An aerial photograph showing a large dam structure in the center, with a deep, narrow channel cutting through the surrounding landscape. The channel walls are steep and show signs of erosion. The text is overlaid on the image in a bold, yellow font.

**Erosion and Deposition of
Channel-side Alluvial Deposits
in Degrading and Stable
Channel Segments
Downstream from Large Dams**

Paul Grams, Jack Schmidt, and Dave Topping

Why is Glen Canyon Important?

- History of bed degradation
 - Spatially and temporally rich data sets.
- There are important resources in the reach.
 - Pre-dam terraces (archeological sites)
 - Gravel bars (spawning bars for introduced trout)
 - Sand bars (recreational resource)
- It defines an extreme in the range of possible responses to flow and sediment regulation.
 - If we're looking for channel and deposit changes that result from a negative sediment budget, Glen Canyon is the place we should find them.

Outline of presentation

- Review the history of bed degradation in Glen Canyon
 - Channel response in this reach is of general interest
 - Illustrates relationship between channel bed adjustment and deposit adjustment
- Focus specifically on how pre-dam terraces in Glen Canyon have changed since dam closure
- Discuss similar findings based on work on the Green River downstream from Flaming Gorge Dam
- Implications for how we direct concern for erosion of pre-dam terraces.

Components of Study

- Changes in bed elevation
 - Reclamation monitoring cross-sections
 - USGS gage station records of bed elevation
- Channel-side deposits
 - Mapping from historical aerial photographs
 - Historical oblique photographs
 - Integration with cross-section data

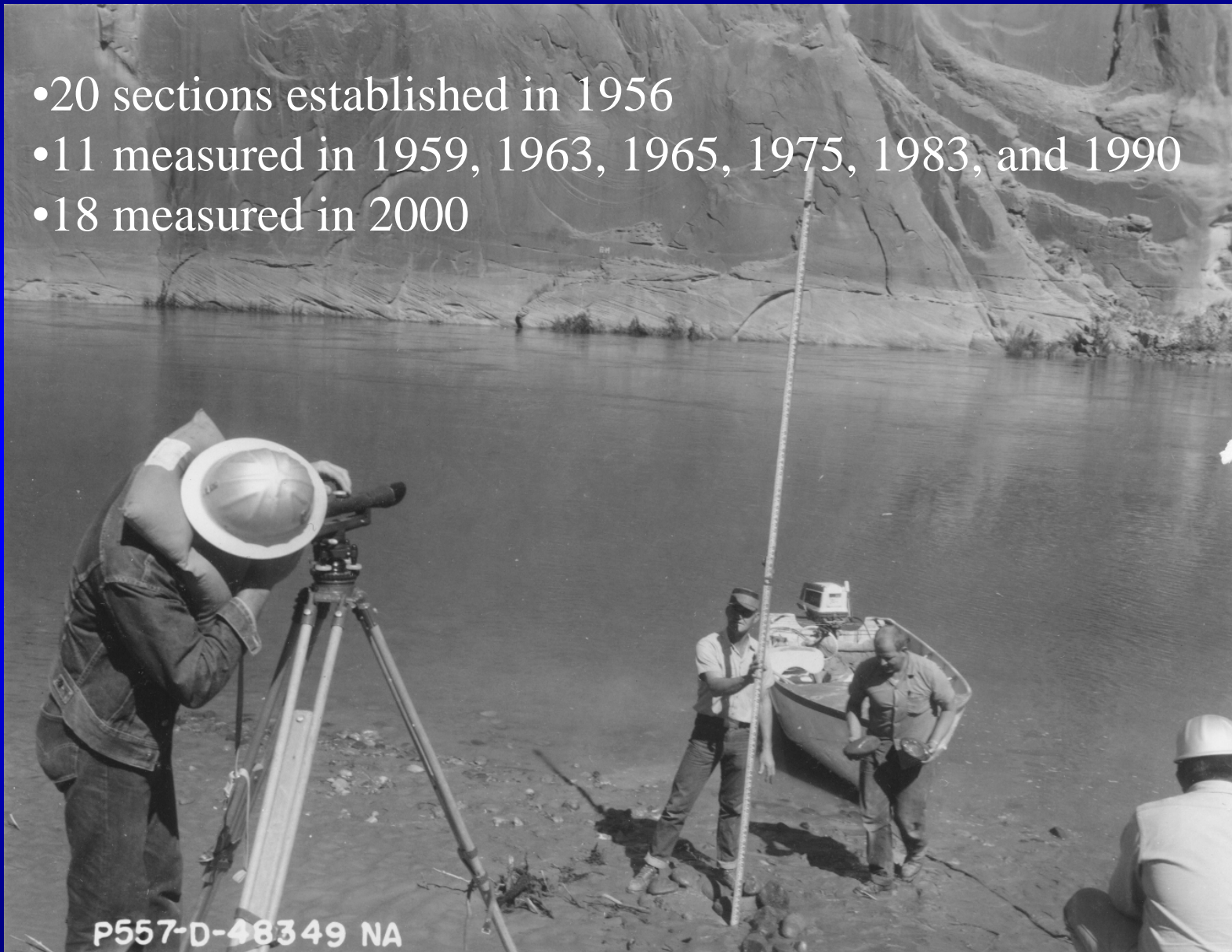
The Reclamation monitoring “Ranges”



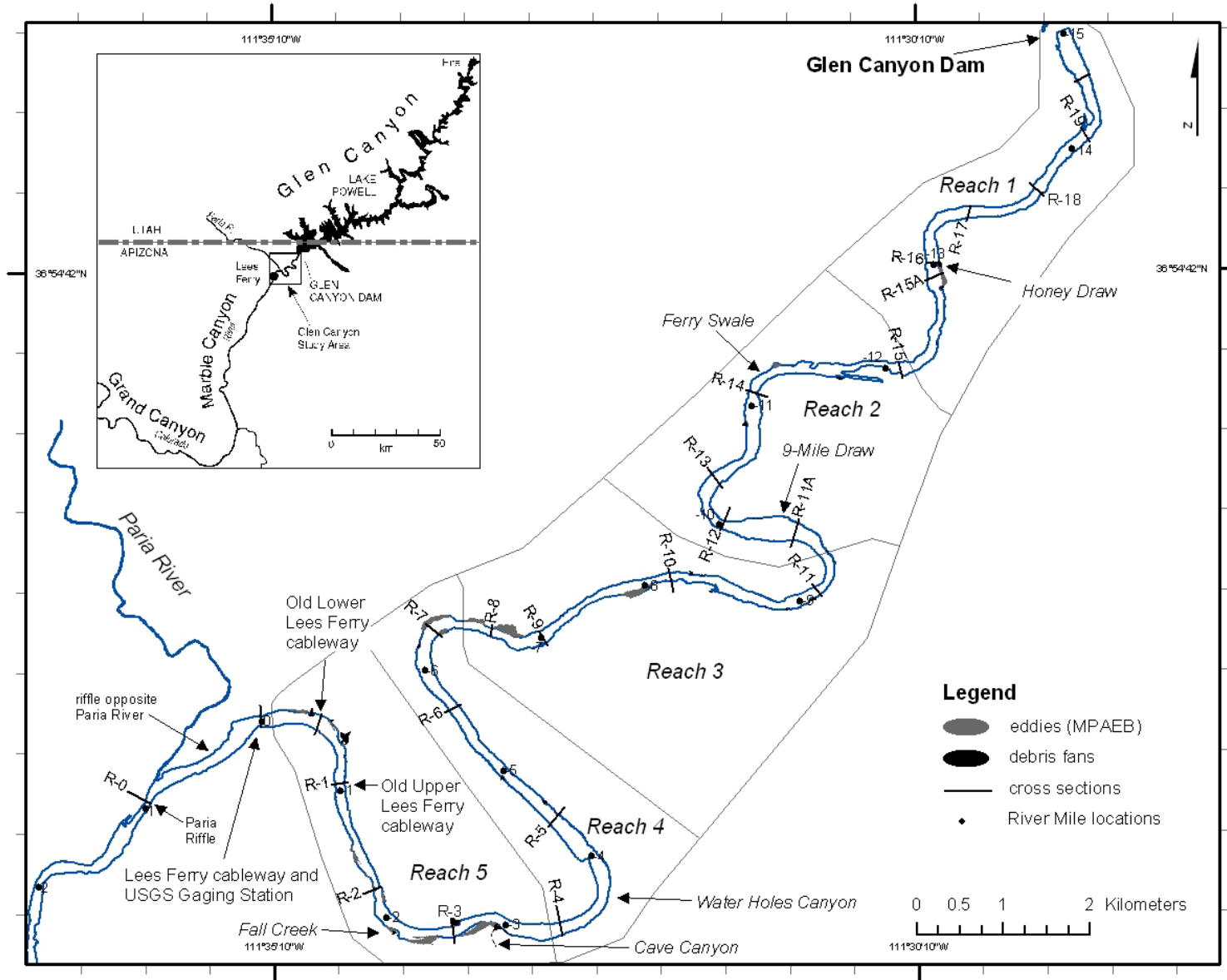
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The Reclamation monitoring “Ranges”

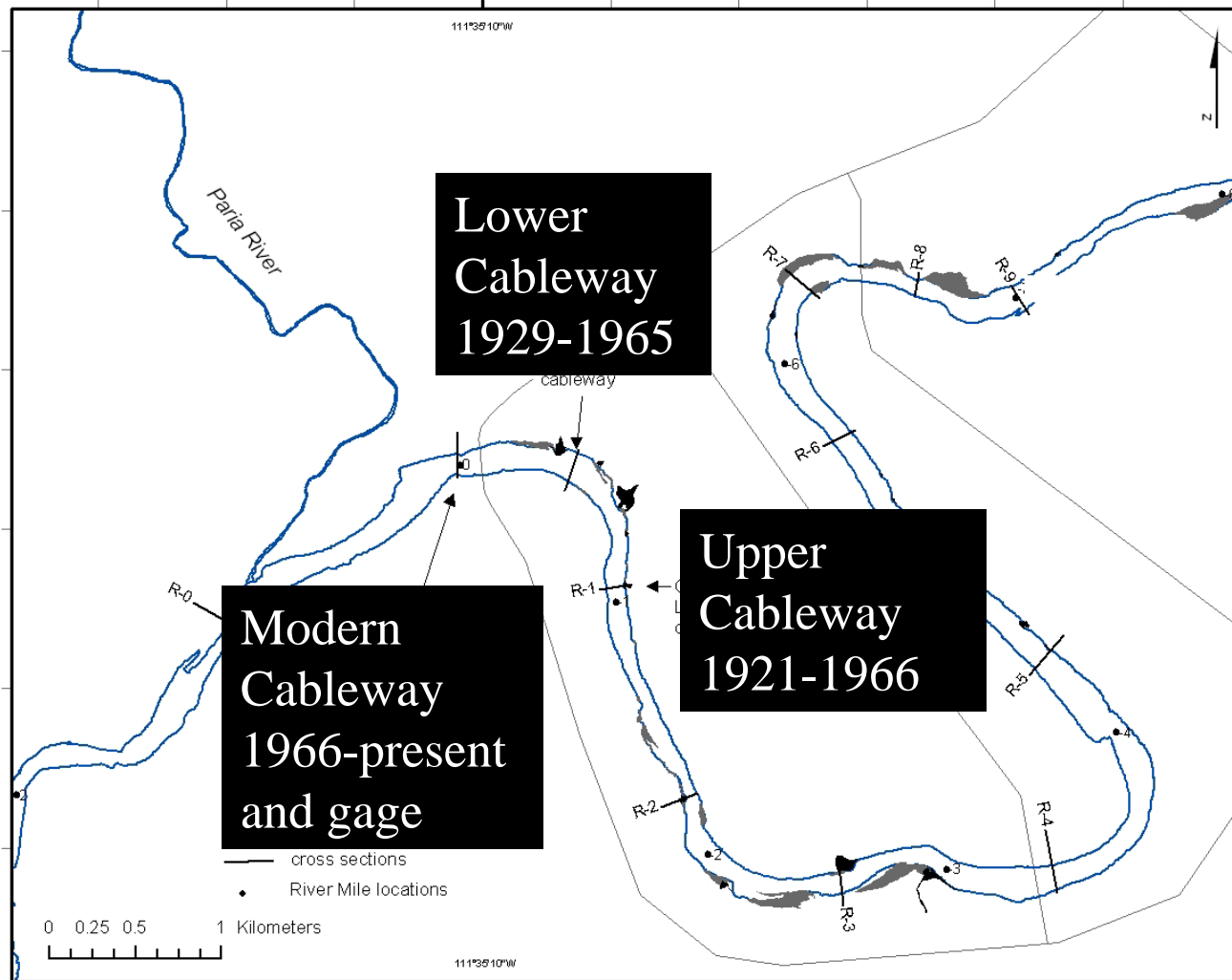
- 20 sections established in 1956
- 11 measured in 1959, 1963, 1965, 1975, 1983, and 1990
- 18 measured in 2000



