LEGACY MONITORING DATA REVIEW PANEL
REPORT TO THE GRAND CANYON MONITORING AND RESEARCH CENTER

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Background

The construction of Glen Canyon Dam was a signal event in the history of the American West. Hydroelectric power provided by the dam helped spur the growth of the Southwestern U.S. that continues today. At the same time, the dam tamed the Grand Canyon portion of the Colorado River that had, since the days of John Wesley Powell, been symbolic of the wildness of the West. Coupled with Hoover Dam, the completion of Glen Canyon Dam marked the triumph of technology over nature in the American psyche.

It was recognized that the creation of Lake Powell behind Glen Canyon Dam would submerge an astounding number of archaeological sites in a little known and poorly understood part of the American Southwest. The charge of salvaging some portion of this record fell to the National Park Service (NPS)-sponsored Glen Canyon Project conducted by two institutions, the University of Utah under the direction of Jesse D. Jennings and the Museum of Northern Arizona under the direction of Ned Danson (Jennings 1966). From 1957 to 1962, these teams surveyed and excavated scores of sites. The project compiled an impressive record: numerous monographs and articles were published; many theses and dissertations were written; and analyses of the materials continue to this day (e.g. Geib 1996).

At the time, little if any thought was given to studying sites below the dam. After all, the dam was designed to control the flow of the river through the Grand Canyon. If anything, it was assumed that sites in the river corridor would be better protected after the completion of the dam because they would no longer be ravaged by the enormous scouring power of the river's periodic floods. Hardly 20 years passed before this assumption was questioned. As sand bars decreased in size and number, National Park Service archaeologists became increasingly concerned about the possible linkage between the declining sediment resource downstream of the dam and archaeological site erosion. These concerns came to a head following the winter of 1982-1983. Winter storms built a tremendous snow pack that was unleashed the following spring. Lake Powell filled up and the Bureau of Reclamation (Reclamation) was forced to release four times the usual amount of water from the dam. Concurrently, during the summer of 1983 and throughout the subsequent high release years of mid 1980s, a series of powerful summer thunderstorms occurred. Downstream heretofore unknown archaeological sites were exposed; new damage from erosion was readily apparent.

There was no denying that the operation of Glen Canyon Dam had an effect on cultural resources (US Department of Interior 1995). What was unclear, however, was how many resources were being affected, what types of sites they represented, and where these resources were located. In the early 1990s a systematic survey of the river corridor answered most of these questions. Archaeologists recorded 475 sites, of which 336 were located within the river corridor affected by dam operations (Fairley and others 1994). To comply with the National Historic Preservation Act (NHPA), Reclamation was required to consider the effects of dam operations on historic properties, or cultural resources listed or eligible for listing in the National Register of Historic Places (NRHP). The number of historic properties was initially determined to be 322 (US Department of Interior 1995); over time the number has dwindled to 264.

To comply with Section 106 of the NHPA, a federal agency, in consultation with the State Historic Preservation Officer (SHPO) and/or Tribal Historic Preservation Officer (THPO), affected tribes, the Advisory Council on Historic Preservation (ACHP; which can also choose not to participate), and other stakeholders who have identified themselves as having an interest, must evaluate the potential effects of the agency's planned activity on historic properties and to the extent possible find ways to minimize the adverse effects on those properties.

In most cases, the parties agree on a course of action, such as resource avoidance or scientific data recovery. For example, in raising the level of Roosevelt Lake in central Arizona, more than 600 NRHP-eligible archaeological sites were identified, which would be affected either directly (i.e., be submerged by the lake) or indirectly (i.e., lie closer to the lake in areas where increased visitor impact was likely). The parties to the Section 106 action agreed that to mitigate the effect of raising Roosevelt Dam, a *sample* of the sites subject to adverse impacts would be selected for data recovery. The excavation, analysis, and curation of the material recovered from this sample of sites resolved the effect of the undertaking on all historic properties.

Grand Canyon National Park is not just another place. It is a unique physiographic unit that our country values and has decided to *preserve*. In practice, preservation means leaving natural and cultural resources alone. Because of this special situation, it was not considered viable to resolve the effects of dam operations on cultural resources through data recovery on some or all sites that may in the future be adversely affected. Instead, the overriding concern has been to preserve sites in place and only conduct limited data recovery on portions of those sites that were in the process of suffering unavoidable damage. This approach required archaeologists to periodically visit each historic property and monitor its condition.

In 1992, a site monitoring program was established in the Grand Canyon River corridor as part of the Park's cultural resource management responsibilities under mandates of the National Historic Preservation Act (Leap and others 2000.) In 1994, the Bureau of Reclamation and the various stakeholders with interests in the cultural resources of the river corridor entered into a programmatic agreement that initiated a program of monitoring that included 1) documenting the overall condition of sites through use of standard forms (provided in Appendix 6) and 2) taking remedial action in the form of preservation treatments where necessary to counter the impacts on archaeological sites of erosion and in some cases of visitation. Documentation of preservation treatments through maps and other records has also added to the information available about the condition of sites that received such treatment. It seems clear that the preservation treatments that have been carried out represent efforts to make a timely response to perceived threats to the resource values of archaeological sites in the corridor. With regard to the standard site-condition monitoring forms noted above, there also have been efforts over the years to make the required observations somewhat more systematic and objective.

Since 1994, questions have been raised about the overall effects on archaeological sites of the operation of upstream dam operations, including whether changes in the hydrological characteristics of the river are leading to increased erosion at sites. It apparently has been implicitly assumed that the standard site condition forms described above could and would provide data useful in measuring the impacts of erosion and site visitation on the population of sites in the river corridor, and also to analyze trends in the conditions of sites in this population.

But is this assumption correct? Unfortunately, few synthetic studies have made substantial analytical use of the large amounts of monitoring and other data that have been collected. As the Grand Canyon Monitoring and Research Center (GCMRC) takes over the cultural resources monitoring program, it is an auspicious moment to examine this key underlying assumption.

Review of Grand Canyon Cultural Resource Monitoring Program

In September 2007, the GCMRC convened a peer review panel to evaluate the potential of the data collected between 1992 and 2005 to address issues of importance to the stakeholders.[1] The review panel focused its attention on the usefulness of the site-condition monitoring forms, but recognized that the original site inventory forms, the records of preservation treatments, and the photographs taken during monitoring and preservation treatment visits might also have the potential to address questions of interest to the GCMRC. Collectively, all these data sources are referred to as "the legacy data" in the following report.

The panel was asked to determine whether the GCMRC should place more effort in studying these "legacy" data to answer such questions as: Can we use the monitoring forms and/or other existing data to examine changes in the erosion rates at archaeological sites? Can we use the existing data to test geomorphic models of erosion and their effects on archaeological sites? Can we use these data to study the effect of dam operations on archaeological sites? As we struggled to determine the efficacy of the monitoring effort to address issues of current interest, we couldn't help but think about how future monitoring programs might be designed to avoid some of the pitfalls we observed. Our report, therefore, looks forward as much as it looks at the past.

In assessing the available data it is important to recognize that data of any sort do not have inherent value; rather their utility can only be assessed relative to their ability to inform on a question or suite of questions. Clearly, the existing monitoring data have been valuable for the preservation goal of assessing the physical conditions of an archaeological resource and deciding if treatment was needed at that time.

Although it is our assessment that the legacy data are inadequate to the task of answering all the many questions posed by diverse stake holders, analyses of these data may nonetheless be useful in beginning to address some of them. In the discussion below, we offer some suggestions of how indicators derived from the available data may be relevant to some of the GCMRC queries. However, addressing many current questions, notably those associated with assessing causes (e.g., distinguishing dam effects from those that could have been caused by natural variation in river flow) will require the collection and analysis of different kinds of data. In our

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[1] Brief biographical sketches of the authors are provided in Appendix 5.

responses we not only provide some prospective guidance on these issues, we specifically recommend experimentation with an innovative procedure proposed here.

For clarity of presentation we first discuss some general concerns about the legacy data and offer some suggestions about how they can be used prior to addressing the specific queries posed by GCMRC in "Guidance for Monitoring Panel Review" (Appendix 1). While we provide, in turn, commentary on each of the 11 topics suggested, it is not possible for us to answer many of the more specific questions about the utility of the legacy monitoring data. Similarly, we are unable to respond directly to the specific "NPS Legacy Data Questions" (Appendix 2). While these questions are certainly reasonable to ask, they simply cannot be answered through a casual inspection of the data by the reviewers. In some cases, it may be possible to answer questions with available legacy data; in others, the data will certainly be inadequate. However to even decide whether the questions could be usefully addressed with the legacy data (much less to actually answer them) would require an in-depth analysis of the available monitoring, preservation-treatment, and site inventory databases and records—an effort that would be far beyond the panel's scope of work. Unfortunately, the lengthy synthesis commissioned by GCMRC failed to quantitatively analyze the data, noting that it would have required too much restructuring of the existing databases (Neal and Gilpin 2000: 98). (Note: The legacy site-condition monitoring database was migrated to a relational format in 2002-2004. However, this restructuring did not resolve many of the more problematic aspects of the data set from an analytical standpoint.)

Finally, the panel notes that because of the close timing between receiving these documents and our review meeting, we did not have time to study all of the documents provided to us, nor were we able to examine carefully all of the annual reports. It is certainly possible that some of our comments and suggestions may already have been addressed in other contexts. However, a great deal of information was presented at our panel meeting and the panel feels that it has an adequate basis for presenting this assessment.

Using Available Legacy Data

It appears feasible to make some quantitative use of legacy data encoded in site inventory, monitoring, and preservation treatment records. Although the way the monitoring forms were designed (see response to query 4, below) makes it difficult to extract robust quantitative data from them, we suggest some ways to use the available qualitative data. We also believe that some of the records of preservation treatments have potential to complement the data obtained from the standard monitoring forms. We present these suggestions in this separate section because we refer to these potential analyses of legacy data in several of the individual responses below.

The following discussion refers to what might be done with the monitoring forms used from 1994 through 1998 (as presented in by Neal and Gilpin 2000) and thereafter if the 1998 version of the form (or a similar one) continued to be used in later monitoring visits.

<u>Erosion Impact Index.</u> The first method we suggest involves using the legacy monitoring forms to create a site-level indicator of erosion. Development of some indicator of erosional impact is an essential step in assessing how the operation of the dam affects the archaeological resources.

Step 1. The first step in creating a tally of erosion indicators is simply to count the number of cells scored as something other than "0" or "NA" for the first six rows of the physical impact matrix in the monitoring form (for 1994 through 1997, this would be rows 7-12; for the forms used in 1998, it would be rows 8-13). Again, for each cell in these rows that had a monitoring response other than a "0" or a "NA," one would be added to the tally. If five cells meet this criterion, the score would be "five" and so forth. (We're not sure that "aeolian/alluvial erosion/deposition" or "side canyon erosion" should be included, but leave it to those who better understand these categories to decide.)

Step 2. Another bit of data comes from item 15 in the physical impacts section of the form. Any answer other than "NA" indicates that arroyos or gullies are present at the site. If the original tally resulted in a zero score, but something other than NA was entered for item15, we can infer that gullies or arroyos were present, even if they evidently did not impact any archaeological features. This would be worth a score of "one. " However, there would be no score from item 15 if the original tally counted at least one erosion indicator (i.e., a tally greater than zero).

Step 3. The management recommendations section of the form provides another piece of information. All the forms used from 1994 to 1998 have an item that deals with impact treatment recommendations and includes "install check dams" as an option. If "install check dams" is checked, this would seem to indicate that the monitoring crew perceived that erosion posed a fairly serious threat to at least some part(s) of the site. If this option is checked, add another "one" to the total score of erosion indicators.

Step 4. To create an "erosion impact index" for the site, divide the tally by the total number of possible erosion indicators for the site (i.e., all the cells or entries that could possibly have contributed to the tally), yielding an "erosion impact index" for the site ranging from 0.0 (no recorded impact) to 1.0 (maximal recorded impact). While the limitations of this index are obvious, it (or some sensible variant) can supply a variable that one could begin to work with in a formal analysis.

<u>Visitor Impact Index</u> A "visitor impact index" could be created using visitor impact variables recorded on the monitoring forms through a procedure analogous to that just described for the Erosion Impact Index.

Taking this approach a step farther, it may be useful to create indices of erosion or visitor impacts to features by using recorded information about actual preservation treatment actions at the sites. This would require extracting data from maps and other records made at the time that preservation treatments such as check dams were installed at a site.

<u>Erosion Treatment Index.</u> A subset of sites has had some type of preservation treatment designed to retard erosion. The number of discrete devices (e.g., check dams) that have been actually installed relative to site size may be a reasonable quantitative indicator of the *severity of erosion at a site with respect to the site's cultural features*. (This assumes, of course, that the number and location of check dams and other treatments were systematically recorded. We did not examine the recording protocols used for preservation treatments.) Further, the number of features or the number of 1x1 m units that have been excavated because of the impacts of erosion could be added to the number of diversion structures. This quantitative index could be standardized to correct for site size and/or number of features. Both site size (by area) and number of features can be obtained from the site inventory form. We might call the measure thus

calculated an "erosion treatment index." It is our impression that a substantial proportion of the sites in the monitoring program have received some type of erosion control treatment. If it is reasonable to assume that sites that have not had any treatments to retard erosion were judged not to need it, then the erosion treatment data seem to provide the most quantitatively sensitive and useful information about erosion impacts at the sites in the monitoring program.

<u>Visitation Treatment Index.</u> Evidently some sites have also received preservation treatments or feature-scale data recovery efforts related to visitor impacts. Using an analogous procedure, a "visitation treatment index" could be derived from these data. It may be that this kind of treatment is less common that that directed toward erosion control, so there might not be enough sites to constitute a group useful for comparative studies.

Panel Commentary on Queries Posed in "Guidance for Monitoring Panel Review"

1. Adaptive Management Objectives

Adaptive management is defined as a systematic process for continually improving management policies, techniques and practices by learning from outcomes of operational programs or interventions (Sitt and Taylor 1998: 2, 50.) Ideally, adaptive management begins with the definition of management problems being faced, then it proceeds to the creation of a management plan that is implemented, monitored, and evaluated. Was the original monitoring program clearly defined in relation to problems or objectives and were the data subsequently collected and analyzed in a manner that would allow managers to determine whether management actions were leading to desired outcomes? If yes, please describe how. If not, how could future monitoring programs be designed to more effectively address adaptive management needs and the concerns raised in previous reviews of the program?

The panel is not in a position to discuss the origins and initial objectives and design of the monitoring program. Concerns regarding the variable selection are discussed under query 4 (p. 12). Data collection issues are also discussed elsewhere in this report. We here focus on the issue of analysis. As discussed above, the existing data have been used to address some key program goals. However, there has been almost no systematic analysis of these data.

The panel's first and most forceful recommendation with respect to adaptive management is that the agencies must have as strong a commitment to systematically analyzing the data as they do to the process of data collection. Without frequent, periodic analysis focused on management objectives, the management cannot be "adaptive" because there is no source of feedback. Such a commitment would entail a substantial commitment of resources on a regular basis. Without such a commitment, much of the information potential value of the data is lost. Analyzing even the best-collected site monitoring data is a difficult and time consuming task requiring considerable quantitative expertise. Management must commit the necessary time of qualified analysts (in- or outside the agencies) and resources for this analysis in order that timely information is available for policy reviews.

The first and perhaps most important, step in reformulating the monitoring program will be to explicitly identify and prioritize the program goals. For these purposes, a laundry list approach will not do. It will almost certainly be infeasible to collect and analyze sufficient data to answer every question of interest to the many stake holders. The program goals will need to be carefully considered, trading off their management importance with the cost of obtaining and analyzing the necessary data. We suggest that it will be better to answer a limited set of questions with some assurance rather than many questions inadequately.

