Recommended Protocols for Core Monitoring of Sediment within the Colorado River Ecosystem Below Glen Canyon Dam: PART IV

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science for a changing world

Four tasks identified to address 3 of top 4 CMINS under Goal 7, top 5 plus 3 additional CMINS under Goal 8, top CMIN under Goal 9, and provide supporting data for Goals 1, 2, 6, and 11

MASS BALANCE PROJECT

- Task 1-1: Monitoring of stage, flow, and "mass balance" of fine sediment in multiple reaches of the CRE

SED TREND PROJECT

- Task 2-1: High-elevation sandbar time series (annual "effectiveness monitoring")
- Task 2-2: Analysis of remote-sensing data (every 4-5 years; not in BHBF years)
- Task 2-3: Monitoring of the fine-sediment "bank account" (annual in different ~30-mile reaches; not in BHBF years)

Goal 7: Establish water temperature, quality and flow dynamics to achieve GCDAMP ecosystem goals (downstream stage, flow, and sediment-flux components only)

- #1 2006 SPG rank - CMIN 7.4.1 – Determine and track releases from Glen Canyon Dam under all operating conditions. -- MASS BALANCE PROJECT

- #1 2006 SPG rank - CMIN 7.4.2 – Determine and track flow releases from Glen Canyon Dam, particularly related to flow duration, upramp, and downramp conditions (same as previous CMIN) -- MASS BALANCE PROJECT

- #3 2006 SPG rank - CMIN 7.2.1 – Determine the seasonal and yearly trends in turbidity, water temperature, conductivity, DO, and pH, (decide below whether selenium is important) changes in the mainstem throughout the CRE. -- MASS BALANCE PROJECT

- #4 2006 SPG rank - CMIN 7.1.2 – Determine and track LCR discharge near mouth (below springs). -- MASS BALANCE PROJECT

Goal 8: Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals

- #1 2006 SPG rank - CMIN 8.1.3 – Track, as appropriate, the monthly sand and silt/clay -input volumes and grain-size characteristics, by reach, as measured or estimated at the Paria and Little Colorado River stations, other major tributaries like Kanab and Havasu creeks, and “lesser” tributaries. -- MASS BALANCE PROJECT

- #2 2006 SPG rank - CMIN 8.1.2 – What are the monthly sand and silt/clay - export volumes and grain-size characteristics, by reach, as measured at Lees Ferry, Lower Marble Canyon, Grand Canyon, and Diamond Creek Stations? -- MASS BALANCE PROJECT

- #3 2006 SPG rank - CMIN 8.1.1 – Determine and track the biennial fine-sediment volume and grain-size changes in the main channel below 5,000 cfs stage, by reach. -- SED TREND PROJECT TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

- #4 2006 SPG rank - CMIN 8.4.1 – Track, as appropriate, the biennial or annual sandbar area, volume and grain-size changes within eddies between 5,000 and 25,000 cfs stage, by reach. -- SED TREND PROJECT TASK 3: *FINE-SEDIMENT BANK ACCOUNT* ; SED TREND PROJECT TASK 1: *NAU SANDBAR TIME SERIES*; SED TREND PROJECT TASK 2: *CRE-WIDE REMOTE-SENSING DATA*; BHBF SCIENCE PLAN PROJECT 1C

- #5 2006 SPG rank - CMIN 8.5.1 –Track, as appropriate, the biennial sandbar area, volume and grain-size changes above 25,000 cfs stage, by reach. -- SED TREND PROJECT TASK 1: *NAU SANDBAR TIME SERIES*; SED TREND PROJECT TASK 2: *CRE-WIDE REMOTE-SENSING DATA*; BHBF SCIENCE PLAN PROJECT 1C

- #1 2006 SPG rank for GOAL 9 - CMIN 9.3.1 – Determine and track the size frequency, and distribution of camping beaches by reach and stage level in Glen and Grand Canyons. -- SED TREND PROJECT TASK 1: *NAU SANDBAR TIME SERIES*; SED TREND PROJECT TASK 2: *CRE-WIDE REMOTE-SENSING DATA*

- CMIN 8.2.1 – Track, as appropriate, the biennial or annual sandbar area, volume and grain-size changes outside of eddies between 5,000 and 25,000 cfs stage, by reach. -- SED TREND PROJECT TASK 3: *FINE-SEDIMENT BANK ACCOUNT* ; SED TREND PROJECT TASK 2: *CRE-WIDE REMOTE-SENSING DATA*

- CMIN 8.3.1 – Track, as appropriate, the biennial or annual sandbar area, volume and grain-size changes within eddies below 5,000 cfs stage, by reach. -- SED TREND PROJECT TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

- CMIN 8.6.1 – Track, as appropriate, changes in coarse sediment (> 2 mm) abundance and distribution. -- SED TREND PROJECT TASK 3: *FINE-SEDIMENT BANK ACCOUNT* ; SED TREND PROJECT TASK 2: *CRE-WIDE REMOTE-SENSING DATA*

Other GCDAMP goals addressed by the MASS BALANCE PROJECT

- Goal 1 – Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels. The mass balance project supports this goal by providing information on flows and turbidity that aids in food base studies, such as the assessment of primary productivity and allochthonous inputs.

