San Francisco State University
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Sand Mobility in a Regulated Riffle-pool Gravel Bed River

A case study of a salmon spawning reach of the San Joaquin River, California

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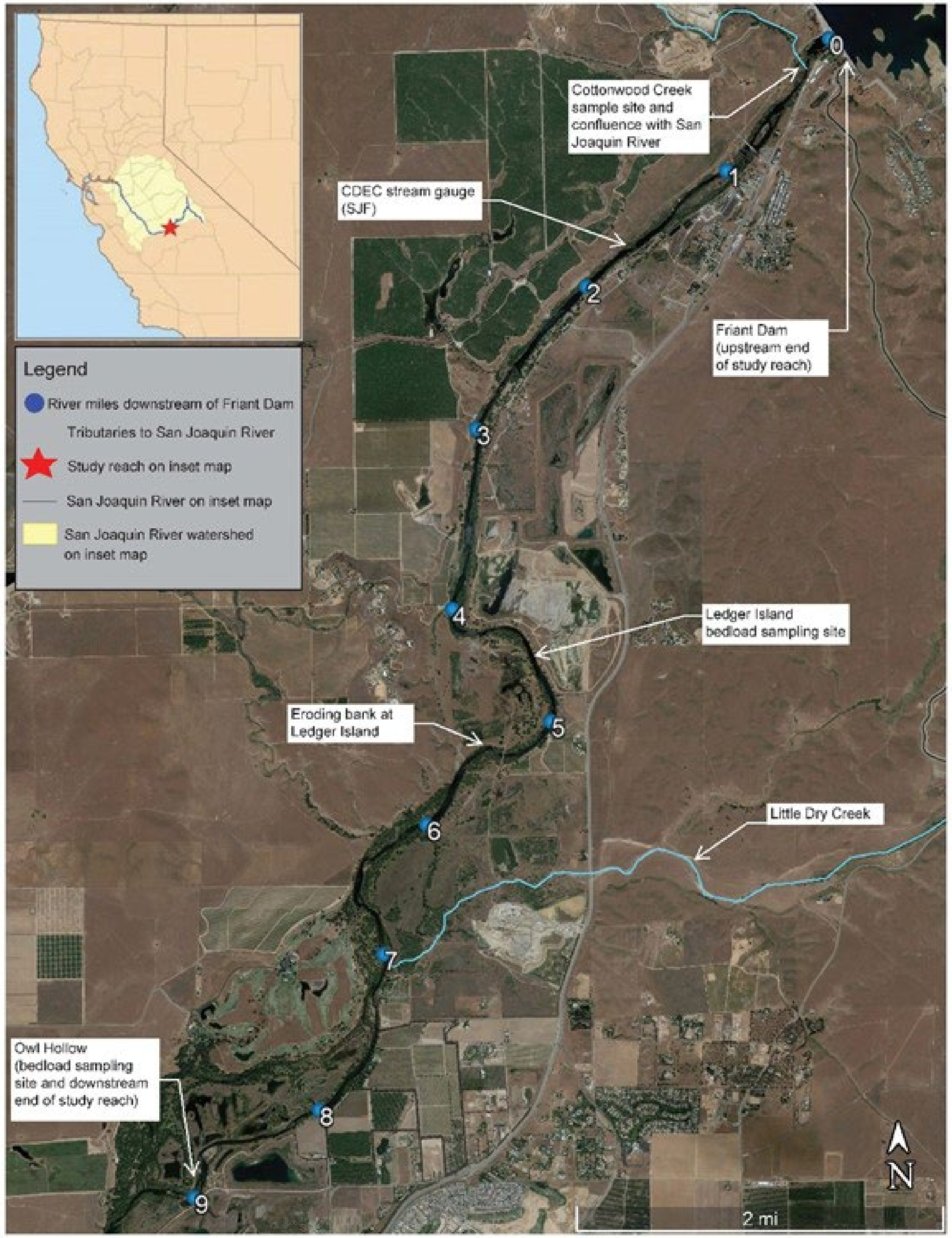
Research question:

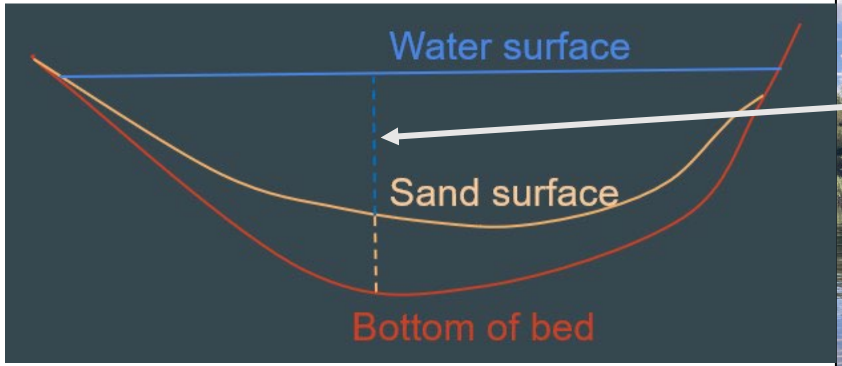
- How does sand move downstream of Friant Dam during low, moderate, and high flow events?

Study site

- San Joaquin River near Fresno, Ca
- 9-mile reach downstream of Friant Dam; interface of foothills and low-land Central Valley
- Gravel bedded, riffle-pool sequence, historic & current gravel mining, two ephemeral tributaries DS of Friant Dam
- Salmon spawning reach, subject to SJRRP
  - Efforts to return Chinook salmon
  - Upper 7 miles is S-R salmon spawning reach (sediment and water temperatures)

