Historic Changes in Fine-Sediment Storage Downstream from Glen Canyon Dam

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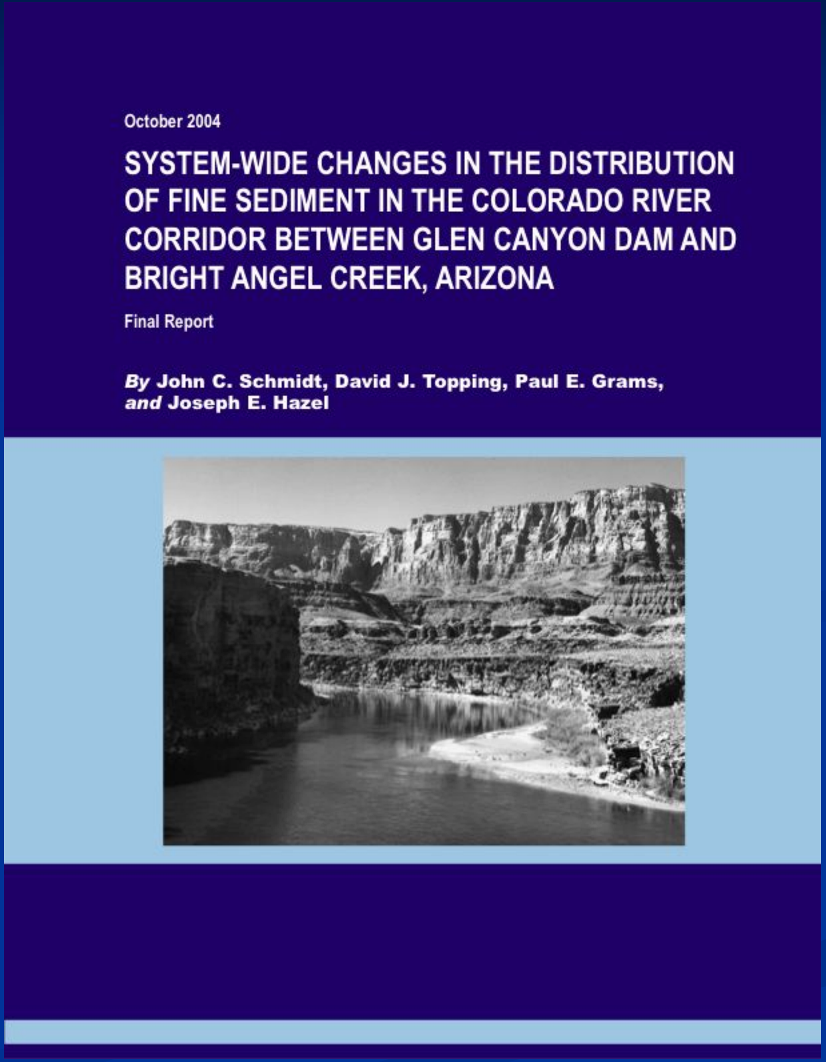
Purpose of the report:

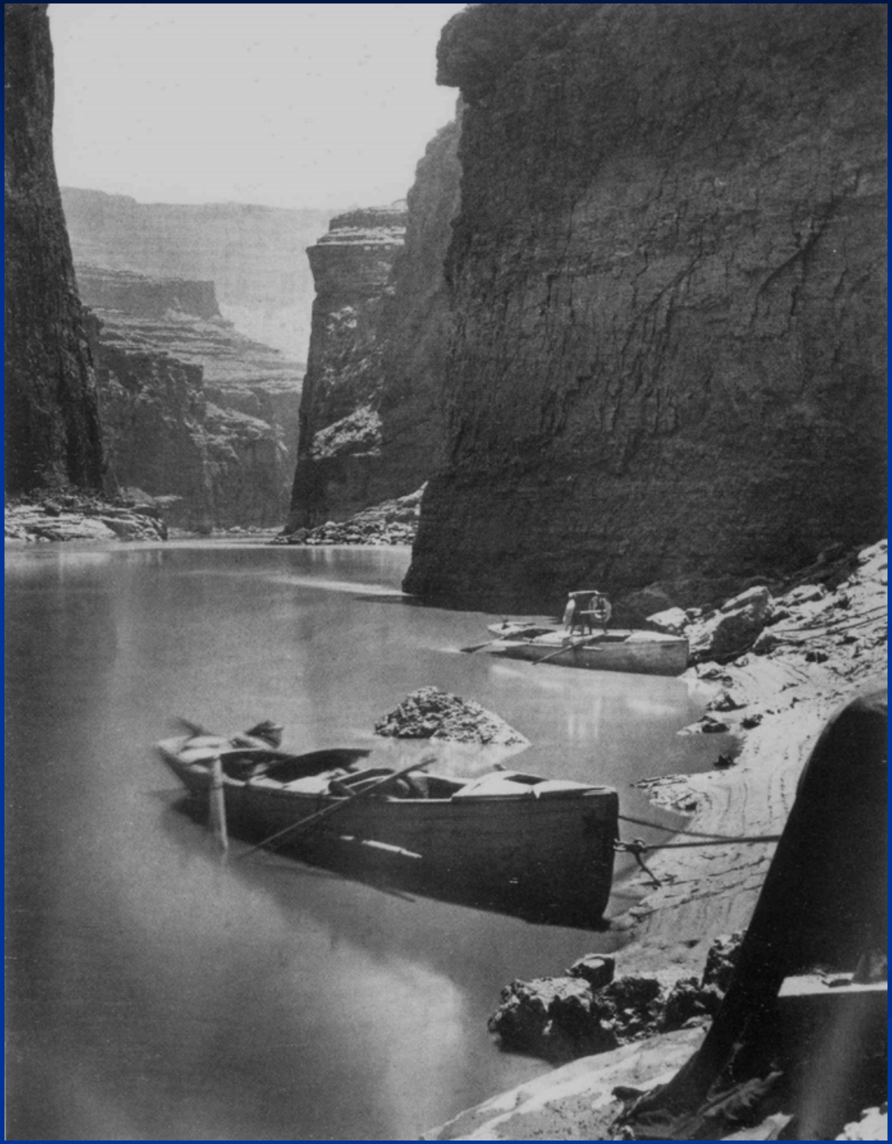
Describe the physical transformation of the channel and alluvial deposits of the Colorado River.

- o fine-grained deposits
- o focus between the dam and the Grand Canyon gage
- o 1930s - 2001.



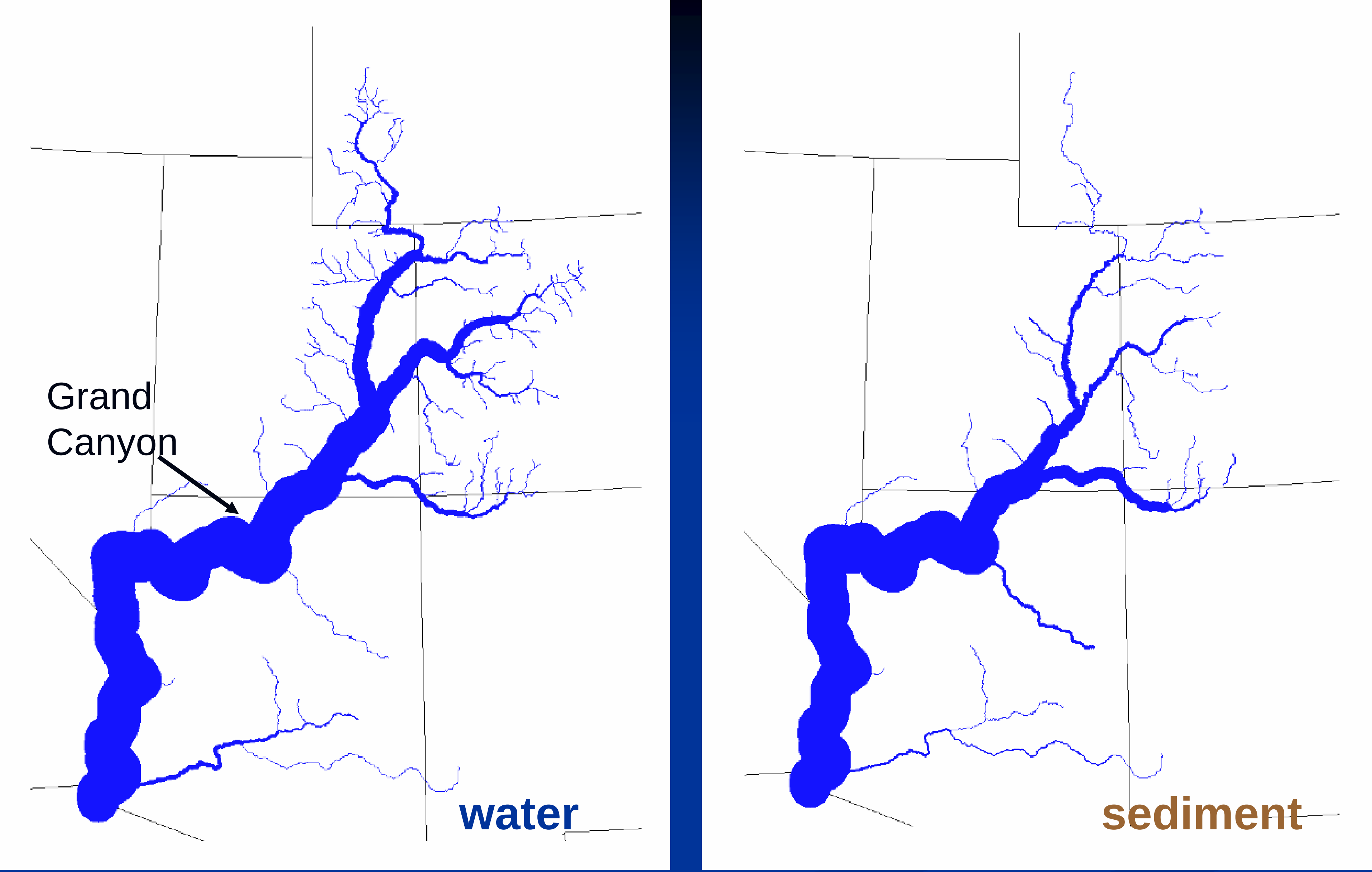
Comprehensive understanding of the history of channel change serves as:

- context for understanding biological change
- informs decisions about reversing attributes of the present riverscape that are deemed undesirable
- benchmark for evaluation of attainment of restoration goals

