UtahStateUniversity

SPRING RUNOFF CONFERENCE

2015

Tuesday, March 31

Water Body Connectivity and the Clean Water Act

Can a new Clean Water Act rule improve the physical, chemical and biological integrity of the Nation's waters?

LAURIE ALEXANDER (Nat'l Center for Environmental Assessment, USEPA)
WALT BAKER (Utah Department of Environmental Quality)
CHARLES HAWKINS (USU) ▪ HANS PAERL (UNC-Chapel Hill)
ROBERT ADLER (University of Utah Quinney College of Law)

Wednesday, April 1

Environmental Flows in a Time of Drought

How much water do rivers need when water is in short supply?

ANNE CASTLE (Former Assistant Secretary Interior for Water and Science)
KEVIN BESTGEN (Colorado State) ▪ DON OSTLER (UCRC)
JENNIFER PITT (Environmental Defense) ▪ CARLY JERLA (Reclamation)
JACK SCHMIDT (USU) ▪ CLINT ALEXANDER (ESSA Ltd)
PAT SHAFROTH (USGS) ▪ KATRINA GRANTZ (Reclamation)
TAYLOR HAWES (Nature Conservancy)

Keynote: Lynn Ingram, UC-Berkeley

"The West Without Water"

Conference attendees are invited to submit abstracts for the March 31 research poster session.

Registration and more information:

water.usu.edu/htm/conference

High Flow Experiments in the Colorado River Ecosystem downstream from Glen Canyon Dam – insights from sediment transport data

Jack Schmidt

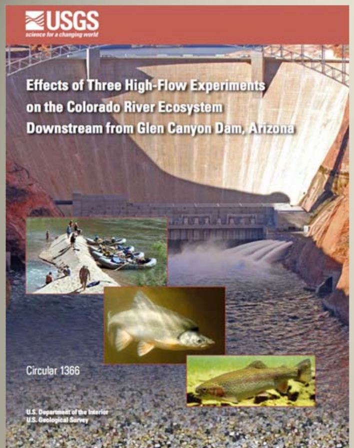
Utah State University

USGS science for a changing world

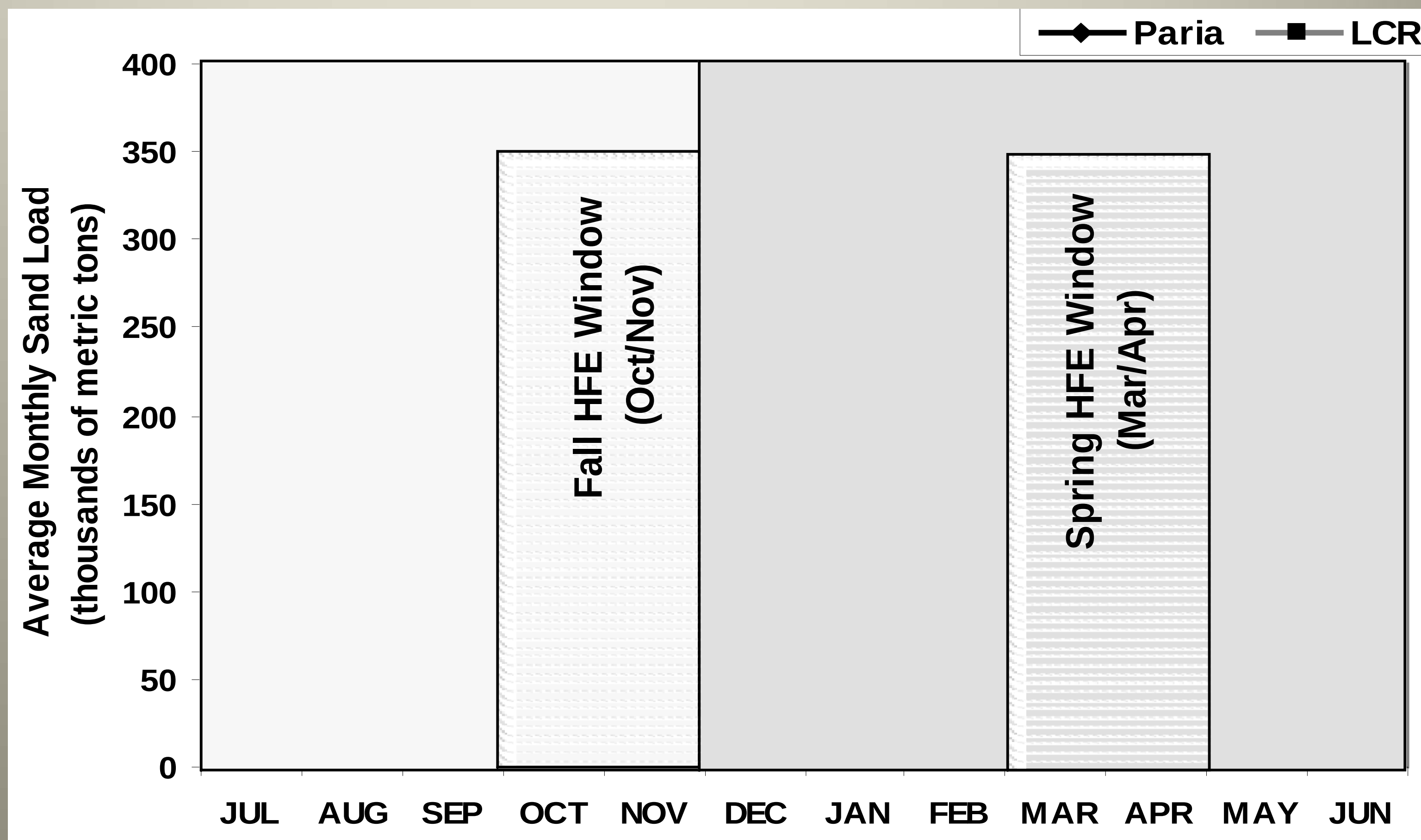
Grand Canyon Monitoring and Research Center

UtahState University

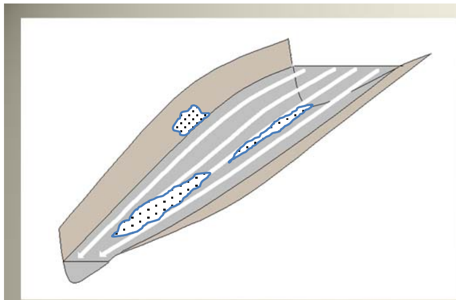
Department of Watershed Sciences



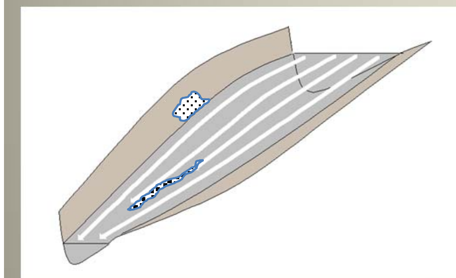
The HFE Protocol defines two seasons of accumulation and two seasons when controlled floods (called High Flow Experiments – HFEs) can occur.



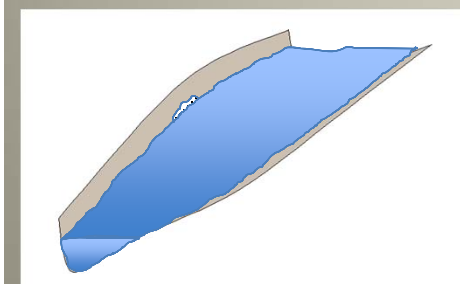
Conceptual model of how Colorado River flows interact with the available fine sediment supply.



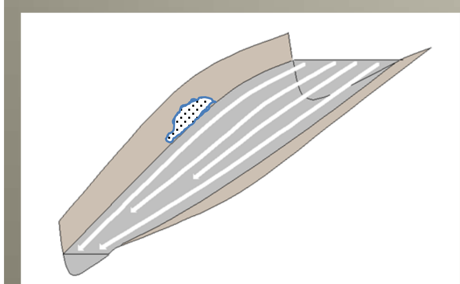
1) When fine sediment enters the river from tributaries …



2) … this sand and mud is quickly transported downstream.

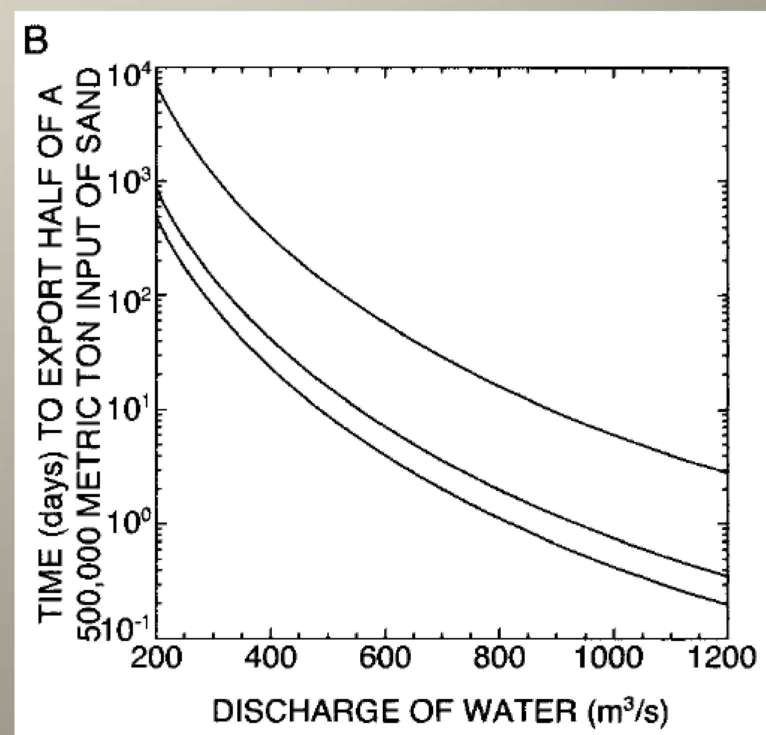


3) Controlled floods mobilize the sand on the bed, thereby transporting sand downstream and depositing a proportion along the channel margin.



4) Upon flood recession, the sand deposits along the channel margin are typically larger, and the amount of sand on the channel bed is much smaller

Time to export half of a hypothetical 500,000 ton input of Paria River sand past RM87 *(Rubin et al., 2002)*.



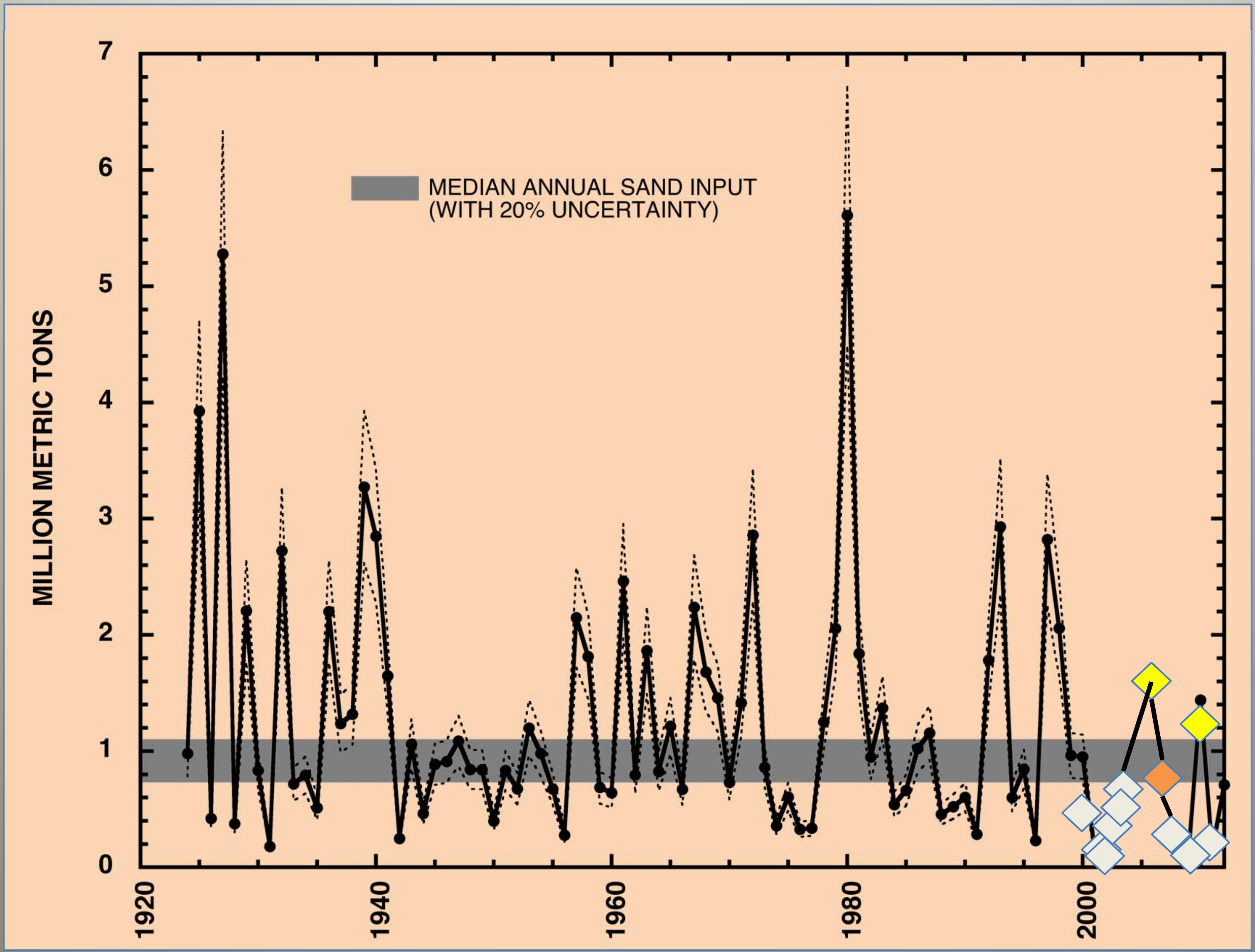
The essential paradigm – sand cannot be accumulated for multi-year periods.

GCMRC Sediment Transport Research Group (Topping et al.)

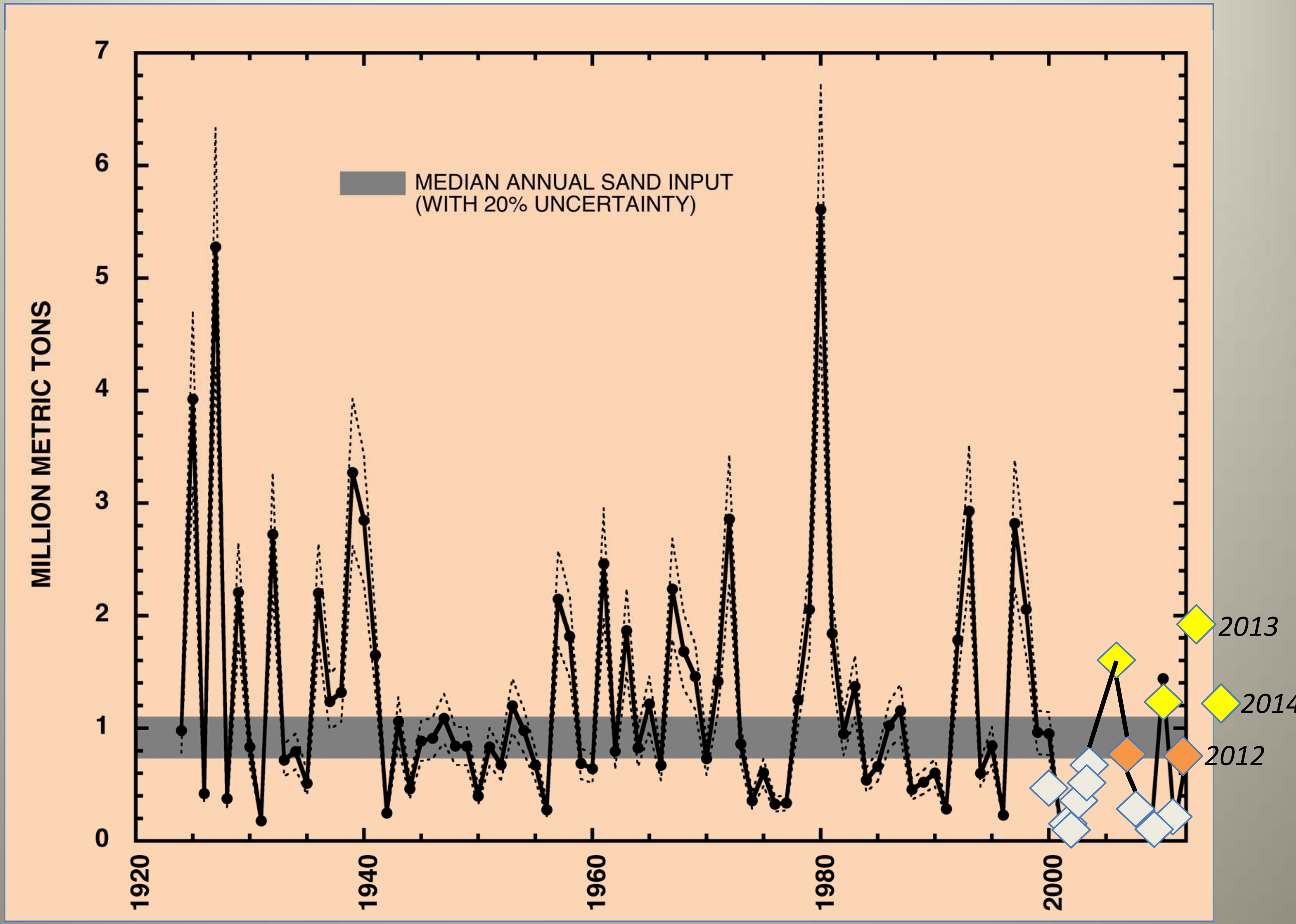
Arizona Water Science Center

Utah Water Science Center

"Long-term records of Paria River sand inputs ... suggest an average sand supply during the summer/fall accounting period ... of about 900,000 metric tons with about 300,000 metric tons on average during the winter/spring ... accounting period." (Wright and Kennedy, 2011)

