Potential of Glen Canyon Releases to Inundate Cultural Sites in Grand Canyon National Park:

A GIS Analysis Using Modeled Virtual Shorelines, and Canyon-Wide Topographic Data

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Impetus for the Analysis

• Availability of 1) topographic, 2) cultural sites, and 3) virtual shoreline datasets

• Mandated by AMWG and TWG
OUTLINE

• Background
• Methods
• Results
• Discussion

BACKGROUND:
Development of Water-Surface Elevations, and Virtual Shorelines

• 2 major components:
  – 1) Water-Surface Elevations - modeling of cross-sections in 1 dimension (HEC-RAS)
  
  – 2) Virtual Shorelines - modeling of the interaction of the 1D cross-sections with topography, in 3 dimensions
1) Water-Surface Elevation Modeling

- 1D model built in HEC-RAS (Hydrologic Engineering Centers River Analysis System), a “standard step” model;
- Uses 1D equations of energy and continuity to predict stage (water-surface elevation) for known discharges at specific cross-sections;
- 2,680 cross-sections generated between Lees Ferry & Diamond Creek, using high-resolution topography for stage above 227 m$^3$/s (8,000 cfs), and synthetic bathymetry below;
- Model for prediction of stage ONLY—other parameters (e.g., bed roughness, velocity) adjusted for each cross-section to predict accurate stage;
- Stage predicted to within:
  - ± 0.4 m (1.31 ft) for discharge less than 1,300 m$^3$/s (<46,000 cfs)
  - ± 1.0 m (3.28 ft) for discharge ranging 1,300–2,500 m$^3$/s (46,000–88,000 cfs)
  - ± 1.5 m (4.92 ft) for discharge ranging 2,500–5,900 m$^3$/s (88,000–210,000 cfs)
2) Modeling Virtual Shorelines

- Used topography generated from 2002 photogrammetry

- Assigned elevation values from 1D model at the 2,680 cross-sections, interpolated between cross-sections to generated a 3D surface

- Generated “areas of inundation” by comparing the elevation of the 3D water surface layer with the topo layer
In Cross-Section

Known topography

modeled stage for each Discharge, at all 2,680 cross-sections
Mock-up cross-section illustrating a possible scenario of interaction between water stage and a cultural site. Figure is not to scale.
Why the new analysis?
What more was done?
RESULTS:
Basic Statistics of Cultural Sites Size Distributions

<table>
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<th></th>
<th>Trtmnt 151 &amp; MNA</th>
<th>Remainder</th>
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<tbody>
<tr>
<td>Total Area of all Sites (m²)</td>
<td>386400</td>
<td>87717</td>
</tr>
<tr>
<td>Count</td>
<td>158</td>
<td>79</td>
</tr>
<tr>
<td>Mean (m²)</td>
<td>2440.9</td>
<td>1110.3</td>
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<tr>
<td>Median (m²)</td>
<td>808.5</td>
<td>313</td>
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<tr>
<td>Max. (m²)</td>
<td>42170</td>
<td>13346</td>
</tr>
<tr>
<td>Min. (m²)</td>
<td>6</td>
<td>5</td>
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</table>
Percentage of Total Number of Cultural Sites Potentially Inundated by Each Discharge

Percentage of the Cumulative Area of Cultural Sites Potentially Inundated by Each Discharge
Limitations of Analysis

• Only ground surface at archaeological sites is considered—how each flow level may affect a cultural site has not been analyzed.

• Modeled water-surface elevations are based on current topography—changes in local topography (e.g., debris flow from side canyon) may change local stage-discharge relationships.

• Synthetic bathymetry suboptimal—Accurate bathymetric data may be used to update model in future.

Mock up cross-section illustrating a possible scenario of interaction between water stage and a cultural site with buried artifacts. In such cases, there is possibility of a given flow affecting the site without the ground surface at the site being inundated. Figure is not to scale.
Mock-up of a cultural site with only surface artifacts and a gully. Modeled water stage indicates site being inundated, when the actual artifacts are not inundated.

Questions?
CITATIONS