With an explicit specification of the goals, the variables that need to be observed and recorded can then be selected. The recording forms and the manner in which the selected variables are recorded must directly reflect analytical needs entailed by the goals and will need to be designed in collaboration with personnel quite experienced in quantitative analysis. Personnel experienced in recording sites in the field will also need to be consulted to ensure that the selected variables can be effectively and efficiently documented in a fieldwork context. With cyclic data collection and analysis it will be possible to recognize and correct inefficiencies or problems in the data collection program and to adapt the program to new management needs. While these points may seem obvious, there was little evident effort to systematically analyze the data collected at great effort and enormous expense through the 1990s and more recently.

2. Applicability of the Data to Address the Question of Dam Effects

The GCD AMP [Glen Canyon Dam Adaptive Management Plan] is concerned with assessing effects of dam operations on resources in the Colorado River ecosystem. Specifically, the AMP is concerned with whether the dam is being operated "in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were created, including but not limited to natural and cultural resources and visitor use." Are the legacy monitoring data suitable for detecting dam effects on archaeological sites? If yes, in what respects? If no, why not?

The legacy data will not provide definitive answers to the question of dam effects. They were not designed to do this and are not well suited to the task.

Use of the Legacy Data with Information on Geomorphic Setting. However, we might ask if it is possible to use the two erosion indexes (erosion impact index and erosion treatment index) derived from the legacy data (as described in the section, Using Available Legacy Data) to address the question of whether post-dam river flow characteristics have contributed to erosion at archaeological sites in the Grand Canyon river corridor. There are clear difficulties in determining whether erosion at archaeological sites in the Grand Canyon is linked to post-dam river flow regimes, to climatic change, to the effects of increased visitation, or to the "ordinary" erosion regimes that have been operating in this area for centuries, or to other factors. Setting that issue aside, can we use the legacy data to investigate, in a preliminary way, whether erosion at archaeological sites is associated with the current river flow regime?

If river flow regimes are affecting rates of erosion in the Grand Canyon, it is through their disproportionate effects on particular kinds of geomorphic features or alluvial deposits. Therefore, sites located on the affected features or deposits should show more indications of erosion than sites located on other types of geomorphic features or deposits. It may be possible to use spatial patterning studies to evaluate the probable impacts of changed river flow regimes.

Ideally, we would use a geomorphic model to identify features and deposits that were more likely and less likely to display increased erosion resulting from post-dam river flow regimes. Our prediction would be that sites located on the "more likely" features or deposits would on average have higher "erosion impact index" and "erosion treatment index" ratings than sites located on "less likely" features or deposits. It is possible that such geomorphic predictions are—or will be—available for only some segments of the Grand Canyon river corridor. If so, the question would be whether enough sites are present in these segments to determine with some confidence whether the spatial patterning predictions are or are not supported.

If formal geomorphic predictions are not available, then we might consider using some kind of proxy predictors, e.g., "sites close to the river horizontally and vertically will have higher erosion and erosion treatment indexes than sites farther from the river horizontally and vertically." This kind of study would be hard to link to changes in river flow regimens, but the results might suggest what kinds of additional information are needed.

Use of Legacy Terrestrial and Aerial Photographs. The panel understands that among the legacy data are sequences of repeated terrestrial photographs of the same locations. These sets of photographs should be investigated for the information they contain about erosion (or visitation). If particular gullies/arroyos have been photographed multiple times from more or less the same angle, it may be possible to make some qualitative or quantitative measures of changes in those erosional features over time. These may be extremely valuable as they may lead to much more direct observations, at an appropriate scale (e.g., a feature) of the processes of interest (Neal and Gilpin 2000: 127, e.g., Fig. 7.14 on p. 141). This kind of evidence would probably be hard to extrapolate to the site as a whole, but it might be useful in conjunction with the other approaches that have been sketched. A pilot study using the photos might be undertaken to assess their usefulness in detecting trends. In pursuing this analysis, it would be well to communicate with others who have done studies of time series of repeated photographs. The resulting information could be related to site features, as suggested for the potential LiDAR (light detection and ranging) study proposed below.

Similarly, GCMRC has proposed analyses of temporal sequences of aerial photographs from the earliest available photos, through the time of the construction and filling of the dam, and up to the present. This analysis may provide some of the most informative data if the available photographs are of sufficient resolution to observe key geological processes (such as arroyo cutting and beach formation and disappearance).

Quantitative changes in elevation (indicative of erosion or aggradation) could be determined from repeated total station maps of a site. While total station maps have undoubted value, they are labor intensive and their creation may cause notable site disturbance. The LiDAR approach proposed in the next section, in which elevations are directly tracked, would provide more precise and more easily quantifiable data with less impact than repeated total station mapping. Overlaying LiDAR data on a total station base map may usefully permit the association of areas of impact (i.e., elevation difference) with the actual archaeological features in those instances where total station maps have delineated the spatial extent of individual archaeological features. Total station maps are available for 68 sites (Leap et al. 2000: 1-16).

Analysis Using New Data and Models. Adequately addressing the question of dam effects demands an understanding of the geomorphic processes implicated. Expert geomorphologists are needed to provide well specified geomorphic models with clearly defined test implications. Data will need to be collected to verify the models and to distinguish among alternatives. Such testing can and should be done on a stratified sample of sites (with stratification depending upon the model expectations). The testing will likely also involve investigation of non-site controls.

Our present understanding of ground-based LiDAR data suggests that it could be used very effectively to answer a number of the questions of interest if it were gathered at the same sites over periods of several years. It is the panel's understanding that LiDAR determined elevations currently are available for several cultural sites, and that at least one has three sets of LiDAR determinations, but only part of one has been post processed for two dates.

LiDAR would also be a highly effective way to collect decisive data for the geomorphic models that need to be developed. One year's LiDAR data for a whole site would give precise determinations of the site's elevations. If LiDAR data were gathered at a subsequent time, such as three years later, elevations could be differenced on a point-by-point basis to give elevation change over the entire site. An average of these differences across the whole site divided by the number of years between the two LiDAR evaluations provides an aggregate measure of annual erosion. However, if arroyos had formed between the times of the two LiDAR evaluations, some of the differences would be much larger than others. A threshold value for potentially serious erosion could be determined, and the proportion of the site area with erosion exceeding this threshold could be regarded as the proportion of the site with excessive erosion. Other attributes of these differences could be defined to reflect other types of erosion.

Because this technique appears so promising, we will provide more detail on its possible use. As indicated above, the basic idea is to use differences between initial LiDAR-determined elevations and determinations made at subsequent times to arrive at several possible measures of site-level erosion.

The sets of elevation differences can be converted into informative measures of erosion several ways. An obvious one is simply to average all of the differences. Site-wide average erosion can be regressed against time to estimate a rate of erosion for individual sites. Site-level estimates of erosion rates could then be related to relevant predictors, such as elevation above the river or distance from nearest river camp site. However, an average aggregates relatively unaffected parts of the site with major changes resulting from recent arroyo cutting. Also, in an average, aggradation in one place would cancel out erosional effects elsewhere, potentially yielding a misleading summary.

Consequently, it is preferable to consider the cumulative distribution function (typically referred to as a "cdf") of differences in elevation, such as displayed in the accompanying figure[2], based on LiDAR elevations which became available after the panel met. The differences in elevations summarized here represent a part of a site known to GCMRC personnel that is in a gully formation stage.

This figure plots the difference between the two measured elevations on the horizontal axis. The vertical axis shows the proportion site area with elevational difference less than or equal to the value on the horizontal axis. In this example, the cdf (vertical axis value) is about 0.4 for an elevation difference of 0. This means that 40% of the site area did not change in elevation or aggraded, whereas about 60% of the area experienced losses in elevation. The differences

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[2] This example is based on real Grand Canyon data supplied by Brian Collins of USGS, (United States Geological Survey) Coastal and Marine Geology Program, developed in cooperation with the USGS, GCMRC in response to a request by Helen Fairley. We thank both of these people for this data. As this data has not been otherwise published, the location to which it applies is deliberately obscure. Computational details regarding the interpolation of the observed elevations needed to derive the differences for this example are provided in Appendix 3.

incorporate measurement error, perhaps to the extent of 0.04 m. The green lines in the figure show the part of the cdf which might represent primarily measurement error. This set of data had (estimated) differences from -0.6445 to 0.5184, both more than half a meter, but had an average of 0.0088 and a median of 0.0091, each a bit less than a centimeter. 42% of the differences were less than zero, whereas 58% were greater than 0. 17.4% were less than the lower error bound of 0.04m, whereas 23.4% exceeded the upper error bound of 0.04. Overall, in this graph about 40.8% of the site experienced changes in elevation of 4 cm or less in one direction or the other.

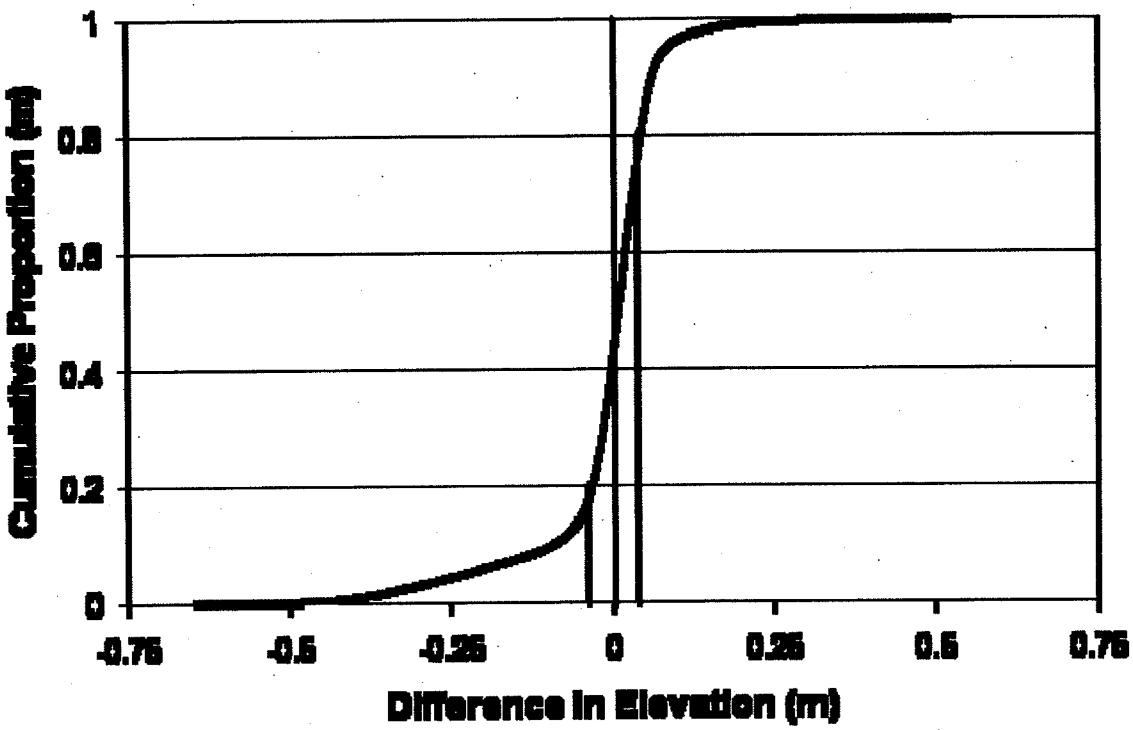

Figure 1: Cumulative Distribution Function (cdf) of Differences in LiDAR Determined Elevations. (The data source is described in the accompanying text. The vertical blue line depicts no change in elevation; the green lines = the limits of the data precision.)

Using graphs of this sort, interested parties could agree on how much change would be regarded as unimportant (or natural), what ranges of values would represent modest change, and what would be regarded as substantial change. The cdf can thus provide relevant indicators of site change, or lack thereof. While this sort of graph provides an easy-to-use overall assessment, the differences in the LiDAR elevations can also be mapped (and overlaid on an accurate site map) so that analysts can observe precisely where the erosion is occurring and how much it threatens site or feature integrity.

Over the longer term, LiDAR evaluations could be repeated on a regular schedule, such as every three to five years. The erosion since the initial measured year at that site could serve as a response which would submit to serious analysis against predictors such as elapsed years, elevation above some standard flow stage, such as 28,000 cfs, distance from river camp sites, a measure of visitor impact, such as number and size of trails to the site.

Although one might think that all sites would require the same revisitation schedule, that isn't the case. In fact if no evaluations were made in a given year, the meaning and utility of the responses suggested here would not be compromised. How often do sites need to be revisited? The suggested analysis approach will work for any revisit schedule. On the other hand, overall (as opposed to site-specific) analyses can not be started until all relevant sites have had LiDAR elevations determined at least twice. Great difference in revisit patterns will lead to substantial differences in how *precisely* the rates of erosion are estimated. If there are great differences in the precision of estimated rates of erosion, weighted regression probably should be used to accommodate this outcome. A way to avoid this would be to have a regular revisit schedule of LiDAR determinations, such as every three to five years. (In the statistical literature this would be called a multi-panel serially alternating temporal plan.) Similar designs have been explored in statistical literature (Urquhart, et al., 1998), but the feature of augmentation usually adopted in the situations investigated there is not essential here. On the other hand, if some cultural sites are of special interest or concern, annual visits present no problems.

In addition to the quality of the quantitative data resulting from ground-based LiDAR, the panel understands it can be gathered relatively quickly and with minimal impact to the site. This may be very important, as persons walking around gathering data may constitute a major impact on some sites by breaking the cryptobiotic crust. Although we see tremendous promise for the use of LiDAR, it is essential that there be sufficient expertise available, either through in-house hiring or contracting, to perform the needed quantitative analyses.

3. Applicability of Data to Other Relevant Legal Mandates

In addition to requiring that effects of dam operations on cultural resources be evaluated, the Grand Canyon Protection Act [GCPA] directs the Secretary of Interior to operate the dam in a manner that is consistent with the National Park Service Organic Act and other relevant laws that apply to National Parks. Can the legacy data be used to assess whether the broader intent of GCPA is being attained? If yes, in what respects? If no, why not?

Are the legacy monitoring data suitable for addressing other legally mandated compliance concerns, such those of the National Historic Preservation Act? In what respects are the data suitable for addressing other compliance requirements under NHPA (for example, are they well suited for identifying and prioritizing sites that may require data recovery or erosion control measures in the near or distant future? To what degree are they suitable for assessing whether erosion control treatments are having their intended effects or not?)

The panel recognizes that a site monitoring plan must today serve the objectives of many different stake holders. From a legal perspective, any monitoring plan 1) must identify pressing needs to treat individual sites due to adverse impacts (whatever the source); and 2) must also collect data designed to inform directly on the human and geological processes (and their causes) that are involved in site disturbance (particularly erosion and visitor impact).

As noted above, the first step should be to get these objectives as clearly articulated as possible by the relevant parties and then negotiate a monitoring plan that is designed to address as many concerns as possible in an integrated way. The objectives agreed upon will dictate the purposes for which sampling is appropriate and inappropriate, and what sorts of sampling strategies would be most effectively employed.

Managers must realize that until the existing or new data are analyzed, it will often not be possible to know the extent to which different legal mandates can be satisfied by different combinations of data collection, sampling, and mitigation. (Of course, the results can be fed back into an adaptive management strategy, as discussed under query 1, above).

4. Issues Related to Variables Selected

Are the parameters and types of variables (e.g., qualitative, quantitative, presence-absence, ordinal, interval etc.) suitable for addressing the questions being asked and the overall needs of the adaptive management program? Which of the legacy data appear to be most useful for monitoring status and trends in resource condition through time?