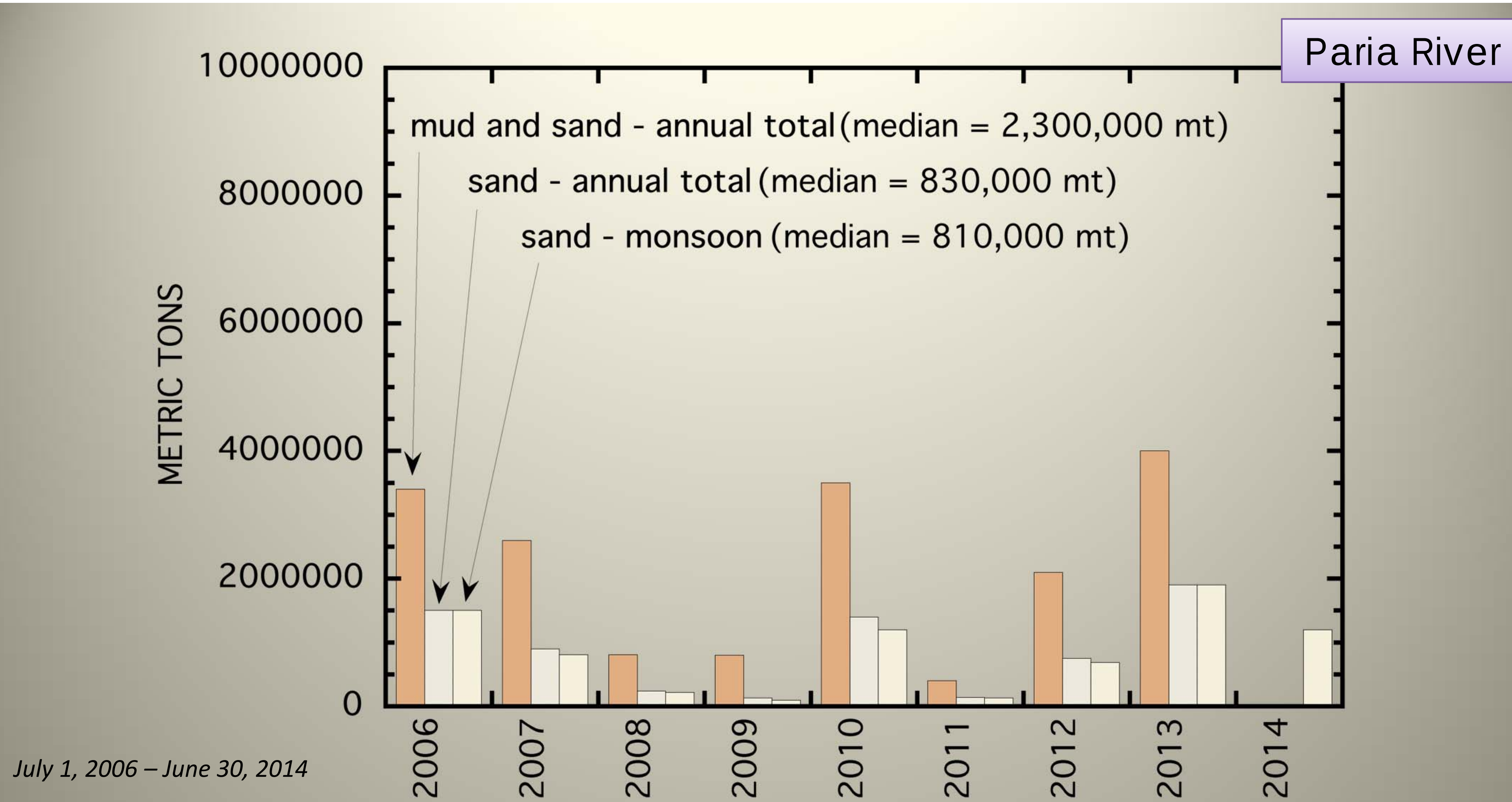


Annual sand delivery from the Paria River to the Colorado River



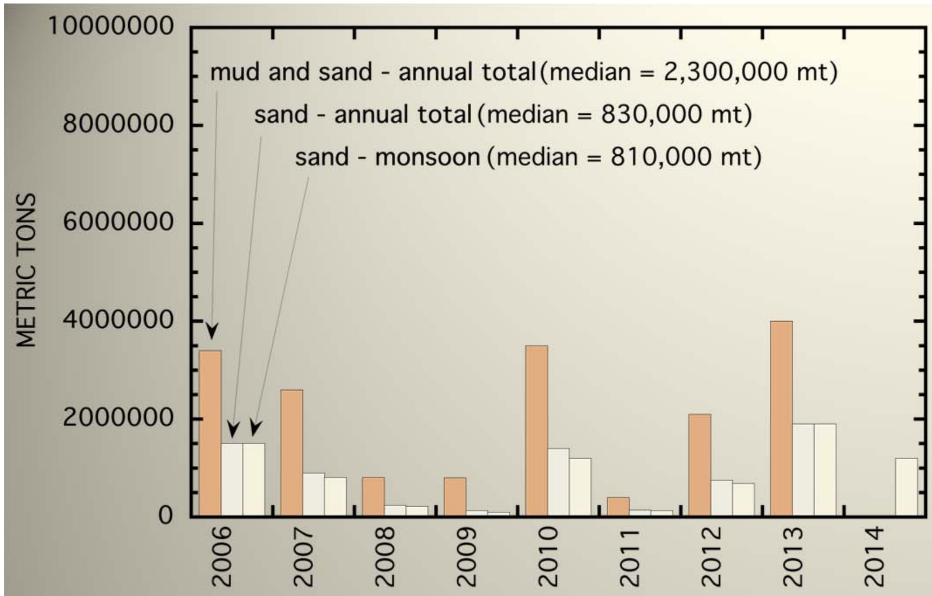
2013 and 2014 exceeded the long-term median inputs

2012 – 750,000 mt (total); 690,000 mt (fall accounting period)
2013 – 1,900,000 mt (total and fall accounting period)
2014 – 1,200,000 mt (fall accounting period)



Since 2006, ~60% of the annual input has been mud; ~40% has been sand

Since 2006, virtually all of the annual sand delivery has occurred during the fall accounting period: ~94% of the total annual sand supply and ~90% of the total annual mud supply was delivered during the fall accounting period.

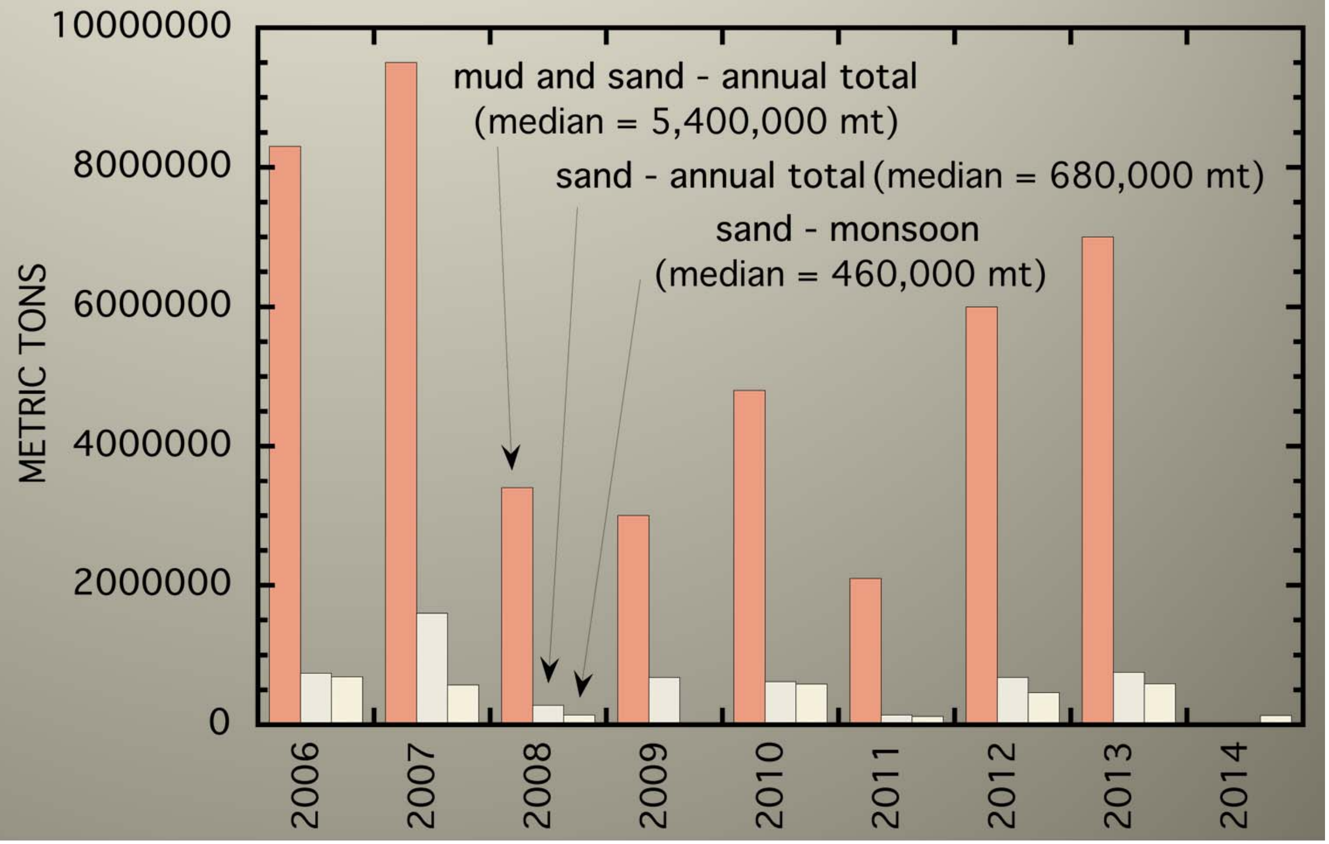


Little Colorado River

Little Colorado River delivered much more mud than sand and delivers less sand to the Colorado River than does the Paria River.

~88% of the annual input was mud; ~12% was sand

~58% of the total annual sand supply and ~77% of the total annual mud supply was delivered during the fall accounting period



July 1, 2006 – June 30, 2014

"During the period 2002-09 ..., the average sand-export rate from Marble Canyon was about 250,000-300,000 metric tons for each accounting period." *(Wright and Kennedy, 2011)*

Sand export rate from Marble Canyon during fall accounting period has been less than anticipated.

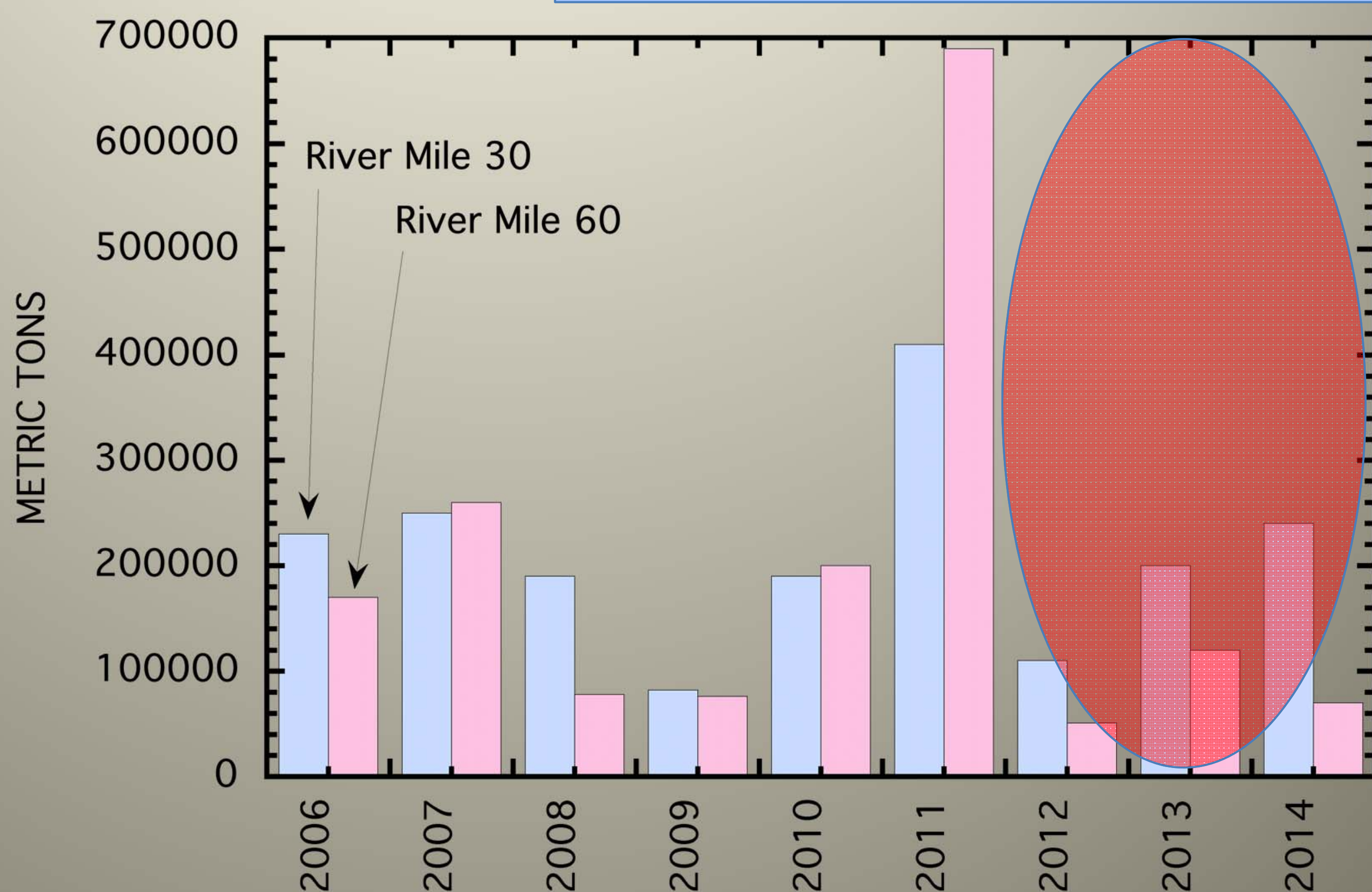
2012 – 110,000 mt (RM30); 51,000 (RM60)

2013 – 200,000 mt (RM30); 120,000 (RM60)

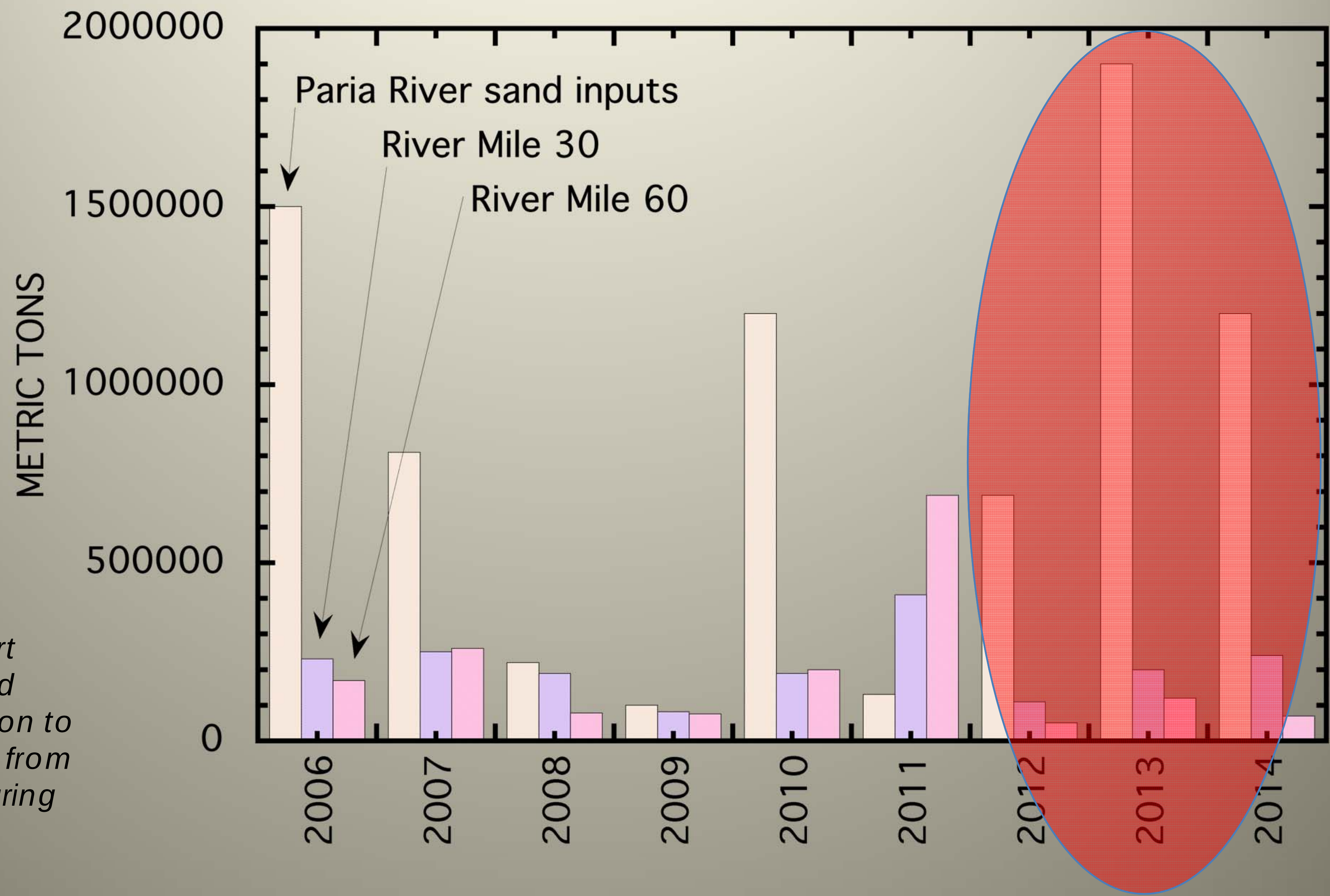
2014 – 240,000 mt (RM30); 70,000 (RM60)

Colorado River sand transport past indicated gage during the fall accounting period

Median for the 9 accounting periods between 2006 and 2014: 200,000 mt (RM30); 120,000 mt (RM60)

