Glen Canyon Dam Adaptive Management Work Group
Agenda Item Information
April 29-30, 2009

Agenda Item

Archaeological Sites Analysis with HEC-RAS Model

Action Requested

✓ Information item only. We will answer questions but no action is requested.

Presenters

Helen Fairley, Cultural Resources Program Manager, Grand Canyon Monitoring and Research Center

Shane Capron, Chair, Technical Work Group

Previous Action Taken

✓ By AMWG: AMWG passed the following motion at its September 2008 meeting by a vote of 12-6:

To direct the Technical Work Group to review the flow levels (as indicated by the currently available shorelines of the HEC-RAS model) associated with each of the 158 archaeological sites that have been identified for monitoring and/or mitigation of impacts, and to report this information and any recommendations with regard to how these data would fit into the process of making choices of sites to be monitored and/or impacts mitigated to the AMWG at its next meeting, with the provision that any recommendation will not alter the choice of sites selected for impacts mitigation in FY09.

✓ By TWG: TWG approved the following motions at its March 2009 meeting by a vote of 12-1:

The TWG recommends to the AMWG that the existing virtual shorelines generated by HEC-RAS model are good predictors of river stage and are reliable predictors of the inundation of archaeological site surfaces. However, river stage is not the only consideration employed for determining which archaeological sites need to be treated. Other proximate, secondary, and tertiary causes must be considered in determining archaeological site condition and the need for treatment. Additional modeling is necessary to evaluate which combination of variables has the most explanatory value in assessing current site condition. The current monitoring and treatment of archaeological sites should continue while the utility of alternative models (i.e. geomorphological) is investigated.

Relevant Science

✓ The following describes the relevant research or monitoring on this subject:

The analysis described below was made possible by the recent publication of a stage/discharge model for the Colorado River between Lees Ferry and Diamond Creek (Magirl and others, 2008).

The model is based on a one-dimensional modeling system originally developed by the U.S. Army Corps of Engineers (Hydrologic Engineering Center River Analysis System [HEC-RAS]). HEC-RAS is a "standard step" model, used in this case to predict water surface elevation associated with various discharges. Magirl and others evaluated the accuracy of this Colorado River stage/discharge model by comparing projected water surface elevations for different discharges against known stage-discharge relationships at 45 sites routinely monitored by Northern Arizona University, 3 permanent USGS gages on the Colorado River in Grand Canyon, and drift-wood lines deposited by historic floods of known magnitude. Based on this analysis, Magirl and others estimated that the modeled water surface elevations were accurate within the following ranges:

- $\pm$0.4 m for discharges less than 45,900 ft^3/s
- $\pm$1.0 m for discharges between 45,900 ft^3/s and 88,300 ft^3/s
- $\pm$1.5 m for discharges between 88,300 ft^3/s and 208,400 ft^3/s

The predicted water surface elevations for each discharge of interest were overlaid onto a digital elevation model to produce predicted "virtual" shorelines for each discharge. The availability of these shorelines, coupled with the creation of GIS polygons delineating archaeological site boundaries as part of the recent treatment planning and cultural resource monitoring R&D projects, allowed this analysis to be conducted.

Background Information

An analysis of virtual shorelines associated with modeled stage discharge levels relative to archaeological site locations was requested by AMWG in a motion passed at the September 2008 AMWG meeting. In October, GCMRC cultural program staff (Mr. Hoda Sondossi) conducted a preliminary analysis which was adequate as an initial assessment of the inundation potential of cultural sites in Grand Canyon by six different discharges. This analysis involved a simple comparison of the modeled water surface elevations associated with discrete discharge levels (25,000 ft^3/s, 45,000 ft^3/s, 97,000 ft^3/s, 125,000 ft^3/s, 170,000 ft^3/s, and 210,000 ft^3/s) to mapped boundaries of each of the cultural sites, in order to determine likelihood for inundation by each discharge. However, the initial analysis did not account for the limits of accuracy associated with the modeled virtual shorelines, as defined by Magirl and others (2008).

At the November 2009 TWG meeting, TWG remanded review of the virtual shoreline analysis to the Cultural Resources Ad Hoc Group, by way of the following motion:

The CRAHG will review the revised virtual shoreline analysis, in relation to archaeological sites, and bring recommendations to the TWG at its next meeting focusing its review on the first part of the AMWG motion assessing the utility of flow lines as simulated (with uncertainty) by the HECRAS model and other error sources.

Subsequently (prior to meeting with the CRAHG on January 6, 2009), GCMRC undertook a more sophisticated GIS analysis using a slightly different approach which involved comparing the modeled water surface elevations associated with discrete discharge levels (25,000 ft^3/s, 45,000 ft^3/s, 97,000 ft^3/s, 125,000 ft^3/s, 170,000 ft^3/s, and 210,000 ft^3/s), and the associated error ranges of these different flow levels defined by Magirl and others (2008), to ground surface elevations within each of the cultural sites. The final results were essentially the same as those of the preliminary analysis.

However, the revised analysis allowed for the full range of possibilities for inundation by each discharge range, given the range of error associated with each modeled discharge level.

It should be noted that although the AMWG motion identified the need to analyze shorelines in relation to 158 sites, a total of 161 sites have been targeted for treatment. The basis for the original reference to 158 site was unclear to GCMRC, but apparently referred to the fact that three sites had been excavated by Utah State University cooperators in 2008 and therefore did not warrant further consideration in this analysis; however, despite having been "treated", most of the 10 sites that have been excavated by USU and Museum of Northern Arizona cooperators since 2007 still retain considerable information and/or historic value and will therefore continue to be managed and monitored in the future. Therefore, the GCMRC analysis considered all sites targeted for treatment located between Lees Ferry and Diamond Creek, regardless of whether or not they were the subject of excavation in 2008. However, three of the 161 sites slated for treatment are located outside of the modeled area (one upstream of Lees Ferry, two downstream of Diamond Creek), therefore the number of treatment sites analyzed ended up being 158. In addition, the analysis also examined virtual shorelines in relation to an additional 79 archaeological sites located between Lees Ferry and Diamond Creek that were evaluated as part of the cultural monitoring R&D project.

Table 1. Number of cultural sites likely to be at least partially inundated by each discharge.

	Treatment sites: 148 + 10 MNA		Other sites (n=79)	
Discharge (ft3/s)	**Maximum**	**Minimum**	**Maximum**	**Minimum**
25,000	4	2	0	0
45,000	12	4	2	0
97,000	62	15	14	2
125,000	88	32	20	6
170,000	121	65	35	15
210,000	137	81	46	27

After hearing the results of the GIS analysis at the CRAHG meeting on January 6, 2009, CRAHG members concluded that while useful for predicting inundation potential at archaeological sites, there were other factors besides just inundation potential that needed to be considered in deciding which sites required future treatment and monitoring. At minimum, these factors include current condition, archaeological information potential, and potential for future degradation. The CRAHG also generally agreed that the last factor might be best evaluated through the development of a geomorphic model. The current recommendation from TWG to AMWG reflects these conclusions.