GOAL7: Streamflow, water quality, and sediment-transport project

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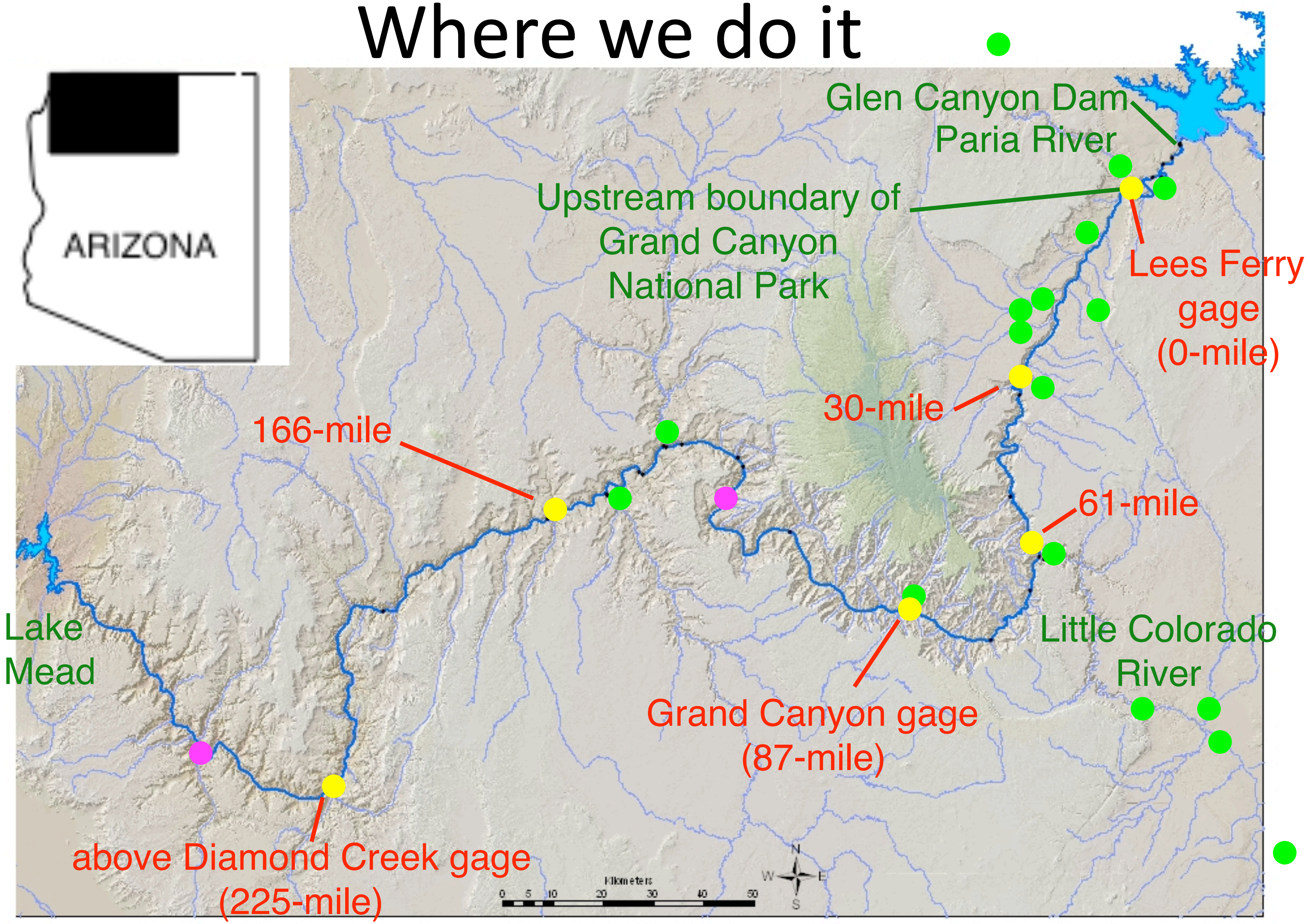
Personnel and Cooperators

- David Topping (project chief)
- Nick Voichick
- Ron Griffiths
- Tom Sabol
- Karen Vanaman
- USGS-Arizona Water Science Center
- USGS-Utah Water Science Center

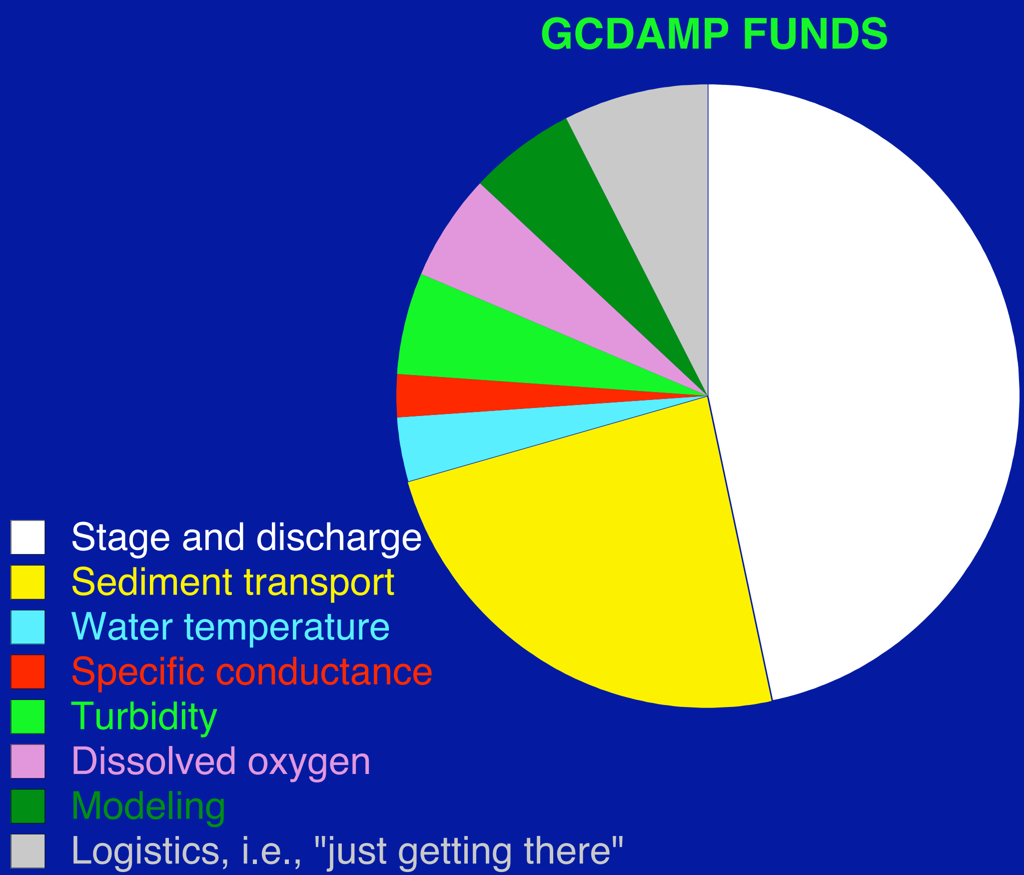
What we do

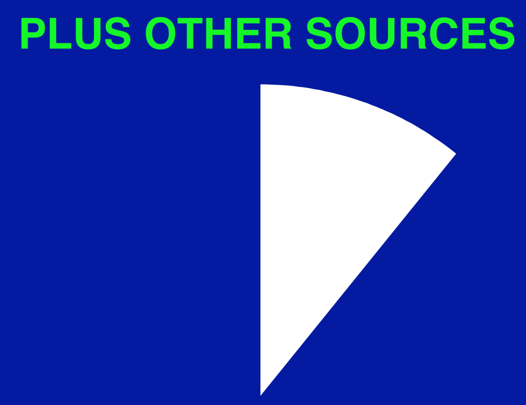
- Stage
- Discharge
- Sediment transport
- Dissolved Oxygen
- Turbidity
- Water temperature
- Specific Conductance
- Mass-balance sediment budgets--used to evaluate effects of dam operations and to trigger and evaluate artificial (controlled) floods

