GCMRC Responses to the SA comments on the Science Plan for Potential 2008 Experimental High Flow At Glen Canyon Dam, dated January 13, 2008.

The following are in response to the overall comments: (SA comments are in italics)

Impacts to the HBC may be avoided by a lack of movement of yoy out of the LCR. However, could winter storm events jeopardize this setting?

Response: Winter storm flows may impact limited numbers of native fishes. No season of the year will entirely avoid potential impacts, but March is one of the months with the lowest probability of such events, so we expect impacts to be minimal.

Benefits to HBC are to be assessed from backwaters. However, it is unclear how benefits will be realized from this test.

Response: The current high flow test plan and ongoing GCDAMP work plan will assess benefits to humpback chub indirectly, predominantly in two ways. First, we will measure backwater attributes, including primary and secondary production and temperature, to tell us if there are (at least temporary) favorable conditions for humpback chub in these habitats. Secondly, we will continue the ongoing monitoring of the humpback chub population to continue the long-term assessment of the status and trends of this species in Grand Canyon.

…more information is needed to structure and test effective hypotheses [about backwaters] in this high flow event.

Response: We intend to apply significant time and other resources to the study of backwater habitats in 2008, hopefully taking advantage of the infrequent high flows in Grand Canyon that create sand bar backwaters. We are in the process of developing a new study (planned to be released for open competition) that will study other near shore habitats, as well as backwaters. We have termed this new study the near shore ecology study.

…we doubt the hydrograph historically peaked as early as March each year.

Response: We agree. In the new, altered environment that is Grand Canyon today, we believe February or March are the best months to have a positive impact on as many resources as possible, while minimizing negative impacts. No one month will be perfect for all resources considered. For example, a modern high flow in June, historically the month when the spring runoff peaked in Grand Canyon, would, today, be an excellent opportunity to broadly spread tamarisk seed in the canyon.

Methods (p. 38) state that an effort will be made "to assess as many backwaters as possible."…sampling bias could be a problem.

Response: We remain very interested in measuring as many of the backwater habitats created by sandbars as possible. We believe we have developed an approach to doing this. We will use data

generated by surveyors using total stations on projects 1C and 1D. Surveyors working on 1D will be working from a prioritized site list. Prioritization factors include: previous humpback chub capture locations, backwaters near humpback chub aggregations, geomorphic reaches, and sites previously mapped in overflights (2002 and 2005). For those sites that cannot be surveyed in this manner due to time constraints, we will measure those habitats with tape measure and level. We expect to measure all, or nearly all, backwater habitats with at least one method.

Page 5, para. 3: It refers to Figure 3 as evidence that humpback chub populations increased in the period 1994 to 2000. However, this figure shows overlapping confidence intervals at the 95% level. Thus, the statement doesn't seem very credible.

Response: Figure 3 shows the trend in humpback chub recruitment to adulthood, not the adult population size, which is shown in Figure 4. However, the confidence interval concern expressed by the reviewer could apply to both figures. It is important to note that these are not the results of pooled field samples, or some other sampling, but are the results of model simulations based on field collections. The simulations are randomized and re-run 1,000 times to test for departure from random. Despite the modest amount of overlap between maximum values from one year and minimum from the next, we think the risk of in incorrect conclusion about the population is extremely small. In other words, the trend in the adult population from 2001 to 2006 is increasing, in all likelihood. There is some risk to this being an incorrect statement, but we, and our exterior reviewers, thought that this risk is very small.

Page 8, para. 5: Will the food base and trout assessments test the hypothesis relating to algae response from "cropping"?

Response: as with other projects in this high flow science plan, we will be integrating these results with the results of other projects. In this case, we will not only be sampling the food base in conjunction with the high flow experiment, but will continue our ongoing aquatic food base project that includes monthly sampling in the Lees Ferry reach (and at Diamond Creek) and quarterly, full river trip sampling throughout Grand Canyon. We expect that this work will address the reviewer's question.

