budget for aerial photography and remote sensing. Orthorectification at 20 beach locations is approximately $ 32,000. Costs for data analysis and report write up will come from the socio-cultural FY2001 monies.

References

Kearsley, L.; Quartaroli, R.; Kearsley, M. (1999). Changes in the number and size of campsites as determined by inventory and measurement. In *The Controlled Flood in Grand Canyon.* Geophysical Monograph 111, American Geophysical Union.

Appendix 22

Grand Canyon Monitoring and Research Center Proposal for Topographic Base Mapping of the Colorado River Corridor from Glen Canyon Dam to Lake Mead

The Grand Canyon Monitoring and Research Center (GCMRC) will develop high resolution (one meter) topographic base maps of the Colorado River corridor from Glen Canyon Dam to Lake Mead inclusive of Grand Canyon using LIght Detection And Ranging technology (LIDAR). One foot resolution black & white digital stereo ortho-photography will be collected simultaneously with the LIDAR. The swath of the topographic base data and ortho-photography will be approximately one kilometer (km) centered on the Colorado River. The Colorado River below Glen Canyon Dam will be held steady at 8,000 cfs for the duration of the data collection.

The data will be collected using a fixed wing Piper Navajo twin engine aircraft equipped with a laser altimeter and digital photogrammetric camera system interfaced to a high precision global positioning system (GPS) and Applanix inertial measurement unit (IMU). The GPS and IMU provide precise geographic positioning and correction for roll, pitch, and yaw of the aircraft respectively. The GPS and IMU combine to provide accurate geo-referencing of the LIDAR data and digital imagery from which an ortho-rectified image base can be generated without the need for ground control. The only ground requirements are the occupation of 4-6 existent geodetic survey marks on the canyon rim needed for GPS base stations, and placement of a small number aerial panels in the canyon corridor for verifying the accuracy of the map products.

The contractor is Horizons, Inc. of Rapid City, South Dakota. The over flight was flown by EarthData, Inc., of Hagerstown, Maryland on March 26th through April 6th, 2000. The products of the proposed over flight are:

1) A one meter contour interval vector coverage of the bald earth (vegetation removed) Colorado River corridor from Glen Canyon Dam to Lake Mead (mile –15 to 277) with additional coverage upstream from the Colorado river at the Little Colorado River (12.5 km), Paria River (5 km), Havasu Creek (3 km), Shinumo Creek (5 km), Kanab Creek (5 km), and Tapeats Creek (5 km). The swath of the coverage will be approximately 1 km.

2) A complete digital elevation model (DEM) of the study area with a cell resolution comparable to the average LIDAR ground point spacing.

3) Miscellaneous raw and intermediate point and vector data.

All deliverables will meet data standards defined by GCMRC for compatibility and format. The products delivered will include the first contiguous set of topographic data ever generated for the Colorado River corridor from the Glen Canyon Dam to Lake Mead at a scale useful to researchers.

For additional information regarding this proposal contact Mike Liszewski, GCMRC Information Technology Program Manager, at 520-556-7458 or mjliszew@flagmail.wr.usgs.gov.

Appendix 23

Grand Canyon Monitoring and Research Center Proposal for Black & White and Color Infrared Aerial Photography, Orthophotography, and Thermal Infrared Imagery of the Colorado River Corridor in Support of Research and Monitoring associated with Low Summer Steady Flows

The Grand Canyon Monitoring and Research Center (GCMRC) will develop Black & White (B&W) and Color Infrared (CIR) aerial photography, orthophotography, and thermal infrared imagery of the Colorado River corridor in support of research and monitoring activities associated with low summer steady flows (LSSF). Pre-experiment B&W stereo aerial photography and a CIR orthorectified mosaic will be developed for the entire Colorado River corridor from Glen Canyon Dam to Lake Mead from data collected in March/April 2000. CIR stereo aerial photography will be developed for the entire Colorado River corridor from Glen Canyon Dam to Lake Mead from data collected during June 2000 as part of GCMRC's annual aerial overflight. Thermal infrared digital imagery will be collected for the first 100 miles of the Colorado River corridor from Glen Canyon Dam to approximately Phantom Ranch during June 2000. B&W stereo orthophotography will be developed for the first 100 miles of the corridor from GCD to approximately Phantom Ranch before and after the fall spike in September. Stereo CIR aerial photography will be collected for the same section of the corridor during the peak of the fall spike. The Colorado River below Glen Canyon Dam will be held steady at 8,000 cfs for the duration of all data collection except the peak fall spike. The flow at the peak of the fall spike will be held steady at 31,000 cfs..