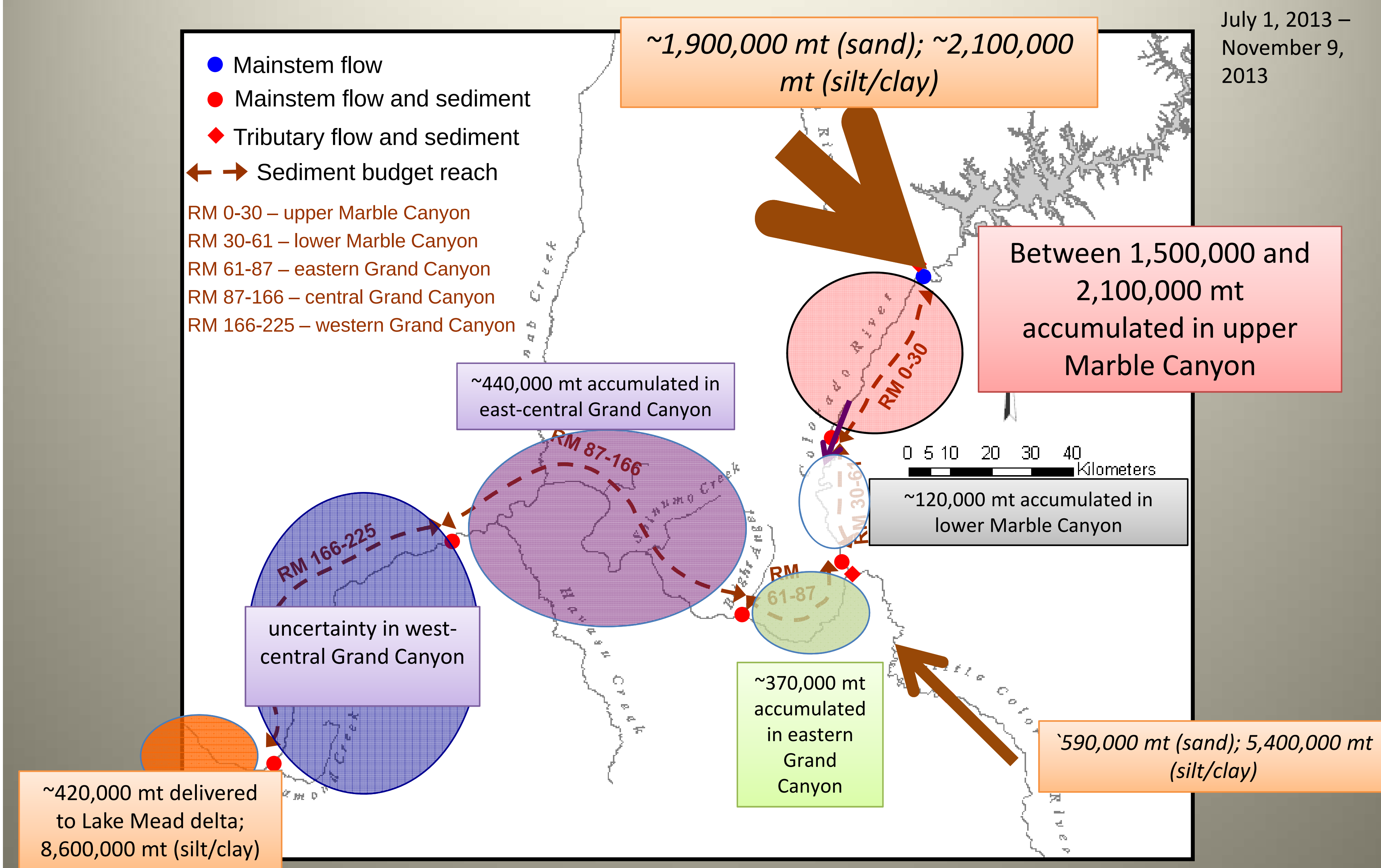


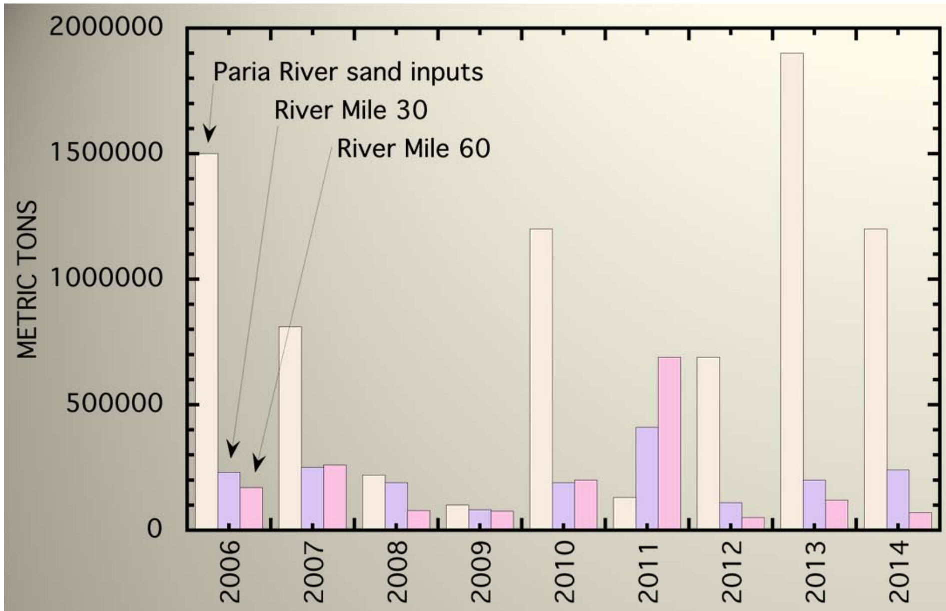
"Thus, if 2002-09 can be considered representative of future conditions ..., the summer/fall accounting period would be expected to have substantial sand accumulation (inputs of about 900,000 and export of about 300,000 metric tons ... (Wright and Kennedy, 2011)



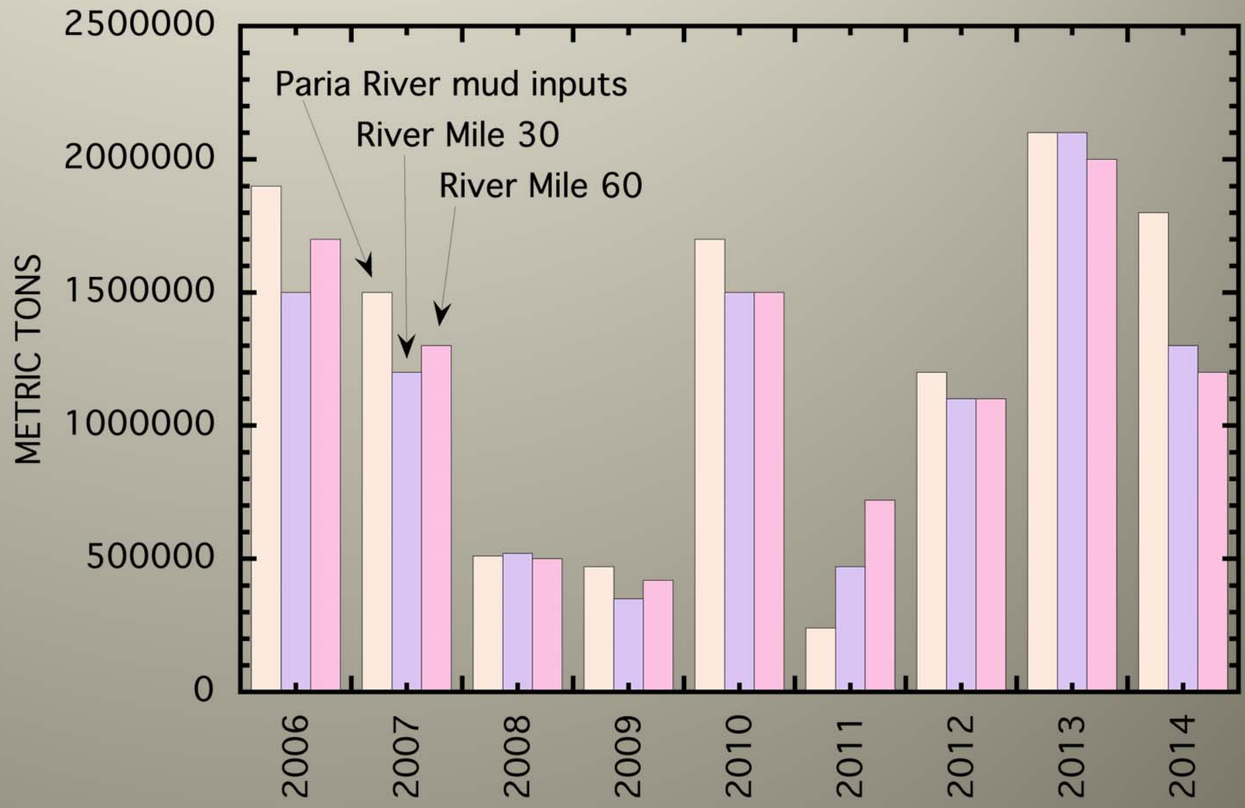
Sand transport past indicated gage in relation to sand delivery from Paria River during the fall accounting period

Monsoon season sand storage primarily occurs in upper Marble Canyon



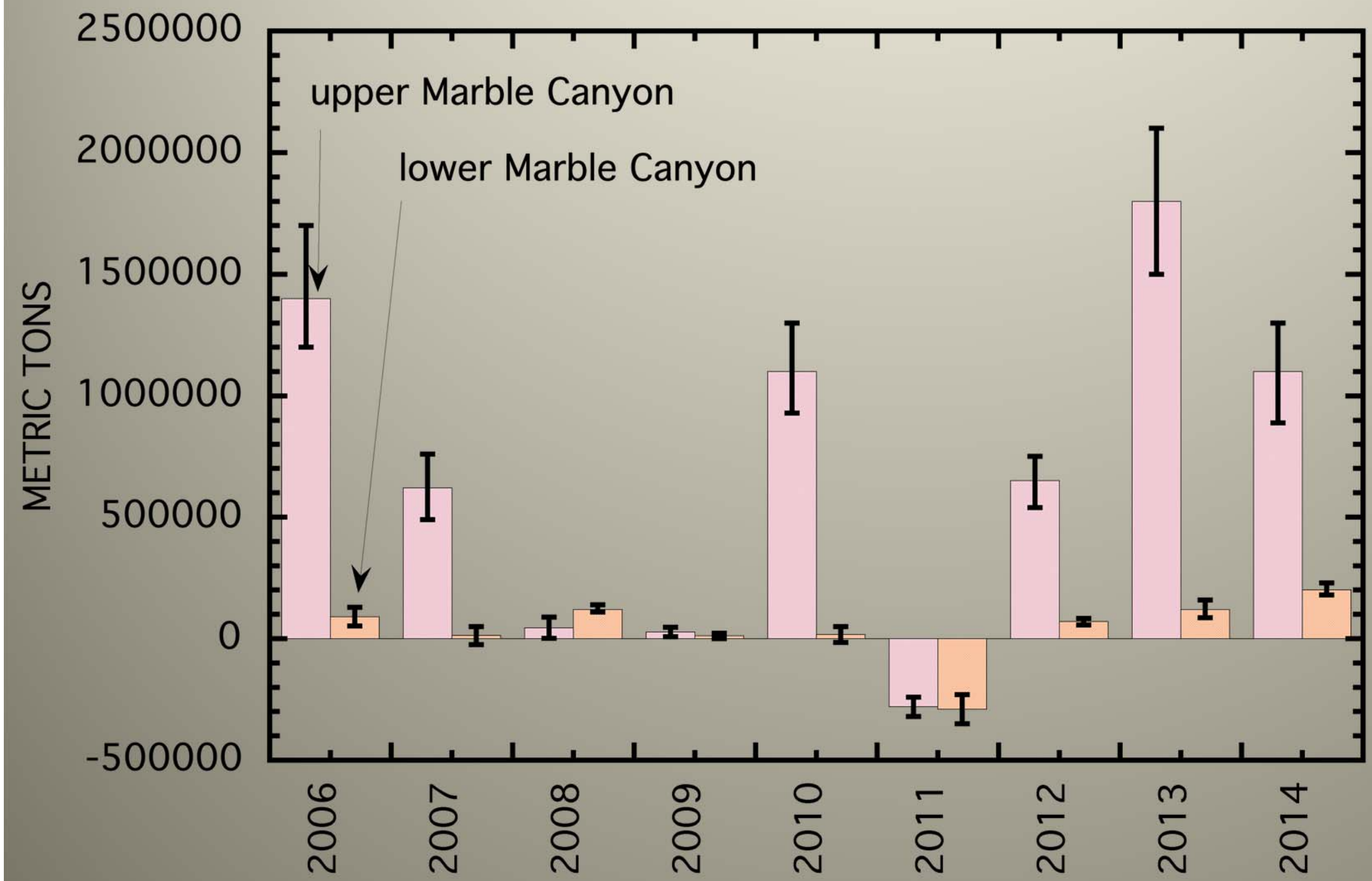


In contrast to sand, mud is not conserved within Marble Canyon during the fall accounting season. Mud is primarily transported directly to Lake Mead.



Using average sand delivery and sand export data, *Wright and Kennedy (2011)* projected that annual accumulation of sand during the fall accounting period would be ~600,000 metric tons.

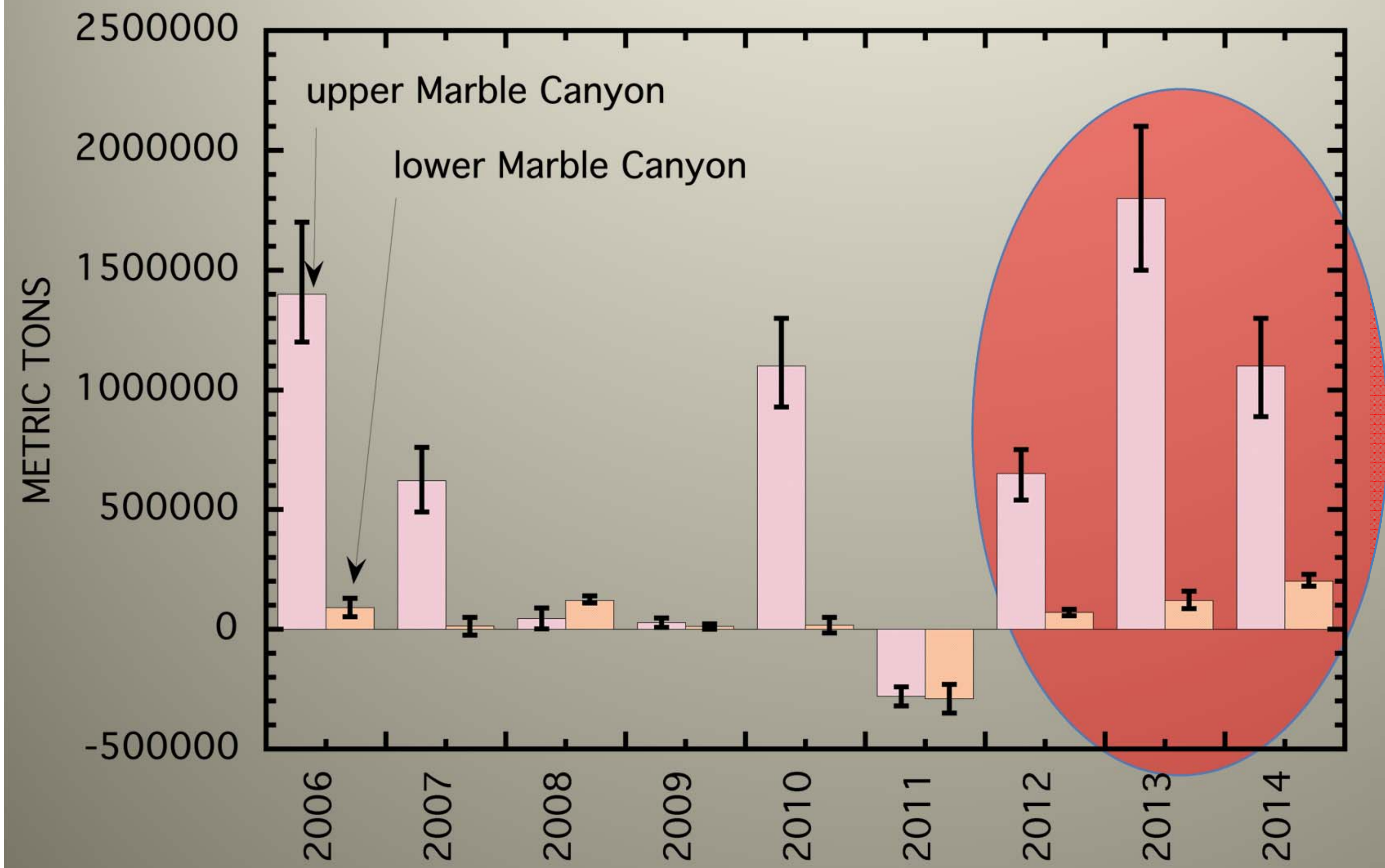
"The smallest HFE that would be conducted … would likely export 200,000 metric tons of sand or less …These approximate numbers suggest that fall HFEs would be triggered frequently, nearly every year … but that spring HFEs would be triggered much less frequently." *(Wright and Kennedy, 2011)*



Sand mass balance for the fall accounting period

In 2012 …
sand accumulation in Marble Canyon during the fall accounting period approximated "average" conditions anticipated by Wright and Kennedy (2011).