Re: rainbow trout (RBT)

Response: our project 4.B. is directed at investigating the fate of young rainbow trout during and after the high flow event. It is a pilot study because we are investigating whether the equipment, sonic tags, will allow us to monitor individual fish in such conditions. Learning more about this species at this life stage helps us evaluate whether these fish resist or return following high flows, or do they move downstream. We also intend this project to help us investigate whether these tags may be used in native fishes in the future to help track their individual movements.

COMMENTS SPECIFIC TO 1C:

In light of concerns raised in the latest SA review, some additional information and clarification about the issues that were perceived as being problematic in the plan, particularly as they pertain to socio-cultural elements of Project 1C, are provided below:

General Response

GCMRC was directed to develop a science plan to guide the research that would take place if a high flow experiment were to occur in FY08. In keeping with the emphasis of the Long Term Experimental Plan, we were also directed to focus the experimental design around sediment dynamics and fish responses. While it is fully recognized that the concerns of the AMP are much broader than just sediment and fish, current priority concerns constrained the scope of our science plan primarily to these two key resource areas, with the understanding that by focusing on these key elements, we would still be able to learn more about how high flows affect other resources, including recreational camping beaches and archaeological sites.

In order to meet these objectives, and also to promote integration of science activities, we designed Project 1 (A-D) to focus on sediment research primarily, but with supplementary research to link the sediment studies to other related resource concerns. One part of Project 1C (a relatively minor part) includes work designed to further our understanding of how changes in sediment stored in sand bars affects camping areas and cultural resources. Because socio-cultural resource concerns are identified in the project description, many previous readers of the science plan misconstrued 1C to be a "cultural project." We tried to address this misunderstanding in our revision of the plan, but apparently we were less than fully successful in doing so, because it is seems from the way in which this project is characterized in the review, some misunderstanding persists.

The SA review states *"This study proposes to examine how high flows from the GCD and "normal" releases will: 1) contribute to--or subtract from—the amount of sediment on sand bars, especially "campable" ones; and 2) determine whether or not aeolian sands will be moved by canyon winds up and over archaeological sites to protect them from the tourists and possibly fill in the erosion gullies currently decimating many of the sites.* " This is partially correct, but it misses the main intent of 1C. In fact, the primary focus of 1C is to compare the 2008 eddy sandbar responses to previous measurements taken of the same features during and following the 1996 and 2004 high flow experiments. This will be accomplished by conducting total station surveys and collecting underwater sonar measurements and grain size data from a sample of sand bars that NAU geologists have been monitoring for the past 17 years. Secondary objectives of 1C are to learn more about how the creation and persistence of sand bars deposited by an HFE affect other sediment-dependent resources such as campsites, cultural sites, and backwaters, but the bulk of the effort and funding in Project 1C is dedicated to gathering measurements from the eddies and sand bars, not socio-cultural sites.

The design of the sand storage study and its primary focus on sand bar measurements imposed a lot of constraints on the socio-cultural elements of this project. Fortunately for the socio-cultural program, about 3/4 of the sand bars to be studied by NAU as part of the HFE experiment are also used as recreational campsites, so at these locations, we will be able to measure campable area in addition to sand bar area and volume. There is however, considerably less concordance between

the NAU sand bar sites and archaeological resources, particularly in terms of archaeological sites with prior high flow data. While it might have been preferable (for many reasons) to design an entirely separate cultural resources study--one that perhaps took an entirely different, systemic approach to evaluating the role of high flow events on cultural resources--many factors prevented us from doing this, including: 1) departmental direction to focus the science plan primarily on sediment and fish; 2) funding constraints; 3) the nature of existing monitoring data and the scope of current monitoring activities for cultural resources; and 4) continuing controversy within the GCDAMP about the area of potential affect from dam operations, and consequently, ongoing lack of agreement among the various program stakeholders as to the appropriate scope of cultural studies in general. Furthermore, an important stated objective for this high flow experiment is to evaluate the responses of resources in comparison to responses measured during previous high flow tests. The limited amount and variable quality of cultural resource-related data collected during previous high flow experiments constrained our options for making comparisons of this nature, but we still felt it was important and worthwhile to attempt to do so. Therefore, we decided to focus most cultural resource-related research around the archaeological sites where we have pre-existing, well documented, quantified measurements to serve as a basis of comparison.