The photography and imagery is being collected to support biological, cultural, and physical research and monitoring activities being conducted as part of the LSSF. These activities address near shore native fish habitat, cultural resource mapping, sand bar change detection, campable beach area, and sediment transport in the ecosystem. The data will be collected using both fixed wing and helicopter aircraft equipped with appropriate camera and sensor system interfaced to a high precision global positioning system (GPS) and inertial measurement unit (IMU). The GPS and IMU provide precise geographic positioning and correction for roll, pitch, and yaw of the aircraft respectively. The GPS and IMU combine to provide accurate geo-referencing of the photography and digital imagery without the need for ground control. The only ground requirements are the occupation of 4-6 existent geodetic survey marks on the canyon rim needed for GPS base stations, and placement of a small number aerial panels in the canyon corridor for verifying the accuracy of the map products.

The proposed contractor is Horizons, Inc. of Rapid City, South Dakota. The products of the proposed over flight are:

1) Pre-experiment B&W stereo digital photography with 60% overlap of the Colorado River corridor from Glen Canyon Dam to Lake Mead at 8,000 cfs steady flows and 30 cm pixel resolution. (mile –15 to 277) with additional coverage upstream from the Colorado river at the Little Colorado River (12.5 km), Paria River (5 km), Havasu Creek (3 km), Shinumo Creek (5 km), Kanab Creek (5 km), and Tepeats Creek (5 km).

2) Pre-experiment CIR orthorectified digital photomosaic of the Colorado River corridor from Glen Canyon Dam to Lake Mead at 8,000 cfs steady flows and 30 cm resolution. Same physical area as number 1
3) Steady flow (late June) CIR aerial photography of the Colorado River corridor from Glen Canyon Dam to Lake Mead at 8,000 cfs steady flows and 10 cm pixel resolution. (mile –15 to 277).

4) Steady flow (late June) thermal infrared imagery of the Colorado River corridor from Glen Canyon Dam to approximately Phantom Ranch at 8,000 cfs steady flows and one meter pixel resolution. (mile –15 to 277).

5) Pre fall-spike B&W stereo digital and hardcopy orthophotography with 60% overlap of the first 100 miles of the Colorado River corridor from Glen Canyon Dam to Phantom Ranch (mile –15 to 85) at 8,000 cfs and 10 cm pixel resolution.

6) Peek fall-spike 1:4800 CIR stereo aerial photography of the first 100 miles of the Colorado River corridor from Glen Canyon Dam to Phantom Ranch (mile –15 to 85) at 8,000 cfs and 10 cm pixel resolution.

7) Post fall-spike 1:4800 B&W stereo digital and hardcopy orthophotography with 60% overlap of the first 100 miles of the Colorado River corridor from Glen Canyon Dam to Phantom Ranch (mile –15 to 85) at 8,000 cfs and 10 cm pixel resolution.

8) High resolution (25 cm) topography of twenty miles of sand bars yet to be determined within the first 100 miles of the Colorado Canyon corridor up to 300,000 cfs before and after fall spike. This product to be derived from pre- and post-spike orthophotography collected above or high resolution LIDAR yet to be determined.

9) High resolution (25 cm) topography of twenty campable beach sites yet to be determined within the first 100 miles of the Colorado Canyon corridor.

All deliverables will meet data standards defined by GCMRC for compatibility and format. For additional information regarding this proposal contact Mike Liszewski, GCMRC Information Technology Program Manager, at 520-556-7458 or mjliszew@flagmail.wr.usgs.gov.

Appendix 24

Grand Canyon Monitoring and Research Center Proposed Survey Activities in Support of Monitoring and Research Associated with Low Summer Steady Flows in the Colorado River Corridor below Glen Canyon Dam

The Grand Canyon Monitoring and Research Center (GCMRC) will provide terrestrial and bathymetric survey support to monitoring and research projects associated with low summer steady flows (LSSF) in the Colorado River corridor below Glen Canyon Dam during the Spring, Summer, and Fall of 2000. Survey expertise, manpower, and equipment will be made available to principal investigators performing monitoring and research in the Canyon to provide sample positioning, vessel positioning, and terrestrial and hydrographic topography data sets associated with the LSSF. Nine LSSF projects require survey support:

1) March 13-April 5, NAU Channel Margin Studies, single beam hydrographic topography of 35 existing NAU sand bar monitoring sites.