Where we do it

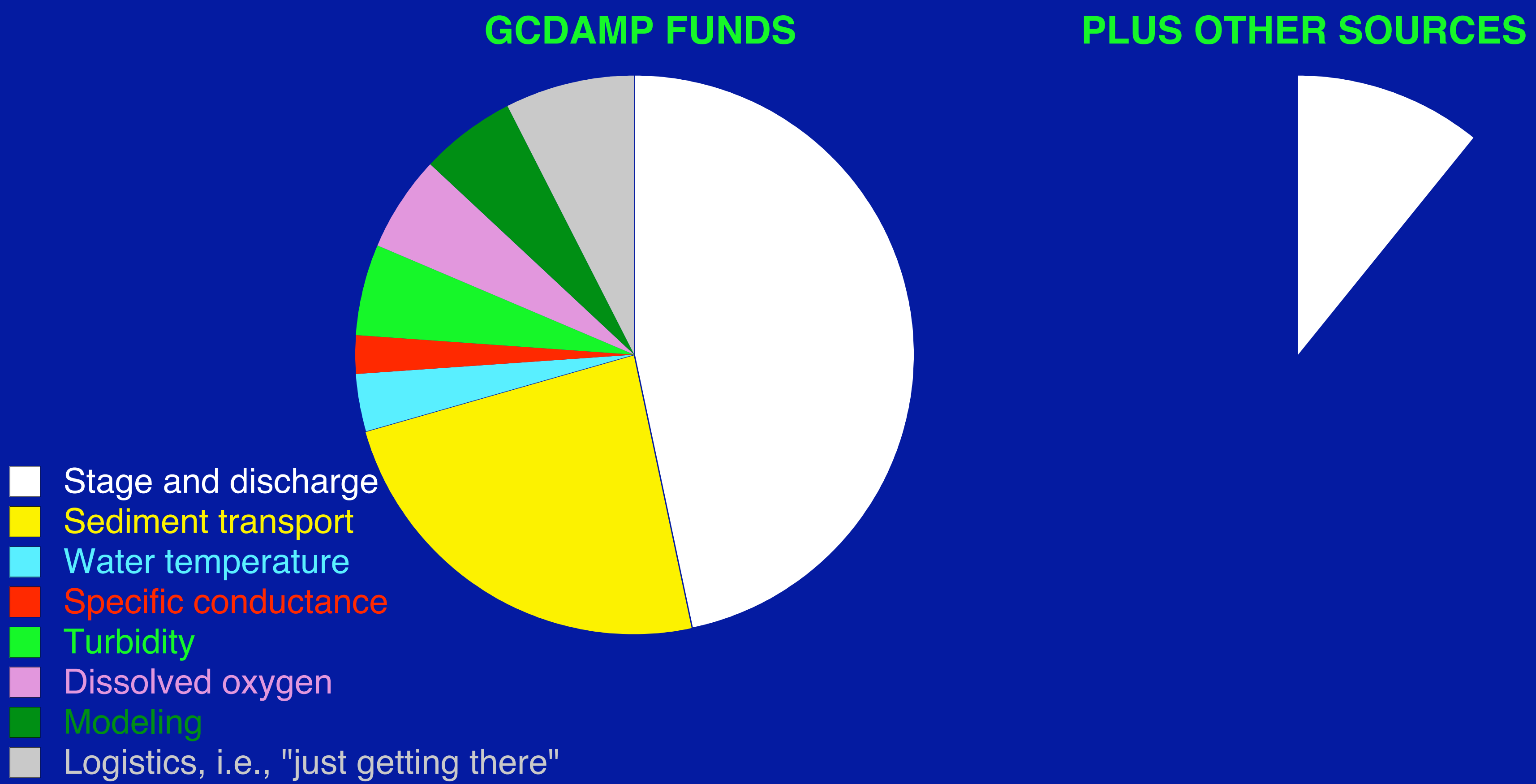


Project breakdown…
we have made the pie bigger





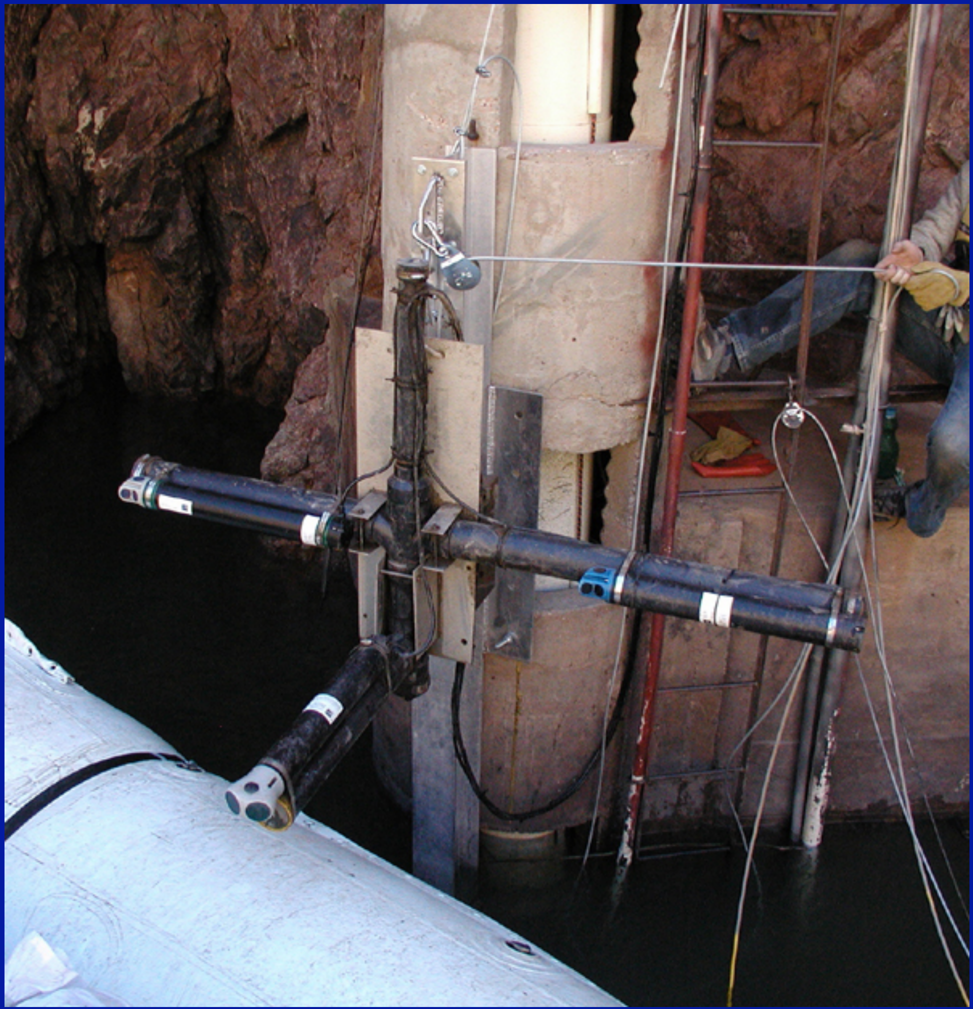
Project breakdown... we have made the pie bigger



but these pies are somewhat misleading because...

...we measure multiple parameters with the same instruments.   For example, with the acoustic-Doppler side-looking profilers, we measure...

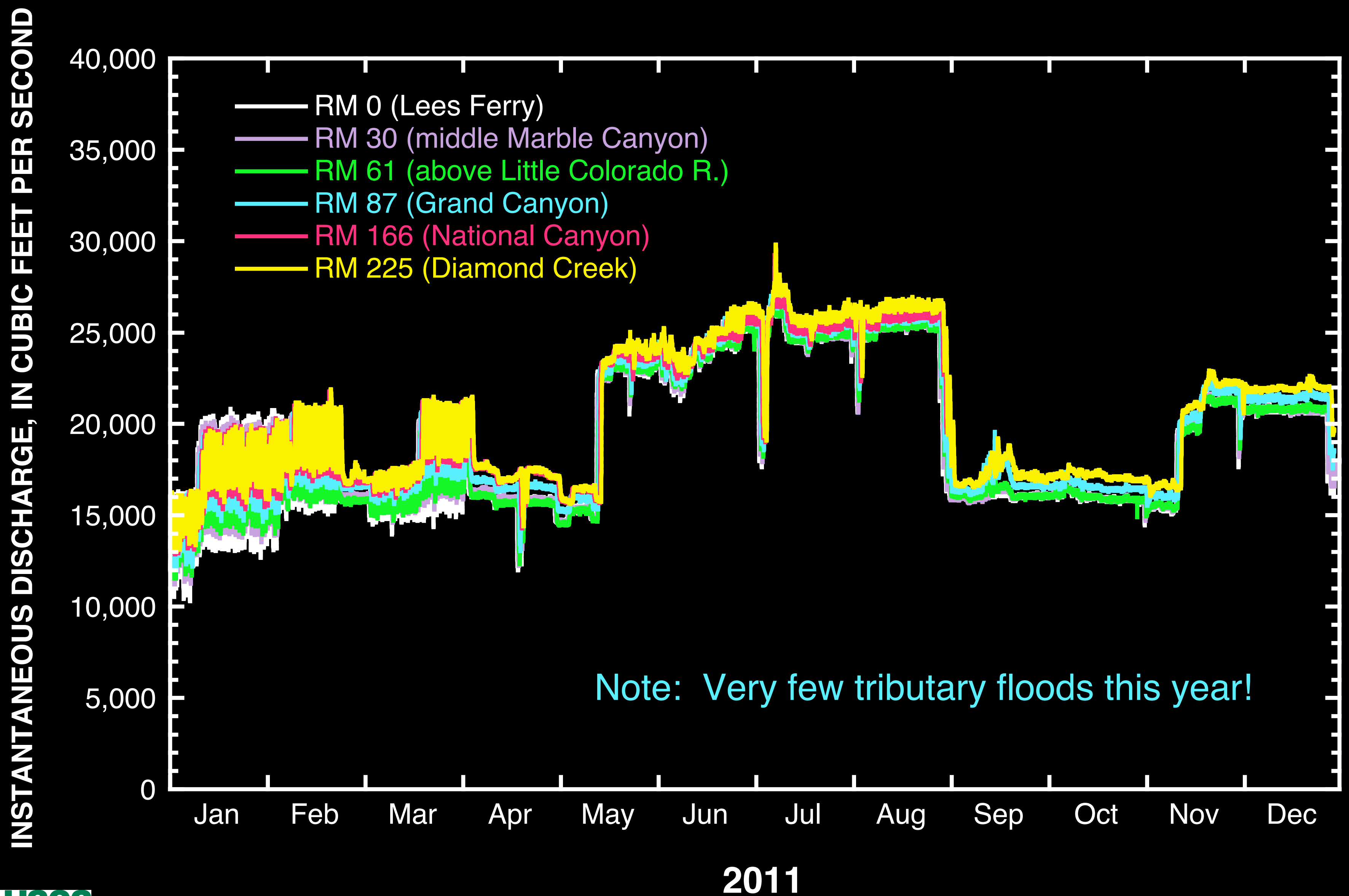
- Stage (used to compute discharge)
- Velocity
- Suspended-sediment concentration and median grain size
- Turbidity (high end)
- Water temperature



Products since 2000

- Since 2000, 58 peer-reviewed papers have been published by this project (see project bibliography handout)
- Findings in these publications were reviewed at July Knowledge Assessment Workshop in Flagstaff (see handout)
- Annual data reports are published every year by the USGS Arizona and Utah Water Science Centers (all data on web)
- Most data collected by the USGS-GCMRC part of this project are on the web (all will be there this year as the GCMRC web site improves)
- Since 2000, 32 peer-reviewed abstracts have been published for presentations made at professional scientific meetings in the US and abroad
- Numerous presentations have been made to the TWG, AMWG, and DOI officials