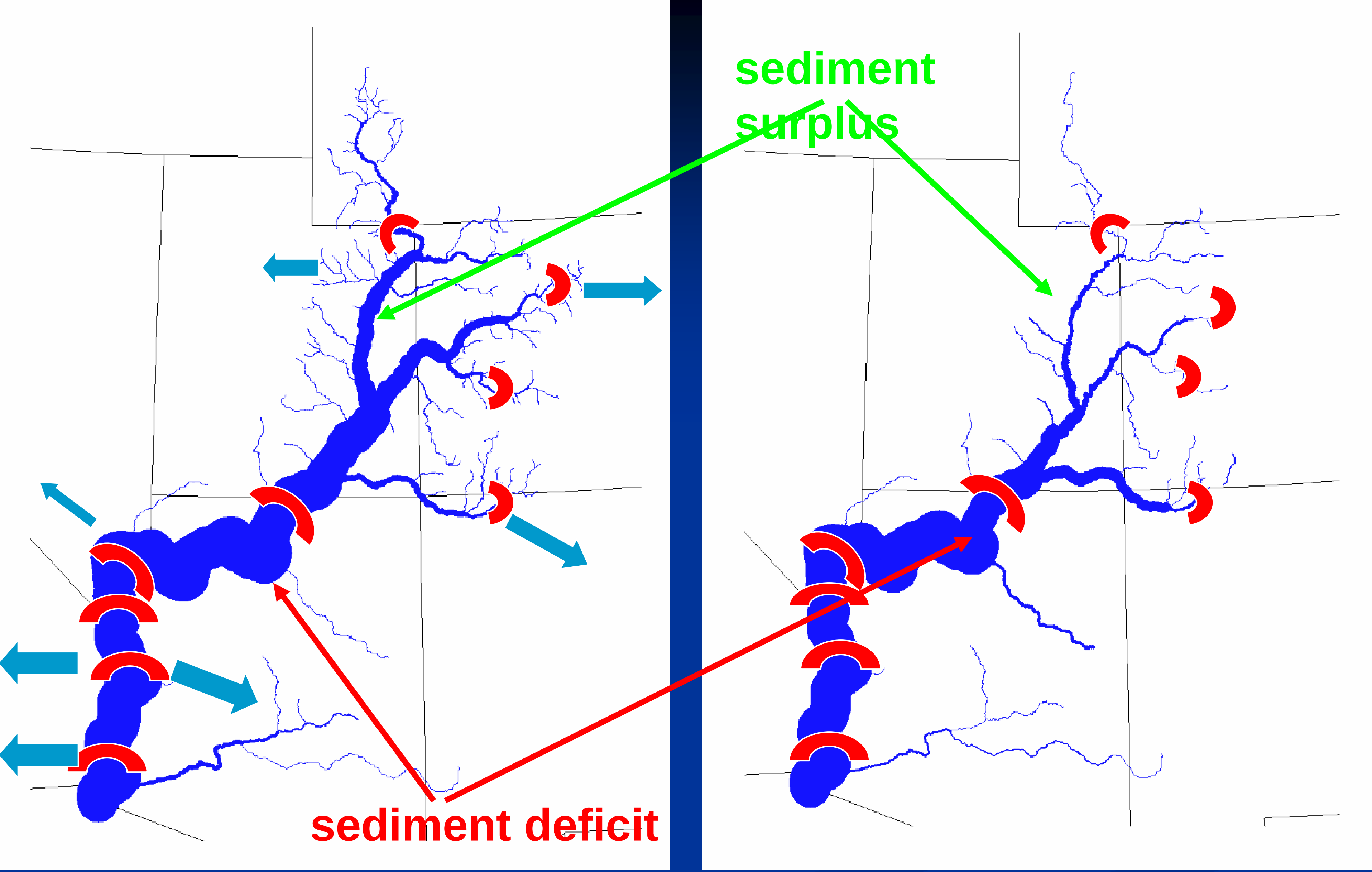


Fine-sediment deposits in Grand Canyon

- Distinctive attribute of the pre-dam riverscape
- Campsites
- Architecture that creates stagnant flow and backwater habitat at some discharges
- Substrate for riparian ecosystem
- Deposits contain archaeological resources or are a source area for subsequent wind deposits at archaeological sites
- Transport creates turbidity



width of river segments are proportional to the pre-dam annual flux



~60% decrease in flood magnitude

increase in base flow

85-95% reduction in fine sediment delivery

Historical Studies

- input - output = Δ storage

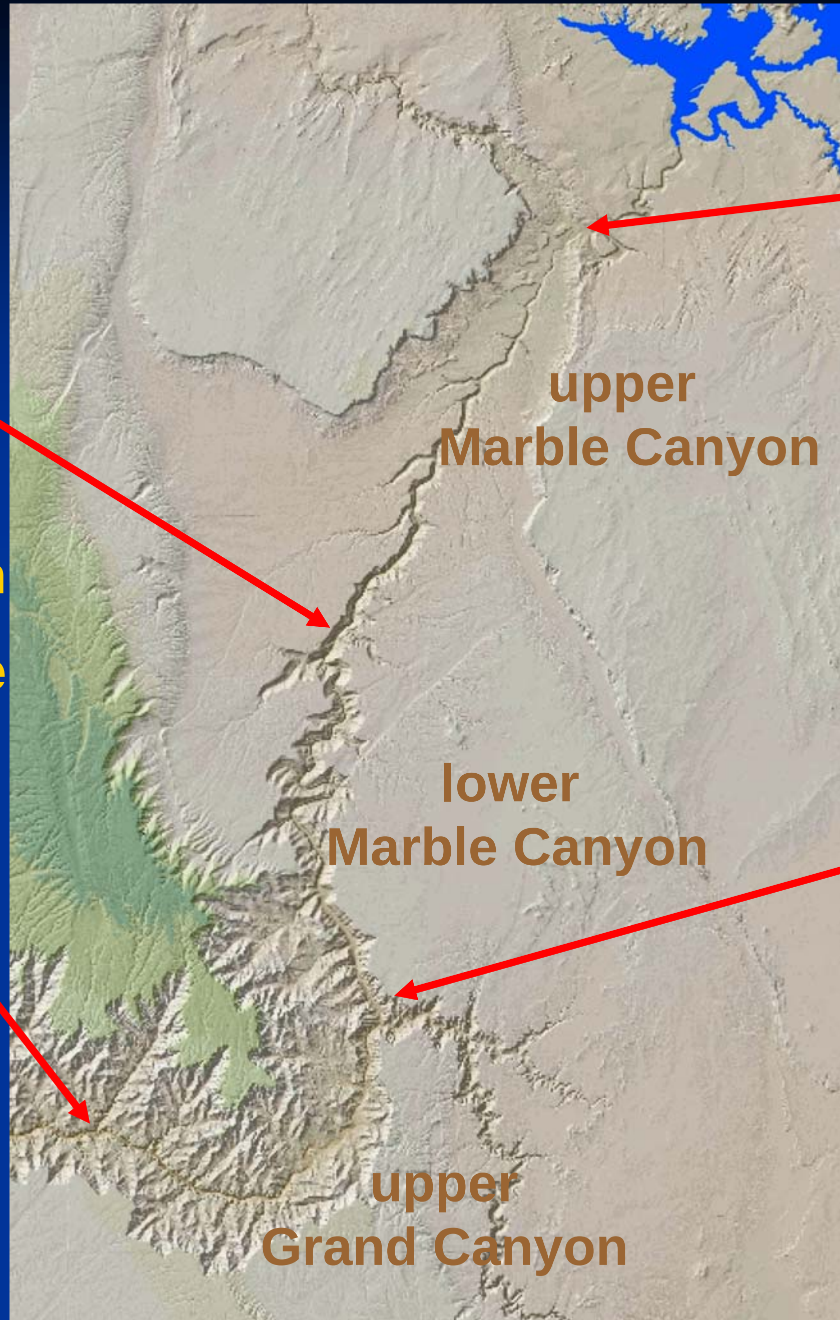
(Topping et al., 2000, 2004)

Glen Canyon: *Grams et al., 2004*

Grand Canyon: ***this study***

Thirtymile
gage

Lees Ferry
gage



Grand Canyon
gage

lower Marble Canyo
gage

Present Process Studies

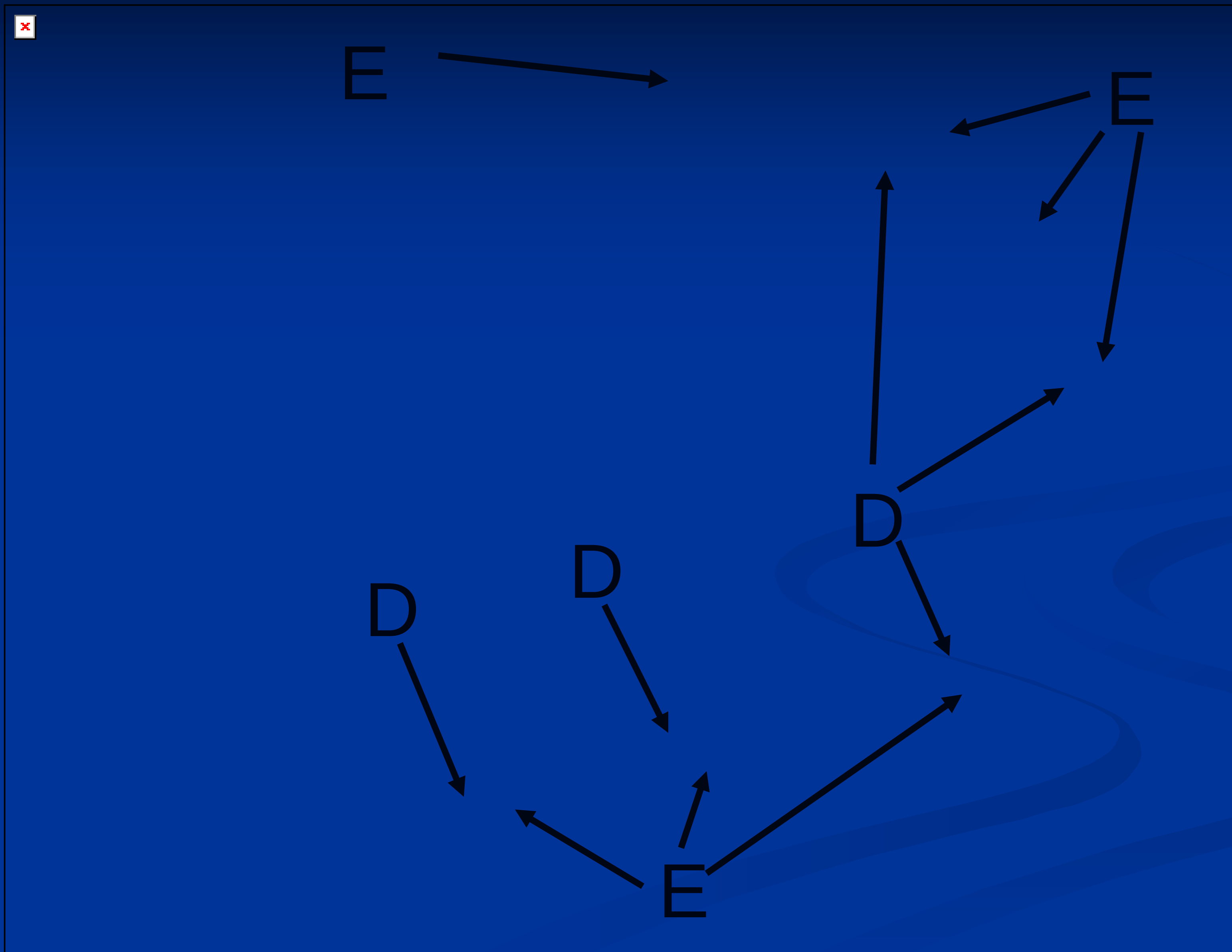
Mass balance project

FIST and CIST projects

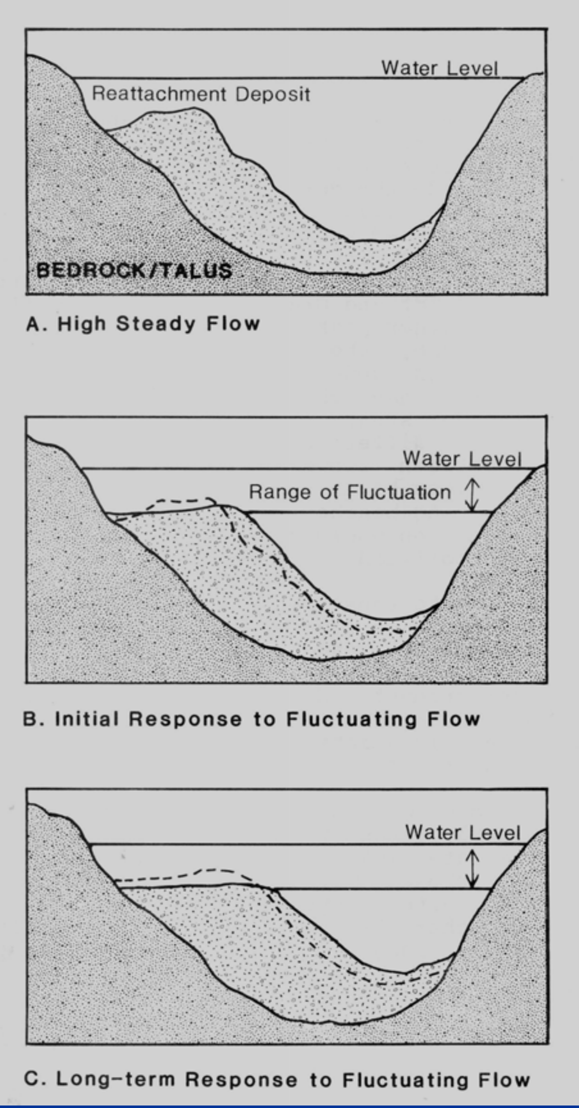
- input - output = Δ storage

- Components of Δ storage
  - main channel bed
    - spawning habitat for trout
    - aquatic food base
  - banks
    - eddies
    - campsites
    - backwaters
    - archaeologic resources
    - fluvial marshes
    - linear channel margins
    - riparian vegetation, archaeologic resources, habitat

Where is fine sediment stored?