2) May 8-May 12, Sediment and reach-wide bedform classification, GPS derived positioning of side scan sonar vessel. Colorado River from Glen Canyon Dam to Diamond Creek.

3) May 22-June 4, LCR stage discharge/velocity project. Providing expertise, manpower, and equipment for geographic control and positioning of flow velocity instrument.

4) June 2-June 20, Combined Sediment Studies. Multi- and single-beam hydrographic and terrestrial topography and control support. 47 approximately one-mile-long reaches, one 10-mile reach and 35 NAU sandbar monitoring sites distributed throughout study area.

5) August 14-August 30, Combined Sediment Studies. Repeat of number 4.

6) August 15-August 27, Sediment and reach-wide bedform classification. Repeat of number 2.

7) September 1-September 20, NAU Sediment Study. Single beam hydrographic topography of 3 existing NAU sand bar monitoring sites before, during, and after fall spike.

8) September 2-September 7, Combined sediment study, multibeam hydrographic topography of 6 miles of channel between Cathedral Wash and Badger pool. Daily surveys.

9) September 8-September 20, Combined Sediment Studies. Repeat of number 4.

For additional information regarding this proposal contact Mike Liszewski, GCMRC Information Technology Program Manager, at 520-556-7458 or mjliszew@flagmail.wr.usgs.gov.

Appendix 25

Final Hypotheses to be tested in WY 2000

Meetings were held at GCMRC, with fisheries biologists on February 9 and with fisheries biologists, other GCMRC supported scientists and stakeholders on February 16. In addition meetings were held with the Lees Ferry trout guides at Marble Canyon Lodge on February 16 and with representatives of the downstream outfitters community on February 23. The intent of these meetings was to discuss the potential for conducting a test of low summer steady flows in WY 2000 and to develop the set of specific hypotheses that should be addressed if such a test is conducted.

Following the meetings on February 9 and 16, GCMRC supported scientists were e-mailed a set of hypotheses developed in conjunction with these two meetings. They were asked to prioritize these hypotheses in terms of their relevance to the potential low summer steady flow experiment and whether or not they could be answered. The respondents ranked the hypotheses from 0 - 3 with 0 meaning they were either not important or could not be answered by the proposed experiment and 3 meaning that they were both important and could be answered by the proposed experiment. GCMRC tallied the responses and including only those receiving votes of 3 in the list shown below as those specific hypotheses that would be considered as part of the proposed test.

Subsequently, GCMRC asked the scientists to propose research activities that would address these hypotheses. Those research proposals have been evaluated by GCMRC staff and are included in the low summer steady flow's science plan GCMRC is proposing for FY 2000.

Hypotheses to be Tested

1. Hypotheses addressing physical habitat parameters

Ho: Current velocities for near shoreline habitats (e.g., talus, debris fans, vegetated shoreline) will not differ significantly between fluctuating and low steady flow conditions.

Low velocity habitats are assumed to be a requirement of young fish. Decreased velocities presumably accompany lower discharges. The lower velocity environments may be reflected in an elongation of a particular low velocity environment or an increase in the number of these environments.

Ho: Areal extent of low velocities does not vary for a range of steady flows.

Discharge may affect current patterns (eddies may get wider or longer), but total area of low velocity environments should remain the same. This helps determine if size of low velocity environment matters.

Ho: Current velocities will increase in tributary confluence areas under higher mainstem flows.

Valdez, et al. (In preparation) recommends a high spring steady flow to pond tributaries and retain young of the year, assuming that velocities will be reduced in tributary confluences. This hypothesis could be tested with flows at 17,500 cfs or higher and if flows are reduced to 14-12 cfs for a sustained period of time.

Ho: Water temperatures in the mainstem will not increase downstream greater than temperatures previously observed under other flow conditions (e.g., fluctuating, higher discharge).

We have an estimate for rate of warming in the mainstem. It would be useful to determine if steady flows affect this rate, and if discharge and steady flows affect this rate (this is particularly applicable for the temperature control device).

Ho: Near shoreline temperatures in structurally complex habitats will not differ significantly from those observed for the mainstem.