Discharge



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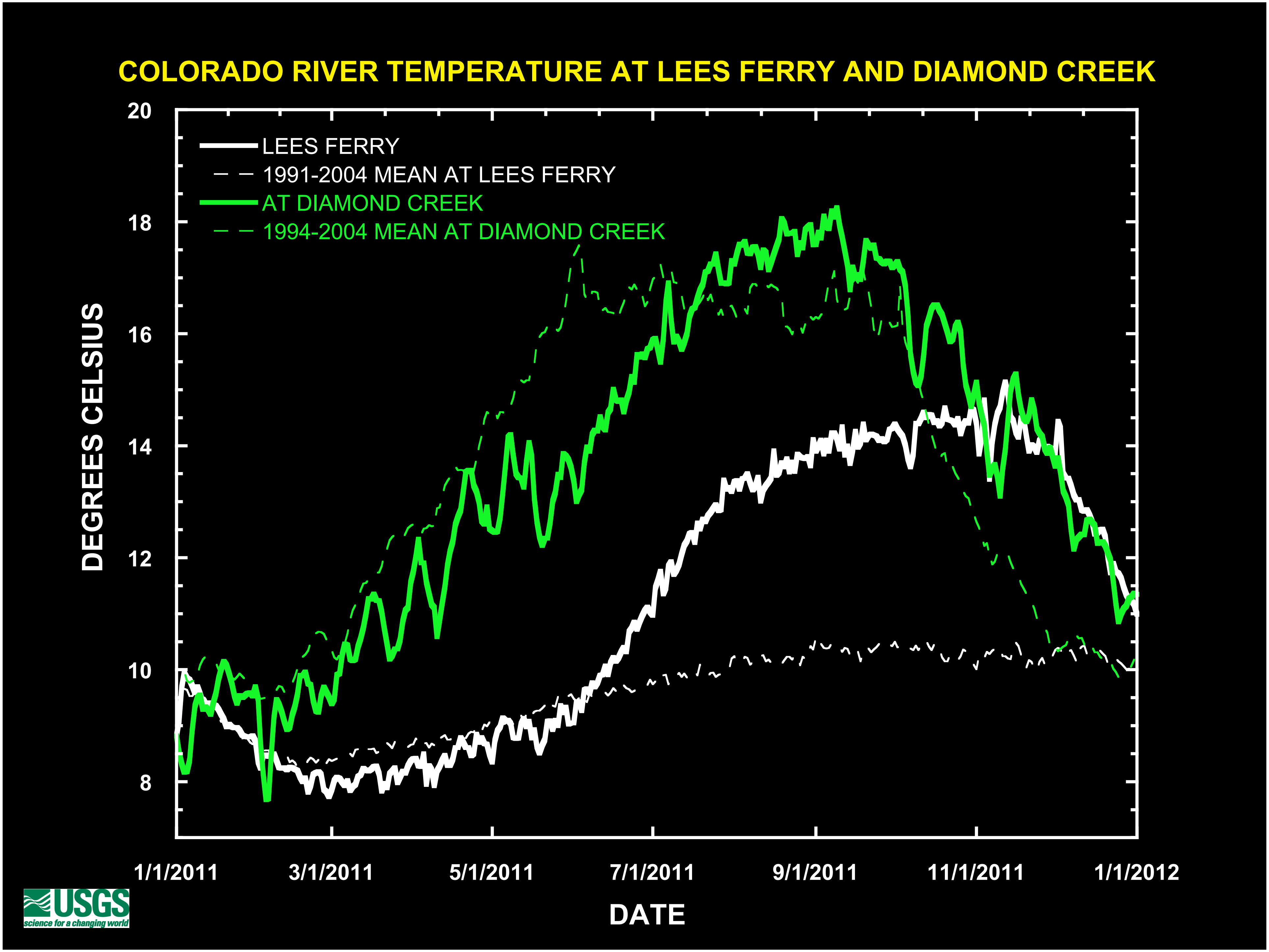
COLORADO RIVER TEMPERATURE AT LEES FERRY AND DIAMOND CREEK
LEES FERRY
1991-2004 MEAN AT LEES FERRY
AT DIAMOND CREEK
1994-2004 MEAN AT DIAMOND CREEK
DEGREES CELSIUS
20
18
16
14
12
10
8
1/1/2011
3/1/2011
5/1/2011
7/1/2011
9/1/2011
11/1/2011
1/1/2012
DATE
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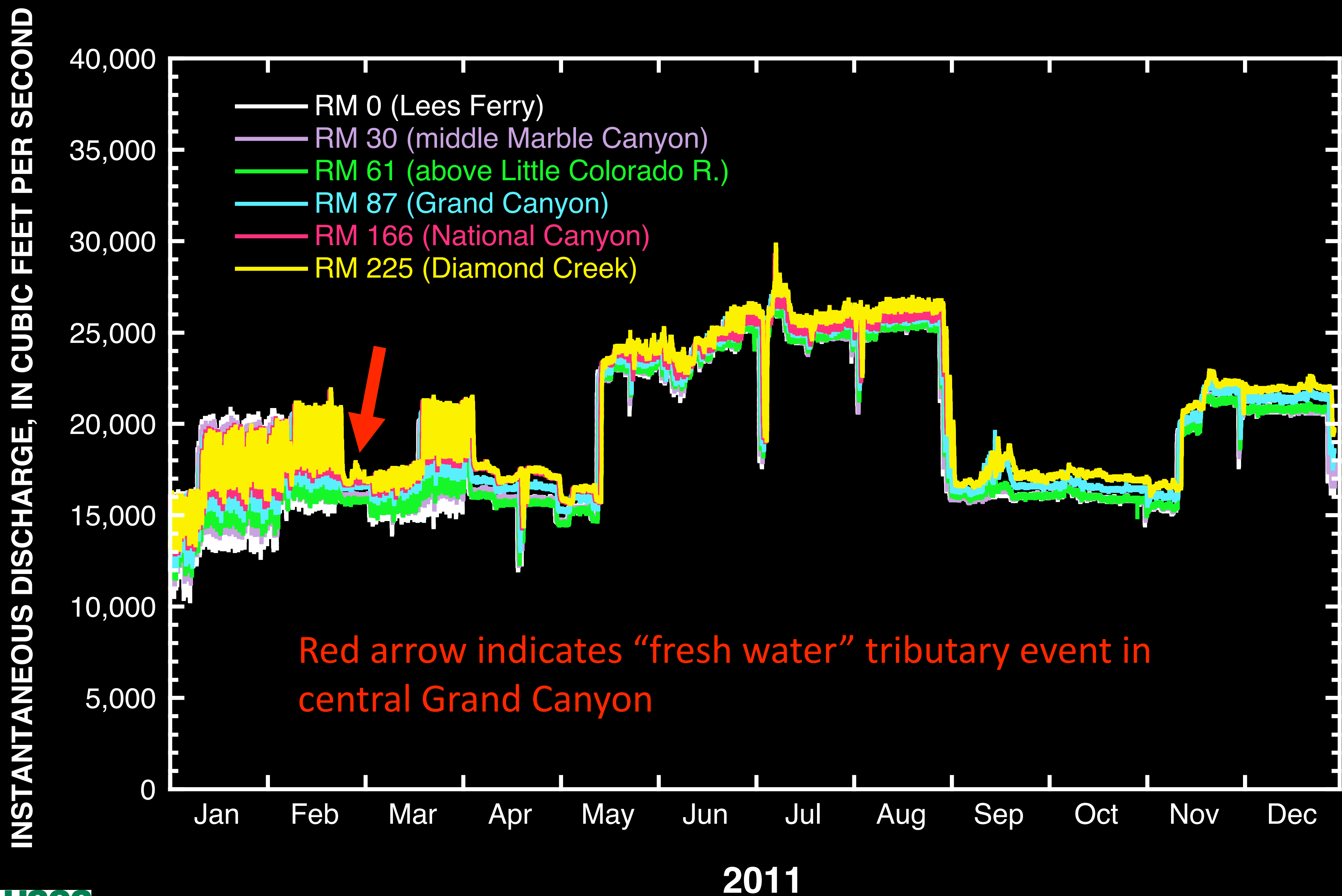
Discharge



