GRAND CANYON HOLOCENE GEOMORPHOLOGY SYMPOSIUM
February 8-10, 2005: CONCLUDING OBSERVATIONS

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GRAND CANYON
GEOMORPHOLOGY:
KEY ISSUES

- Long-Term Evolution: Geomorphic Setting
- Post-Dam Channel Bed Changes
- Holocene Landscape Evolution: Terraces
- Erosion of the Holocene Record: Gullies
WHAT DO WE KNOW?

- Long-term \((10^5-10^6 \text{ years})\) incisional trend recorded by flight of Pleistocene terraces
- Well-defined variations in valley morphology, and corresponding preservation of depositional records, in the downstream direction correlate with lithology and structure
- Long profile details are controlled by balance between debris-flow inputs and their reworking by the trunk stream
- Clear contrasts in fluvial processes and style between the glacial and interglacial river
WHAT DO WE REALLY NEED TO KNOW?

• A better understanding of the initial conditions for the Holocene, and the archaeological record: when did the river reach its present level?
  • Has it flowed at a lower level?
  • Is this its lowest elevation or depth of incision?
POST-DAM CHANGES IN CHANNEL
MORPHOLOGY AND PROCESS

WHAT DO WE KNOW?

• Solid understanding of sediment routing in the channel, especially the coupling between tributary influx and the main stem
• Solid understanding of the major changes in sediment supply due to dam construction, especially the loss of fine sediment
• Reasonable understanding of relations between short-term deposition along the channel margin and flow modulation - we know how to build a beach
POST-DAM CHANGES IN CHANNEL MORPHOLOGY AND PROCESS

WHAT WE KNOW - CONT.

• Deposition and erosion of fine vs. coarse sediments have a different trajectory
• The dam-proximal reach has degraded significantly
• Farther downstream, there has been no net change, or even slight aggradation, of the channel bed
• The channel bed has, however, been transformed from a mixed gravel-sand system to a highly enhanced pool-riffle channel
WHAT DO WE REALLY NEED TO KNOW?

• How do we disentangle the effects of the dam from the inherited trajectory of channel change due to an ever changing climate?
  • This may be a fundamentally unresolvable issue, but we should try.
• We need to know more about the natural coupling between climate and fluvial processes.
• How do we preserve a beach? What sequence of flows, what level of sediment supply are needed?
HOLOCENE LANDSCAPE EVOLUTION: THE TERRACES

WHY IS THIS IMPORTANT?

• Holocene terraces correspond to the time period of human occupation, and represent the repository for cultural resources and dateable material.
• Holocene terraces record human-landscape interactions, and the nature of the environment at particular points in time.
• The Colorado River integrates surface processes over a large area of the American West.Holocene terraces are the best record of fluvial activity, and changes in fluvial activity through time in response to climate change and other factors.
HOLOCENE LANDSCAPE EVOLUTION:
THE TERRACES

WHAT DO WE KNOW?

- Reasonably agreed-upon sequence of depositional events
- Deposits are well-mapped (lines on the maps are very good) in many areas, including the culturally-relevant areas
- Deposits consist of overbank fluvial, colluvial, and eolian facies of varying proportions
- At any one reach where mapping has been completed, deposits are reasonably well-dated
WHAT WE ARE LESS CERTAIN ABOUT

• How deposits precisely correlate from reach to reach, and between Grand Canyon and other areas
• Genetic origins of these landforms and deposits:
  • Depositional environments and relative proportions of fluvial, eolian, and colluvial inputs
  • Splitting vs. lumping of units.....which way is best?
  • Origin and position of basal erosional surface and its implications for river incision history
  • Role of “extreme” vs. “normal” floods
• How much of the record is missing - particularly the early to middle Holocene? What are the implications for geological and archaeological interpretations?
• How is the terrace record coupled to external forcing?
EROSION OF THE HOLOCENE RECORD: THE GULLIES

WHY IS THIS IMPORTANT?

• Thought to be the primary short-term mechanism for loss of cultural resources
• Has been proposed to be, at least partially, a result of operations of Glen Canyon Dam
WHAT DO WE KNOW?

• Fluvial landscapes are in a constant state of revision, and for any given flood stage, there are locations of erosion, deposition, and subsequent modification.
  • Gully erosion happens, and the only reason the issue is a front-burner here is the proposal that accelerated erosion is due to dam presence and/or dam operations, and the associated mandate to preserve archaeological resources.
  • Gullies always grow in the headward direction, and tend to be initiated at some break in slope.
• Reasonable evidence exists that accelerated gully erosion corresponds to the post-dam period.
EROSION OF THE HOLOCENE RECORD: THE GULLIES

WHAT DO WE KNOW - CONT.

- The post-dam period corresponds to one of the wettest periods in the historical record.
- We see no clear evidence that gullies are initiated by dam-related processes.
- Flood sediments can fill gully mouths, and can persist for years to exert short-term influences on the lower reaches of gully networks (to the first nickpoint?)
- We see no clear evidence that deposition of flood sediments in gully mouths will heal existing gullies, permanently stem gully erosion, or have much effect on the long-term evolution of gully systems.
- The supply of sand for eolian transport, and potential healing of gullies, has decreased due to dam presence.
WHAT WE ARE LESS CERTAIN ABOUT

• Exact links between gully erosion and “base level” are not well understood
  • If gullies are graded to the low flow channel, then base level has been raised due to dam presence
  • If gullies are graded to sand bars, then in some cases base level has been lowered due to dam presence
  • How does something called base level relate in any way to gullies on the upper terraces?
• What are the precise controls on gully initiation vs. gully propagation vs. gully healing (senescence)
• What are the longer-term effects of gully mitigation, especially the “unintended consequences”?
WHERE TO FROM HERE?

• Develop a true, fully integrated interdisciplinary perspective and methodological approach to Grand Canyon archaeological and human ecological research

• Given the dynamic nature of the landscape, and limited budgets, all archaeological resources should not be considered of equal significance and value

• Develop a rational strategy to maximize return on public investment by driving archaeological and human ecological research with fundamental questions
  • Comprehensive evaluation of sites relative to present geomorphic setting and paleolandsapes
  • Clear understanding of the archaeological significance of “at risk” and non at-risk sites, and what questions can be answered from each
WHERE TO FROM HERE?

- At the **gully scale**, build on past and current research to develop fully predictive physical models of erosion potential and site vulnerability.

- At the **landscape scale**, undertake a new generation of detailed and integrated studies that focus on the coupling of the archaeological record and Holocene landscape evolution:
  - Process-based studies of Holocene framework to more fully understand origin and genetic significance of main stem landforms and deposits.
  - Geochronology needs to be more fully developed through creative and extensive use of techniques such as $^{14}$C, OSL, and cosmogenic nuclides.
  - How do records of landscape evolution link to local vs. regional vs. global climate and climate change?