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

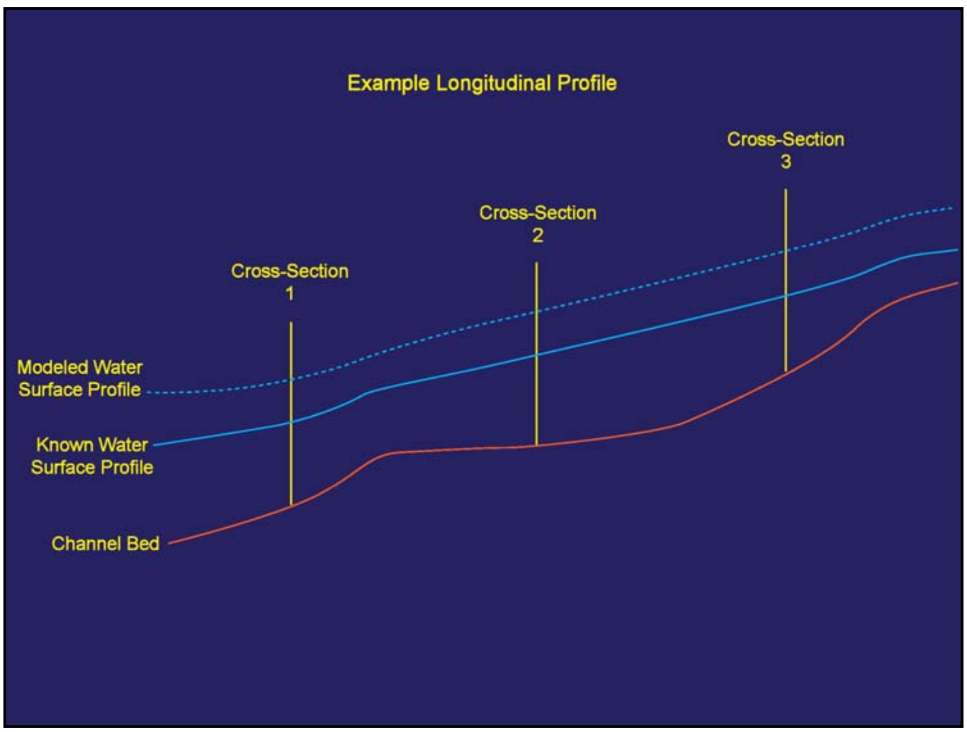
- Background
- Methods
- Results
- Discussion

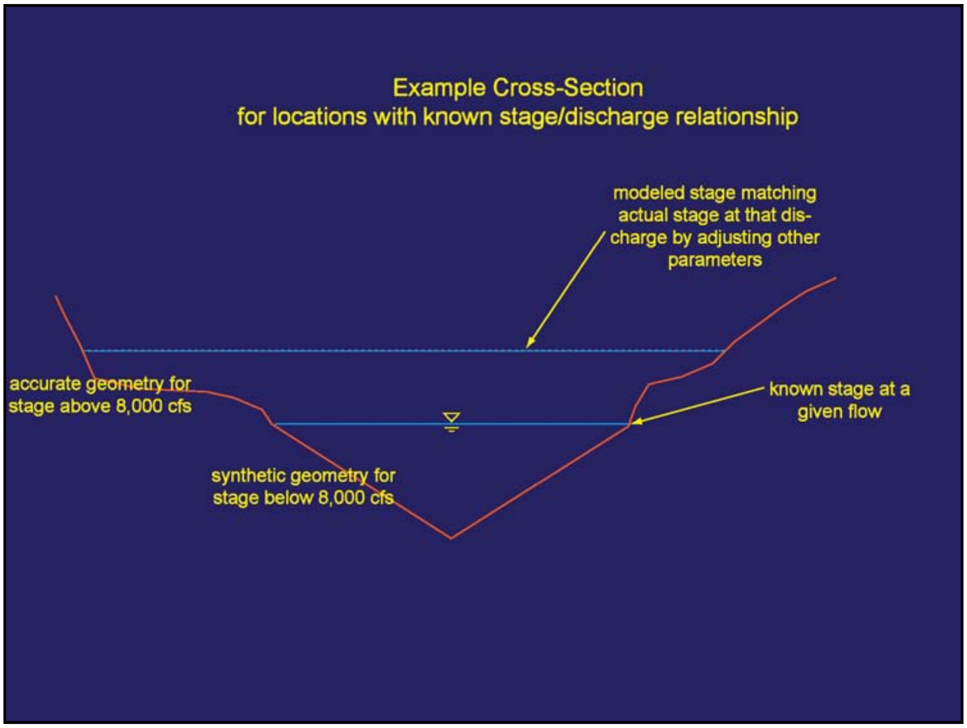
BACKGROUND: Development of Water-Surface Elevations, and Virtual Shorelines