In 2013 and 2014 …
sand accumulation exceeded anticipated "average" conditions



Sand mass balance for the fall accounting period

Marble Canyon sand accumulation during fall accounting period
2012: ~720,000 mt
2013: ~1,900,000 mt
2014: ~1,300,000 mt

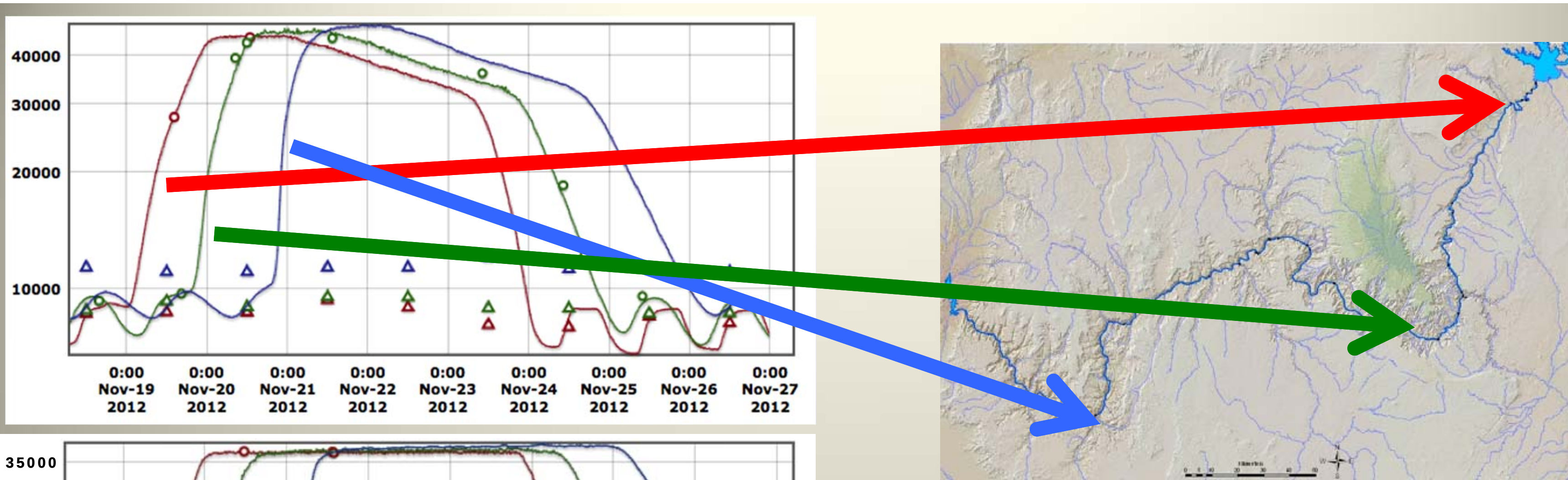
Although regulatory compliance exists for HFEs to have a peak magnitude of 45,000 ft^3/s, ongoing maintenance of turbines in the Glen Canyon power plant restricted the peak magnitude in 2013 and 2014.

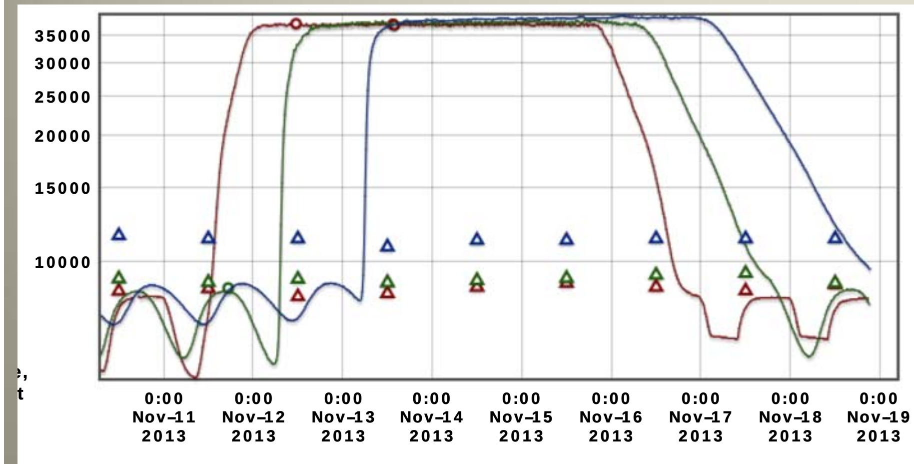
Glen Canyon Power Plant Provisional Unit Outage Schedule for Water Year 2015

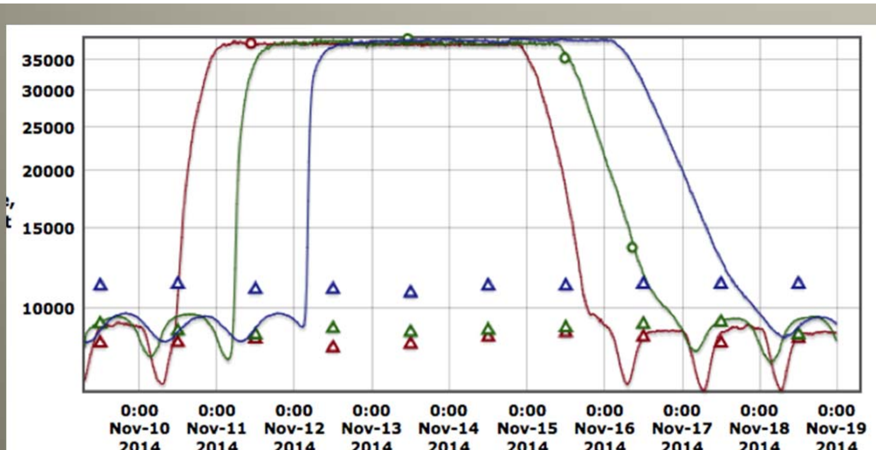
Unit Number	Oct 2014	Nov 2014	Dec 2014	Jan 2015	Feb 2015	Mar 2015	Apr 2015	May 2015	Jun 2015	Jul 2015	Aug 2015	Sep 2015	
1													
2													
3													
4													
5													
6													
7													
8													
Units Available	5	7	6	6	4 / 6	4 / 6	6	6 / 5	6	6	6	6	
Capacity (cfs)	14,400	21,500	18,000	18,000	11,300 / 18,000	11,300 / 18,000	18,000	18,000 / 14,600	18,000	18,000	18,000	17,800	
Capacity (kaf/month)	910	1,280	1,110	1,110	750	850	1,070	980	1,070	1,110	1,170	1,130	
Max (kaf) [1]	--	--	800	950	670	940	1,084	1,220	1,300	1,300	1,300	1,300	12.1
Most (kaf) [2]	598	776	866	860	600	650	600	700	800	1,050	800	700	9.0
Min (kaf) [1]	--	--	800	800	650	650	600	650	800	1,000	1,050	800	9.0

Peak magnitude of HFEs measured at Lees Ferry:

2012 – 44,800 ft^3/s
2013 – 37,400 ft^3/s
2014 – 38,300 ft^3/s







The rate of rise of the flood wave steepens downstream.

2012 -- duration of rise from 10,000 – 41,700 ft^3/s

Lees Ferry: 20.5 hrs

Grand Canyon: 15.5 hrs

Diamond Creek: 12.25 hrs

2013 – duration of rise 10,000 – 36,000 ft^3/s

Lees Ferry: 11 hrs

Grand Canyon: 8 hrs

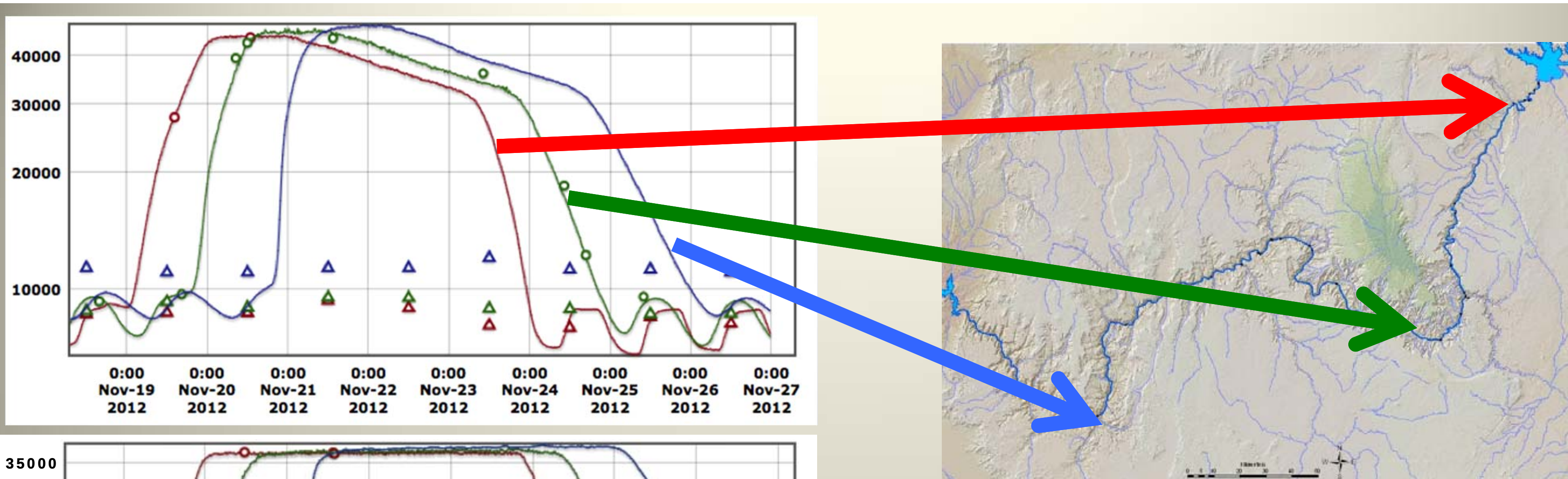
Diamond Creek: 5 hrs

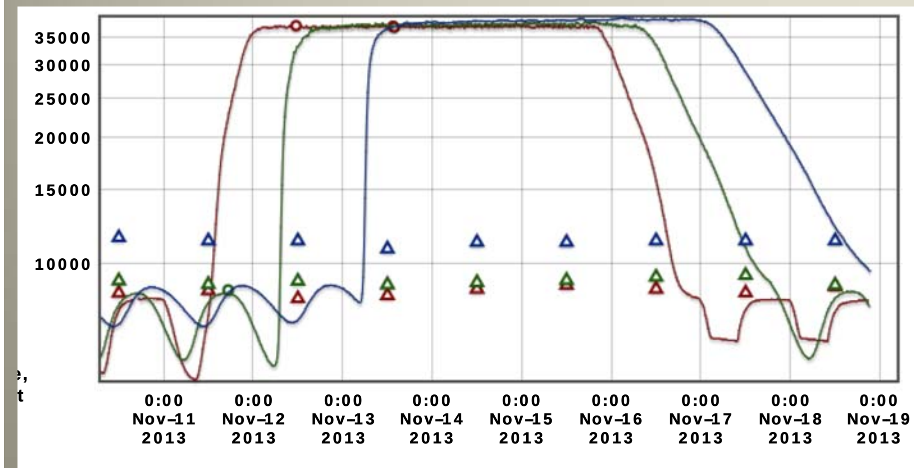
2014 – duration of rise 10,000 – 37,000 ft^3/s

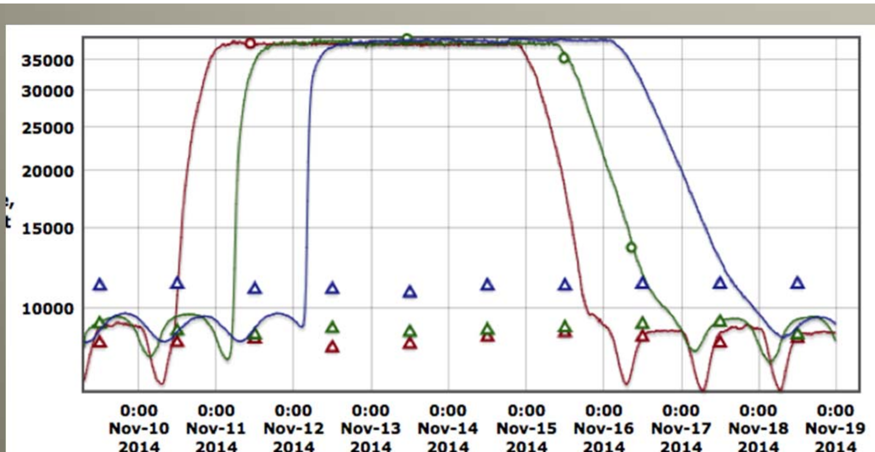
Lees Ferry: 12.5 hrs

Grand Canyon: 9.5 hrs

Diamond Creek: 7.25 hrs







The rate of recession of the flood wave decreases downstream.

2012 -- duration of recession from 40,000 – 10,000 ft^3/s

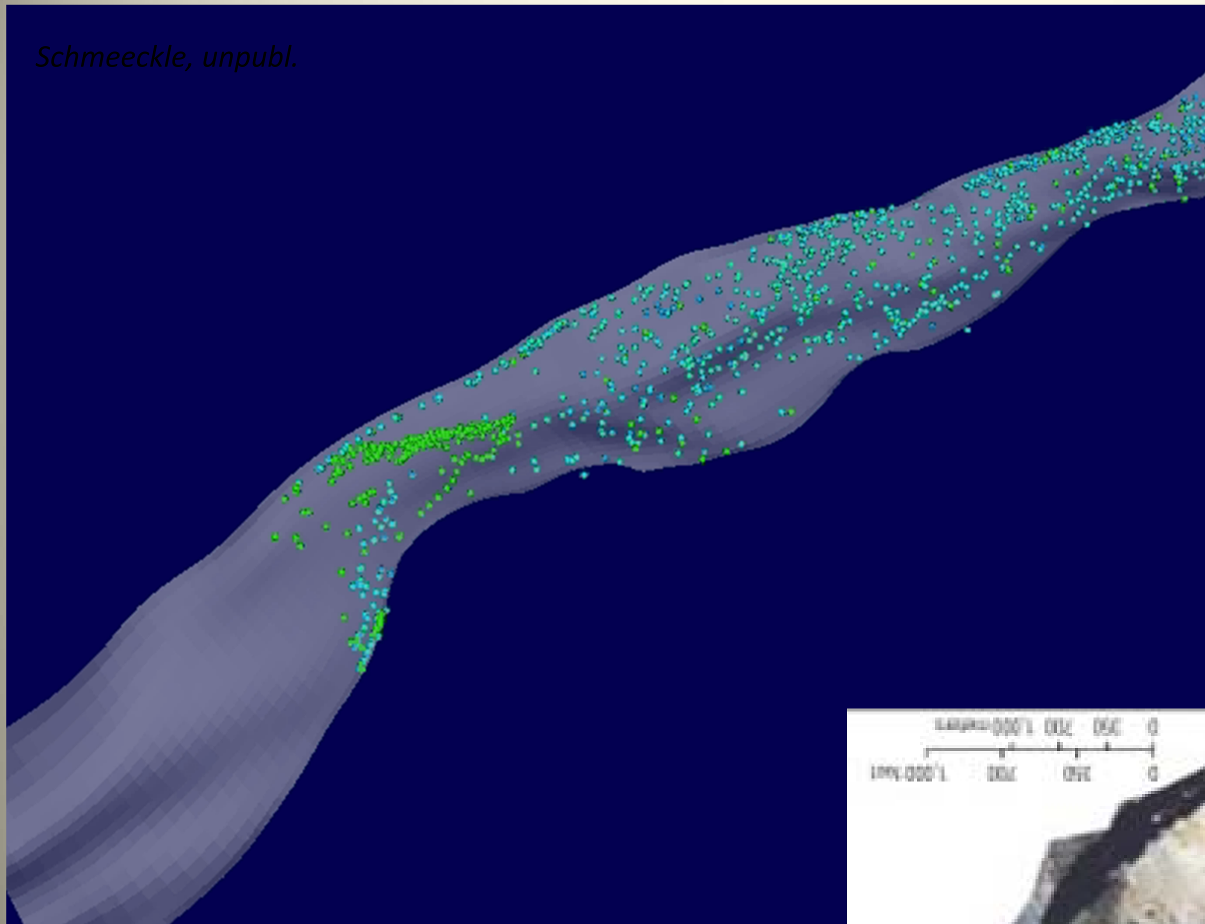
Lees Ferry: 52.75 hrs
Grand Canyon: 51.25 hrs
Diamond Creek: 65.75 hrs