- Goal 2 – Maintain or attain a viable population of existing native fish, remove jeopardy for humpback chub and razorback sucker, and prevent adverse modification to their critical habitats. The mass balance project supports this goal by providing sediment concentration data that is used to adjust for catch efficiency in population models, flow and stage data that is important to understanding the effects of nearshore habitat disruption caused by fluctuating flows, and information on sandbars which create backwater habitats that are thought to be important for native fish.

- Goal 6 – Protect or improve the biotic riparian and spring communities within the CRE, including threatened and endangered species and their critical habitat. The mass balance project tracks stage, flow, and the transport and fate of fine sediment which provides the substrate for riparian vegetation and marsh communities.

- Goal 9 – Maintain or improve the quality of recreational experiences for users of the CRE within the framework of AMP ecosystem goals. The mass balance project provides information to understand flow dynamics and the size and abundance of sandbars, which are resources that affect the recreational experiences of Colorado River users.

- Goal 11 – Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations. The mass balance project collects sediment-transport information relevant for sandbars that provide a source of sediment, through aeolian transport, to high elevation sand deposits that contain archaeological resources.

Other GCDAMP goals addressed by the SED TREND PROJECT

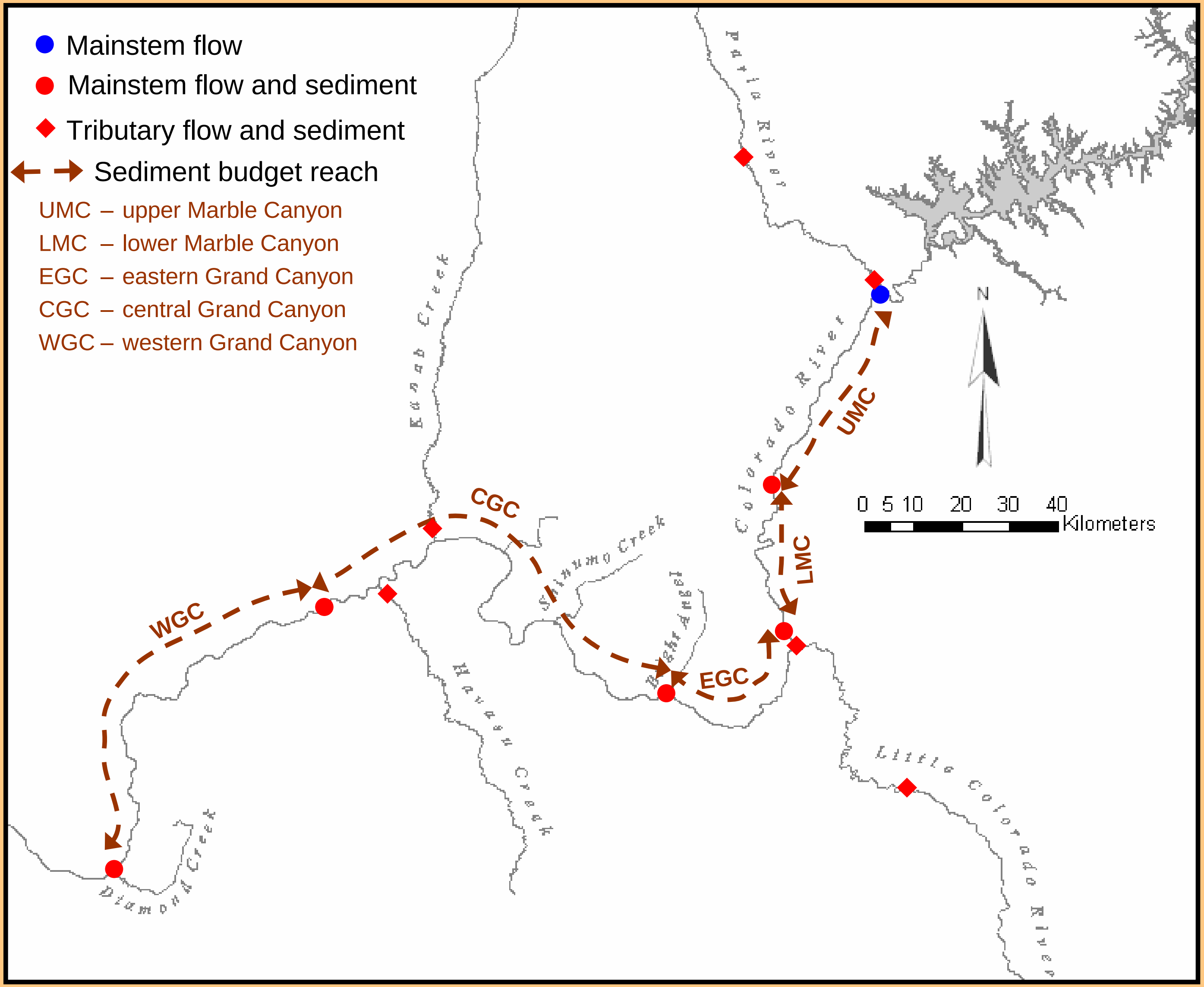
- Goal 9 – Maintain or improve the quality of recreational experiences for users of the CRE within the framework of AMP ecosystem goals. The SED TREND project provides information on the size and abundance of sandbars, which are resources that affect the recreational experiences of Colorado River users.