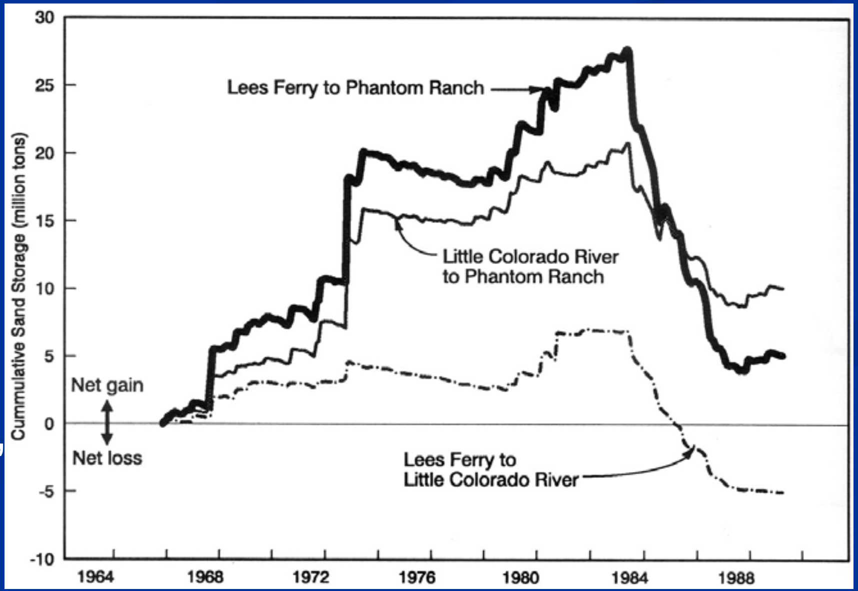


A Conceptual Model of Sediment Storage Unconstrained by Data



(GCES, 1989)

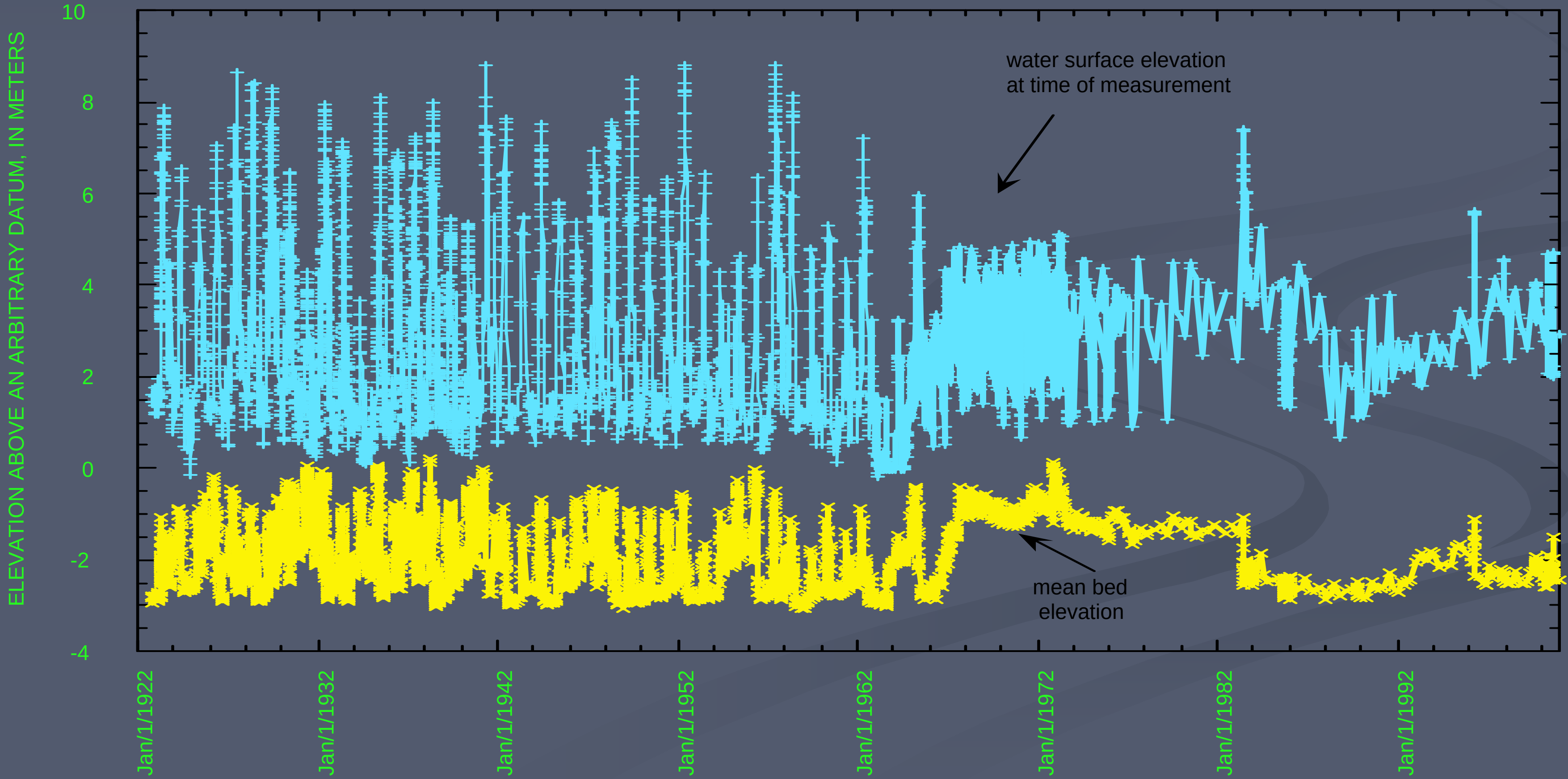
- This model was proposed as consistent with the sediment budgets estimated in the 1990s

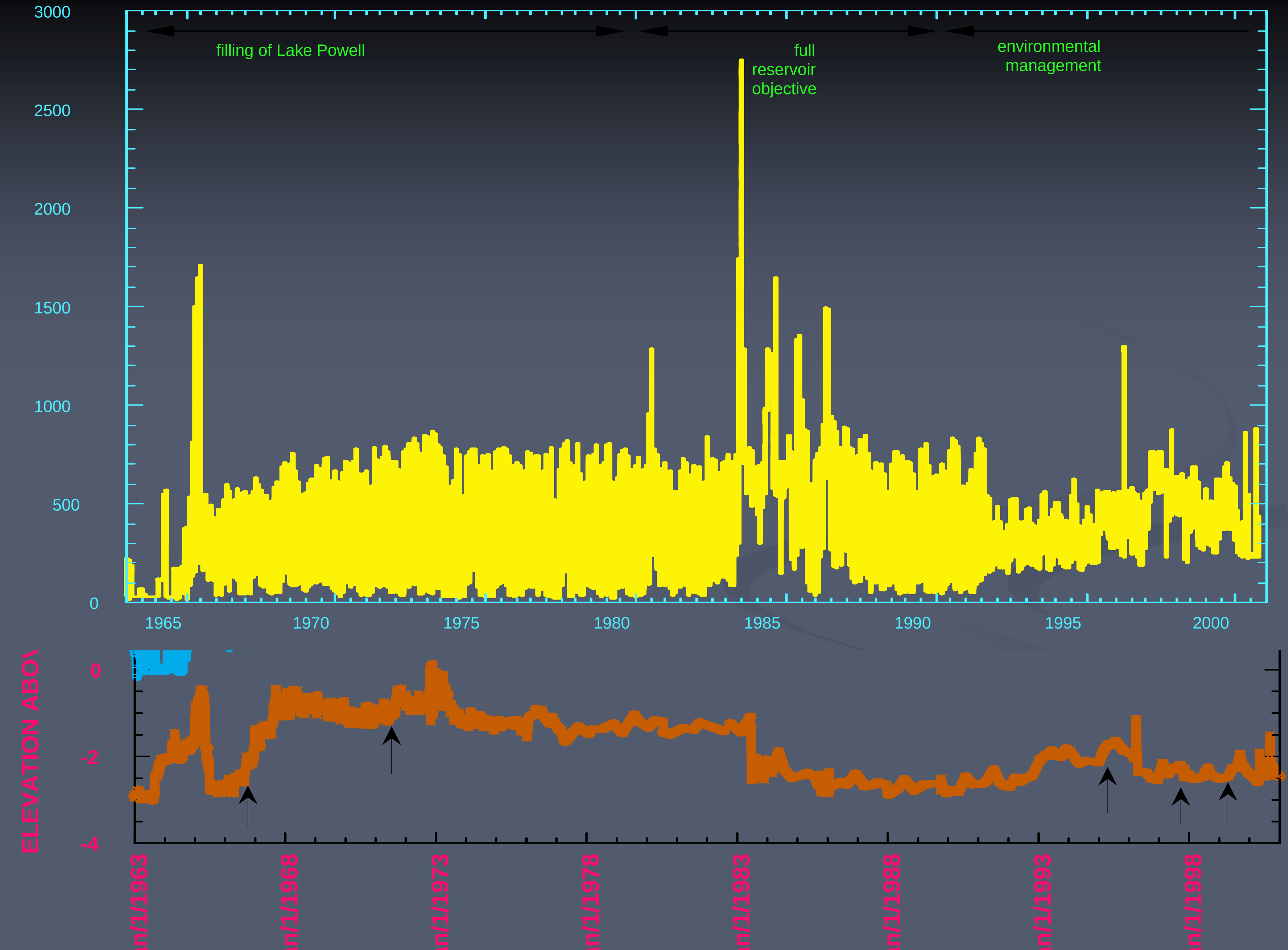


(USDI, 1995)

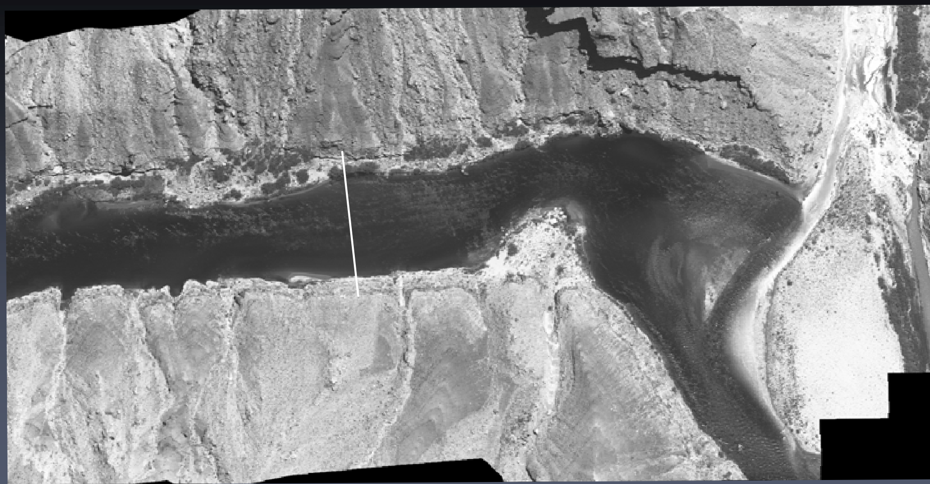
Long-term (1922-1962) degradation of bed of pool = 1.6 cm/yr