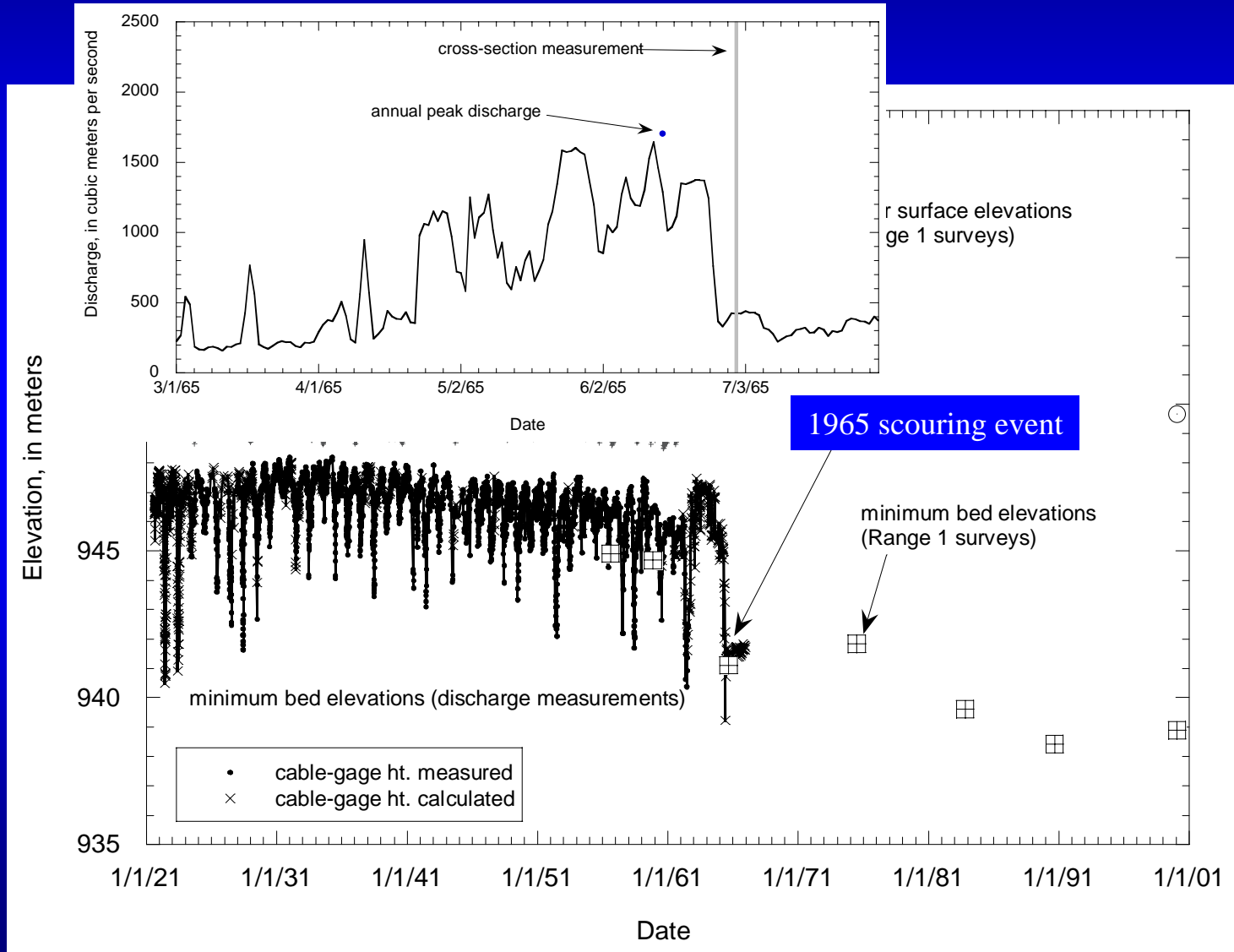
Glen Canyon Location Map



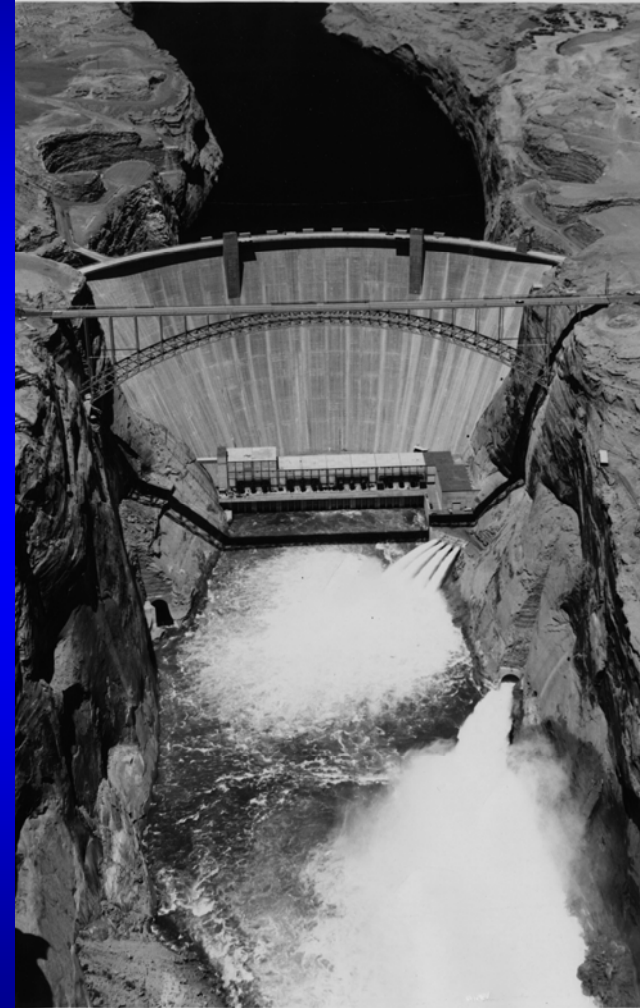
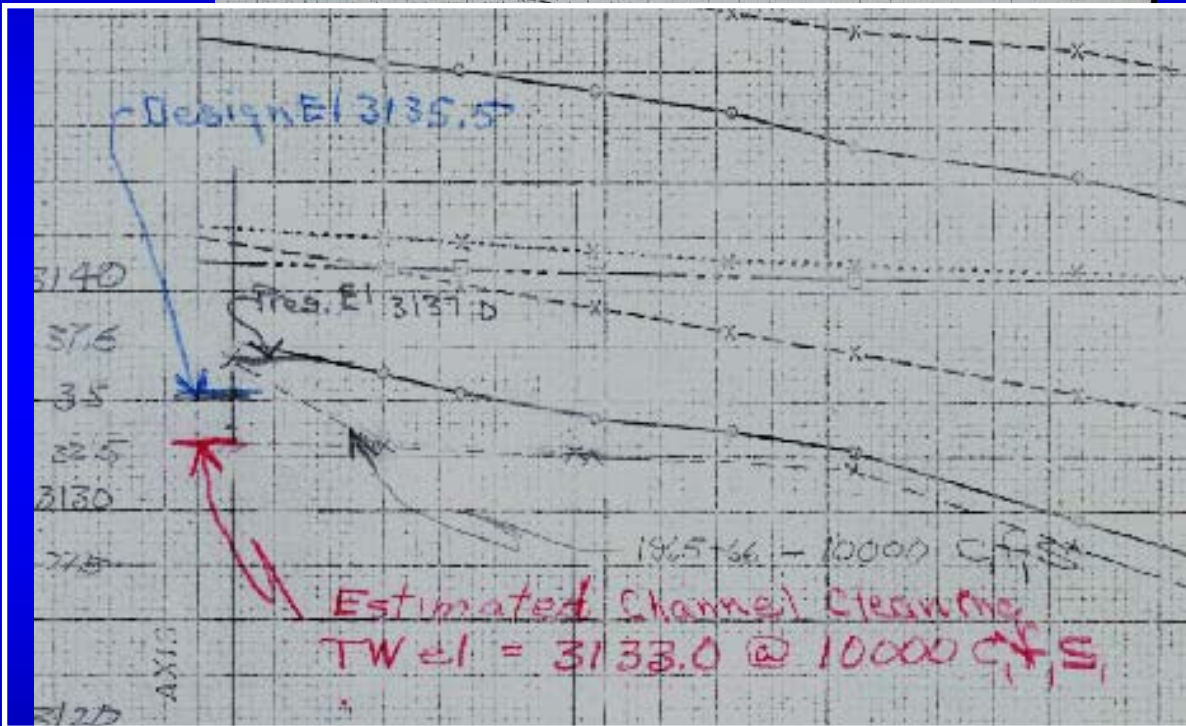
Lees Ferry Gaging Station



Lees Ferry Upper Cableway Minimum Bed Elevation

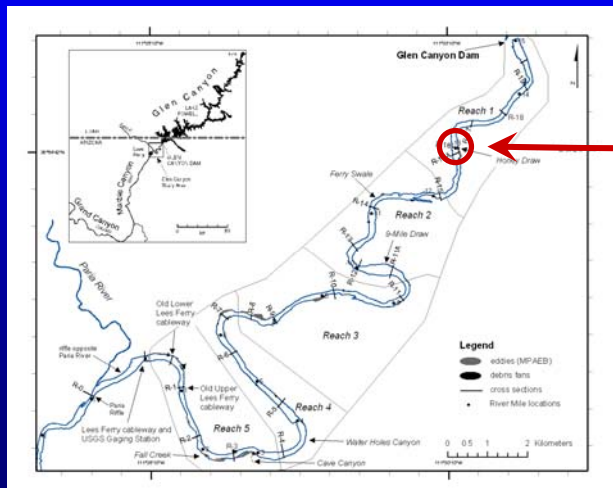
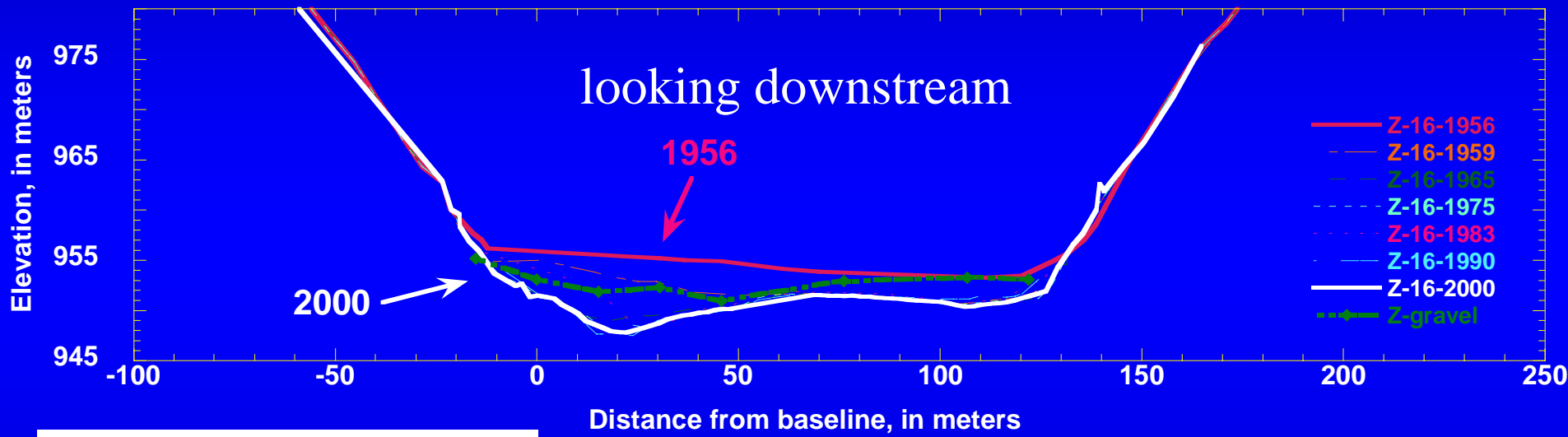


