TWG 12-8-98 L. Stevens
attachment 4
PRELIMINARY SUBJECT TO REVIEW

Draft GCMRC Response to the
Glen Canyon TWG (ad-hoc group) Request for Assessment of:

A Proposal to Develop a Research Plan to Analyze Resource Responses to Alternative BHBF and Load-Following Releases from Glen Canyon Dam

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I) INTRODUCTION

This draft report is a response to the May 30, 1998, letter entitled "**Proposal to Develop a Research Plan to Analyze the Response of Natural Resources below Glen Canyon Dam to a Beach Habitat Building Flow (BHBF) Greater than 45,000 cfs. and Fluctuations During Periods of High Powerplant Releases;**" an information request from the Glen Canyon Technical Workgroup's ad-hoc group on testing alternative BHBFs and Load-Following (TWG). The ad-hoc group's letter is contained here as Attachment 1. On the basis of the best available knowledge and information from its staff and cooperating scientists, the Grand Canyon Monitoring and Research Center (GCMRC) has prepared this draft assessment, and will present its contents at the December 8, 1998, meeting of the TWG for discussion. In preparing this draft assessment, the GCMRC has drawn upon the expertise of its staff, existing knowledge about the Colorado River ecosystem, expertise of external peer review panel members, currently funded science cooperators, results of two workshops on the Colorado River ecosystem conceptual model, and previous discussions with the Glen Canyon TWG.

The *Operations of Glen Canyon Dam – Final EIS* (DOI, 1995; p. 40), specifically indicates that Beach/Habitat-Building Flows (BHBF) from the dam are to be:

"high releases of short duration designed to rebuild high elevation sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system."

Under this definition, the BHBF is clearly intended as a tool for mainly preserving physical attributes of the Colorado River channel and its ecosystem – specifically sandbars with recreational value (beaches), and other types of sandbars that form unique aquatic and terrestrial habitats (backwater channels; see DOI, 1995; p. 97).

Grand Canyon scientists have concluded that there is little chance of identifying a single restoration management tool that will preserve all river resources of concern to stakeholders (Schmidt et al., 1998; see Attachment 2). Rather than being intended as a panacea for restoring and preserving all river ecosystem resources, the BHBF described in the EIS was intended as a mechanism for preserving sand and silt-based deposits that are a natural part of the river. Preservation of these features was intended to be achieved by periodically increasing dam releases (within described BHBF limits) to mobilize sand that had accumulated in the channel under a low fluctuating-flow regime, and redeposit it along shorelines (beach-building). It was hoped that such flood flows would also modify certain sandbars (mostly reattachment-type) with return-current channels so as to provide habitat useful to native fishes.

Schmidt and Graf (1990), Kearsley et al. (1994), Kearsley and Quarteroli (1997), and Kaplinski et al. (1998), have all variously suggested that sandbars and therefore "beaches" (sandbars with recreational value) tend to erode under powerplant releases, including current operations. However, Kearsley and Quarteroli (1997), Kearsley et al., and Hazel et al. (both in press), have shown that occasional flood flows can build beaches and sandbars to higher elevations. Schmidt et al. (in press), have concluded that an initial test of the BHBF in 1996 (BHBF-Test), resulted in smaller bars than were built by flood flows between 45,000 and 96,000 cfs during the mid-1980s. It remains unclear whether this fact is the result of limited stage elevations achieved during the BHBF-Test, limitations in sediment supply in upstream reaches, geomorphic channel characteristics, or all of the above factors combined. With regard to coarser sediments in the mainstem channel, reworking of aggraded debris fans and rapids was shown to only partially occur during the BHBF-Test by Webb et al. (1997), but reworking was hypothesized to increase with increased stage and flow magnitude irrespective of flood-flow duration.

Adaptive Management – Learning-by-Doing

Because adaptive management assumes that knowledge about ecosystem dynamics is never perfect, that management actions are always experiments, and that knowledge is built upon large-scale experiments (Walters, 1997; Walters and Holling, 1990), this assessment is provided mainly to facilitate further discussion between scientists and decision makers about why larger controlled floods might be required, and how such experimental treatments might benefit adaptive ecosystem assessment and management below Glen Canyon Dam. Walters and Holling (1990; see Attachment 3) describe several real challenges faced in designing large-scale experiments intended to support adaptive ecosystem assessment decision making:

1 – Need to demonstrate clearly that substantial, deliberate changes in current policies are required to sustain resources,
2 – Need to expose uncertainties and management decision choices in the form of alternate hypotheses that identify safer, more imaginative experimental options,
3 – On the basis of the above, need for using statistical tools for decision-making support, such as Bayesian methods (Bergerud and Reed, 1998; Nyberg, 1998),
4 – Need to identify designs that can distinguish local versus large-scale effects, and then to use this information to promote replication and comparison,
5 - Need to create designs that permit unambiguous assessment of transient responses to policy changes,
6 – Need to set priorities for investing in research, monitoring, management and design of institutional arrangements such that they can survive long enough to detect large-scale responses that may not occur or become obvious for several decades.

The difficult nature of meeting such challenges when conducting "non-controlled" experiments must be considered and resolved by stakeholders and scientists involved in the Glen Canyon adaptive management program as future flood flows, and other types of experiments, are considered and implemented with respect to the Colorado River ecosystem. In a recent article, Ludwig et al. (1993), propose that resource sustainability may have less to do with managing resources than with managing people. Testing and eventual implementation of alternative-magnitude controlled floods in conjunction with higher load following from Glen Canyon Dam to maintain downstream resources may provide one test for such a hypothesis.

The Draft Assessment and Review of Background Information

This draft assessment is not intended as a recommendation to either the Glen Canyon Adaptive Management Group (AMWG), or its TWG. This assessment intends only to provide information to the Alternative BHBF ad-hoc working group regarding its request (Attachment 1).

In considering testing and implementation of alternative BHBFs and increased load-following operations from Glen Canyon Dam, the GCMRC believes that it is important to review information on what the BHBF was originally intended to achieve with respect to the Colorado River ecosystem (river miles minus 15-to-276). The reader will find additional information on the BHBF summarized from the *Operations of Glen Canyon Dam – Final EIS* (DOI, 1995) in Appendix 1. It is also important to review past criteria by which the initial BHBF-Test was evaluated by the Glen Canyon Environmental Studies in 1996 (Appendix 2). Following completion of the EIS in 1995, and the BHBF-Test, the Record-of-Decision (ROD; a modified version of the "Modified Low-Fluctuating Flow" preferred alternative), was signed by the Secretary of Interior in fall 1996. Additional mention of the BHBF is included in the ROD, and further discussion of this information is found in Appendix 3. The GCMRC has also summarized results of the BHBF-Test, and related topics such as the Hydrologic Triggering Criteria (HTC), and implications of changes made to the preferred alternative before the ROD was signed that have affected BHBF implementation. Collier et al. (1997), also provides an overview of the BHBF-Test. Additional background information and discussion on the BHBF is found in Appendix 4. Descriptions of three potential scenarios under which alternative BHBFs and load-following operations might be studied are presented in Appendix 5 and shown in Table 1.

II) GCMRC RESPONSES TO THE LETTER OF 30, MAY 1998

TWG Proposal Part-A: *"Recommend the magnitude, timing, duration, and pre- and post-flow regimes for a test flow between January and July that best meets the objectives of a BHBF. This should include flows greater than 45,000 cfs."*

GCMRC Response: First, the GCMRC believes that several hypotheses should be carefully considered with regard to the BHBF for purposes of the proposed research, as proposed by the TWG ad-hoc group:

H_1: Shorter (2-4 instead of 7 days) duration BHBFs of 40,000 to 45,000 cfs can be used to restore beaches and promote sand conservation through shoreline storage in sandbars.

H_2: Increased load following, [daily fluctuation flows of 25,000 to 31,500 cfs], following a 40,000 to 45,000 cfs. BHBF is more effective at maintaining beaches than is prolonged (at least one month), high-constant flows (25,000 to 31,500 cfs).

H_3: Release of a BHBF at 60,000 cfs. will both rejuvenate backwater channels and build beaches.

H_4: As a management tool, BHBFs of 45,000 cfs. and above effectively conserve sand system-wide by rapidly coarsening bed sediments, thus reducing downstream sediment transport (export) that would otherwise occur after cessation of controlled flood flows.

H_5: Releasing BHBFs of 45,000 cfs. does not adversely affect any downstream resources when implemented during any month from January through July.

In addition, consideration of several alternative hypotheses might be useful in discussions of whether alternative BHBFs and load-following experimental treatments are undertaken:

aH_1: Long-term, frequent implementation of BHBFs will eventually deplete the ecosystem of limited supplies of tributary input sand and silt/clay, resulting in degradation.

aH_2: Despite readjustment of sandbars to a lower flood-frequency regime (shoreline erosion) associated with dam operations, sufficient fine sediment will remain along shorelines to sustain the ecosystem even without periodic BHBFs.

aH_3: Owing to sand supply limitations and limited flood-flow magnitude, repeated implementation of BHBFs accelerates erosion of pre-dam terraces that contain cultural resources.

aH_4: Although higher magnitude BHBFs may be found to restore backwater channels, these habitats play no significant role in sustainability of endangered native fishes,

aH_5: Repeated implementation of BHBFs of a magnitude less than floods that occurred in pre-dam times will result in greater navigational hazards in rapids,

aH_6: Mechanical, intrusive methods are more effective at building beaches and providing critical habitats for endangered species than are controlled flood flows in the post-dam era,

AH_7: Load-following releases above 25,000 cfs export greater sand loads than steady flows, and erode sandbars and backwater channels at a more accelerated rate than high, steady operations.

With respect to the information requested above on testing alternative BHBFs and load following, and the above hypotheses, the GCMRC suggests that the TWG consider the following suggestions:

BHBF Magnitudes:	45,000 to 60,000 cfs., [titration strategy],
Jan.-Jul. Timing:	Ideally, testing in February through April,
Duration:	2 to 4 days,
Pre/Post Flows:	For Monitoring and Research Purposes, Pre- and Post-BHBF flows should be held steady for 4 days at levels equivalent to the lowest flows that have occurred under normal operations during the period 90 day prior to implementation of the BHBF.

TWG Proposal Part-B: *"Define a test flow regime to reduce beach erosion rates during periods of high powerplant releases (>1.5 maf/mo.). These should include fluctuating flows, (within current daily, upramp, and downramp limits) above 25,000 cfs up to powerplant capacity."*

GCMRC Response: Under the current Hydrologic Triggering Criteria (HTC), it is assumed that the post-BHBF flow regime will be high and constant for at least one month. Such operations may continue for several months if the runoff forecast and inflows remain the same or increase. For testing the influence of increased load following on sandbar maintenance, the currently adopted daily ramping rates and diurnal ranges based on monthly release volumes should be continued during fluctuating flows above 25,000 cfs. that last for at least one month, and in as many months following the BHBF that the forecast remains high enough to force monthly releases of 1.5 maf. or greater.

During this testing period, it is suggested that the peak of diurnal fluctuations be increased to 31,500 cfs. to study the maximum erosional or maintenance effects of such operations. This alternate load-following treatment should be continued and measured at a variety of beach study sites on a daily-to-monthly basis until the forecast requires a reduction in monthly flow-release volume to below 1.5 maf., at which time "normal" operations under the ROD resume. The monitoring of beaches would continue for at least one year following the alternative treatments. Ideally, results of such a test need to be comparable with effects of high, steady operations on beaches with similar initial volumes and areas (geometries).