- Goal 11 – Preserve, protect, manage, and treat cultural resources for the inspiration and benefit of past, present, and future generations. The SED TREND project collects information on the sandbars that provide a source of sediment, through aeolian transport, to a number of high-elevation sand deposits that contain archaeological resources. Through analysis of the canyon-wide remote-sensing data SED TREND project provides information on changes in the high-elevation sand deposits that contain archaeological resources.

- Goal 1 – Protect or improve the aquatic food base so that it will support viable populations of desired species at higher trophic levels. The SED TREND project supports this goal by providing information on coarse sediment inputs which provide the substrate for parts of the aquatic food base.

- Goal 2 – Maintain or attain a viable population of existing native fish, remove jeopardy for humpback chub and razorback sucker, and prevent adverse modification to their critical habitats. The SED TREND project supports this goal by providing information on sandbars which create backwater habitats that are thought to be important for native fish.

- Goal 6 – Protect or improve the biotic riparian and spring communities within the CRE, including threatened and endangered species and their critical habitat. The SED TREND project monitors the status of the fine-sediment deposits which provides the substrate for riparian vegetation and marsh communities.


Mainstem flow
Mainstem flow and sediment
Tributary flow and sediment
Sediment budget reach
UMC – upper Marble Canyon
LMC – lower Marble Canyon
EGC – eastern Grand Canyon
CGC – central Grand Canyon
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Paria River
Colorado River
Kanab Creek
Shinumo Creek
Bright Angel
Havasu Creek
Diamond Creek
Little Colorado River
UMC
LMC
EGC
CGC
WGC
N
0 5 10 20 30 40
Kilometers

Science Advisors' Review (June 2007)

- "It is our opinion that all four of the major monitoring components are needed to document and understand trends in sediment transport and storage within the CRE and their relationships to other resources."

- "Adjustments in the implementation of the four major monitoring components in response to the occurrence of BHBFs form an important component of the proposed protocols for core monitoring."

Key sediment-resource strategic science question

"Is there a 'Flow-Only' operation (i.e. a strategy for dam releases, including managing tributary inputs with BHBFs, without sediment augmentation) that will rebuild and maintain sandbar habitats over decadal time scales?"

Corollary

If BHBFs are to be a successful tool for the rebuilding and maintenance of sandbars in the CRE, then the volume of fine sediment in the long-term fine-sediment "bank account" must not decrease over longer timescales as a result of the occurrence of the BHBFs.

Sediment budgeting

- Over shorter timescales (up to several years) --- mass balance project (uncertainties increase over time, however)

- Over multiple years to longer than decades ---- direct geomorphic monitoring of changes in the fine-sediment “bank account”

SED TREND PROJECT TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

Sand budget in at least upper third of CRE was negative prior to onset of low-release years in 2000 despite large tributary sand inputs (but a period with no BHBFs)

- Do future dam releases (including BHBFs) continue to mine the sediment “bank account” (stored largely at elevations less than the stage associated with a discharge of 8,000 cfs)?