- 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

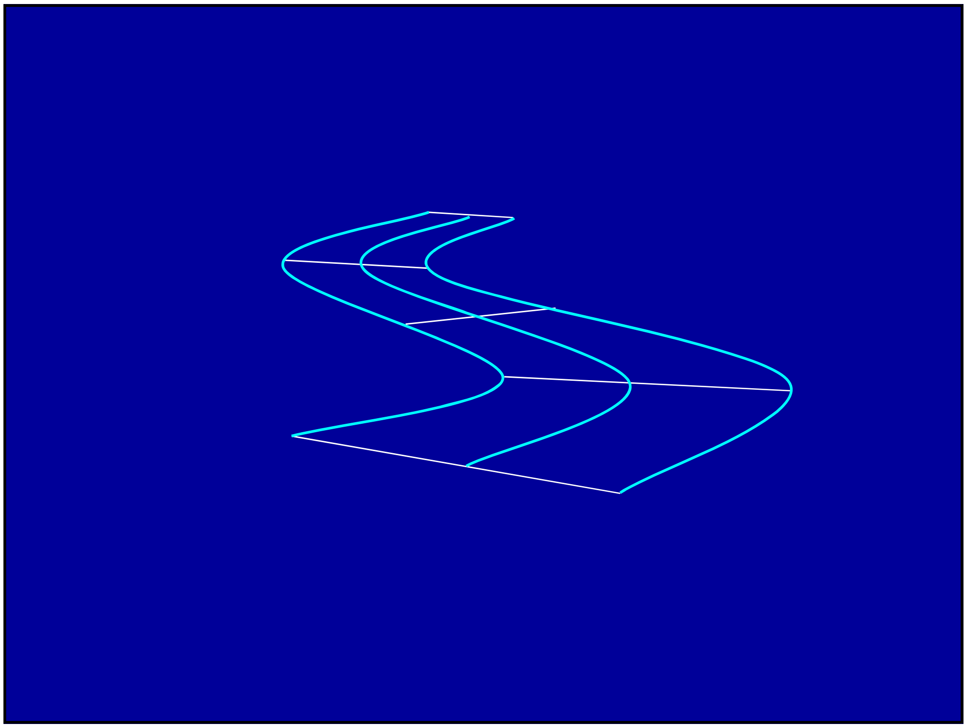
- 1D model built in HEC-RAS (Hydrologic Engineering Centers River Analysis System), a “standard step” model;
- Uses 1D equations of energy and continuity to predict stage (water-surface elevation) for known discharges at specific cross-sections;
- 2,680 cross-sections generated between Lees Ferry & Diamond 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)