For a description of various experimental strategies for studying effects of steady versus alternate load-following releases relative to beach maintenance, please see Appendix 5 and Table 1.

TWG Proposal Part-C: *"Assess the advisability of conducting research on A and B sequentially and/or separately,"*

GCMRC Response: For reasons explained more thoroughly in Appendix 5, high-flow research on both proposals A and B, as shown in Table 1, Scenario III, within the same spring runoff season is not suggested, from an experimental and scientific perspective.

The complications of interpreting uncontrolled flood-flow experiments where multiple parameters (treatments) are manipulated, relative to initial evaluation of the BHBF-Test make the Scenario III experiment an inferior scientific strategy.

However, because the strategy of the Hydrologic Triggering Criteria (HTC) by definition means that BHBFs are to be followed by above-normal operations, testing of increased load following versus high, steady flows with respect to beach maintenance should be done sequentially with implementation of BHBFs. A critical component of the sequential approach is to isolate the two treatments and document them so that beach-building and beach maintenance can be interpreted separately, on a quantitative, statistical basis. This will require rapid deployment of aerial photographic coverage and field teams immediately before, during and after implementation of BHBFs, followed by a schedule of beach monitoring for several months to a year afterward.

And,

Proposal Part-D: *"Evaluate, based on best current knowledge, the* [potential] *positive and negative impacts of implementing the proposed test flows."*

GCMRC Responses:

Physical Resources – Higher-magnitude BHBFs have several potential advantages for sediment (beach) and habitat (backwater) resources of the Colorado River ecosystem. However, the benefits versus costs of flood flows at and above 45,000 cfs. still need to be fully evaluated; mainly in terms of effects on the system-wide sand budget through repeated implementation in the long-term, and on potential increased erosion in critical reaches and at specific sites in the short-term.

Pros of Higher BHBFs:

*Larger and higher-elevation beaches than those built by the BHBF-Test.

*Increased conservation of sand - likely achieved through: 1) storage of larger volumes of sediment along shorelines at higher elevations where it may remain for relatively longer periods, 2) rapid coarsening of channel-stored sand that dramatically reduces the suspended and near-bed sand transport rate in the mainstem channel, thus reducing system-wide export of limited sand resources between high-flows.

*Greater degree of reworking of debris fans and rapids aggraded by debris flows that may improve navigation of rapids.

*Potential for significantly increased scientific knowledge about fluvial processes in the Colorado River ecosystem, including suspended and near-bed sand transport that will allow managers to make more informed decisions in the future.

*Increased potential for rejuvenation of reattachment bars that form backwater (return-current channels) habitats.

Cons of Higher BHBFs:

*Possible increased erosion of some beaches where channel-stored sand is minimal (Glen and Upper Marble Canyon), or where geomorphic controls (debris fans) are low profile relative to the high stage.

*Depending on antecedent sand storage in the mainstem channel and alternative BHBF duration, potential for increased sand export from the ecosystem.

*Some increased potential for lateral bank erosion of pre-dam terraces where cultural resources are preserved.

Pros of Higher Load-Following Operations:

*Potential for higher diurnal stages to maintain new beaches in higher-elevation geometry until operations are reduced to normal ROD parameters.

*Potential for higher stage fluctuations to modify newly formed backwater channels in such a way that they are more accessible to native fishes once operations are decreased.

Cons of Higher Load-Following Operations:

*Possibly increased sand export from the ecosystem for a given monthly flow-release volume.

*Increased limitation of campable area use above elevations of 25,000 cfs. during periods when higher load-following operations occur, one to several months.

Biological Resources –

Aquatic Ecosystem Responses

* The aquatic foodbase may be expected to be slightly scoured by any BHBF, but is likely to quickly (1-6 months) recover to pre-BHBF levels.

* A short-duration 45,000 cfs. BHBF is unlikely to detrimentally affect young or adult RBT in the Lees Ferry reach; however, the impacts of higher and/or longer duration BHBF's are unknown and must be considered detrimental until demonstrated to be otherwise.

* No flow from January through April is likely to detectably affect HBC; however, flows in May-July may detrimentally affect young HBC that occupy mainstream shoreline habitats. BHBF's in excess of 45,000 cfs. prior to May, might provide rejuvenated backwater nursery habitats for native fish later in the growing season.

* Flows of duration longer than 2 days may be required to rejuvenate return current channels (RCC's), but the optimal duration is presently unknown and was poorly measured during the BHBF-Test. This duration could be determined by measuring grainsize and velocities under flows rising from normal levels to 45,000 cfs. at several backwaters to predict when scour may occur.

***Biological Cont.* - Riparian Ecosystem Responses**

* BHBF's, particularly those >45,000 cfs., are predicted to detrimentally affect marsh distribution by maintaining coarser grainsize on sandbars (limiting distribution of marsh vegetation) and by scouring channel margin marsh vegetation.

* Burial of established vegetation may result in improved N availability, but not P availability.

* High flows later than the second week of April are likely to stimulate germination of tamarisk and potentially other non-native plant species.

* Higher elevation sandbars may shift riparian plant composition away from dominance by sandbar willow and towards dominance by non-native tamarisk.

* Flows >44,000 cfs. are presently prohibited by several BO's because of take of KAS habitat. KAS take has been established by FWS as not exceeding 10 percent of the habitat. A flow of 60,000 cfs. would greatly exceed FWS take levels of KAS habitat and population.

* Prolonged high flows may detrimentally affect the foraging of wintering bald eagles, while fluctuating flows may benefit bald eagle foraging.

* BHBF's are unlikely to affect peregrine falcon foraging or nesting success.

* BHBF's later than the first of April are likely to affect nesting Neotropical avifauna, and flows >45,000 cfs. in May-June may substantially reduce nesting success of some species.

* BHBF's are unlikely to improve or maintain the SWWF population in Grand Canyon, which strongly affected by the enhanced cowbird population.

* Flows >44,000 cfs. are likely to scour marshes associated with SWWF nesting habitats, which has been designated as critical habitat. Acceptable levels of SWWF critical habitat take has not been established by FWS. A flow of 60,000 cfs. may largely remove those marsh habitats.

Cultural Resources - Cultural resources include archaeological resources and traditional resources of importance to tribal groups. Traditional resources can include ethnobotanical resources, landforms at specific locations, springs, and mineral deposits.

Higher BHBFs have the potential to positively affect certain resources. In other locations and other resources, the benefit of higher BHBFs may be mixed.

Archaeological Resources

Higher BHBFs have the potential to redeposit sediments into pre-dam terrace arroyos containing archaeological materials and slow erosion rates. The effectiveness of sediment redeposition appears related to the stage level of the arroyos, terraces, and the flow releases. In the Glen Canyon reach, pre-dam terrace arroyos are located at stages that appear to be in excess of 100,000 cfs and sediment deposition would not occur in these arroyos. Sediments deposited at the base of these terraces are beneficial but may not be as long lasting. In areas where sediment buffering does not occur at the base of high terraces, some lateral bank retreat may occur.

High steady flows following have the potential to erode recently deposited sediments. However at select locations, sediment remnants of the 1996 test flow remain (M. Yeatts, personal commun., Hopi Tribe).

Traditional Resources

Higher BHBFs have the potential to scour some ethnobotanical resources immediately following high flows. However, results from the 1996 test flow indicate that vegetation was rejuvenated in subsequent months (Phillips, personal com.). Higher flows to the vicinity of the Godding Willow in Granite Park may deposit sediments and nutrients that positively affect the tree. However, high steady flows may remove sediments gained from the high flows, resulting in reduced material at the base of the tree.

Traditional resources in the vicinity of the Little Colorado River confluence include sediment deposits at the base of traditional salt mines and these areas may benefit from sediments deposited from higher flows. However, the effects of sustained steady flows on these areas may be reduced materials at the base of the mines.

Socio-Economic Resources -

Beaches

Higher BHBFs should produce larger and higher-elevation beaches similar to those created during the BHBF-Test. However, high steady flows may limited the campable area of beaches in certain locations at specific stage levels. Recently collected field data on campable areas (J. Hazel, personal commun., NAU Geology department) versus stage/discharge at long-term sandbar monitoring sites can provide some insight on the potential need for higher stages with respect to beach building and maintenance (Table 2). These data should be carefully considered when planning future BHBF research.

Fishing

Fishing activities may be affected by higher BHBF in that some gravel bars used for fishing may be inundated during higher flows and during subsequent high steady flows.

Rafting Activities

Day rafting activities may experience some effects from higher flows in that travel times may be reduced and some shoreline areas of interest may be inundated. Negative impacts from higher flows and high steady flows are not anticipated.

White water rafting below Lees Ferry may experience affects during higher BHBFs at locations of rapids. Depending on the configuration of the rapid, some rapids may become less challenging, while others may become more challenging.

Economic Concerns

Hydropower concerns may be affected by the loss of water releases through the river outlets and the bypass of the generator systems. However, high steady releases through the generators following the BHBF may compensate for revenue losses during the BHBF.

Conceptual Model Development – An Adaptive Environmental Assessment Model (conceptual model) of the Colorado River ecosystem was developed in FY 1998 and FY 1999. The conceptual model provides critical input into the selection of parameters to be monitored and is also being used to evaluate proposed management actions for their potential effect on downstream resources of concern.

The process of building the conceptual model has provided an opportunity to organize complicated relationships into an understandable framework of study, test assumptions, and develop hypotheses of how the resources being managed may respond to proposed management actions. The conceptual model has also provided a general framework for understanding how the Colorado River ecosystem works, requiring the organization of many scattered pieces of information into an integrated framework.

In general, conducting additional BHBFs provides the opportunity to test the structural relationships embedded in the model, refine parameter estimates, and identify specific additional modules that need to be developed. Therefore, running a BHBF is considered beneficial to the overall development and validation of the conceptual model. The desire to compare model output with observed effects on the Colorado River ecosystem from specific treatments suggests that one should not run a flood event and fluctuating flows as a single treatment. However, model development will benefit equally from running a BHBF of 45,000 cfs or 60,000 cfs. In any case, to assist with model development, the specific action to be run should be specified and the computer model should be run as a means of identifying specific monitoring and research activities to be conducted and to be able to compare model output with monitored responses.

III) SUMMARY AND CONCLUSIONS

In this draft assessment, the GCMRC has considered and responded to stakeholder's requests for information on testing of alternative BHBFs and increased load-following effects with respect to beach maintenance. In addition, three scenarios were summarized for consideration by Glen Canyon Adaptive Management stakeholders with respect to: 1) alternative BHBFs, and 2) diurnal fluctuating-flow operations from Glen Canyon Dam, as improved methods for building and maintaining beaches, and aquatic habitats thought to have critical value to the Colorado River ecosystem (Appendix 5 and Table 1). The GCMRC believes that the experimental strategy described under Scenario I (three experiments in three separate years) is the most sound approach for testing most of the hypotheses included in Section II of this report.

Existing information suggests that alternative BHBFs of at least 60,000 cfs. may be needed to restore backwater channels. Beaches were shown to build in response to the BHBF-Test (45,000 cfs.), and most of those beaches are hypothesized to build to even higher elevations under larger magnitude BHBFs, but backwater channels were not restored at the 45,000 cfs. level. While there is some potential for erosion of beaches and pre-dam terraces in critical reaches and at specific sites resulting from higher BHBFs, there is also great potential for increasing system-wide conservation of sand.