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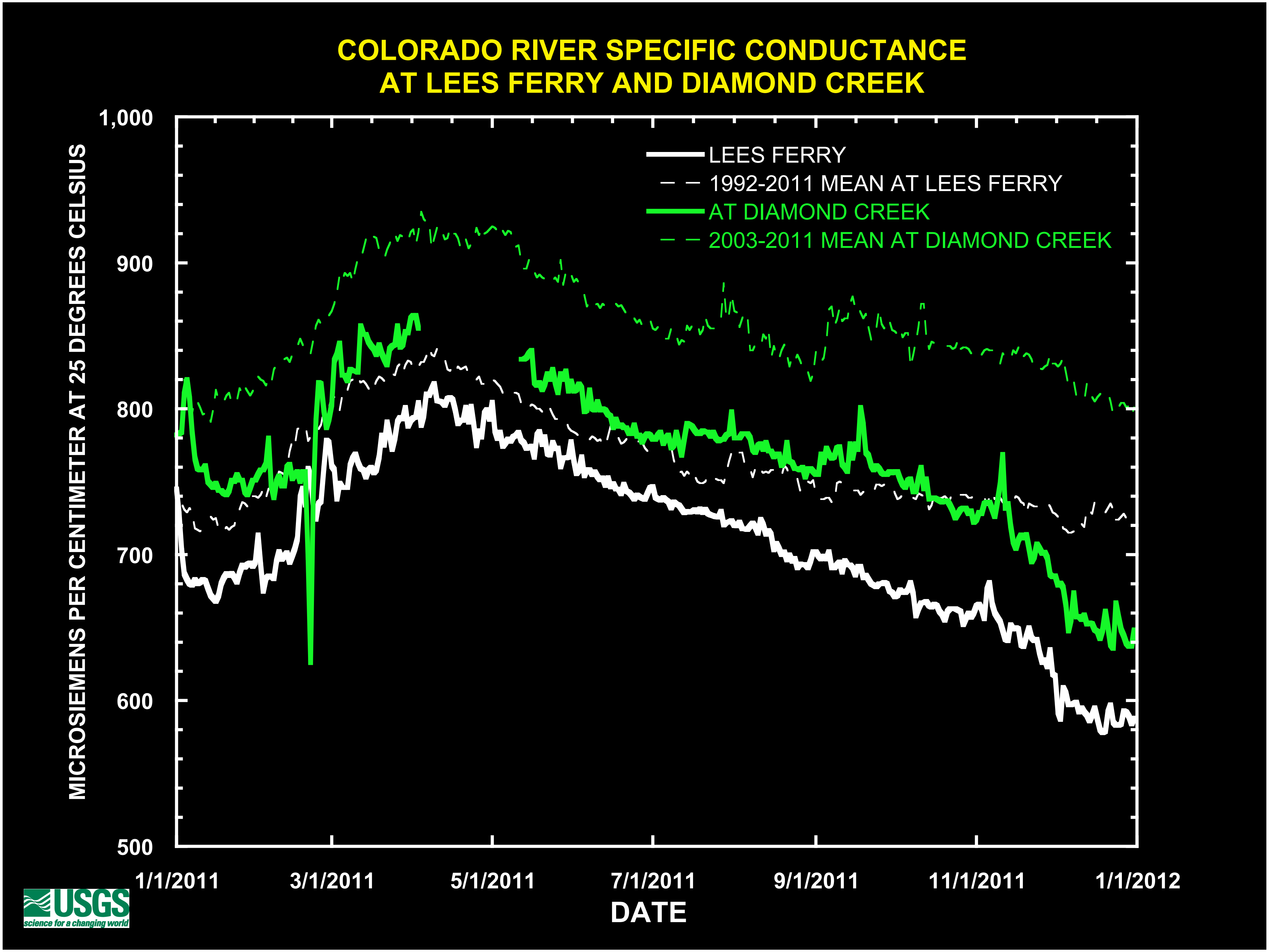
COLORADO RIVER SPECIFIC CONDUCTANCE
AT LEES FERRY AND DIAMOND CREEK
LEES FERRY
1992-2011 MEAN AT LEES FERRY
AT DIAMOND CREEK
2003-2011 MEAN AT DIAMOND CREEK
MICROSIEMENS PER CENTIMETER AT 25 DEGREES CELSIUS
1,000
900
800
700
600
500
1/1/2011
3/1/2011
5/1/2011
7/1/2011
9/1/2011
11/1/2011
1/1/2012
DATE
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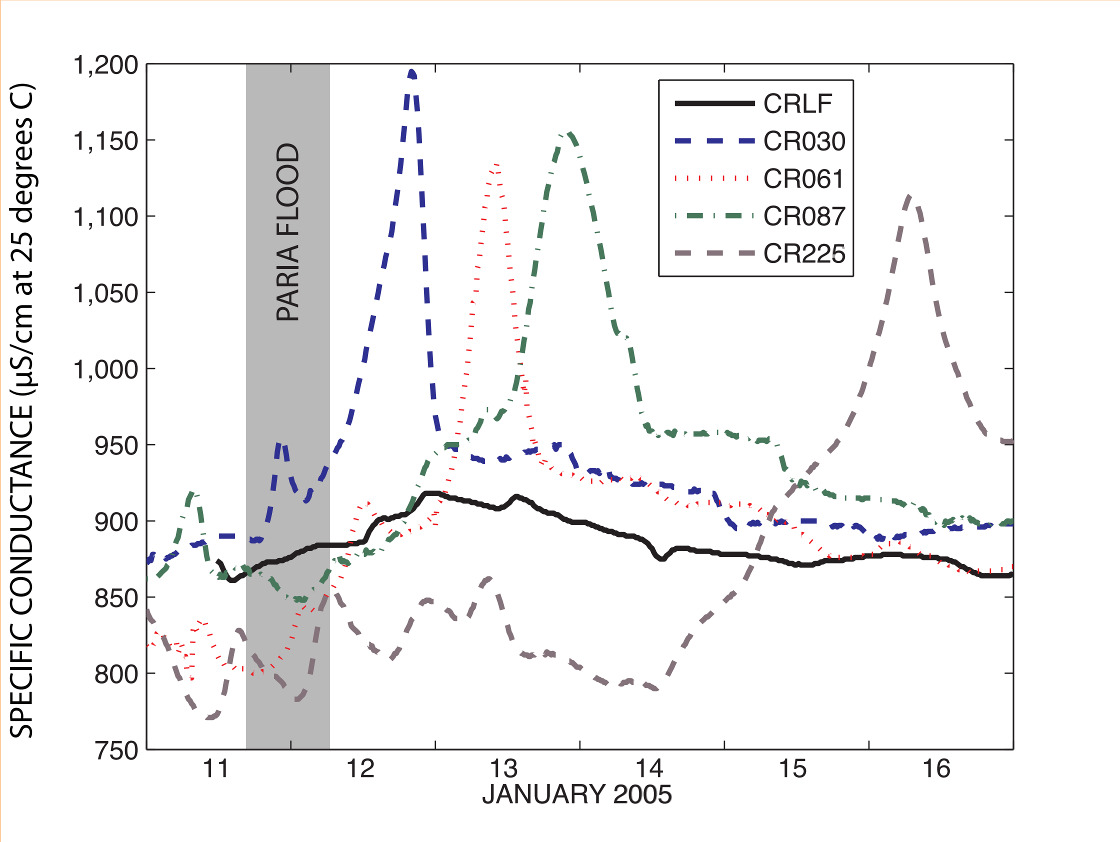
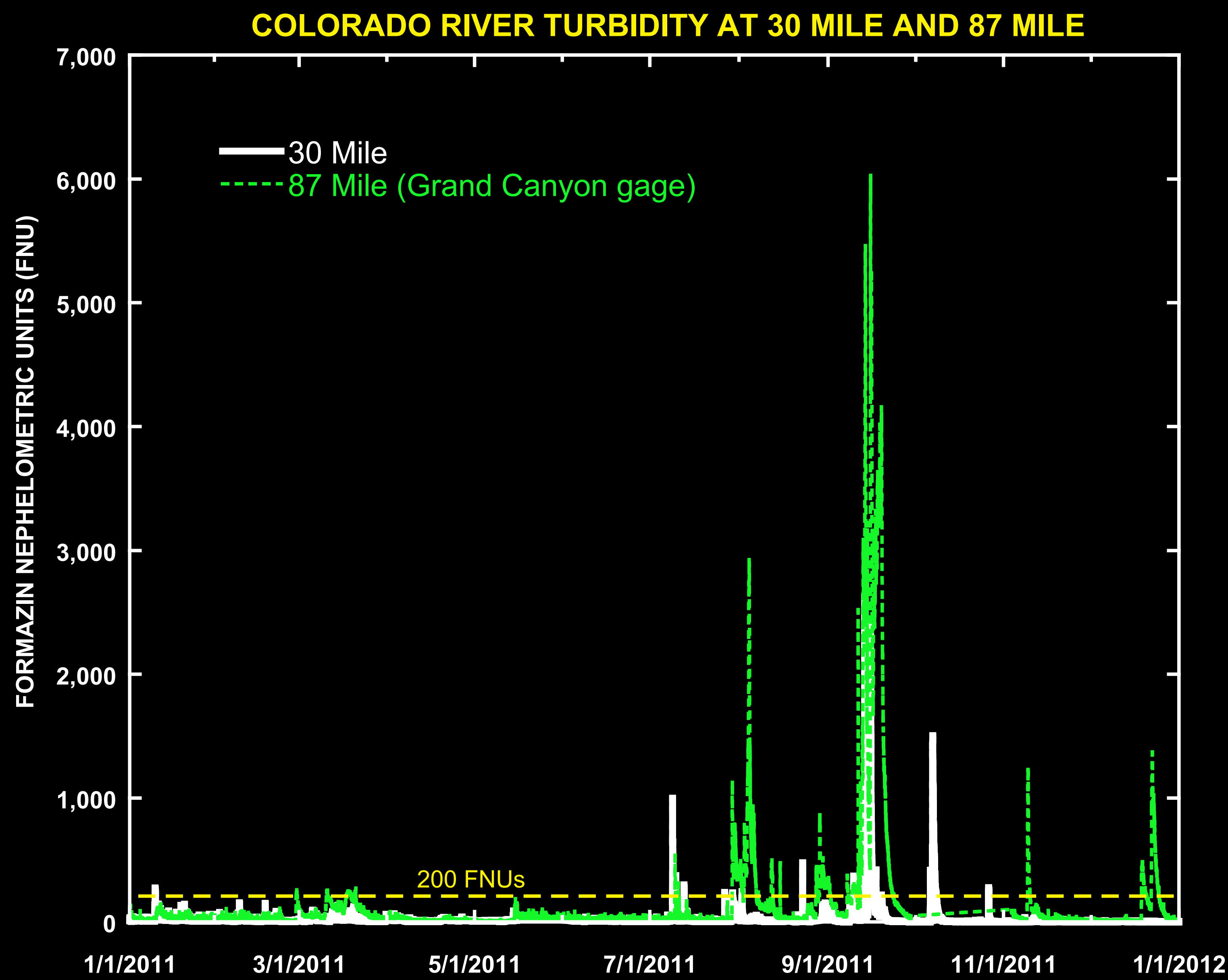
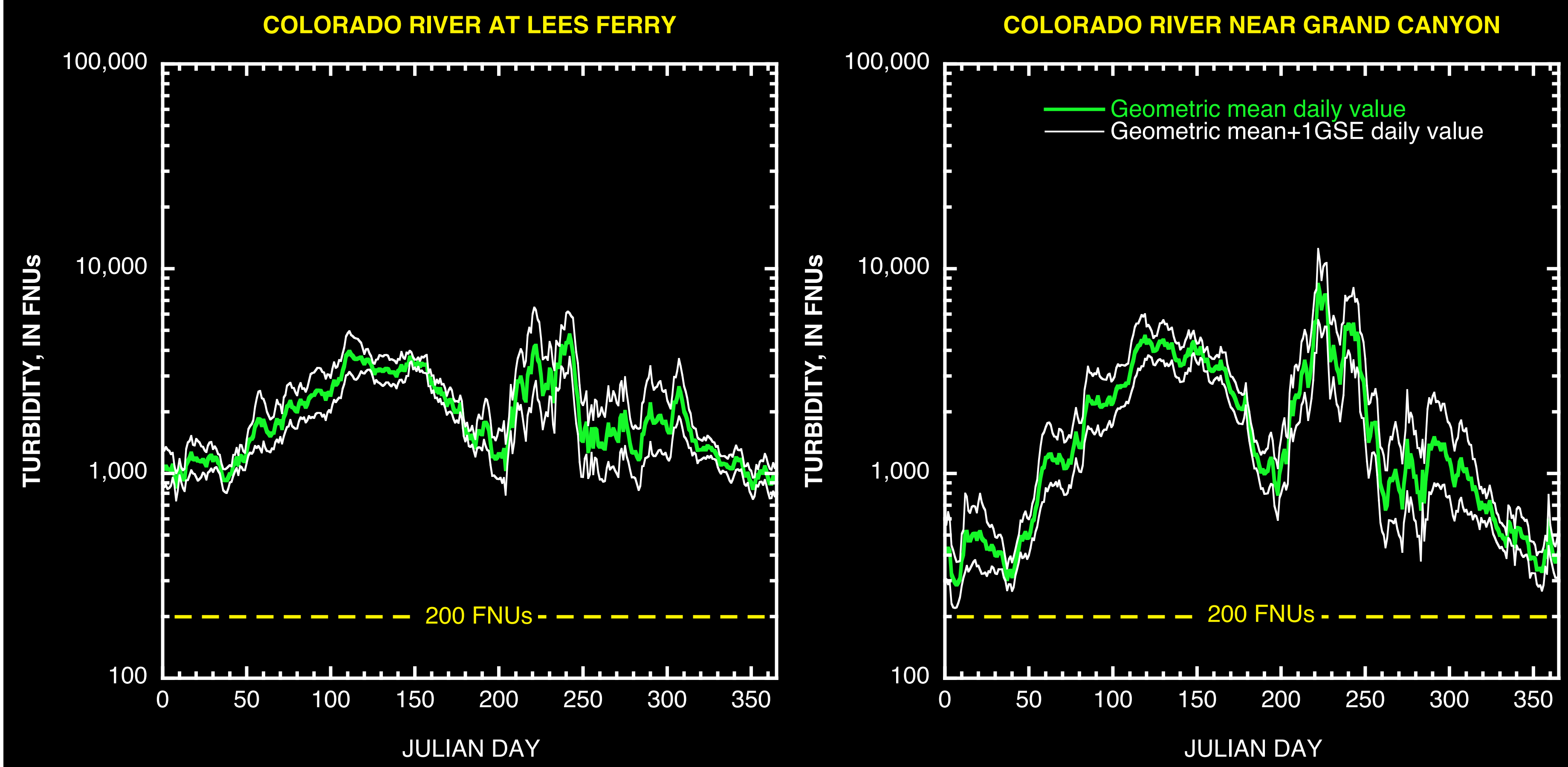
Paria River floods provide natural “salty water” to Colorado River that allows the velocity of biologically important “water parcels” to be measured; remember from Wiele and Smith (1996)...water moves much more slowly than the daily discharge waves!