Key variables in the dataset based on the site monitoring forms, while generally relevant to the concepts at issue, were not represented in a way that allows them to directly answer questions now being posed. In particular, data better suited to quantification are highly desirable. It is far more useful to know that 3 of 4 structures are affected by gullies than to know that gullies are affecting structures. This returns us to an earlier point. Had the monitoring data already collected been more intensively analyzed, many of the weaknesses of the present system would long ago have been revealed. Some of the other components of the legacy data, e.g, preservation treatment maps and records, and sequential photographs, may have potential for addressing the questions being asked, even though these records were not made with these questions in mind. Their usefulness could only be determined by actually attempting to extract relevant data from these records.

To the extent that stake holders can agree on objectives, such as slowing the physical deterioration of archaeological sites, then variables to be measured can be designed to efficiently indicate the factors directly relevant to the objectives. Clearly there are costs associated with more detailed recording (if that turns out to be necessary). In any case, the benefits of information return must be carefully weighed against the required effort for *any* data collection and that can only be done in the context of a set of questions and analyses directed to answering those questions.

In this context, there seems to be a widespread desire to assess "overall site condition." As an unexamined concept this may seem unproblematic. However, we suggest that without a careful definition it is essentially meaningless. Site condition is probably a multidimensional concept that needs to be unpacked into multiple variables that have to do, for example, with interpretive value, research value, stability, and lack of disturbance over the last century. There needs to be a precise specification of the dimensions that are to be measured. To the extent that an aggregate measure is needed, agreement must be reached on how these dimensions should be weighted to yield a generally acceptable result. This also needs to be done with "site integrity," which is also a multidimensional concept for which different stake holders may reserve different meanings. Examples of relevant dimensions might be the utility of the site for excavation or interpretation. These dimensions could be measured as presence-absence, or perhaps better by an ordinal ranking (perhaps on a 1 to 5 scale, from none to very high).

As new recording protocols are agreed upon and field forms designed, they need to be developed in collaboration with individuals experienced in analyzing these sorts of data. Careful attention needs to be paid to distinguishing the absence of an effect from missing data, to clearly establishing hierarchical relationships among variable values (for site type, does "burial" take precedence over "habitation" or the other way around; or better yet, designing coding schemes where these hierarchies are unnecessary—such as coding counts of many different feature types instead of embedding this information in a list of site types), and eliminating ambiguous situations. Forms need to be carefully field tested with sample results analyzed quantitatively before they are implemented.

Once a new recording program is implemented, consistency is of the essence and a comprehensive quality assurance plan must be implemented. Site forms can be designed to reduce errors or electronic "smart forms" used that can identify inconsistencies at data entry time. Field forms should be checked by an experienced supervisor. Analyses of the recorded data should be conducted to locate individual recorders whose recording differs systematically from that of others. Those individuals are not necessarily wrong, but the systematic deviations suggest the need for investigation.

As indicated, on-site LiDAR data can provide very precise quantitative data on volumes at scales (e.g., focused on a single feature or arroyo) congruent with the data needs of some of the most pressing questions faced in the Canyon. However, even this method should be tested at a limited sample of sites over time before being extensively deployed.

5. Issues related to changes made to the monitoring database structure through time

Initially (1992-1993), the monitoring program employed a semi-quantitative approach that involved ranking different kinds/levels of impacts at each site, then summing the rankings to arrive at a "condition index rating" for that site. After 1994, this approach was abandoned in favor of a more streamlined one that noted the presence or absence of different types of erosion features and visitor impacts relative to various physical characteristics of the sites. The final condition assessment was arrived at independently from the presence/absence impact observations (in other words, final condition evaluations were not dependent on the monitoring data directly.) In 1997, the monitoring form was modified again to distinguish between active impacts and previously documented impacts that were no longer occurring but whose effects were still visible. Also, aeolian erosion/deposition was added as a variable, and several other modifications were implemented. Given these changes, can the legacy data be processed or filtered in some manner so as to allow data collected prior to 1997 to be compared with those collected later?

Generally speaking, the panel believes that as long as the records with different recording protocols are sensibly integrated then analytical problems can be overcome, assuming of course that the necessary data were recorded through the period of interest. For example, on question 15 in the Natural Impacts sections of the monitoring forms, for 1994-97 a code of 2 means "NA" but in 1998-99 a code of 2 means "side canyon based" and 3 means "NA". Obviously the 2's from earlier periods need to be translated to 3's in a combined dataset.

One first needs to identify a specific question, its test implications, and the minimal data needed. Then one must identify the years for which the underlying minimal data are available. Then all data for those years needs to be reduced to a sort of least common denominator on a variable-by-variable basis. This is fairly straightforward conceptually but can be time consuming and fairly tricky to execute in practice (and easily leads to errors that are hard to ferret out.) Because of some ambiguity in the forms, in practice, analyzing across years in which relevant data are differently recorded will be best accomplished with participation of individuals who have detailed knowledge of what recorders were actually doing in the field.

For future recording protocols, changes and the reasons for them need to be explicitly recorded in metadata.

In order that it remain possible to connect the many years of data recorded in the past with data collected under new data collection protocols, the participating agencies should insure that there is an explicit and thoroughly documented connection between the earlier and new recording protocols. Ideally one would collect both sets of data in parallel for a time.

6. Issues related to frequency of observations

Between 1992 and 2005, archaeological sites were monitored at different frequencies depending on the archaeologists' perceptions of levels, types and numbers of threats and impacts. Sites with few or low levels of impacts might be monitored once every five years, others with moderate impacts once every 2-3 years, while sites that received a lot of impacts might be monitored every year or sometimes, twice per year. Also, if impacts appeared to be increasing, frequency of monitoring would be increased, while if impacts appeared to be stable or decreasing after several visits, the monitoring frequency might be reduced. Thus, sites exhibiting higher levels of impacts generally have many more monitoring records than sites with lower levels of impacts. Can the monitoring data be "processed" in some fashion so that the data are not skewed towards higher numbers/levels of impacts, and if so, what would be the best approach for doing this?

When doing analyses across time, problems associated with different frequencies of site observations in the legacy data can generally be adequately dealt with. In the current monitoring database, the observation (line in the database) corresponds to a *monitoring event*. To do comparisons across time one must eliminate sites with only one monitoring episode unless one is willing to assume that the fact that a site is visited only once means it is stable over time. (This assumption could readily be checked by revisiting the sites in question.) Then the data for all monitoring events at a given site need to be aggregated so that the observation becomes the *site* with variables representing the number of monitoring episodes, the length of time over which observations were made and the changes observed over that interval.

When the monitoring program began in 1992, approximately 269 sites were included in the monitoring program. Over the years, approximately 100 sites were dropped from the program for a variety of reasons. Many sites were dropped because they showed little if any change from one monitoring visit to the next; others were dropped because NPS managers decided that they were too sensitive to be monitored or because the managers decided that the sites probably were not within the area of potential dam effects after all. By 2005, the pool of monitored sites had shrunk to approximately 161, representing mostly sites that showed active erosion or ongoing impacts from visitor use. What are the implications of this history on the utility of the legacy monitoring data for detecting trends through time, assessing the overall condition of sites in the CRE [Colorado River Ecosystem] system, tracking improvement or deterioration in site condition over time, etc.?

Dropping sites from the monitoring regime presents no major analytical problems. Depending on the question, one can either retroactively eliminate observations for sites that were later dropped from the protocol. Alternately, one can separately analyze both the later dropped sites and the continuously monitored sites over the period during which both were recorded and evaluate any biases between the two sets. Or, if it can be verified that dropped sites have had little or no change in condition, they could be included in the analysis. (Also please note the comments above on "overall site condition".)

We would question the wisdom of completely dropping sites because they appear to be reasonably stable. Apparent stability might well be a reason to monitor these sites less frequently (which would also pose no substantial analytical problems) or perhaps less intensively by brief visits. However, retaining them in the database might well allow stronger analyses because they would represent stable conditions.

The panel cannot overemphasize the importance of consistently applied definitions of responses across time. For time series of responses to have any practical utility, the responses must have the same definition, regardless of by whom or when the evaluation was made. Two things are essential to accomplish this: clear definitions, and consistent training in the applications of those definitions. For some responses, especially ordinal ones, pictures to illustrate the various scores provide solid adjunct to careful verbal descriptions. Pictures or even video clips also can be used for some of the more complex measures. With the current state of portable computers, such images can be taken to the field in a computer; much of the recording of data could be done on the same computer.

7. Data Redundancy

A preliminary analysis of the legacy [site-monitoring] data performed showed clustering between certain types of impacts, and this led to the conclusion that some of the data fields are redundant. For example, sites with arroyos showed a tendency to also exhibit bank slumpage. Likewise, the variables "surface erosion" and "aeolian/alluvial erosion/deposition" showed considerable overlap, so the author recommended that these fields be combined. On the other hand, other variables such arroyos and gullies did not exhibit as much redundancy as might have been expected. What other analyses could or should be performed to detect and evaluate redundancy in the data? What are the implications of combining and/or reducing the numbers of variables in terms of being able to detect trends in the data through time?

Variables are unlikely to be redundant in an absolute sense. For any specific question, there may be some redundancy. However to be confident of this redundancy—even for a specific question—would require considerable analysis, not just a single analysis indicating a correlation or clustering. The benefits of such an analytical exercise for the legacy site-monitoring data probably would not justify the effort.

However, where there are logical connections among variables, they may be productively lumped, not permanently, but for analytical purposes. For example, in an erosion analysis, gullies and arroyos might be reasonably lumped in contrast to their absence. (However in practice some kinds of lumping may be complicated by the presence/absence recording scheme in the legacy site-monitoring data.) Alternately, as described elsewhere in this document, it may be desirable to process sets of recorded variables to achieve proxy variables that may more closely match the target concepts

For future recording protocols, considerable effort should be invested in concept formulation, variable definitions, form design, and testing (see query 4, above).

For the legacy data, during a presentation to the review panel, a program leader noted that the records produced by one or a few specific recorders are generally regarded as unreliable or suspect. These records should simply be removed from further analysis. Similarly, where long sequence of monitoring episodes exist, it is probably wise to eliminate obviously anomalous observations (e.g., a feature going from intact to destroyed to intact) as one often removes extreme values in any analysis.

8. Trend Detection

Are the data suitable for detecting trends in resource condition through time? If yes, in what respects can trends be detected? How can the data be used to detect trends in overall site condition through time?

Conceptually the issue of temporal trends is closely related to several points made in response to queries already discussed. In particular, the lack of quantitative variables and problems with the concept of overall site condition are discussed above. Nonetheless, when there have been multiple monitoring visits to a site, the four derived indices could be calculated for each visit, and then the results compared to determine whether trends are evident.

In addition to temporal trends, it is also possible to consider synchronic spatial trends. For example there might be synchronic upstream/downstream differences in variables associated with erosion that could be evaluated in the context of an appropriate question. Similarly one could look at atemporal spatial trends in visitor disturbance (with new or legacy data) based on knowledge of common campsites and visitor stops and their distance from sites, stratified by visibility and interest (e.g. rock art or structures).

It would be possible to use legacy data to look for patterns in visitor impacts using methods similar to those suggested for analyses of legacy data for dam effects described in the section, Using Available Legacy Data. It seems likely that information is available on the location of regularly-used campsites and of archaeological sites that are regular stops for visitors. For each site, distances from the site to the nearest camp or regular archaeological attraction could be calculated. The expectation would be for a negative correlation between distance to nearest campsite/archaeological attraction and the two visitation indexes. There may be other ways to estimate expected visitor impacts, i.e., using average distance to the nearest two or three campsites/attractions to predict visitor impact on nearby sites.

It is possible that visitation effects (as measured by the two visitation indexes) are also related, or even more strongly related, to on-site characteristics of archaeological sites, rather than to distances to points of visitor concentration. For example, visitor impacts might be greatest at sites having visible architectural features, or rock art, or some combination of these features. The basic inventory forms could be examined to develop some kind of score of on-site attractions (e.g., number of visible architectural features plus number of rock art panels, or something like that). These raw scores might be used to assign sites to several "attractiveness classes". The prediction would be that the higher the attractiveness score or class, the higher the indexes of visitation impacts.

It might even be possible to examine the question of whether erosion at archaeological sites is more closely associated with visitation than with geomorphic setting. Results of the several studies on legacy data envisioned in our discussion of query 2 and immediately above might be compared to address this question.

There are several questions on the monitoring forms that provide some additional data on whether erosion or visitation impacts are increasing or not (e.g., questions 16 and 24). These responses could probably be used in some way to check or compare with the results of the studies sketched above. The comment fields and other notes associated with the monitoring forms may also be a source of evidence about changes in erosion or visitation impacts at sites that have had multiple monitoring visits. This information might enable a classification of sites into "stable" or "increasing impact" categories for the revisited sites. This classification might be useful in conjunction with other studies as sketched above. In at least some cases it appears that sites that were not revisited were judged stable with respect to impacts. If much weight is to be given to the several possible trend studies, a sample of the "one-visit" sites should be revisited to determine whether or not they have been stable with respect to erosional and/or visitation impacts.

The suggested analyses of the legacy data all have potential pitfalls. However, agreement of the results of more than one such analysis would provide considerably more confidence in the results than any single analysis standing alone. In particular, use of data from preservation treatment records, etc., in addition to data from the site-monitoring forms, may provide opportunities for stronger inferences.

In considering trends, we need to attend closely to the scales implied by our questions. For example, in considering dam effects, the target may be a specific type of archaeological feature or geological location, not an entire site.

9. Controls

Were the monitoring data gathered in a manner that allows them to be evaluated relative to controlled variables? Are the data suitable for assessing the effectiveness of treatments in the future? What would be the best way to control for variability in the data due to natural environmental variation or other factors that may influence condition changes other than dam effects?

Research designs with carefully selected controls can produce particularly persuasive results. Depending on the questions, controls may not need to be in locations with sites, or could be at sites out of the area of potential effect. For example, a geomorphic model such as Hereford's model does not need to be tested on a site and indeed may be best not tested on a site. Treatments such as check dams could be employed and tested on non-sites as well as sites.

10. Applicability of the legacy data for developing new monitoring protocols to address previous concerns and the current "core monitoring information need" for archaeological sites?

The cultural Protocol Evaluation Panel conducted in March 2000 made numerous recommendations about how to revise the monitoring program to focus more specifically on evaluating effects of dam operations on cultural resources and evaluate the efficacy of erosion control treatments.

In October 2005, the cultural resources ad hoc group (CRAHG) of the GCD AMP Technical Work Group (TWG) reviewed the core monitoring information needs identified in the GCD AMP strategic plan and determined that most of the previously identified information needs were not *truly "core monitoring information needs" after all. The CRAHG subsequently revised the core monitoring information need for archaeological resources to read as follows:*

> *11.1.1 Determine the condition and integrity of prehistoric and historic sites in the Colorado River ecosystem through tracking rates of erosion, visitor impacts, and other relevant variables. 2) 11.2.1 Determine the condition and integrity of TCPs [Traditional Cultural Properties] in the Colorado River ecosystem.*

In what respects could the legacy monitoring data be processed, extracted, analyzed or synthesized to address the above information needs and/or help inform the future monitoring program currently being developed to address previous concerns of the Cultural PEP and this revised core monitoring information need for archeological sites (and TCPs) in the Colorado River Ecosystem?

The legacy data are probably sufficient to show the presence of erosion but not to assign a process or cause. However, even a convincing demonstration of its existence would take some careful analysis with proxy variables, as such those suggested above. The legacy data may show change but because of the scale and presence/absence nature of the observations, they can't effectively track *rates* of erosion or visitor impacts. For this we need quantitative data.

As indicated above, more attention needs to be devoted to taking apart concepts such as "overall site condition." Nonetheless, legacy data have some ability to inform on the condition and integrity of sites (CRAHG 11.1.1)—but not TCPs that have not been monitored in the same way (CRAHG 11.1.2).