Existing information suggests that under widely ranging diurnal fluctuations, sand transport for a given daily volume of flow is increased relative to steady flows (DOI, 1995). However, the EIS does not address the hypothesis that geomorphic processes associated with limited-range fluctuations near powerplant capacity may also have a higher potential for beach maintenance. This hypothesis remains to be tested in a scientifically definitive manner. It is also possible that sand export under fluctuating flows between 23,000 and 31,500 cfs. is roughly equivalent to that of steady operations above 25,000 cfs. Estimates are possible for such transport values, export rates on these two operations are known to vary greatly depending on antecedent sediment-storage conditions in the mainstem channel. However, field measurements for suspended-sediment transport rates made during flow testing will provide optimal information to compare these two maintenance flow regimes.

Although current HTC allow for potential implementation of BHBFs in all months beginning in January through July, existing resource criteria suggest that such management flows might not be implemented in the months of May though July. Hydrologic output from the conceptual model indicate that the majority of months in which the HTC are met in most years will be either May, June or July. Hence, the proposition that present HTC result in more frequent opportunities for implementation of managed flood flows from Glen Canyon Dam may be more hypothetical than actual. Also, because resource criteria might preclude BHBFs in late spring or early summer, the

GCMRC suggests that the ad-hoc group on HTC-design meet to reconsider the probabilistic rationale for current HTC with the GCMRC and TWG in future meetings.

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APPENDIX 1. – *Beach/Habitat-Building Flow Characteristics* (DOI, 1995)

With respect to BHBF magnitude, the EIS states that:

"Magnitudes would be at least 10,000 cfs greater than the allowable peak discharge in a minimum release year for a given alternative but not greater than 45,000 cfs."

Under the "Modified Low-Fluctuating Flow" alternative adopted as the ROD in December 1996, and mandated as operating criteria for Glen Canyon Dam by the Secretary of Interior in February 1997, the BHBF is presently limited to managed "flood flows" of between 40,000 and 45,000 cfs (see p. 40, Table II-6, DOI, 1995).

With regard to timing and implementation, the EIS also states that BHBFs:

"could be scheduled in the spring (to coincide with the May/June peak in the natural hydrologic cycle) or in late summer when, due to local thunderstorms, tributaries are expected to supply large quantities of sediment (especially silt and clay) and nutrients... The exact season and duration would be determined through adaptive management."

With regard to implementation, the EIS states that:

"Such flows would be scheduled only in years when projected storage in Lake Powell on January 1 is less than 19 maf (low reservoir condition). Scheduling beach/habitat-building flows during high reservoir conditions would be avoided because of increased risk of unscheduled flows greater than powerplant capacity."

GCMRC Comments: To resolve legal conflicts regarding releases above powerplant capacity (flood flows) from Glen Canyon Dam with respect to BHBF implementation and Lake Powell storage, the ROD stipulates that under the preferred alternative, BHBFs will only be implemented in years when both inflow and storage in Lake Powell are expected to be high. As a result, stakeholders have agreed on an implementation protocol under which BHBFs will only occur in years when flood flows are likely to occur naturally from Glen Canyon Dam on the basis of antecedent storage conditions and forecasted upper Colorado River Basin runoff.

This change in the preferred alternative, from that described in the EIS, has several important implications for sediment and related resource preservation below Glen Canyon Dam. One of the most obvious, is the possibility of implementing BHBFs greater than 45,000 cfs when the reservoir storage elevation is above 3,648 feet (minimum spillway floor elevation). Another implication is that downstream resource conditions are now a primary consideration in guiding implementation of BHBFs during wet hydrologic conditions when Glen Canyon Dam powerplant operations will necessarily be higher than average – that is when the potential for sand export from the ecosystem is greatest. Although an unintended consequence of altering the original EIS criteria for implementation of BHBFs, the current strategy may in-fact provide a more conservative strategy for keeping sand in critical reaches of the ecosystem, on the basis of new knowledge gained from the BHBF-Test. Unfortunately, testing of the BHBF in months that coincide or immediately follow summer tributary inputs is presently precluded by the fact that BHBFs can only be implemented during the months of January through July.

APPENDIX 2. – *Previously Identified Criteria Used by the Glen Canyon Environmental Studies for Evaluating the 1996 Test of the Beach/Habitat-Building Flow* (DOI, 1997)

KEY -
Primary Objectives [versus]
Implied Beneficial Effects

Redeposition of high elevation sand, followed by decreasing erosion rates;
Preserve and restore camping beaches;
Flush non-native fishes;
Rejuvenate backwater habitat for native fishes;
Maintain open sandbars for camping (scour New-High-Water Zone vegetation);
Provide water to Old-High-Water-Zone vegetation;
Protect cultural resources;
Meet objectives without significant adverse impacts to: endangered species; cultural; trout fishery and economics.

GCMRC Comment: Although the EIS mentions many ways that BHBFs might affect and even benefit a variety of physical, social and cultural resources below Glen Canyon Dam, cooperating scientists generally agree that the primary reasons for implementing such managed high flows are intended to manipulate sediment resources, specifically:

> **"to rebuild sandbars, deposit nutrients, restore backwater channels, and provide some of the dynamics of a natural system (DOI, 1995; p. 40)."**

To achieve many other objectives associated with evaluation criteria studied during the BHBF-Test in 1996, the GCMRC suggests that stakeholders evaluate the potential usefulness of management actions and tools other than controlled flood flows.

APPENDIX 3. – *Additional GCMRC Assessment of the Record-of-Decision (ROD) With Respect to the Beach/Habitat-Building Flow* (DOI, 1996).

GCMRC Comments: The 9 October 1996 Record of Decision (ROD) states that the basis for selection of the preferred alternative was to "...find an alternative dam operating plan that would permit recovery and long-term sustainability of downstream resources while limiting hydropower capability and flexibility only to the extent necessary to achieve recovery and long-term sustainability."

The ROD reiterates the EIS's BHBF objectives, stating:

"under certain conditions, steady flows in excess of a given alternative's maximum will be scheduled in the spring for periods ranging from 1 to 2 weeks. Scheduling, duration, and flow magnitude will be recommended by the Adaptive Management Work Group and scheduled through the Annual Operating Plan process. The objectives of these flows are to deposit sediment (elsewhere as "sandbars") at high elevations, re-form backwater channels, deposit nutrients, restore some of the natural system dynamics along the river corridor, and help the National Park Service manage riparian habitats." Also, "in the final EIS, it was assumed that these flows would occur in the spring when the reservoir is low, with a frequency of 1 in 5 years (DOI, 1996)."

With regard to the magnitude of BHBF's, the ROD states:

"...the frequency of unanticipated floods in excess of 45,000 cubic feet per second will be reduced to an average of once in 100 years."

Therefore, triggering criteria to exceed 45,000 cfs do not appear to be permissible within the ROD.

The phrase "deposit nutrients" as an objective for high flows is problematic. Long-term alteration of nutrient dynamics in the post-dam Colorado River is one of the largest impacts of flow regulation. In the low-productivity pre-dam Colorado River, high flows transported a large pulse of organic carbon (C) in various fractions and some nitrogen (N), as well as large quantities of phosphorus (P)-bearing fine sediments. Most of these nutrients probably swept through Grand Canyon, but some was stored in driftwood piles or buried (especially C and N) or was deposited as silt-enriched sediment deposits (P). As demonstrated by the 1996 experimental flood, post-dam floods can move relatively large quantities of organic C; however, a novel result of post-dam floods was the widespread burial of existing vegetation, resulting in increased N availability within sandbars for a period of about 2 yr. following the flood (Stevens et al., 1996). With regards to P (which several scientists consider to be a limiting nutrient in this river ecosystem; see Wegner et al., 1983; Stevens and Ayers, 1992; Stevens et al., 1995), post-dam floods are scouring events that remove accumulated silt and clay from reworked sediments (Stevens, 1989). The reworked sediment deposits from the 1996 flood had very low silt and clay concentrations, and were primarily fine sand; the P-rich silt and clay fraction was either entrained and exported or was buried and made unavailable. Increasing P concentration on a system-wide basis is better served by low flows, which permit deposition of tributary-derived silt and clay fractions in low velocity environments, such as return current channels. Therefore, the objective of high flows to "deposit sediments" is either largely contrary to natural flooding processes for C and N, or is largely unattainable for P.

It should also be noted that the ROD explicitly states under the Emergency Exception Criteria section that:

"This commitment provides for exceptions to a given alternative's operating criteria during special studies and monitoring..."

APPENDIX 4. – *Additional Background Information on the Beach/Habitat-Building Flow, Objectives, and the EIS Preferred Alternative, Considered in Assessment of the BHBF Alternative Proposal.*

GCMRC Comments: One fundamental assumption underlying the "Preferred" alternative described in the EIS, is that "Modified Low-Fluctuating Flow" operations would significantly reduce sandbar erosion and system-wide sand export (through a combination of reduced hourly ramping rates, daily fluctuating ranges and average flows), while promoting sand storage in main-channel pools and eddies. Under such enhanced main channel sand storage conditions (presumed), the primary objective of the BHBF is to occasionally mobilize sand from storage areas at low elevations and redeposit it in longer-term storage zones along shorelines at higher elevations as sandbars. Theoretically, this is a sound strategy for conserving fine sediment, and thereby sandbars and related habitats, but one that can only be expected to succeed if assumptions about long-term trends in tributary inputs, and residence time for sand storage in pools, eddies and shoreline environments are valid. The ideal frequency of BHBFs, with respect to system-wide sediment conservation ultimately depends then on BHBF magnitude and duration relative to the balance between tributary sediment inputs, residence time and net storage potential for pools and eddies, influence of dam operations during intervening periods, and erosion rates of terrestrial sandbars.

A test of the BHBF below Glen Canyon Dam in 1996 (BHBF-Test), showed that abruptly increasing dam releases from 8,000 to 45,000 cfs. can result in rapid aggradation of sandbars and reworking of debris fans over relatively shorter periods than previously hypothesized in the EIS. Perhaps more importantly, the BHBF-Test also suggested that relatively frequent, short-duration high flows might be more important with respect to system-wide sand conservation than are modified low-fluctuating flows. Because the BHBF-Test, resulted in rapid shoreline storage of large volumes of sand (Rubin et al., 1998), the high flow coarsened channel-stored sediment, thereby reducing sediment transport in the main channel to rates below those that would have otherwise occurred. On the basis of the BHBF-Test results, Rubin et al. (1998) concluded that for any given high-flow regime, fine channel-bed sediments are depleted from the river bed through shoreline deposition. This depletion of channel-stored fine sediment forces sediment transport rates to be reduced until such time that either tributary inputs, or erosion of shoreline deposits, once again add fine sediment to main channel storage sites. The net result of the BHBF-Test with respect to sand was that the concentration of suspended sand and silt decreased during the first three days of the seven-day high flow, while the relative percentage of coarse suspended sand transport was increased Rubin et al. (1998). The fact that these processes occurred so rapidly (over three days) provided new information about how floods could be used to preserve resources, and to some extent, revolutionized potential strategies for conserving sediment below Glen Canyon Dam.

Because both shoreline deposition and bed coarsening occurred relatively quickly, and because both processes favor system-wide sediment conservation, cooperating GCMRC physical scientists hypothesize that optimally timed BHBFs of varied magnitude and duration may not only rebuild beaches to higher elevations, but may also promote system-wide sand conservation during intervening periods when flood flows do not occur, but high powerplant releases do occur.

