Relative Importance of Eddy versus Channel Sand Storage in Marble Canyon, 1996-2000

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

input - output = change in storage (△s)

Main-channel bed

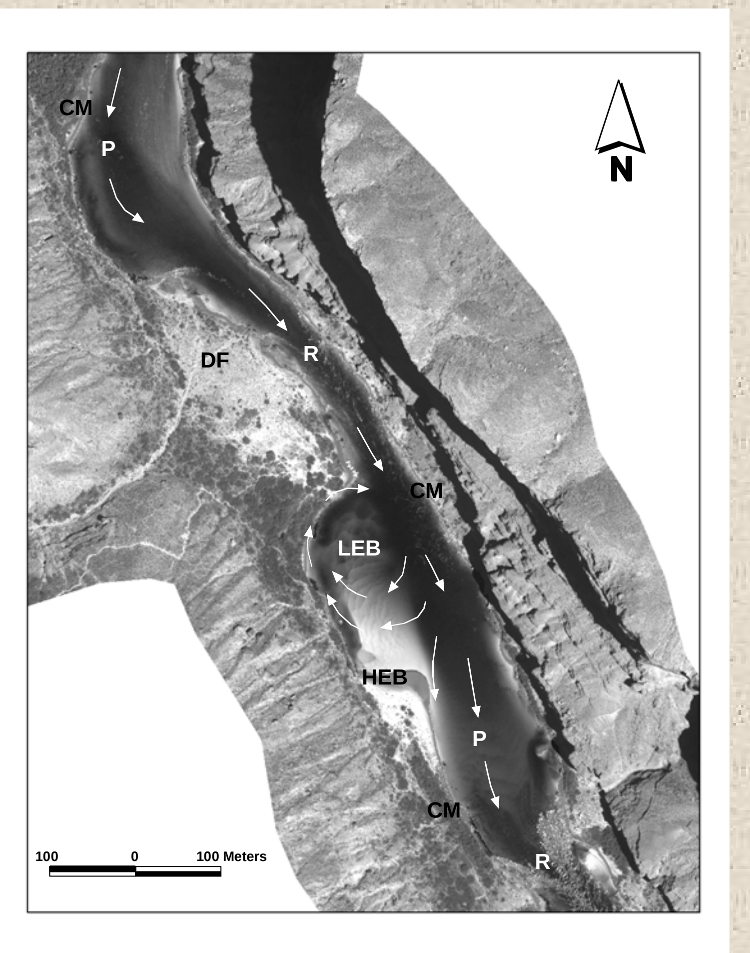
- primarily composed of **gravel, boulders and bedrock**
- overlying the coarse material are **discontinuous sandy deposits**

Eddies

- **debris fans** determine the locations
- large eddies contain **bars that may be more than 10 m thick**

Channel-margin deposits

- **narrow, thin veneers** of fine sediment on steeply sloping banks



Implication of Whether the Bed or the Eddies is the Primary Repository of Sand

- If eddies are the primary storage site, then sandbars in …Marble Canyon will be progressively eliminated in the face of a long-term and progressive negative sediment budget *(Rubin et al., 1994)*

Objectives of this Study

- Quantify the total volume of active storage within the two main storage environments, eddies and the main channel

- Develop sediment budgets for two post-dam periods when dam releases were high and when influx and efflux of sediment were simultaneously measured

- Determine which environment is the primary source of sand during high clear water releases from Glen Canyon Dam

Quantify the total volume of active storage within the two main storage environments

- Eddies occupy a small percentage (~17%) of total channel area
- 51 to 94% of the sand in Marble Canyon is stored in eddies

Sediment Budget Components	Lees Ferry	Roaring Twenties	Redwall Gorge	Point Hansbrough	Tapeats Gorge	Marble Canyon Average
Length (km)	14.0	7.5	10.0	10.8	2.9	99.0
Eddies >1000 m^2 per km	2.2	4.4	3.3	3.8	5.7	3.5
Average eddy area inundated by the 1996 controlled flood (m^2)	6210	3310	3230	6240	5160	4830
Average new channel margin deposit area in 1996	520	780	770	3930	1440	1760
Average new channel margin deposit area in 2000	---	---	---	1110	---	460
Channel area excluding eddies at 227 m^3/s (m^2/km)	132,840	58,460	70,200	86,330	73,740	84,850