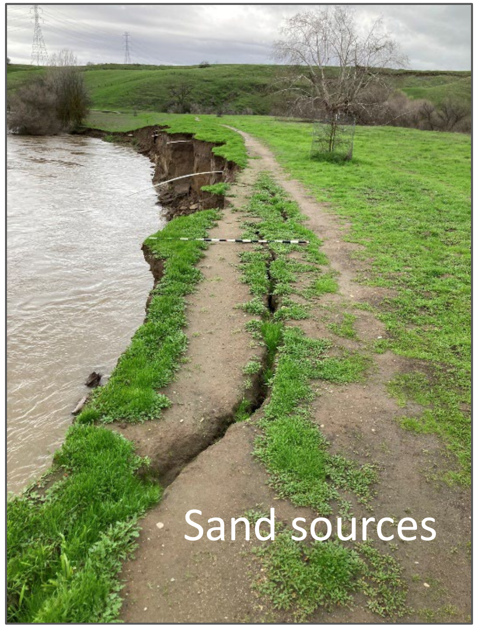


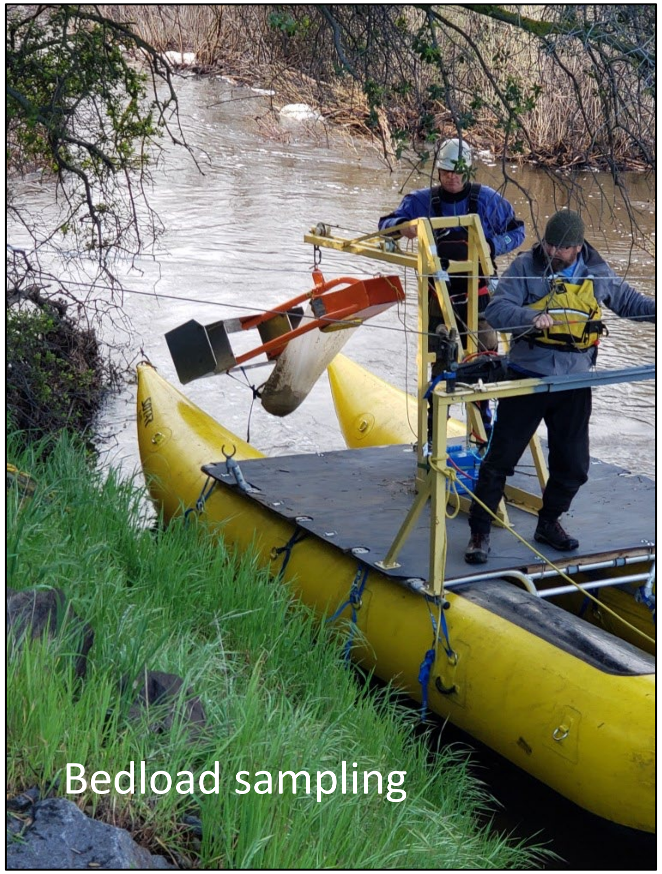
Methods




Sand probing & mapping

- Measuring sand storage and volumes
  - Delineating in-channel sand storage locations
  - Rebar probe to calculate sand thickness and storage – 50 transects
- Measuring sand transport
  - Bedload transport through mainstem SJR (low flow, bank full flow, high flow)
- Measuring sand supplied
  - Sand inputs to mainstem SJR
  - Tributary Cottonwood Creek
  - Eroding bank