With this general background in mind, responses to some of the more specific questions that were raised in the SA review are provided below:

It would be nice to see more details on some of the new efforts in 1C in particular, such as exactly how they plan to measure aeolian transport, how long monitoring will continue after the BHBF, and details of the spatial sampling (number of gullies, resolution of surveys).

Response: We admit that the science plan is short on details. In fact, early versions of the plan included considerably more detail about the cultural components of Project 1C, but this created an awkward and unbalanced document because only cultural elements of Project 1C were discussed in detail while most of the other project elements simply referenced previously published studies. In the end, the managers and editors of the science plan decided to forego including details about methods and rationales and just reference previously published studies where these details were already described. In subsequent revisions to the plan, we removed additional text relating to the cultural resources portion of 1C in an attempt to balance the presentation and fix misconceptions about the primary focus of Project 1C.

As previously noted, the cultural program is not positioned to evaluate the responses of cultural resources on a systemwide basis. We are currently awaiting the results of a geomorphic assessment that characterizes the geomorphologic settings and processes affecting individual sites and are working with another branch of USGS to refine a HEC-RAS model that will in the future allow us to project flow elevations in relation to archaeological sites, but neither of these tools were available for use in designing this experiment. We also lack the requisite data that would be needed to model aeolian transport potential at individual sites on a systemwide basis. What we are positioned to do through this experiment is evaluate the responses of individual archaeological sites to an HFE event and compare the responses to those documented during previous HFEs. The purpose in doing this is to determine whether previously measured

responses are replicable and to monitor the potential persistence of those responses following the HFE.

The proposed cultural research is focused at archaeological sites where studies were conducted in conjunction with the 1996 and 2004 experimental high flows and for which we have pre-existing weather data, aeolian transport data, and arroyo survey data, to provide a basis for comparison to the results of this next high flow test. Several of these sites are also being monitored as part of the Cultural Monitoring R&D effort that started in 2006, so we will have a fair amount of previously collected monitoring and research data with which to evaluate the outcomes of a 2008 HFE. These sites were originally selected (for previous study by other researchers) because they were located where the interaction between cultural resources, geomorphic processes of interest (gully erosion, aeolian deposition), and effects from a high flow experiment potentially could be measured. Therefore, although the data gathered from these sites will be very useful for comparing the outcomes of the 2008 experiment to those of previous experiments, they are not suitable for characterizing the response of cultural sites systemwide. To provide some balance to our interpretation of results, we will also be comparing the responses observed and measured at previously studied sites with those from other cultural sites that were not studied in past experiments but are currently included in the cultural R&D project. Some of the latter sites are located more than a ¼ mile from the river, so we will have sites in a variety of geomorphic settings with which to evaluate responses to an HFE test. Obviously, if a primary goal of this proposed experiment had been to characterize systemwide responses of cultural resources to an HFE, a different approach (and much more funding) would have been required; however, for reasons already mentioned, measuring systemwide responses of cultural resources is not a primary focus of the proposed HFE.

One of the goals of 1D is to determine where backwater habitats will develop, but isn't that really part of the goals of 1-B and 1-C?

Response: 1B specifically focuses on documenting how a few eddies in the Eminence area respond to changing sediment and flow conditions over the course of the HFE. This information is needed by sediment scientists to better understand and model the mechanisms and process of sand evacuation from and deposition in eddies during a high flow event. 1B does not look at where backwaters develop, but only at how. The backwater project component, 1D, was not incorporated in Project 1C because it represents an entirely new effort and approach. The primary focus of Project 1C is to repeat measurements made during previous high flows to enable comparison of response between the 2008 event and the earlier events. In response to concerns raised during earlier reviews of the experimental plan, Project 1D was designed to provide a system wide characterization of changes in backwater habitat to the 2008 high flow.

The Abstract for the study admits . . . that the high flow experiments of 1996 and 2004 did little to "increase campable areas at sandbars on a more sustainable basis" (p. 26). The immediate question is, why might the next one produce a more positive outcome?