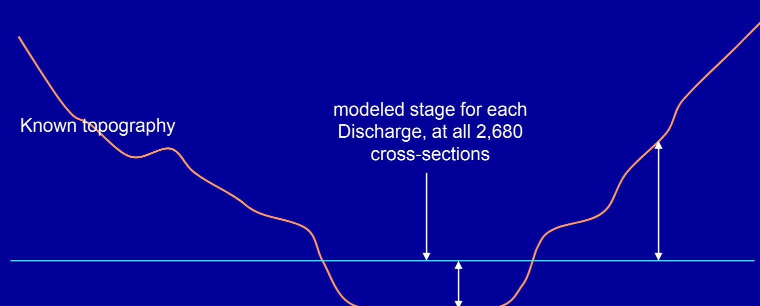


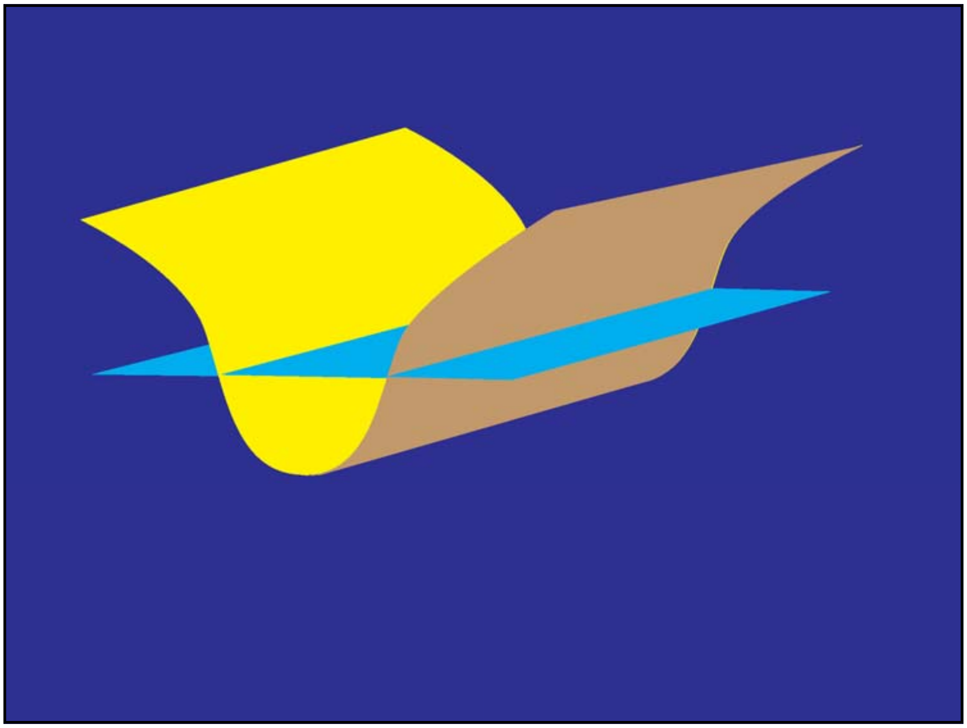
2) Modeling Virtual Shorelines

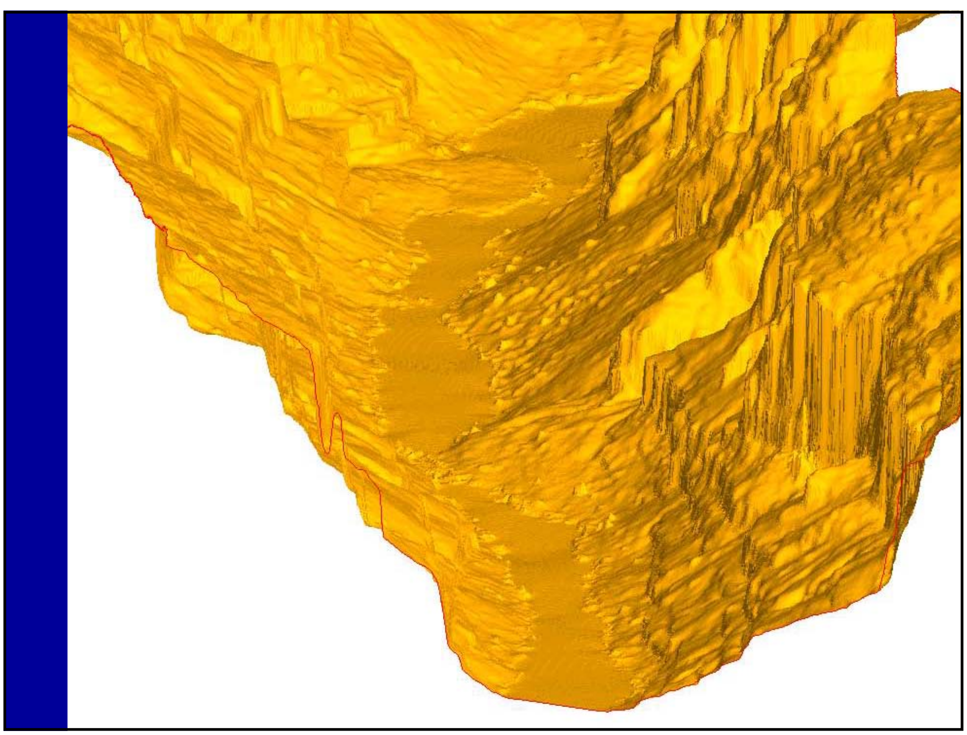
- Used topography generated from 2002 photogrammetry
- Assigned elevation values from 1D model at the 2,680 cross-sections, interpolated between cross-sections to generated a 3D surface
- Generated “areas of inundation” by comparing the elevation of the 3D water surface layer with the topo layer