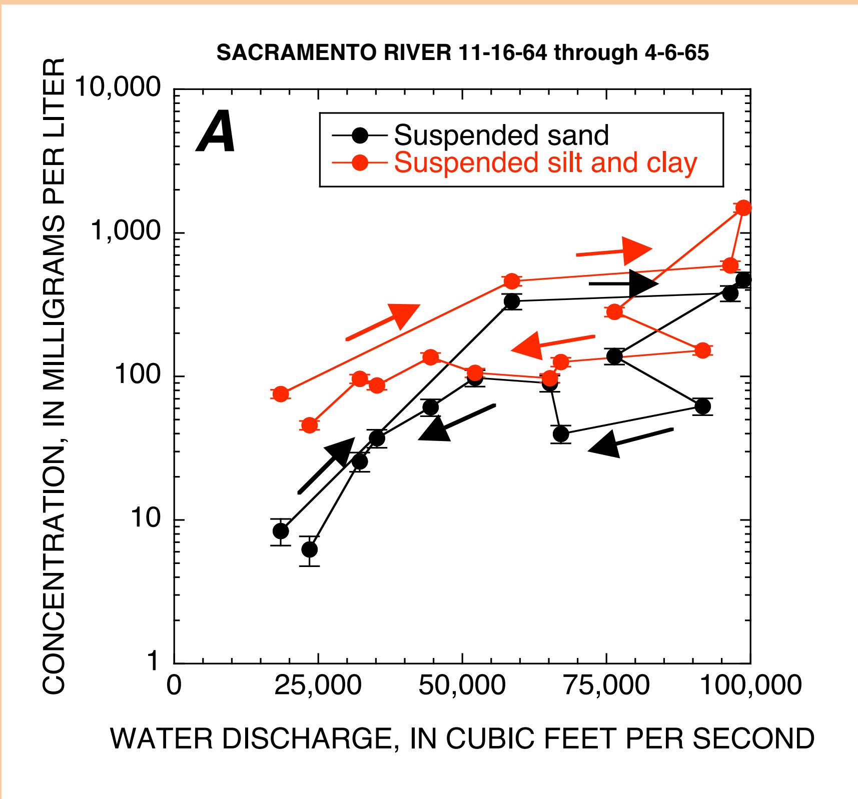
Voichick (2008); Voichick and Topping (2010)

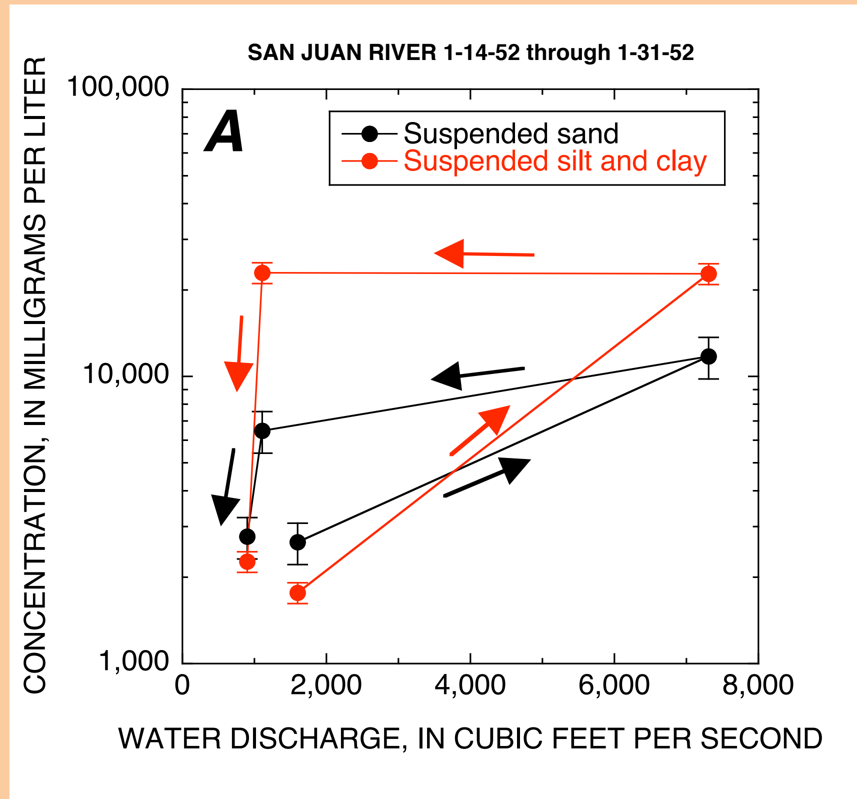

COLORADO RIVER TURBIDITY AT 30 MILE AND 87 MILE
FORMAZIN NEPHELOMETRIC UNITS (FNU)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
30 Mile
87 Mile (Grand Canyon gage)
200 FNUs
1/1/2011
3/1/2011
5/1/2011
7/1/2011
9/1/2011
11/1/2011
1/1/2012

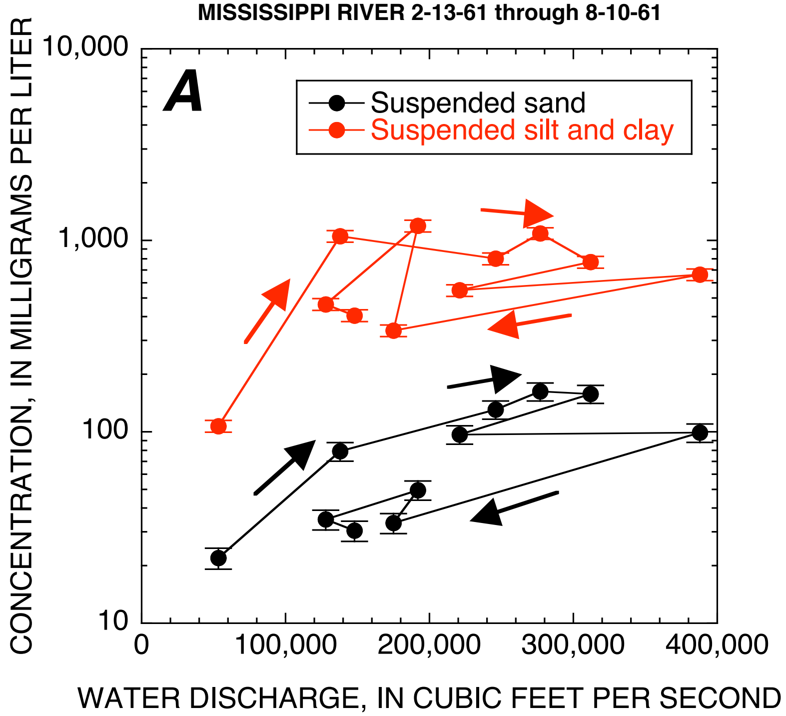
Unlike the modern river, the natural river was never clear



Substantial discharge-independent variation in suspended-sand concentration is common and is always coupled to systematic grain-size changes







- To compute accurate sand loads, suspended-sand data must be collected at temporal resolutions higher than the timescale of the discharge-independent variation [<1 hour in the Colorado River] (after Gray and Simoes, 2008)

- Use of sand-rating curves (fixed relations between discharge and sand concentration, the approach used in the 1995 EIS) can easily result in load errors of 900 to 4,000% (e.g., Walling, 1977; Glysson and others, 2001)

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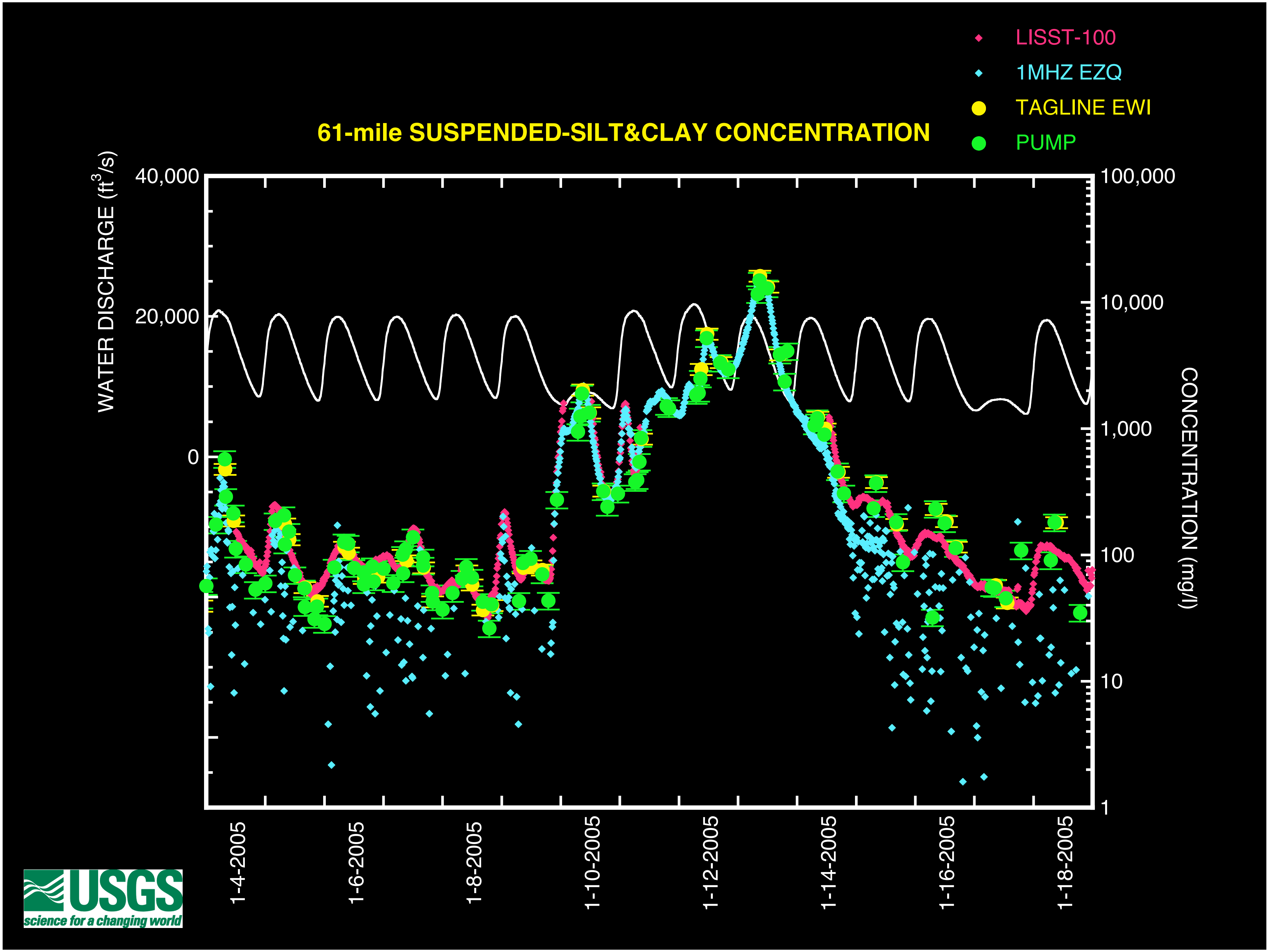