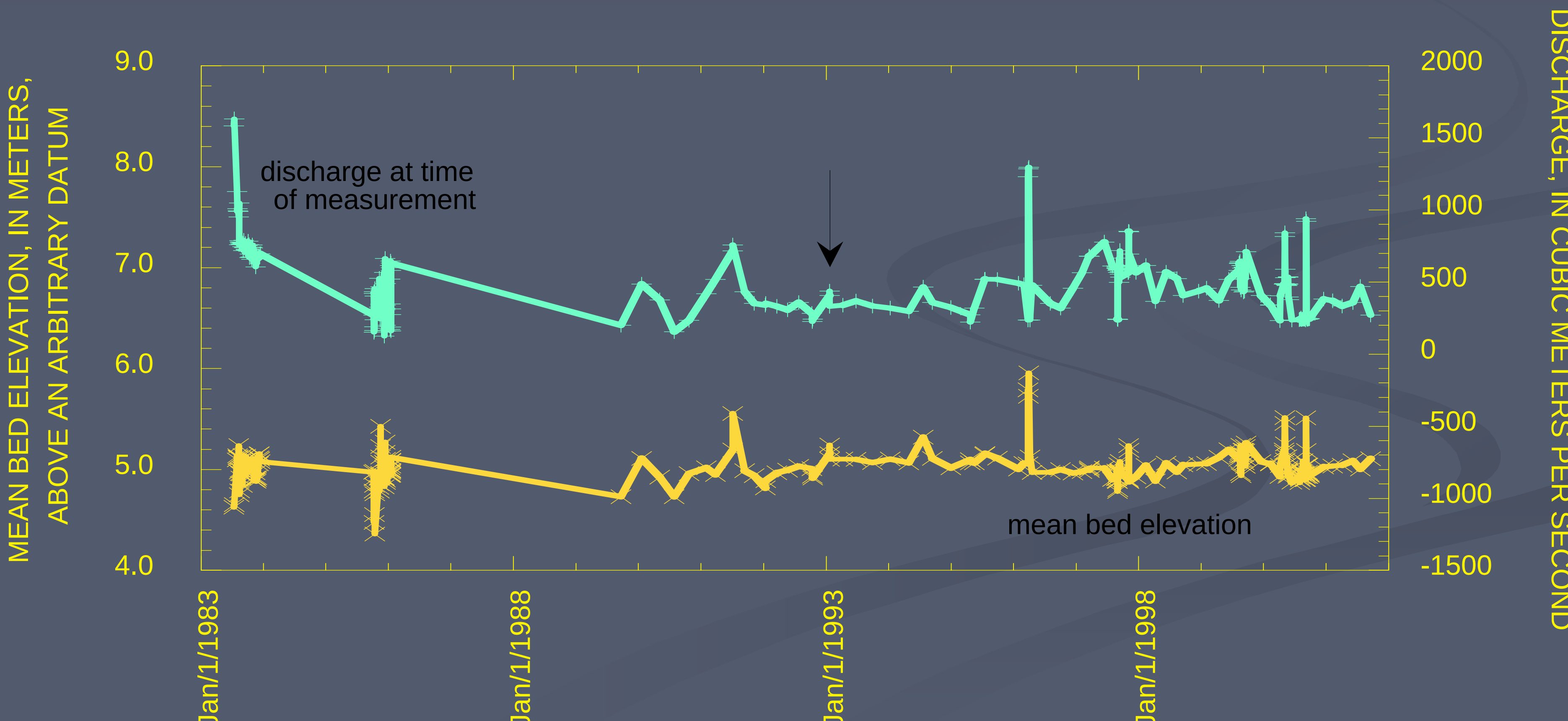
Due to long-term decrease in sediment delivery (Topping et al. 2000)





3000
2500
2000
1500
1000
500
0
filling of Lake Powell
full
reservoir
objective
environmental
management
1965
1970
1975
1980
1985
1990
1995
2000
ELEVATION ABO\
0
-2
-4
n/1/1963
n/1/1968
n/1/1973
n/1/1978
n/1/1983
n/1/1988
n/1/1993
n/1/1998



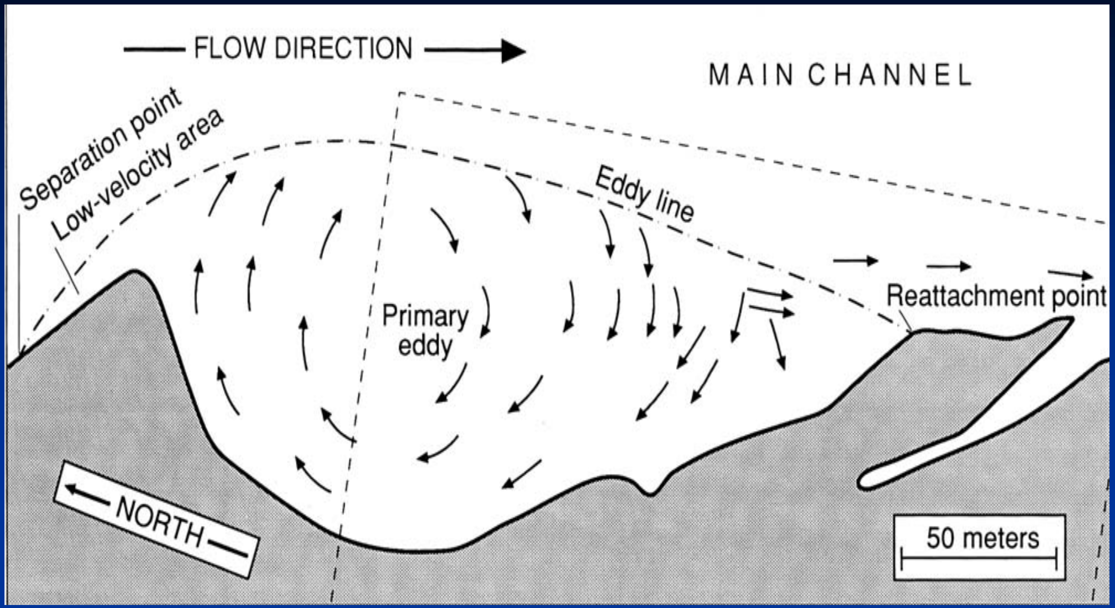


MEAN BED ELEVATION, IN METERS, ABOVE AN ARBITRARY DATUM
DISCHARGE, IN CUBIC METERS PER SECOND
9.0
8.0
7.0
6.0
5.0
4.0
2000
1500
1000
500
0
-500
-1000
-1500
discharge at time of measurement
mean bed elevation
Jan/1/1983
Jan/1/1988
Jan/1/1993
Jan/1/1998

The Main Channel Bed

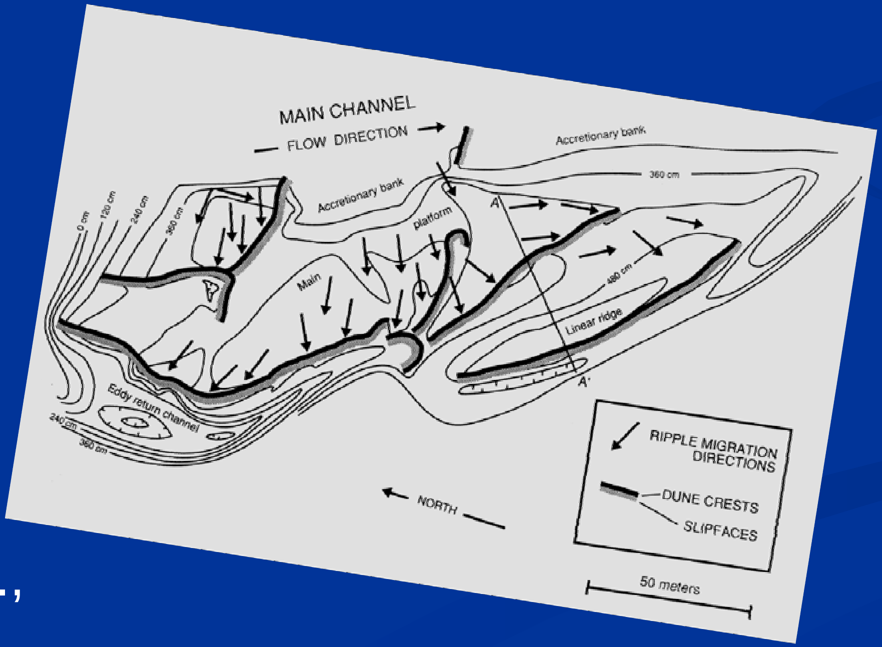
- Long-term slow loss of fine sediment in pre-dam period
- <30% of bed played significant role in pre-dam seasonal accumulation
- Pre-dam: ~50% of fine sediment in active storage was on bed
- Post-dam: <10% of fine sediment in active storage is on bed
- Multi-year accumulation only in short reaches following change in hydraulic control
- No evidence of system-wide multi-year accumulation

Eddies -- where the action is



~90% of post-dam fine sediment stored here

Eddies have capacity to store all of the seasonal accumulation that occurred each year in the pre-dam era