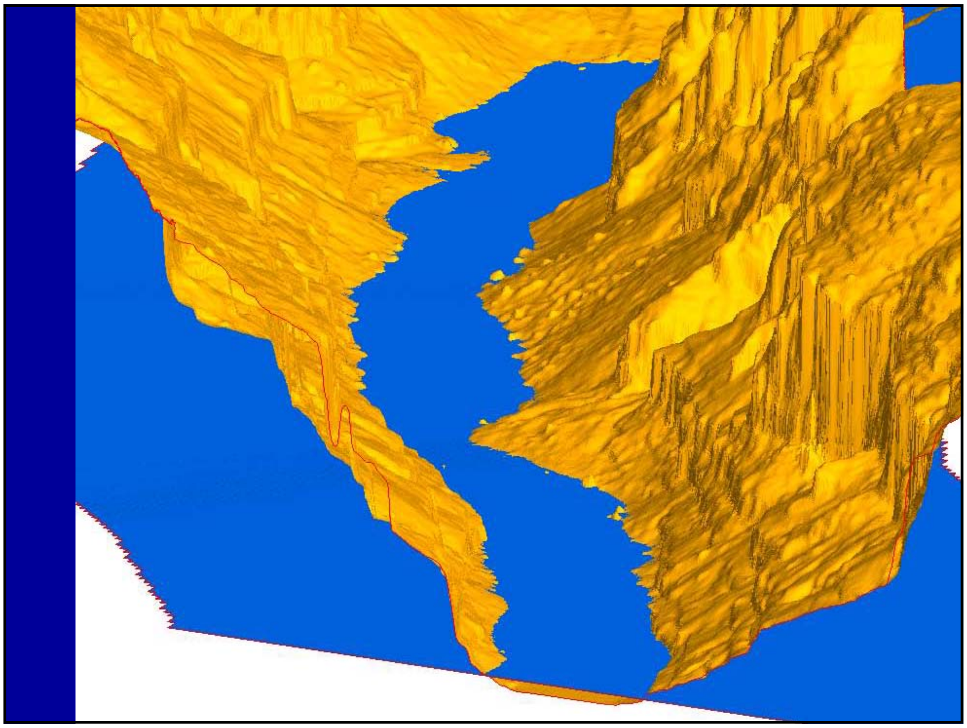


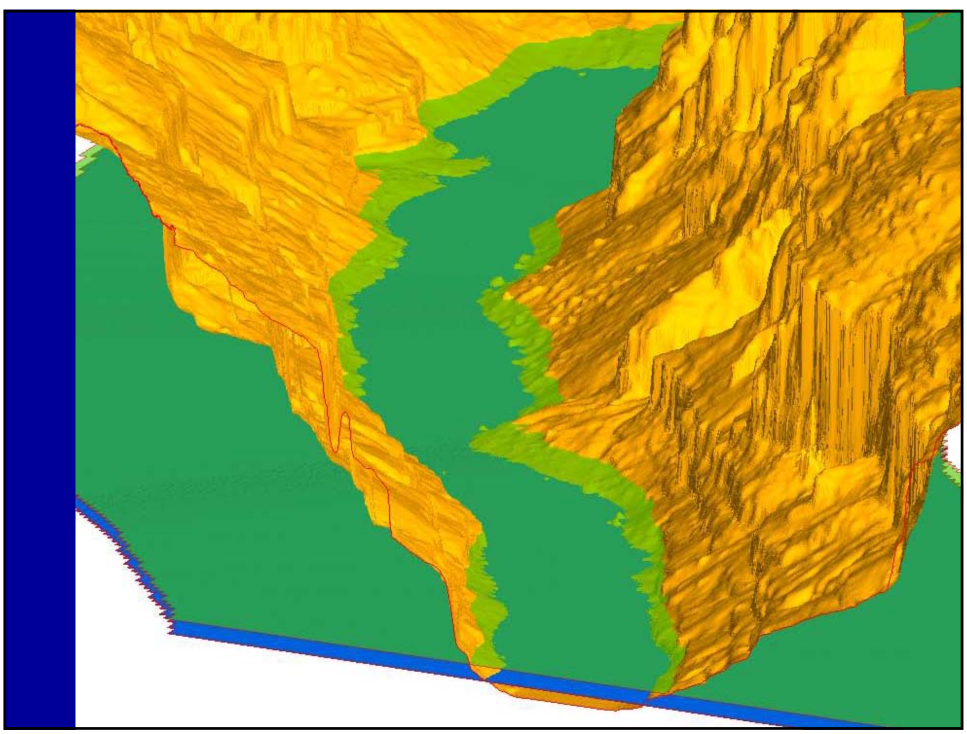
In Cross-Section

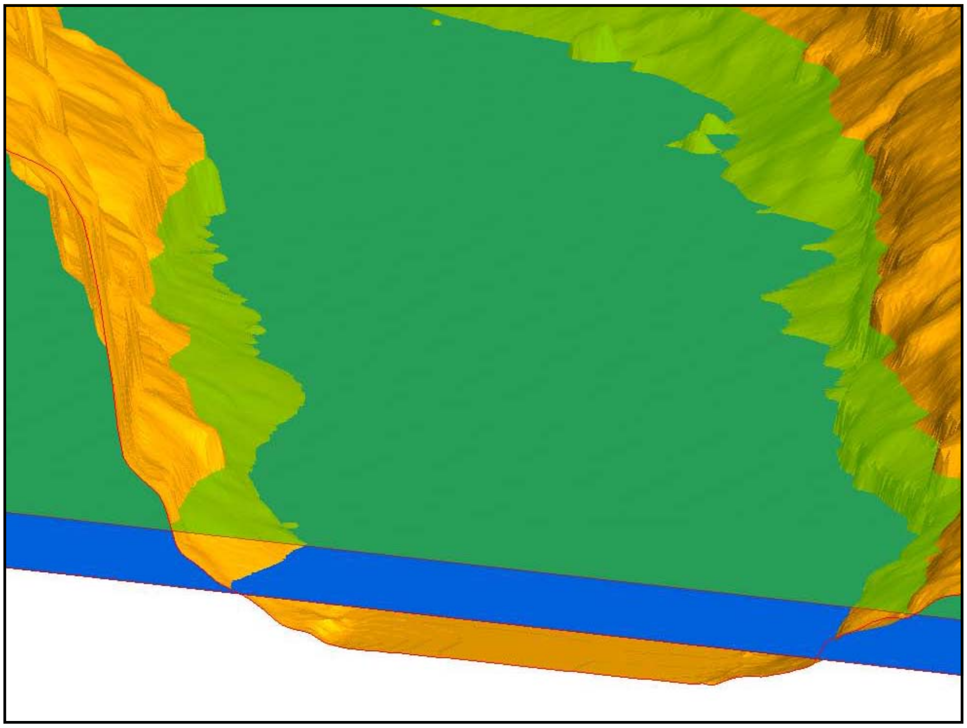


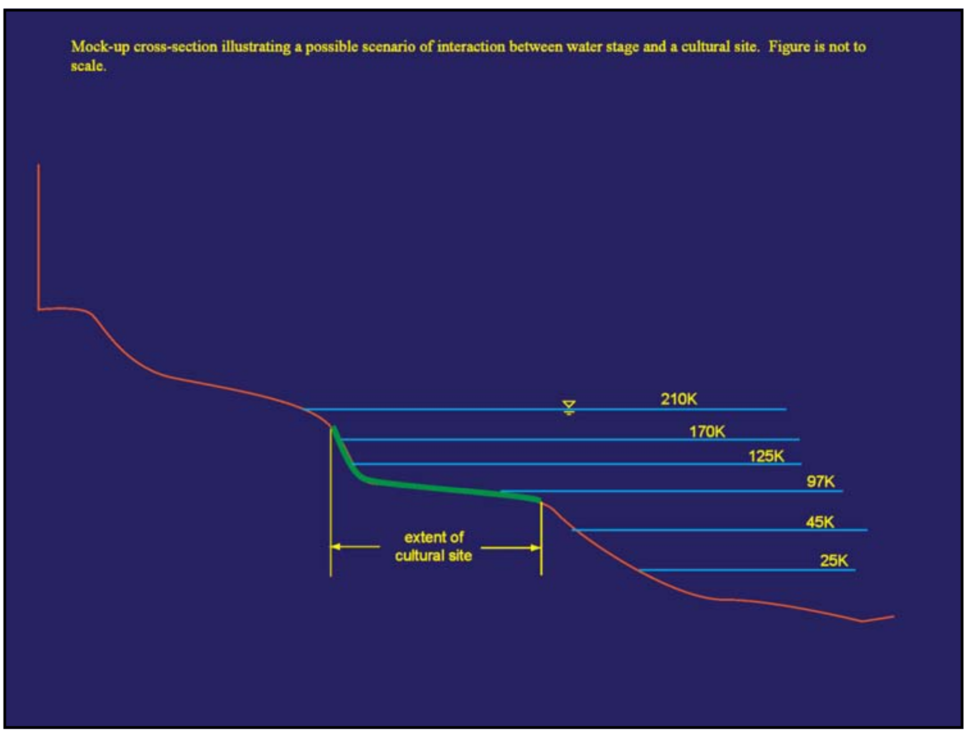