LISST-100
1MHZ EZQ
TAGLINE EWI
PUMP
61-mile SUSPENDED-SILT&CLAY CONCENTRATION
WATER DISCHARGE (ft3/s)
40,000
20,000
0
CONCENTRATION (mg/l)
100,000
10,000
1,000
100
10
1
1-4-2005
1-6-2005
1-8-2005
1-10-2005
1-12-2005
1-14-2005
1-16-2005
1-18-2005
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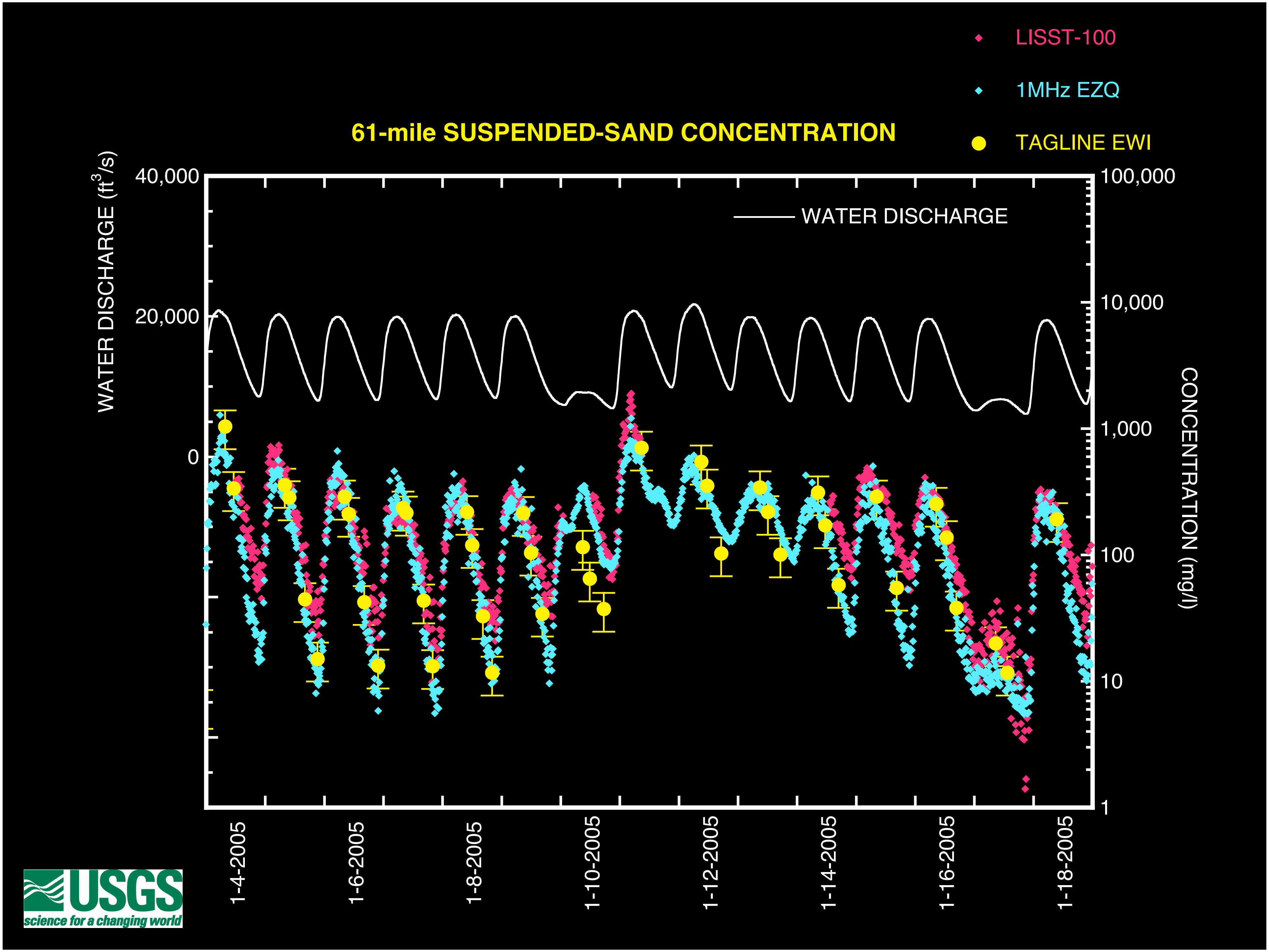

61-mile SUSPENDED-SAND CONCENTRATION
LISST-100
1MHz EZQ
TAGLINE EWI
WATER DISCHARGE
WATER DISCHARGE (ft3/s)
40,000
20,000
0
100,000
10,000
1,000
100
10
1
CONCENTRATION (mg/l)
1-4-2005
1-6-2005
1-8-2005
1-10-2005
1-12-2005
1-14-2005
1-16-2005
1-18-2005
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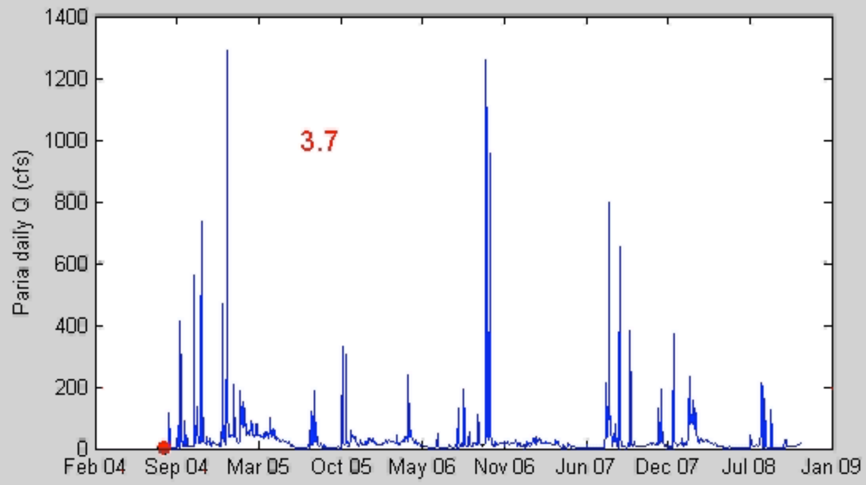
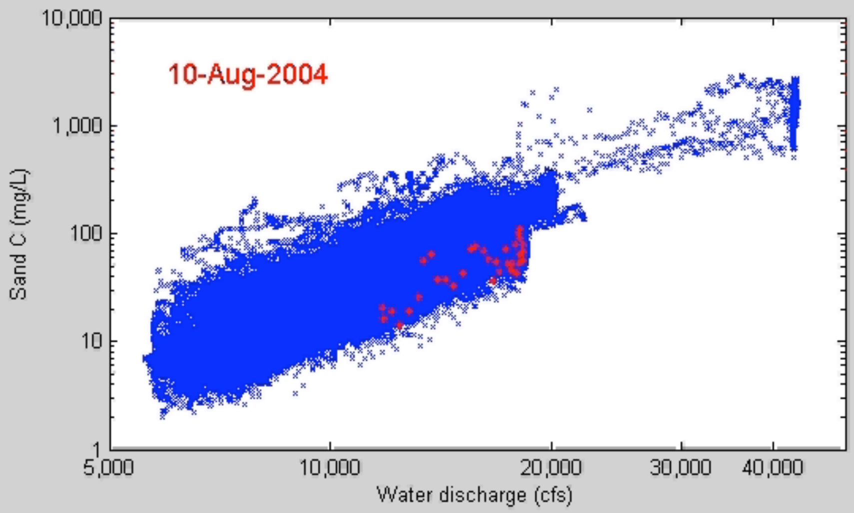
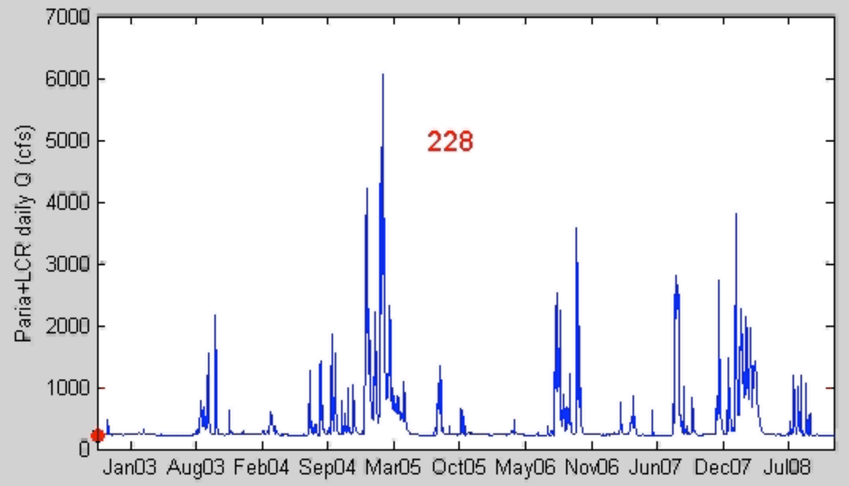
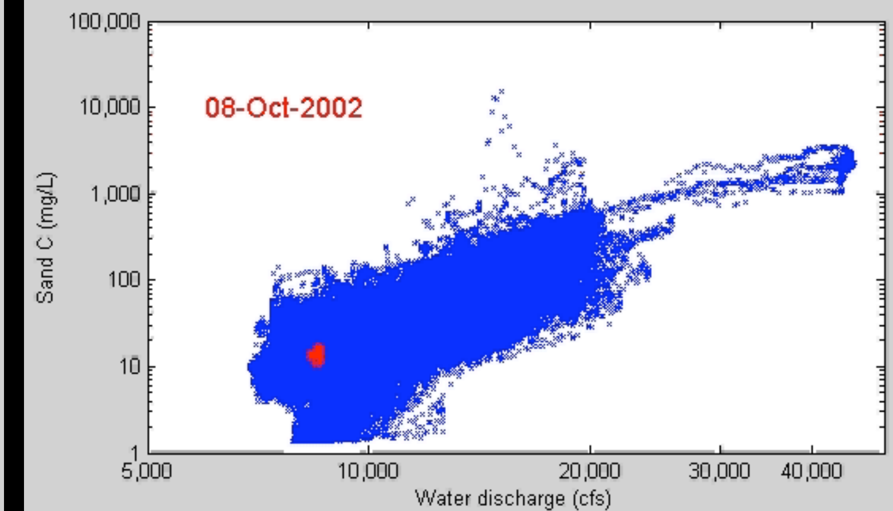
30 mile