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

Sediment input to Marble Canyon

- Determined from a predictive flow and sediment transport model (Topping, 1997); zero during each high-flow event

Sediment output from Marble Canyon

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

Sediment Storage, Δs

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

Sand Output 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 Output 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, $\Delta S = \sim 285{,}000$ Mg in Marble Canyon

Two independent techniques were used to estimate changes in sediment storage (Δs)

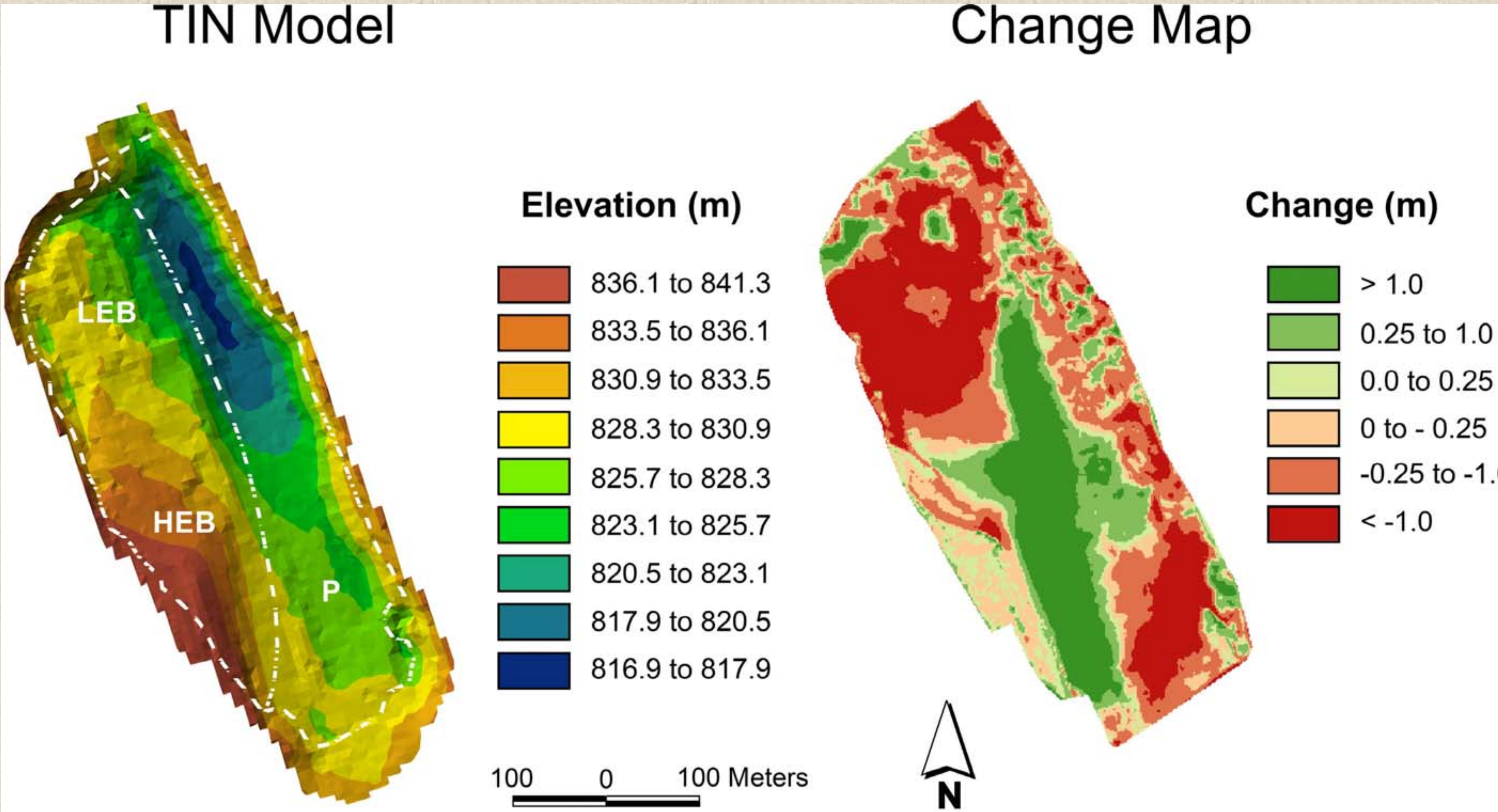
Source environments based on direct measurements of topography