Sand sources

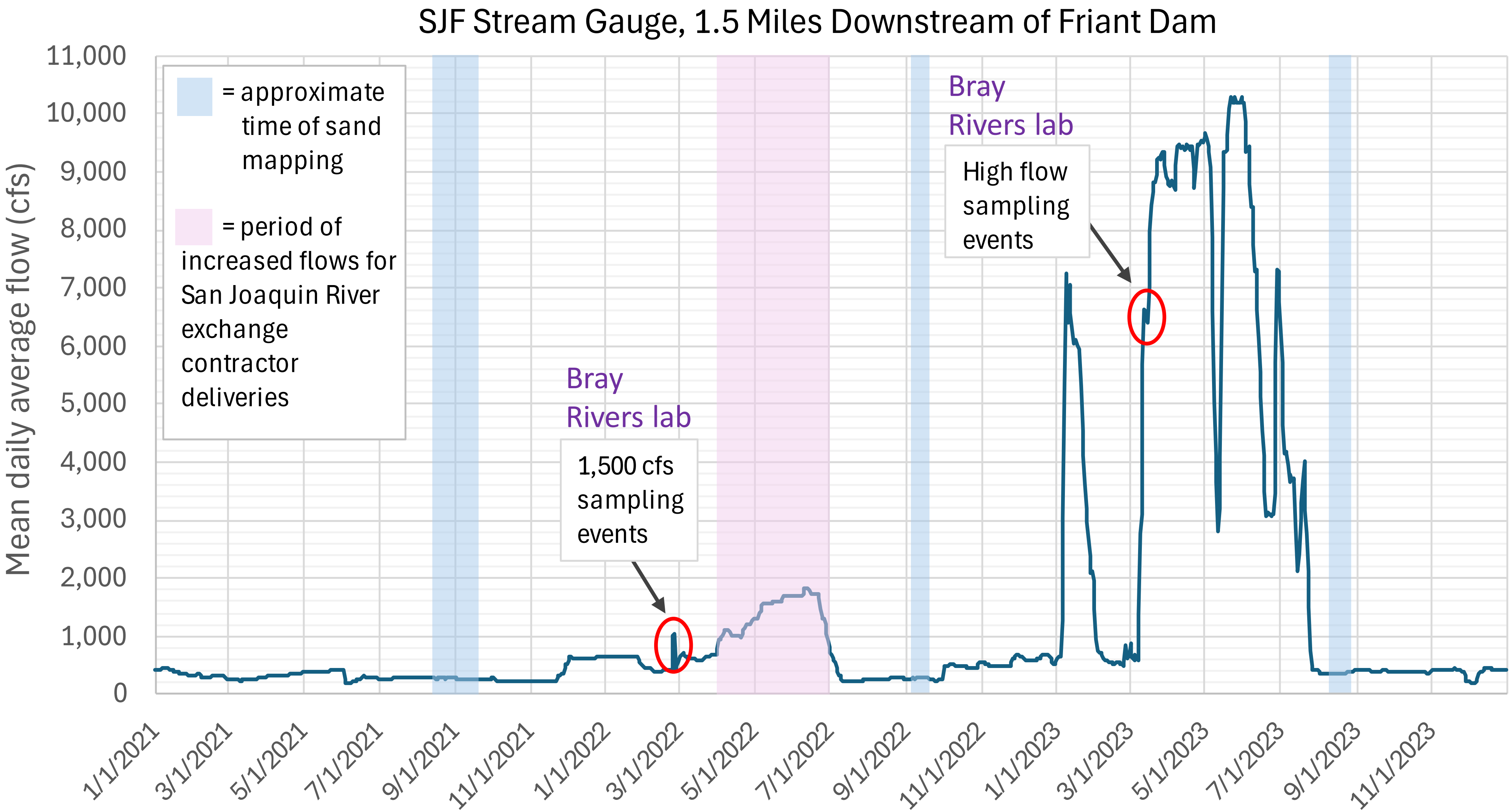

Bedload sampling

Note: sand is defined as particles < 2mm



Hydrograph and field sampling timeline

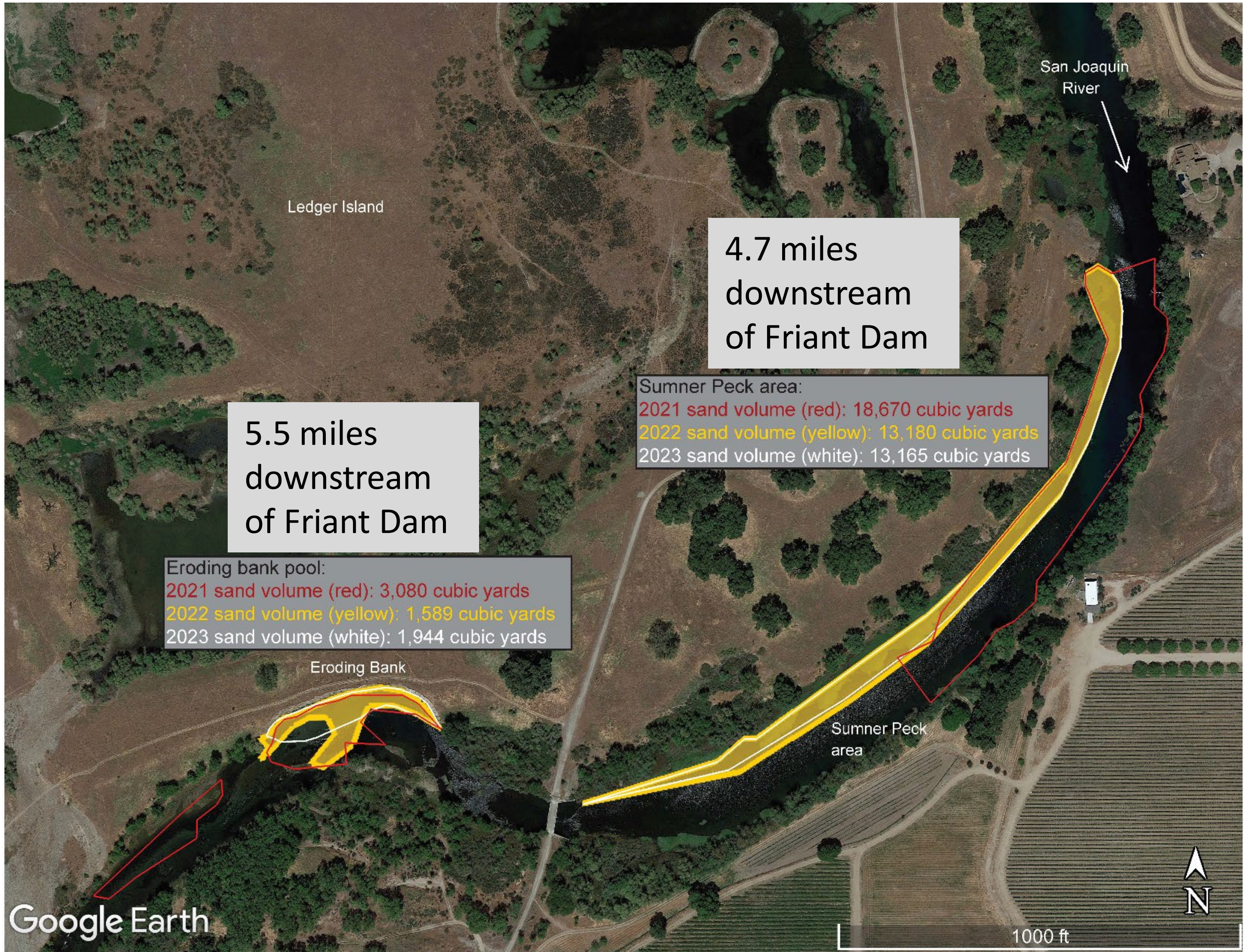
2000 - 2023	
Recurrence Interval (years)	**Flow (cfs)**
1.5	822
2	1,641
5	5,690
10	8,612
25	11,043



How much sand is in the reach, and how does it change from year to year?

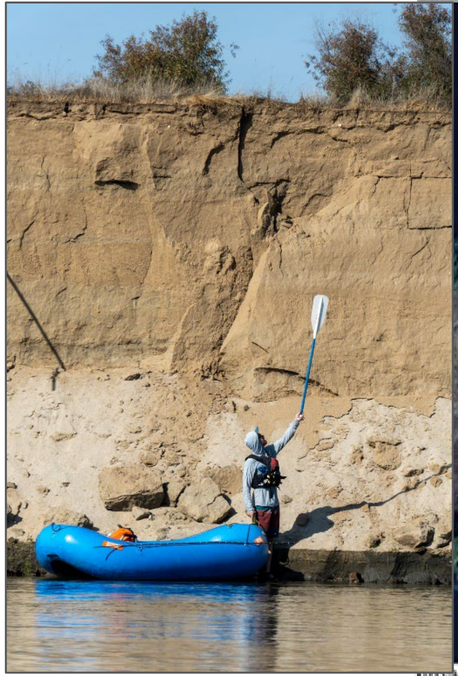
- Sites
  - Eroding bank pool at Ledger Island;
  - Sumner Peck pool
- Mapping color corresponds to mapping year
- Both sites show decreases in sand content each year

- 2021 dry year
- 2022 dry year with moderate flows
- 2023 historical wet year – highest snow pack since 1952!