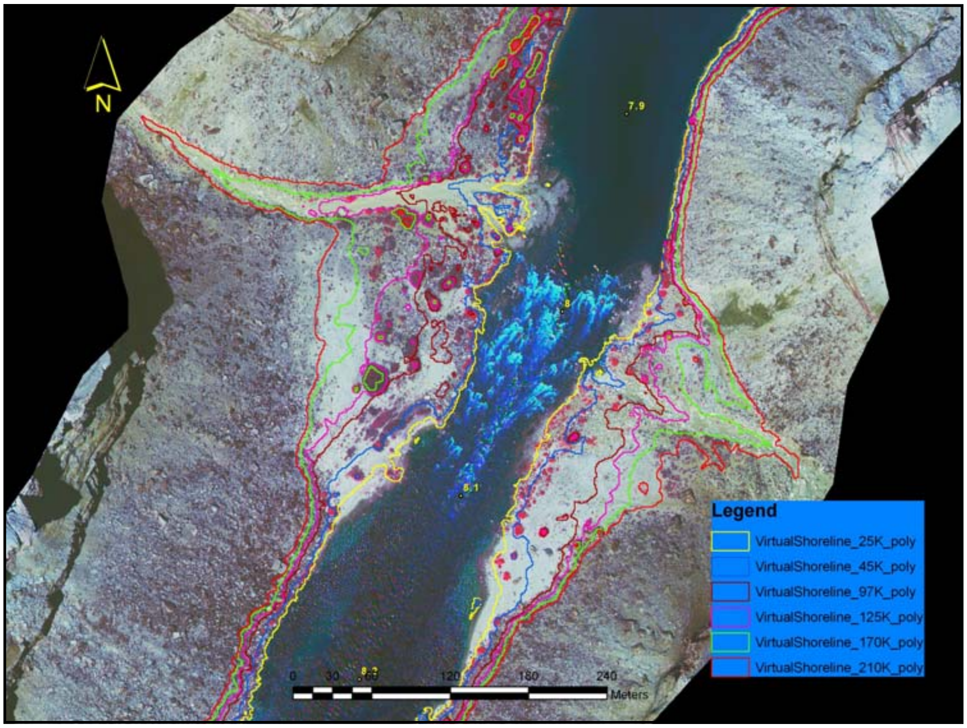




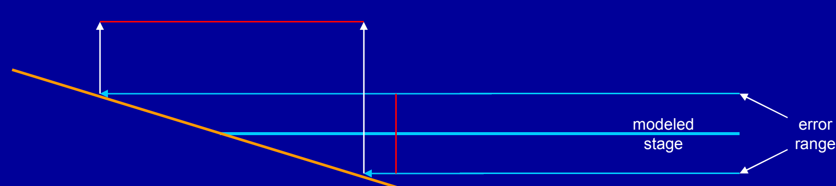


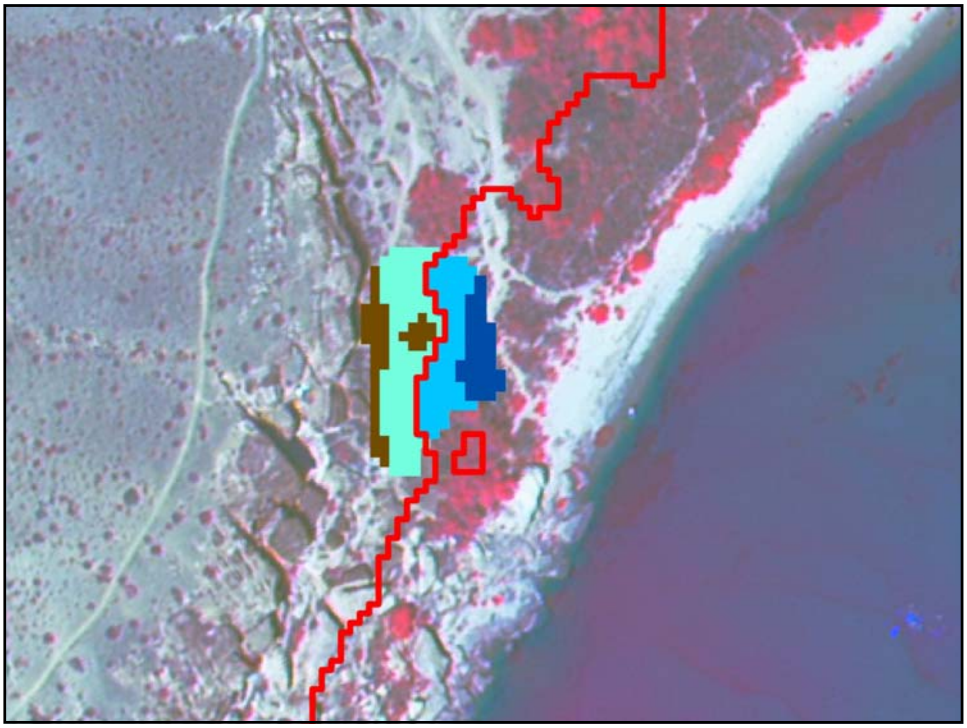



Mock-up cross-section illustrating a possible scenario of interaction between