- **Relies on substantial extrapolation of area and limited site measurements**

Source environments based on partitioning by grain size

- **No measurements of topographic change**
- **Requires measurement of the grain size distributions in each storage environment**

Direct measurements of topography at 11 detailed study sites



Average thickness changes from the study sites

Topographic Storage Components	1996 Controlled Flood (m)	Sept. 2000 Powerplant Capacity Flow (m)
High Elevation Sand	+0.18 ± .05	+0.03 ± .02
Low Elevation Sand	-0.56 ± .18	-0.15 ± .08
Channel Margin Bar	0.30 to 0.10	0.15 to 0.17
Main-Channel Bed	-0.49 ± .13	-0.08 ± .07

Source environments based on partitioning by grain size

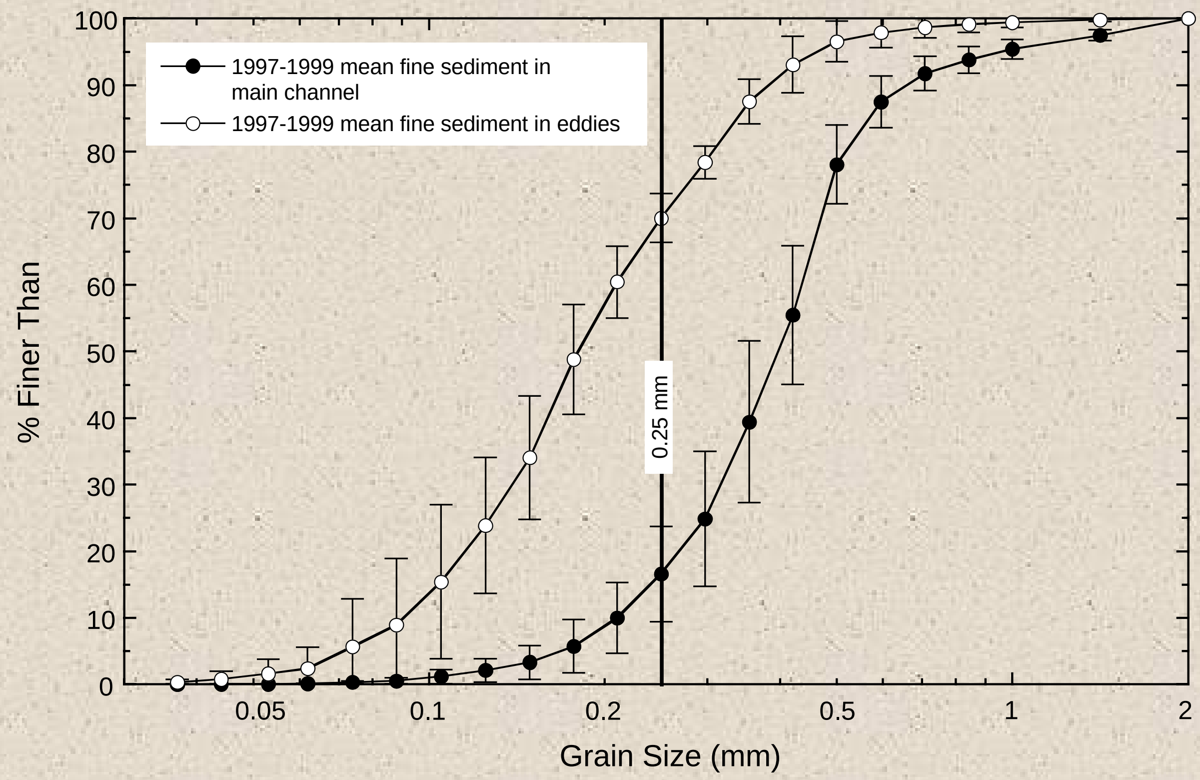