The mission of the GCMRC, in part, is to provide information to stakeholders on whether operations of Glen Canyon Dam under the Record-of-Decision (ROD) are effective in achieving the intent of the Grand Canyon Protection Act of 1992. Hence, investigation of alternative BHBF flows that might better achieve the goals of that legislation are of scientific concern to both the GCMRC and to the adaptive management program.

Hydrologic Triggering Criteria, (HTC) – as presently adopted by the Glen Canyon adaptive Management Group (AMWG) for determining years and months in which BHBFs may be recommended to the Secretary of Interior for implementation. In addition, resource criteria have been designated by stakeholders for secondary evaluation once HTC are met. With respect to sand conservation, it is hypothesized that short-duration high releases above powerplant capacity that occur immediately before prolonged, high powerplant discharges are preferable as long as shoreline storage sites are open. Monitoring data collected on sandbars from April 1995, through April 1998, suggest that high, constant powerplant releases associated with wetter basin hydrology and high storage conditions in Lake Powell, result in accelerated erosion of terrestrial sandbars (Northern Arizona University, Geology Department, 1997 annual report).

For the month of January, the HTC are based on projected January 1st storage in Lake Powell of 21.5 maf, and forecasts for above average (140 percent of normal) Upper Colorado River Basin runoff (April-July). After January, any monthly forecast update that forces a monthly release volume of 1.5 maf. or greater also is a trigger. Such hydrologic forecasts usually begin in January and are updated on a monthly basis through July. Hence, occurrence of BHBFs of any magnitude in late summer or fall, when tributaries are actively discharging sediment, is not presently possible, except as a "test" flow designation. Although it is possible for the AMWG to recommend implementation of experimental test flows to the Secretary by consensus in any month or year, concerns among stakeholders regarding the Law of the River and flood flows from Glen Canyon Dam have proven to be a constraint on testing "flood flows" in months other than January through July, or in years of low storage and projected inflow to Lake Powell. As presently agreed upon by stakeholders, the HTC restrict months for BHBF implementation to January through July of projected higher-than-normal runoff years. This is seen by the GCMRC as a real constraint for large-scale experimentation and adaptive management. However, the GCMRC does recognize that the present HTC do allow for potential increased sediment conservation prior to periods when sand export and sandbar erosion are expected to be highest; that is when constant powerplant flows are adjusted to equal or exceed 25,000 cfs on the basis of runoff forecasts.

Current "Non-Hydrologic" Resource Triggering Criteria, - Although the hydrologic triggering criteria may be met for any one year, other resource criteria may not. The process of resource evaluation and deciding whether to recommend proceeding with a

BHBF is dependent upon 1.) the state of resources, particularly the 10 "significant" resources (i.e., endangered species, trout and cultural resources), 2.) the management objectives for the resources and 3.) the effect of timing, magnitude and duration of the BHBF on resources. Evaluating these elements and coming to a decision is based on a set of supporting documents that point out critical time of year for resources, critical life stages for a resource, or describe stage/discharge relationships associated with physical habitats, structures, or properties with specific geographic locations. Current management objectives and the state of the knowledge regarding resources suggest that BHBF should not occur after April of any year. For further information regarding the non-hydrologic resource criteria review the "resource criteria documents."

Unforeseen, Potential Benefits of Modified Antecedent Conditions for BHBFs, - Because projected reservoir storage will necessarily be higher than 19 maf before implementation of BHBFs under current HTC (reservoir minimum spillway elevations of 3,648 feet or greater), flows above 45,000 cfs are possible for testing and eventually for management purposes through use of one or both spillways at Glen Canyon Dam. Under the original implementation criteria for BHBFs described in the EIS, it was assumed that the flood flow release potential for the powerplant and river outlet works was 45,000 cfs. This was mainly a limitation of hydraulic head and the fact that the reservoir elevation would potentially fall below 3,648 feet, as well as the perception that very large floods were damaging and that spillways could only be used for emergency purposes. During early 1998, stakeholders resolved the question about whether spillways at Glen Canyon Dam could be used for non-emergency management purposes periodically, concluding that such releases were feasible under limited conditions.

If BHBFs were only allowed in years with Lake Powell storage below 19 maf, as the EIS recommends, then alternative BHBF magnitudes greater than 45,000 cfs would likely not be possible. Finally, it must be recognized that the current HTC were agreed upon by stakeholders with the realization that they potentially provide more frequent opportunities to implement BHBFs than previously inferred from the EIS (from about 1 in 10 years, to as frequently as 1 in 6). Scientists from the U.S. Geological Survey (D. Rubin and D. Topping, personal communication; Rubin et al., 1998) have hypothesized that more frequent BHBFs might be the most effective strategy for conserving sand (perhaps as frequently as annually), especially if greater shoreline storage areas can be accessed by stages above 45,000 cfs. Field observations during the 1998 field season by GCMRC staff indicate that large volumes of sand deposited by the peak flow of 1983 remain in storage along shorelines despite high erosion rates documented through the 1980s and 1990s (Schmidt and Graf, 1990).

It is clear that while the original intent of limiting BHBFs to only relatively dry periods had some conservation merit, it was a strategy that imposed limits on BHBF magnitude and in its own way limited testing of flood flows as conservation and restoration tools. Implementation of BHBFs during relatively wetter periods allows for more flexibility in the range of flood flows that can be implemented. On average, the HTC also provide more frequent opportunities to conserve sand and modify habitats and do so during periods when powerplant releases would otherwise likely degrade downstream sediment resources. Also, implementation of BHBFs prior to constant, high powerplant releases reduces sand transport, and hence export of what is a limited resource. Under the present HTC, the potential for restoring spring flood dynamics that characterized the natural ecosystem is high, but potential for depositing nutrients (clay/silt and organic materials) is somewhat limited since BHBFs cannot presently be implemented in late summer when tributary inputs of fines commonly occur.

Results of the 1996 Controlled Flood Flow Experiment, - (BHBF-Test) Several criteria were identified for evaluating the effects of the 1996 BHBF-Test flow (Appendix 1), although only 2 of these 8 criteria can truly be identified as BHBF objectives. Test results suggested that most biological resources were neither benefited nor severely degraded by the 45,000 cfs test release for 7 days. However, sediment resources were clearly benefited in two ways: 1) beaches (sandbars with recreational value) generally built to higher elevations, and in many cases to nearly the water surface; and 2) sediment transport in the main channel was reduced following the high flow because of dramatic winnowing of fines from channel-bed stored sand. Backwater channels, however, were not restored.

While backwater channels were not restored, arroyos draining pre-dam terrace sites where cultural resources are preserved were partially aggraded. The general consensus of most physical scientists who studied the BHBF-Test was captured as a new hypothesis: that is, that sediment conservation might be greatly enhanced system-wide by relatively frequent BHBFs for shorter duration at or above 45,000 cfs. It was also recognized that while backwater channels were not restored by the BHBF-Test, these features were restored by the peak discharge of 1983, about 95,000 cfs. Scientists also hypothesized that some higher magnitude BHBF above 45,000 cfs would therefore be required to restore backwater channels. Recently aggraded rapids, clogged by boulders deposited by debris flows, were only partially reworked by the BHBF-Test. Since most of the debris fan reworking occurred during the rising limb of the test flood, researchers also hypothesized that higher magnitude, shorter duration BHBFs in the future would facilitate greater rapid reworking at sites where navigation was an issue. Although higher magnitude BHBFs might better achieve intended goals of beach and habitat building, additional costs in terms of the net sediment budget and degradation of other resources must be considered.

For instance, while the BHBF-Test did show some benefit to preserving pre-dam terraces containing cultural resources, it remains unclear whether increased sand deposition to higher elevations at some cultural sites would offset possible erosion of other sites during higher BHBFs, for instance in the Glen Canyon reach. This is certainly a topic that requires more intensive monitoring and research if alternative BHBFs are studied in the future.

GCMRC-Identified Objectives for BHBF Releases (October 1998), - In light of the recent and ever-growing body of scientific information about the Colorado River ecosystem, the GCMRC first recommends that members of the TWG review of the *Final Operations of Glen Canyon Dam EIS* for insights about the original intended objectives for implementing BHBFs as a means of restoration and preservation of the riverine ecosystem. This first step in the alternative BHBF assessment process is critical, since some scientists have suggested that not all evaluation criteria that guided planning and implementation of the BHBF-Text were intended as true BHBF objectives. To help in this review process, the reader is encouraged to review the criteria used to evaluate the effects of the 1996 experiment (Appendix 2), as well as excerpts of the EIS (Appendix 1), where the BHBF release is specifically referred to. It is important to note that the BHBF was intended as a component of ROD dam operations under all alternatives considered in the EIS process excerpt for the no action alternative, and that these managed floods are considered a vital part of the ROD that was signed in December 1996 (Modified Low Fluctuating Flow Alternative). Because of this fact, the GCMRC believes that further study of BHBF releases is scientifically warranted.

On the basis of a reevaluation of the BHBF described in the EIS and related text in that document, the primary intent of implementing the BHBF release is to replenish sediment-dependent geomorphic features of the main channel which support the aquatic habitat, delay erosion of pre-dam terraces containing cultural resources, support "beaches" for recreational use, and maintain open navigation of rapids.

On page 97, under the heading "Sandbars (Beaches and Backwaters)" the EIS states:

"Sandbars are important for vegetation, riparian habitat for fish and wildlife, and recreation. Beaches are sandbars that have recreational value. Backwaters are low velocity areas formed by low elevation sandbars."

Hence, a literal interpretation of the term "Beach/Habitat-Building Flow," would be any flow above 40,000 cfs that is effective at building sandbars at elevations:

"...several feet above the (highest normally achieved under the ROD) water surface to be dry and suitable for wildlife habitat or camping." (DOI, 1995; p. 40).

In its purest form then, the BHBF is intended to be a release from Glen Canyon Dam above powerplant capacity that results in entrainment and transport of sediment in the main channel, and deposition of sand, and finer material along the shorelines of the main channel. The EIS specifically mentions the following details about the BHBF as:

"scheduled high releases of short duration designed to

rebuild high elevation sandbars (Sand Conservation and Sandbar Preservation),

deposit nutrients (Sustain Nutrient Budget Through Deposition of Silt/Clay),

restore backwater channels (Physical Habitat Restoration Related to Maintenance of Specific Sandbar Morphologies),

and

provide some of the dynamics of a natural system (Restoration of the Pre-Dam Flood Disturbance Regime)."

While previous efforts to evaluate the BHBF-Test by GCES included criteria other than those objectives listed above, it is important to recognize that the main reason for implementing BHBFs is conservation and manipulation of sediment and restoration of sediment-related geomorphic features such as beaches (recreational) and return-current channels associated with aquatic habitats (backwaters). Although secondary benefits of the BHBF releases may include removal of debris from aggraded rapids, and deposition of sand in the mouths of some arroyos, there is no reason to believe that the BHBF as described in the EIS was ever intended to: 1) flush non-native fishes, 2) specifically maintain open sandbars through scouring of new-high-water-zone vegetation, 3) provide water to old-high-water-zone vegetation, or even to 4) prevent erosion of cultural resources. There does seem to be a clear intent to ensure that the beach and habitat building that was intended, occurs without significant adverse impacts to endangered species (specifically, young-of-year humpback chub).