“Channel Cleaning” Flows



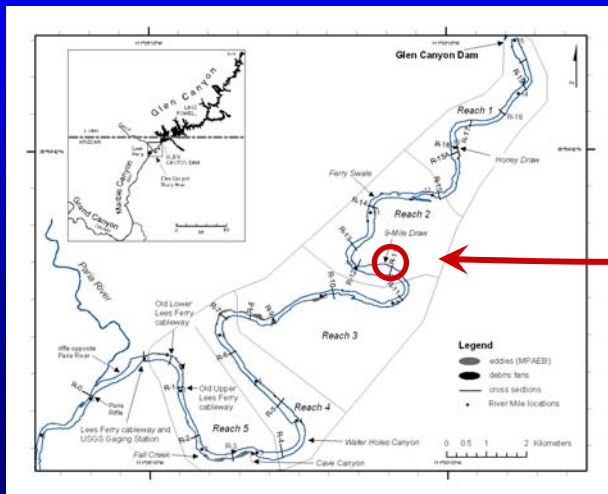
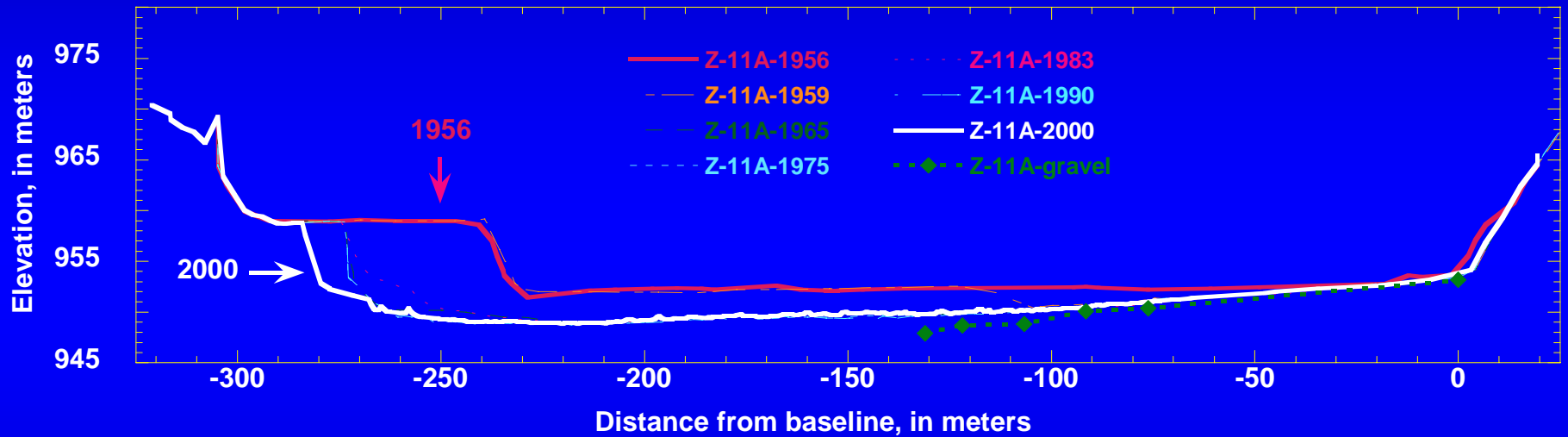
Cross section showing bed degradation, 1956-2000

Range 16, 4.3 km downstream from Glen Canyon Dam



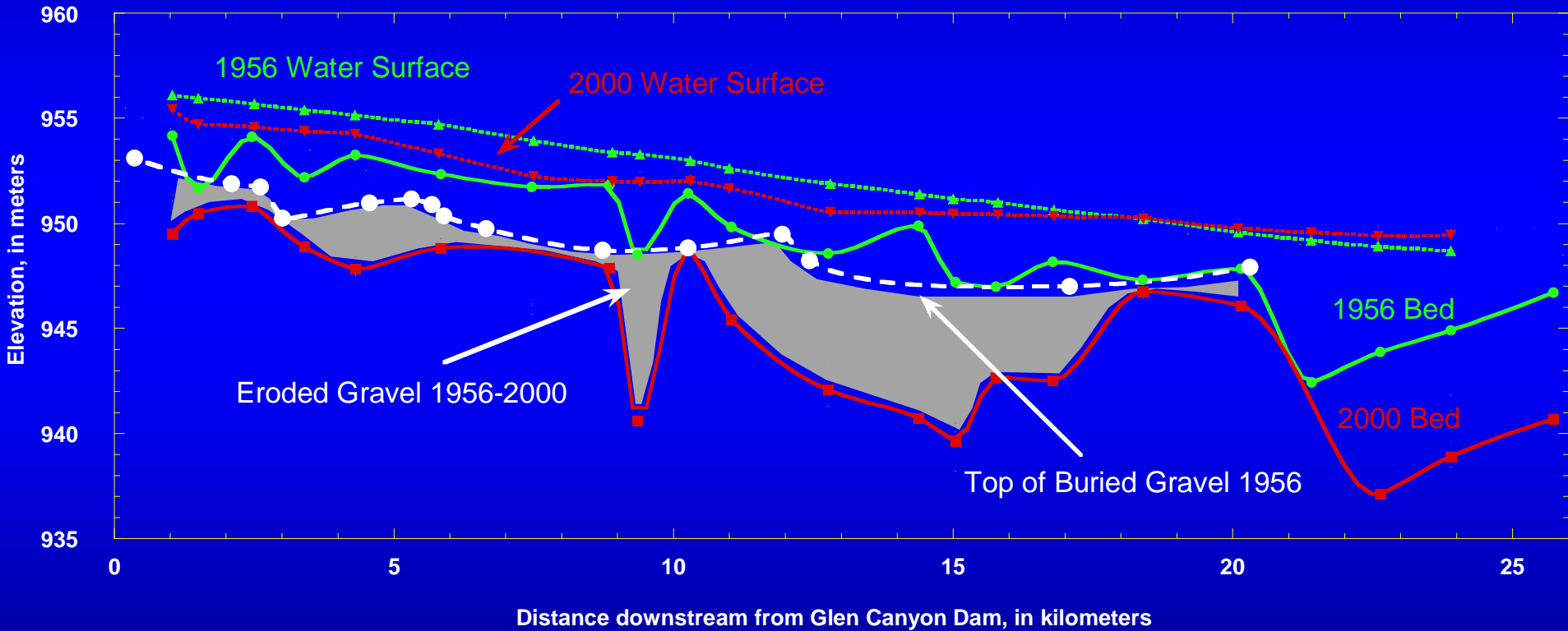
Cross section showing bed degradation, 1956-2000

Range 11a, 10.3 km downstream from Glen Canyon Dam

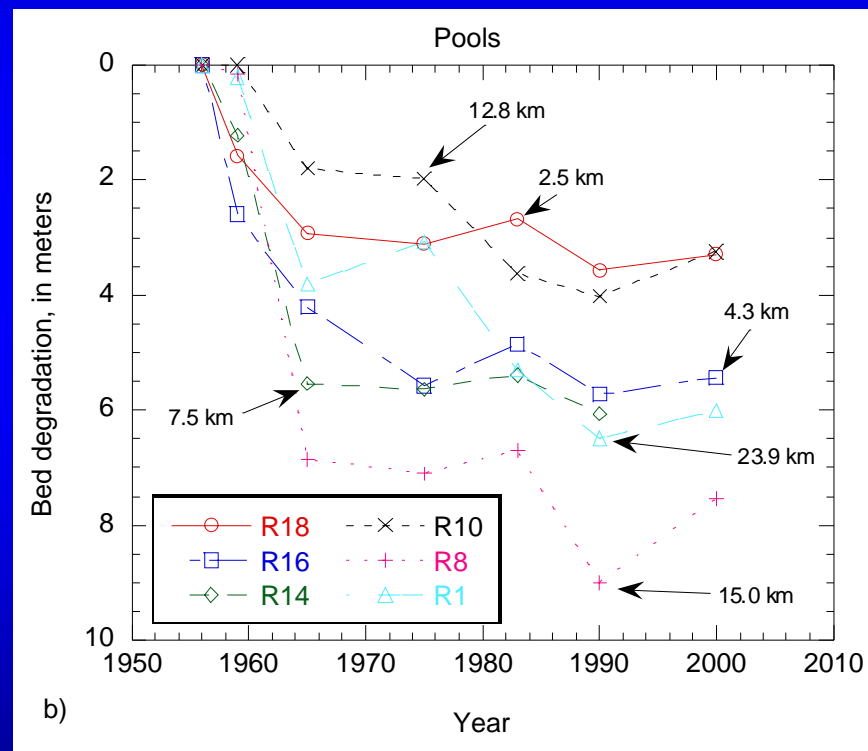
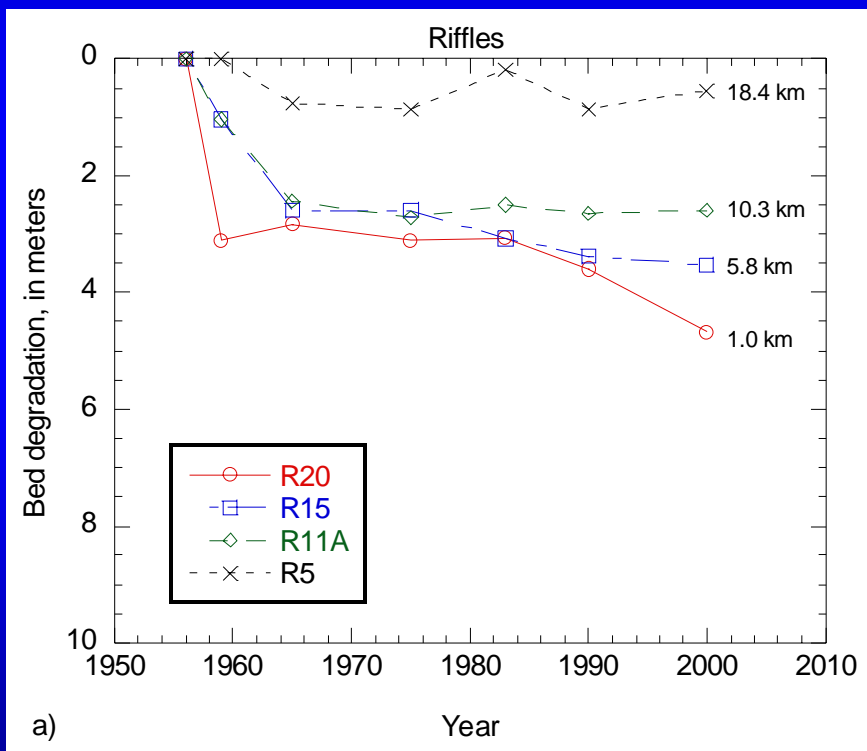