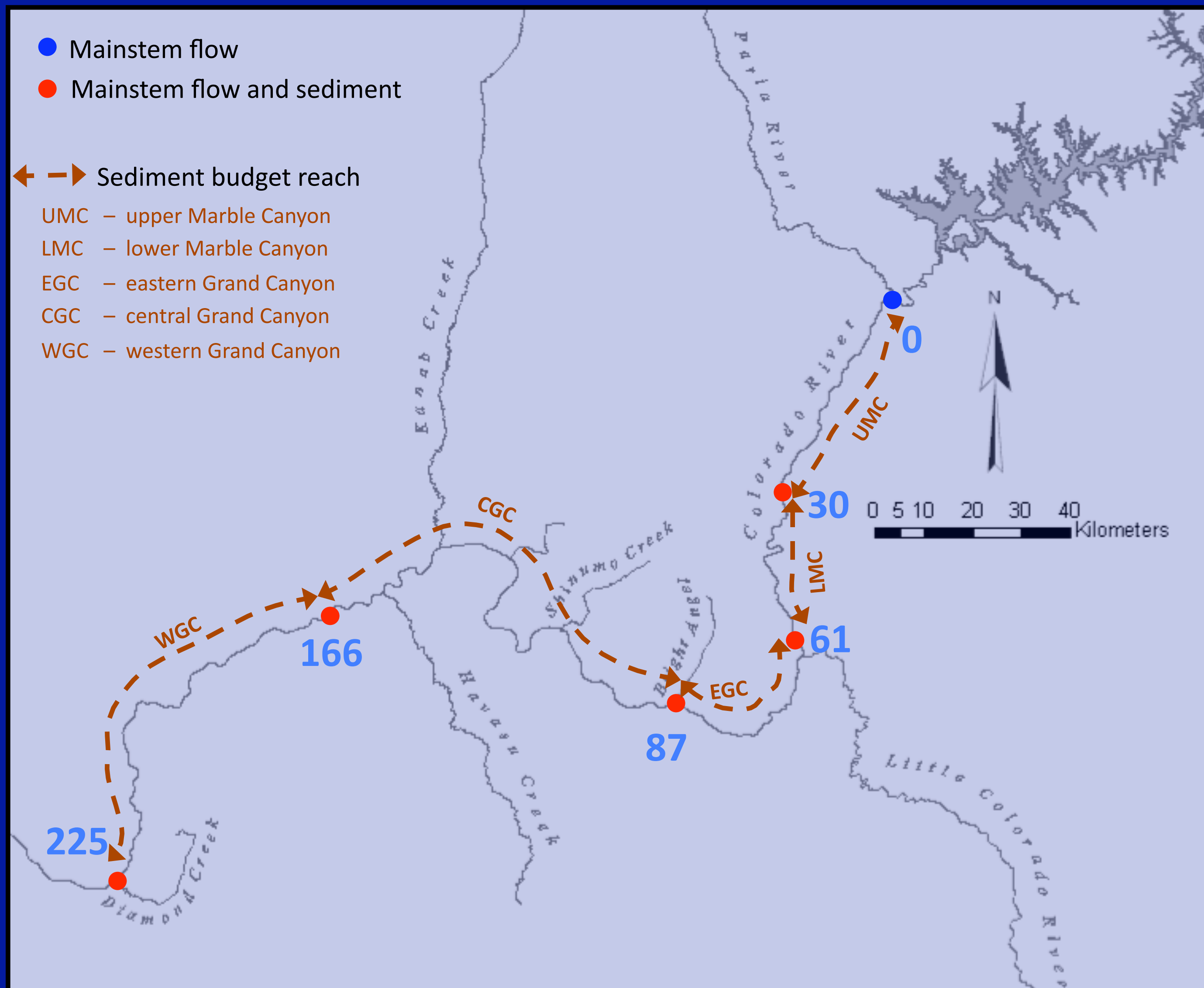


225 mile





Measurement sites bracket long reaches to define mass balance in sand and silt & clay



The grain-size distributions of the sand carried in suspension are typically similar to those in transient storage in the sandbars and are only rarely similar to those stored in the channel bed, thus changes in the mass-balance sand budgets generally reflect changes in sandbar storage integrated over long reaches (after Rubin and others, 1998; Topping and others, 2000a, 2000b, 2006; Hazel and others, 2006; Draut and others, 2010).

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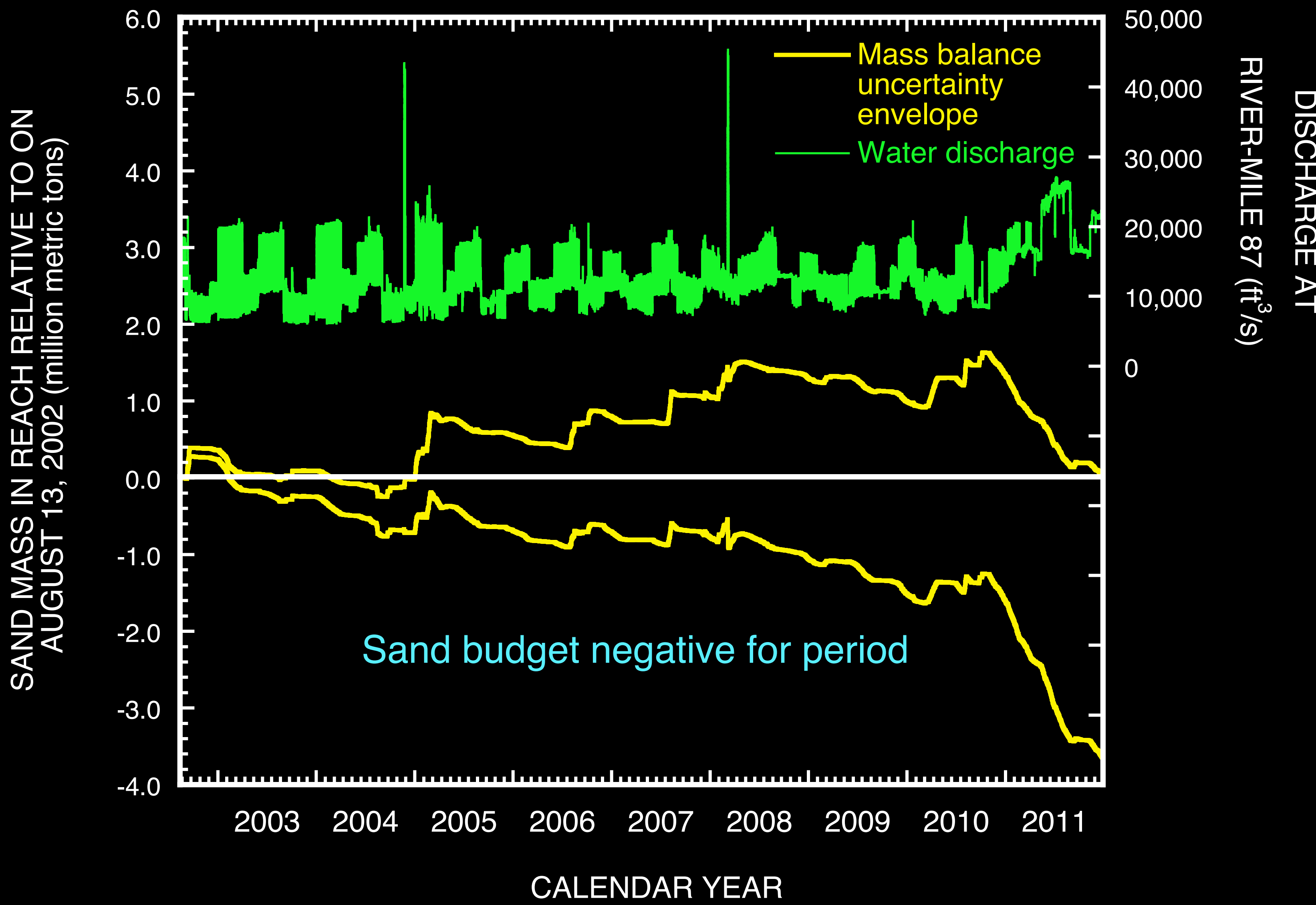
EASTERN GRAND CANYON
2002-2011 MASS-BALANCE SAND BUDGET



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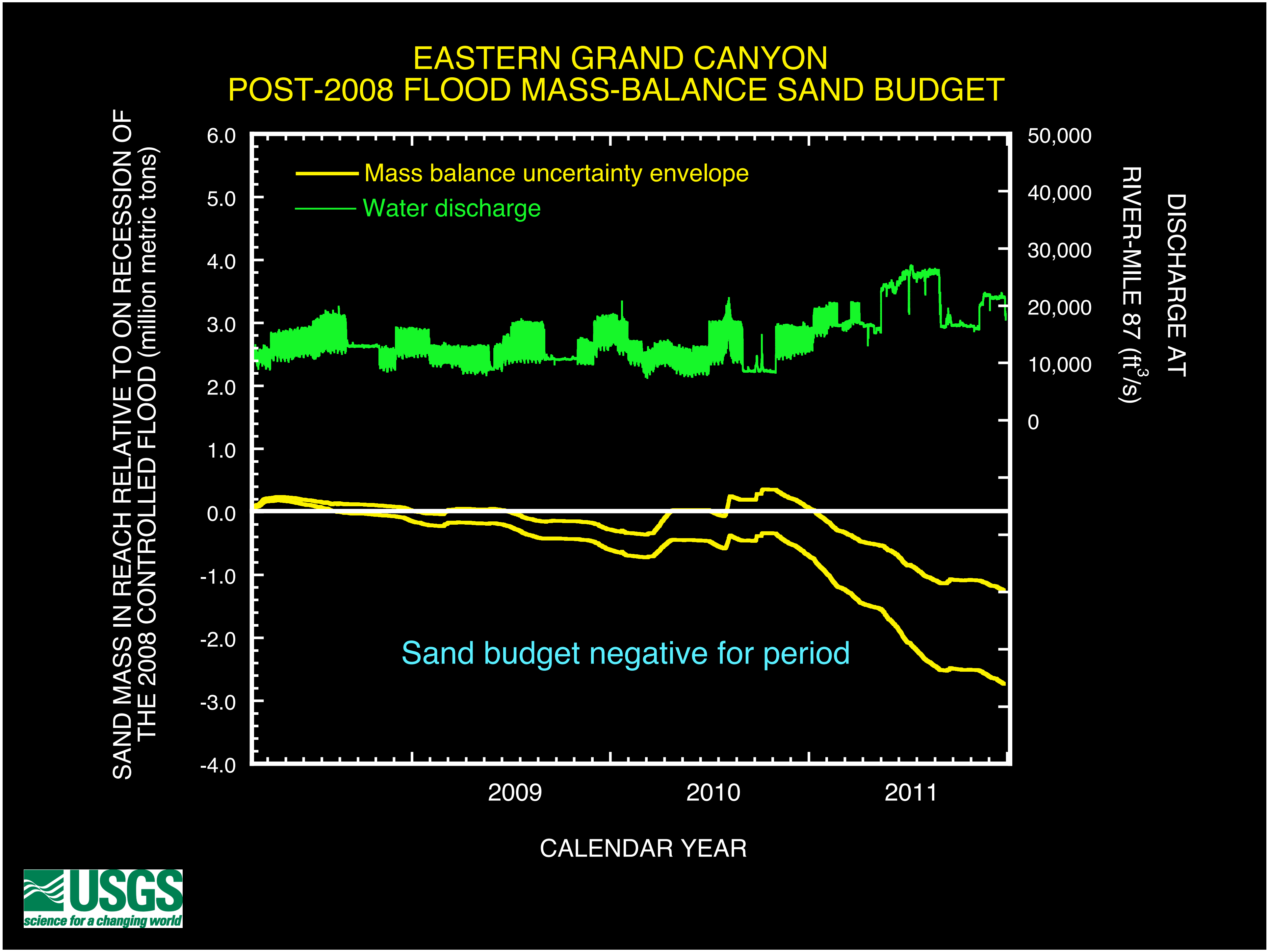
EASTERN GRAND CANYON
POST-2008 FLOOD MASS-BALANCE SAND BUDGET
Mass balance uncertainty envelope
Water discharge
Sand budget negative for period
SAND MASS IN REACH RELATIVE TO ON RECESSION OF THE 2008 CONTROLLED FLOOD (million metric tons)
DISCHARGE AT RIVER-MILE 87 (ft3/s)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
50,000
40,000
30,000
20,000
10,000
0
2009
2010
2011
CALENDAR YEAR
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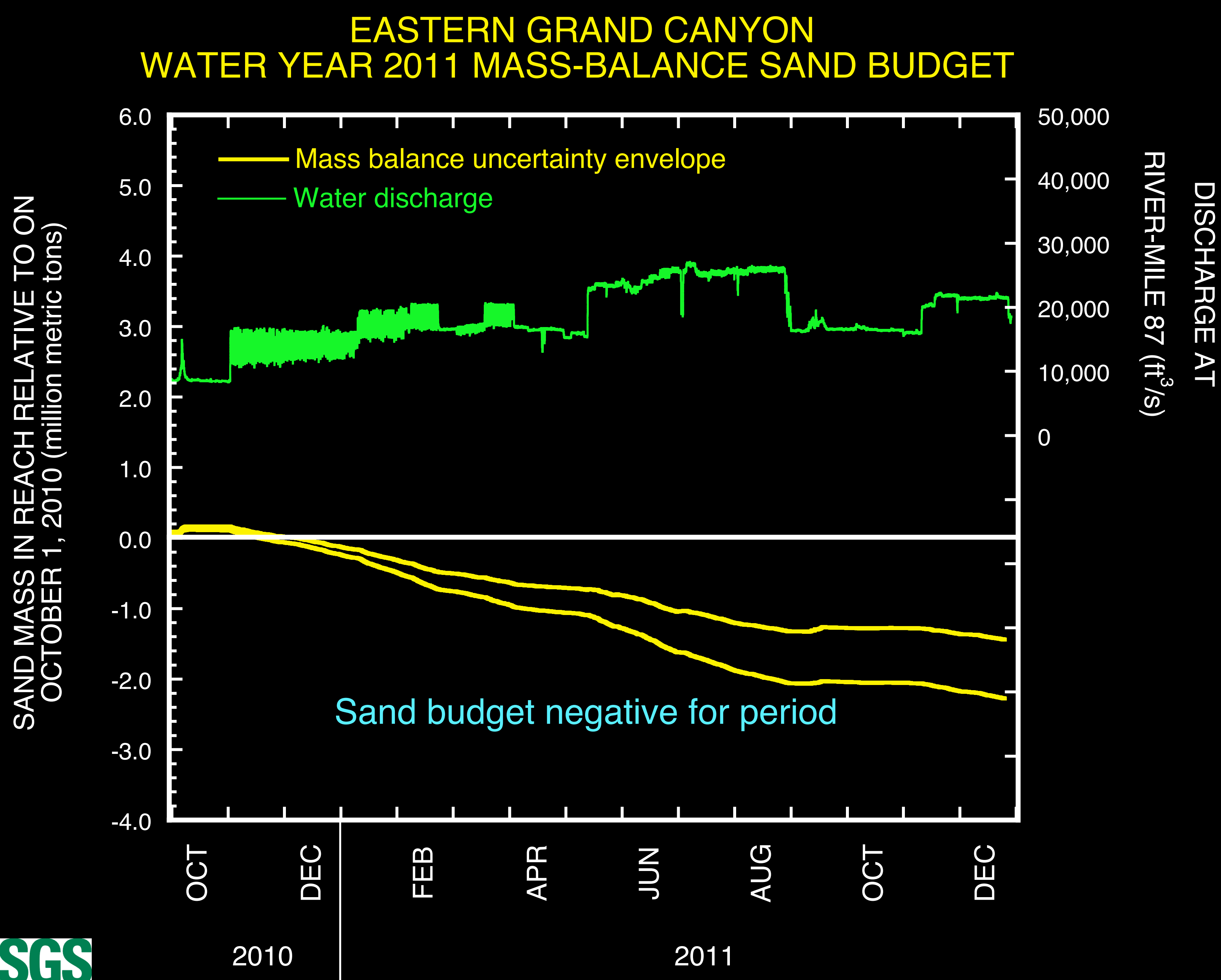