Upon review of the EIS with regard to the BHBF, it is clear that periodic, controlled releases from Glen Canyon Dam above powerplant capacity were not intended to be a panacea for all management concerns related to the Colorado River ecosystem, such as several of the criteria originally used by GCES to evaluate the BHBF-Test. The BHBF was more clearly intended to be a management tool for rebuilding sandbars defined by the term "beaches" and sandbar-dependent habitats such as "backwaters."

Additional GCMRC Perspectives on Implementation of the BHBF – Additional considerations held to be important by GCMRC scientists about implementing BHBFs with respect to resources include: 1) avoid or limit dispersal of non-native species, particularly riparian plant species such as tamarisk, camelthorn, and various non-native grasses, 2) Avoid impacts or injury to recreational river runners, and 3) Maintain or enhance the long-term sustainability of populations of special concern. This objective recognizes that short-term losses during a BHBF are anticipated to be offset by longer-term (6+ month or greater) benefits to wildlife habitat and food resources.

Adaptive Management and Large-Scale Experimentation - Adaptive management (AM), as propounded by the GCMRC and the research community (Walters and Holling, 1990; Attachment 3), is based on the goal of maintaining healthy, sustainable ecosystems through time. AM is a scientific process which emphasizes that ecosystem management actions are scientific experiments. These management experiments should involve: 1) testing of clearly stated hypotheses, with sufficient planning, funding for the appropriate intensity and timing of measurements; 2) verification of results through replication and consistent monitoring, and further testing of issues left uncertain by previous tests; 3) control of other, potentially confounding variables to the greatest extent possible; 4) collection of data to produce models which can be used to simulate predict the impacts of future management actions; and 5) timely, understandable reporting of peer-reviewed results to managers. The AM management philosophy is based on learning by doing at the ecosystem level, and one in which surprises, new developments and new relationships are expected, potentially dramatically altering management directions through time to achieve more effective resource sustainability.

Reference to adaptive management as the preferred means of fine tuning the BHBF suggests that sound research design and scientific investigation should guide management decisions about implementation with respect to timing, duration, magnitude, frequency, hydrograph shape, etc. for maximum benefit to the ecosystem and minimal adverse impact. Owing to limitations imposed by the presently agreed upon means of implementing BHBFs (see the section on Hydrologic Triggering Criteria), controlled flood flows greater than powerplant capacity can only occur in the months of January through July. Flows up to 45,000 cfs (within the ROD), or greater (outside the ROD) in non-runoff forecast months (August through December) may be implemented by the Secretary for purposes of research, but are technically designated as "Test Flows." For the purpose of this report, it is the belief of the GCMRC that any controlled flood flows from Glen Canyon Dam approved by the Secretary, that fall outside the ROD operating criteria must be considered as test flows until such time that the ROD is modified to include such flows, for instance BHBFs greater than 45,000 cfs, or fluctuating flows that exceed 25,000 cfs.

APPENDIX 5. – *Descriptions of Possible Alternative BHBF and Load-Following Scenarios.*

The GCMRC suggests that the ad-hoc group first consider a multiple-year experimental approach (potentially starting in Water Year 1999), rather than an approach in which several parameters are manipulated relative to the one controlled flood previously tested. The strategy of manipulating only one flow parameter at a time is considered scientifically most prudent if stakeholders wish to use "uncontrolled experiments" for the purpose of researching impacts of a BHBF of 60,000 cfs, and evaluation of higher load-following (fluctuating flows), versus high steady powerplant operations following BHBF releases, with respect to beach/habitat-building and beach maintenance (see Table 1).

Because manipulations of high flow in the Colorado River ecosystem are at best considered uncontrolled experiments, partial replication of the 1996 BHBF controlled flood (BHBF-Test) will test the hypothesis derived from that initial experiment, that a shorter duration 45,000 cfs BHBF (2-4 days) is also effective at rebuilding beaches, but still cannot restore backwater channels. The following text and information found in Table 1, describes two main scenarios under which alternative BHBFs and effects of load following releases might be tested. Scenario I, consists of three separate experimental flow releases conducted in three separate years.

Scenario – I *(Single-Treatment Experimental Design[Preferred])* - In Flow I of Scenario I, the only flow parameter of the BHBF that is manipulated is its duration, from 7 to 4 days. It is important to recognize that differences in antecedent storage of sand in the channel and along shorelines from one BHBF to the next may strongly influence each future outcome. For this reason, it is critical to have a consistent physical and biological monitoring program established that can document starting conditions before all high flows. A second difference between the BHBF-Test and Scenario I, Flow I, occurs with respect to the flow regime following the BHBF. Rather than fluctuating flows below 25,000 cfs, as occurred in spring and summer 1996, dam operations under Flow I following the BHBF would consist of steady powerplant releases at a level somewhere between 25,000 and 31,500 cfs. Because one goal of future flow research is to determine whether high constant flows (>25,000 cfs), or higher fluctuating flows (between 25,000 and 31,500 cfs) are better at maintaining newly built sandbars after BHBFs occurs, it is critical to first better understand how newly built beaches are effected by high, steady flows.

Ideally, implementation of this secondary treatment in conjunction with future management flood flows will be determined by the results of the first two parts of the three-phase high-flow research. With regard to fluctuating versus steady flows and sand transport, page 97 of the EIS (figure III-16) indicates that sand transport nearly doubles under widely fluctuating flows versus steady flows for a given volume of water over one day. However, the geomorphic depositional response to more widely ranging daily flows is not accounted for in this simplified comparison. It is possible that under a limited range of fluctuations near powerplant capacity, that the sand transport is not significantly greater than under high, steady operations. This could be even more likely after the bed of the mainstem channel has been coarsened by a high-magnitude flood flow. It is important to test both the steady and the fluctuating flow regimes in the first two phases of this research to determine differences in total export volumes (precise field measurements of suspended sediment) versus effectiveness of sandbar maintenance (precise field topographic measurements) for monthly flow volumes in excess of 1.5 maf (the current threshold of monthly flow volume needed to meet the hydrologic triggering criteria for BHBF implementation). It is feasible that high-steady flows in such months export less sand from main channel storage than fluctuating flows, but are poor at maintaining newly built sandbars. In contrast, fluctuating flows above 25,000 cfs may better maintain sandbars, but at the cost of increased sand export. Ultimately, either response must be evaluated with respect to it impact on the sediment budget for sand in critical reaches, such as Marble and Glen Canyons.

Scenario II *(Accelerated Single-Treatment Design)* – From an experimental perspective, this scenario is not as ideal as Scenario I. It consists of two experiments instead of three, and is somewhat more rigorous in experimental design than Scenario III. Here, the effects of steady flows above 25,000 cfs. on newly built beaches are assumed to be the same as the beach erosion documented by the sandbar monitoring data collected in winter and spring 1997, under steady flows that reached 27,000 cfs (Kaplinski et al., 1998). The first phase of the test includes a 45,000 cfs. BHBF for 2-4 days, followed by alternative load-following operations above 25,000 cfs. Although not directly comparable owing to different initial beach conditions, data from phase I are evaluated with respect to the 1997 data to choose flows that will be implemented following a 60,000 cfs. BHBF that is then implemented in Phase II of this scenario. Although not as ideal from an experimental viewpoint, this scenario likely provides the most useful information to managers if the length of the testing period is a significant consideration, especially if the HTC are not likely to be met twice in a period of two to four years.

Scenario III *(Multiple Experimental Treatments)* – In this third scenario, several new treatments are imposed on the resources of the ecosystem in a single two-part test flow. On the basis of the HTC, an alternative BHBF of 60,000 cfs is released for two days potentially (changes in duration, magnitude and antecedent conditions of sediment storage compared with the BHBF-Test of 1996) in any month from January through July. As in the other scenarios above, the GCMRC believes that two to three weeks advance planning and notice (HTC driven), will not be sufficient to prepare for a higher magnitude BHBF, from either a scientific research, permitting, or public safety viewpoint. In this scenario, it will be tempting to attribute any major sandbar responses following the larger magnitude BHBF primarily to flow magnitude, when in fact the response may also be as equally related to increased sediment storage from large-volume Paria and Little Colorado River inputs in summer 1997 and 1998. This scenario fails to provide any level of replication of the BHBF-Test, and provides little information that can be rigorously compared with the 1996 flood-flow results.

Effects of alternative higher fluctuating flows on sandbar maintenance will not be directly comparable to flows and bar erosion following the BHBF-Test, because the starting conditions of beaches built by the larger magnitude BHBF will likely be radically different. This scenario, with such complex treatments in the uncontrolled setting of the

Colorado River make evaluation of the treatment with respect to single parameters problematic from a scientific viewpoint.

While the GCMRC appreciates the applied nature of science and experimentation within the context of adaptive management, the legal and political constraints of doing high-flow research in other-than years when HTC are met, and the need to gather new information in a timely manner, this approach cannot be supported from a technical perspective over the one-year experimental approach shown in Table 1. The complex, one-season study approach under strict HTC limitations is not provide an optimal scientific basis for researching impacts of a BHBF exceeding 45,000 cfs, and higher fluctuating flows following BHBF releases. If the overall goal is to determine whether high constant flows (>25,000 cfs), or higher fluctuating flows (between 25,000 and 31,500 cfs) are better at maintaining newly built sandbars after BHBF occurs, and whether there are significant added benefits (without adverse impacts) to the resources of the ecosystem by periodic BHBF releases greater than 45,000 cfs, then the major treatments need to be isolated to the greatest extent possible.

Although the 1997, high, steady flow beach data (27,000 cfs.) could be compared with the load-following effects on bars in this scenario, the initial geometry of beaches following the 60,000 cfs. BHBF is likely to be very different from those studied in 1997 following the HBF-Test. This fact will make a meaningful comparison of the two flow regimes difficult to interpret in a scientifically reliable manner. Also, this scenario is the only one besides the No-Action scenario that does not allow for at least one replication of beach-building to the same elevation as occurred in the BHBF-Test. Designing uncontrolled experiments with respect to temporal and spatial scales that promotes replication and comparison is one of the challenges of the adaptive ecosystem assessment process.

Scenario IV *{No Alternative-BHBF Actions}* – This scenario will occur under existing HTC and ROD operations without further recommendations from the AMWG to test alternative BHBFs. Under this scenario, sediment conservation and beach preservation potential can only be expected to occur to the levels observed in the BHBF-Test, since storage sites to the elevation of the 45,000 cfs stage are limited. Restoration of backwater channels will not occur with BHBFs limited to 45,000 cfs, and can be expected to continue filling in with fine sediment. This situation will limit managers' understanding with regard to a fuller range of options for preserving beaches at elevations above 45,000 cfs, reducing sand export, and restoring backwater channels under a greater variety of resource and hydrologic conditions. Also, by failing to test the geomorphic hypothesis that higher fluctuating flows are better at maintaining newly built sandbars, diurnal fluctuating-flow operations will likely remain limited to 25,000 cfs, as mandated under the ROD.

GCMRC Comment: The potential for BHBF study flows to occur in different months under the three parts of Scenario I is recognized as a problem, both from the perspective of resource criteria and evaluation of biological impacts. Further, the present resource criteria indicate that BHBFs should perhaps be avoided in all years during the months of May through July. Finally, the implementation of a BHBF above 45,000 cfs under current Hydrologic Triggering Criteria is not advocated by the GCMRC. Using the HTC to trigger alternative BHBF and load-following tests for the more preferred strategies (Scenarios I and II), means that the research may not be completed for up to several years; especially is a drought period is encountered before the next trigger occurs. Even if multiple triggering years occur beginning in and following Water Year 1999, there is a high likelihood that trigger months will be May, June and July. Implementation of alternative BHBF testing may be precluded in these months on the basis of biological resource criteria.