Response: The question posed for campsites reflects the focus of the main strategic science question driving Project 1 and the GCMRC physical science program as a whole: "Is there a flow only operation that will rebuild and maintain sandbar habitats over decadal time scales?"

We already know that we can increase campable area on a temporary basis by conducting a single high flow test – this has been demonstrated by the work of Kaplinksi and others with data collected around previous high flow events. Now we want to learn if this can be done on a sustainable basis by focusing more attention on the fate of the bars following the high flow test.

The November 2004 test flow produced a positive sandbar response in the upper portion of the canyon, along with an increase in campable area, but the experiment was followed a month later by high fluctuating winter flows in January through March which rapidly eroded many newly formed bars. The 2005 winter high fluctuating flows were essentially a mitigation measure designed to generate power and possibly suppress rainbow trout reproduction; they were not considered to be an integral element of the experiment, and consequently, their effects on sand bars were not systematically monitored as part of the 2004 HFE. This time we will be monitoring the response of bars following the high flow event by taking daily photographs and periodic repeat measurements to improve our understanding of how dam operations following an HFE affect the newly formed bars over time. Ultimately, what the sediment scientists are trying to find out is whether it is possible to manage sediment in the system on a sustainable basis (and by extension, also sustain campable area) through implementing a combination of periodic high flow events under sediment enriched conditions in conjunction with carefully managed intervening operations. We propose to answer this question incrementally, using knowledge gained directly from this high flow experiment and through other means, such as modeling.

The Abstract goes on to ask, "Do sandbars deposited by high-flow experiments contribute to the preservation of archaeological sites in the river corridor?" The answer, at least as observed by those on the June 2007 SA river trip, is that sandbars, however derived, do not appear to contribute to the preservation of sites.

Response: Please review the reports produced by Draut and others (cited in the science plan and referenced at the end of this document) for more background information on the aeolian issue. The archaeological sites that the SAs visited in June were not chosen specifically to illustrate the role of aeolian processes as they affect archaeological site preservation in the river corridor; they were selected because they fit within the SA trip itinerary, did not require much time or effort to access, and allowed us to illustrate a diversity of issues that are relevant to understanding cultural resource concerns in the river corridor. Many (but by no means all) of the sites in the river corridor are built on or partially buried by sediment derived from the Colorado River and reworked by wind. In the past, high flow events periodically redeposited sand at higher elevations along the river, where the sediment was readily available for redistribution by wind. Now high flow events rarely occur, sand bars and Aeolian sand deposits are diminishing, and there is little opportunity for sand to be replaced at higher elevations once it is removed. IF the primary strategic science question for sediment can be answered and "a flow-only operation that will rebuild and maintain sandbar habitats over decadal time scales" can be identified through experimentation and modeling, then it is possible that degradation of archaeological sites could be slowed in some parts of the river corridor through periodically rebuilding high elevation sand bars and sustaining them long enough for wind to rework and redistribute the sediment over the sites. The knowledge gained from this experiment will contribute towards learning whether the AMP goal for cultural resources is attainable or not, but a single high flow test will certainly not resolve all the issues affecting cultural resource condition in the river corridor

The big sites we saw at the Palisades area would require many cubic meters of aeolian sand to fill existing gullies that run directly through the sites and then remain there.

Response: We agree. Portions of the Palisades area are now so severely eroded that there is little that can be done to change its degraded condition. This is one reason why one site in this area is now slated for data recovery in 2008-2009. The reason that arroyos and sand transport are being measured at this particular location as part of the current experiment is because several other sites in this area are not eroded to the same degree as the ones visited by the SAs, and these sites are currently being monitored as part of the cultural R&D effort, plus we have multiple years of previous data and measurements from this area, including detailed survey and aeolian transport measurements around the high flow events of 1996 and 2004, so it will be possible to directly compare effects of the proposed 2008 event with those of previous high flow tests (e.g., Yeatts 1996, 1998; Hazel and others, in review.)