looking downstream

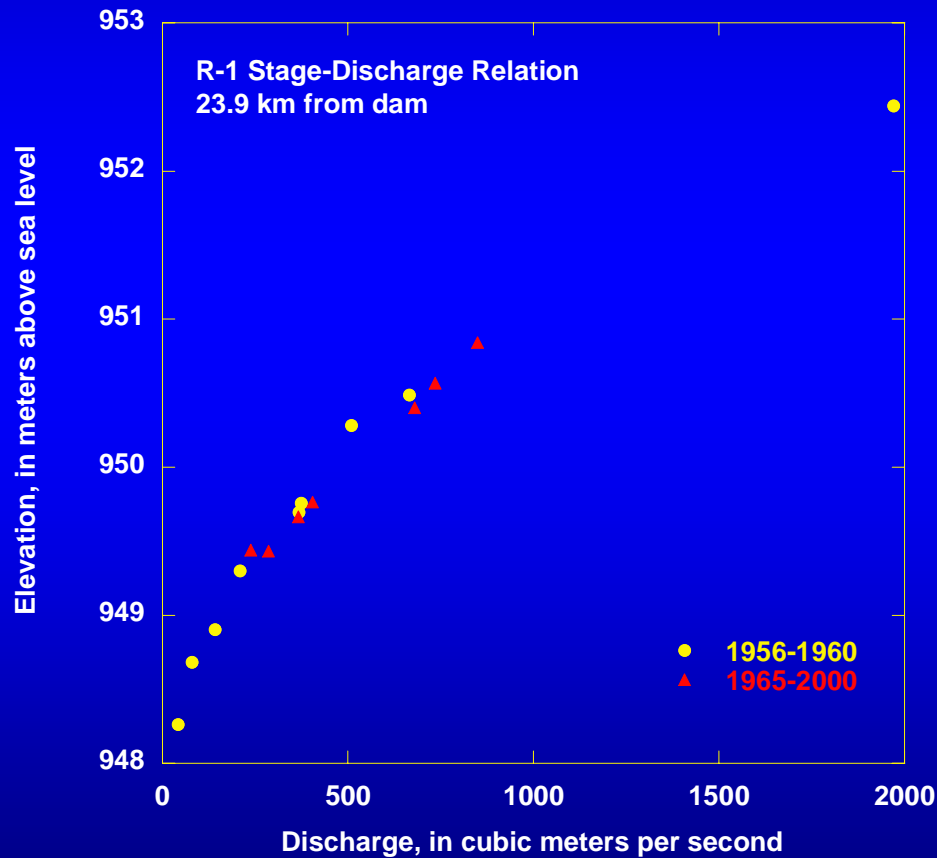
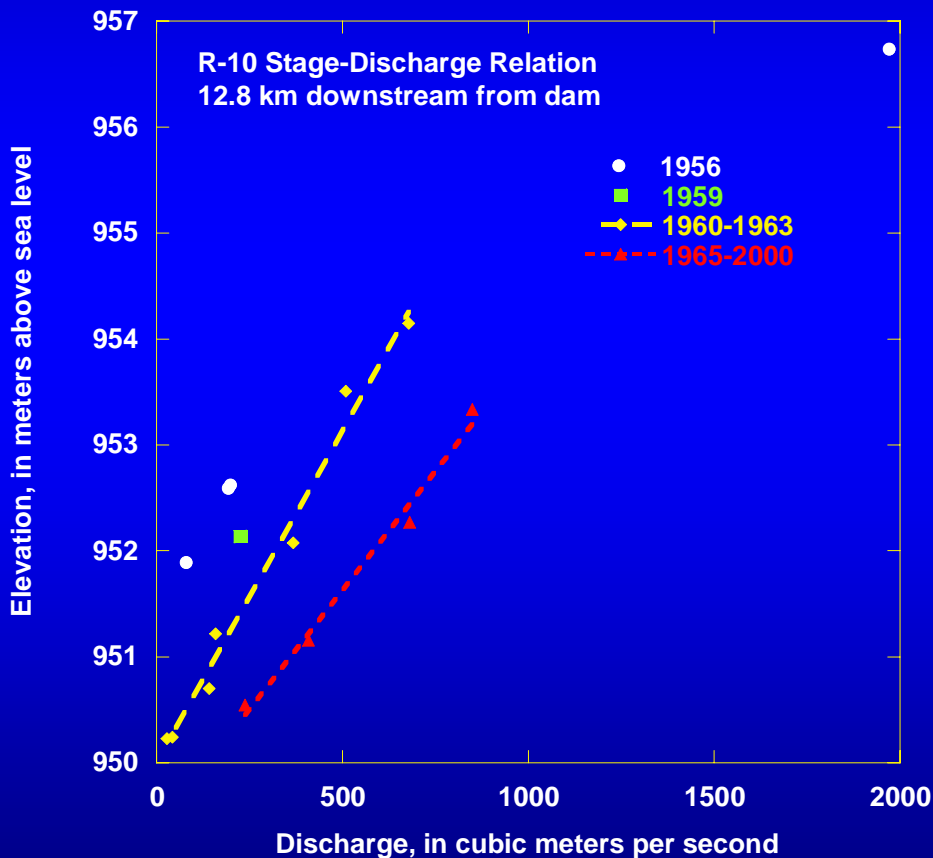
Longitudinal Profile of Bed Degradation: 1956 - 2000



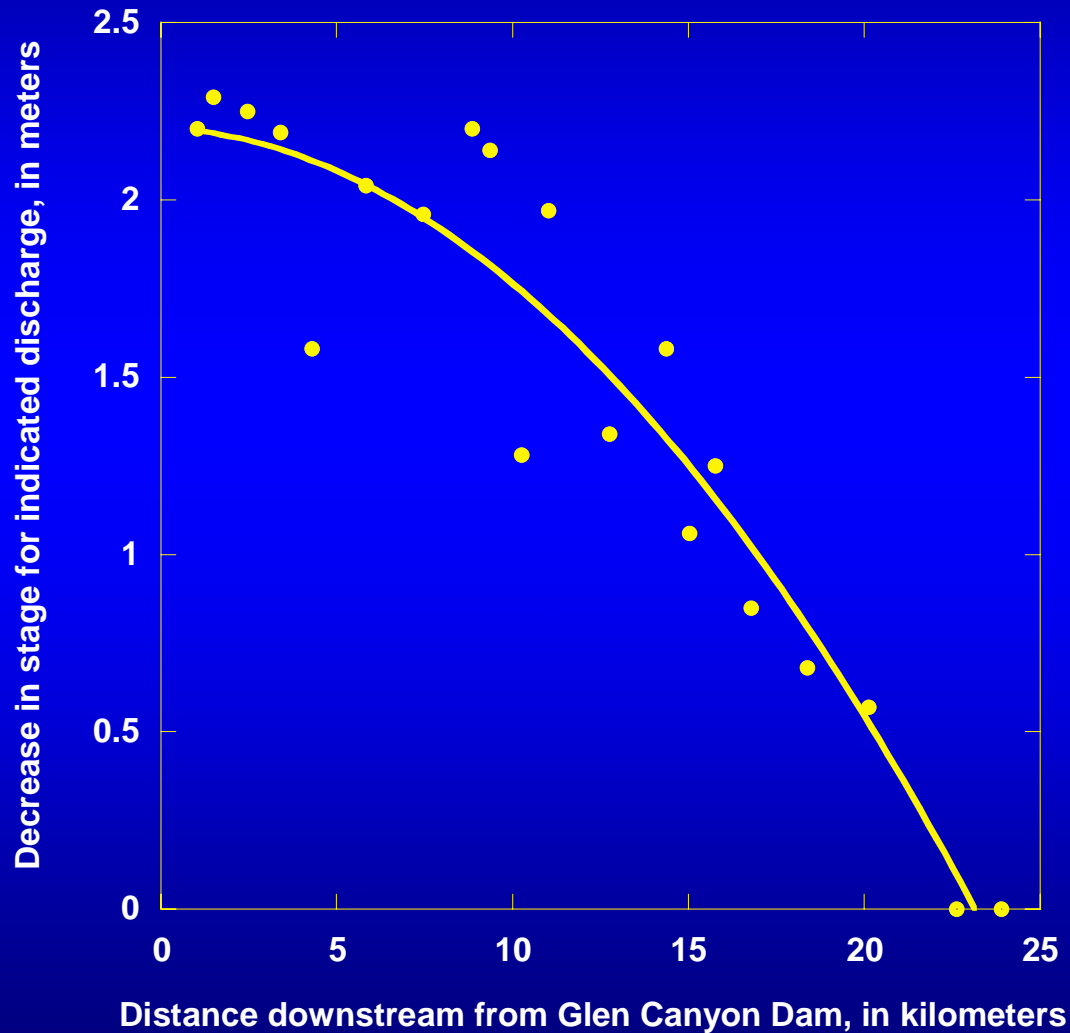
Minimum bed elevation from 1956 to 2000 for cross-sections located in riffles and pools



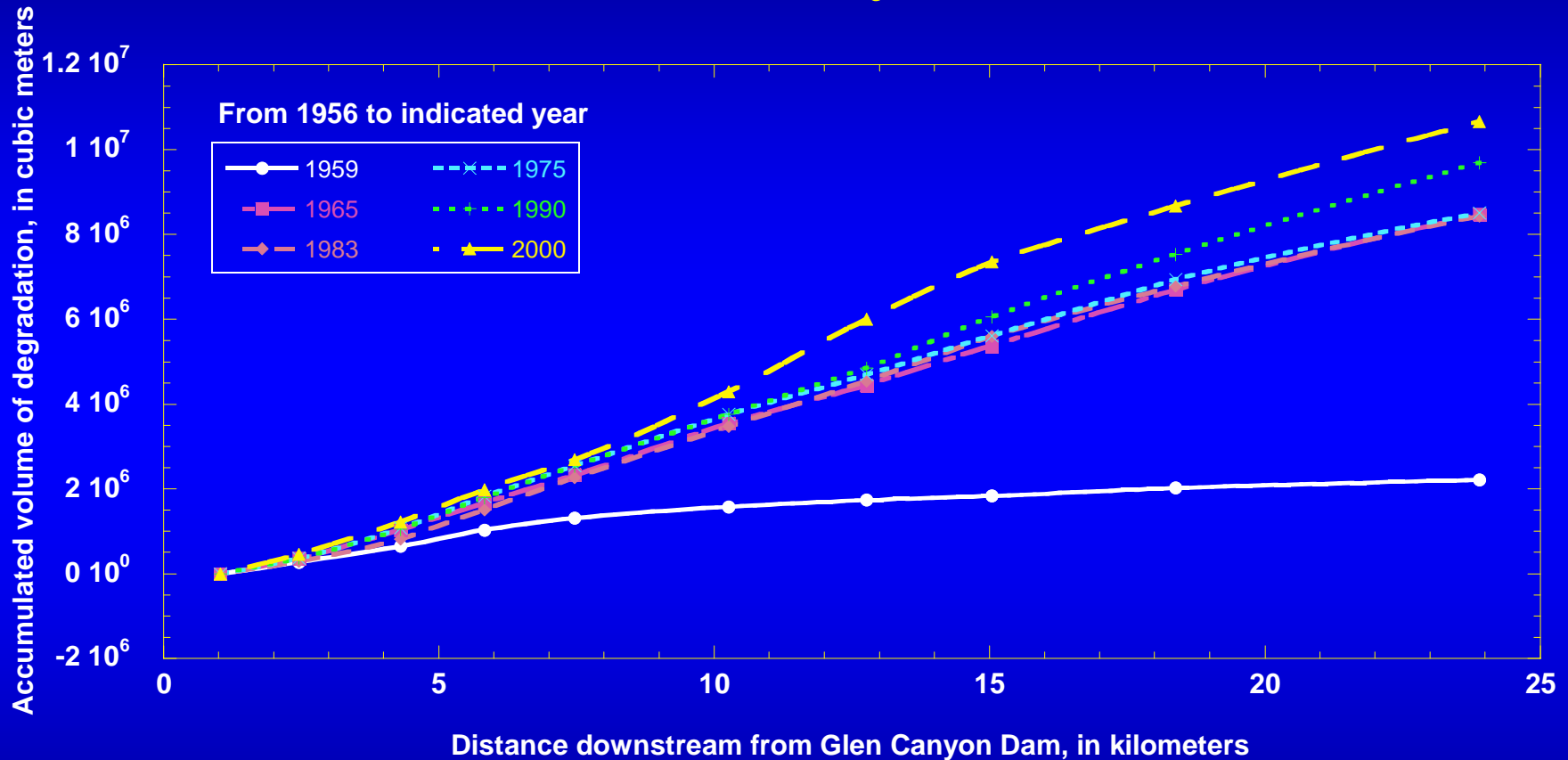
Adjustment of Stage-Discharge Relations: Greatest at upstream end of Reach



Drop in Stage-Discharge Relation Decreases with Distance Downstream



Accumulated sediment evacuation from Glen Canyon



8.3 million m³ sediment evacuation predicted in 1957

9.9 million m³ measured in 1975

10.7 million m³ measured in 2000 – exceeds predicted by ~ 30%

Summary -- Bed Degradation

- Most degradation resulted from 1965 channel-cleaning flows
- Pool and riffle segments have emerged in the process of bed degradation
 - Degradation of riffles decreases in downstream direction, has decreased with time, and has probably stopped.
 - Degradation of pools does NOT decrease with distance below dam and continues during post-dam high flows.
- Degradation of channel controls has caused corresponding changes in stage-discharge relations.

Measuring Changes in Channel-Side Deposits

- Long pre- and post-dam record of deposit elevation changes at Lees Ferry Lower Cableway.
- Spatially comprehensive depiction of deposits between Glen Canyon Dam and Lees Ferry from aerial photographs taken in 1952, 1984, 1990, 1992, and 1996.