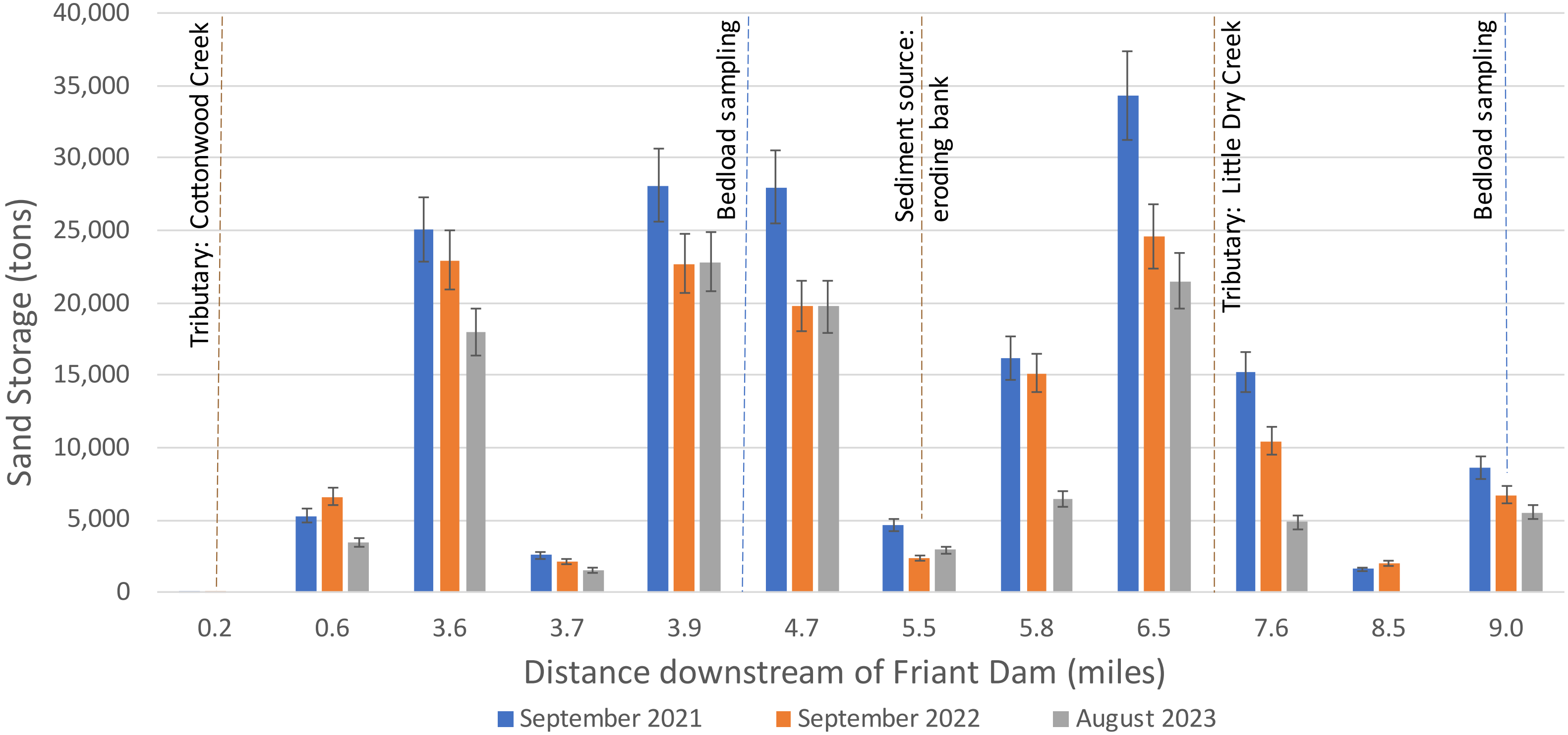
Results: Bank sand storage and supplied into channel

- Erosion pattern of a bank at Ledger Island, one of 3 potential sediment sources within the study reach.
- 71 feet of erosion from 2011 – 2023
- 14 feet of erosion from 2021 – 2023
- 20k tons supplied from 2011 – 2023
- 4k tons supplied from 2021-2023



Result: Bed sand storage decreased each year

- Sand volumes stored on the bed along 9-mile reach **decreased** after a bank full flow event in 2022 and after high flows in 2023
- 2021: 170,000 tons
- 2022: 135,000 tons
- 2023: 105,000 tons
- ~ 35% decrease from 2021-2023



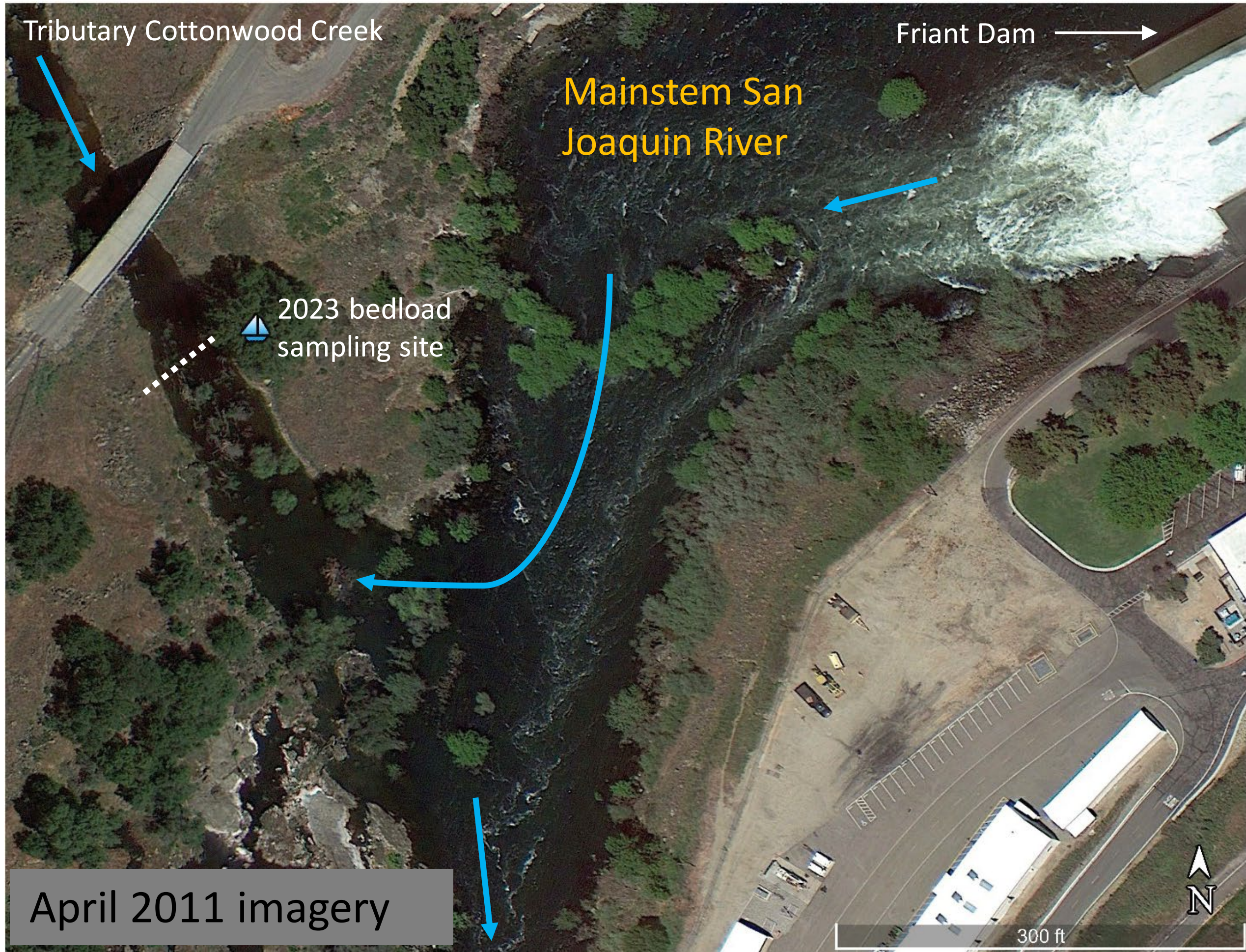
We have field measured evidence that what was stored on the bed got flushed out from 2021 to 2023. This begs the question **where did the sand go, and at what rate was it being transported**?