The intent of steady flows is to warm shoreline low velocity environments, if the amount of warming is negligible then perhaps temperature along the shoreline is not a limiting factor for recruitment of native fish, but low velocities are.

Ho: Turbidity levels will remain constant during the LSSF experiment.

Turbidity does affect sight feeders like trout and affects photosynthetic activity (primary productivity). Interactions between this physical variable and the biotic components may affect growth of fish or predation rates. We are not recommending predator-prey studies at this time, but do advocate determining a relationship between flow and suspended sediment (turbidity).

Hypotheses addressing biotic habitat questions

Ho: Backwater number and total area will not differ significantly from values measured during previous fluctuating flows at equivalent stages.

Historic data regarding backwaters is associated with fluctuating flows and documented by overflights at 8,000 cfs. Antecedent conditions may not effect backwater number and areas at 8,000 cfs.

Ho: Backwater number and total area will not differ significantly throughout the period of steady flows.

Addresses sedimentation rates in eddy return current channels and the change in backwaters over time. Do they become less available over time?

2. Hypotheses addressing productivity (primary and secondary) questions

Ho: Germination and densities of *Tamarix ramosissima* will not significantly differ from preceding years during fluctuating flows.

Tamarisk and other exotic species may be advantaged by the high spring discharge and low steady flow regime resulting in increased shoreline of tamarisk seedlings and eventually tamarisk encroachment along shorelines of camping beaches.

Ho: There will be no significant difference observed in the benthic or macrophytic community for biomass or composition due to spike flow treatments.

The 31,000 cfs spike has been suggested to be of sufficient magnitude to negatively affect aquatic food base biomass and composition, particularly in the fall. The effect needs to be determined.

Ho: There will be no significant difference in biomass, densities or composition observed for the benthic and macrophytic communities due to a LSFF treatment.

Low steady flows may increase water clarity and allow for increase productivity, but the area available for productivity may be decreased by discharge, and result in no significant increase or change in the benthic and macrophytic community.

Ho: The quantity and composition of drift will not significantly vary during the duration of the LSFF treatment.

Fluctuating flows are suggested to help maintain drift downstream by causing desiccation and subsequent renewed growth. If this is true, one would see a decline in quantity of drift over time under steady flows. Also the composition of the drift may change over time associated with different rates of senescence of benthos and macrophytes and tributary inputs.

Ho: The quantity and composition of drift during a LSFF treatment will not significantly vary in comparison with years of other steady or fluctuating flows.

Does magnitude of discharge matter or pattern of discharge affect drift quantity or composition? This hypothesis collects the same data as the above hypothesis, but compares it to other flows.

Ho: There is no lag time in the rate of colonization for *C. glomerata* and epiphytes.

Does time since exposure affect colonization rates of cladophora. If colonization rates are the same for similar substrate subjected to different levels of exposure, then other factors may be affecting colonization.

3. **Hypotheses addressing fish response questions**.

Ho: Relative frequencies (CPUE) of young-of-year native and non-native fish species in rearing habitats will not differ significantly during the LSSF, BHBF nor in comparison with prior fluctuating flow periods at comparable discharges.

Steady flows are assumed to be beneficial to young-of-year fish. If stable environments foster survivorship of young fish relative frequency should increase, provided sampling effort is sufficient to capture this information.

Ho: Relative frequencies (CPUE) of young-of-year native and non-native fish species will be the same in all rearing habitats during steady flows.

Does the pattern of occurrence of young-of-year fish change among shoreline habitats or are all shoreline habitats used equally by young-of-year. This may help determine if one habitat type is used disproportionately more than another.

Ho: Condition factor of native and nonnative fish species will not change significantly during the experimental flow period.

Condition factor is a measure of food availability over time and is most likely to be reflected in older fish.

Ho: Spike flows preceding and following steady flow conditions will not actively displace non-native fish species in near shoreline nor backwater habitats for prolonged periods of time.

Spike flows of a magnitude of 31,000 cfs are recommended to remove small bodied exotics and reduce the competitive advantage these species may have incurred over the course of steady flows.

Ho: Relative frequency of YOY trout will not vary significantly during the entire experimental flow period inclusive of spike and LSSF.

Reduced available habitat and food resources in the Lees Ferry reach may exclude young-of-year and may result in reduced number (i.e., relative frequency) of young-of-year compared to baseline data.