TABLE 1. – *Experimental BHBF Scenarios Considered in this Assessment.*

Note: **[Here, Scenario I, is offered as the preferred approach because it avoids multiple-treatment effects being implemented simultaneously, and because it builds on resource effects learning.]**

Scenario I – *[Three Tests Done in Three Separate Water Years.]*

Flow 1, Hydrologic Triggering Criteria and Resource Criteria Implemented BHBF at 45,000 cfs, followed by steady powerplant releases at or above 25,000 cfs for one or more months following the BHBF.

Flow 2, Hydrologic Triggering Criteria and Resource Criteria Implemented **BHBFs at 45,000 cfs, followed by diurnal fluctuating powerplant releases above 25,000 cfs for one or more months following the BHBF.**

Flow 3, Hydrologic Triggering Criteria and Resource Criteria Implemented BHBF of 60,000 cfs, followed by either diurnal fluctuating powerplant releases above 25,000 cfs, or by steady powerplant releases at or above 25,000 cfs for one or more months following the BHBF. The post-BHBF flow regime that best maintains beaches in Flows 1 or 2, will be chosen for the period following the BHBF in Flow 3.

Scenario II – *[Two Tests Done in Two Separate Water Years, and Compared with Existing High, Steady-Flow Beach Data from 1997]*

Flow 1, Hydrologic Triggering Criteria and Resource Criteria Implemented BHBFs at 45,000 cfs, followed by diurnal fluctuating powerplant releases above 25,000 cfs for one or more months following the BHBF.

Flow 2, Hydrologic Triggering Criteria and Resource Criteria Implemented BHBFs of 60,000 cfs, followed by either diurnal fluctuating powerplant releases above 25,000 cfs, or by steady powerplant releases at or above 25,000 cfs for one or more months following the BHBF. The post-BHBF flow regime in flow 2 will be determined on the basis of results from Flow 1, versus beach data collected before and after high, steady flows that occurred in 1997.

Scenario III – *[A Single Test Done in One Water Year]*

Flow 1, Hydrologic Triggering Criteria and Resource Criteria Implemented BHBFs of 60,000 cfs, followed by diurnal fluctuating powerplant releases above 25,000 cfs for one or more months following the BHBF. Both treatments to be implemented in a single runoff season sequentially, and the test flow will occur on the basis of HTC being met.

Scenario IV – *[No Alternative BHBF Studies – NO ACTION]*

Hydrologic Triggering Criteria and Resource Criteria Implemented BHBFs of 40,000 to 45,000 cfs, followed by high, steady powerplant releases of 25,000 to 31,500 cfs for one or more months following the BHBF.

TABLE 2. – *Stage and Discharge Relationships Associated with Campable Areas at selected Study Sites Below Glen Canyon Dam Associated with 45,000 and 60,000 cfs. BHBF magnitudes.*

Study Site (river mile) / Width of Channel Reach	Bar Type	20-25k cfs Area (m^2)	20-25k cfs % of total	25-45k cfs Area (m^2)	25-45k cfs % of total	45-60k cfs Area (m^2)	45-60k cfs % of total	Above 60k cfs Area (m^2)	Above 60k cfs % of total
8n	S								
16n	S	0	0.0	305	83.1	62	16.9	0	0.0
16.1n	S	164	52.9	69	22.3	60	19.4	17	5.5
22n	r	46	41.1	53	47.3	13	11.6	0	0.0
30n	r	20	6.3	260	82.0	37	11.7	0	0.0
32w	u	0	0.0	86	13.4	426	66.4	130	20.2
43w	r								
44.6w	s	182	13.8	437	33.2	461	35.0	237	18.0
47w	r	25	3.2	411	52.0	294	37.2	60	7.6
50w	s	75	10.5	431	60.4	204	28.6	3	0.4
51w	r	102	7.4	1264	91.7	13	0.9	0	0.0
55w	r	46	41.1	53	47.3	13	11.6	0	0.0
62w	r	0	0.0	198	78.3	11	4.3	44	17.4
65n	r								
68n	u	10	1.1	456	50.0	382	41.9	64	7.0
81n	u	0	0.0	1151	98.6	16	1.4	0	0.0
87n	u	0	0.0	178	81.7	23	10.6	17	7.8
87.1n	s	3	1.2	130	51.0	51	20.0	71	27.8
91n	s	0	0.0	12	4.2	274	95.8	0	0.0
93n	u	0	0.0	192	94.6	11	5.4	0	0.0
104n	r	0	0.0	96	72.2	36	27.1	1	0.8
119n	r	139	30.5	146	32.0	25	5.5	146	32.0
122n	r	426	38.3	440	39.5	229	20.6	18	1.6
123n	r	377	33.4	295	26.1	336	29.7	122	10.8
136.6n	r	93	8.3	363	32.3	662	58.9	6	0.5
136.7		285	51.7	61	11.1	203	36.8	2	0.4
136.8		8	4.5	165	92.7	5	2.8	0	0.0
139w	u	0	0.0	106	32.9	101	31.4	115	35.7

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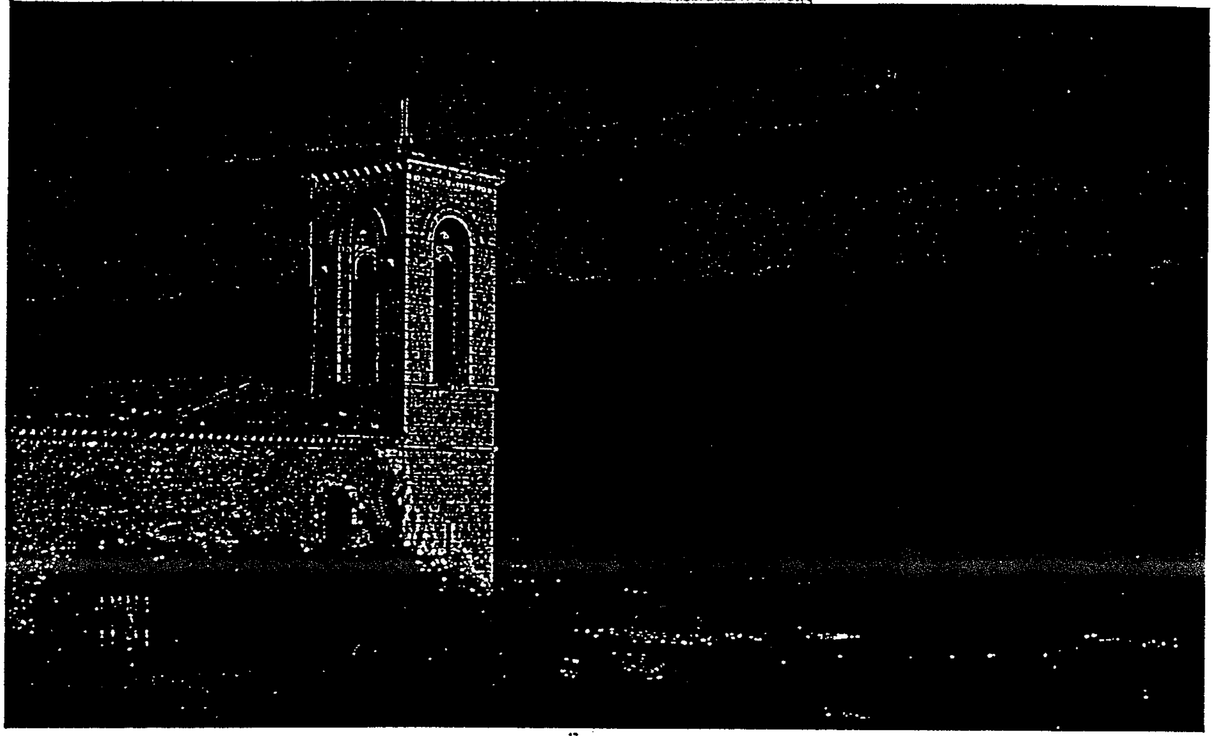

The Basilica of Sant'Ubaldo, on the mountain overlooking Gubbio, Italy. A twelfth-century Bishop of Gubbio, Saint Ubaldo, led the citizens up the Bottaccione Gorge at night (past the K/T boundary) and circled around, surprising and driving off the combined armies of eleven nearby towns which were besieging Gubbio. *Photo by Walter Alvarez*

The Gentle Art of Scientific Trespassing

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ABSTRACT

Research on impacts and mass extinctions has been interdisciplinary in the extreme. As the field has developed, the scientists involved have learned a number of ways of bridging the barriers that normally separate specialties. The most difficult problems involve different training in the primary and secondary sciences, different cultures in different sciences, perceptions of a hierarchy or pecking order of sciences, judging the quality of scientific work, and the barrier of jargon and technical language. Doing interdisciplinary science involves learning the languages of different fields, and when this is done, most of the other barriers melt away. Perhaps the interdisciplinary style that is growing up in this field may eventually be as important as the things we are learning about impacts and mass extinctions.

Author's Note: In 1988 Frank Asaro was organizing a symposium at a meeting of the American Chemical Society and asked me to speak on the topic "How geologists view chemists." Recognizing the potential for disaster inherent in that title, I convinced him to let me speak instead on "How scientists view each other across discipline boundaries" (a written version will appear in the Proceedings of the 1988 Snowbird II Conference [Alvarez, 1991]). At Eldridge Moores's suggestion, I have revised that article for *GSA Today*.

INTRODUCTION

There seems to be a close association between interdisciplinary science and revolutionary developments in geology, although it's not clear which (if either) is cause and which is effect. You might disagree, but I think I see four revolutions in 20th century geology. The first brought us radiometric dating. The interdisciplinary character of this development could be symbolized by the collaboration at Berkeley in the 1950s and 1960s between physicist John Reynolds, geologist Garniss Curtis, geophysicist Jack Evernden, and paleontologist Don Savage (Glen, 1982).

The second revolution, which brought us plate tectonics, had an aborted start with the meteorologist Alfred Wegener, then took off with geologist Harry Hess and geologists, geophysicists and paleontologists, physicists, and chemists too numerous to list.

Looming on the horizon is a coming revolution in understanding Earth as a system, which will surely involve people from biology, earth sciences, engineering, physics, chemistry, and mathematics.

Interdisciplinary work has also been characteristic of the currently active and controversial revolution over the role of impacts and other catastrophic events in Earth history. This development is forcing the rejection of classical uniformitarianism, as we realize that modern geologists must be able to think about both sudden and gradual changes in order to understand the history of Earth. Shortly before the discovery of the Italian Cretaceous-Tertiary iridium anomaly, we were already doing interdisciplinary research at Gubbio, in the Apennines, as a team ranging from paleomagnetist Bill Lowrie to micropaleontologist Isabella Premoli Silva correlated the biostratigraphic and magnetostratigraphic time scales (Alvarez et al., 1977). The iridium anomaly discovery paper (Alvarez et al., 1980) was written by a particle physicist, a geologist, and two nuclear chemists. Almost immediately, other interdisciplinary groups began to work on the problem. One early paper was written by an oceanographer, an atmospheric scientist, and a planetary geologist (Emiliani et al., 1981), and a more recent, extreme example was written by two astronomers, two geologists, and four paleontologists (Hut et al., 1987).