water stage and a cultural site. Figure is not to scale.
210K
170K
125K
97K
45K
25K
extent of
cultural site



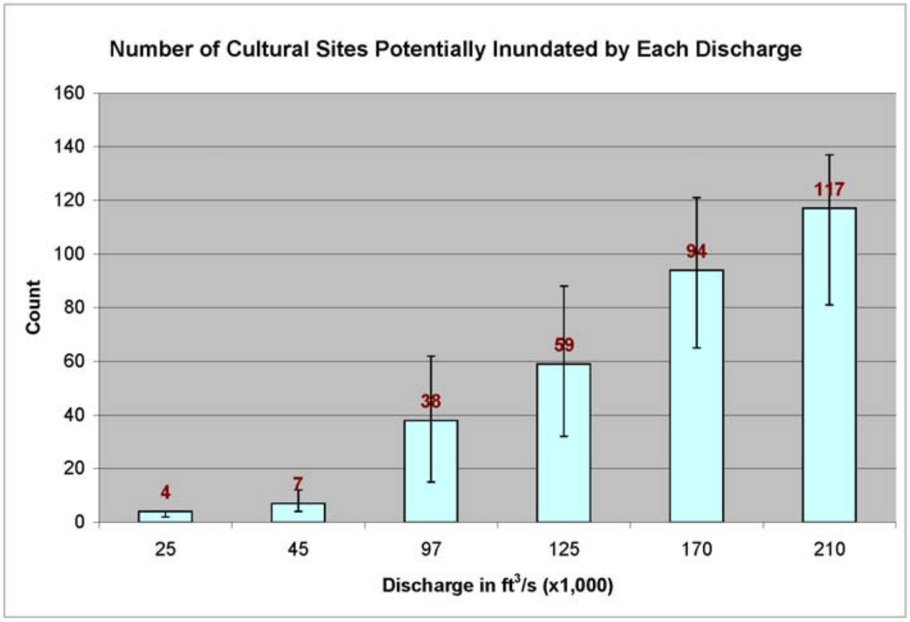
Why the new analysis?
What more was done?



