The Relative Roles of Channel and Eddy Sediment Storage in Marble Canyon

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Sediment Budgets for the 1996 Controlled Flood and the September 2000 Powerplant Capacity Flow

- Has the relative role of channel and eddy storage of sand-sized sediment changed since closure of Glen Canyon Dam?
- What proportion of the sand input to the canyon is stored within eddy and channel environments?
- Are eddies the primary source of sand during high clear water releases from Glen Canyon Dam?

Sediment budgets: a tool to understanding changes in fine-sediment deposits

input - output = **change in storage**

channel bed

- spawning habitat for trout
- habitat for macro invertebrates and aquatic vegetation

eddies

- campsites
- backwaters
- archaeology
- fluvial marshes

channel margins

- riparian vegetation, archaeology, habitat

Measuring Components of the Sediment Budget

Sediment supply to Marble Canyon

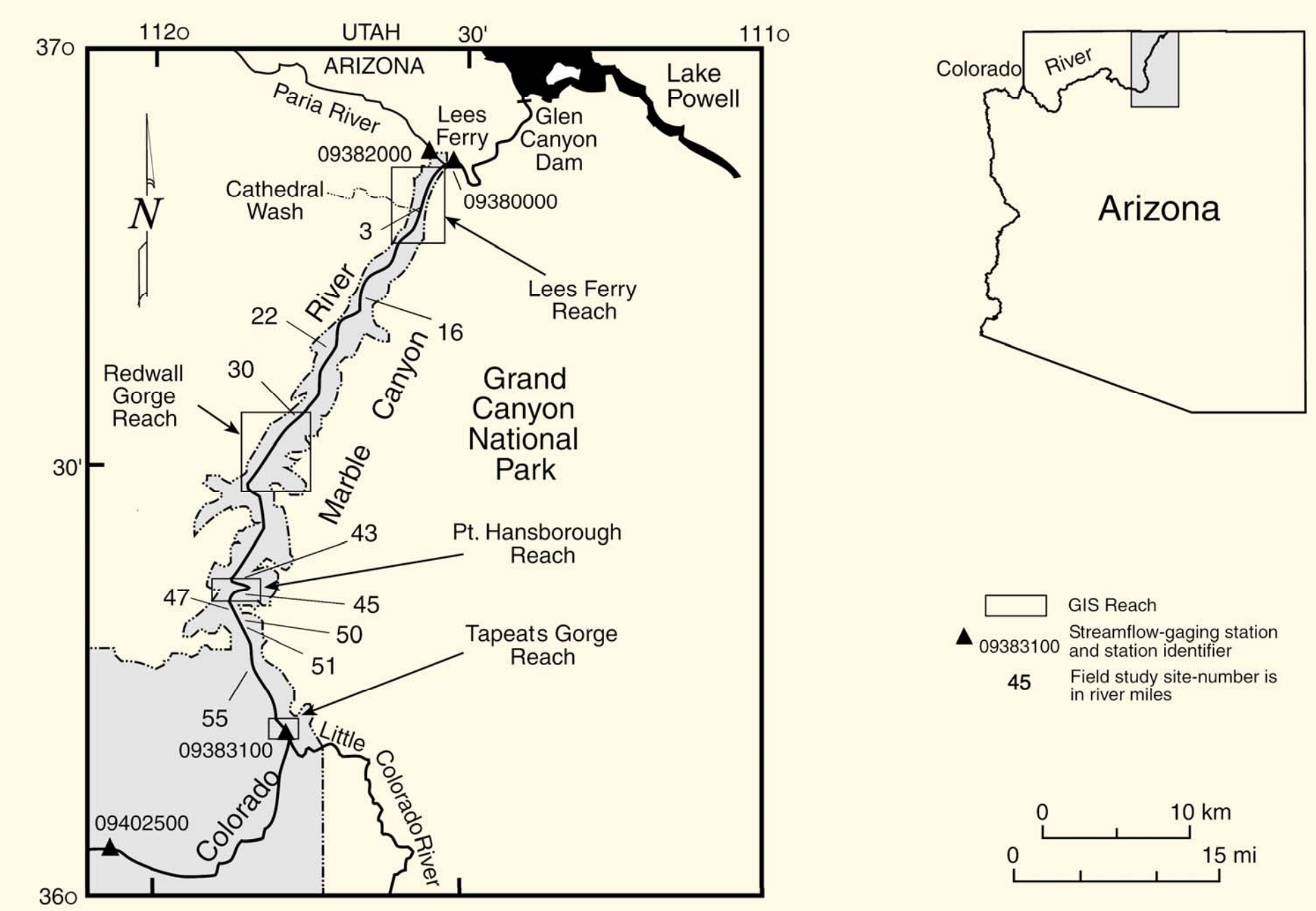
- Determined from a predictive flow and sediment transport model (Topping, 1997)