What’s being transported, at what rates, and at what flows?

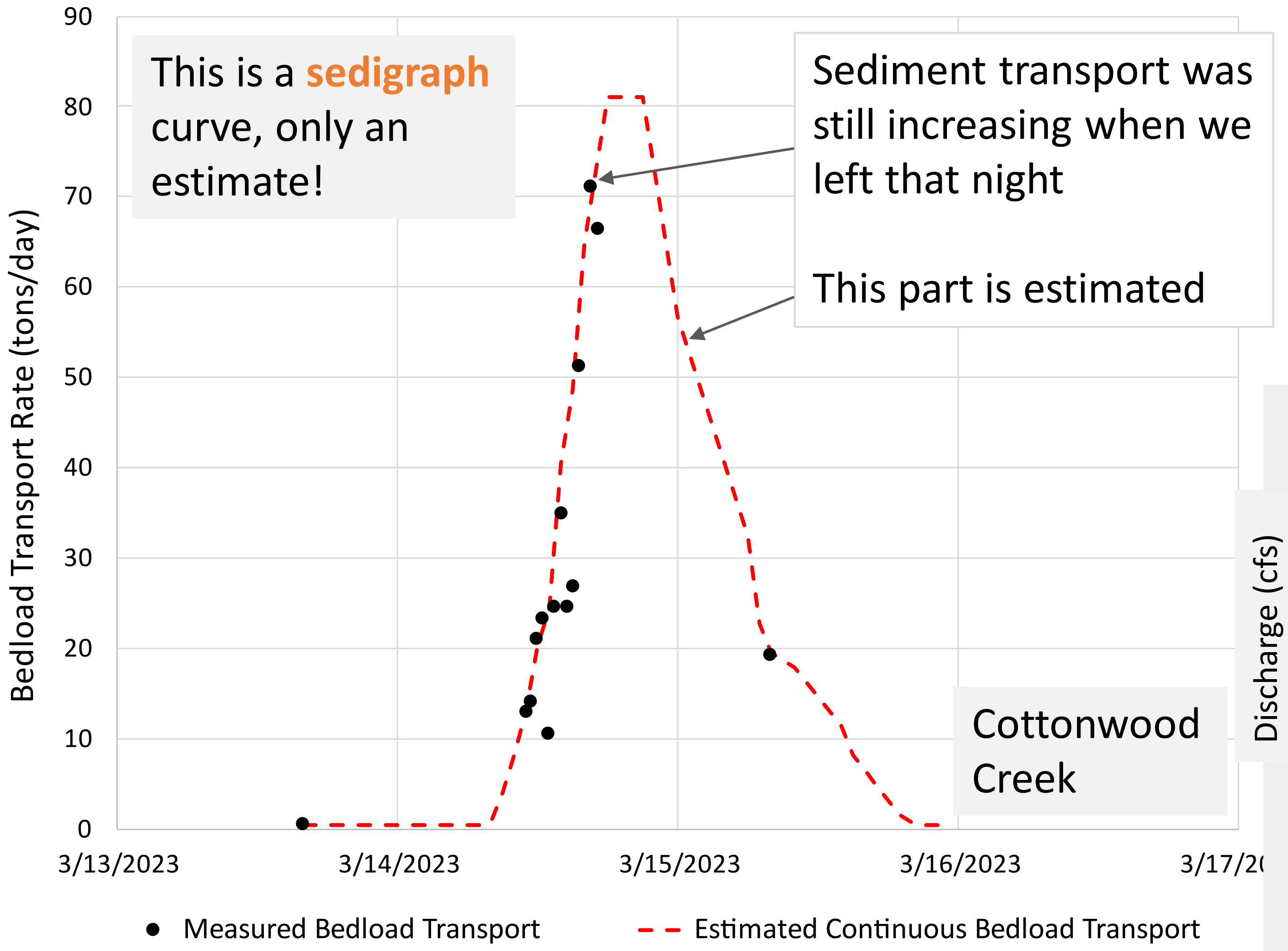
- How do geomorphologists answer this question?
- Hydraulic/transport models:
  - Estimate shear stress at various flow scenarios
  - Plug into equation
  - Get a value… do we trust it?
- Empirical field measurements
  - Measure bedload transport rates across a range of flow scenarios
  - Build a sediment rating curve (bedload transport rate to stream discharge)

What’s the sand input from Cottonwood Creek at the top of the study reach?