11. Summary

In summary, how would you recommend utilizing the legacy data in the development and implementation of a monitoring program to track the status and trends of archaeological site condition in the CRE, evaluate the effectiveness of treatments, and elucidate the relationship between dam operations and changes in site condition through time?

The panel believes that a number of the key points relative to designing a monitoring program have been described in the foregoing discussions.

Although it is our assessment that these legacy data are inadequate to the task of providing adequate answers to the many questions posed to us, analyses of these data may nonetheless be useful in beginning to address some of them. We have offered a number of suggestions for how indicators derived from the available data may be relevant to some of the GCMRC queries. However, the costs of performing those analyses, which have limited expected benefit, should be traded off with the costs of applying new approaches that can be closely focused on contemporary information needs.

In summary, we reiterate the need for a strong focus on clearly articulated objectives, questions, and concepts and the need for a design and execution of quantitative data collection and analytical strategies that can measure key variables as directly as possible. Any new program should rely importantly on verified geomorphological models and models of visitor impact. With measures of sensitivity to these two types of disturbance, an effective and well justified adaptive management plan that includes highly variable monitoring intervals for sites in different sensitivity classes could be developed, tested, and implemented leading to reduced costs and reduced impacts.

Other Recommendations

Since the Grand Canyon records 10,000 years of human activity and a equally long history of erosion, there are good reasons to believe that there may be additional sorts of buried sites that would not have been discovered by surface investigation and examination of arroyo banks. The panel also recommends that more effort be invested in systematically searching for previously undiscovered (especially buried) sites. This is another activity that would be greatly enhanced with the development of successful geomorphic models for the Canyon. Given predictions based on the model, appropriate locations to be examined and methods, such as coring, could be selected.

Some of the panel's suggestions for uses of the legacy data and historic photographs might be done economically as masters projects at universities with suitable archaeology graduate programs. Suggestions for such projects are provided in Appendix 4.

Concluding Summary

Legacy Monitoring Data. Like any other data, the legacy site-monitoring data do not have inherent value; their utility is relative to their ability to inform on specific questions. The existing monitoring data augmented by records of preservation treatments, and perhaps in some cases by photographs or other types of records, are suited to qualitative, site-by site assessments of physical conditions that guide decisions on needed treatments.

However, variables in the legacy dataset were not represented in a way that allows them to answer many key questions posed to the panel. In particular, the design of the monitoring forms precludes extracting the robust quantitative data essential to answer these questions. While analyses of existing data may be useful in *starting* to address some questions, the costs of performing those analyses (of limited expected benefit) should be traded off with the costs of applying new approaches that can be closely focused on contemporary information needs.

There was little evident effort to systematically analyze the several types of data collected at great effort and enormous expense through the 1990s and more recently. Had these data been more intensively analyzed, many of the weaknesses of the present system would long ago have been revealed. With this in mind, we provide recommendations for the revision of the monitoring program.

Recommendations for a New Monitoring Program. The first and perhaps most important, step in reformulating the monitoring program is to explicitly identify and prioritize the program objectives, trading off their management importance with the cost of obtaining and analyzing the necessary data. Concepts employed in articulating the program objectives must be explicitly defined. This is especially critical for concepts that are inherently multidimensional and subject to alternative interpretations (notably, site condition and site integrity).

Objectives of the monitoring program will certainly include both identification of pressing needs to treat individual sites due to adverse impacts *and* development of rigorous understandings of the human and geological processes that are involved in site disturbance. Questions associated with assessing causes (e.g., distinguishing dam effects from those that could have been caused by natural variation in river flow) will require the collection and analysis of different kinds of data in the context of explicit models of visitor impact and geomorphic processes. Expert geomorphologists will be needed to provide well specified geomorphic models with clearly defined test implications.

With a clear specification of the goals, it will be possible to select observational variables that provide indicators directly tied to the objectives through explicit analytical strategies. Particular attention must be given to the observational scale. In many cases, a greater focus on features, rather than sites, may be advantageous.

The recording forms and the manner in which the selected variables are recorded must directly reflect analytical needs entailed by the goals and will need to be designed in collaboration with personnel quite experienced in quantitative analysis. Forms need to be carefully field tested with sample results analyzed quantitatively before they are implemented. LiDAR appears to provide a low impact, cost-effective method to collect a good deal of decisive data.

Once a new recording program is implemented, consistency is of the essence and a comprehensive quality assurance plan must be implemented. With cyclic data collection and analysis it will be possible to recognize and correct inefficiencies or problems in the data collection program and to adapt the program to new management needs. Changes to the recording protocols, and the reasons for them, need to be explicitly recorded in metadata.

The objectives will also dictate monitoring intervals needed for sites in different sensitivity classes, the purposes for which sampling is appropriate and inappropriate, and what sorts of sampling strategies would be most effectively employed. Research employing carefully selected controls can produce particularly persuasive results. And, depending on the questions, controls may not need to be in locations with sites.

An effective and well justified adaptive management plan can be developed and implemented, leading not only to lower costs but also to reduced impacts. To achieve this objective, the agencies *must* have as strong a commitment to systematically analyzing the data as they do to collecting them. Management must, on a regular basis, commit substantial financial and personnel resources to these analyses, including the necessary time of qualified analysts (in- or outside the agencies).

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List of Appendices

Appendix 1

GUIDANCE FOR MONITORING PANEL REVIEW

The purpose of this review is to evaluate the legacy monitoring data from a variety of perspectives, including: 1) the relevance and responsiveness on the legacy data to the identified needs of the Glen Canyon Dam Adaptive Management Program and the Grand Canyon Protection Act (specifically the issues identified in the Cultural PEP [Protocols Evaluation Program] review, previously sent to you); and 2) applicability of the legacy data to the development of a new monitoring direction that GCMRC is in the process of designing. The second objective is ultimately most important due to the extensive investment that has already been made in gathering these data over the past 10+ years and the interest of GCMRC and the Glen Canyon Dam Adaptive Management in utilizing these previously collected data to the maximum extent possible in developing the new program direction consistent with the recommendations of the 2000 Cultural Protocol Evaluation Panel review.

With the regards to the second objective, reviewers are asked to considered the data from at least two different angles: 1) utility of the existing data in terms of the fields that may be important to continue in order to identify trends in resource condition through time; 2) appropriate analyses that could be undertaken with the legacy data to inform development of the new monitoring program and protocols.

To assist reviewers in addressing these issues, a series of questions are provided below, grouped under two general categories: 1) Adaptive Management al Objectives and Compliance and 2) Experimental/Monitoring Design and Data Integrity Issues.

I. Adaptive Management Objectives and Compliance

1. Adaptive Management Objectives

Adaptive management is defined as a systematic process for continually improving management policies, techniques and practices by learning from outcomes of operational programs or interventions (Sitt and Taylor 1998: 2, 50.) Ideally, adaptive management begins with the definition of management problems being faced, then it proceeds to the creation of a management plan that is implemented, monitored, and evaluated. Was the original monitoring program clearly defined in relation to problems or objectives and were the data subsequently collected and analyzed in a manner that would allow managers to determine whether management actions were leading to desired outcomes? If yes, please describe how. If not, how could future monitoring programs be designed to more effectively address adaptive management needs and the concerns raised in previous reviews of the program?

2. Applicability of the data to address the question of dam effects

The GCD AMP is concerned with assessing effects of dam operations on resources in the Colorado River ecosystem. Specifically, the AMP is concerned with whether the dam is being operated "in such a manner as to protect mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were created, including but not limited to natural and cultural resources and visitor use." Are the legacy monitoring data suitable for detecting dam effects on archaeological sites? If yes, in what respects? If no, why not?

3. Applicability of data to other relevant legal mandates

In addition to requiring that effects of dam operations on cultural resources be evaluated, the Grand Canyon Protection Act directs the Secretary of Interior to operate the dam in a manner that is consistent with the National Park Service Organic Act and other relevant laws that apply to National Parks. Can the legacy data be used to assess whether the broader intent of GCPA is being attained? If yes, in what respects? If no, why not?

Are the legacy monitoring data suitable for addressing other legally mandated compliance concerns, such those of the National Historic Preservation Act? In what respects are the data suitable for addressing other compliance requirements under NHPA (for example, are they well suited for identifying and prioritizing sites that may require data recovery or erosion control measures in the near or distant future? To what degree are they suitable for assessing whether erosion control treatments are having their intended effects or not?)

Experimental Design, Monitoring Design and Data Integrity Issues

4. Issues related to variables selected

Are the parameters and types of variables (e.g., qualitative, quantitative, presence-absence, ordinal, interval etc.) suitable for addressing the questions being asked and the overall needs of the adaptive management program? Which of the legacy data appear to be most useful for monitoring status and trends in resource condition through time?

5. Issues related to changes made to the monitoring database structure through time

Initially (1992-1993), the monitoring program employed a semi-quantitative approach that involved ranking different kinds/levels of impacts at each site, then summing the rankings to arrive at a "condition index rating" for that site. After 1994, this approach was abandoned in favor of a more streamlined one that noted the presence or absence of different types of erosion features and visitor impacts relative to various physical characteristics of the sites. The final condition assessment was arrived at independently from the presence/absence impact observations (in other words, final condition evaluations were not dependent on the monitoring data directly.) In 1997, the monitoring form was modified again to distinguish between active impacts and previously documented impacts that were no longer occurring but whose effects were still visible. Also, aeolian erosion/deposition was added as a variable, and several other modifications were implemented. Given these changes, can the legacy data be processed or filtered in some manner so as to allow data collected prior to 1997 to be compared with those collected later?

6. Issues related to frequency of observations

Between 1992 and 2005, archaeological sites were monitored at different frequencies depending on the archaeologists' perceptions of levels, types and numbers of threats and impacts. Sites with few or low levels of impacts might be monitored once every five years, others with moderate impacts once every 2-3 years, while sites that received a lot of impacts might be monitored every year or sometimes, twice per year. Also, if impacts appeared to be increasing, frequency of monitoring would be increased, while if impacts appeared to be stable or decreasing after several visits, the monitoring frequency might be reduced. Thus, sites exhibiting higher levels of impacts generally have many more monitoring records than sites with lower levels of impacts. Can the monitoring data be "processed" in some fashion so that the data are not skewed towards higher numbers/levels of impacts, and if so, what would be the best approach for doing this?

When the monitoring program began in 1992, approximately 269 sites were included in the monitoring program. Over the years, approximately 100 sites were dropped from the program for a variety of reasons. Many sites were dropped because they showed little if any change from one monitoring visit to the next; others were dropped because NPS managers decided that they were too sensitive to be monitored or because the managers decided that the sites probably were not within the area of potential dam effects after all. By 2005, the pool of monitored sites had shrunk to approximately 161, representing mostly sites that showed active erosion or ongoing impacts from visitor use. What are the implications of this history on the utility of the legacy monitoring data for detecting trends through time, assessing the overall condition of sites in the CRE system, tracking improvement or deterioration in site condition over time, etc.?

7. <u>Data Redundancy</u>

A preliminary analysis of the legacy data performed showed clustering between certain types of impacts, and this led to the conclusion that some of the data fields are redundant. For example, sites with arroyos showed a tendency to also exhibit bank slumpage. Likewise, the variables "surface erosion" and "aeolian/alluvial erosion/deposition" showed considerable overlap, so the author recommended that these fields be combined. On the other hand, other variables such arroyos and gullies did not exhibit as much redundancy as might have been expected. What other analyses could or should be performed to detect and evaluate redundancy in the data? What are the implications of combining and/or reducing the numbers of variables in terms of being able to detect trends in the data through time?

8. <u>Trend Detection</u>

Are the data suitable for detecting trends in resource condition through time? If yes, in what respects can trends be detected? How can the data be used to detect trends in *overall site condition* through time?

9. <u>Controls</u>

Were the monitoring data gathered in a manner that allows them to be evaluated relative to controlled variables? Are the data suitable for assessing the effectiveness of treatments in the future? What would be the best way to control for variability in the data due to natural environmental variation or other factors that may influence condition changes other than dam effects?

10. <u>Applicability of the legacy data for developing new monitoring protocols to address previous concerns and the current "core monitoring information need" for archaeological sites?</u>

The cultural Protocol Evaluation Panel conducted in March 2000 made numerous recommendations about how to revise the monitoring program to focus more specifically on evaluating effects of dam operations on cultural resources and evaluate the efficacy of erosion control treatments.

In October 2005, the cultural resources ad hoc group (CRAHG) of the GCD AMP Technical Work Group (TWG) reviewed the core monitoring information needs identified in the GCD AMP strategic plan and determined that most of the previously identified information needs were not truly "core monitoring information needs" after all. The CRAHG subsequently revised the core monitoring information need for archaeological resources to read as follows:

> 11.1.1 Determine the condition and integrity of prehistoric and historic sites in the Colorado River ecosystem through tracking rates of erosion, visitor impacts, and other relevant variables. 2) 11.2.1 Determine the condition and integrity of TCPs in the Colorado River ecosystem.

In what respects could the legacy monitoring data be processed, extracted, analyzed or synthesized to address the above information needs and/or help inform the future monitoring program currently being developed to address previous concerns of the Cultural PEP and this revised core monitoring information need for archeological sites (and TCPs) in the Colorado River Ecosystem?

11. Summary

In summary, how would you recommend utilizing the legacy data in the development and implementation of a monitoring program to track the status and trends of archaeological site condition in the CRE, evaluate the effectiveness of treatments, and elucidate the relationship between dam operations and changes in site condition through time?

Appendix 2

NPS LEGACY DATA QUESTIONS

cont. from INs and MOs sent 4-19-06. Keep in mind that we can use the monitoring data, IMACS [Intermountain Antiquities Computer System] site form data and the ASMIS [Archeological Sites Management Information System] condition data potentially.

Here are just a few:

1. Are there trends through time in the monitoring data?
2. By combining arroyo cutting and gullying, do specific features have more of these impacts than other features?
3. Are there trends in impact evident after 1997 when form/field methods were revised?
4. Are 1992 and 1993 data even worth maintaining?
5. Does bank slump only occur where gullies or arroyos exist?
6. Do the comment fields accurately reflect impacts noted in the matrices?
7. Does the most recent monitoring schedule reflect the presence of active physical impacts? (are annual sites more active than 5 year schedule sites?)
8. Do physical impacts increase in intensity/presence through time or is there a shift evident between surface erosion to gullying to arroyo cutting?
9. What type of geomorphic setting (including vegetation) is common for river-based drainages? Terrace-based drainages?
10. Are terrace-based drainages more effectively preserved than river-based drainages?
11. What types of features receive the most physical impact?
12. Is there a correlation between overall gradient of the site and the types of physical impacts observed?
13. Are physical impacts more visible at sites closer to the dam or farther away?
14. What are the agents that are most commonly found when a site is considered stable? Active?
15. Can an impacts threshold be created using the data collected?
16. Take a sample of all the repeat photos (as identified in the database) and measure change through time (Manone 2003 report).

Appendix 3

COMPUTATIONAL APPENDIX: ELEVATION INTERPOLATION

N. Scott Urquhart

The elevation data consisted of two files, one representing elevations determined by LiDAR in May of 2006, and a second representing elevations similarly determined in September, 2007. Each file consisted of two parts, vertex elevations and facet specifications. The vertex part of the files (344,877 points for 2006, and 342,014 points for 2007) listed east/west (x) and north/south (y) coordinates, and an elevation (z), each expressed in meters. The remainder of the files listed sets of three point identifiers from the earlier part of the file (686,524 sets for 2006, and 680,833 sets for 2007) which defined facets. A facet is a triangle defined by three (x, y, z) sets of coordinates. The facets have been determined so that there are no other points interior to the triangle defined by the three sets of (x, y) coordinates listed in each set. The coordinates and elevations were recorded using the NAD83 Ellipsoid heights for the vertical, and NAD83 AZ State Plane in meters for the horizontal.