Glen Canyon - 1956



PP-1591

Glen Canyon 1889 - 1992



1889

Stanton Expedition



1992

R.H. Webb collection

Glen Canyon 1956 - 2000



July 1956



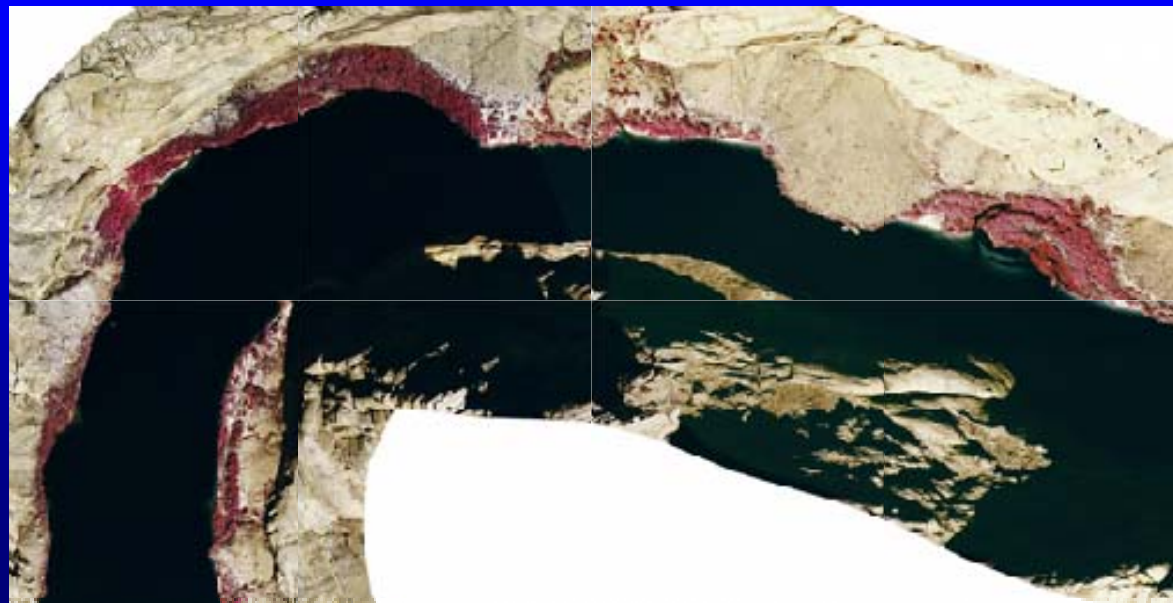
September 2000

Glen Canyon 1952 - 1999

1952



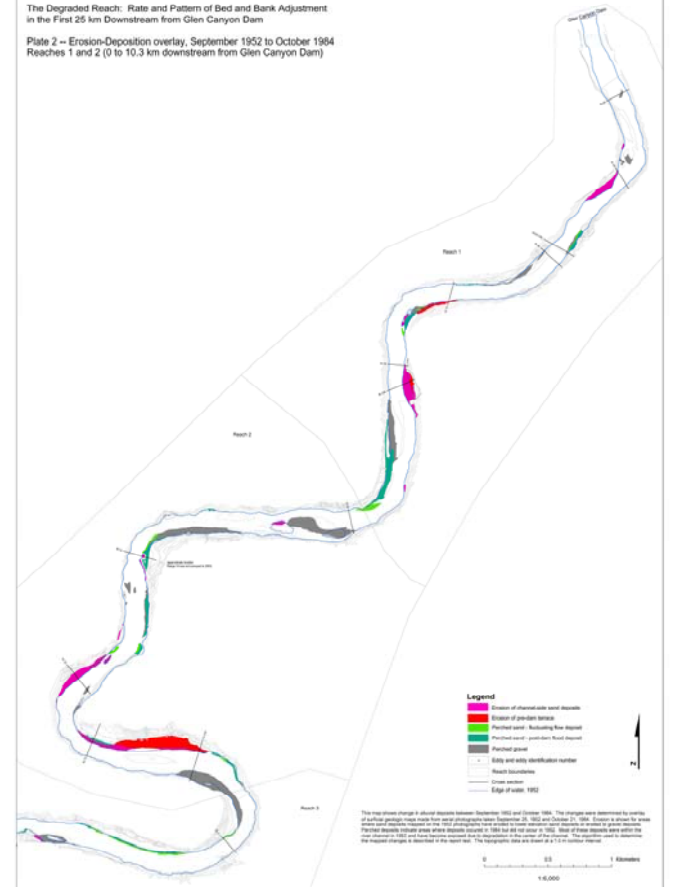
1998



Mapping from Air Photos

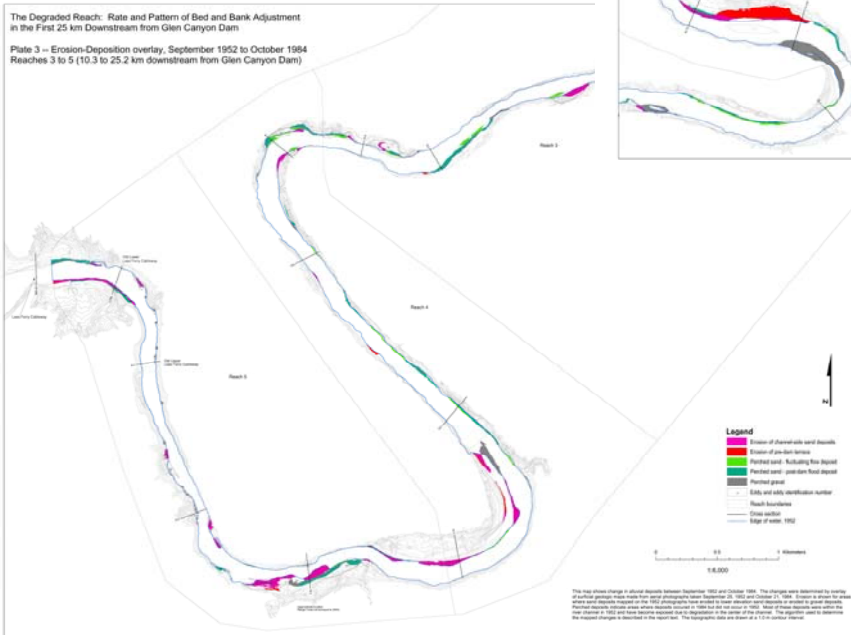
The Degraded Reach: Rate and Pattern of Bed and Bank Adjustment in the First 25 km Downstream from Glen Canyon Dam

Plate 2 – Erosion-Deposition overlay, September 1952 to October 1964 Reaches 1 and 2 (0 to 10.3 km downstream from Glen Canyon Dam)

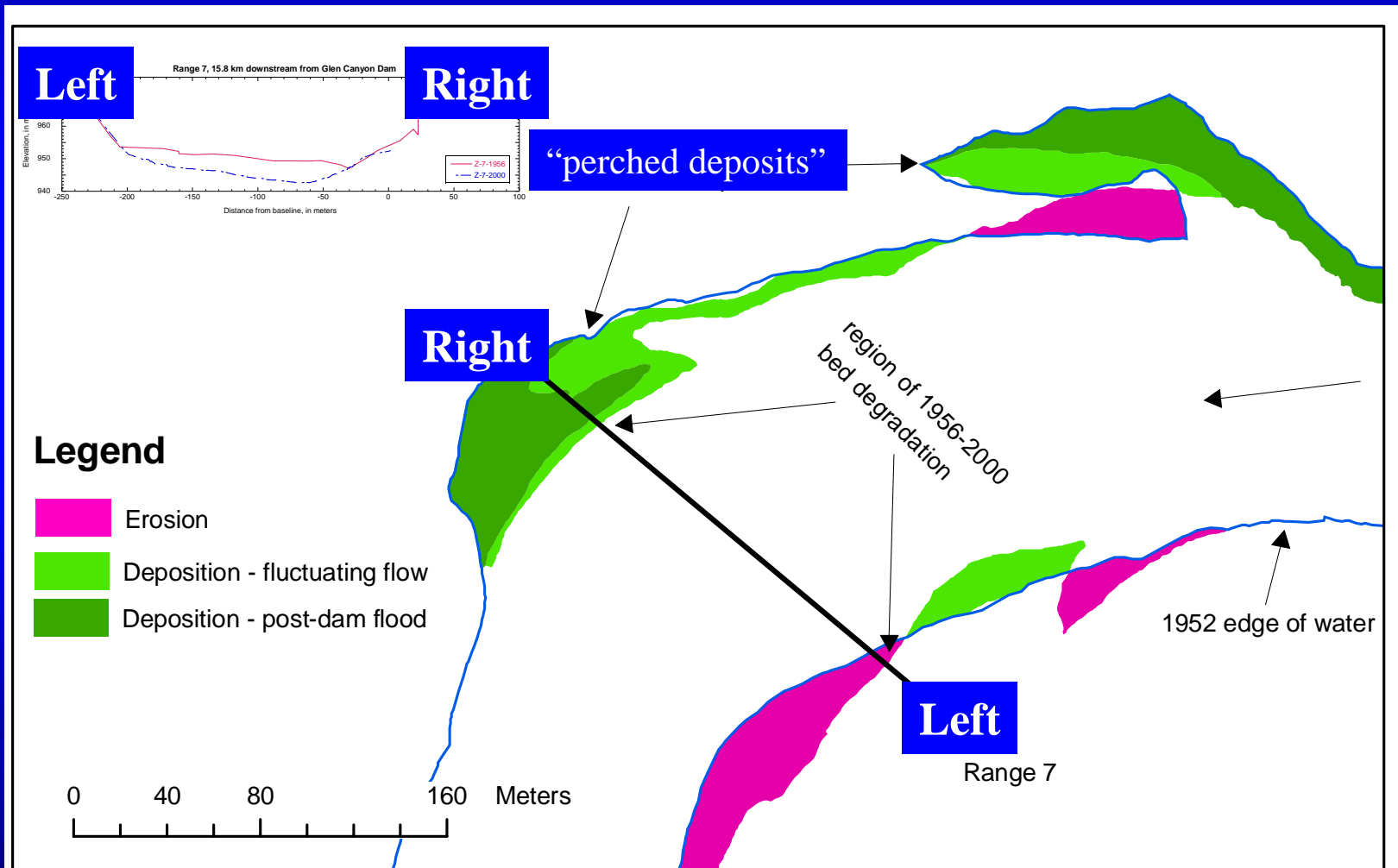


The Degraded Reach: Rate and Pattern of Bed and Bank Adjustment in the First 25 km Downstream from Glen Canyon Dam

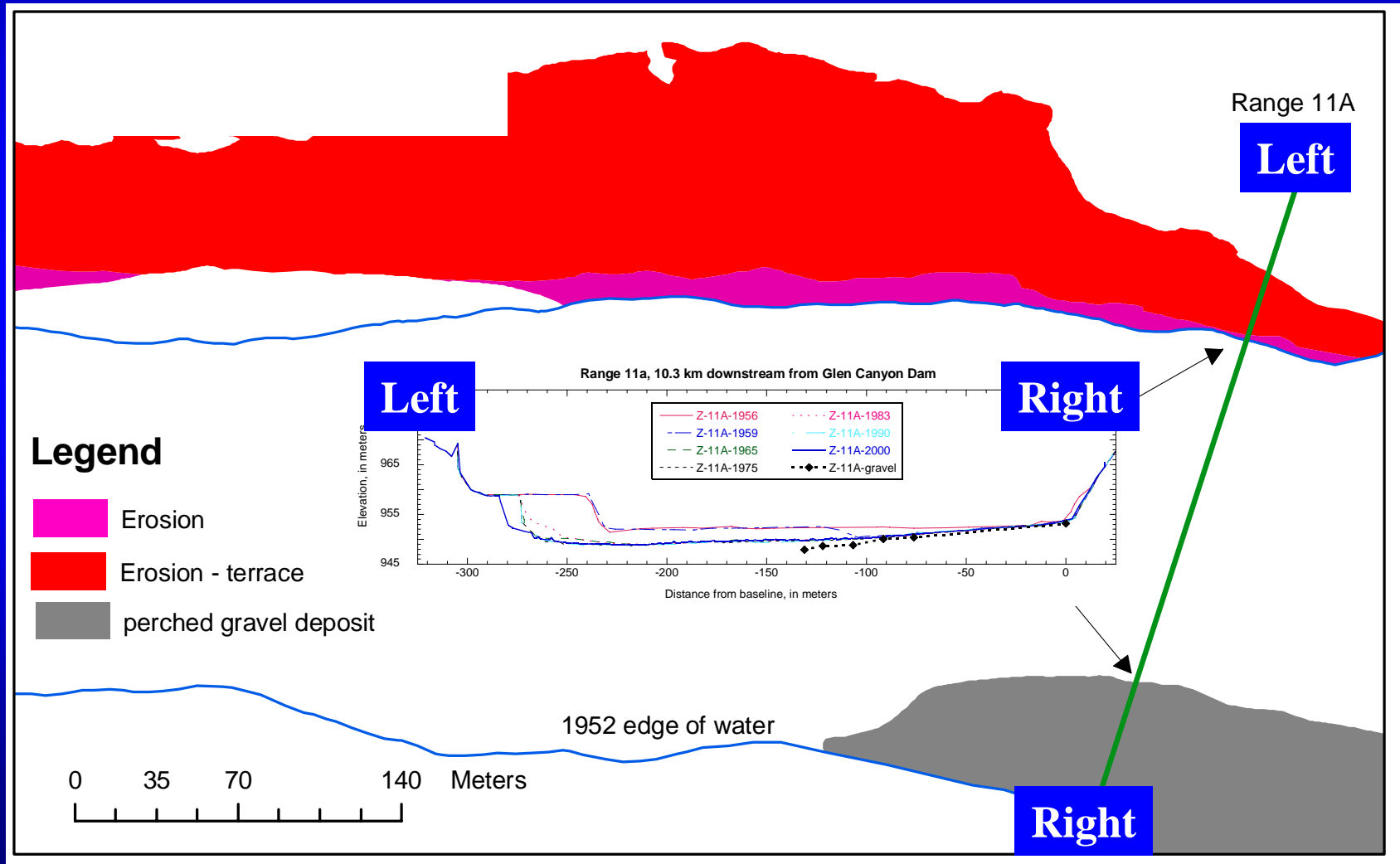
Plate 3 – Erosion-Deposition overlay, September 1952 to October 1964 Reaches 3 to 5 (10.3 to 25.2 km downstream from Glen Canyon Dam)