2013 – duration of recession from 36,000 – 10,000 ft^3/s

Lees Ferry: 18.75 hrs
Grand Canyon: 29 hrs
Diamond Creek: 40.75 hrs

2014 – duration of recession from 37,000 – 10,000 ft^3/s

Lees Ferry: 12 hrs
Grand Canyon: 32.25 hrs
Diamond Creek: 41.25 hrs

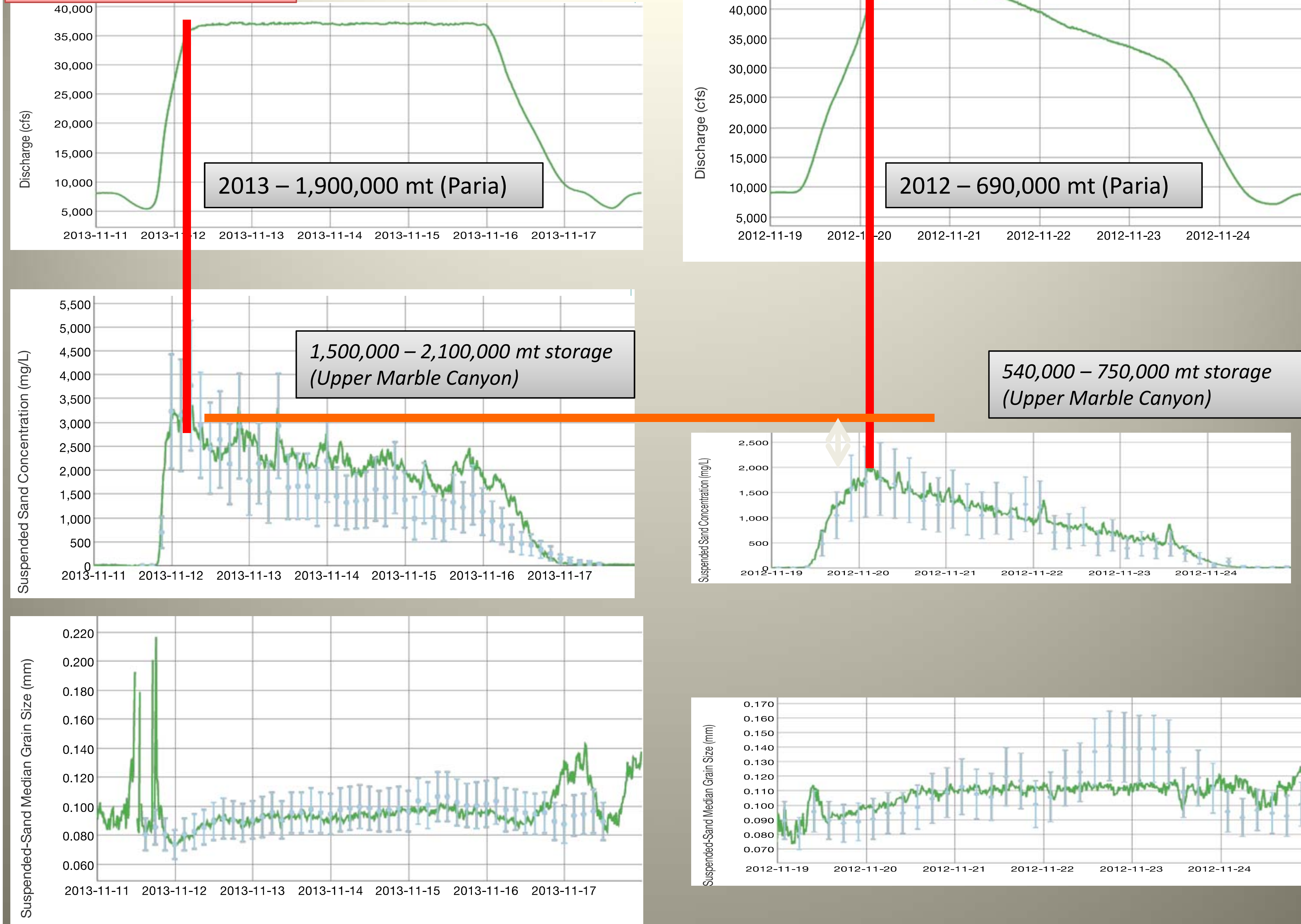


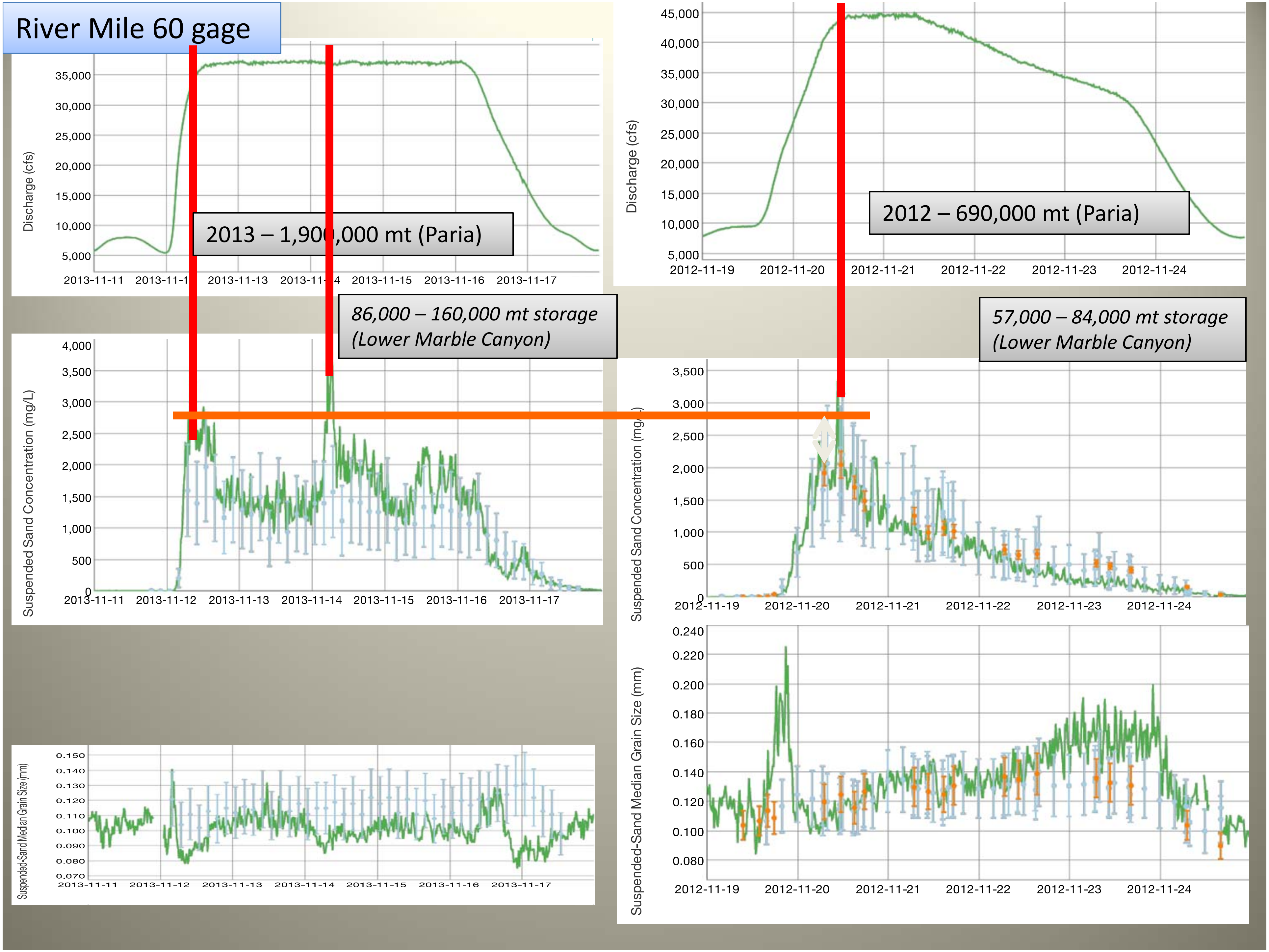
Higher mainstem suspended sand concentrations lead to larger eddy sand bars.

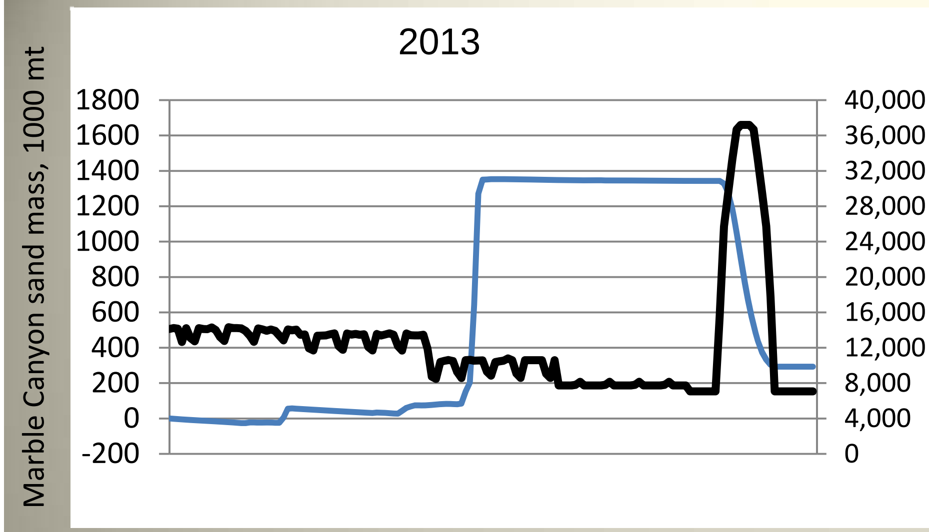
Measured depth averaged horizontal velocities at peak flow during 2008 HFE

(Wright and Kaplinski, 2010)

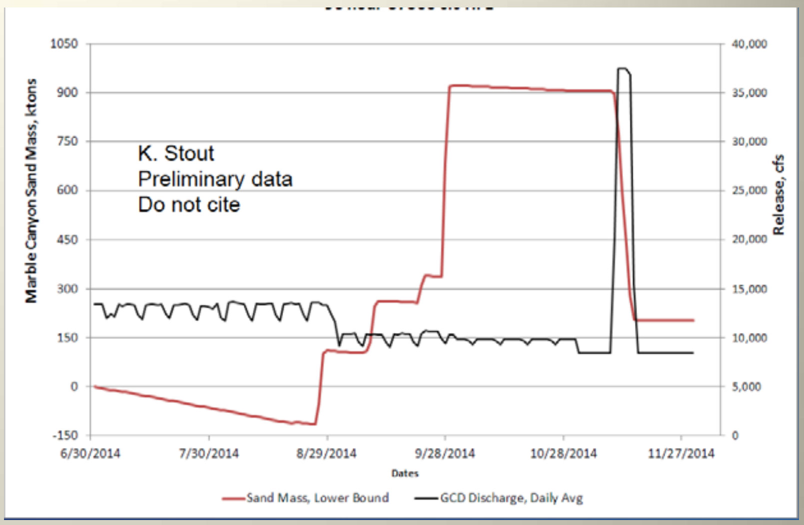
River Mile 30 gage



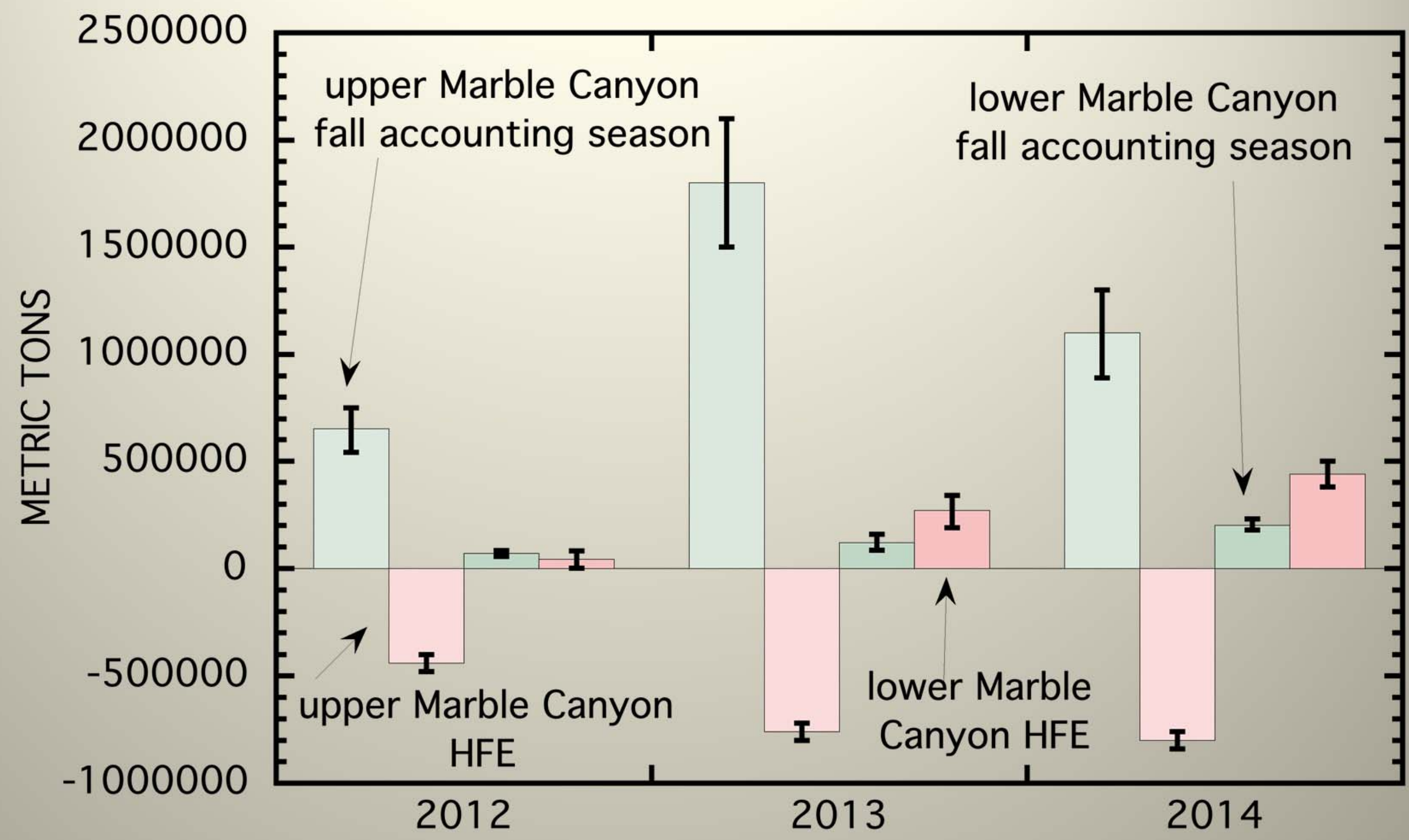

River Mile 60 gage
2013 – 1,900,000 mt (Paria)
86,000 – 160,000 mt storage (Lower Marble Canyon)
2012 – 690,000 mt (Paria)
57,000 – 84,000 mt storage (Lower Marble Canyon)
Discharge (cfs)
Suspended Sand Concentration (mg/L)
Suspended-Sand Median Grain Size (mm)
2013-11-11
2013-11-12
2013-11-13
2013-11-14
2013-11-15
2013-11-16
2013-11-17
2012-11-19
2012-11-20
2012-11-21
2012-11-22
2012-11-23
2012-11-24



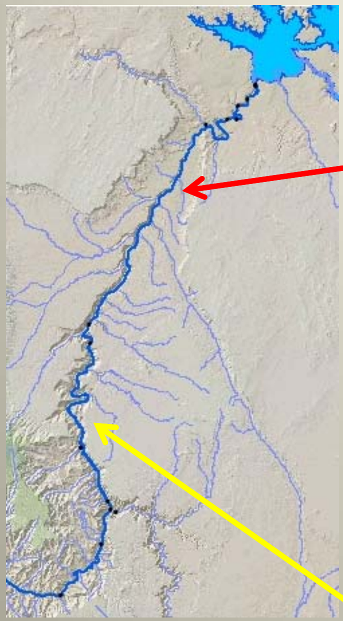
2014

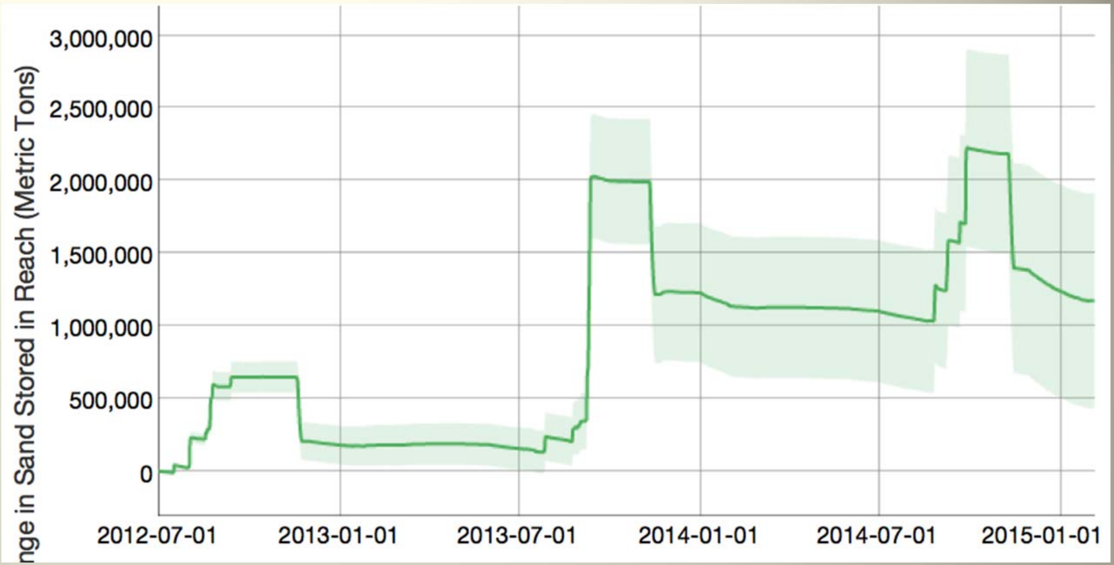


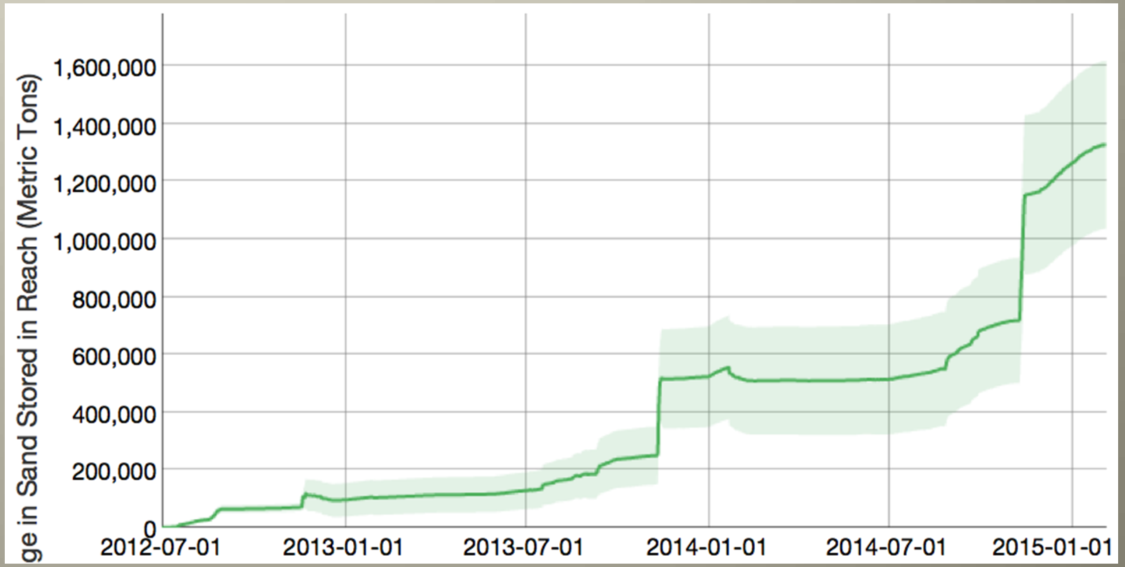
The objective of HFE planning is to evacuate from Marble Canyon slightly less sand during each flood than was delivered into Marble Canyon in the immediately preceding fall accounting season.



Each HFE evacuated less sand from upper Marble Canyon than had been delivered there in the immediately preceding fall accounting season. Each HFE delivered sand into lower Marble Canyon.