Differences in elevation between these two dates are not readily available for specific points directly from this data, because the exact coordinate locations differ between the two dates. Differences were determined this way: For each point in the May, 2006, data, a line was run up or down to intersect the appropriate facet in the September, 2007, data. The elevation at which this line intersected the facet was taken as the elevation for 2007 to match the 2006 elevation. The difference in these two elevations was recorded as the data shown in Figure 1 in the body of the report.

This sounds simple, but was substantially more complex than it sounds, especially given the size of the files, so the computational details are recorded here. The horizontal coordinates were all of the numerical form of (222,xxx.xxxxxx , 569,xxx.xxxxxx) , so the common digits (222,000, 569,000) were subtracted off to speed computation and increase the accuracy of the interpolation. The initial problem was to identify which facet in the 2007 data was above or below each 2006 elevation. The first step was to find the nearest (x,y) in the 2007 data for each point in the 2006 data. This was done in two steps for computational speed: All of the points in 2007 data whose coordinates differed by no more than 0.25 m from the coordinates of the 2006 point were identified, reducing the 342,014 points to somewhere around 100 points. Figure A1 shows one such set of points, associated with the 200th point listed in the 2006 data set, having (x,y) = (425.154755, 594.817464). This location is marked in the appendix figures with an "X". Actual horizontal distances were then computed from the 2006 point of interest to each of this reduced set of 2007 (x,y) points. Figure 2A displays a subset of the points in Figure 1A. The leftmost point in Figure 2A,

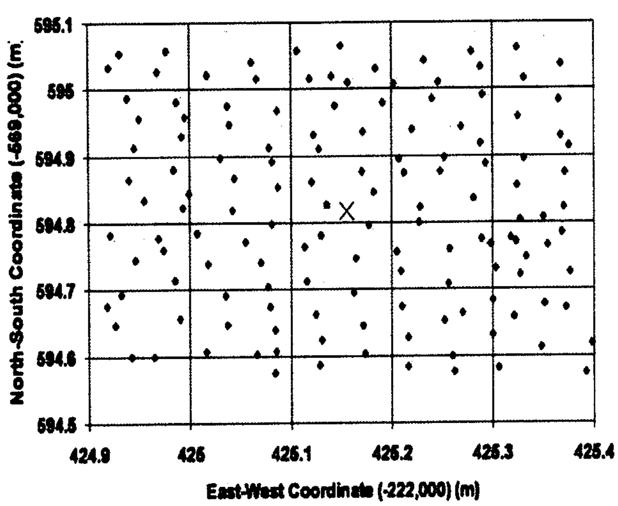

Figure 1A: Locations of points in the 2007 data set near point 200 (marked "X") in the 2006 data set.

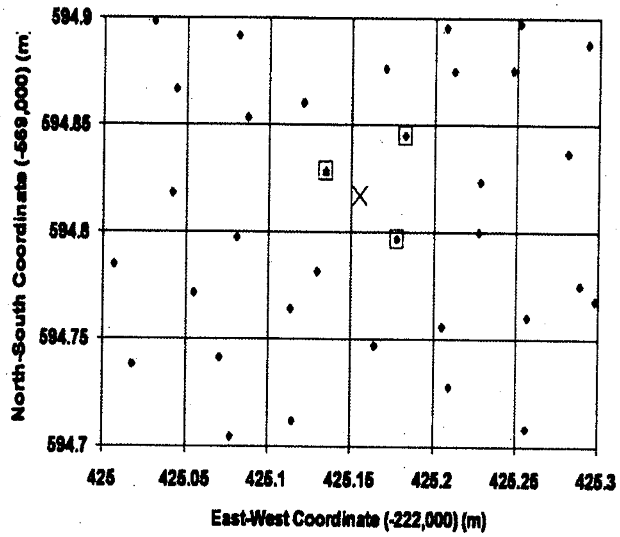

Figure 2A: Center part of Figure 1A with the point nearest the "X" marked with the leftmost square, and with the other corners of the bounding triangle marked with squares.

A line was determined through the point of interest and the nearest point; it ordinarily intersects two edges of the facets surrounding the nearest point, the outside red and black edges in Figure 3A; the point of interest is between the nearest point and one of the edge intersections, but not the other. This identifies the facet over the 2006 point. A plane was fit through the three points determining the corners of the facet, and its value was evaluated at the (x,y) coordinates of the point of interest. This was taken as the 2007 elevation of the point of interest.

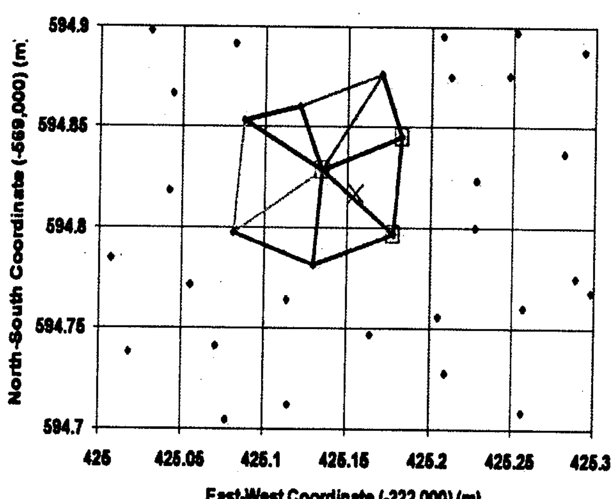

Figure 3A: Figure 2A showing the triangles with vertex at the point nearest to 2006's #200. Colors approximately match those in the adjacent table.

surrounded by a box, is the point closest in the 2007 data (#46,970) to the 2006 point marked with the "X". The closest point has coordinates of (425.13459, 594.828776). The table below lists all of the facets containing point number 46,970.The three boxed points display the horizontal coordinates of the triangle in which "X" lies. All facets containing the "nearest" point were identified, as shown in the table below, and in Figure 3A. The color of the points in the table are approximately the same as those of the outside lines in Figure 3A.

Facet ID	2007 FACET POINTS		
92842	**46322**	**46638**	**46970**
93482	**46638**	**46636**	**46970**
93483	**46322**	**46970**	**46971**
94120	**46970**	**46636**	**47609**
94121	**46971**	**46970**	**47280**
95399	**47921**	**46970**	**47609**

The differences between the 2006 and 2007 elevations were taken as the data summarized in the report. According to Brian Collins of the USGS, who developed the data used here, the precision of the measurements is about ~1.5 cm x 2 = 3.0 cm (±). Nearly 50% of the differences were in this range. As differences have been used, this error bound probably should be increased by the square root of 2, giving a bound of about 4 cm, or 0.04 m; slightly more than 60% of the differences were in this range.

Appendix 4

Possible Masters Thesis or Student Research Projects

Existing data, or existing data augmented by modest numbers of additional field observations might be effectively used in substantial graduate student projects or theses. Several possible topics are suggested in this appendix. At the outset, care should be taken to thoroughly think through the analytical steps needed to address a clearly articulated objective. The data requirements implied by the analytical strategy must be squared with the availability of relevant data or the reasonable opportunity to acquire them. Many of these projects would benefit from moving the focus away from archaeological sites as the central observational units. Working at the cultural feature level may prove productive because some of these sites appear to be spatially extensive with numerous features while others are small with only one or a few cultural features/artifact concentrations.

Some of these projects would require substantial work organizing and recoding the monitoring forms and/or other sources of data. Much could be accomplished through analyses that relate the monitoring records to other sources of information including site inventory forms, photographs, and preservation treatment maps and notes. The latter promise to provide fairly detailed data on intra-site occurrence of features/artifact scatters, as well as on the occurrence of erosional and other types of impacts on specific features and site areas. Some of these suggested projects might be combined or others might need to be pared down to comprise a thesis-scale study.

1. <u>Evaluating Erosion and Visitor Impacts using Impact Indices.</u> Simple exploratory data analysis methods could be used with the suggested indices computed from the monitoring forms (see Using Available Legacy Data) to search for patterns with respect to factors such as topographic position or distance from visitor stops.

2. <u>Evaluating Erosion and Visitor Impacts using Preservation Treatment Records</u>. Preservation treatment maps and notes, inventory forms, and other sources of information could be similarly used to relate impacts of erosion and visitor use to selected variables.

3. <u>Evaluating Erosion and Visitor Impacts using Archival Photographs</u>. Series of archival photographs that document the same erosional features on sites through time could be used attempt to identify trends over time and patterns across space and relate these observations to processes that have been argued to be implicated in the erosion.

4. <u>Assessing Effectiveness of On-site Preservation Treatments using Existing Data.</u> Where preservation treatments have been in place for a period of years, photographs, monitoring data, and preservation treatment records might allow some through-time assessment of the effectiveness of the treatments in different sorts of situations (e.g., different topographic settings or placements with respect to visitor stops).

5. <u>Assessing Effectiveness of On-site Preservation Treatments Incorporating New Data</u>. Revisit a sample of sites with preservation treatments (e.g., check dams) and assess their effectiveness, over time, with respect to the cultural features that were to be protected. How well the older ones are holding up? Does their effectiveness diminish over time. This

would require careful development and preliminary testing of protocols used to describe and evaluate the effectiveness of younger versus older protective treatments.

6. Effectiveness of Check Dams in Slowing Erosion. Select a sample of sites where check dams were installed and a comparable sample of sites without check dams and use the legacy data to assess the effectiveness of this technique.

7. Settlement Pattern Study. Inventory form data, preservation treatment maps, and existing GIS systems could be used to do a settlement pattern study integrating both feature types and site types. It could examine variations in the distribution and density of site types, site sizes, feature types, etc. along the river corridor, as well as at the association of these cultural manifestations with environmental and possibly visitor-use variables. A more demanding approach would be to set this up as an exercise in predictive model construction, with part of the data set used to construct the model, and the remainder used to test it. Such a study would be informative about the archaeological history of the river corridor, and should also have applications for resource management and preservation.

8. Predictive Models of Erosional Processes. Current arguments about the geological processes contributing to erosion and aggradation could be used with available geological and hydrological data to develop predictive models (based on alternative process arguments) of settings most and least vulnerable to recent and ongoing erosion. Existing archaeological inventory, monitoring, and preservation treatment data could then be used to see if sites in these locations show the expected degrees of erosion or stability.

9. Aerial Photograph Analysis of Erosion Models. Similarly, temporal sequences of aerial photographs from the earliest available photos could be used to assess expectations derived from different models of erosional process in both on- and off-site locations.

10. Pilot study of LiDAR Data. Existing LiDAR data from selected sites could be used to further evaluate this method of assessing erosional impacts on particular types of cultural features. This thesis could to develop guidelines and protocols for future use of this method. It would require a student with significant quantitative expertise.

11. LiDAR Assessments of the Effectiveness of Preservation Treatments. If the needed LiDAR observations are available, quantitatively assess the effectiveness of check dams or other preservation treatments in mitigating erosional effects.

12. Assessing Site Stability. Revisit sites previously judged to be stable (and not in need of monitoring) in order to assess the accuracy of the original judgments and comparisons with sites that have been eroding (as judged from preservation treatment records and site monitoring forms). An attempt could then be made to identify geomorphological or other variables associated with varying degrees of stability/erosion. A predictive model of sorts might be developed from this analysis—i.e., of kinds of sites and features, and kinds of site/feature settings more and less vulnerable to erosion. Such a study could have important implications for the design of future monitoring intervals and revisitation strategies.

Appendix 5 – Biographical Sketches

Keith W. Kintigh

Education & Professional Registration

PhD	Anthropology	University of Michigan	1982
MS	Computer Science	Stanford University	1974
AB	Sociology (with honors)	Stanford University	1974
RPA	Registered Professional Archaeologist		1998

Academic Appointments

1995- Professor, Department of Anthropology, Arizona State University

1987-95 Associate Professor, Department of Anthropology, Arizona State University

1986-87 Associate Professor, Department of Anthropology, University of California, Santa Barbara.

1985-86 Assistant Professor, Department of Anthropology, University of California, Santa Barbara.

1980-85 Associate Archaeologist, Arizona State Museum, University of Arizona.

Selected Publications

Briggs, John M., Katherine A. Spielmann, Hoski Schaafsma, Keith W. Kintigh, Melissa Kruse Kari Morehouse l and Karen Schollmeyer

2006 Why Ecology needs archaeologists and archaeology needs ecologists. *Frontiers in Ecology* 4(4): 180-188.

Kintigh, Keith W. (Ed.)

2006 The Promise and Challenge of Archaeological Data Integration. *American Antiquity* 71(3): 567-578.

Hunt, Robert C., David Guillet, David R. Abbott, James Bayman, Paul Fish, Suzanne Fish, Keith Kintigh, and James A. Neely

2005 Plausible Ethnographic analogies for the Social Organization of Hohokam Canal Irrigation, *American Antiquity* 70(3):433-456.

Kintigh, Keith W., Donna M. Glowacki, and Deborah L. Huntley

2004 Long-term Settlement History and the Emergence of Towns in the Zuni Area. *American Antiquity* 69(3): 432-456.

Lovis, William A., Keith W. Kintigh, Vincas P. Steponaitis, and Lynne G. Goldstein

2004 Archaeological Perspectives on the Native American Graves Protection and Repatriation Act: Underlying Principles. *Legal Perspectives on Cultural Resources*, edited by Jennifer R. Richman and Marion P. Forsyth, pp. 165-184. Altamira Press, Walnut Creek.

Kintigh, Keith W.

2003 Coming to Terms with the Chaco World. *Kiva* 69(2): 93-116.

2001 L'organisation de l'archéologie aux États-Unis. *Les Nouvelles de L'Archéologie* 85 (3e trimestre) 5-8.

Babbitt, Bruce, Frank McManamon, and Keith Kintigh
2000 The Future of Public Archaeology: A Conversation with Interior Secretary Bruce Babbitt, his Chief Archeologist Frank McManamon, and Society for American Archaeology President Keith Kintigh. *Common Ground* Winter 1999: 17-23.

Goldstein, Lynne, and Keith Kintigh
2000 Ethics and the Reburial Controversy. In *Repatriation Reader: Who Owns American Indian Remains*, edited by Devon A. Mihesuah, pp. 180-189. University of Nebraska Press, Lincoln. (republication of a 1990 *American Antiquity* article.)

Deboer, Warren R, Keith W. Kintigh, and Arthur Rostoker
1996 Ceramic Seriation and Site Reoccupation in Lowland South America. *Latin American Antiquity* 7(3):263-278.

Howell, Todd L. and Keith W. Kintigh
1996 Archaeological Identification of Kin Groups Using Mortuary and Biological Data: An Example from the American Southwest. *American Antiquity* 61(3): 537-554.

Kintigh, Keith W.
1994 Chaco, Communal Architecture, and Cibolan Aggregation. In *The Ancient Southwestern Community: Methods and Models for the Study of Prehistoric Social Organizations*, edited by Wirt H. Wills and Robert Leonard, pp. 131-140. University of New Mexico Press, Albuquerque.

Kintigh, Keith W.
1990 Intrasite Spatial Analysis: A Commentary on Major Methods. In Mathematics and Information Science in Archaeology: A Flexible Framework, edited by Albertus Voorrips. *Studies in Modern Archaeology* 3: 165-200. HOLOS-Verlag, Bonn.

1990 Protohistoric transitions in the Western Pueblo area. In *Perspectives on Southwestern Prehistory* edited by Paul E. Minnis and Charles L. Redman, pp. 258-275. Westview Press, Boulder.

Goldstein, Lynne, and Keith Kintigh
1990 Ethics and the Reburial Controversy. *American Antiquity* 55(3): 585-591.

Kintigh, Keith W.
1988 Monte Carlo evaluation of the effectiveness of subsurface testing for the identification of archaeological sites. *American Antiquity*. 53(4): 686-707.

1985 Settlement, Subsistence, and Society in Late Zuni Prehistory. *Anthropological Papers of the University of Arizona* 44. University of Arizona Press, Tucson. (x & 132pp.