Many other questions in geology involve input from chemistry or biology or physics, but they do not often attract chemists and biologists and physicists to work on them; they stay strictly in the mainstream of geology. Why did this particular topic,

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The Bottaccione Gorge at Gubbio. White pelagic limestones in the foreground are the Lower Cretaceous Majolica formation. In the distance are the pink pelagic limestones of the Upper Cretaceous-Eocene Scaglia rossa formation, with the K/T boundary about half way up the cliff. The near horizontal structure is a twelfthcentury aqueduct that brought water to Gubbio (this is the "Bottaccione," or "big water barrel").

Trespassing *continued from p. 29*

the mass extinction 65 m.y. ago, draw in so many people from so many other fields? I think it is because the impact of a 10 km extraterrestrial body on Earth is such an unusual and extreme event that it led to unexplored parts of other fields, not to their central, well-known bodies of information. Suppose one had gone to a chemist or physicist and asked for help in understanding some aspect of the K/T boundary. If that chemist or physicist had been able to say, "Well, why don't you just look in the index of any elementary textbook?," there would have been little incentive for that person to join in the research.

However, this extraordinary event has led to new kinds of thinking in every branch of science it has touched. In biology, it required thinking about non-Darwinian mechanisms of evolution. In geology, it forced a reevaluation of the central geological doctrine of "uniformitarianism" or "gradualism," which for 150 years had discouraged any thinking about catastrophic events. In chemistry, it focused on iridium, an almost comically obscure element, and created a demand for very fast analytical capabilities at the parts-per-trillion level. And new problems have been opened up in ecology, geophysics, astrophysics, and atmospheric science, as well.

Impact research has thus led to forefront work in a variety of different sciences. But progress in working out the implications for each science has depended on keeping in touch with what is happening in each of the other sciences. For example, think about astrophysicists, exploring the idea that a hypothetical companion star to the Sun (Davis et al., 1984; Whitmire and Jackson, 1984) might cause periodic impacts and mass extinctions on Earth by gravitationally disrupting the Oort comet cloud of the outer Solar System as it comes close to the Sun every 25 to 30 m.y. Calculations as to whether such a wide binary star system would be stable (Hut, 1984) depend on the latest information from geology and paleontology bearing on the timing of impacts and extinctions: are impacts periodic or aperiodic (Raup and Sepkoski, 1984, 1986; Grieve et al., 1985; Shoemaker and Wolfe, 1986; Baksi, 1990)? If they are periodic, what is the time interval between them?

The whole field of research on impact crises has been built on interdisciplinary research, and trespassing on other people's fields has become a privilege and a pleasure for those of us involved in it, as has welcoming visitors from other parts of science who get interested in our own disciplines. So let us consider the experience of crossing discipline boundaries in science.

BARRIERS TO CROSSING DISCIPLINE BOUNDARIES

It seems to me that there are several barriers to crossing discipline boundaries, some minor and others more difficult. In practice, however, it is quite possible to bridge these barriers, and doing so brings great rewards, both personal and scientific.

Academic Departmental Structure

First of all, interdisciplinary work is hindered by the departmental structure of the universities. In academia, at least, we live our lives surrounded by people in the same general field. Yet this is largely a matter of habit. At Berkeley, and I am sure elsewhere, there are many opportunities, both formal and informal, for moving out of the confines of one's department; this is no excuse!

Disciplinary Structure of Funding Agencies

A second obvious problem is that interdisciplinary research tends to fall into the cracks between programs at funding agencies like NSF. Perhaps there ought to be a special division at NSF, or a separate agency, aimed at funding maverick interdisciplinary proposals. Meanwhile, as we wait for this Utopian dream to come true, it is worth noting that interdisciplinary research topics are more likely to interest private donors and the generalists who run private foundations than are the narrowly focused projects that appeal to specialists.

Asymmetry in Training Between Primary and Secondary Sciences

Turning to the more subtle problems that raise barriers to interdisciplinary science, our third problem concerns the difference between what we might call primary and secondary sciences. As students we are all trained in the primary or basic sciences—mathematics, physics, and chemistry. However, the secondary sciences—geology, paleontology, biology—are studied almost exclusively by practitioners of those sciences. Almost all geologists have a basic understanding of chemistry, but few chemists know anything at all about geology. This puts a one-way valve in the communications system, and as you will see, good communications are the prime consideration and the prime difficulty in doing good interdisciplinary science. Because of the asymmetry in training, a somewhat harder burden falls on people from the basic sciences, but anyone wishing to cross disciplinary boundaries will have to learn—or will have the pleasure of learning—someone else's science.

Varying Cultures and Traditions in Different Sciences

The fourth problem concerns the different cultures and traditions of the different sciences. Because of our different subject matter, scientists in various disciplines must work in different ways. Chemists and physicists work in controlled laboratory settings, isolating the phenomenon they wish to study, and carrying out elegant and repeatable experiments. Geologists and paleontologists are restricted to studying what nature has preserved for us—or, sometimes, what the highway department has chosen to excavate, and has not chosen to pave over.

Our differing traditions go back centuries and are picked up and internalized by each of us as students. Chemists honor Marie Curie and Mendeleev; physicists honor Newton, Einstein, and Fermi; biologists honor Wallace and Darwin. As a geologist, I count G. K. Gilbert, Alfred Wegener, and Harry Hess among my heros. Although we are all scientists, we have had to develop quite different ways of doing science, and when people with these different backgrounds join together to work on a common problem there is inevitably misunderstanding at first, and friction. However, our experience is that these problems do not last long when people get together to work on an intriguing interdisciplinary problem.

The Spectrum or Hierarchy of Sciences

One of the misunderstandings emerges as we look at the fifth problem, which concerns the hierarchy, or pecking order, of the sciences. The scientific pecking order appears to reflect the prestige of the various disciplines. Why does this hierarchy exist? I'm leaning toward the view that the higher prestige disciplines are able to formulate general laws that require considerable mathematical sophistication to understand, whereas the lower prestige disciplines deal with subject matter of great complexity, which must be described and classified before it can be understood. In this view, the hierarchy of sciences has nothing to do with the relative merits of the different sciences, but is instead a function of the kind of subject matter with which they deal. If we drop the loaded terms like "hierarchy" and "pecking order" and simply arrange the sciences in a spectrum from mathematically sophisticated at one end to descriptively complex at the other, we would probably not differ too much in assigning a sequence something like the following: mathematics, physics, chemistry, astronomy, geology, paleontology, biology, psychology, sociology.

Let us trace one strand of impact-extinction research across the spectrum of sciences and watch the complexity increase. Nuclear chemists like Frank Asaro, Helen Michel, and Carl Orth use techniques from physics to do neutron activation analysis for elements like iridium. They measure the neutron flux that irradiates their sample, and as the radioactivity decays they measure the energy and release time of de-excitation gamma rays. They end up with a reliable value and uncertainty for the concentration of iridium in a sample, —say 37.9 ±2.3 (1 SD) × 10^{-12} g Ir/g whole rock.

Stratigraphers like Sandro Montanari and Jan Smit, studying an Ir profile across the K/T boundary, must consider less quantifiable uncertainties, including sedimentary reworking, burrowing by bottom-dwelling organisms, and chemical remobilization as they determine whether the Ir was deposited instantaneously.

Paleontologists like Gerta Keller, Hans Thierstein and Peter Ward, trying to decide whether the Ir input coincided in time with a mass extinction, must decide how to define a mass extinction—they have to choose the taxonomic level to use and whether to focus on taxa lost or on biomass destruction—and then they must consider whether hiatuses and fossil reworking

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Trespassing *continued from p. 30*

are complicating the record, and whether an apparent diversity decline is real or just a sampling artifact.

If the evidence for impact seems to coincide with the extinction level, paleoecologists like David Milne and David Jablonski have to consider what the geographical extinction pattern was, what were the life styles of victims and survivors, and which of the suggested killing mechanisms—darkness, acid rain, greenhouse heating, fires, etc. (Gilmour et al., 1989)—might have affected each group.

Finally, if it is concluded that impact causes mass extinctions, evolutionists like Steven Gould and Digby McLaren must consider the extent to which this forces us to revise Darwin's concept of evolution by natural selection. From counting gamma rays to revising Darwin there is an unbroken chain of interdisciplinary science, but the levels of mathematical sophistication and descriptive complexity vary dramatically.

What is the effect of this spectrum of sciences on interactions across the disciplines? It causes real problems because the spectrum is often interpreted as a ranking in order of merit. But when a healthy interdisciplinary field grows up, most of the people in it simply see through the fallacy of this pecking order and recognize that each science has developed the techniques it needs for its kind of problem. My father once told me, after visiting me in the field, that he admired the work of geologists, but that he would stick to physics, thank you, because geology was just too complicated for him.

Judging the Validity of Scientific Results in Someone Else's Field

Continuing the list of barriers to interdisciplinary work, number six is this: How do you estimate the level of confidence you can have in data and interpretations from someone else's field? We are all accustomed to doing this every day in our own field, where

Trespassing *continued on p. 34*

Environmental Issues

Polyethylene, Recycled Paper, and GSA Publications

Jim Clark
Manager, GSA Publications Production and Marketing

One of the major challenges of the 1990s is conservation of our environment. Beginning this month, GSA is implementing changes that will make our publications program more environmentally responsible. These changes result from a two-year investigation that focused on two specific areas in our publications program:

1. Should we continue using polyethylene (poly) as a packaging medium for our publications; and, if any use is justified, which type (recyclable or degradable) best serves the environment?
2. Are the printing papers we use for our periodicals and books recyclable? Could we use recycled papers and continue meeting the standards for paper permanence, especially for library materials?

The Use of Poly

The first question was easy to answer. The use of poly has provided GSA with economic and marketing advantages. However, two indisputable facts now overshadow the advantages: (1) poly is made from hydrocarbons, a nonrenewable resource that we should use responsibly; and (2) pure poly is inherently recyclable, but for an unacceptably high percentage of people there is no *ready means* for recycling it, and far too much finds its way into landfills.

We can no longer avoid the conclusion that poly should be used only when the desired function cannot be performed adequately by an alternative that is better for the environment. Therefore, GSA is discontinuing or modifying its use of poly in the following areas.

Journal Subscribers

Poly is being discontinued as the packaging medium for our original fulfillment mailings of *GSA Bulletin*, *Geology*, and *Abstracts with Programs* to all domestic U.S. subscribers. These periodicals will be mailed without packaging, as is *GSA Today*. Copies damaged in the mail will be replaced free by GSA—just call or write the Membership Department.

Until we find a more suitable alternative, we will continue to use poly for mailing periodicals to our overseas subscribers. The U.S. Postal Service *requires* packaging for these, and because they move by ship we feel that poly offers the most protection against moisture and other hazards of ocean shipment.

Back-Label Journal Mailings

For the past two years we have used poly to mail back-label journal orders from our warehouse. These are copies of back issues that go to members when they pay their dues after the start of the subscription year. We will stop using poly for this purpose when our current supply is exhausted.

Catalogs and Flyers

We will no longer use poly in our publications marketing efforts. In the future, catalogs and flyers will be mailed in recyclable packaging or, when possible, without packaging.

GSA Books

GSA books have traditionally been shrink-wrapped with a special poly to protect them during shipment and mailing. We are working with our printers to phase out the use of poly for this purpose. We intend to substitute other environmentally safe packaging methods, or use no packaging at all.