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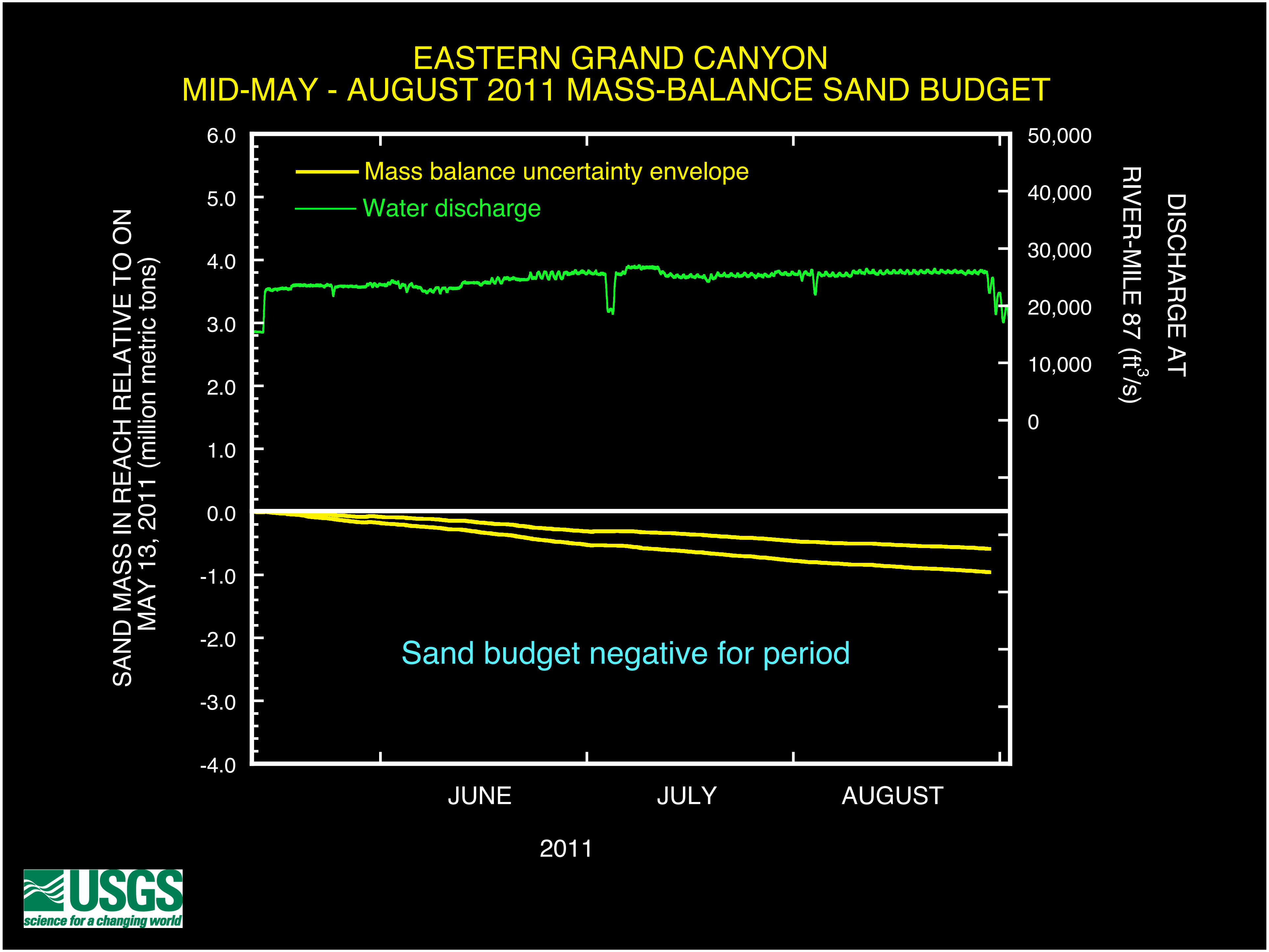
EASTERN GRAND CANYON
MID-MAY - AUGUST 2011 MASS-BALANCE SAND BUDGET
Mass balance uncertainty envelope
Water discharge
Sand budget negative for period
SAND MASS IN REACH RELATIVE TO ON MAY 13, 2011 (million metric tons)
DISCHARGE AT RIVER-MILE 87 (ft3/s)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
50,000
40,000
30,000
20,000
10,000
0
JUNE
JULY
AUGUST
2011
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August 2002 through December 2011

- Likely less sand is present now in Marble and eastern Grand Canyons now than in August 2002

- **1.3 ± 1.4** million metric tons of sand were eroded from Marble Canyon
  - RM 0-30 lost **0.9 ± 1.3** million metric tons
  - RM 30-61 lost "**0.4 ± 0.9"** million metric tons

- No demonstrable net change in sand mass occurred in all of Grand Canyon (RMs 61-225), but
  - RM 61-87 lost **1.8 ± 1.8** million metric tons
  - RM 87-225 gained **1.8 ± 2.1** million metric tons

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Post-2008 controlled flood through December 2008

- Between 1.8 and 4.0 million metric tons LESS sand is present now in Marble and Grand Canyons than upon recession of the 2008 controlled flood

- **1.7 ± 0.5** million metric tons of sand were eroded from Marble Canyon
  - RM 0-30 lost **1.4 ± 0.4** million metric tons
  - RM 30-61 lost **0.3 ± 0.4** million metric tons

- **1.2 ± 1.0** million metric tons of sand were eroded from Grand Canyon
  - RM 61-87 lost **2.0 ± 0.7** million metric tons
  - RM 87-166 gained **0.6 ± 0.9** million metric tons
  - RM 166-225 “gained” **0.2 ± 0.7** million metric tons

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October 2010 through December 2011

- Between 2.7 and 3.7 million metric tons LESS sand is present now in Marble and Grand Canyons than on October 1, 2010

- **1.6±0.3** million metric tons of sand were eroded from Marble Canyon
  - RM 0-30 lost **1.4±0.3** million metric tons
  - RM 30-61 lost **0.2±0.3** million metric tons

- **1.6±0.6** million metric tons of sand were eroded from Grand Canyon
  - RM 61-87 lost **1.9±0.4** million metric tons
  - RM 87-166 "lost" **0.1±0.5** million metric tons
  - RM 166-225 gained **0.4±0.4** million metric tons

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Mid-May 2011 through August 2011

- Discharges were typically 23,000 to 26,000 cfs during this period
- This high-flow equalization period alone eroded between 2.0 and 2.4 million metric tons of sand from Marble and Grand Canyons
- This amount equates to more than 50% of the sand eroded from Marble and Grand Canyons since recession of the 2008 controlled flood, and exceeds the total amount of sand likely eroded from Marble and Grand Canyons since 2002
- **1.4 ± 0.1** million metric tons of sand were eroded from Marble Canyon
  - RM 0-30 lost **1.1 ± 0.1** million metric tons
  - RM 30-61 lost **0.3 ± 0.1** million metric tons
- **0.9 ± 0.2** million metric tons of sand were eroded from Grand Canyon
  - RM 61-87 lost **0.8 ± 0.2** million metric tons
  - RM 87-166 lost **0.4 ± 0.3** million metric tons
  - RM 166-225 gained **0.3 ± 0.3** million metric tons

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High-flow equalization periods pose a serious problem for sand management

- The May-August 2011 high-flow equalization period eroded up to a factor of 2 more sand from each reach in Marble and Grand Canyons than did any of the 1996, 2004, or 2008 controlled floods

- Unlike these controlled floods (that build high-elevation sandbars), the May-August 2011 high-flow equalization period resulted in erosion of high-elevation sandbars

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The decade of the 2000s was "abnormal"

- Paria River sand, and silt & clay inputs were all roughly 50-60% of 1923-2000 average
- LCR sand inputs were roughly 40% of the 1947-1970 average, and LCR silt and clay inputs were roughly 70% of the 1947-1970 average
- Dam operations were relatively low for most of this decade compared to previous decades

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Pop Quiz
(to foster discussion)

- So how do you manage sand during higher dam release periods?

- Especially if tributary sand inputs remain below average?