1984 Measuring archaeological diversity by comparison with simulated assemblages. *American Antiquity* 49(1): 44-54.

Parsons, Jeffrey R., Keith W. Kintigh, and Susan Gregg
1983 Archaeological settlement pattern data from the Chalco, Xochimilco, Ixtapalapa, Texcoco and Zumpango Regions, Mexico. *Technical Reports of the Museum of Anthropology, University of Michigan* 14 (vii and 222 pages, 9 maps).

Kintigh, Keith W., and Albert J. Ammerman
1982 Heuristic approaches to spatial analysis in archaeology. *American Antiquity* 47(1): 31-63.

Selected Extramural Grants and Awards

Kintigh, Keith W., K. Selçuk Candan, Hasan Davulcu, Margaret Nelson, Katherine Spielmann
2006 Archaeological Data Integration for the Study of Long-term Human and Social Dynamics . National Science Foundation (IIS-0624341), $749,984, 11/01/06 – 10/31/09.

Nelson, Margaret C., Marty Anderies, Michelle Hegmon, Keith W. Kintigh, Ben A. Nelson.
2005 Long-Term Coupled Socioecological Change in the American Southwest and Northern Mexico. National Science Foundation (BE/CNH-0508001), $540,955 9/15/2005-8/31/2008

Kintigh, Keith W.
2005 Outstanding Doctoral Mentor for 2004, Division of Graduate Studies, Arizona State University.

Kintigh, Keith W., John M. Anderies, K. Selçuk Candan, Peter H. McCartney, Margaret C. Nelson
2004 Enabling the Study of Long-Term Human and Social Dynamics: A Cyberinfrastructure for Archaeology. National Science Foundation. (SES-0433959) $100,000, 9/15/2004-8/31/2006.

Kintigh, Keith W., and Elizabeth Brandt
2004 Kewevkapaya Cultural Site Survey. Fort McDowell Yavapai Nation/National Prk Service. $28,200, 12/12/04-9/30/06.

Extramural Service

National Endowment for the Humanities, Archaeology Panel, 2007

Wenner Gren Foundation, Review Panel, 2006-2008

National Science Foundation, Systematic Collections Review Panel, 1989-1991

Society for American Archaeology
President 1999-2001 President-elect, 1998-99(national elected office)
Secretary, 1995-97; Secretary-Elect, 1994-95 (national elected office)
Executive Committee, 1985-1987 (national elected office)
Committee on Repatriation/Task Force on Reburial and Repatriation, chair/member (1989-)

Union Internationale des Sciences Préhistoriques et Protohistoriques, Commission 4: Data Management and Mathematical Methods in Archaeology (elected member) Vice President 1991-2001, Secretary, 1987-1991

Native Peoples Magazine, Editorial Associate, 1988-

CHAIRMAN

Jeffrey H. Altschul

Education
- Ph.D., Anthropology, Brandeis University, 1982
- B.A., Anthropology, Reed College, 1975

Qualifications
- Has worked on over 1,000 projects in the U.S. Northeast, Southeast, Midwest, and Southwest; the Southern Plains; California; the Great Basin; and central and northern Mexico since 1969

Areas of Interest and Expertise
- Spatial analysis and quantitative methods; predictive modeling; and cultural landscapes

Professional Experience
- 2005–present, President, SRI Foundation
- 2005–present, Chairman, Statistical Research, Inc.
- 1983–2004, President, Statistical Research, Inc.
- 1977–1983, Project Director and Principal Investigator, New World Research, Inc.
- 1975–1977, Crew and Crew Chief, Brandeis and Tulane Universities CRM program

Selected Projects as Senior Principal Investigator
- On-call CRM services, Barry M. Goldwater range, Luke Air Force Base, Arizona, 1999-present.
- On-call CRM services, Bureau of Land Management, New Mexico, 2005–2009
- Adaptive Management and Planning Models for Cultural Resources in Oil and Gas Fields, New Mexico, Department of Energy, 2002–2005
- On-call military and civil projects, U.S. Army Corps of Engineers, Los Angeles District, 1987–present

Professional Affiliations
- Register of Professional Archaeologists (10225) (formerly Society of Professional Archaeologists) (President 2006–2007, President-elect 2004–2005, Board of Directors 1993–1995, 2001–2003)
- American Anthropological Association, Archaeology Division (Board of Directors, 2001–2003)
- American Cultural Resources Association (Board of Directors, 2000–2002)
- Arizona Archaeological and Historical Society (Board of Directors, 1990–1995)
- Society for American Archaeology (Treasurer, 1998–1999; Treasurer-elect 1997; Nominating Committee, 2000 (Chair), 2005; Consulting Archaeology Committee 1999–2003)
- Governor's Archaeology Advisory Commission (2002-2007)

Selected Publications and Reports
- 2008 *Fragile Patterns: The Archaeology of the Western Papaguería* (edited with A. Rankin). SRI Press, Tucson.
- 2007 The Mescal Wash Site: A Persistent Place in Southeastern Arizona (with Rein Vanderpot). In *Hinterlands and Regional Dynamics in the Ancient Southwest*, edited by A.P. Sullivan III and J.M. Bayman. University of Arizona Press.
- 2005 Significance in American CRM—Lost in the Past. In *Heritage of Value, Archaeology of Renown: Reshaping Archaeological Assessment and Significance*, edited by C. Mathers, T. Darvill, and B. Little. University Press of Florida, Gainesville.
- 2004 The Impact of Big Projects on Southwest Archaeology. In *From Campus to Corporation: The History of CRM in the Southwest*, edited by H. Roberts, R.V.N. Ahlstrom, and B. Roth. Society for American Archaeology, Washington, D.C.
- 2000 Social Complexity and Residential Stability during the Basketmaker III Period (with E. Huber). In *New Research on Basketmaker III*, edited by P. Reed. University of Utah Press.

Grants and Honors
- ESTCP Grant for Integrating Modeling in DoD cultural resources program, Department of Defense, 2007-2011
- Legacy Resource Management Program Grants for Predictive Modeling, Department of Defense, 2002-2007
- Professional Poster of the Year, Society for American Archaeology, 2001
- Award in Public Archaeology, Arizona Archaeology Advisory Commission, 1998
- Matching Grants-in-aid, Teacher Workshops for Project Archaeology (Historic Preservation Division, State of New Mexico), 1994–1997
- Historic Preservation Survey and Planning Grant-in-aid, National Park Service and Arizona State Historic Preservation Office, 1989–1994

William D. Lipe

Education

Ph.D., Anthropology, Yale University (1966)
BA, U. of Oklahoma (1957)

Honors and Awards

2006	McGimsey-Davis Distinguished Service Award, Register of Prof. Archaeologists
2006	Conservation and Heritage Management Award, Archaeological Institute of America
2002	Byron S. Cummings Award, Arizona Archaeological and Historical Society
2000	Distinguished Service Award, Society for American Archaeology
1998	John F. Seiberling Award, Society of Professional Archeologists
1997	Distinguished Faculty Achievement Award, Washington State University

Professional Experience

1976-present	Associate Professor to Professor Emeritus, Washington State University
1985-1993	Research Director, Crow Canyon Archaeological Center (part-time)
1972-1976	Research Archaeologist and Asst. Director, Museum of Northern
1964-1972	Assistant to Associate Professor, SUNY, Binghamton
1963-1964	Instructor, University of Oklahoma
1958-1960	Research Archaeologist, University of Utah

Offices and Other Professional Activities

2003-present	Advisory Committee, Canyon of the Ancients Nat'l Monument (BLM)
1995-present	Board of Directors, Crow Canyon Archaeological Center
1997-2000	SAA Representative, Board of Directors, Register of Prof. Archaeologists
1994-97	President-elect (1994-1995) and President (1995-1997), Soc. for Amer. Archaeol.
1986-90	Member-at-large, Section H Committee (Anthropology), AAAS
1984-86	Washington State Heritage Council
1979-81	Executive Board, Society of Professional Archaeologists (SOPA)
1977-79	Executive Board, Soc. for American Archaeology
1977-78	Chair, SAA Nominating Committee
1973-76	Chair, Southwestern Anthropological Research Group (SARG)

Selected Publications

2006 (in press) The Mesa Verde Region During Chaco Times. In The Mesa Verde World, edited by David Grant Noble. School of American Research Press, Santa Fe, NM.

2006 Notes from the North. In The Archaeology of Chaco Canyon, edited by Stephen H. Lekson. School of American Research Press, Santa Fe, NM.

2004 The Mesa Verde Region: Chaco's Northern Neighbor. In In Search of Chaco, edited by David Grant Noble, pp.107-115. School of American Research Press, Santa Fe, NM.

2002 Social Power in the Central Mesa Verde Region, A.D. 1150-1290. In Seeking the Center Place: Archaeology and Ancient Communities in the Mesa Verde Region, edited by Mark Varien and Richard Wilshusen, pp. 203-232. University of Utah Press, Salt Lake City.

2002 Public Benefits of Archaeological Research. In Public Benefits of Archaeology, edited by Barbara Little, pp. 20-28. University Press of Florida, Gainesville

2000 (first author, with Scott G. Ortman) Spatial Patterning in Northern San Juan Villages, A.D. 1050-1300. Kiva 66(1):91-122

2000 In Defense of Digging: Archaeological Preservation as a Means, Not an End. In Ethics in American Archaeology, second rev. edition, edited by Mark Lynott and Alison Wylie, pp. 113-117. Society for American Archaeology, Washington, D.C. (Reprint of Lipe 1996)

2000 Conserving the in situ Archaeological Record. Conservation: The Getty Conservation Institute Newsletter 15(1):17-20.

1999 (first editor, with M. Varien and R. Wilshusen) Colorado Prehistory: A Context for the Southern Colorado River Basin. (562 pages) Colo. Council of Prof. Archaeologists, Denver

1995 The Depopulation of the Northern San Juan: Conditions in the Turbulent 1200s. Journal of Anthropological Archaeology 14:143-169

1992 (editor) The Sand Canyon Archaeological Project: A Progress Report (159 pages). Occasional Paper No. 2, Crow Canyon Archaeological Center, Cortez, CO

1990 Wilderness Values and Archaeological Resource Management. In Managing America's Enduring Wilderness Resource, edited by D. Lime, pp. 305-310. U. of Minnesota, St. Paul

1989 (first editor, with Michelle Hegmon) The Architecture of Social Integration in Prehistoric Pueblos (175 pages). Occas. Paper No. 1, Crow Canyon Archaeological Center, Cortez, CO

1988 (Second author, with R. G. Matson and W. R. Haase) Adaptational Continuities and Occupational Discontinuities: The Cedar Mesa Anasazi. Journal of Field Archaeology 15(3):245-264

1988 (First editor, with J. N. Morris and T. A. Kohler) Anasazi Communities at Dolores:Grass Mesa Village (Site 5MT23) (2 volumes, 1316 pages). US Bureau of Reclamation, Denver

1986 Modeling Dolores Area Cultural Dynamics. In Dolores Archaeological Program: Final Synthetic Report, compiled by D. A. Breternitz et al., pp. 439-467. US Bur. Reclamation.

1985 Conservation for What? American Society for Conservation Archaeology Proceedings: 1984:1-11.

1984 Value and Meaning in Cultural Resources. In Approaches to the Archaeological Heritage, edited by Henry Cleere, pp. 1-11. Cambridge University Press, Cambridge, England

1983 The Southwest. In Ancient North Americans. Edited by J. D. Jennings, pp. 421-493. Freeman, San Francisco. (Fully revised version of 1978 Chapter)

1978 Grants, Contracts, and Bureaucrats: Some Emerging Problems in Conservation Archaeology. In Papers in Honor of Irving B. Rouse, edited by R. Dunnell and E. Hall, pp. 121-147. Mouton, New York

1978 A Conservation Model for American Archaeology. In Conservation Archaeology: A Guide to Cultural Resource Management, edited by Michael Schiffer and George Gumerman, pp. 19-42. Academic Press, New York. (Reprinted version of 1974 Kiva article)

1977 (Co-author, with Mark Grady and Bruce McMillan) "Cultural Resource Management," in The Management of ArchaeologicalResources, edited by C. R. McGimsey III and and Hester Davis, pp. 25-63. Society for American Archaeology Special Publication

1974 (First editor, with A. J. Lindsay) Proceedings of the 1974 Cultural Resource Management Conference, Federal Center, Denver, CO (214 pages). Mus. of N. Arizona, Flagstaff.

1970 Anasazi Communities in the Red Rock Plateau. In Reconstructing Prehistoric Pueblo Societies, ed. by W. Longacre, pp. 84-139. U. of New Mexico Press, Albuquerque

N. Scott Urquhart

Education

Ph.D. Statistics, Colorado State University, 1965
M.S. Statistics, Colorado State University, 1962
B.S. Mathematics and Statistics, Colorado State University, 1961

Summary of Experience

Dr. Urquhart is a statistical consultant who specializes providing statistical support to a wide range of projects, especially in the environmental sciences, ecology and agriculture -- for more than 40 years. In addition to this diverse collaborative research, Dr. Urquhart has developed and taught a number of courses in applied statistics, mainly for graduate students, for students in a wide range of disciplines. During 1991 – 2000, he taught a course on environmental sampling to students of statistics and ecology at Oregon State University. Most recently (2001- 2006) he managed an EPA-funded cooperative agreement at Colorado State University entitled Space-Time Aquatic Resources Modeling and Analysis Program. (See http://www.stat.colostate.edu/starmap)

Dr. Urquhart has helped develop innovative measurement processes and indicators throughout his career. During the 10 years he collaborated closely with EPA's Environmental Monitoring and Assessment Program (EMAP), he was very involved in the development, evaluation, and redefinition of many of the indicators utilized by Surface Waters. Most of the EMAP studies he collaborated in developing and implementing were regional in scope

Dr. Urquhart has served as an external reviewer for several agencies, including USGS and EPA. For example, chaired the Protocol Evaluation Panel for the Near-River Terrestrial Research in 2000. He also served on the surface waters component of the panel which reviewed the technical document for EPA's first Report on the Environment.

The breadth of his experience with the measurement and monitoring of ecological resources is evidenced by some of his publications listed below. All are jointly authored, indicating his commitment to collaborative work.

Publications

(The following citations have been selected from 1 book, 58 journal articles, 18 proceedings publications, 14 agency publications, 14 posters, and 62 other sorts of professional writing.)