Rubin et al., 1991

Changes at Badger Creek Rapids

June 19, 1952

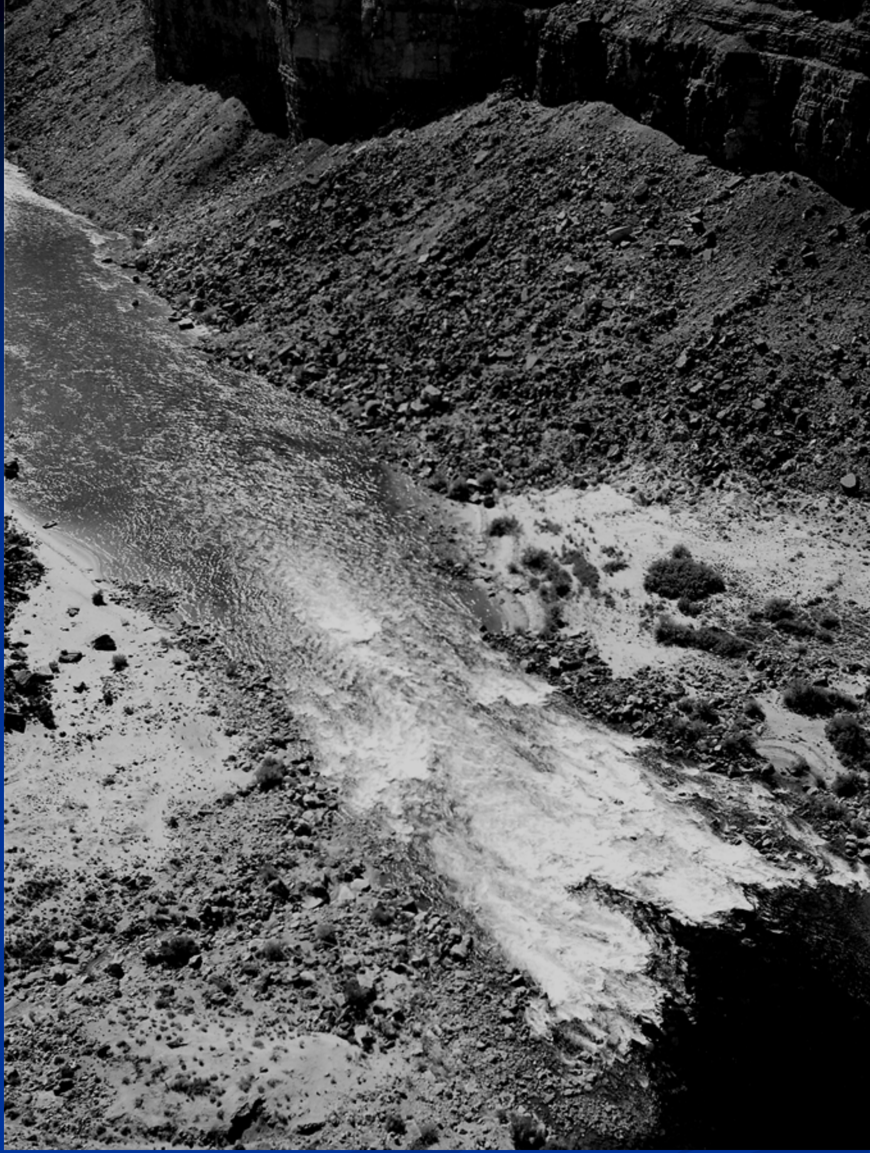
January 2, 1954

July 1956

August 1964

October 1968

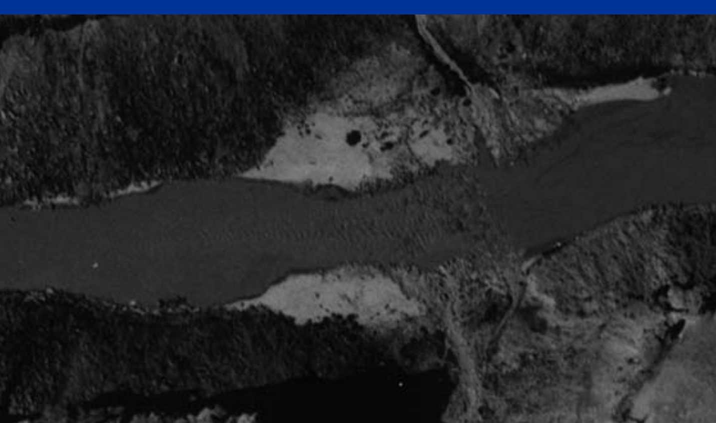
August 21, 1972



October 4, 1991

193
5

1935



1952

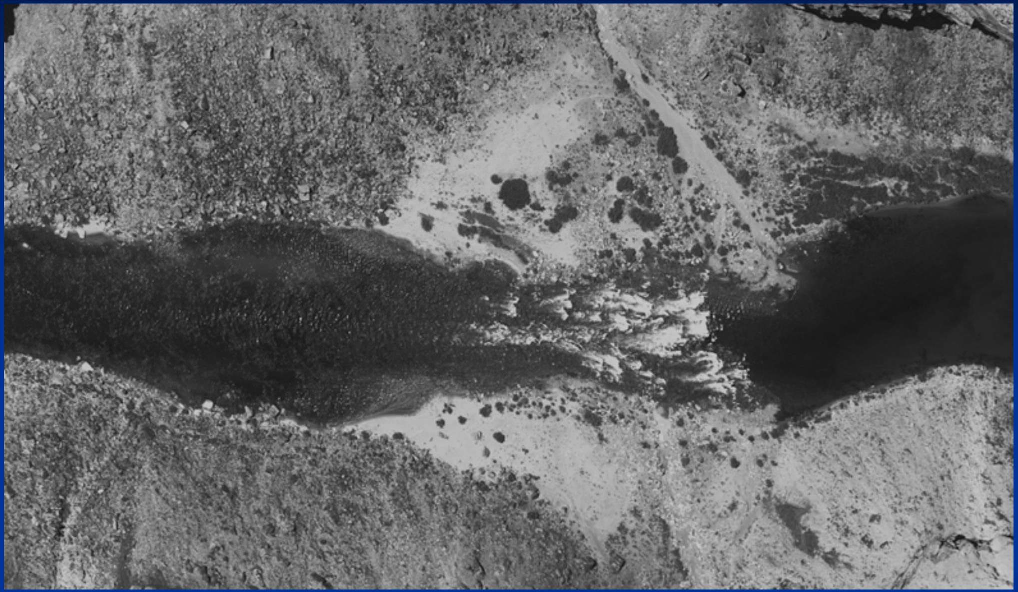
1965

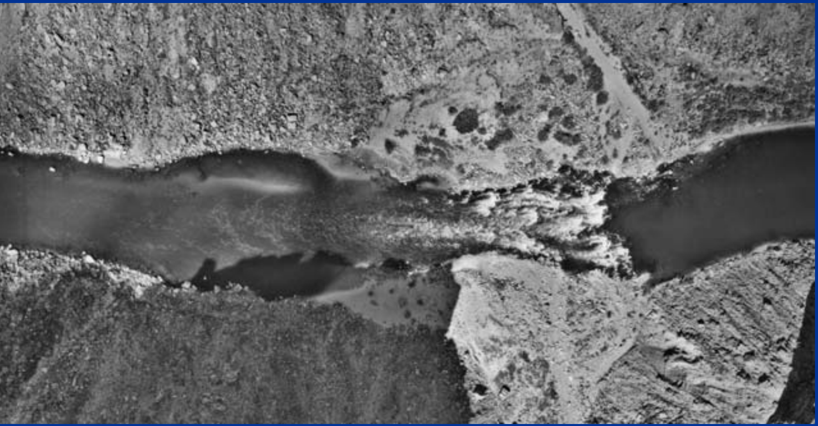
1973

1984

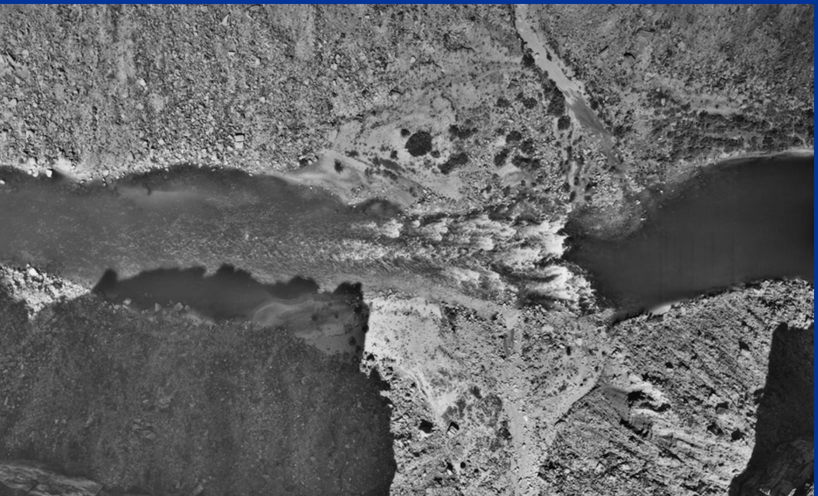
1935

May 2002

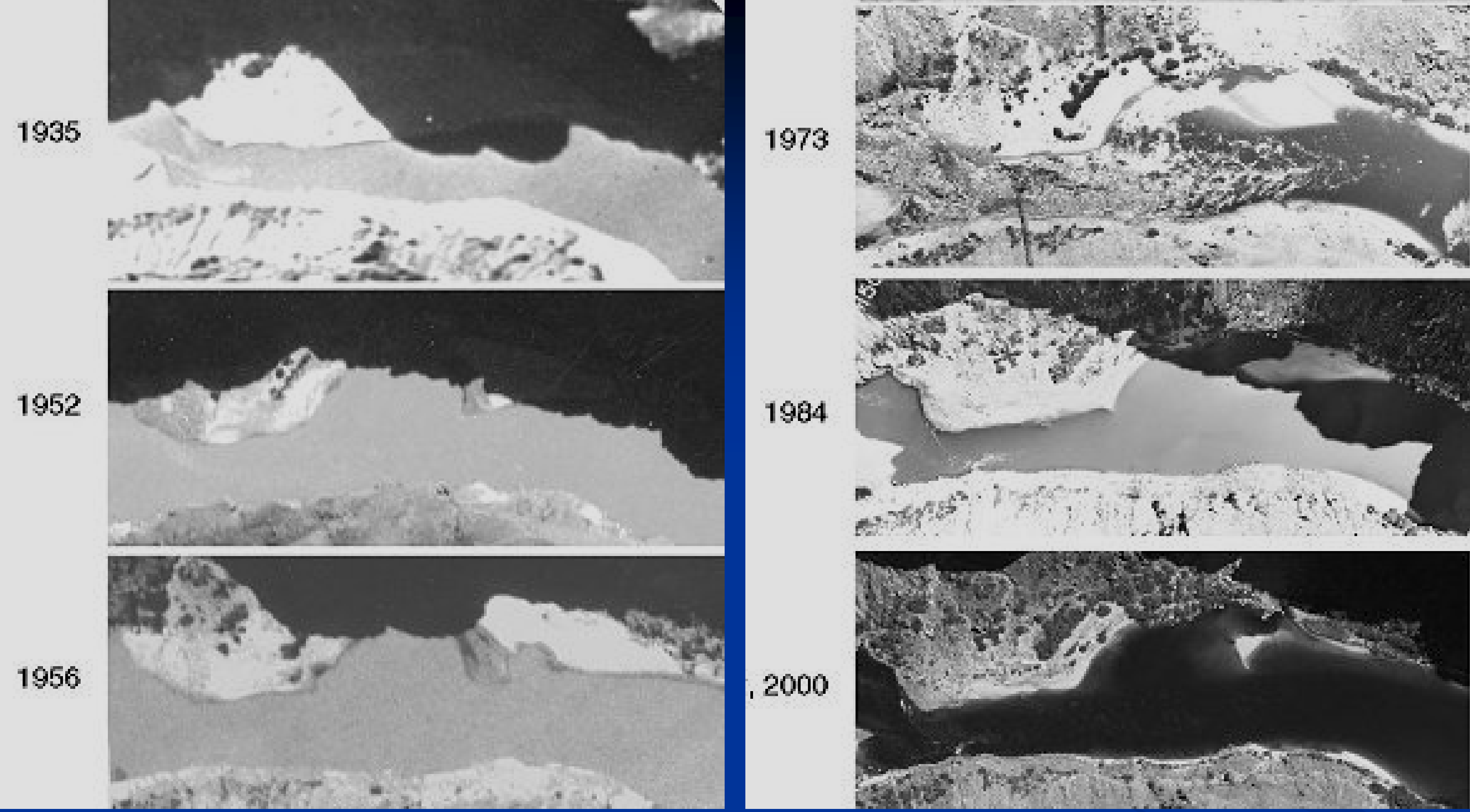




March 1996



April 1996



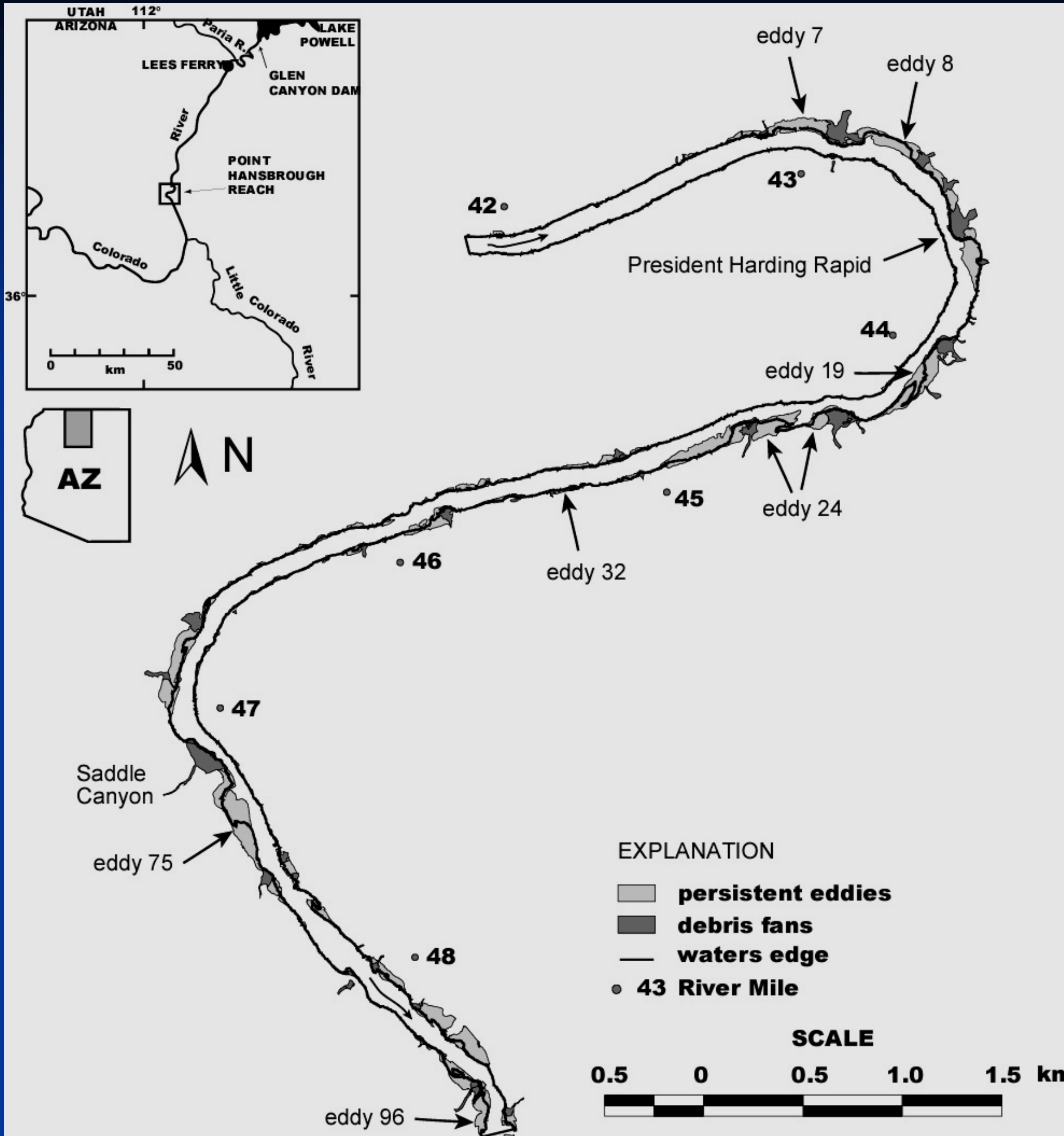
Eminence camp

189
7

1994