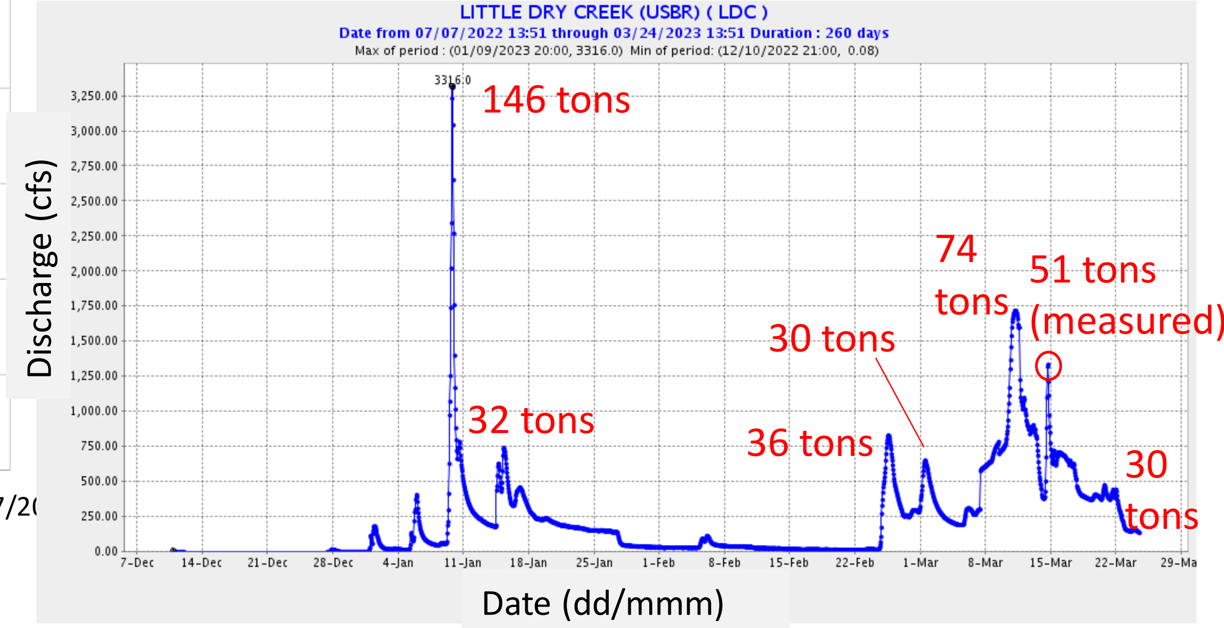
- No stream gauge on Cottonwood Creek, ephemeral and usually dry
- Backwater effect from mainstem San Joaquin River
- So how do we estimate sand supplied to the mainstem?



Results: Tributary bedload transport measured continuously over duration of storm

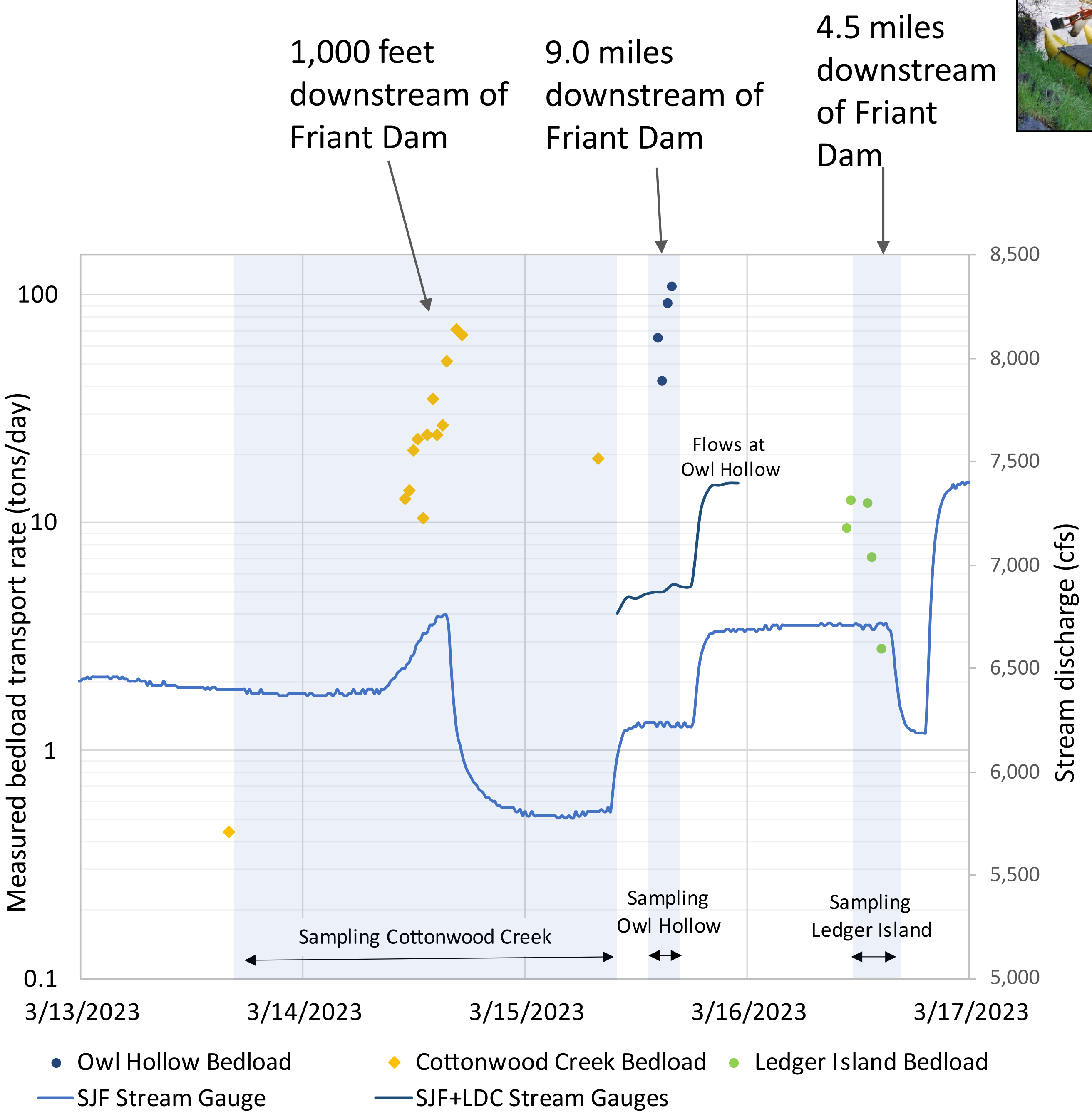


- Estimate of sand supplied over the storm: ~51 tons
- Estimate of 2023 sand supply: ~450 tons