A relevant question is, assuming the sand did somehow get properly distributed, how would such loose deposits resist fast running water coming down through the existing gullies from cliffs and terraces above? The check dams previously built across the gullies at the Palisades sites were obviously of no avail. This is not sufficiently addressed in the study methods.

Response: These specific questions fall outside the scope of the current HFE science plan. As discussed in the plan, research proposed in the HFE science plan is intended to supplement--not replace or duplicate--work already underway as part of the annual work plan. We are currently actively evaluating different monitoring protocols for evaluating how fast sediment is being removed from archaeological sites as part of the cultural R&D effort. USU researchers are also examining how weather events, check dams, and specific geomorphic attributes such as soil tensile strength and permeability affect rates of erosion, so these questions are being addressed through the annual research program.

The part of the study relating to the cultural sites does not appear to be a legitimate scientific matter, at least as stated in Section 1.C. It is, rather, an ethical archaeological issue (Fowler1, Jolie and Salter 2008; Green 2008).

Response: We are perplexed by this comment and require additional clarification in order to respond. While we have not had an opportunity to review the second referenced article, the first one discusses archaeological ethics in terms of diverse contexts such as national and international legal frameworks, knowledge making and professionalism, conservation of resources, trafficking in antiquities, relations with self-defined groups, and partisan politics. With the exception of antiquities trafficking, all of the above mentioned ethical contexts are

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[1] Fowler, D.D., E.A. Jolie and M.W. Salter. 2008 Archaeological Ethics in Context and Practice, In *Handbook of Archaeological Theories,* edited by R.A. Bentley, H. Maschner and C. Chippindale, pp.409-422. AltaMira Press, Lanham, Md.

Green, T. J. 2008 Cultural Resource Management. In *Handbook of Archaeological Theories,* edited by R.A. Bentley, H. Maschner and C. Chippindale, pp.375-394. AltaMira Press, Lanham, Md.

directly relevant to ongoing issues and concerns of the Glen Canyon Dam Adaptive Management Program. Nevertheless, it is unclear to GCMRC how the SAs' comment was intended to apply to the high flow experiment science plan specifically.

GCMRC is charged with conducting research and monitoring to help managers understand how dam-controlled flows--including experimental high flows--affect and potentially benefit natural, cultural, and recreational resources. Do the SA's have information to indicate that this issue has been sufficiently studied already or that it is not a viable scientific issue worthy of investigation? Is the SAs' ethical concern that insufficient effort and funding is being directed towards recovering information from actively eroding archaeological sites while research and costly experimentation continues to take place? This last concern is currently being addressed by the Bureau of Reclamation as an NHPA compliance issue through initiation of a multiyear, multi-million dollar archaeological excavation project. In light of the serious implications of this comment, we request that the SAs clarify its' context and intended meaning in relation to the HFE science plan review.

How specifically does, or might, aeolian sands get blown onto sites and what keeps them there? How, specifically, does, or might, aeolian sands get blown into erosion gullies across sites and what keeps them there? The questions are not meant to be facetious, but rather to say, "Provide us with more information." As presently stated, the "experiment" does not read like a well designed inquiry into a difficult, possibly intractable, problem.

Response: As previously mentioned, the HFE science plan specifically describes additional research and monitoring activities that will be implemented in conjunction with a short-term high flow test. These activities are intended to supplement, but not duplicate or replace, monitoring and research activities identified in the FY08 annual work plan. HFE research and monitoring activities have been specifically designed to build upon and complement existing monitoring and research plans, not replicate them. Once again, we refer you to the previously mentioned publications by Draut and others for some of the answers to your questions (a list of reports is provided below) and to the cultural monitoring R&D proposal for more details on the development of a long-term approach for examining methodological and process issues that affect how we can track and evaluate various geomorphic processes and factors—including occasional high flow releases—that contribute to archaeological site preservation or degradation in the CRE. We request your patience while reports on the geomorphic field studies conducted over the past two years by USU and USGS researchers as part of the cultural R&D effort are completed. We expect reports on that work to be available later this spring and in early summer 2008.

COMMENTS SPECIFIC TO 1D:

We are concerned by the lack of detail regarding the geomorphic aspects of 1D, the study of backwaters.