Summary of photo comparisons

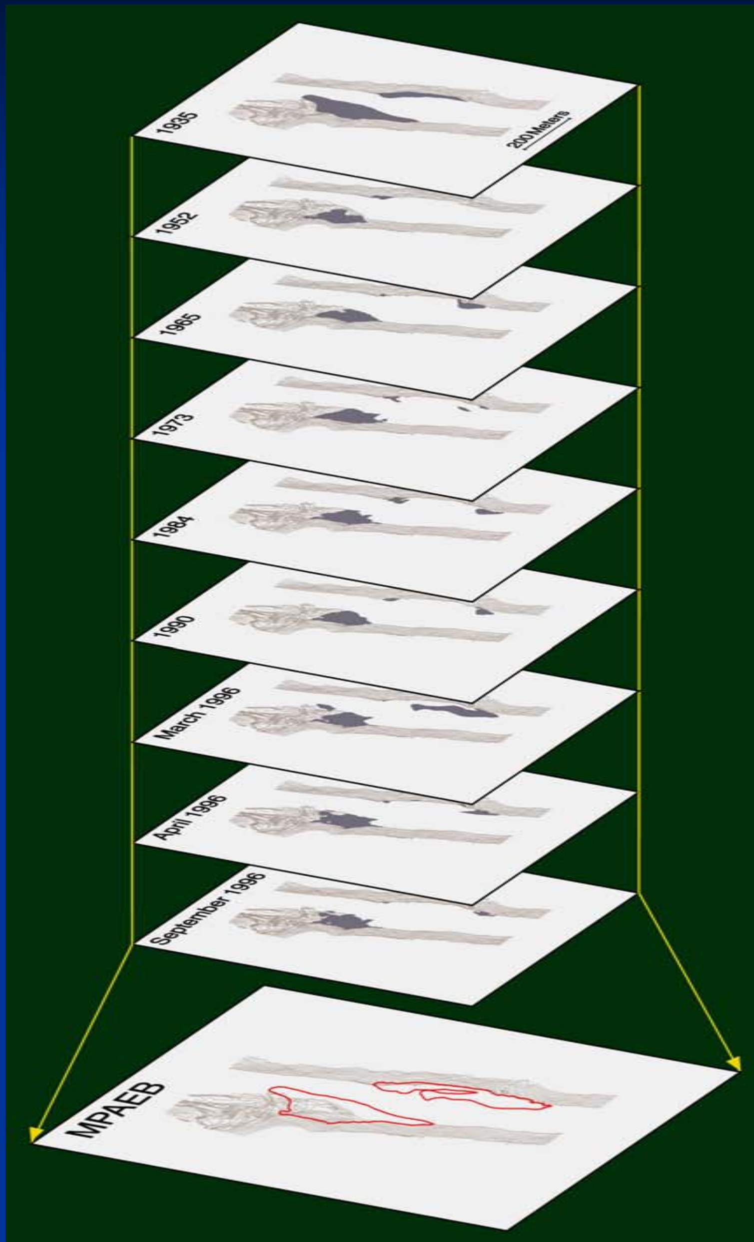
- Webb (1996) found that bars upstream from RM125 are smaller today
- Webb et al. (2002) interviews with "old timers" report loss of sand
- 16 of 51 photo matches compared in present study showed less sand today (2 showed more sand)

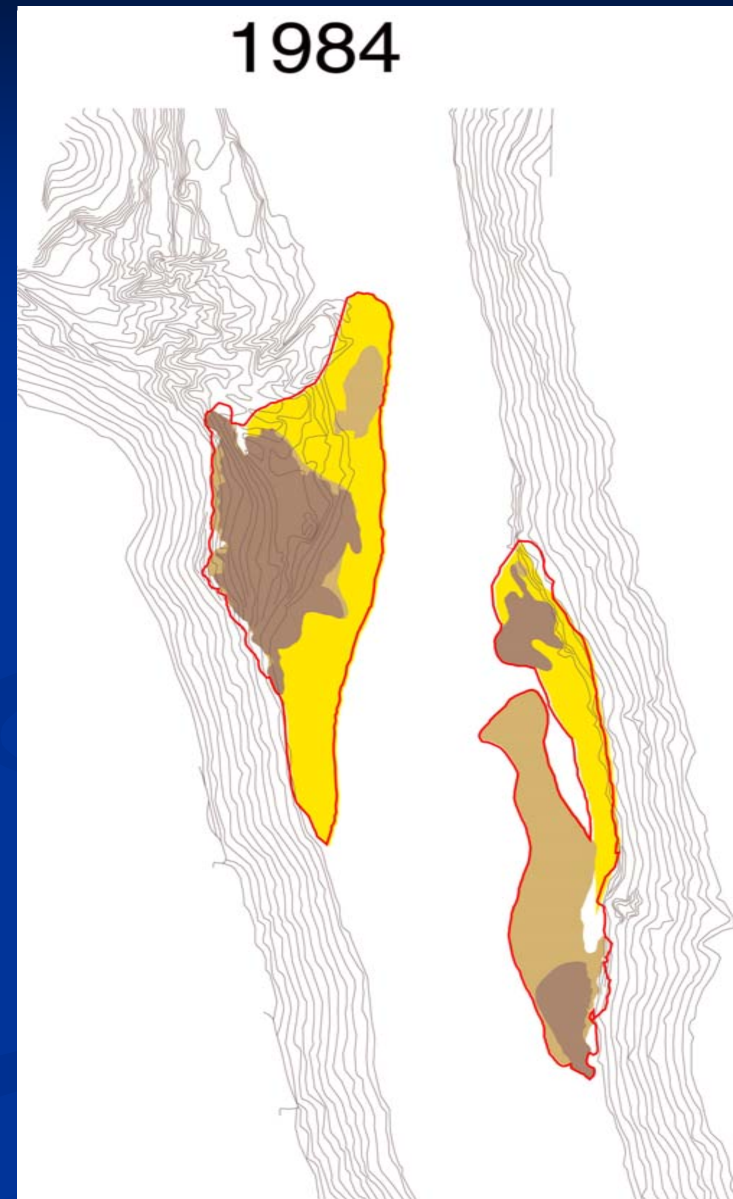


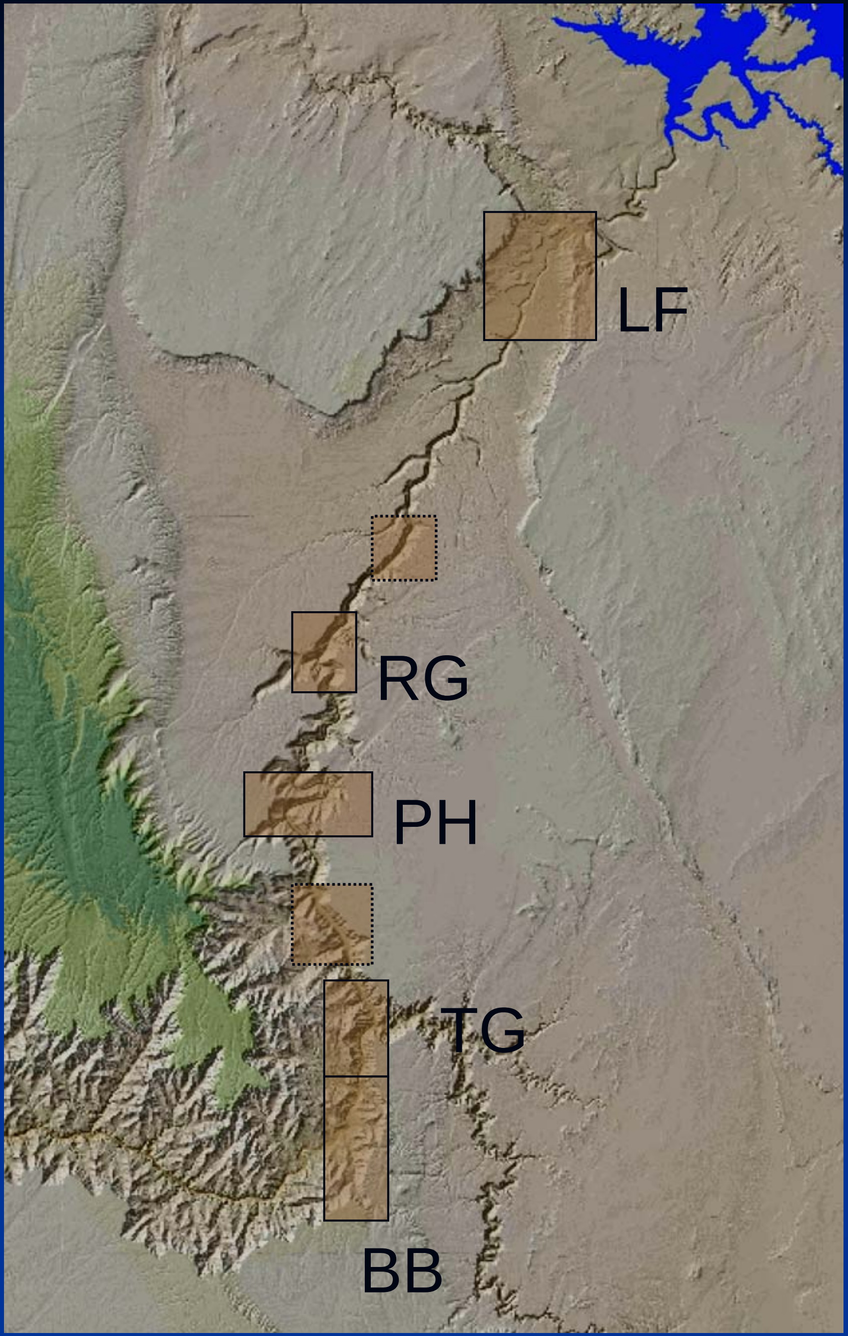
Eddies -- where the action is

Generalize about changes in eddies by comparing the area of sand in different years for a large sample size of eddies

Eddy Deposition Zone (EDZ)