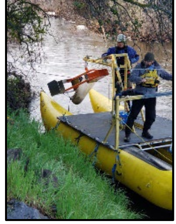


Results: Bedload transport rates at high flows

- High flows: Bedload sampling at a tributary and two points on the mainstem SJR relative to Friant Dam releases during high flows
- Bedload transport rates were highest at the tributary (input below dam) and the downstream end of study reach
- Bankfull flows: trace bedload
- Low flows: trace bedload



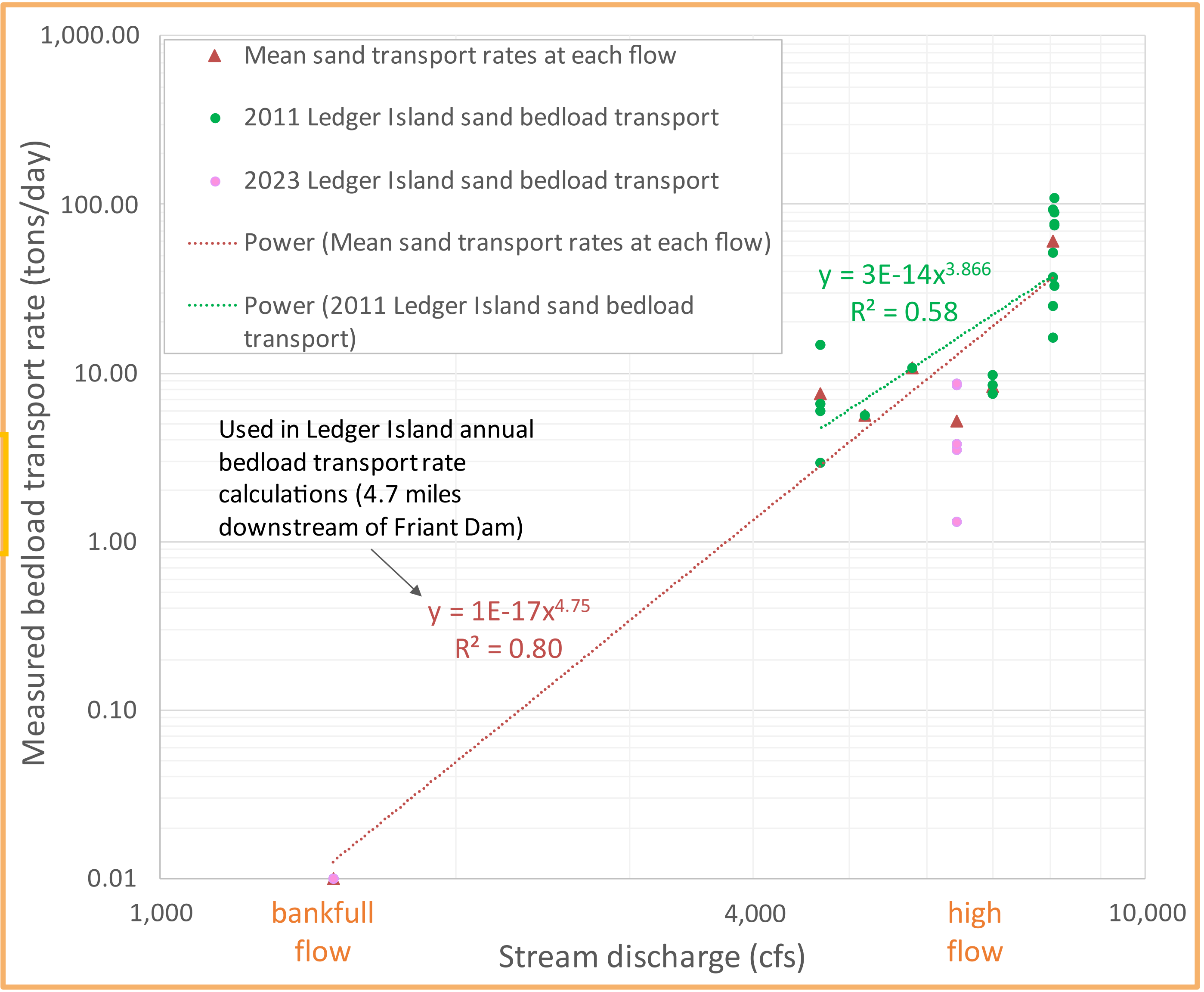
Results: Bedload transport rates across a range of flows



Location (distance downstream of Friant Dam)	Average Bedload Transport Rate Measured (March 2023)	Estimated Bedload throughout study period (2021 – 2023)
Cottonwood Creek (1,000 feet)	20 tons/day	450 tons
Ledger Island (4.5 miles)	5.4 tons/day	5,750 tons
Owl Hollow (9 miles)	64 tons/day	~46,000 tons*