Bookstore Shopping Bags

If you have visited the GSA Bookstore at any Section or Annual Meeting, AGU, or AAPG meeting, you are familiar with the blue and white poly book bag that thousands of customers use to carry their purchases. We will continue to offer these until our present supply is exhausted. By that time we hope to find an affordable, environmentally safe replacement for this give-away bag.

GSA now offers a new cotton-canvas shopping bag. These are similar in size and shape to bags offered for sale by many supermarkets. They are too expensive to give away; however, you can buy them at our cost ($3.50 net, less than supermarkets charge), or you can get one as a gift on any order to GSA Publication Sales that includes two or more items totaling $55 or more, net, before taxes.

Now to address the last part of the poly question: "If any use of poly is justified, which type (recyclable or degradable) best serves the environment?"

When we began using poly several years ago, GSA opted for 100% pure material. It still seems to be a better choice environmentally than "degradable" poly for two reasons: first, pure poly is the only kind that *can* be recycled. Poly materials labeled "degradable" contain additives such as starch that disintegrate—biologically or through photosynthesis—leaving behind unrecoverable poly fibers. These additives are detrimental to recyclers because even a small undiscovered amount of them in the recycling stream can ruin an entire batch of recycled poly.

Second, the label "degradable" encourages many people to feel more comfortable tossing the item into the trash headed for landfills where, current research indicates, it may never degrade.

In summary, although neither type of poly conserves our nonrenewable resource, pure poly is the better choice because it's recyclable.

Recycled and Recyclable Papers

The paper industry is regionally oriented, with many mills, each featuring its own line of papers and making its own decisions about producing recycled papers.

Partly because of this, paper that is inherently recyclable may or may not be acceptable by recyclers in all areas. Recyclers have to live with the economic realities of "who, where, and when—who will buy it, how far must it be shipped, and when will it be needed?"

As more mills decide to produce recycled papers, recyclers will find it profitable to accept a wider variety of waste at local levels. But any improvement will occur only in relation to the demand by the public and major paper users, like GSA, for broader lines of new papers that are better for the environment.

For now, these papers are available in limited supply, with limited characteristics, in two categories: (1) recy*clable* papers, commonly containing mostly virgin fiber, sometimes mixed with mill broke; and (2) recy*cled* papers, mixes of up to 50% or more virgin fiber, 40% or so of preconsumer waste, manufacturing byproducts, and mill broke, rounded out by up to 10% or so of postconsumer fiber (waste paper you and I recycle).

A little skepticism is healthy in evaluating claims that paper is recycled. Many papers claiming to be "recycled" in fact contain no postconsumer fiber. For most of us, this is contrary to the basic meaning we attribute to that word.

GSA Has Long Used Recyclable Papers

Since 1984, the text papers used for GSA publications have been recyclable new paper. There is nothing inherent in them to prevent recycling. But in some areas where recycling is not yet well developed it is difficult to recycle them or other paper products. Only continued public demand will change that.

GSA Bulletin and *Geology* are printed on a coated, matte-finish, acid-free paper that is widely recyclable. This paper contains 26% recycled waste (preconsumer).

Our books, with rare exceptions, are printed on uncoated matte-finish, acid-free book papers which are commonly accepted by virtually all recyclers. Because books are rarely discarded, an insignificant number flow into the waste stream.

GSA Begins Using Recycled Paper

GSA News & Information and *Abstracts with Programs* have, for years, been printed on common 50 pound offset paper, a sheet which contains varying portions of preconsumer waste and is widely sought after by recyclers.

In January 1991, *GSA Today* replaced *GSA News & Information*. It is printed on a recyclable paper with a preconsumer waste content. We hope to find a paper with a postconsumer recycled content in 1991.

In the marketing area, we intend to print our future catalogs and updates on recycled and recyclable papers, starting with the October 1991 catalog.

The situation is more difficult for our journals and books. We are compelled to continue using papers that meet widely accepted standards for science publishing, a tradition from the earliest days of GSA. We want to use papers with a postconsumer recycled component, and we have examined many different sheets so far in that search. As yet, however, we have not located any that meet library standards for permanence, foldability, strength, etc., and also meet our requirements for appearance, availability, weight, and cost.

The cost factor is a major obstacle. The cost of paper containing 10% or more of postconsumer recycled waste, and otherwise meeting the EPA 1988 standard for recycled papers, generally run between 60% and 100% more than papers without postconsumer content. Because paper represents one of the major cost components in our journal prices, that kind of increase would make our journals prohibitively costly to many of our subscribers.

We will continue searching aggressively for affordable papers with postconsumer waste content. As soon as the right combinations become available, we intend to start using them. ■

Comments?
If you have comments or suggestions on these issues, please write to J. Clark, Production Manager, Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140.

Geology is more complicated than physics: When physicist Luis W. Alvarez visited the K/T boundary at Gubbio, it disturbed him that the beds were dipping at 45°. He leaned over and had this picture taken with the camera tilted, so that audiences of physicists would understand the originally horizontal bedding.

Trespassing *continued from p. 31*

we have the experience to evaluate the quality of a particular piece of research, or where we have worked on the same topic ourselves, or where we know the reputations of the people involved. Judging the quality of a piece of research in a completely different science is much more difficult, and the criteria may be quite different. At least at the beginning, one is probably dependent on the judgments of colleagues from that other science. It is of course even more difficult for the press and the public to make accurate judgments about the validity of particular scientific results.

Given this problem, it is important for workers in an interdisciplinary subject to go out of their way to make it possible for scientists from remote fields to judge published results. One needs to take more care in documentation than when writing for fellow specialists. This may mean (Editors, take note!) giving explanations or making citations that would be considered unnecessary or patronizing in most technical literature.

To facilitate judgments about the reliability of results, we can make use of a whole variety of techniques available to scientists. Familiar approaches include the determination of analytical confidence limits, estimating confidence levels for less quantitative observations, rigorous statistical testing of hypotheses, interlaboratory calibration of analytical standards, and the independent analysis of blind samples from critical locations. (Blind analysis of some critical, disputed levels across the Italian K/T boundary is currently being carried out under the supervision of Robert N. Ginsburg of the University of Miami.) One can often invent or modify special techniques suited to particular questions; Muller's (1988) description of the use of the "Game Program" to decide a confidence level in a proposed periodicity is an excellent example.

The key to judging research results across disciplines thus comes down to rigorous care and full explanation on the part of the producer, and the willingness of the reader to delve deeply into an unfamiliar literature. This last consideration brings us to the question of how well a scientist from one field can understand what a practitioner of a remote specialty is saying or writing.

Jargon and Technical Language as a Barrier to Communications

The final item in this list of problems in crossing disciplinary barriers is thus the matter of technical language and jargon. I have come to see this as a major barrier to communication, both in reading the literature and in conversation with scientists from other disciplines. Nevertheless, this barrier can be overcome, and overcoming it is in itself an interesting process.

What is the role of jargon and technical language in science? Why do they exist? Technical language is clearly a necessary part of science. We need new words to describe new phenomena that are not covered by the vocabulary of the common tongue. But jargon seems to play two additional roles in science, one detrimental and the other beneficial. In its detrimental role, jargon serves to exclude the untrained from a specific high priesthood—those who are initiated in a particular discipline or specialty. In its more beneficial role, jargon serves as a tool for calibrating the level of expertise of a new acquaintance, and helping you choose the level on which to communicate.

To me, jargon and technical language present the highest barrier to crossing discipline boundaries. The other major barriers, especially cultural differences and notions about a hierarchy of sciences, melt away once the language problem is surmounted.

AN APPROACH TO CROSSING DISCIPLINE BOUNDARIES

So how does one overcome the language barrier between disciplines? It seems to me that language fluency comes almost automatically, if we treat the boundaries between disciplines not as barriers, but as gateways leading to new things to explore. After all, as scientists we are driven by curiosity about nature. Why can't we be just as curious about the workings of somebody else's field of science? Each field has its own history, its own traditions and ways of thinking and working, its own folklore, and even its own language.

I have come to view language learning as the key to interdisciplinary work. There is no practical way to get different specialists to use the same tongue, so those wanting to cross barriers simply must learn other scientists' languages.

What does this language learning involve? First of all, we need to know what the words mean. The same word may carry very different meanings when used by two different people. We know about this in foreign languages; for example, *burro* means donkey in Spanish, but it means butter in Italian. Or to take an extreme case, *ne* means no in Yugoslavia, but across the border in Greece, it means yes. No wonder Balkan history has been so troubled. Different meanings for the same word arise through time in the same language. In order to understand Shakespeare's plays, we need to know that words like *compass* and *conceit* meant something quite different to the Elizabethans than they do to us. To a chemist, *radiation* means light, but to a paleontologist it means appearance of new species from a common ancestor. However, even this doesn't end the problem, for *species* has different meanings to a paleontologist and a chemist.

A second observation about language is that certain key phrases act as passwords for recognition among speakers of the same dialect. If we hear phrases like "right on" or "jolly good," we immediately know which side of the Atlantic the speaker comes from. The same thing holds true in scientific dialects. Trivial as it may seem, I found that my main breakthrough into the physics community came when I stopped saying that something "was a hundred times larger," as a geologist would, and began saying "two orders of magnitude greater."

At a more subtle level, one finds that cadence and style reflect the complexity, the traditions, and the folkways of a particular science and define recognizable dialects. For example, there is a dialect known as Physics Macho, in which any derivation that takes a sophisticated mathematician less than a week is referred to as "an exercise for the student." Another example is a dialect called Ecologic Jargon Overkill. Here is a sample from the literature, only slightly edited: "Dissimilatory anoxic oxidation is carried out in the sulfuretum by photolithotrophic bacteria like the Chlorobiaceae, which are obligate photolithoautotrophs and strict anaerobes, the Chromatiaceae, which are partly obligate, partly facultative photolithotrophs, and the Rhodospirillaceae, which are photoheterotrophs ... although many of them are able to grow photolithotrophically as well."

Geological dialect undoubtedly has its own sillinesses, too, which I would like to report to you if I could, but they are much harder for a native speaker like me to recognize. Perhaps an outside observer would find the dialect of geology to be colored by the description and classification of complex phenomena, which has been a major task of our science. Thus our dialect might be represented by a paper, published in the last century, with this title: "A Description of the Dessicated Human Remains in the California State Mining Bureau" (Anderson, 1888).

The difficulty of learning a language or a scientific dialect is clearly related to its complexity. Russian, with its ornate system of declensions, is harder for English speakers to learn than are Romance languages. Geology is a more complexly descriptive subject than physics (though not necessarily more difficult), and as a result, its dialect is harder for physicists to learn than vice versa. For the same reason, biologese has been very difficult for me to learn. I still can't speak Ecologic Jargon Overkill, but I'm working on it.

Serious understanding of another field does not immediately result from learning scientific dialects. But with the language mastered, you have the tools for discussing the subject matter and reading the literature in depth, and the practitioners of the field will take you seriously. Many people have done this in the general field of research on impacts and mass extinctions, and have found it to be scientifically and personally rewarding. I believe it is the key to successful interdisciplinary research.

CONCLUSION

As science penetrates deeper and deeper into the unknown, most fields become of necessity more and more separated and specialized. Yet some topics seem naturally to bridge the gaps between fields. The study of impacts and mass extinctions seems to be one of these bridging topics. Perhaps the scientific style that is growing up in this field may eventually be as important as the things we are learning about nature.

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