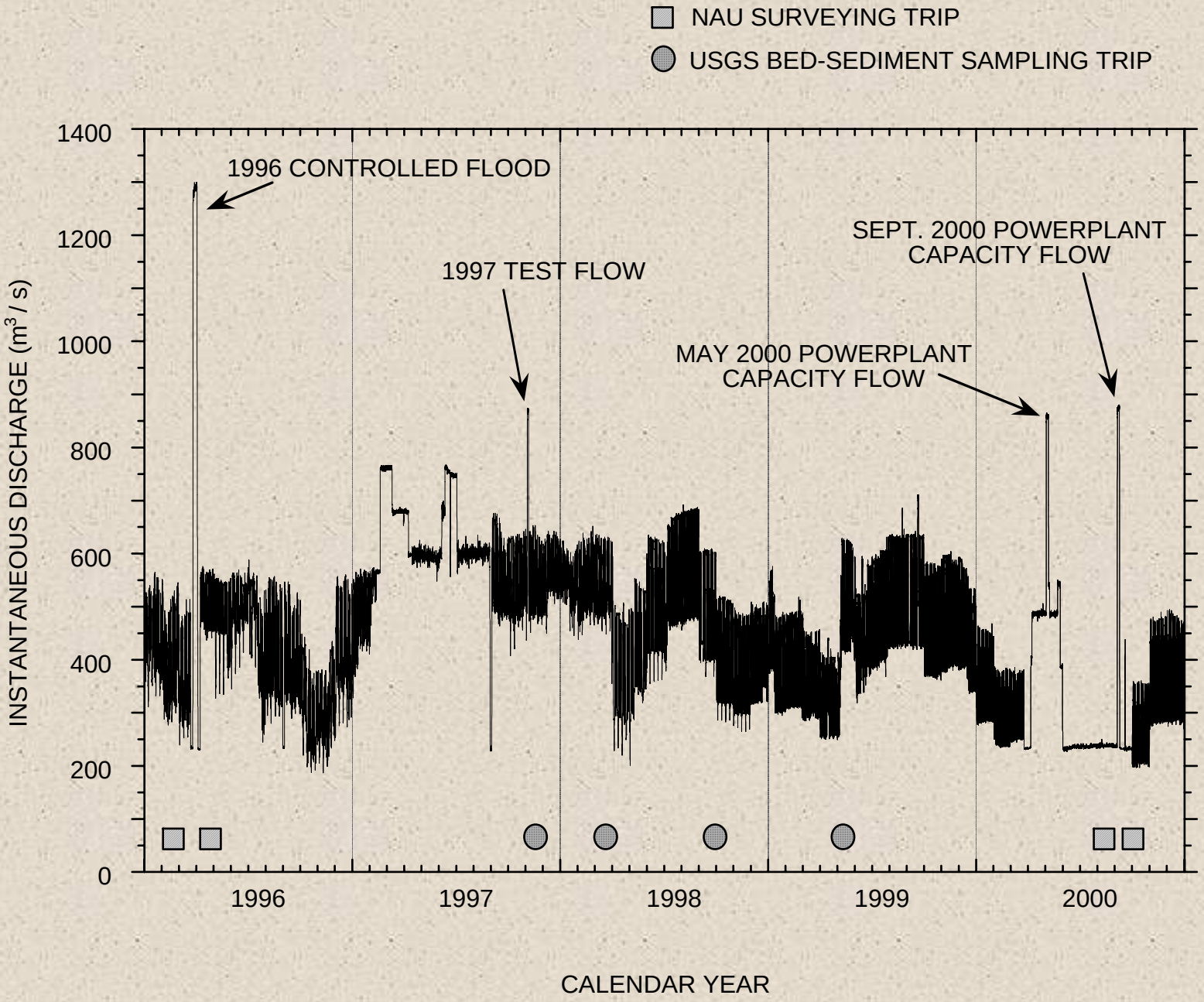
Sediment export from Marble Canyon

- Suspended sediment samples collected by the U.S.G.S. at the Lower Marble Canyon gage