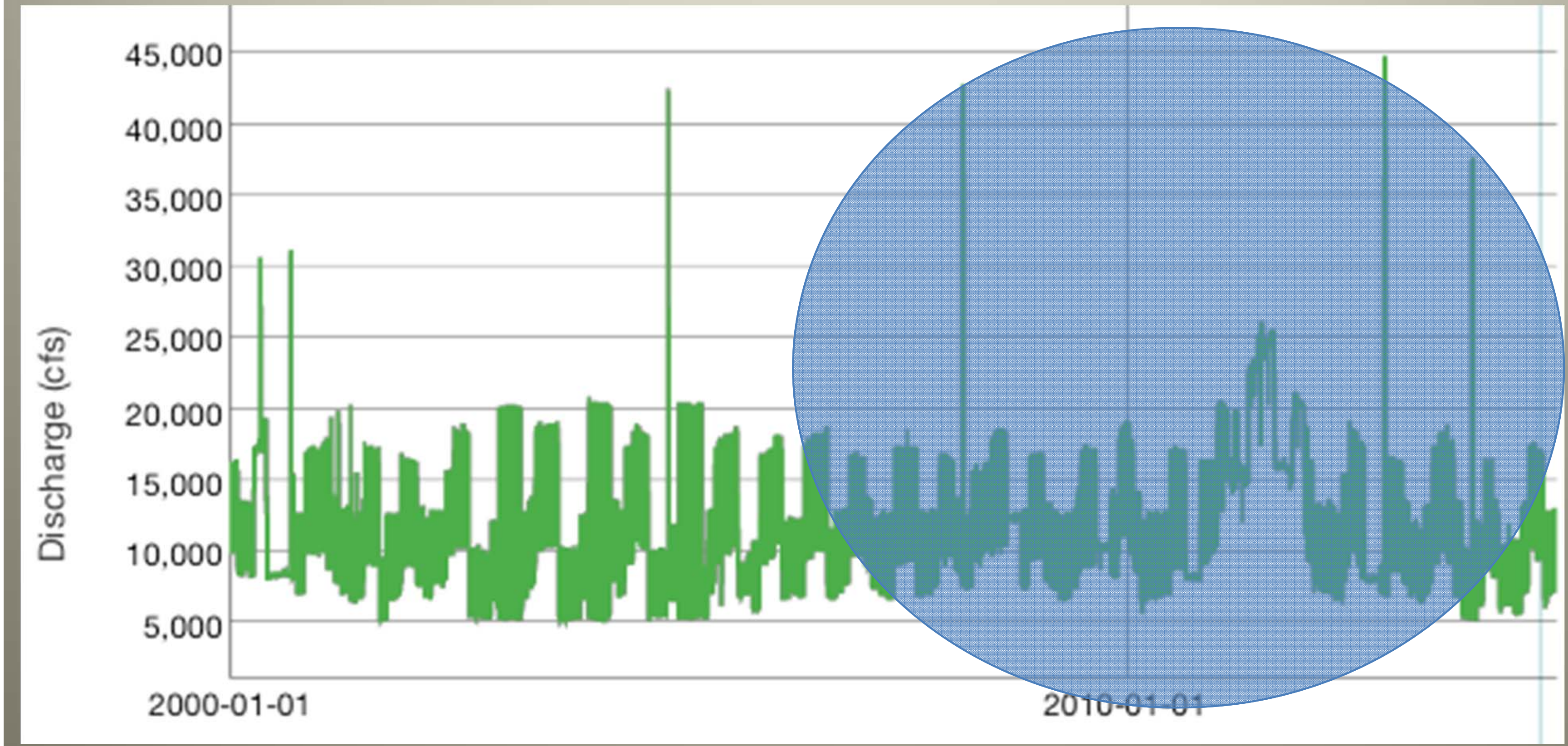






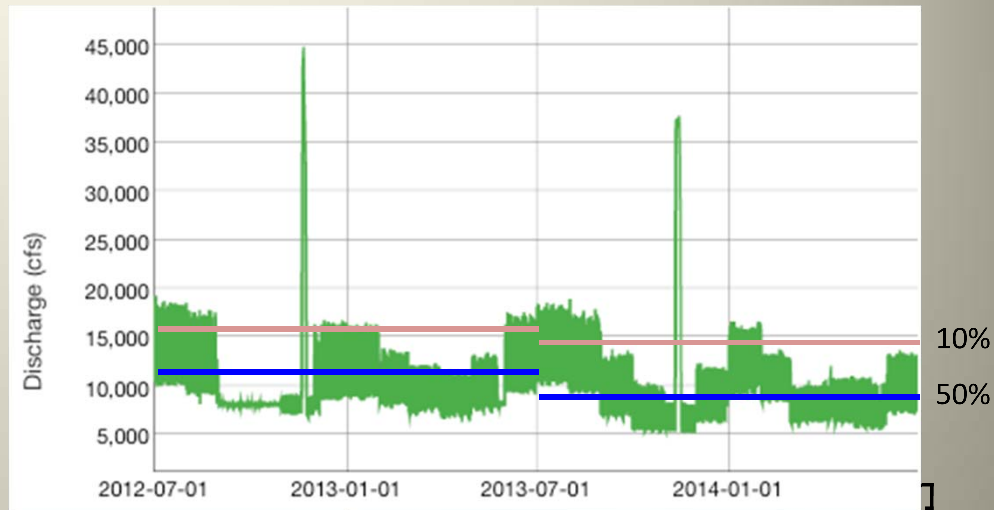
The net effect of less sand being evacuated by each HFE in relation to each year's sand delivery from tributaries has led to progressive sand accumulation in upper and lower Marble Canyon

Taking the long view …

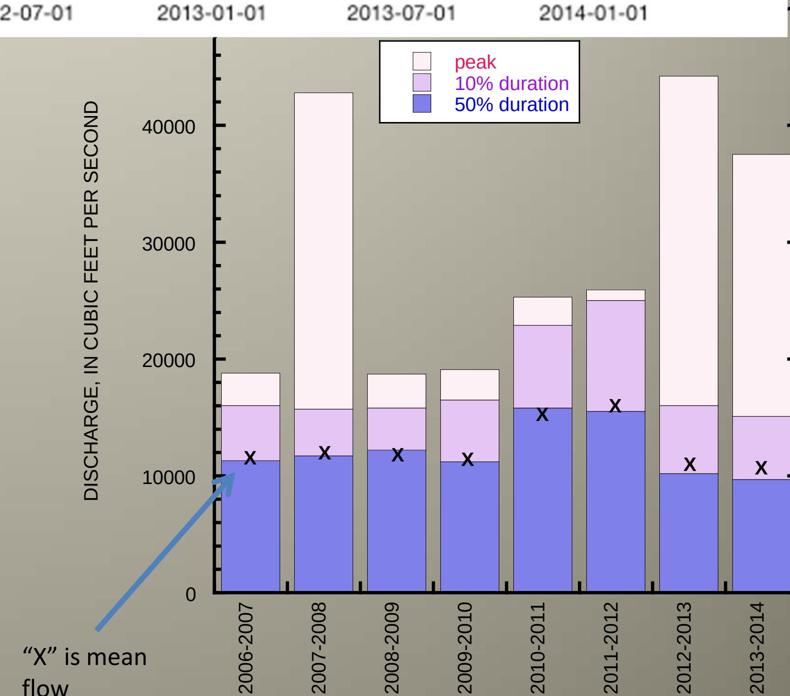


There have been three characteristic flow regimes since 2006

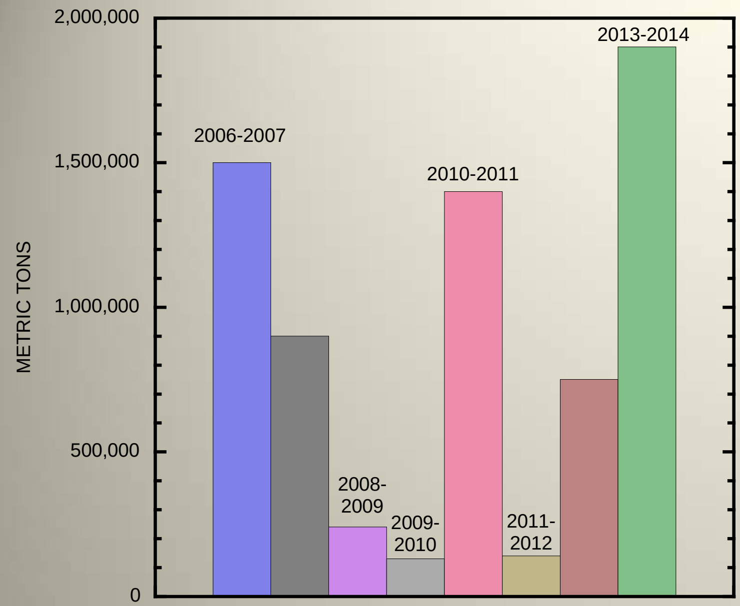
normal operations with controlled floods (2012-2013, 2013-2014)

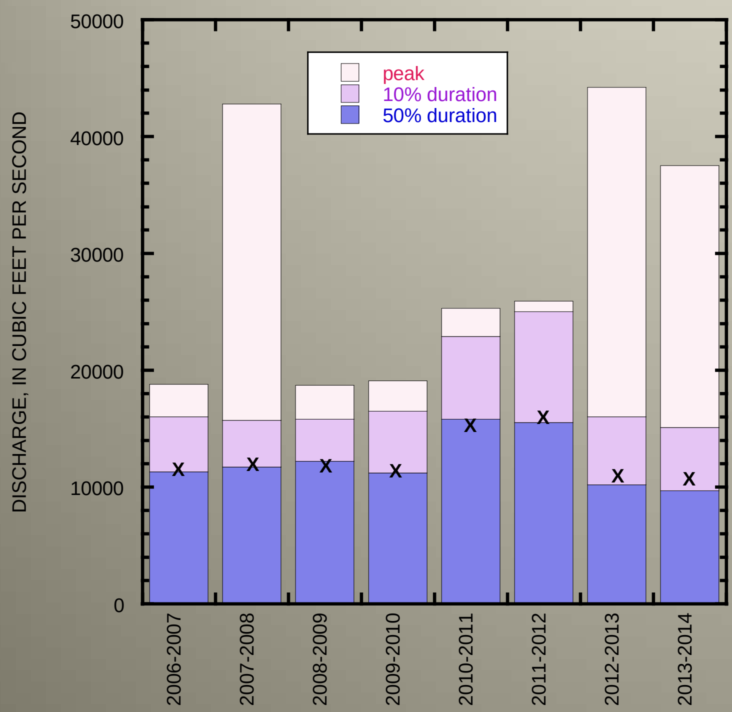


equalization without controlled floods (2010-2011, 2011-2012)



normal operations without controlled floods (2006-2007, 2008-2009, 2009-2010)





There have been years of large sand inputs from the Paria and years of small or moderate inputs, resulting in 6 hydrology/sediment supply scenarios.

normal operations without controlled flood; **large inputs** (2006-2007)

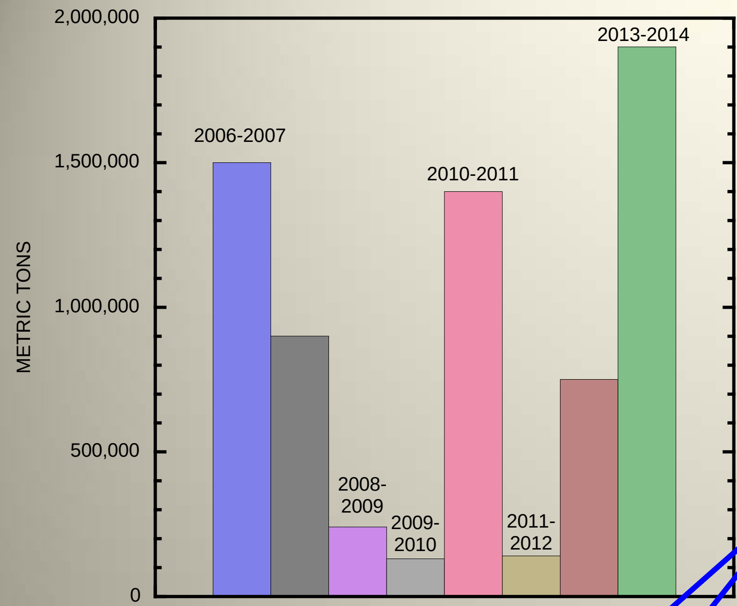
normal operations without controlled flood; **small inputs** (2008-2009; 2009-2010)

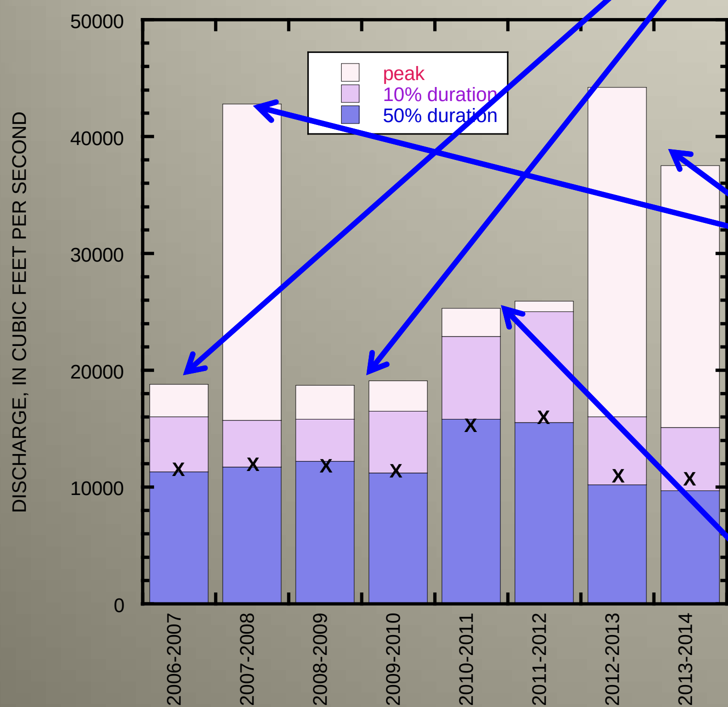
normal operations with controlled flood; **moderate inputs** (2007-2008; 2012-2013)

normal operations with controlled flood; **large inputs** (2013-2014)

equalization: **large inputs** (2010-2011)

equalization; **small inputs** (2011-2012)





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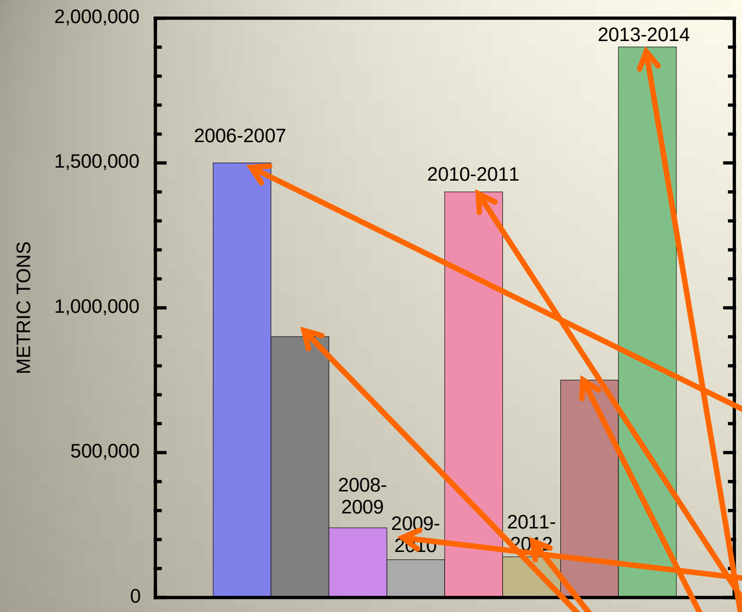

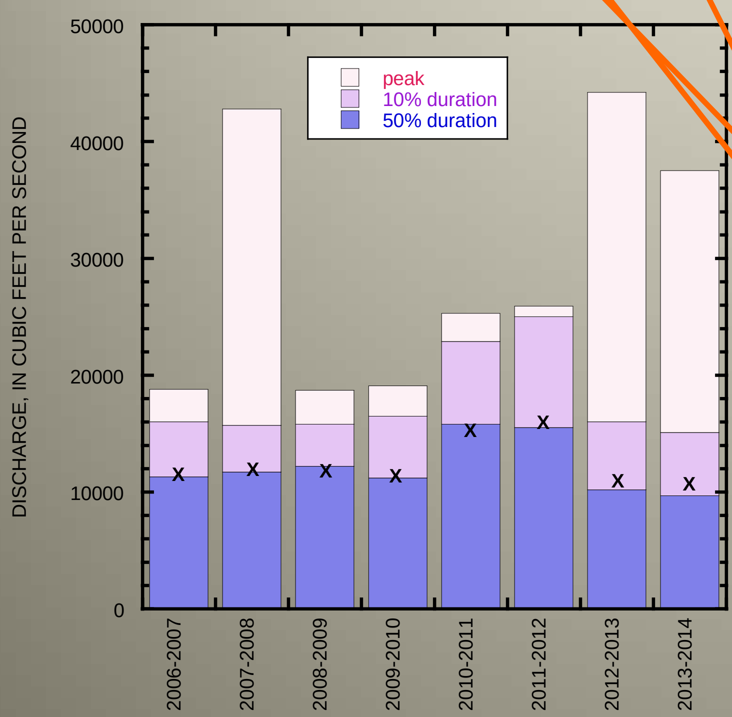

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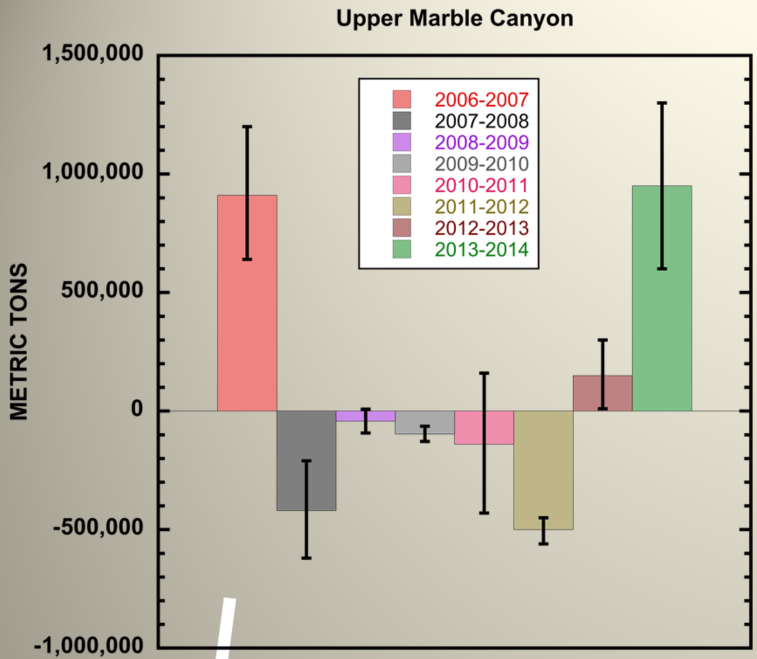
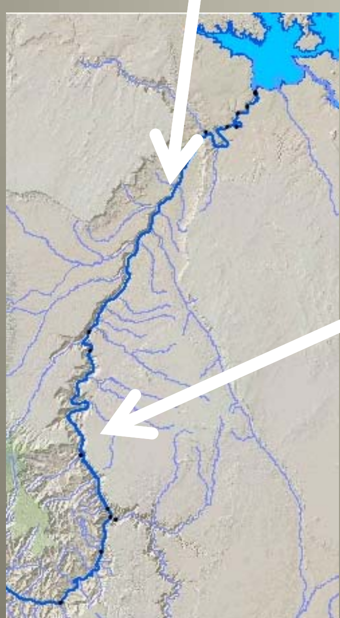


Upper Marble Canyon

Sand accumulation in years of large or moderate inputs and normal operations.