Average median grain sizes of sediment

Eddies

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

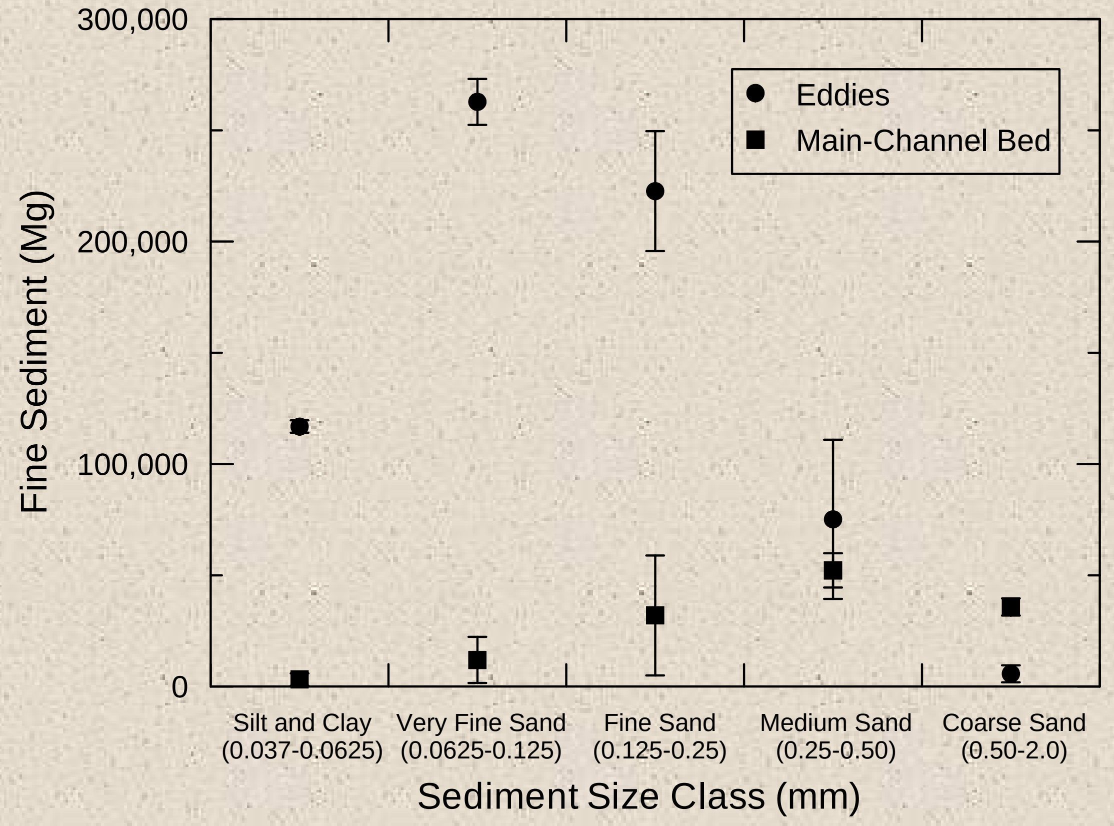
Main channel

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



Source environments based on partitioning by grain size

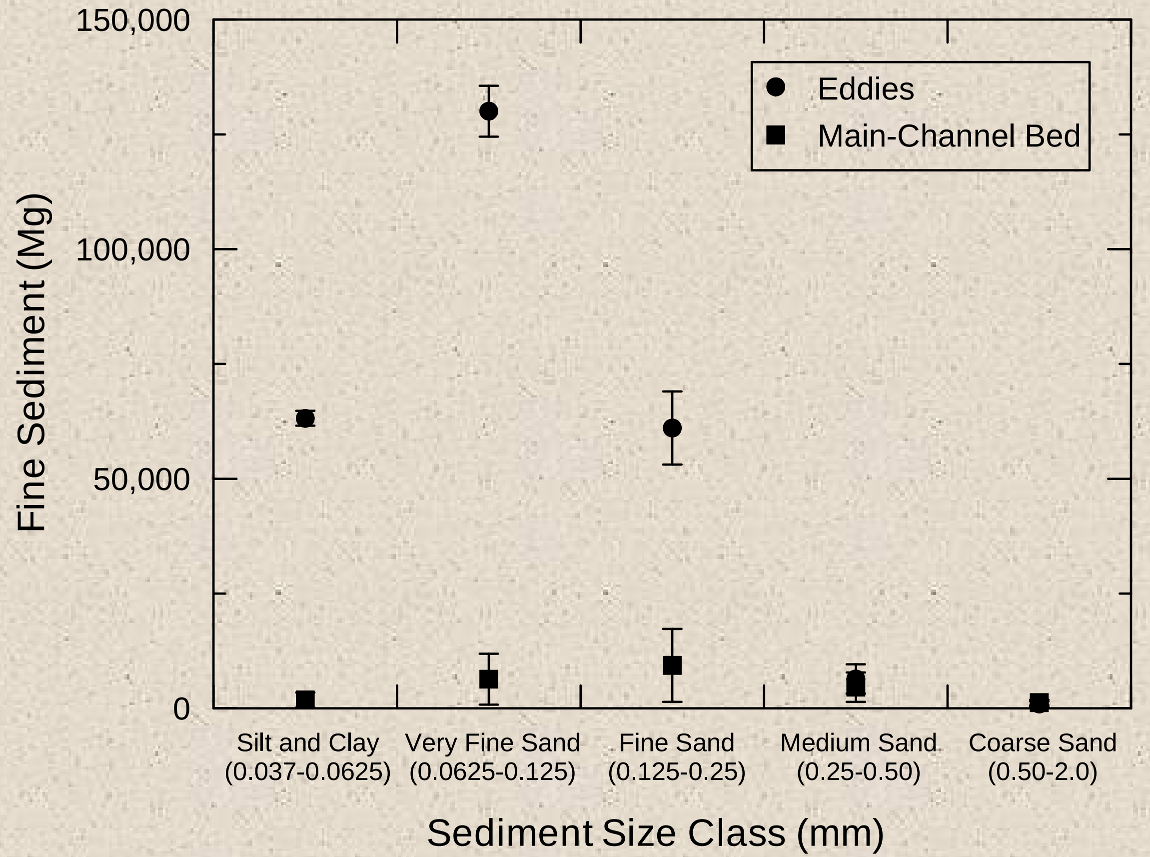
The proportions of eddy and channel derived sediment in 1996



Nearly all the silt and clay and the majority of very fine and fine sand was eroded from eddies, whereas the medium to coarse sand was eroded from both eddies and the main channel

Source environments based on partitioning by grain size

The proportions of eddy and channel derived sediment in 2000



Nearly all the silt and clay and the majority of very fine and fine sand was eroded from eddies, whereas the medium to coarse sand was eroded from both eddies and the main channel

The estimates of Δs in eddies provides an estimate of the accuracy of the topographic data to the reach scale

1996 Controlled Flood

- **Topographic estimate = 1.0 ± 0.36 million Mg**
- **Grain-size estimate = 0.68 ± 0.08 million Mg**

Sept. 2000 Powerplant Capacity Flow

- **Topographic estimate = 0.34 ± 0.17 million Mg**
- **Grain-size estimate = 0.26 ± 0.02 million Mg**

Conclusions

- Two independent sediment budgeting techniques indicate that ~90% of the sediment exported from Marble Canyon was derived from eddy storage
- 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