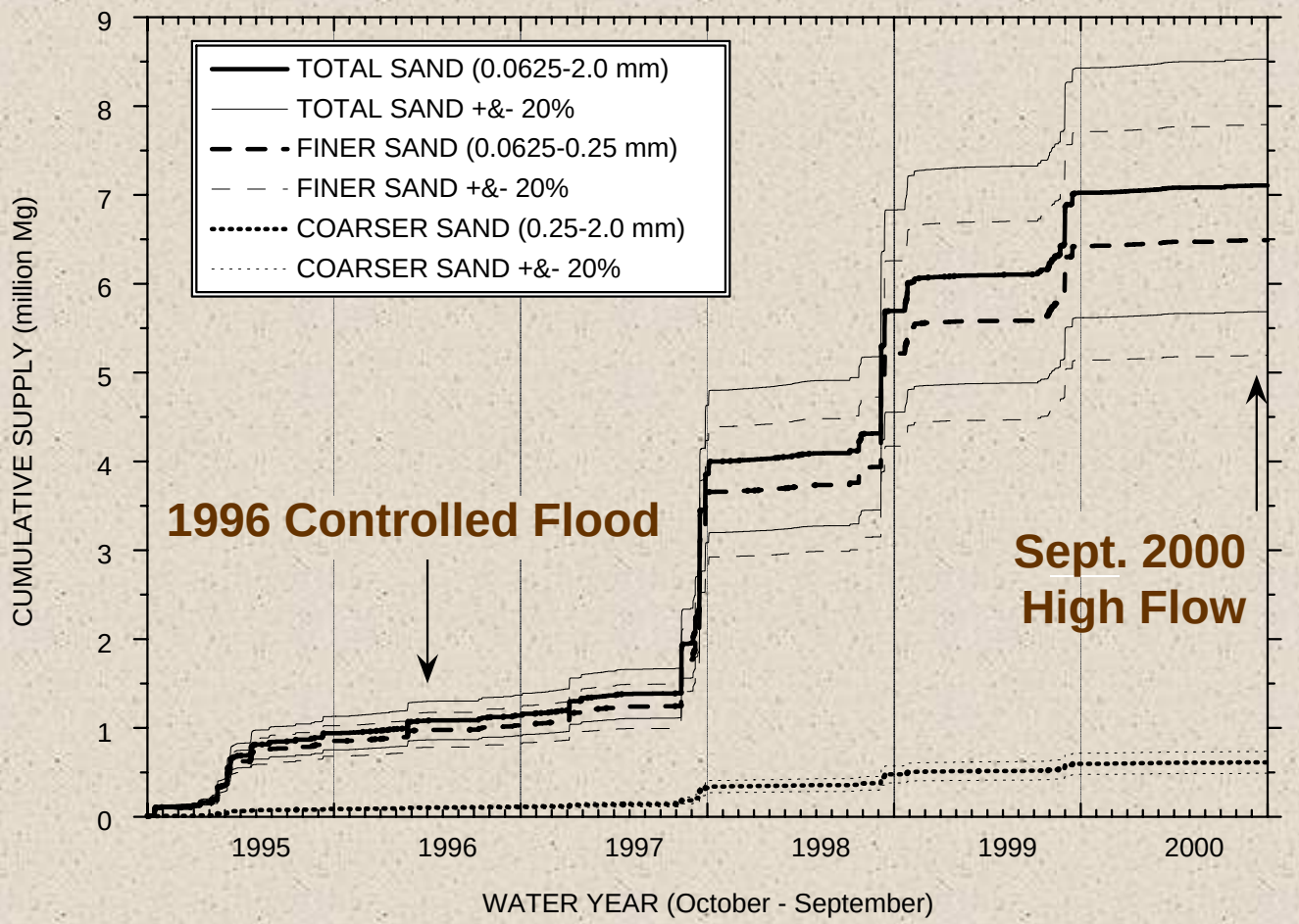
Sediment Storage

- Sizes of sediment in eddies and the main channel bed
- The relative distribution of sand on the channel bed and in eddies
- Topographic data


112o
UTAH
30'
111o
37o
ARIZONA
Lake Powell
Paria River
Lees Ferry
Glen Canyon Dam
09382000
09380000
Cathedral Wash
3
N
Lees Ferry Reach
22
River
16
Canyon
Redwall Gorge Reach
30
Grand Canyon National Park
Marble
30'
43
Pt. Hansborough Reach
47
45
50
Tapeats Gorge Reach
51
55
09383100
Little Colorado River
09402500
Colorado
36o
Colorado River
Arizona
GIS Reach
09383100
Streamflow-gaging station and station identifier
45
Field study site-number is in river miles
0
10 km
0
15 mi


NAU SURVEYING TRIP
USGS BED-SEDIMENT SAMPLING TRIP
1996 CONTROLLED FLOOD
1997 TEST FLOW
SEPT. 2000 POWERPLANT CAPACITY FLOW
MAY 2000 POWERPLANT CAPACITY FLOW
INSTANTANEOUS DISCHARGE (m3 / s)
0
200
400
600
800
1000
1200
1400
1996
1997
1998
1999
2000
CALENDAR YEAR

Cumulative supply from the Paria River



- Supply between Oct. 1994 and Sept. 2000 was ~7 million Mg of sand
- 90% was finer than 0.25 mm
- Ungaged tributaries supply ~ 5 to 20% of the Paria River (Webb et al., 2000)

Average median grain sizes of sediment in eddies and on the channel bed

Eddies

- Subaerial eddy sandbars ~0.13 mm
- Subaqueous eddy sandbars ~0.18 mm
- 70% of the sediment was finer than 0.25 mm

Main channel

- ~0.40 mm
- 17% of the sediment in the main channel was finer than 0.25 mm

Estimating the area of storage components

Sediment Budget Components	Lees Ferry	Redwall	Point Hansbrough	Tapeats Gorge	Marble Canyon
Length (km)	14.0	10.0	10.8	8.0	99.0
Eddies >1000 m^2 per km	2.2	3.2	3.2	4.1	3.0
Average eddy area inundated by the 1996 controlled flood (m^2)	6000	3600	7000	5500	5100
Average new channel margin deposit area in 1996	1616	840	2780	948	1600
Average new channel margin deposit area in 2000	620	590	470	430	550
Channel area excluding eddies at 227 m^3/s (m^2/km)	101,600	68,300	88,800	85,200	81,500

Source: Sara Goeking, Utah State U.