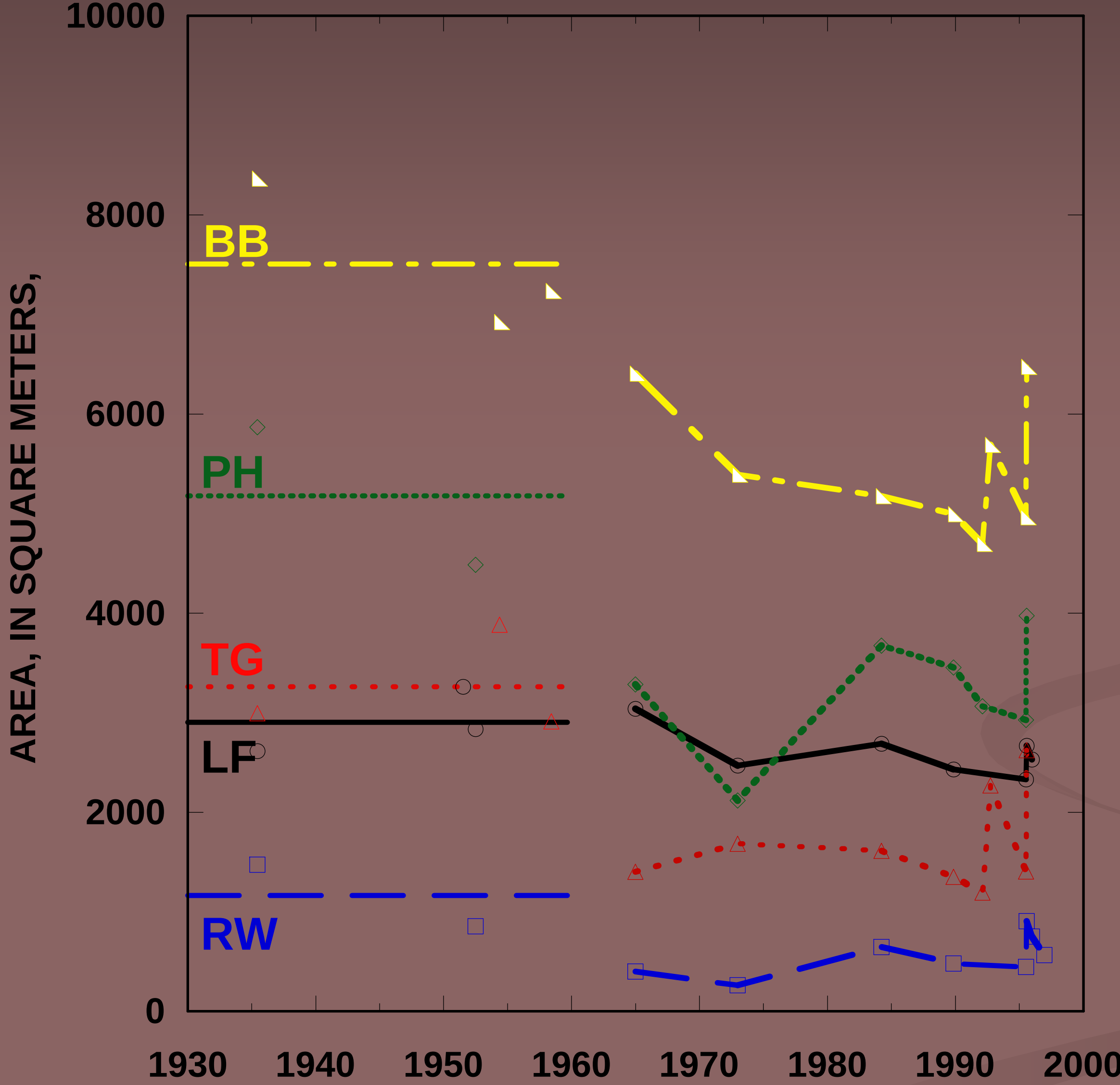


Mapping completed in 5 reaches

7-9 years compiled

1935
1950s
1965
1973
1984
1990s

~15,000 polygons in data base



Area of eddy bars is now smaller than in average pre-dam conditions.

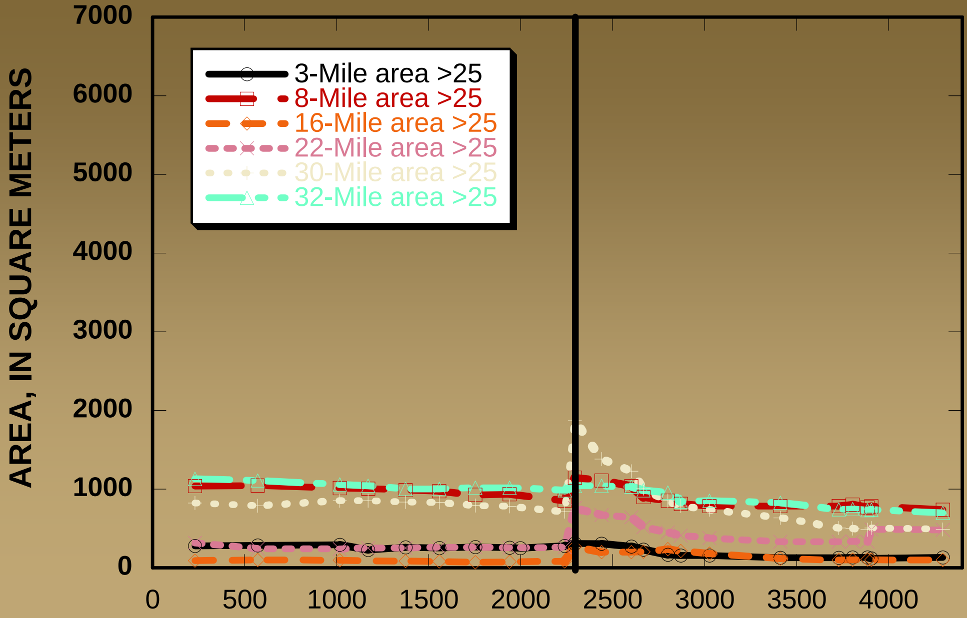
GIS analysis of bar changes

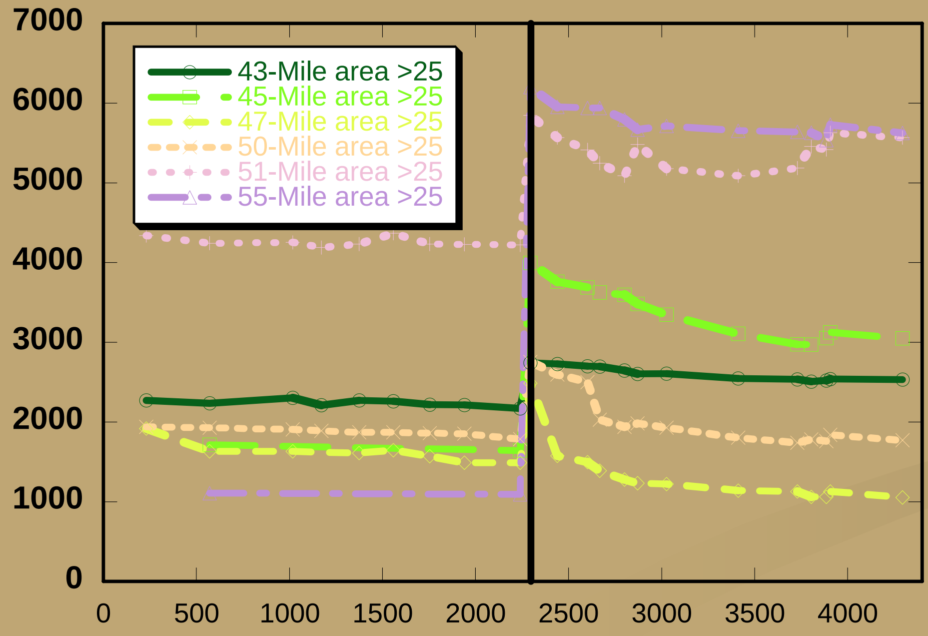
- all inventory methods and all metrics indicate smaller bars in the 1990s in relation to average pre-dam conditions, despite the bias in all analytical methods in favor of showing larger bars today
- Range of estimates of change 0-50%, depending on metric and location of reach
- Average magnitude of change ~ -25% in area of bars; losses everywhere in study area; losses seem to be greater in wide reaches

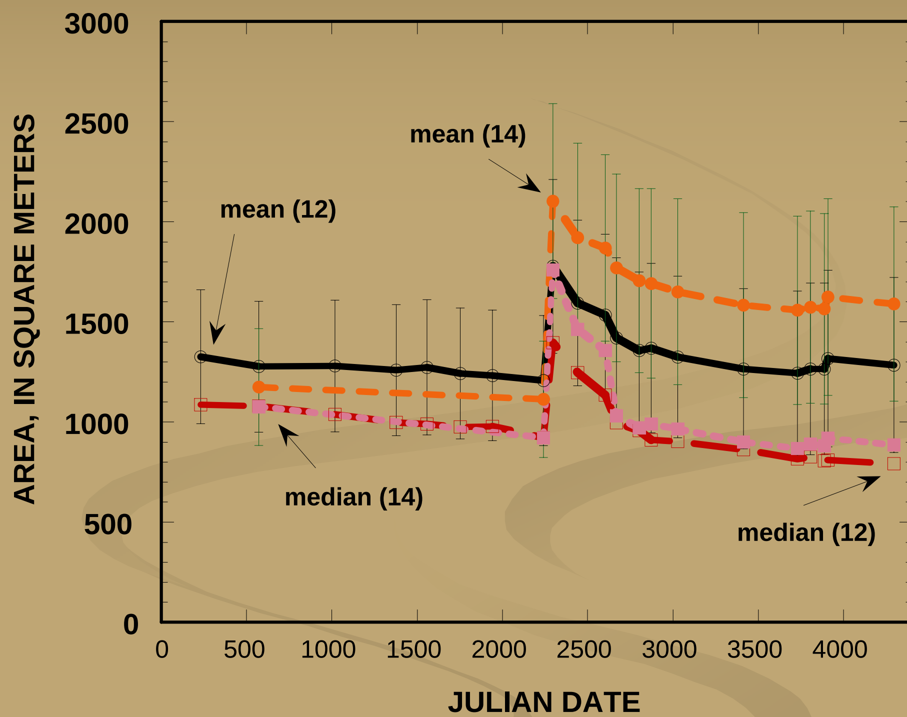
Post-dam flood zone:

Changes in area 1990-2002

NAU surveys



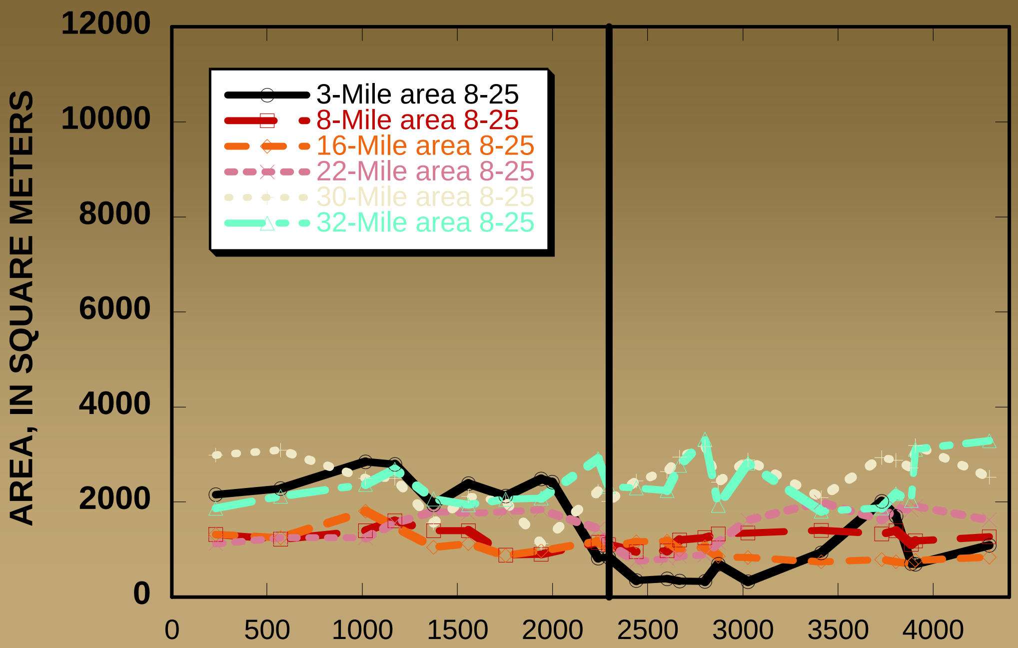


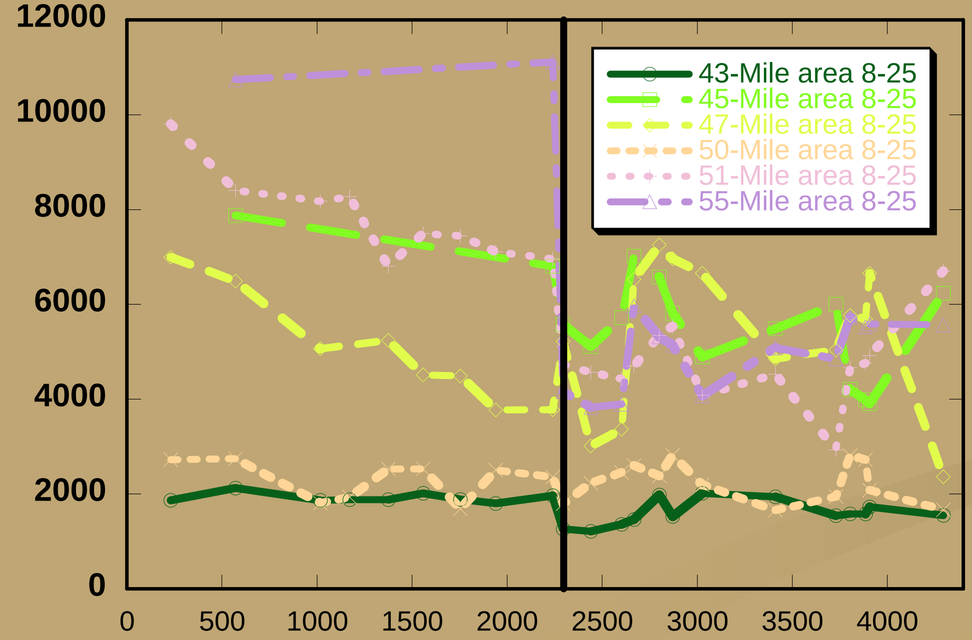


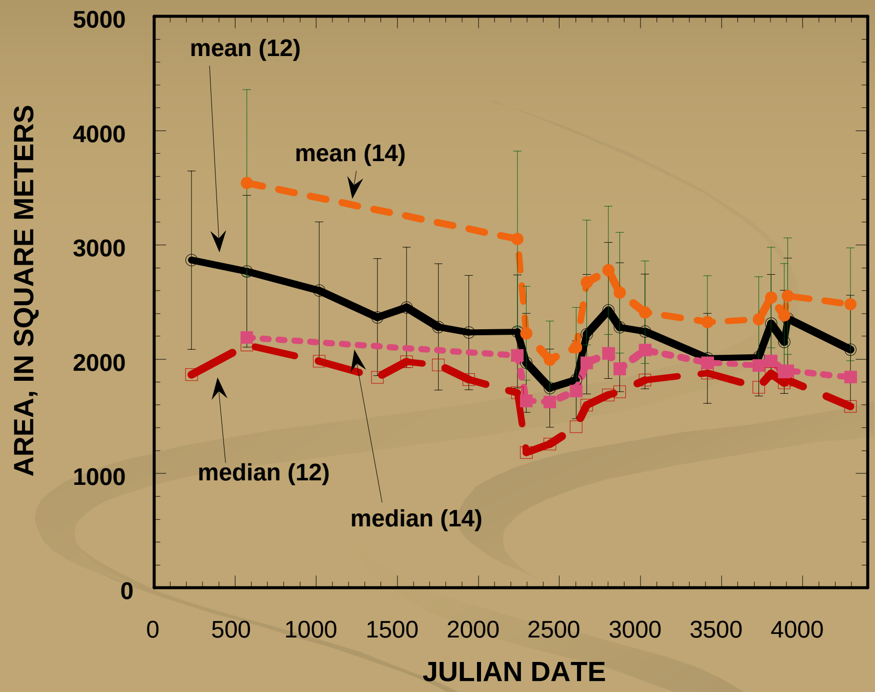
How are we doing in the restoration of lost bars?

Fluctuating flow zone:

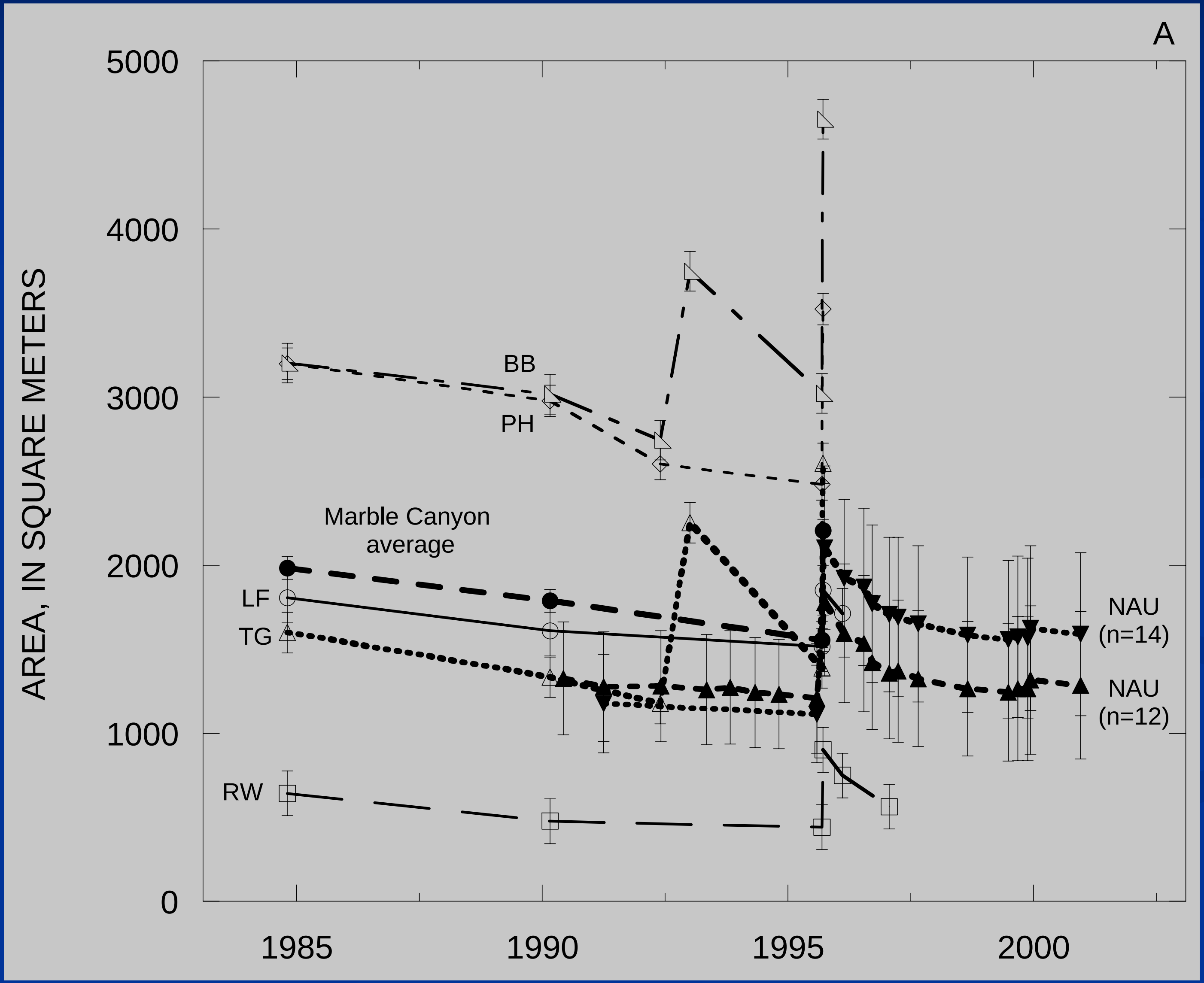
Changes in area 1990-2002



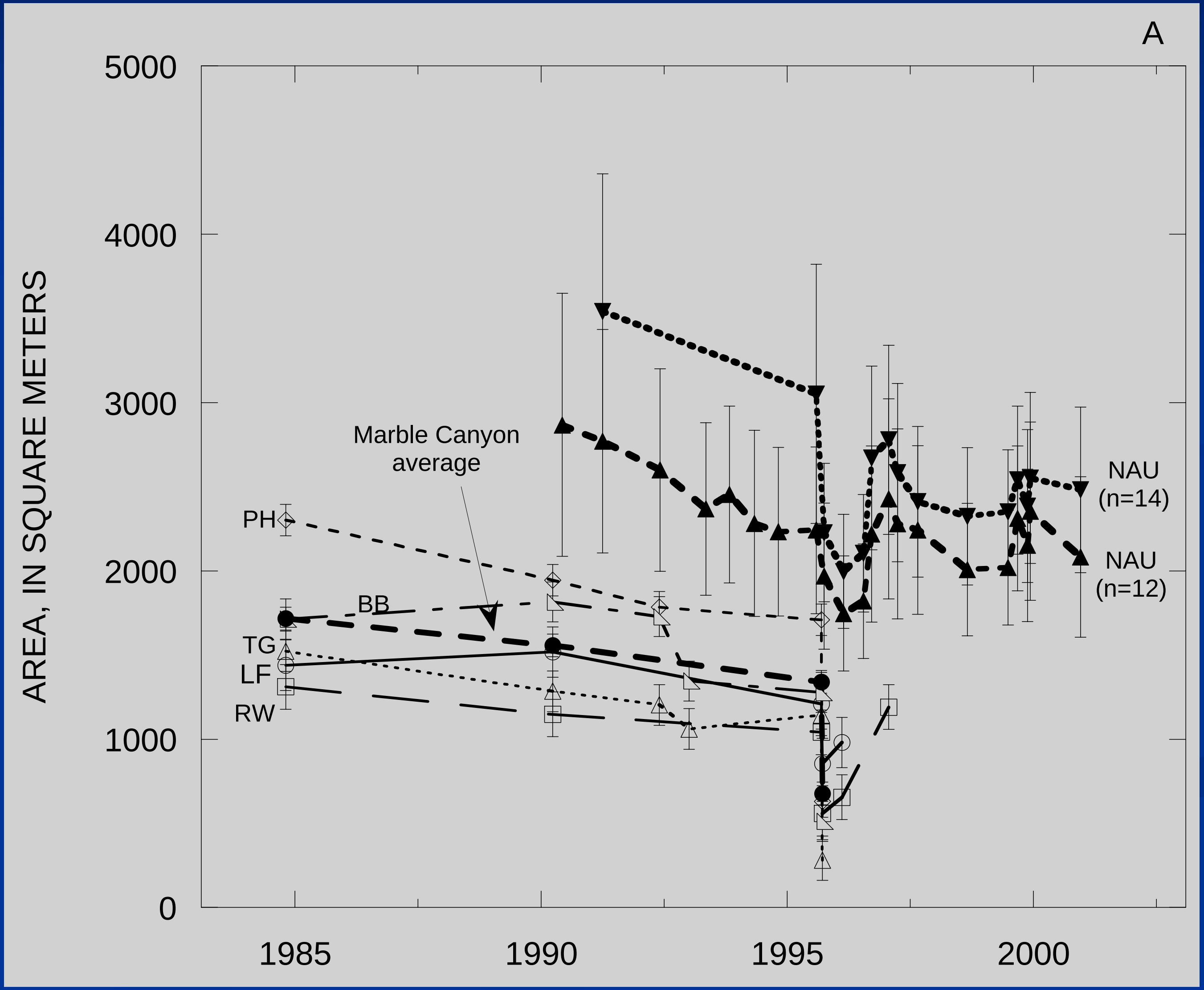




Post-dam flood deposits, integration of NAU data with aerial photograph data in 1984



Low elevation sand -- integration of 1984 photography data with NAU survey data



Findings about changes in eddies

- All evidence points to smaller deposits, and decrease is not entirely due to tamarisk
- Post-dam flood zone area is ~ 25% less than average pre-dam
- Sand is less since 1984
- Sand is less than 1990
- Sand is less at low elevation as well as at high elevation

A 90% reduction in sediment delivery to Grand Canyon has caused a 25% reduction in long-term average area of sand in eddy bars and a complete loss of the main channel bed as a temporary storage site for sand.

Implications

In the pre-dam river, eddy sand bars were maintained by annual resupply during the period of seasonal accumulation. In the post-dam river, sand is primarily moved from low to high elevation within eddies and from upstream eddies to downstream eddies (i.e., mining the upstream sites). The only time that there is net transfer from the main channel bed to eddies is immediately after tributaries deliver fine sediment to the channel.

Reversals in the area of eddy sand are temporary and short-lived. They erode back into the river or blow away. Increasing the long-term average size of these bars requires shorter intervals between bar building floods, which in turn requires larger quantities of fine sediment available for transport during those floods.