- If the amount of fine sediment in this “bank account” continues to decrease, then dam operations will ultimately not be able to sustain the fine-sediment resources at higher elevations……HIGH-ELEVATION MONITORING ALONE WILL NOT ADDRESS THIS ISSUE!!! ....because it does not necessarily measure signal

Challenges to sediment-flux monitoring in mass balance project

- Requires knowing inputs from major and lesser tributaries, with uncertainties -- done this for Paria, LCR, other Glen and Marble Canyon tributaries

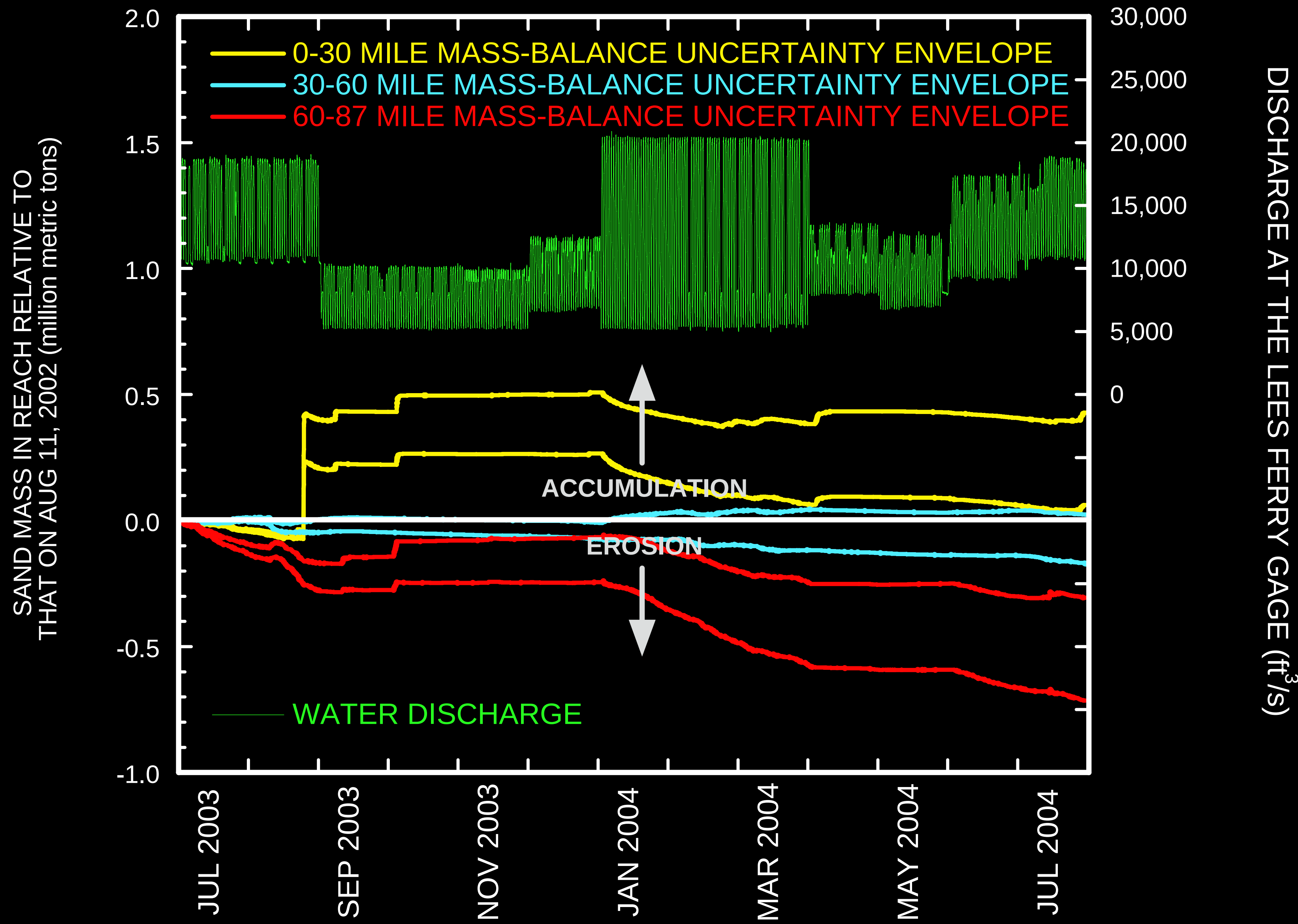
- Sand transport in Colorado River changes independently of changes in the discharge of water (over timescales less than hours) -- solved this through addition of acoustic and laser-diffraction technologies to conventional methods

- Uncertainties accumulate over time -- still addressing magnitudes of uncertainties, SED TREND TASK 3 can help place further constraints on these