52 to 95% of the sand in Marble Canyon is stored in eddies

Eddies

- Total eddy area inundated by the 1996 controlled flood was 1,550,000 m^2
- Mean thickness of sand in the 11 eddies was 2.02 ± .10 m

Area x Thickness = 3.1 x 10^6 m^3 or 5.4 million Mg

Main Channel

- 8, 000,000 m^2 of channel area
- 10% of the in-channel area is rapids or riffles and contain no sand
- 20% of the remaining bed is covered by a 0.5 m thickness of sand

Area x Thickness = 0.72 x 10^6 m^3 or 1.2 million Mg

Sand Export from Marble Canyon during the 1996 Controlled Flood

- Total export
  - **sand: 670,000 +/- 30,000 Mg**
    - **41% very fine (0.0625 - 0.125 mm)**
    - **38% fine (0.125-0.25 mm)**
    - **19% medium (0.25-0.50 mm)**
    - **2% coarse and very coarse (>0.5 mm)**
  - **silt/clay: 120,000 +/- 10,000 Mg**

- $\Delta S = I - O$
- thus, ΔS = ~800,000 Mg in Marble Canyon

Sand Export from Marble Canyon during the September 2000 Powerplant Capacity Flow

- Total export
  - **sand: 220,000 +/- 10,000 Mg**
    - **62% very fine (0.0625 - 0.125 mm)**
    - **32% fine (0.125-0.25 mm)**
    - **5% medium (0.25-0.50 mm)**
    - **1% coarse and very coarse (>0.5 mm)**
  - **silt/clay: 65,000 +/- 5,000 Mg**

- $\Delta S = I - O$
- thus, ΔS = ~285,000 Mg in Marble Canyon

Source environments based on partitioning by grain size

1996 Controlled Flood

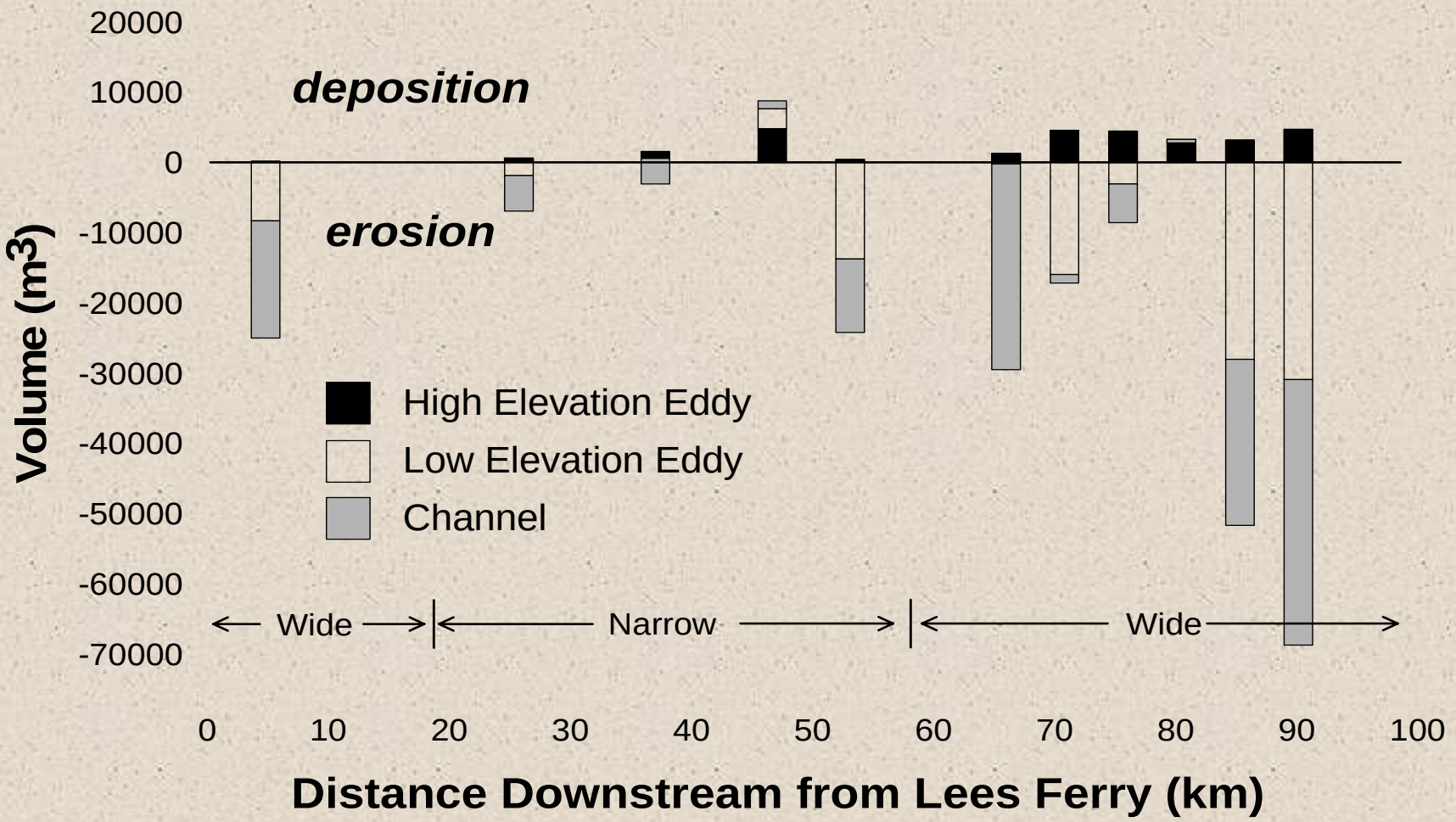
- eddies
  - silt/clay: 110,000 to 120,000 Mg (almost all)
  - sand: 490,000 to 650,000 Mg (72 to 95%)
- channel
  - silt/clay: 0 to 6,000 Mg
  - sand: 20,000 to 180,000 Mg (5 to 28%)