Response: We have been increasing our staff to better address this project, and are now in the process of increasing the amount of detail regarding the geomorphic aspects of this study.

[Study 1D] In paragraph 3 of this plan it states that highest densities of humpback chub occur in vegetated shorelines and only 5% or less are captured in backwaters. This indicates that some shorelines (perhaps eddies or shallow runs) are important for the fish.

Response: on page 35 of the December 27, 2007 version of the plan, it states: "Protected backwater habitats are a relatively small portion (approximately 5% or less, depending on conditions and flows) of the nearshore habitat in the Colorado River in Marble and Grand Canyons." The 5% reference is to the habitat, not fish captures. That said, we share the reviewer's concern that other habitats need to be considered when evaluating relative value of different habitats, which is why we propose to develop an ecology of near shore habitats project that investigates native fish habitat use in a variety of habitats.

We would like to see 1D(b) changed…to indicate: "why fish use them."

Response: We believe that the productivity and temperature data that we will collect will address this information need, at least indirectly. If backwaters offer a thermal refuge from the mainstem, have slower velocities (less energetically expensive than the mainstem), and offer more food items than the mainstem, we would infer that these advantages would serve as attractants to native fishes, as well as nonnatives.

Study 1D is a good design, but why the emphasis solely on autochthonous production, particularly in backwaters?

Response: We have previously made measurements of allochthonous production and inputs and have found it to be minimal. That said, we expect that both autochthonous and allochthonous production will be investigated in our proposed near shore ecology project.

Table 4 (pg. 40) does not include a schedule for ecological measurements of chlorophyll, NPP, phytoplankton, or zooplankton.

Response: We will be investigating the additional physical and biological parameters suggested during the 1D trips in February, March, May, and September.

Comments on study 2.

Response: These comments are very constructive and we will use them and the cited references to review our field protocol and to incorporate into the eventual reporting on this project.

Project 1D (backwater study)

The issues raised in the Science Advisor review of the High Flow Science Plan pertaining to project "1D" relate mainly to whether the project contains an adequate emphasis on geomorphic process and the degree of coordination and integration between the backwater study and other elements of the experimental plan.

These concerns are valid and reflect the fact that backwaters have received much less research attention than many other aspects of the physical system in Grand Canyon and that this research is a new component of the experimental plan. This discussion will attempt to clarify the geomorphic components of the current backwater (project 1D) study plan. In the context of this discussion (and the 2008 High Flow Experimental Plan), we use the term backwater to refer to areas of stagnant flow or low velocity flow that occur in embayments separated from the main current by eddy-deposited sand bars (Schmidt and Graf, 1990; Rubin et al., 199?; Goeking et al., 2003).

The geomorphic component of the backwater project is designed to address the high flow science questions of (1) does the high flow create backwater habitat? And (2) do backwaters persist through Record of Decision flows that will occur following the high flow? Addressing these questions requires some emphasis on form and changes in form over detailed process measurements. The plan does, however, include some process measurements and also includes systematic geomorphic measurements that will be used to improve our understanding of the connection between backwater form and other channel morphologic characteristics. In summary, the plan includes (1) an inventory that will provide some measure of system-wide response to the high flow and following dam operations, (2) topographic/bathymetric surveys that will provide measurements of backwater form for a large number of study sites, and (3) measurements of topography/bathymetry and flow structure during the high flow experiment at three eddies under project 1B.

Inventory Measurements

Previous studies of backwaters (Goeking et al., 2003) and continuing investigation within GCMRC have indicated high spatial and temporal variability in backwater size and abundance. Goeking et al. (2003) identified from 0.5 to 3 backwaters per km in the 21 km they studied, implying a total population of at least 200, but possibly 1000 or more backwaters in Grand Canyon. There is, therefore, much concern that detailed measurements made at a few sites will not be representative of system-wide response. While a system wide inventory of backwaters could be conducted with pre- and post-high flow aerial imagery, such imagery will not be conducted for the 2008 experiment. Therefore, one component of the experimental plan includes an inventory of all backwaters before and after the experimental flow.