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Employment History

2007 -	Statistical consultant; retired from academia
2001 - 2006	Professor and Senior Research Scientist, Statistics, Colorado State University Director of the EPA-funded STARMAP
1991- 2001	Research Professor, Statistics, Oregon State University
1975 - 1991	Professor, Experimental Statistics, New Mexico State University
1988 -1989	Visiting Professor, Department of Mathematical Sciences and Systems Ecology Research Group, San Diego State University
1970 - 1975	Associate Professor, Experimental Statistics, New Mexico State University
1969 - 1970	Associate Professor (tenured), Biometrics Unit, Cornell University
1965 - 1969	Assistant Professor, Biometrics Unit, Cornell University

Appendix 6

RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORMS

FY92
ARCHAEOLOGICAL SITE RIVER MONITORING FORM

MANAGEMENT INFORMATION

1. Site # AZ : : 2. Monitor session #

3. Monitor(s)________________________________

4. Date / /

5. USGS Quad map 7.5'______________ 6. Use Area Name__________________

7. Date of first visit / /

8. UTM location (Zone 12)__________East__________North

9. General location description

10. Does this site have any visible structures? 0 = no, 1 = yes ___

11. River mile ____ River bank (L=left, R=right, B=both) ___

12. Is this site located in or on Colorado River fluvial deposits?
 0=no, 1=yes ___
 If yes, describe the setting specifically:

13. Distance/direction from and height above current high water (approx. 30,000 cfs) to lowest boundary of site area:
 Distance ____ mtrs Direction ____ degrees Height ____ mtrs Slope ____ degrees

14. Distance/direction from and height above current high water to a central site datum
 Distance ____ mtrs Direction ____ degrees Height ____ mtrs Slope ____ degrees

ENVIRONMENTAL SITUATION

15. PRIMARY physiographic setting: 1. Riverside beach/dunes 2. Alluvial terrace
 3. Talus slope 4, Base of cliff 5. Bedrock Ledges 6. Non-riverside dunes
 7. Other ______________________ ___

16. Degree of shelter: 1. Open 2. Overhang/cave 3. Combination ___

17. DOMINANT soil type: 1. Alluvium/Aeolian 2. Colluvium 3. Bedrock
 4. Residual ___

18. DOMINANT soil texture: 0. Not sandy or gravelly 1. Gravelly
 2. Sandy 3. Gravelly and Sandy ___

NATURAL IMPACTS (use the following scores: 0=none, 1=minor (<10% of site area affected), 2=moderate (>10% but less than 50% of site area affected), 3=extensive (50% of site area affected)

19. Evidence of surficial sheet washing? ___

20. Evidence of gullying (cuts 10-100 cm deep)? ___

21. Active arroyo cutting (cuts >100cm)? ___

22. Evidence of animal-caused erosion? (Sum of items below) ___
   (a) general trampling ___
   (b) trailing through site ___
   (c) burrowing ___
   (d) Other ___

23. Evidence of other erosion? (Sum of items below) ___
   (a) wind deflation ___
   (b) bank slumpage ___
   (c) dune migration ___
   (d) Other ___

TOTAL NATURAL IMPACT

24. First method: if score for items 18-23 is greater than zero, item # = 1. (Sum total - maximum total = 5). First Method Total ____

25. Second method: sum actual scores for all items. Maximum score for items 19-21 equals 3 each; maximum score for items 22 and 23 equals 12 each. (Maximum possible for all items combined is 33.) Second Method Total ____

26. Characterize the stability of the site: 0=stable (no active erosion) 1=incipient erosion, 2=active erosion ___

27. Do any of the above impacts appear to be related to river/dam operation? 0=no, 1=yes ___

   Indicate with a '1' any that apply:
   (a) direct inundation within past 30 years (post-dam) ___
   (b) bank slumpage/steepening adjacent to current highwater zone ___
   (c) headward migration of arroyos due to lowered base level ___
   (d) Other ________ ___

28. If arroyos or gullies are present, do they drain all the way to the river? (Note: Some drainages die out in dune fields or on terraces before reaching the river.) 0=no, 1=yes, 2=N/A ___

29. Comments: (Explain/describe river-related impacts in more detail: any new features or structures exposed by erosion; changes in types or degree of erosion; imminent threats; what to look at on next visit, etc.):

HUMAN IMPACTS EVALUATION

30. Collection Piles: 0= None 1= 1 pile 2= > 1 pile ___
If more than one pile, list total number: 0

31. Trails: 0 = No distinct trails 2 = 1-2 distinct trails
4 = >2 distinct trails ___

32. Trails eroded >5 cm below ground level? 0=no, 1=Yes ___
(Show all distinct trails on site map.)

33. Evidence of on site camping? 0=None; 2=minimal (1 of the below);
4=Considerable (2 or more of the below) ___

Indicate with a "1" what kinds of evidence are present?
a. Fire scars, fire pits, recent charcoal: ___
b. Rearrangement/clearing of rocks: ___
c. Recent camper trash: ___
d. Obvious concentrated soil compaction
(tent site): ___
e. Other: ___

Does this evidence appear to be recent (< 5 years old)? ___

Did evidence appear since last visit? ___

34. Evidence of deliberate vandalism? ___
0= None
1= Surficial disturbance only (e.g., grafitti)
2= Slight amount of subsurface disturbance(<1 m2 excavated)
3= Substantial subsurface disturbance (>1 m2 area excavated)

Does this evidence appear to be recent (<5 years old)? ___

Did evidence appear since last visit? ___

35. Any other evidence of visitation other than above (e.g. obvious erosion/compaction from human trampling, scattered surface trash, etc)
0=no, 1=yes ___
If yes, describe:

TOTAL HUMAN IMPACT RATING ___

36. Human Impact Condition Class (see rating system below) ___
Condition Class 1: No human impacts (Impact rating = 0)
Condition Class 2: Minimal impact (Impact rating 1-3)
Condition Class 3: Moderate impact (Impact rating 4-6)
Condition Class 4: High impact (Impact rating 7-9)
Condition Class 5: Very high impact (Impact rating 10-12)
Condition Class 6: Extreme impact (Impact rating 13-15)

37. Describe changes/new human impacts since last visit:

RIVER-RELATED HUMAN IMPACTS

38. How close is the nearest rivercamp to this site? ___
    1=>1 km; 2=<1 km but >500 m; 3=<500 m but >100 m; 4=<100 m

39. Are any of the human impacts directly related to river fluctuations and/or dam operations? 0=no, 1=yes ___
    If yes, indicate with a '1' any that apply)
    (a) development of new trailing to avoid highwater ___
    (b) availability of new beaches in proximity to site ___
    (c) other: ___

40. Any human impacts directly related to recent recording/monitoring activities? 0=no. 1=yes ___

    If yes, indicate with a '1' any that apply
    (a) development of new trails ___
    (b) damage to cryptogamic crust ___
    (c) other: ___

MANAGEMENT ASSESSMENT AND RECOMMENDATION

41. What types of impacts threaten this site? (i.e. what to watch out for)
    Rank each threat according to the criteria listed below:

    0: Not a threat now or in the foreseeable future
    1: Possible threat
    3: Definite threat
    5: Actively occurring at the present time

a) bank slumpage from river/dam related processes ___
b) development of new gullies and/or headward migration of arroyos due to river/dam related base level lowering ___
c) bank slumpage from non-river related processes ___
d) deepening/widening of arroyos from non-river related natural processes (i.e. side canyon flooding) ___
e) exposure/destabilization of features due to a or b ___
f) exposure/destabilization of features due to c, d, or weathering ___
g) exposure/destabilization of features due to visitation ___
h) impacts from human visitation (other than g) ___
i) burial or exposure of features due to dune migration ___
j) other ___ ___

42. Recommended Actions: 0=never/not necessary or applicable; 1=eventually (>3 years from :
2=soon (within 1-3 years); 3=immediately (within 1 year/less if possible);
4=action currently in progress

Discontinue monitoring	___
Monitor visitation with remote sensing devices	___
Monitor erosion with stationary cameras	___
Retrail or define existing trails	___
Obliterate trails	___
Install check dams	___
Plant vegetation to stabilize site surface	___
Stabilize banks with rock armor or similar technique	___
Stabilize structures	___
Surface collect entire site	___
Test for presence/depth of subsurface cultural deposits	___
Map as a form of data recovery (excavation not warranted)	___
Full data recovery (excavation)	___
Close site to all public visitation	___
Develop for public interpretation	___

43. Justify your recommendation:

44. Ranking - See MONITORING PRIORITY RANKING CRITERIA

Stability	___
Accessibility	___
Visibility	___
Natural Impacts	___
Human Visitation	___

45. What is the monitoring priority rank of this site. ___

46. Has this value changed from previous visit? 0=no, 1=yes ___
If yes, explain below.

47. Additional comments/continuations

Monitoring Priority Scores

Circle one value within each category:

<u>Stability</u>

1 Stable—no exposed fragile features such as rock art, standing masonry, middens, etc.

2 Moderately stable—fragile features present but not deteriorating (protected by overhang, etc.)

3 Moderately unstable—fragile features present with definite potential for deterioration

4 Unstable—fragile features exposed and deteriorating

<u>Accessibility</u>

1 Protected—located more than 1 km from road/trail/camp or difficult access (technical climbing)

2 Moderately protected—located 1 to 1/2 km from road/trail/camp with moderate to difficult access (exposure)

3 Moderately unprotected—located 1 to 1/2 km from road/trail/camp with easy access, or 500-100 m with moderately difficult access (exposure but no technical climbing)

4 Unprotected—located less than 100 m from road/trail/camp with easy access

<u>Visibility</u>

1 Low profile—site difficult to recognize, few or no artifacts, subtle features

2 Moderately low profile—site not readily apparent, sparse scattered artifacts, features not obvious

3 Moderately high profile—site is easily recognized from close proximity, abundant surface artifacts, features obvious

4 High profile—site sticks out, attracts attention from a distance, lots of artifacts, well-defined features

<u>Natural Impacts</u>

1 None—natural impact score (Method 1) equals 0

2 Slight—natural impact score equals 1

3 Moderate—natural impact score equals 2-3

4 High—natural impact score > 4

<u>Human Impacts/Visitation</u>

1 None—human impact condition class equals 1 (no impact)

2 Slight—human impact condition class equals 2 (minimal)

3 Moderate—human impact condition class equals 3

4 High—human impact condition class equals 4 or more

Rank	Total Score	
1	20-17	Sites with these scores require monitoring biannually or quarterly; high priority
2	16-13	Sites with these scores require at least annual monitoring; second-highest priority
3	12-9	Sites with these scores require a longer monitoring cycle, perhaps every 2 to 3 years
4	8-5	Sites with these scores should be monitored every 3-5 years; lowest priority
5	-	Site discontinued.

FY93
ARCHAEOLOGICAL SITE RIVER MONITORING FORM

MANAGEMENT INFORMATION

1. Site # AZ : : 2. Monitor session #

3. Monitor(s)____________________

4. Date _/_/_______

5. USGS Quad map 7.5'____________ 6. Use Area Name______________

7. Date of first visit / /

8. UTM location (Zone 12)________East________North

9. General location description

10. Does this site have any visible structures? 0 = no, 1 = yes ___

11. River mile ____ River bank (L=left, R=right, B=both) ___

12. Is this site located in or on Colorado River fluvial deposits? 0=no, 1=yes ___
If yes, describe the setting specifically:

13. Distance/direction from and height above current high water (approx. 30,000 cfs) to lowest boundary of site area:
Distance ____ mtrs Direction ____ degrees Height ____ mtrs Slope ____ degrees

14. Distance/direction from and height above current high water to a central site datum
Distance ____ mtrs Direction ____ degrees Height ____ mtrs Slope ____ degrees

ENVIRONMENTAL SITUATION

15. PRIMARY physiographic setting: 1. Riverside beach/dunes 2. Alluvial terrace 3. Talus slope 4. Base of cliff 5. Bedrock Ledges 6. Non-riverside dunes 7. Other ______________ ___

16. Degree of shelter: 1. Open 2. Overhang/cave 3. Combination ___

17. DOMINANT soil type: 1. Alluvium/Aeolian 2. Colluvium 3. Bedrock 4. Residual ___

18. DOMINANT soil texture: 0. Not sandy or gravelly 1. Gravelly 2. Sandy 3. Gravelly and Sandy ___

NATURAL IMPACTS (use the following scores: 0=none, 1=minor (<10% of site area affected), 2=moderate (>10% but less than 50% of site area affected), 3=extensive (50% of site area affected)

19. Evidence of surficial sheet washing? ___

20. Evidence of gullying (cuts 10-100 cm deep)? ___

21. Active arroyo cutting (cuts >100cm)? ___

22. Evidence of animal-caused erosion? (Sum of items below) ___
    (a) general trampling ___
    (b) trailing through site ___
    (c) burrowing ___
    (d) Other ___

23. Evidence of other erosion? (Sum of items below) ___
    (a) wind deflation ___
    (b) bank slumpage ___
    (c) dune migration ___
    (d) Other ___

TOTAL NATURAL IMPACT

24. First method: if score for items 18-23 is greater than zero, item # = 1. (Sum total - maximum total = 5). First Method Total ___

25. Second method: sum actual scores for all items. Maximum score for items 19-21 equals 3 each; maximum score for items 22 and 23 equals 12 each. (Maximum possible for all items combined is 33.) Second Method Total ___

26. Characterize the stability of the site: 0=stable (no active erosion) 1=incipient erosion, 2=active erosion ___

27. Do any of the above impacts appear to be related to river/dam operation? 0=no, 1=yes ___

    Indicate with a '1' any that apply:
    (a) direct inundation within past 30 years (post-dam) ___
    (b) bank slumpage/steepening adjacent to current highwater zone ___
    (c) headward migration of arroyos due to lowered base level ___
    (d) Other ___ ___

28. If arroyos or gullies are present, do they drain all the way to the river? (Note: Some drainages die out in dune fields or on terraces before reaching the river.) 0=no, 1=yes, 2=N/A ___

29. Comments: (Explain/describe river-related impacts in more detail; any new features or structures exposed by erosion; changes in types or degree of erosion; imminent threats; what to look at on next visit, etc.):

HUMAN IMPACTS EVALUATION

30. Collection Piles: 0= None 1= 1 pile 2= > 1 pile ___
    If more than one pile, list total number: 0

31. Trails: 0 = No distinct trails 2 = 1-2 distinct trails
    4 = >2 distinct trails ___

32. Trails eroded >5 cm below ground level? 0=no, 1=Yes ___
    (Show all distinct trails on site map.)

33. Evidence of on site camping? 0=None; 2=minimal (1 of the below);
    4=Considerable (2 or more of the below) ___

    Indicate with a '1' what kinds of evidence are present?
    a. Fire scars, fire pits, recent charcoal: ___
    b. Rearrangement/clearing of rocks: ___
    c. Recent camper trash: ___
    d. Obvious concentrated soil compaction
       (tent site): ___
    e. Other:___

    Does this evidence appear to be recent (< 5 years old)? ___

    Did evidence appear since last visit? ___

34. Evidence of deliberate vandalism? ___
    0= None
    1= Surficial disturbance only (e.g., grafitti)
    2= Slight amount of subsurface disturbance(<1 m2 excavated)
    3= Substantial subsurface disturbance (>1 m2 area excavated)

    Does this evidence appear to be recent (<5 years old)? ___

    Did evidence appear since last visit? ___

35. Any other evidence of visitation other than above (e.g. obvious erosion/compaction from human trampling, scattered surface trash, etc)
    0=no, 1=yes ___
    If yes, describe:

TOTAL HUMAN IMPACT RATING ___

36. Human Impact Condition Class (see rating system below) ___
    Condition Class 1: No human impacts (Impact rating = 0)
    Condition Class 2: Minimal impact (Impact rating 1-3)
    Condition Class 3: Moderate impact (Impact rating 4-6)
    Condition Class 4: High impact (Impact rating 7-9)
    Condition Class 5: Very high impact (Impact rating 10-12)
    Condition Class 6: Extreme impact (Impact rating 13-15)

37. Describe changes/new human impacts since last visit:

RIVER-RELATED HUMAN IMPACTS

38. How close is the nearest rivercamp to this site?
1=>1 km; 2=<1 km but >500 m; 3=<500 m but >100 m; 4=<100 m ___

39. Are any of the human impacts directly related to river fluctuations and/or dam operations? 0=no, 1=yes ___
If yes, indicate with a "1" any that apply)
(a) development of new trailing to avoid highwater ___
(b) availability of new beaches in proximity to site ___
(c) other: ___
____

40. Any human impacts directly related to recent recording/monitoring activities? 0=no, 1=yes ___

If yes, indicate with a "1" any that apply
(a) development of new trails ___
(b) damage to cryptoganic crust ___
(c) other: ___
____

MANAGEMENT ASSESSMENT AND RECOMMENDATION

41. What types of impacts threaten this site? (i.e. what to watch out for)
Rank each threat according to the criteria listed below:

0: Not a threat now or in the foreseeable future
1: Possible threat
3: Definite threat
5: Actively occurring at the present time

a) bank slumpage from river/dam related processes ___
b) development of new gullies and/or headward migration of arroyos due to river/dam related base level lowering ___
c) bank slumpage from non-river related processes ___
d) deepening/widening of arroyos from non-river related natural processes (i.e. side canyon flooding) ___
e) exposure/destabilization of features due to a or b ___
f) exposure/destabilization of features due to c, d, or weathering ___
g) exposure/destabilization of features due to visitation ___
h) impacts from human visitation (other than g) ___
i) burial or exposure of features due to dune migration ___
j) other _______________________________ ___

42. Recommended Actions: 0=never/not necessary or applicable; 1=eventually (>3 years from n
2=soon (within 1-3 years); 3=immediately (within 1 year/less if possible);
4=action currently in progress

- Discontinue monitoring ___
- Monitor visitation with remote sensing devices ___
- Monitor erosion with stationary cameras ___
- Retrail or define existing trails ___
- Obliterate trails ___
- Install check dams ___
- Plant vegetation to stabilize site surface ___
- Stabilize banks with rock armor or similar technique ___
- Stabilize structures ___
- Surface collect entire site ___
- Test for presence/depth of subsurface cultural deposits ___
- Map as a form of data recovery (excavation not warranted) ___
- Full data recovery (excavation) ___
- Close site to all public visitation ___
- Develop for public interpretation ___

43. Justify your recommendation:

44. Ranking - See MONITORING PRIORITY RANKING CRITERIA
- Stability ___
- Accessibility ___
- Visibility ___
- Natural Impacts ___
- Human Visitation ___

45. What is the monitoring priority rank of this site. ___

46. Has this value changed from previous visit? 0=no, 1=yes ___
If yes, explain below.

47. Additional comments/continuations

10/94

FY94 and FY95

Grand Canyon National Park

RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORM

MANAGEMENT

1. Site Number AZ: ____________ 2. Monitor Session ____________

3. River Mile ______ Bank (L/R/B): ____ 4. Date ____________

5. Monitor (s) ________________________________

6. Site Type ________________________________

NATURAL IMPACTS

0 = Absent; 1 = Present; 2 = Increase; 3 = Decrease; 4 = NA (for items 7 - 14)

		Structures / Storage	Artifacts	Roasters/ Hearths	Perishables/ Midden	Rock Art	Other
7.	Surface Erosion (0-10cm)						
8.	Gullying (10-100cm)						
9.	Arroyo Cutting (>1m)						
10.	Bank Slumpage						
11.	Eolian/Alluvial Erosion/Deposition						
12.	Side Canyon Erosion						
13.	Animal-Caused Erosion (trailing, burrowing)						
14.	Other Natural Impacts (spalling, roots)						

15. If arroyos or gullies are present, do they drain to the river? (Note: Some drainages die out in dune fields or on terraces before reaching the river.) 0 = no; 1 = yes; 2 = NA ____________

16. Do any of the above impacts appear to have occurred since the last monitoring episode? 0=no; 1=yes If yes, explain in 17. ____________

17. Comments:

HUMAN IMPACTS

Site Number :
Monitor Session :

0 = Absent; 1 = Present; 2 = Increase; 3 = Decrease; 4 = NA (for Items 18 - 24)

18.

	Structures / Storage	Artifacts	Roasters/ Hearths	Perishables/ Midden	Rock Art	Other
Visitor Impacts						

19. Collection Piles: If present, explain in 26. ______
20. Trails: If present, explain in 26. ______
21. On-site Camping: If present, explain in 26. ______
22. Criminal vandalism/ARPA violations: If present, explain in 26. ______
23. Other: If present, explain in 26. ______
24. Human impacts since last monitoring: ______
25. Are any human impacts directly related to river fluctuations and/or dam operations? 0 = no; 1 = yes If yes, explain in 26 (i.e., development of new trails to avoid high water, availability of new beaches in proximity of site). ______
26. Comments:

MANAGEMENT ASSESSMENT AND RECOMMENDATION

27. Monitor Schedule: 1) discontinue 2) semiannually 3) annually 4) every-other-year 5) every three to five years ______
28. Monitor with a stationary camera: 0 = no; 1 = yes ______
29. Recommended measures to reduce site impacts: 0 = no; 1 = yes

Retrail ______
Obliterate trail(s) ______
Plant vegetation ______
Install check dams ______
Stabilize ______
Close site to visitors ______

30. Recommended measures to protect the site's integrity: 0 = no; 1 = yes

Surface collect entire site ______
Map as a form of data recovery ______
Test for depth of subsurface cultural deposits ______
Excavate entire site ______

31. Comments: (i.e., surface sample unit)

11/95

FY96

Grand Canyon National Park

RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORM

MANAGEMENT

1. Site Number AZ: ____________ 2. Monitor Session ____________

3. River Mile ______ Bank (L/R/B): ____ 4. Date ____________

5. Monitor (s) ____

6. Site Type ____

PHYSICAL IMPACTS

0 = Absent; 1 = Present; 2 = Increase; 3 = Decrease; 4 = NA (for items 7 - 14)

		Structures / Storage	Artifacts	Roasters/ Hearths	Perishables/ Midden	Rock Art	Other
7.	Surface Erosion (0-10cm)						
8.	Gullying (10-100cm)						
9.	Arroyo Cutting (>1m)						
10.	Bank Slumpage						
11.	Eolian/Alluvial Erosion/Deposition						
12.	Side Canyon Erosion						
13.	Animal-Caused Erosion (trailing, burrowing)						
14.	Other Natural Impacts (spalling, roots)						

15. If arroyos or gullies are present, do they drain to the river? (Note: Some drainages die out in dune fields or on terraces before reaching the river.) 0 = no; 1 = yes; 2 = NA ____________

16. Do any of the above impacts appear to have occurred since the last monitoring episode? 0=no; 1=yes If yes, explain in 17. ____________

17. Comments:

VISITOR-RELATED IMPACTS

Site Number :

Monitor Session :

0 = Absent; 1 = Present; 2 = Increase; 3 = Decrease; 4 = NA (for items 18 - 24)

18.

	Structures / Storage	Artifacts	Roasters/ Hearths	Perishables/ Midden	Rock Art	Other
Visitor Impacts						

19. Collection Piles: If present, explain in 26. ______
20. Trails: If present, explain in 26. ______
21. On-site Camping: If present, explain in 26. ______
22. Criminal vandalism/ARPA violations: If present, explain in 26. ______
23. Other: If present, explain in 26. ______
24. Visitor-related impacts since last monitoring: ______
25. Are any visitor-related impacts directly related to river fluctuations and/or dam operations? 0 = no; 1 =yes If yes, explain in 26 (i.e., development of new trails to avoid high water, availability of new beaches in proximity of site). ______
26. Comments:

MANAGEMENT ASSESSMENT AND RECOMMENDATION

27. Monitor Schedule: 1) discontinue 2) semiannual 3) annual 4)biennial 5) every three to five years 6) inactive ______
28. Recommended measures to reduce site impacts: 0 = no; 1 = yes

Retrail ______ Plant vegetation ______ Other ______

Obliterate trail(s) ______ Install checkdams ______ Close site to visitors ______

29. Recommended measures to protect the site's integrity: 0 = no; 1 = yes

Surface collect entire site ______ Test for depth of subsurface cultural deposits ______

Map as a form of data recovery ______ Data recovery ______

30. Comments: (i.e., surface sample unit)

2/97

FY97

Grand Canyon National Park

RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORM

MANAGEMENT

1. Site Number AZ ______________
2. Monitor Session ______________
3. River Mile ______ Bank (L/R/B) ____
4. Date ______________
5. Site Type ______________________________
6a. Monitor (s) ______________________________
6b. PA Signatories ______________________________

PHYSICAL IMPACTS

0 = Absent; 1 = Present; 2 = Increase; 3 = Decrease; 4 = NA (for items 7 - 14)

		Structures / Storage	Artifacts	Roasters/ Hearths	Perishables/ Midden	Rock Art	Other
7.	Surface Erosion (0-10cm)						
8.	Gullying (10-100cm)						
9.	Arroyo Cutting (>1m)						
10.	Bank Slumpage						
11.	Eolian/Alluvial Erosion/Deposition						
12.	Side Canyon Erosion						
13.	Animal-Caused Erosion (trailing,burrowing)						
14.	Other Natural Impacts (spalling, roots)						

15. If arroyos or gullies are present, do they drain to the river? (Note: Some drainages die out in dune fields or on terraces before reaching the river.) 0 = no; 1 = yes; 2 = NA ______________

16. Do any of the above impacts appear to have occurred since the last monitoring episode? 0=no; 1=yes If yes, explain in 17. ______________

17. Comments:

VISITOR-RELATED IMPACTS

Site Number :
Monitor Session :

0 = Absent; 1 = Present; 2 = Increase; 3 = Decrease; 4 = NA (for Items 18 - 24)

18

	Structures / Storage	Artifacts	Roasters/ Hearths	Perishables/ Midden	Rock Art	Other
Visitor Impacts						

19. Collection Piles: If present, explain in 26. ______
20. Trails: If present, explain in 26. ______
21. On-site Camping: If present, explain in 26. ______
22. Criminal vandalism/ARPA violations: If present, explain in 26. ______
23. Other: If present, explain in 26. ______
24. Visitor-related impacts since last monitoring: ______
25. Are any visitor-related impacts directly related to river fluctuations and/or dam operations? 0 = no; 1 =yes If yes, explain in 26 (i.e., development of new trails to avoid high water, availability of new beaches in proximity of site). ______
26. Comments:

MANAGEMENT ASSESSMENT AND RECOMMENDATION

27. Monitor Schedule: 1) discontinue 2) semiannual 3) annual 4) every-other-year (biennial) 5) every three to five years ______
28. Monitor with a stationary camera: 0 = no; 1 = yes ______
29. Recommended measures to reduce site impacts: 0 = no; 1 = yes

Retrail ______ Plant vegetation ______ Stabilize ______
Obliterate trail(s) ______ Install check dams ______ Close site to visitors ______

30. Recommended measures to protect the site's integrity: 0 = no; 1 = yes

Surface collect entire site ______ Test for depth of subsurface cultural deposits ______
Map as a form of data recovery ______ Excavate entire site ______

31. Comments: (i.e., surface sample unit)

FY98
Grand Canyon National Park

RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORM

MANAGEMENT

1. Site Number AZ: ________ ___ __
2. Monitor Session ________
3. River Mile ______ Bank (L/R/B) ______
4. Date ________
5. Site Type ________
6. Monitor(s) ________
7. PA Signatories ________

PHYSICAL IMPACTS

Coding: 0 = Absent, 1 = Active, 2 = Inactive, 3 = NA (for items 8 - 14)

		Structures / Storage	Artifacts	Roasters / Hearths	Perishables / Midden	Rock Images	Other
8.	Surface Erosion (0 - 10 cm)						
9.	Gullying (10 - 100 cm)						
10.	Arroyo Cutting (> 1 m)						
11.	Bank Slump						
12.	Eolian/Alluvial Erosion/Deposition						
13.	Side Canyon Erosion						
14.	Other Physical Impacts (animals, spalling, roots)						

15. If arroyos or gullies are present, do they drain to the river? (Note: Some drainages die out in dunes or terraces before reaching the river.) 0 = No, 1 = Yes, 2 = Side Canyon Based, and 3 = NA ______
16. Do any of the above impacts appear to have occurred since the last monitoring episode? 0 = No, 1 = Yes. If yes, explain in Question # 17. ______
17. Comments:

Grand Canyon National Park

RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORM

VISITOR-RELATED IMPACTS

Site Number:
Monitor Session:

Coding: 0 = Absent, 1 = Present, 3 = NA (for items 18 - 24)

		Structures / Storage	Artifacts	Roasters / Hearths	Perishables / Midden	Rock Images	Other
18.	Visitor Impacts						

19. Collection Piles: If present, explain in Question # 26. ______
20. Trails On-Site: If present, explain in Question # 26. Explain any off-site trails also. ______
21. Camping On-Site: If present, explain in Question # 26. ______
22. Criminal vandalism/ARPA violations: If present, explain in Question # 26. ______
23. Other visitor impacts: If present, explain in Question # 26 ______
24. Visitor-related impacts since last monitoring: ______
25. Are any visitor-related impacts directly related to river fluctuations and/or dam operations, i.e development of new trails to avoid high water, availability of new beaches in proximity of site. 0 = No, 1 = Yes. If yes, explain in Question # 26. ______
26. Comments:

RECOMMENDATIONS

27. Monitor Schedule: 1) Discontinue 2) Semiannual 3) Annual 4) Biennial 5) Every three to five years 6) Inactive ______
28. Preservation Options: 0 = No, 1 = Yes

    Retrail ______ Plant vegetation ______ Other Preservation Options ______
    Obliterate trail(s) ______ Install checkdams ______

29. Recovery Options: 0 = No, 1 = Yes

    Test ______ Data Recovery ______ Other Recovery Options ______

30. Comments:

FY99

9/98 **Grand Canyon National Park and Glen Canyon National Recreation Area**

RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORM

MANAGEMENT

1. Site Number AZ: ____________ 2. Monitor Session ____________
3. River Mile ______ Bank (L/R/B) ______ 4. Date ____________
5. Site Type ____________
6. Monitor(s) ____________
7. PA Signatories ____________

PHYSICAL IMPACTS

Coding: 0 = Absent, 1 = Active, 2 = Inactive, 3 = NA (for items 8 - 14)

		Structures / Storage	Artifacts	Roasters / Hearths	Perishables / Midden	Rock Images	Other
8.	Surface Erosion (0 - 10 cm)						
9.	Gullying (10 - 100 cm)						
10.	Arroyo Cutting (> 1 m)						
11.	Bank Slump						
12.	Eolian/Alluvial Erosion/Deposition						
13.	Side Canyon Erosion						
14.	Other Physical Impacts (animals, spalling, roots)						

15. If arroyos or gullies are present, do they drain to the river? (Note: Some drainages die out in dunes or terraces before reaching the river.) 0 = No, 1 = Yes, 2 = Side Canyon Based, and 3 = NA ______

16. Do any of the above impacts appear to have occurred since the last monitoring episode? 0 = No, 1 = Yes. If yes, explain in Question # 17. ______

17. Comments:

Grand Canyon National Park and Glen Canyon National Recreation Area
RIVER CORRIDOR ARCHAEOLOGICAL SITE MONITORING FORM

VISITOR-RELATED IMPACTS

Site Number:

Monitor Session:

Coding: 0 = Absent, 1 = Present, 3 = NA (for items 18 - 24)

		Structures / Storage	Artifacts	Roasters / Hearths	Perishables / Midden	Rock Images	Other
18.	Visitor Impacts						

19. Collection Piles: If present, explain in Question # 26. ______
20. Trails On-Site: If present, explain in Question # 26. Explain any off-site trails also. ______
21. Camping On-Site: If present, explain in Question # 26. ______
22. Criminal vandalism/ARPA violations: If present, explain in Question # 26. ______
23. Other visitor impacts: If present, explain in Question # 26 ______
24. Visitor-related impacts since last monitoring: ______
25. Are any visitor-related impacts directly related to river fluctuations and/or dam operations, i.e development of new trails to avoid high water, availability of new beaches in proximity of site. 0 = No, 1 = Yes. If yes, explain in Question # 26. ______
26. Comments:

RECOMMENDATIONS

27. Monitor Schedule: 1) Discontinue 2) Semiannual 3) Annual 4) Biennial 5) Every three to five years 6) Inactive 7) Control Group ______
28. Preservation Options: 0 = No, 1 = Yes
    - Retrail ______ Plant vegetation ______ Other Preservation Options ______
    - Obliterate trail(s) ______ Install checkdams ______
29. Recovery Options: 0 = No, 1 = Yes
    - Test ______ Data Recovery ______ Other Recovery Options ______
30. Comments:

Hualapai may monitor this site on their trip leaving 4/16/99.