Sept. 2000 Powerplant Capacity Flow

- eddies
  - silt/clay: 62,000 to 65,000 Mg (almost all)
  - sand: 180,000 to 220,000 Mg (81 to 97%)
- channel
  - silt/clay: 0 to 3,000 Mg
  - sand: 4,000 to 36,000 Mg (3 to 19%)

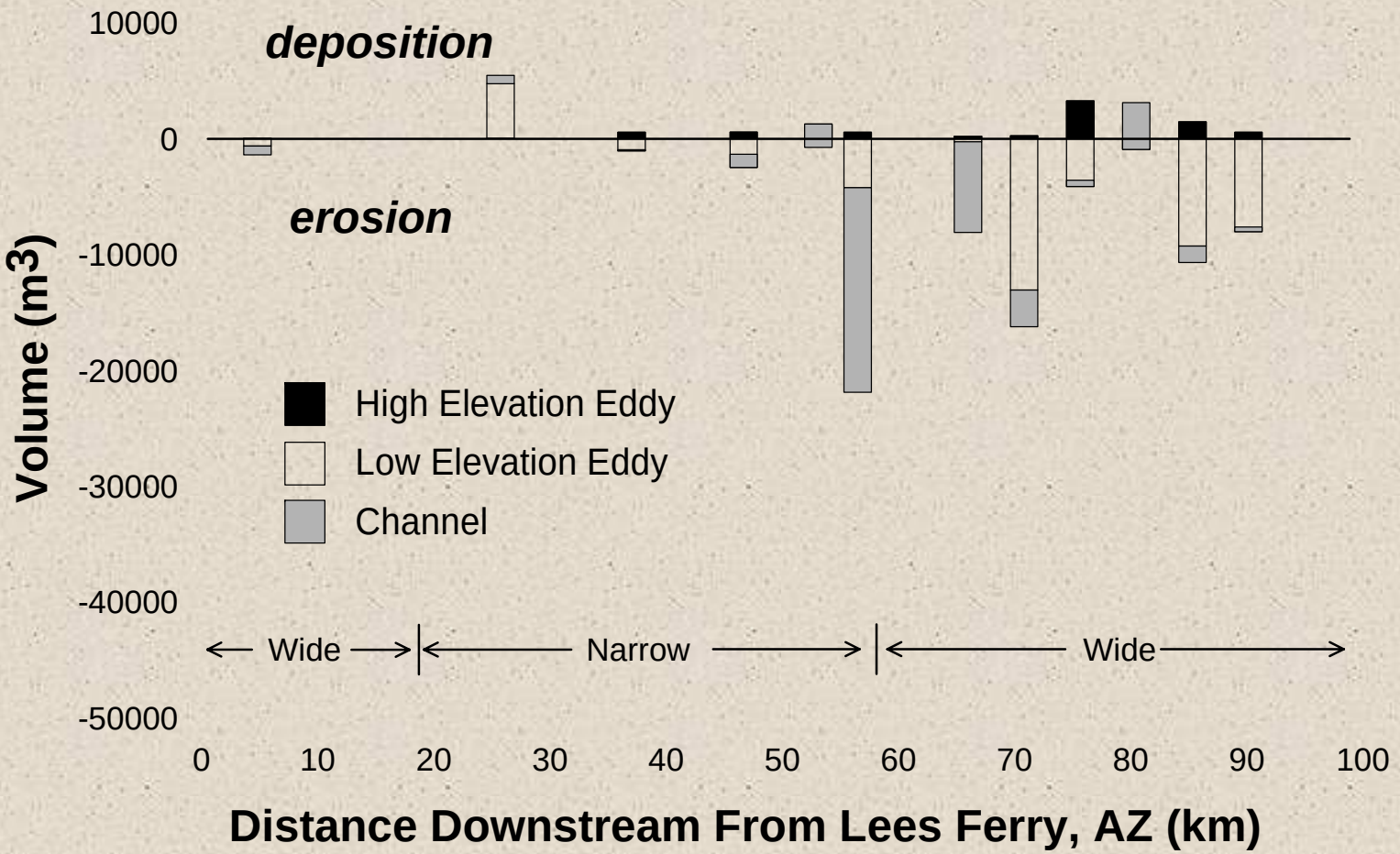
Source environments based on direct measurements of topography

1996 Controlled Flood



Source environments based on direct measurements of topography

Sept. 2000 Powerplant Capacity Flow



Average thickness changes from the study sites

Topographic Storage Components	1996 Controlled Flood	Sept. 2000 powerplant capacity flow
High Elevation Sand (m)	+0.18 ± .05	+0.03 ± .15
Low Elevation Sand (m)	-0.55 ± .18	-0.15 ± .08
Channel Margin Bar Thickness (m)	0.25 to 0.50	0.10 to 0.20
Channel Bed Thickness	-0.51 ± .14	-0.08 ± .07

Sediment budgets for the 1996 controlled flood and the Sept. 2000 powerplant capacity flow

Budget Components	1996 Controlled Flood ($\times 10^6$ Mg)	Sept. 2000 Powerplant Capacity Flow ($\times 10^6$ Mg)
Supply from the Paria River	0	0
High-elevation eddy sand	0.35 to 0.61	0.04 to 0.12
High-elevation channel margin sand	0.07 to 0.14	0.009 to 0.019
Low-elevation eddy sand	-1.0 to -1.9	-0.19 to -0.61
Channel sand	-0.02 to -0.18	-0.004 to -0.39
Total storage change	**-0.59 to -1.4**	**-0.14 to -0.51**
Export past Lower Marble Canyon Gage	**-0.79**	**-0.29**
Partitioned Grain Size Method	**-0.49 to –0.65**	**-0.18 to -0.22**

Conclusions

- Two independent sediment budgeting techniques indicate that eddies are the primary source of sand during high clear water releases
- Given uncertainties in the methods, considerably more than half of the sand in Marble Canyon is stored in eddies under post dam conditions
- The grain size distribution of the sand stored in eddies is far more similar to the distribution of the sand supplied by the Paria River