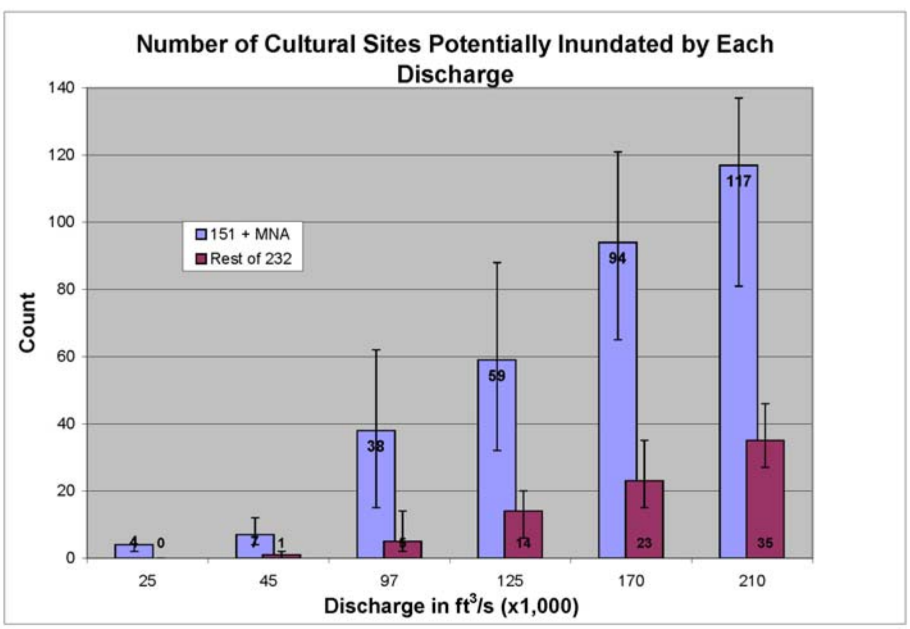


RESULTS:
Basic Statistics of Cultural Sites Size Distributions

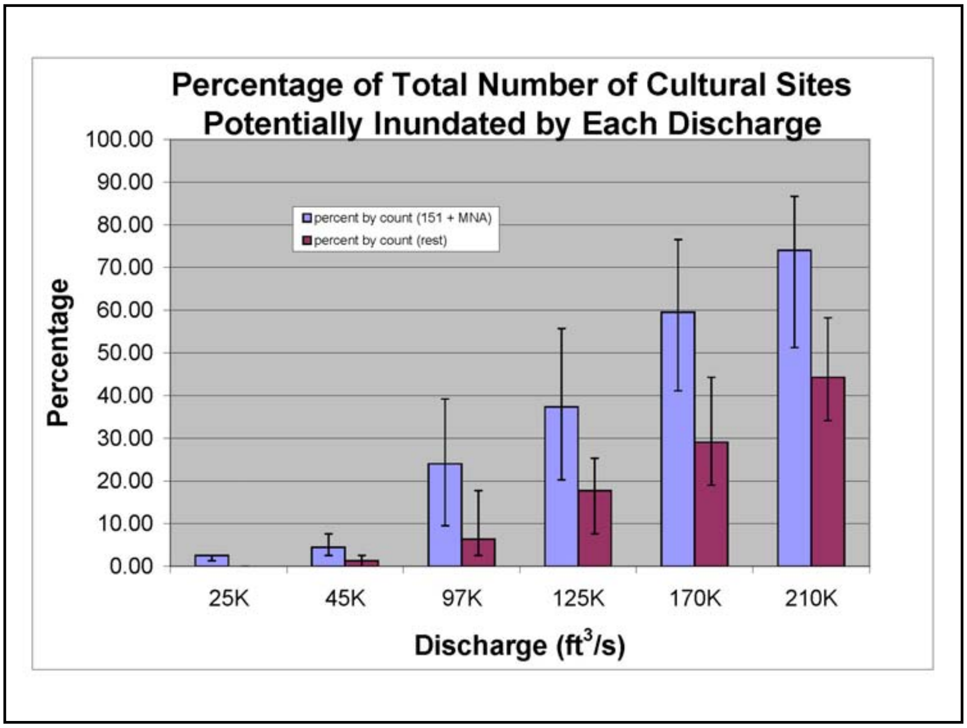
	Trtmnt 151 & MNA	Remainder
Total Area of all Sites (m^2)	386400	87717
Count	158	79
Mean (m^2)	2440.9	1110.3
Median (m^2)	808.5	313
Max. (m^2)	42170	13346
Min. (m^2)	6	5