*subject to uncertainty, only an estimate

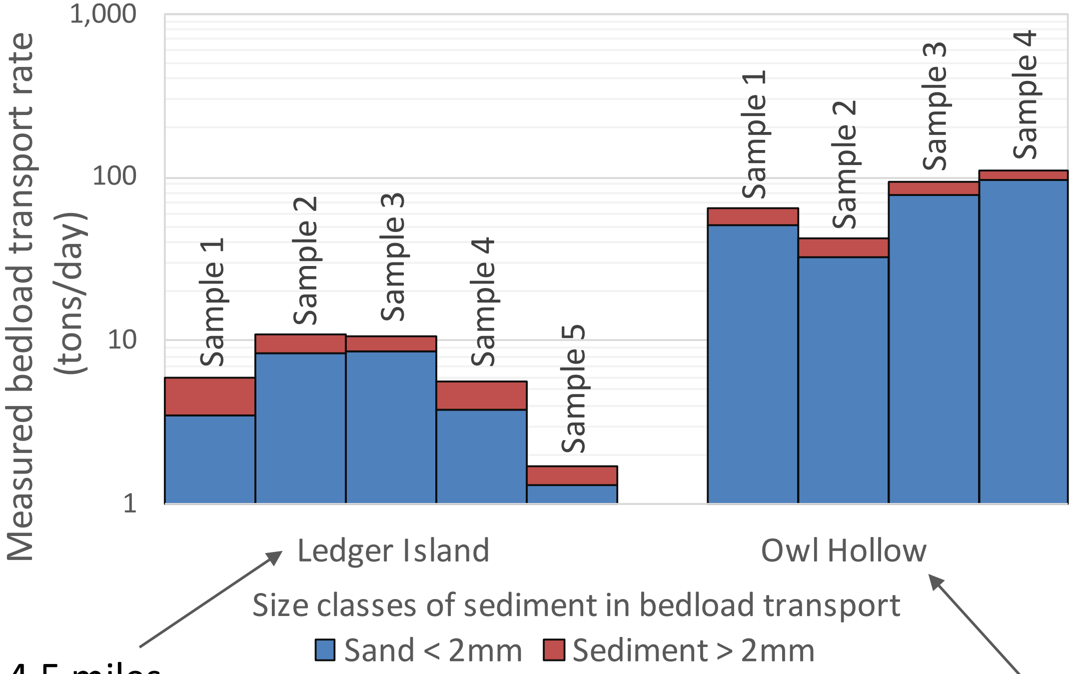
Ledger Island Sediment Rating Curve



Which grain sizes are in transport at high flows?

- Sand was the dominant grainsize in transport at high flows
- Transport rates were an order of magnitude higher at Owl Hollow than Ledger Island, *which agrees with expectations from calculated bed shear stress*

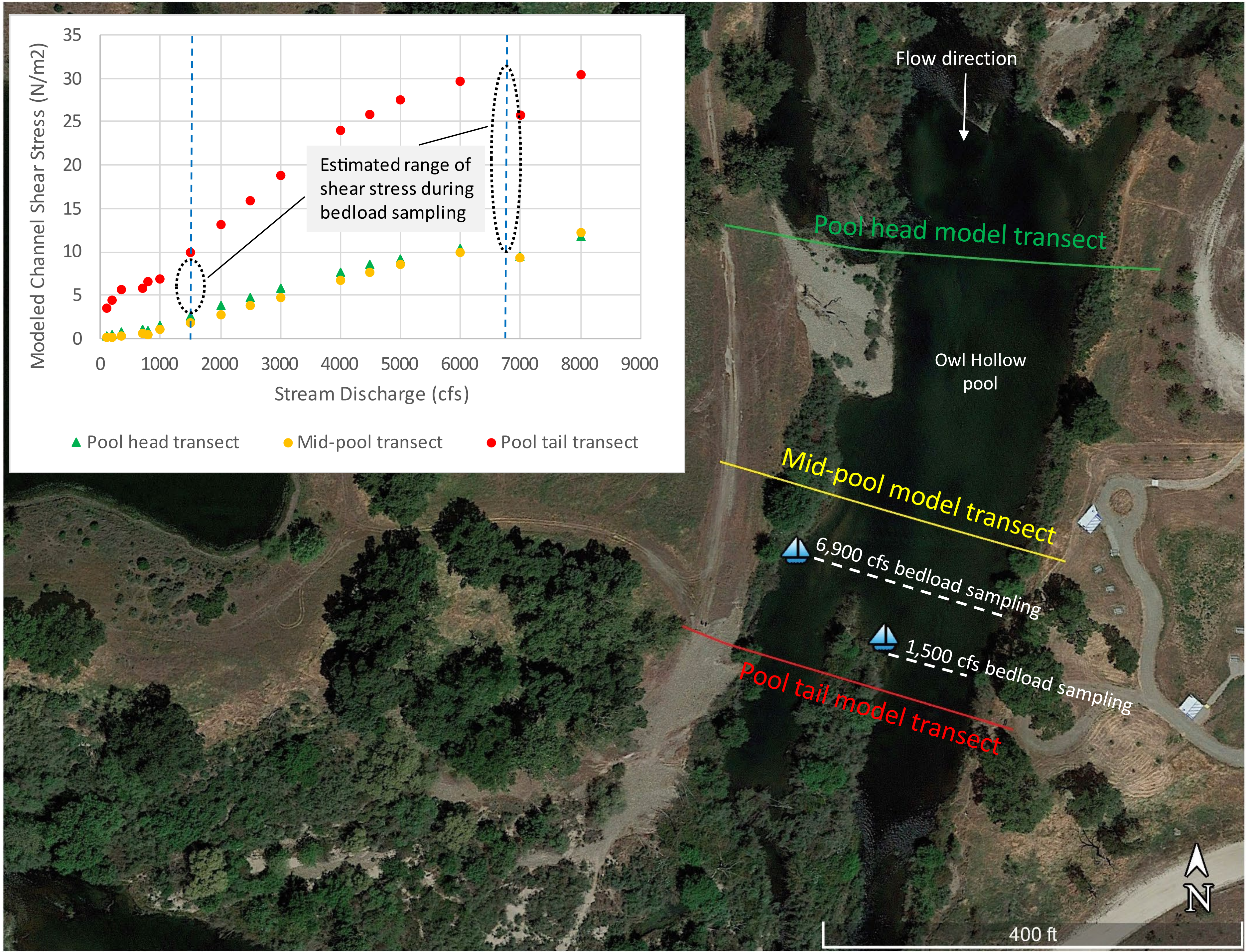
Spring 2023 bedload transport measurements at high flows



4.5 miles downstream of Friant Dam

9 miles downstream of Friant Dam

- At bank full flow (1,500cfs) and high flow sampling events (6,900 cfs), shear stress can vary 3-fold
- This is why predicting bedload transport is hard and we need empirical measurements.
- This is even harder to predict accurately at high flows, and that's when we expect to see the most sediment mobilized



Conclusions

- Sand storage on bed decreased throughout the 9-mile study reach after an extended bank full flow and 20-year high flows
- Sand supply from the ephemeral tributary at the top of the study reach is infrequent, but can be prolific during flows
- Bedload transport occurs at very low rates at low and bank full flows; the inception of substantial transports rates remains unknown
- Sand bedload transport (at high flows) is about 10x higher at downstream end of study reach than it is at the halfway point
- A 6,000 - 7,000 cfs flow is capable of mobilizing the size ranges of sand that we see being stored on the bed

Questions?

End