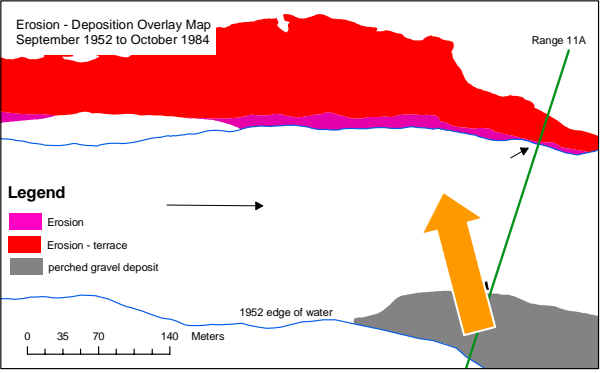


Styles of channel adjustment in segments with degrading bed and **decreasing** stage-discharge relation: Eroded and “perched” channel-side deposits

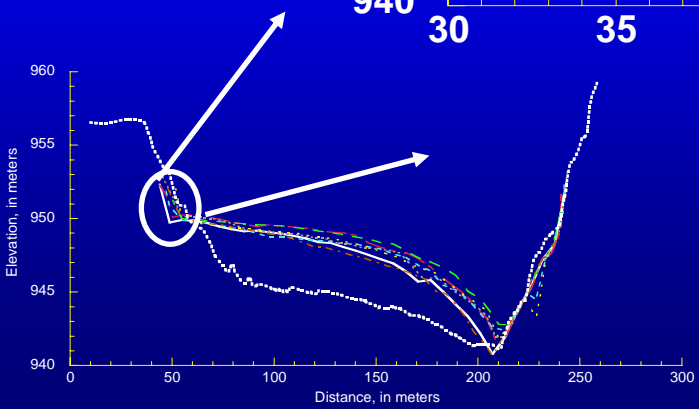
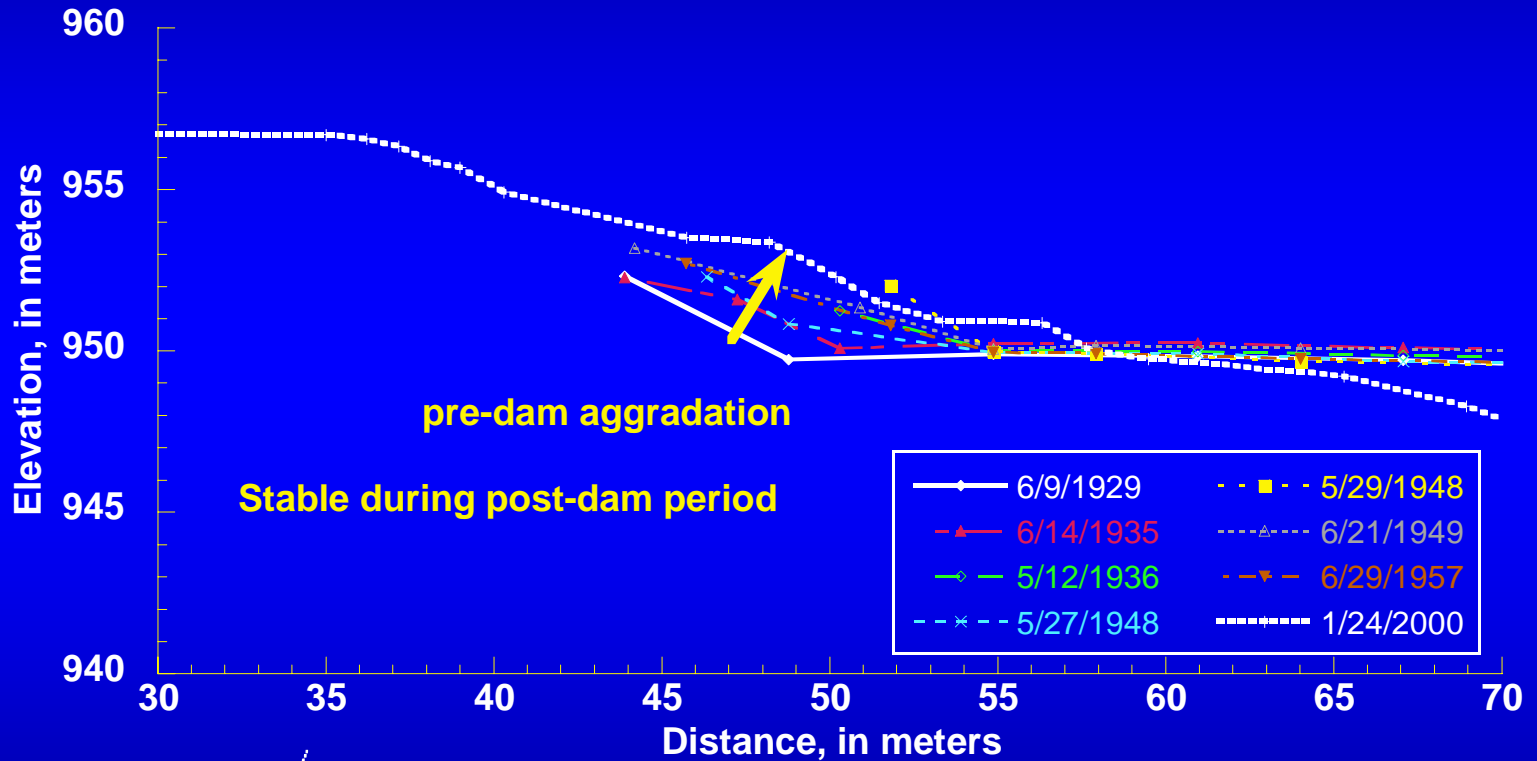


Styles of channel adjustment in segments with degrading bed and **decreasing** stage-discharge relation: Eroded pre-dam terrace and perched gravel bar



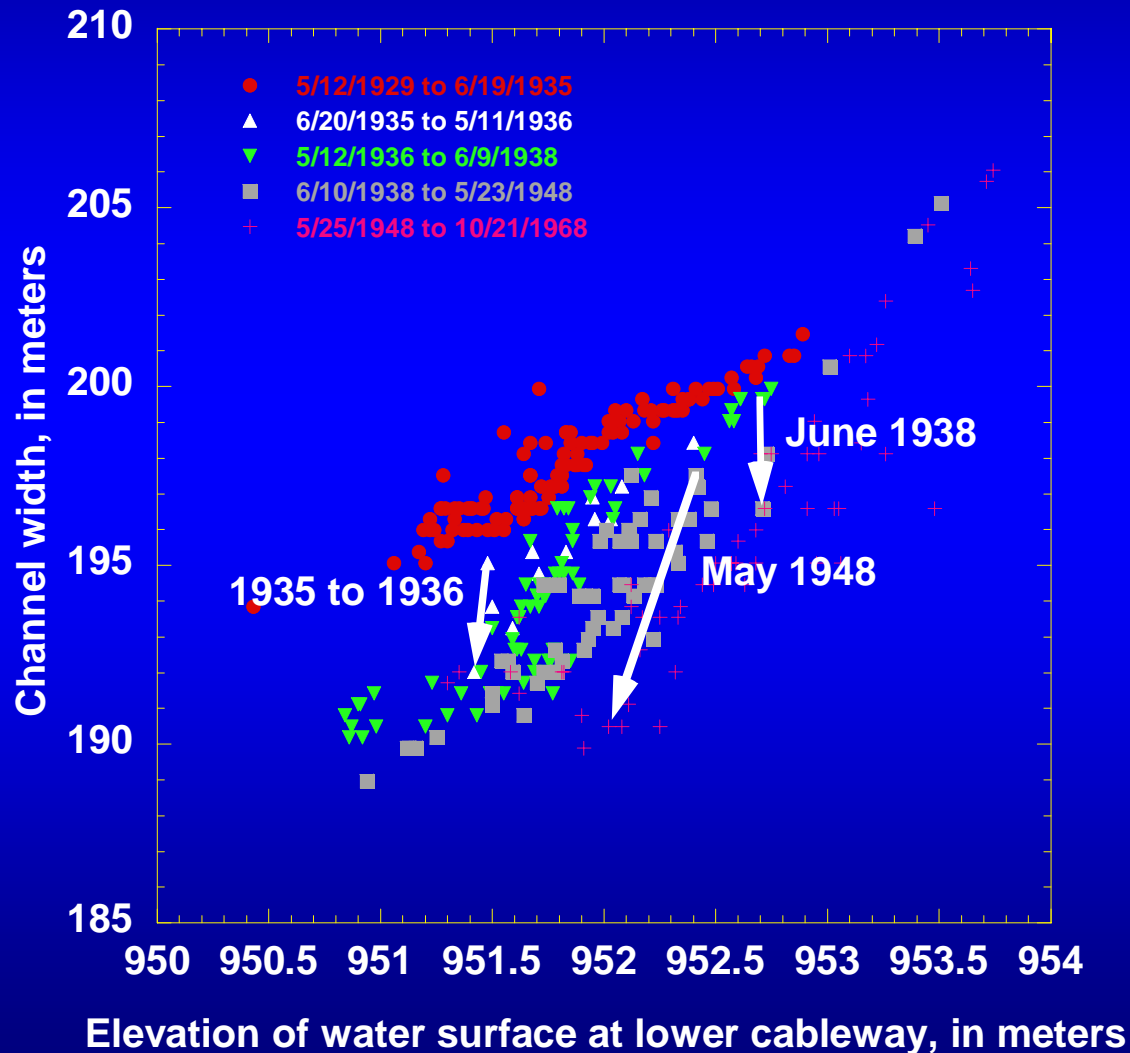


Styles of channel adjustment in segments with degrading bed and **stable** stage-discharge relation: Bed Scour and bank deposition

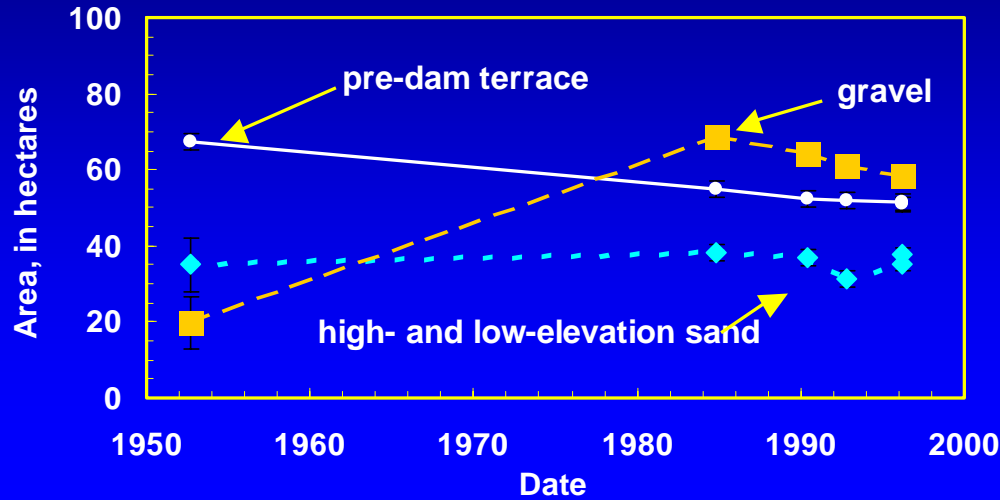


Lees Ferry, Lower Cableway

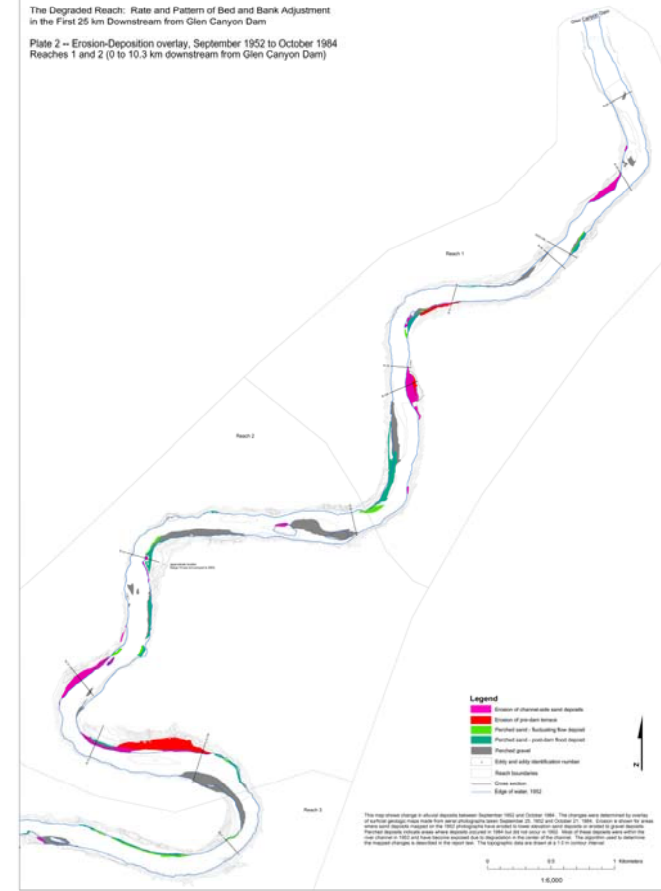
Progressive decrease in channel width at Lower Cableway