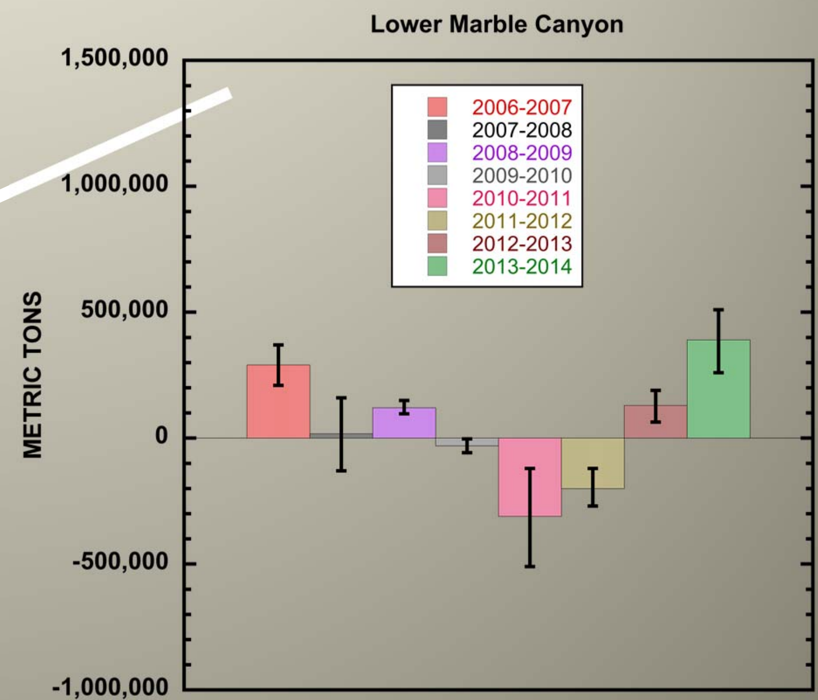
Sand evacuation whenever small inputs; evacuation when large inputs but equalization

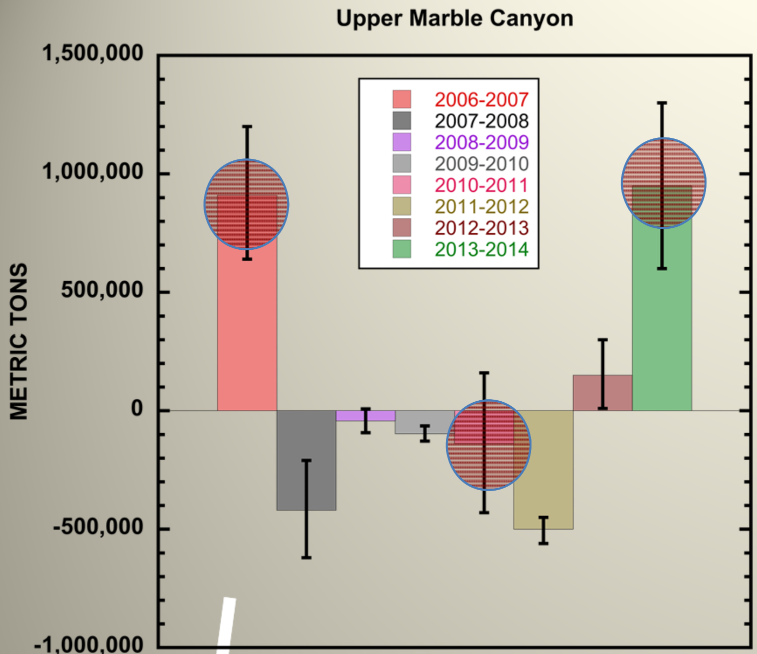


Lower Marble Canyon

Sand accumulation with normal operations and small, moderate, large inputs

Sand evacuation with small inputs or equalization (regardless of inputs)





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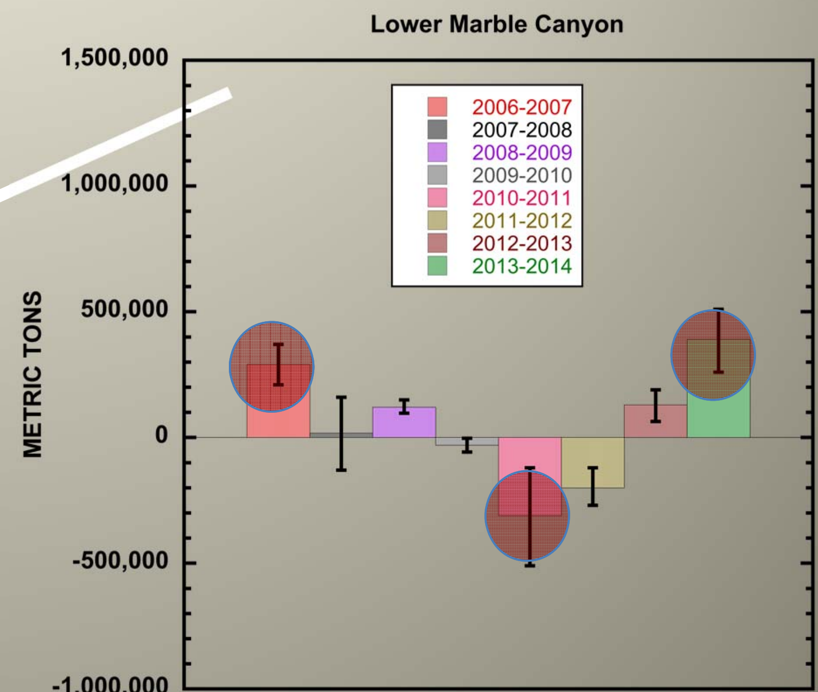
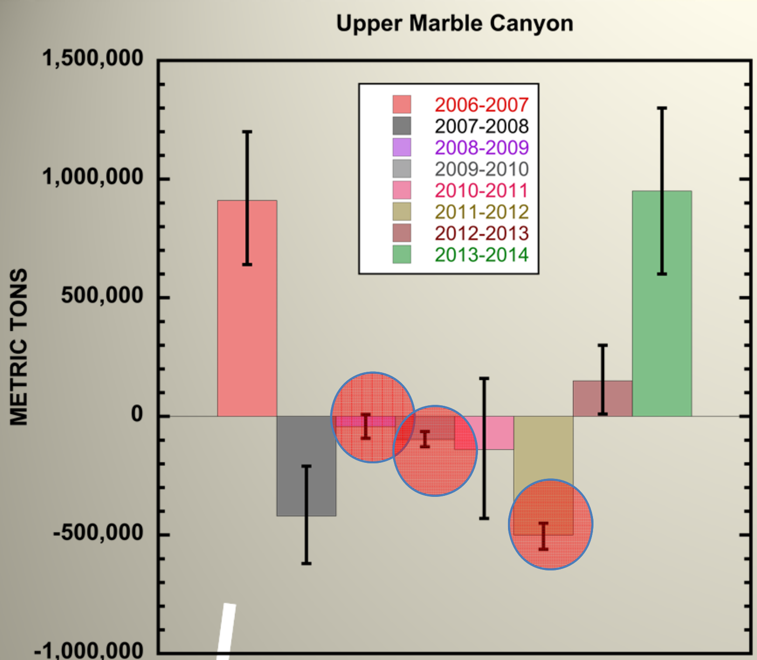
Sand accumulation with normal operations and small, moderate, large inputs

Sand evacuation with small inputs or equalization (regardless of inputs)



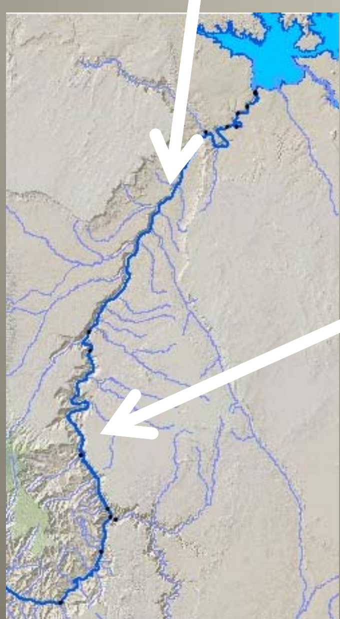
years of large Paria inputs



Upper Marble Canyon

Sand accumulation in years of large or moderate inputs and normal operations.

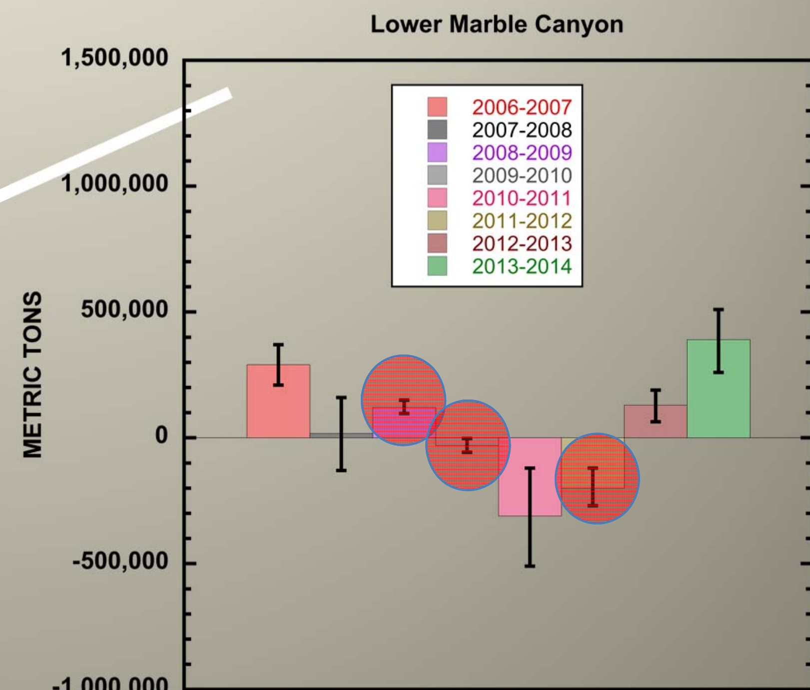
Sand evacuation whenever small inputs; evacuation when large inputs but equalization



Lower Marble Canyon

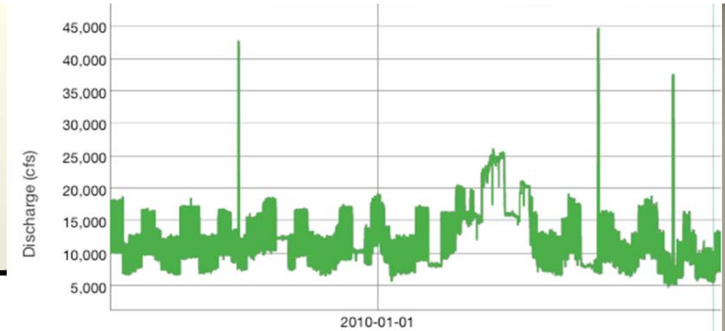
Sand accumulation with normal operations and small, moderate, large inputs

Sand evacuation with small inputs or equalization (regardless of inputs)

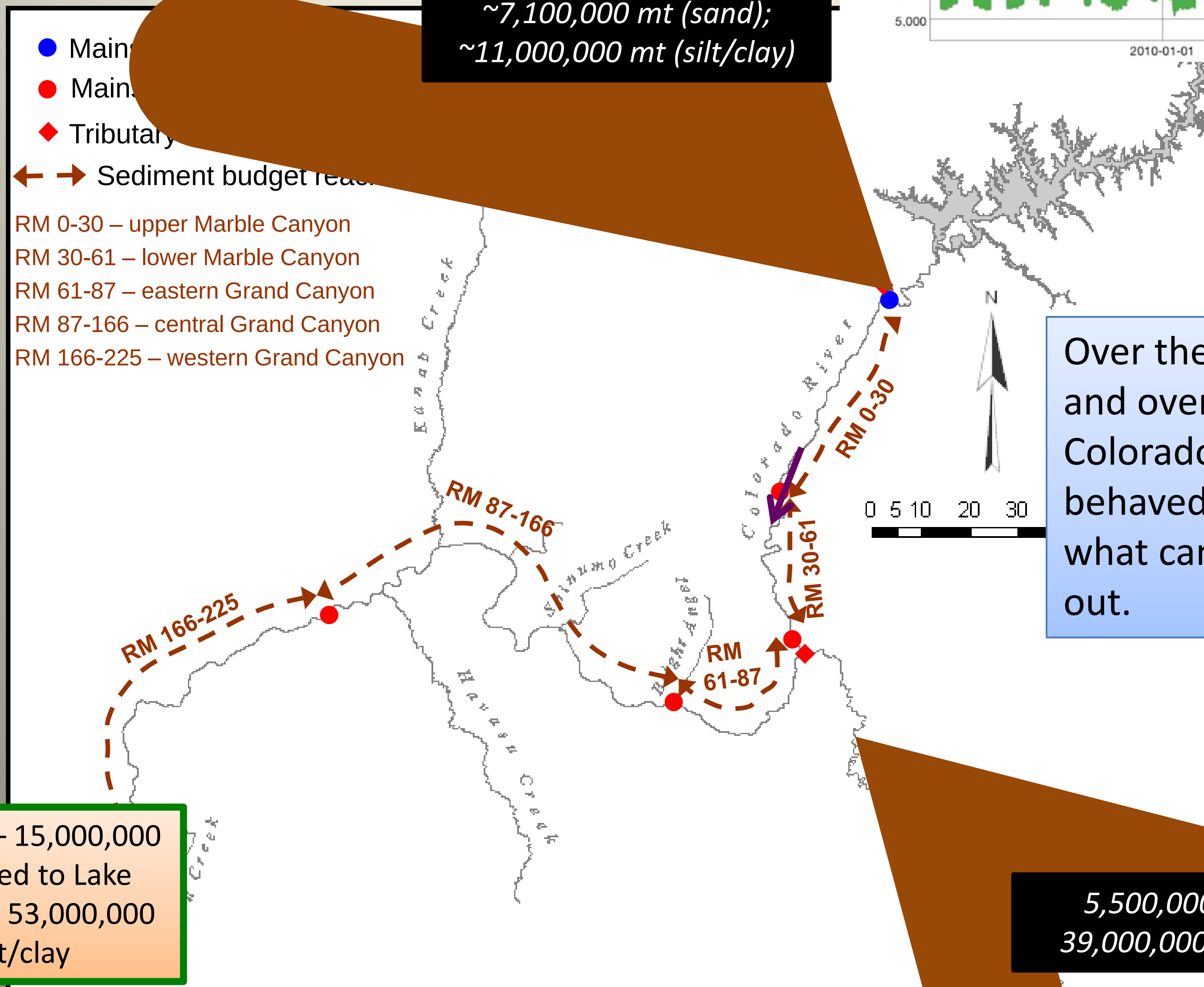


years of small Paria inputs

July 1, 2006 –
June 30, 2014



~7,100,000 mt (sand);
~11,000,000 mt (silt/clay)



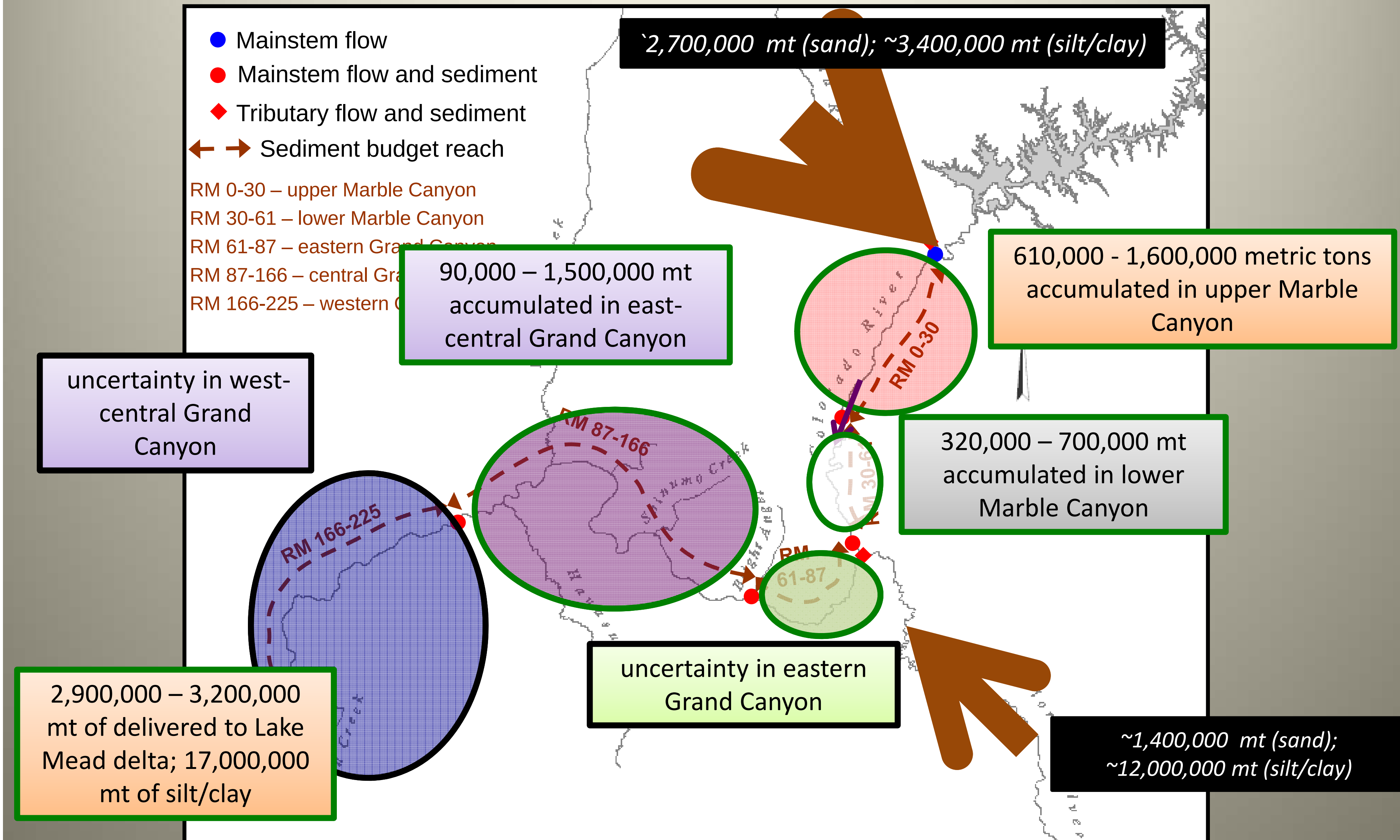
Over the entire canyon and over 8 years, the Colorado River behaved like a pipe – what came in went out.