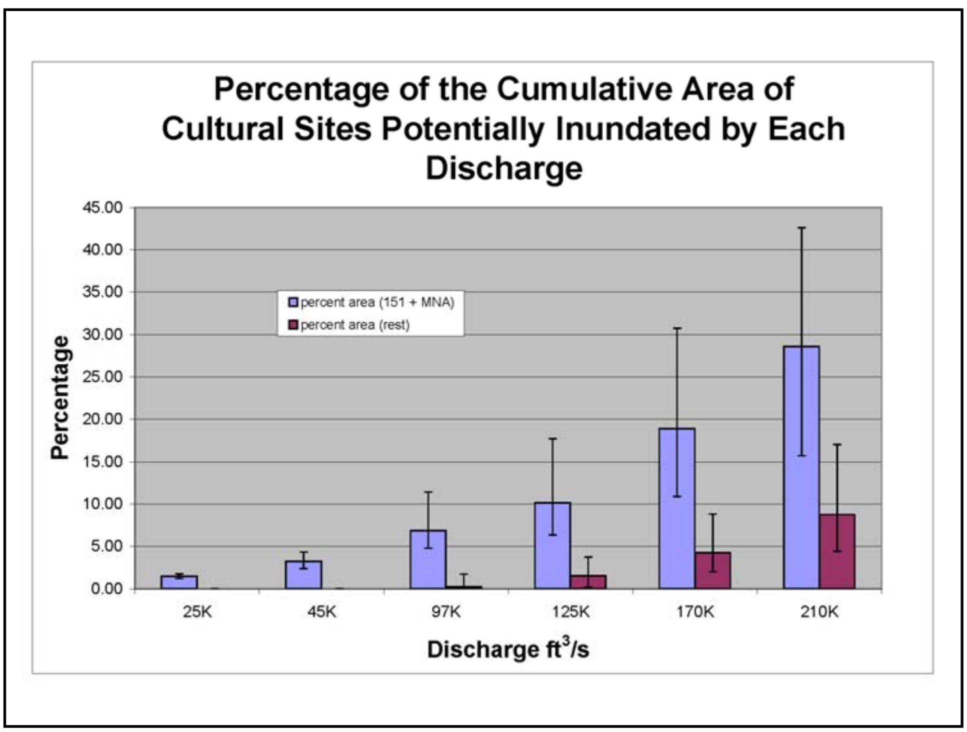


Number of Cultural Sites Potentially Inundated by Each Discharge
Count
Discharge in ft^3/s (x1,000)
0
20
40
60
80
100
120
140
160
25
45
97
125
170
210
4
7
38
59
94
117



Number of Cultural Sites Potentially Inundated by Each Discharge
Count
Discharge in ft^3/s (x1,000)
151 + MNA
Rest of 232
0
20
40
60
80
100
120
140
25
45
97
125
170
210
4
0
7
1
38
5
59
14
94
23
117
35

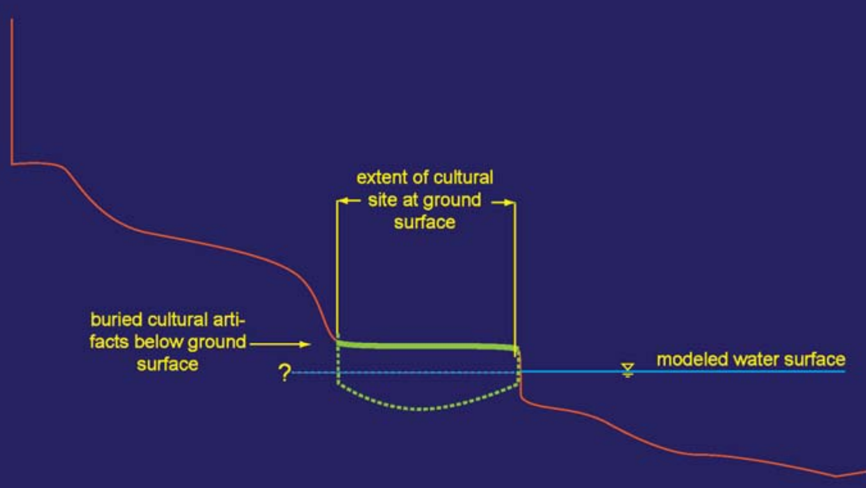

Percentage of Total Number of Cultural Sites Potentially Inundated by Each Discharge
Percentage
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
percent by count (151 + MNA)
percent by count (rest)
25K
45K
97K
125K
170K
210K
Discharge (ft³/s)


Percentage of the Cumulative Area of Cultural Sites Potentially Inundated by Each Discharge
Percentage
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
percent area (151 + MNA)
percent area (rest)
25K
45K
97K
125K
170K
210K
Discharge ft³/s

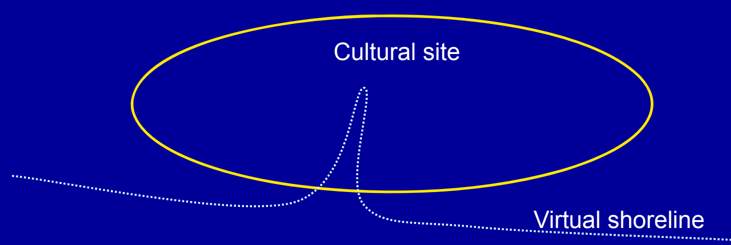
Limitations of Analysis

- 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

- Christopher S. Magirl, Michael J. Breedlove, Robert H. Webb, and Peter G. Grifiths. 2008. *Modeling Water-Surface Elevations and Virtual Shorelines for the Colorado River in Grand Canyon, Arizona*. USGS Scientific Investigation Report 2008-5075

- G.W. Brunner. 2002. *HEC-RAS River Analysis System: Hydraulic Reference Manual, Version 3.1*. Davis, California, U.S. Army Corps of Engineers, Institute for Water Resources, Hydrologic Engineering Center.