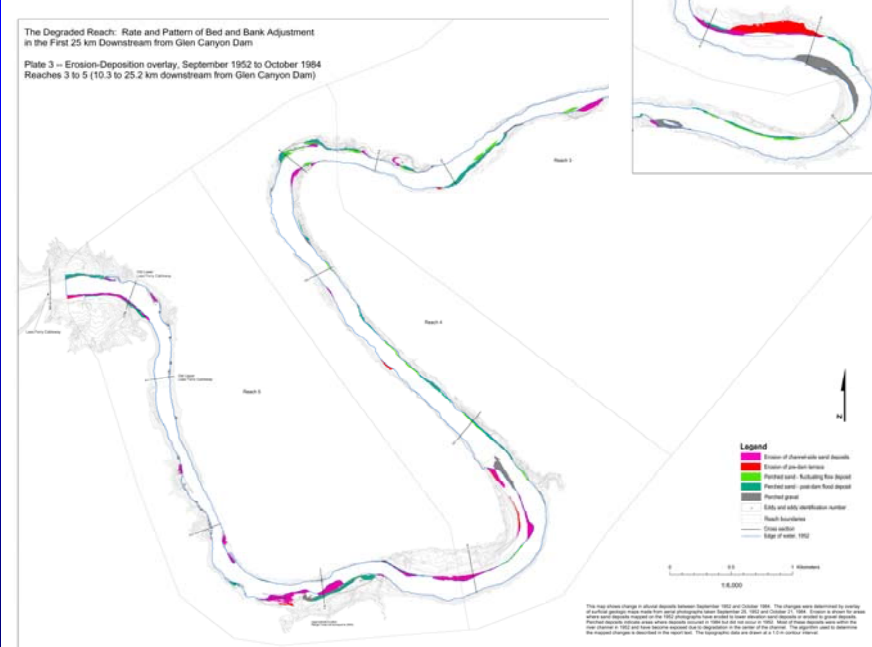
Post-dam distribution of alluvial deposits



The Degraded Reach: Rate and Pattern of Bed and Bank Adjustment in the First 25 km Downstream from Glen Canyon Dam
 Plate 2 – Erosion-Deposition overlay, September 1952 to October 1984 Reaches 1 and 2 (0 to 10.3 km downstream from Glen Canyon Dam)



The Degraded Reach: Rate and Pattern of Bed and Bank Adjustment in the First 25 km Downstream from Glen Canyon Dam
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Legend

- Erosion of pre-dam terrace
- Erosion of pre-dam terrace
- Pre-dam terrace - post-dam flood deposit
- Pre-dam terrace - post-dam flood deposit
- Pre-dam terrace
- High and low elevation sand
- Reach boundaries
- Class within
- Edge of reach, 1952

The map shows the change in alluvial deposits between September 1952 and October 1984. The deposits were determined by aerial photography taken from the aerial photography taken September 20, 1952 and October 21, 1984. Erosion is shown for areas where the 1952 deposits were not present in 1984. Deposition is shown for areas where the 1984 deposits were not present in 1952. Reach boundaries are shown as dashed lines. Class within is shown as solid lines. The edge of reach, 1952, is shown as a solid line.

0 50 100 Meters
1:6,000

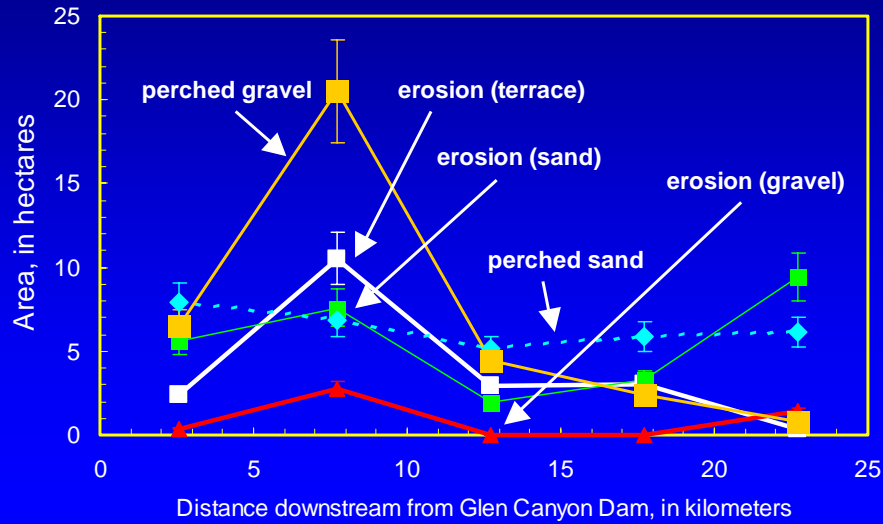
Legend

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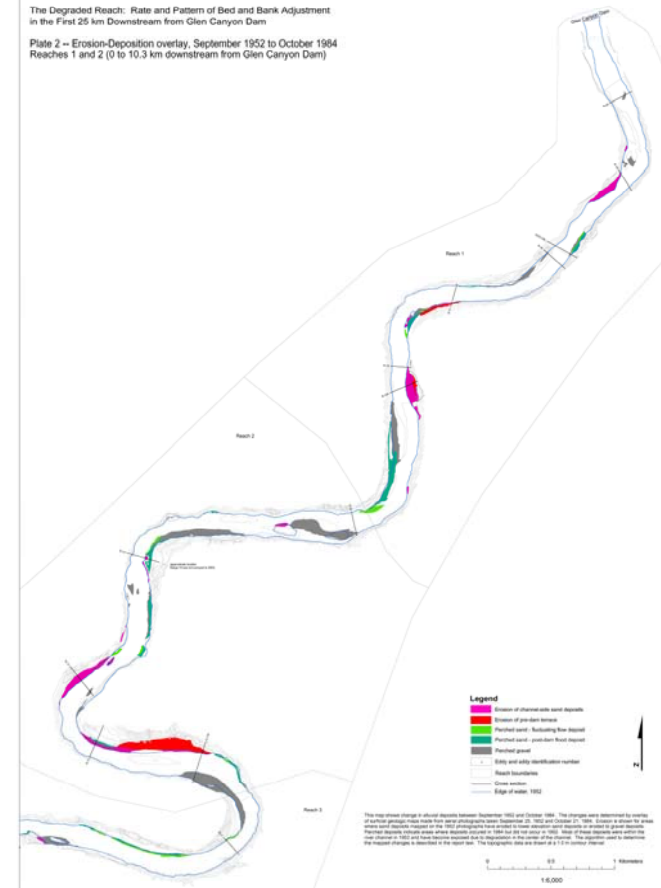
0 50 100 Meters
1:6,000

Post-dam distribution of alluvial deposits



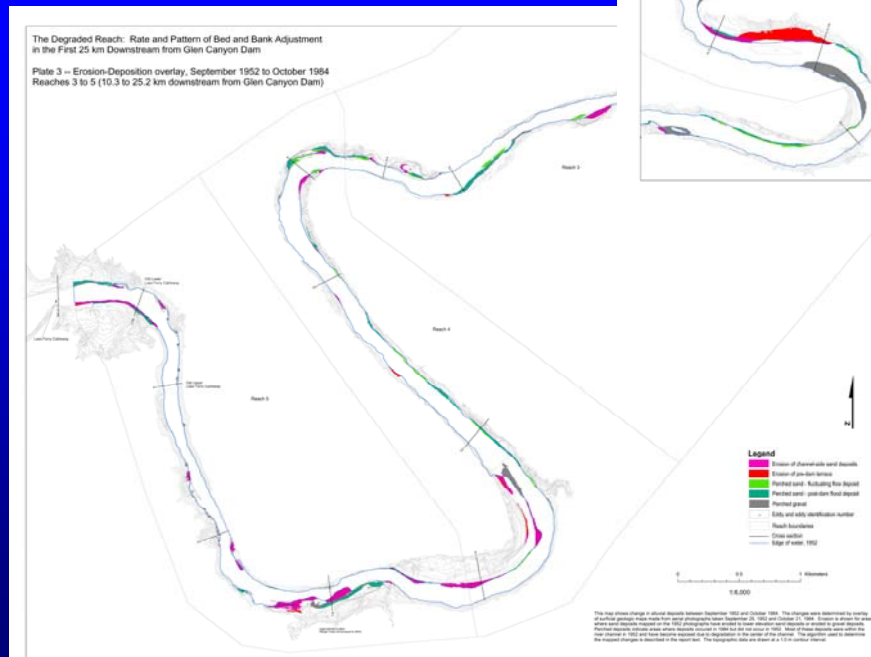
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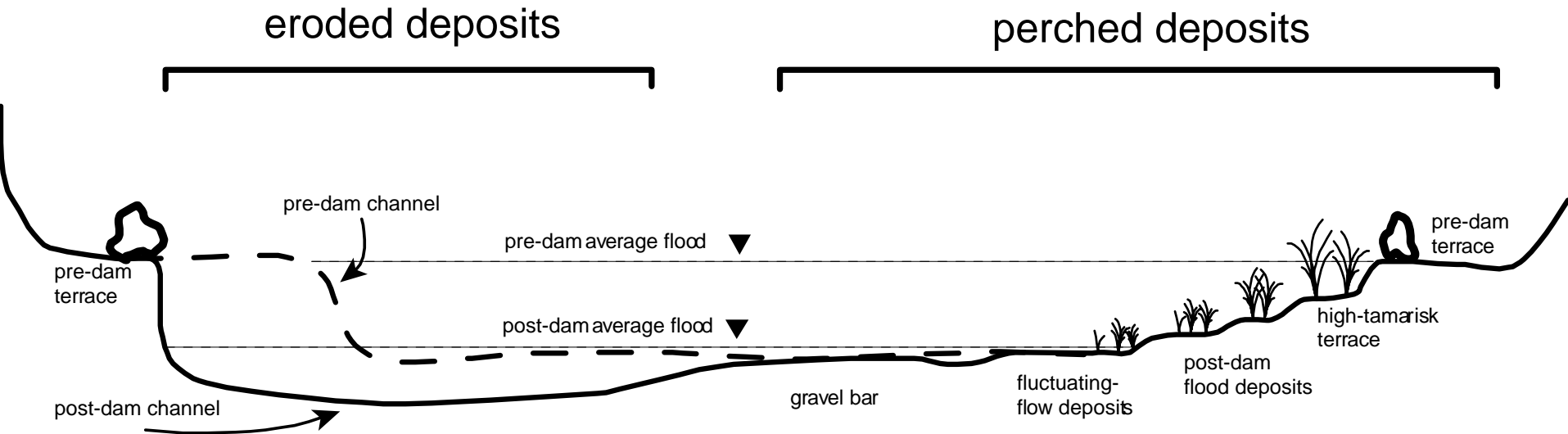