The inventory measurements will be made on the six trips identified as the “tape and level” measurements in Table 4 of the Science Plan. Every sandbar-controlled backwater will be visited during these trips and measurements will be made of backwater area and volume at the discharge of observation and the daily high flow based on evidence of the high stage. Backwater relief will also be measured as the elevation of the backwater trough relative to the adjacent sandbar crest.

Surveys

Approximately 60 to 80 individual backwaters will be selected as detailed study sites for topography/bathymetric surveys of the backwater and adjacent sand bar. These surveys will initially be referenced to local control points and will eventually be referenced to the GCMRC control network. Using measurements of water surface and high water marks, local stage-

discharge relations will be developed at each study site. The topographic information from each survey and the stage-discharge relations will be used to determine relations for backwater area and volume as functions of discharge. This will enable calculation of backwater area and volume for discharges other than those observed in the field. It will also be possible to determine which of the studied backwaters are present only over a narrow range of flows and which persist over a broad range of flows including the upper range of Record of Decision flows. We also anticipate that building a database of backwater geomorphic information will help to identify connections between channel characteristics and backwater characteristics. Surveys of backwaters at sites that are included in the long-term sandbar monitoring studies will be made as part of project 1C. Approximately 60 additional backwaters will be surveyed in project 1D. Although the measurements made in project 1C will include bathymetry and topography over a larger area, both will include comparable data collection for the backwater and adjacent sandbar crest.

Process Measurements – connections with project 1B

Project 1B includes detailed measurements of topography and/or bathymetry and flow structure at up to three eddies during the high flow. Although the connection between this effort to increase our understanding of the processes of sandbar formation and the processes of backwater formation was not articulated in the Science Plan, it is clear that understanding of the processes of backwater creation first require understanding of the processes that lead to the formation of sand bars in eddies. Importantly, each of the eddies selected for study in project 1B contains a backwater and monitoring changes to the backwaters is an additional focus of this work and part of the motivation for that project component.

REFERENCES:

[1] Fowler, D.D., E.A. Jolie and M.W. Salter. 2008 Archaeological Ethics in Context and Practice, In *Handbook of Archaeological Theories*, edited by R.A. Bentley, H. Maschner and C. Chippindale, pp.409-422. AltaMira Press, Lanham, Md.

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Yeatts, M., 1996, High elevation sand deposition and retention from the 1996 spike flow: an assessment for cultural resources stabilization: Unpublished report on file at the Grand Canyon Monitoring and Research Center, Flagstaff, AZ., 32 p.

Yeatts, M., 1998, High elevation sand retention following the 1996 spike: Unpublished report on file at the Grand Canyon Monitoring and Research Center, Flagstaff, AZ., 15 p.

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Draut, A.E., and Rubin, D.M., 2006, Measurements of wind, aeolian sand transport, and precipitation in the Colorado River corridor, Grand Canyon, Arizona-January 2005 to January 2006: U.S. Geological Survey Open-File Report 2006-1188, 88 pages, http://pubs.usgs.gov/of/2006/1188/

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Draut, A.E., Rubin, D.M., Dierker, J.L., Fairley, H.C., Griffiths, R.E., Hazel, J.E. Jr., Hunter, R.E., Kohl, K., Leap, L.M., Nials, F.L., Topping, D.J., and Yeatts, M, 2005, Sedimentology and stratigraphy of the Palisades, Lower Comanche, and Arroyo Grande areas of the Colorado River corridor, Grand Canyon, Arizona: U.S. Geological Survey Scientific Investigations Report 2005-5072, 68 pages, http://pubs.usgs.gov/sir/2005/5072/

Publications relevant to the HFE currently in press or undergoing peer review:

Draut, A.E., and Rubin, D.M., The role of aeolian sediment in the preservation of archaeological sites in the Colorado River corridor, Grand Canyon, Arizona: U.S. Geological Survey Professional Paper, in press.

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Kaplinski, M., Hazel, J.E., Parnell, R., and Fairley, H.C., Campsite Area Monitoring in the Colorado River Ecosystem from 1998 to 2006. U.S. Geological Survey Open File Report, in review.