14,000,000 – 15,000,000 mt delivered to Lake Mead delta; 53,000,000 mt silt/clay

5,500,000 mt (sand);
39,000,000 mt (silt/clay)

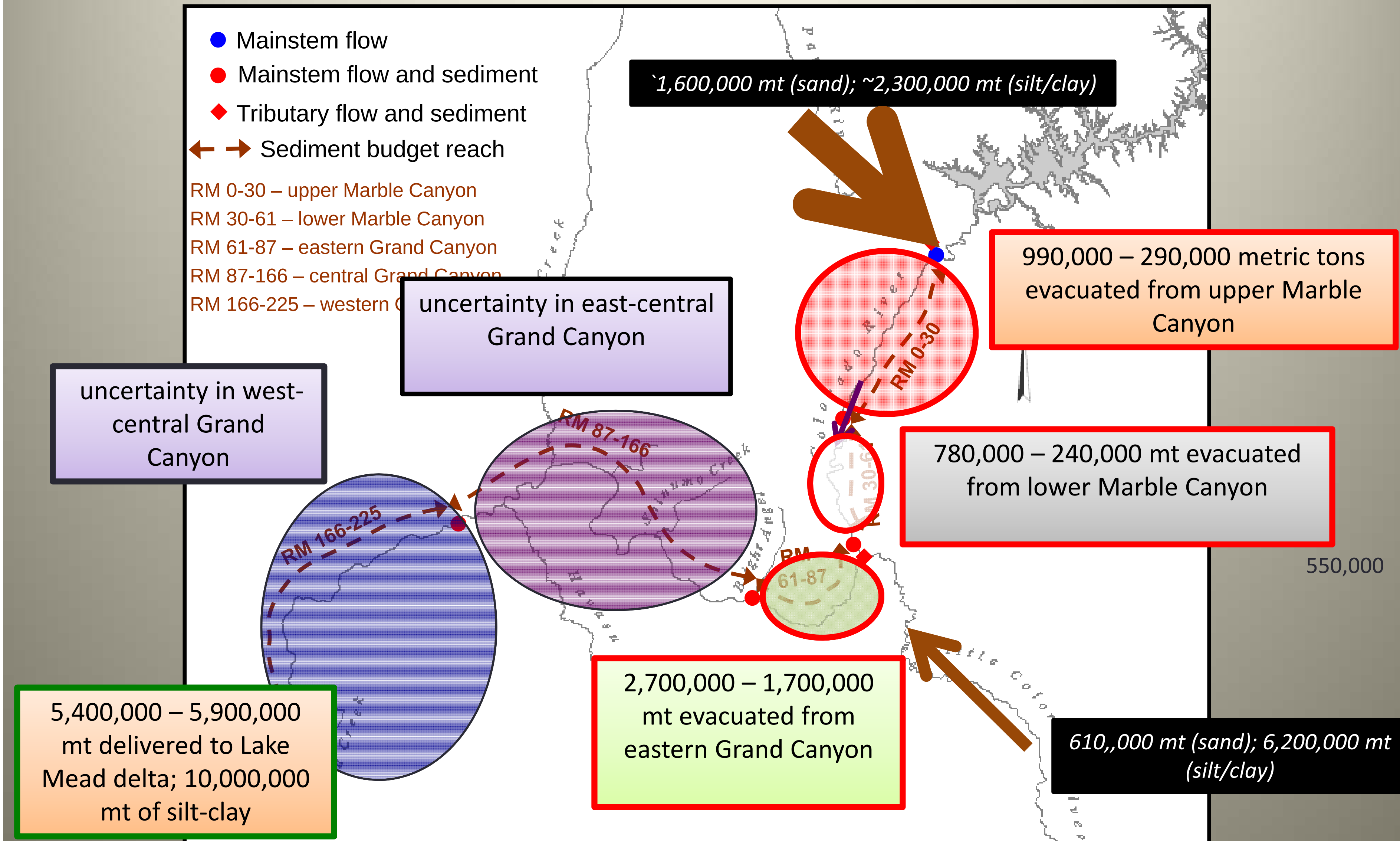
For the first two years of the HFE Protocol, sand accumulated in most of Grand Canyon

July 1, 2012 –
June 30, 2014



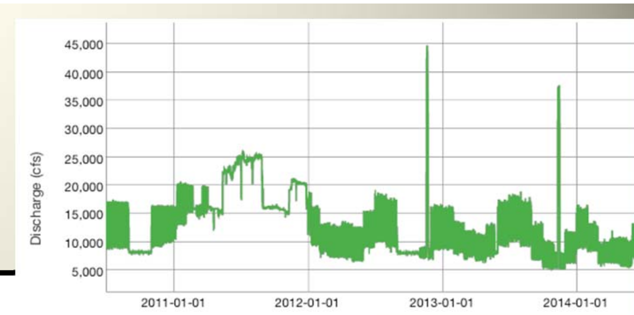
July 1, 2010 –
June 30, 2012

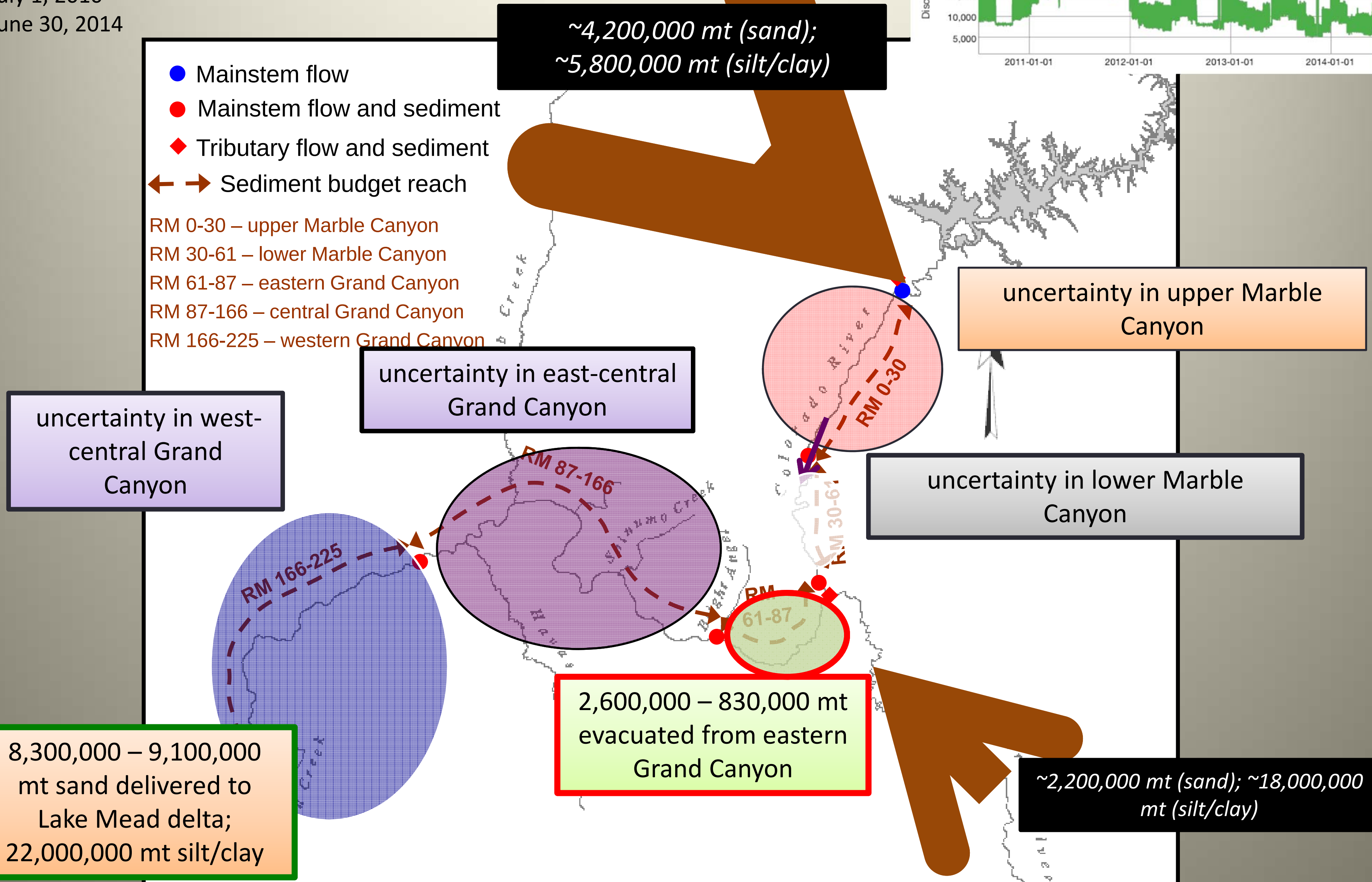
In the years of equalization flows, there was large-scale evacuation of sand

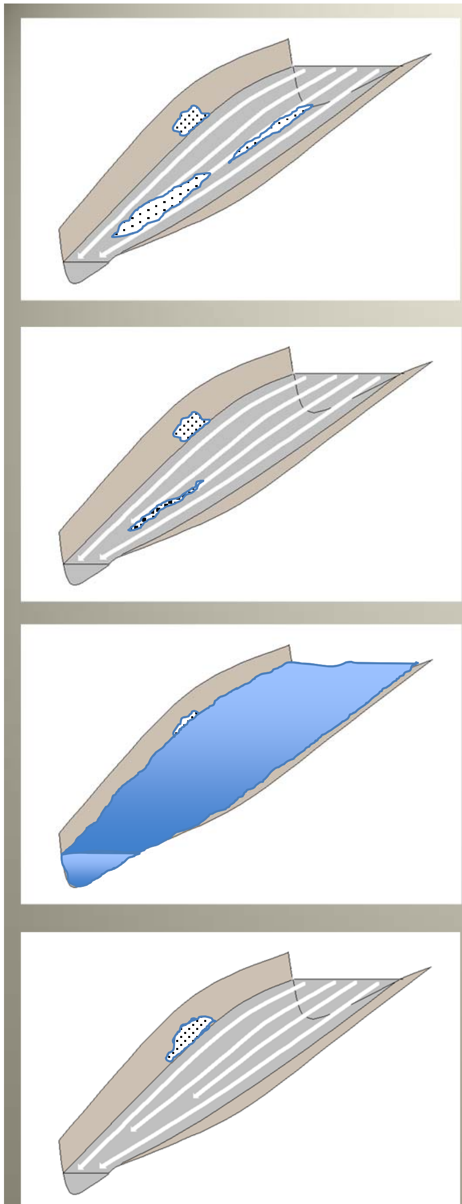


Thus, the mass balance for the past four years is the result of the effects of the equalization flows and the effects of more recent large tributary inputs

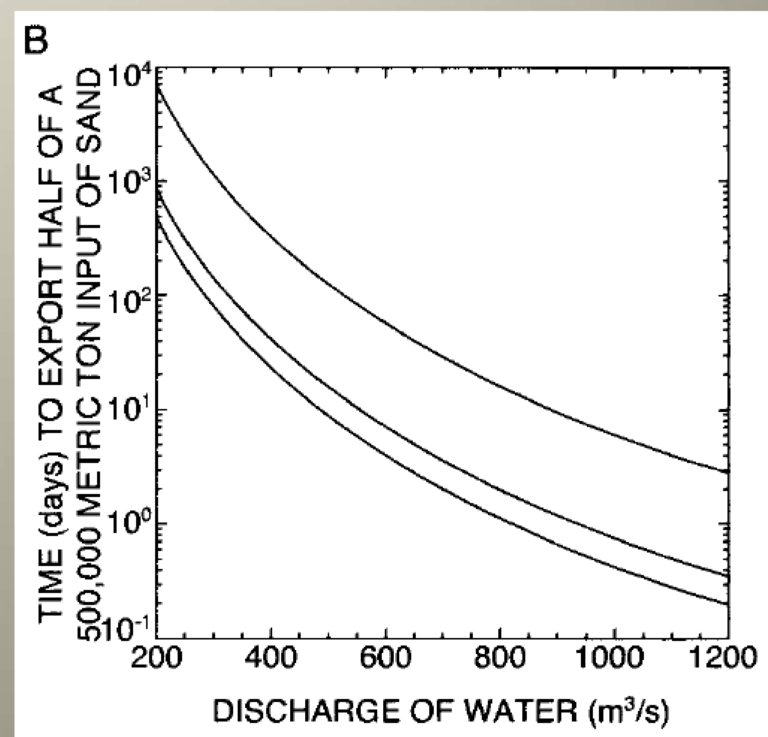
July 1, 2010 –
June 30, 2014





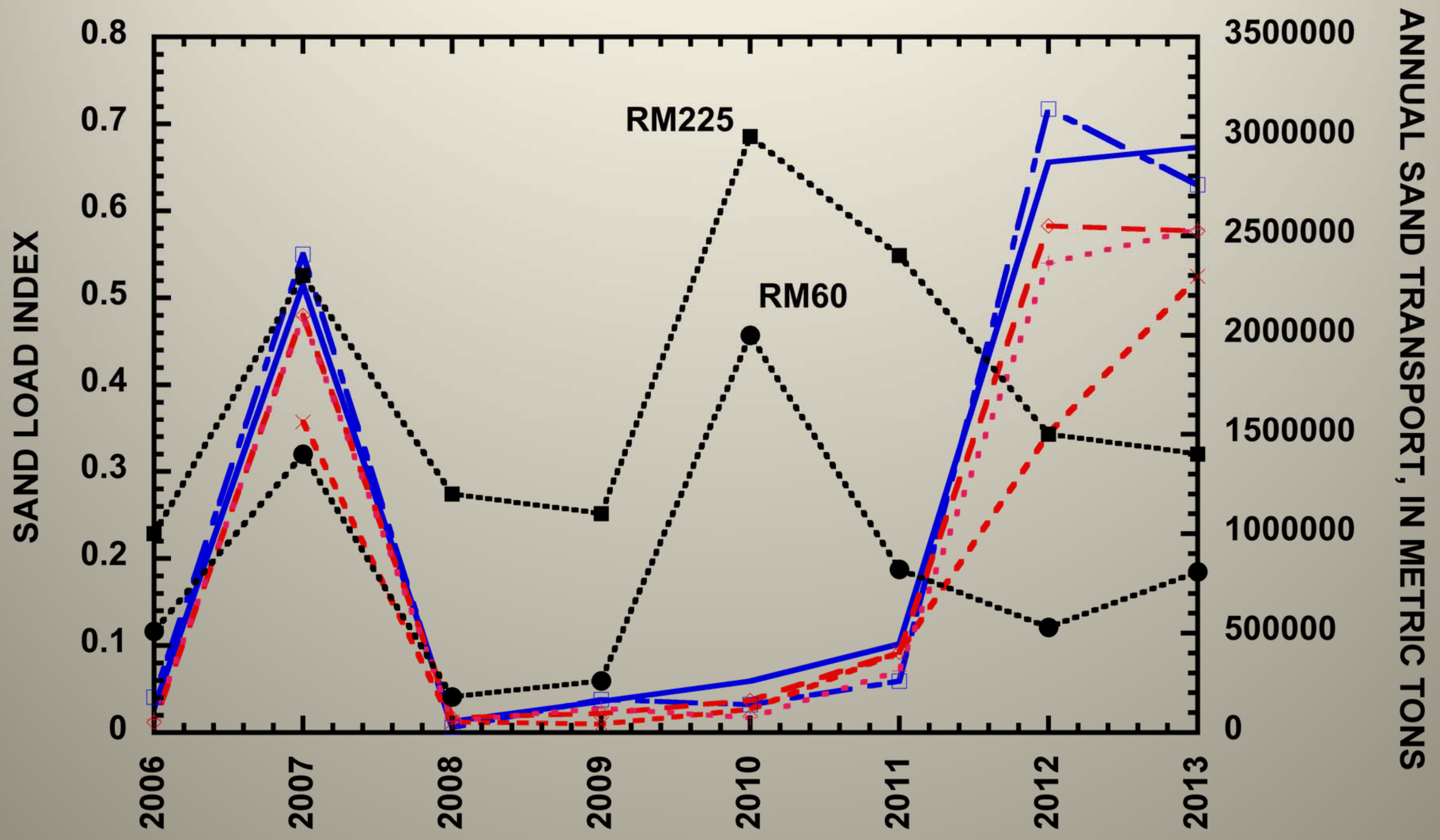


Sand can accumulate for multi-year periods and is not necessarily entirely evacuated to Lake Mead each year. The river system ***may*** be in approximate equilibrium at a decadal time scale, but this results from the balance between large losses during equalization and large recent inputs.



Sand inputs from the Paria are the largest determinant of sand mass balance

Sand Load Index since 2006 and in Relation to Total Annual Sand Transport



Color lines are sand transport index in ***Marble Canyon*** *and in* ***Grand Canyon***