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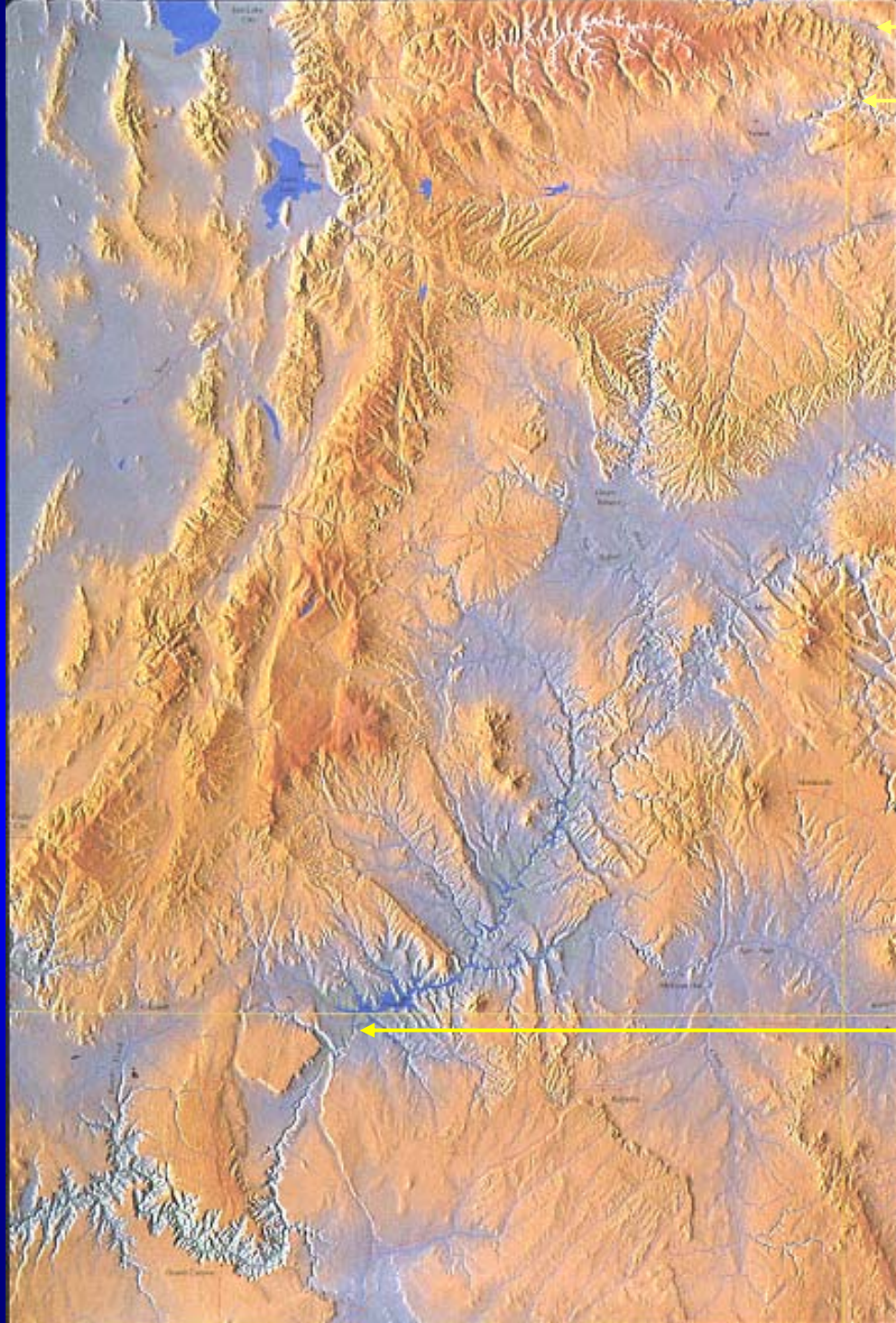


Sketch of Pre- and Post-Dam Channel Cross-Section



Summary – Channel-side deposits

- Segments with degrading bed and decreasing stage-discharge relation
 - Sand and gravel deposits “perched” above active channel and stabilized by vegetation
 - Massive terrace erosion at localized sites during the channel cleaning flows, not widespread throughout reach and current rates of erosion are very low
- Segments with degrading bed and stable stage-discharge relation
 - Pre- and post-dam deposition on channel margins and stabilization by riparian vegetation, resulting in channel narrowing



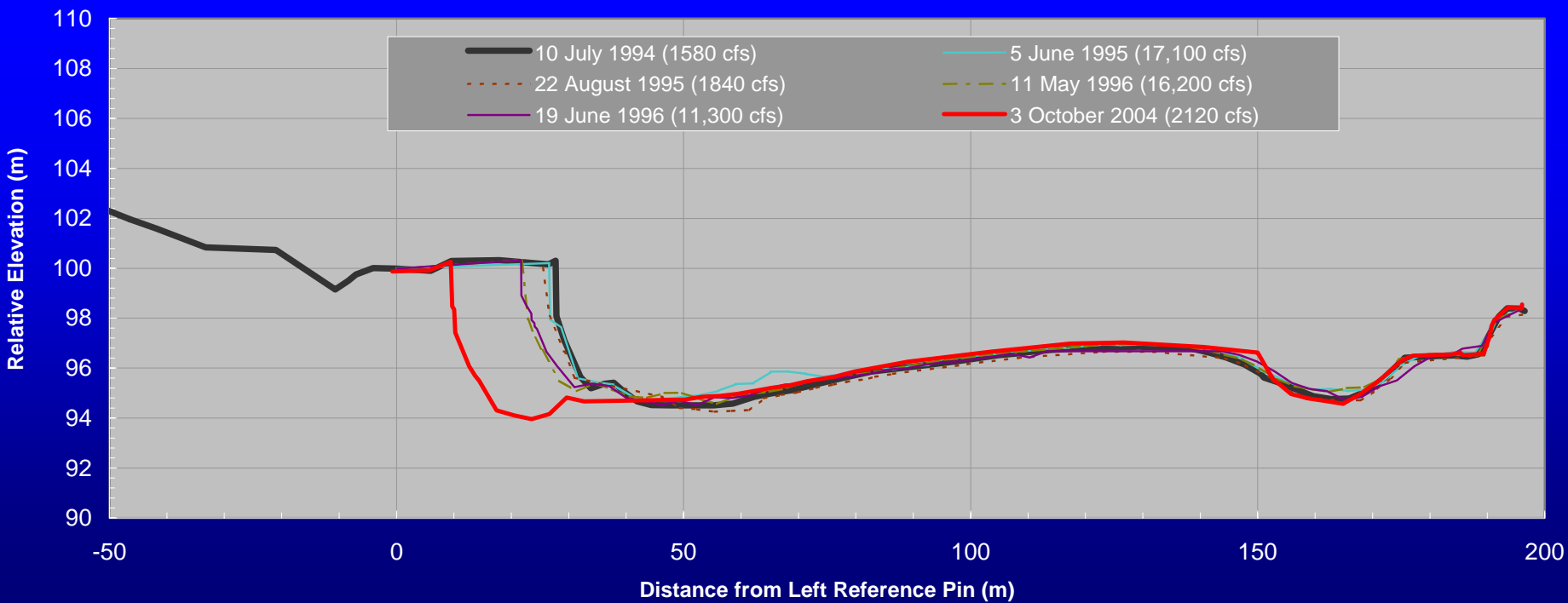
Browns Park

Echo Park

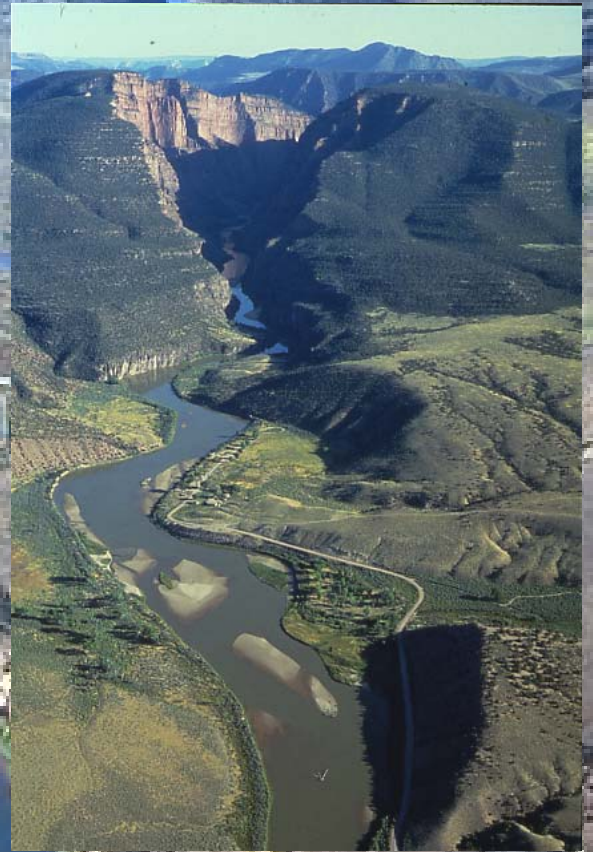
Glen Canyon



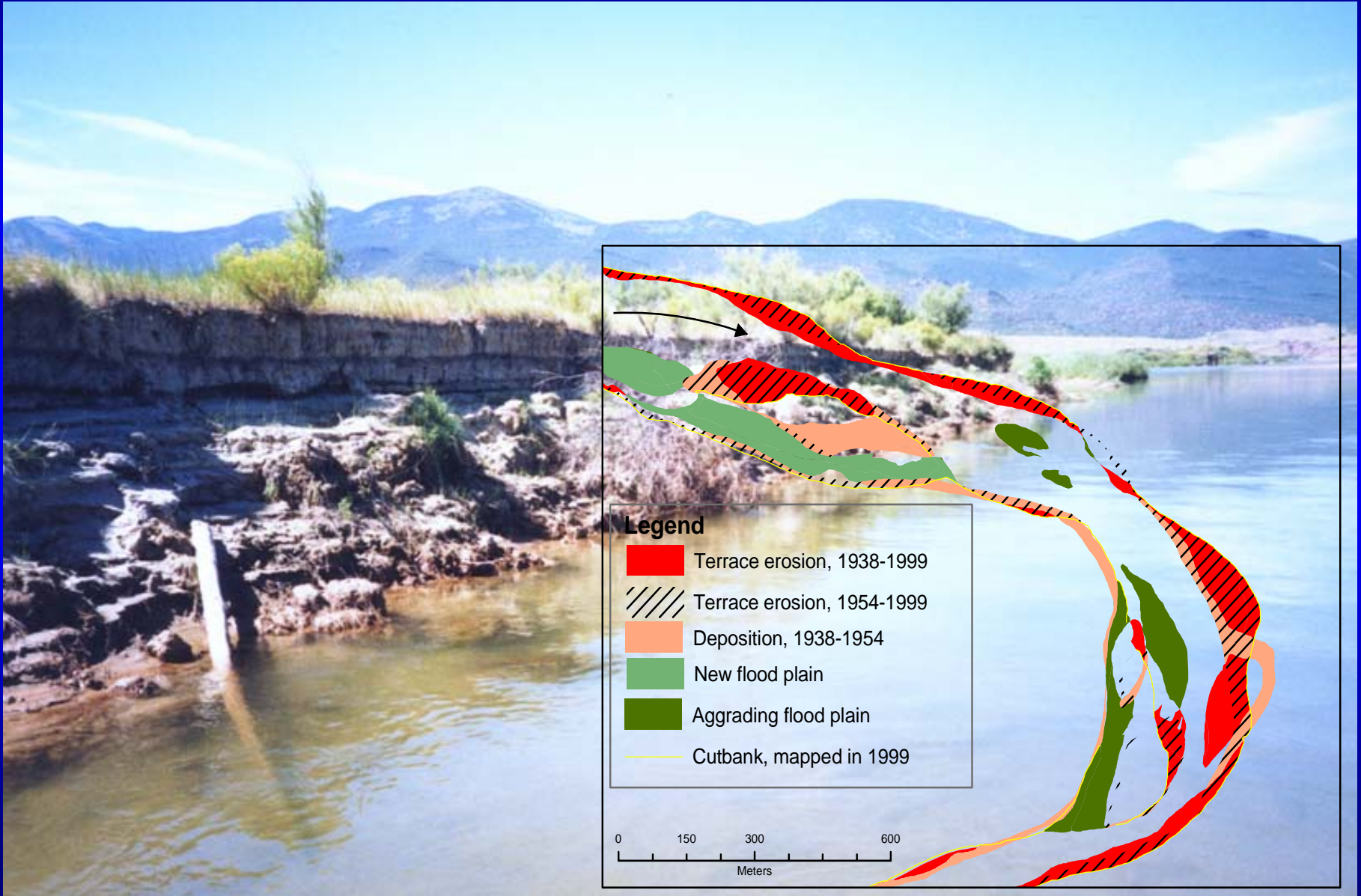
Green River in Echo Park



Green River in Browns Park



Green River in Browns Park



Conclusions

- Degradation of the bed in Glen Canyon has altered the geomorphic organization of this segment of the Colorado River
 - Smooth gradient, sand-bedded alluvial river replaced by pool-riffle “trout stream” with channel controls at tributary confluences
 - Perched sand and gravel deposits where stage-discharge relations have dropped
 - Aggrading channel-side deposits where stage-discharge relations have been stable
- Because of the degrading channel, many of the pre-dam deposits are perched above the range of power plant operations and most post-dam floods
- Erosion of pre-dam terraces:
 - Erosion of one large terrace was probably the result of the position of that deposit relative to stable gravel deposits across the channel
 - Pre-dam terrace deposits have eroded in Echo Park resulting from changing deposition patterns downstream from a major tributary
 - Post-dam rates of terrace erosion in Browns Park have been similar or less than pre-dam rates of erosion, and have been approximately balanced by post-dam deposition at lower elevations