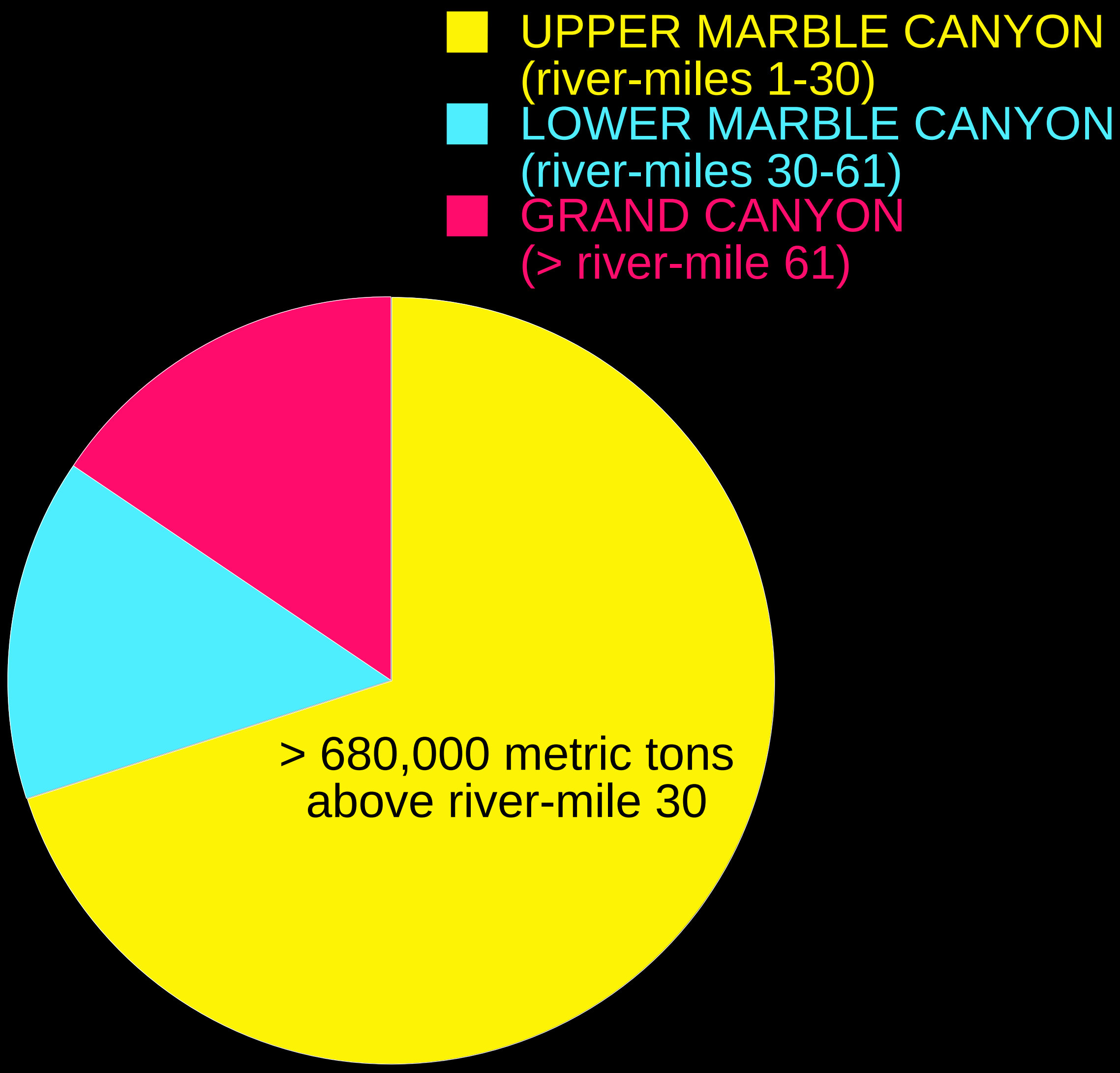
1998, 1999, 2006 PEP Reviews

“The panel believes that it is critical to have the more robust mass balance because our understanding of the system is insufficient at this point to make recommendations about controlled floods” (Wohl and others, SED-PEP III, 2006)

SEDIMENT-YEAR 2004 MASS-BALANCE SAND BUDGET



Where was the sand from the October 2006 Paria River floods as of March 1, 2007?



Mass balance project linkages

- Provides the sediment data required for triggering future BHBF tests and management actions

- Provides data that is essential to the development and testing of numerical predictive models of discharge, stage, sediment transport, sandbar morphology, and other water-quality parameters such as temperature

- Supports new research focused on the food web of the river ecosystem by providing continuous data on surface flow in the main channel and major tributaries, as well as suspended-sediment concentrations and grain size for suspended particles in transport

- Supports science activities in the fisheries program by providing flow and quality-of-water data that may be used by the fisheries biologist in evaluating their fish catch data, as well as growth, movement and habitat use information

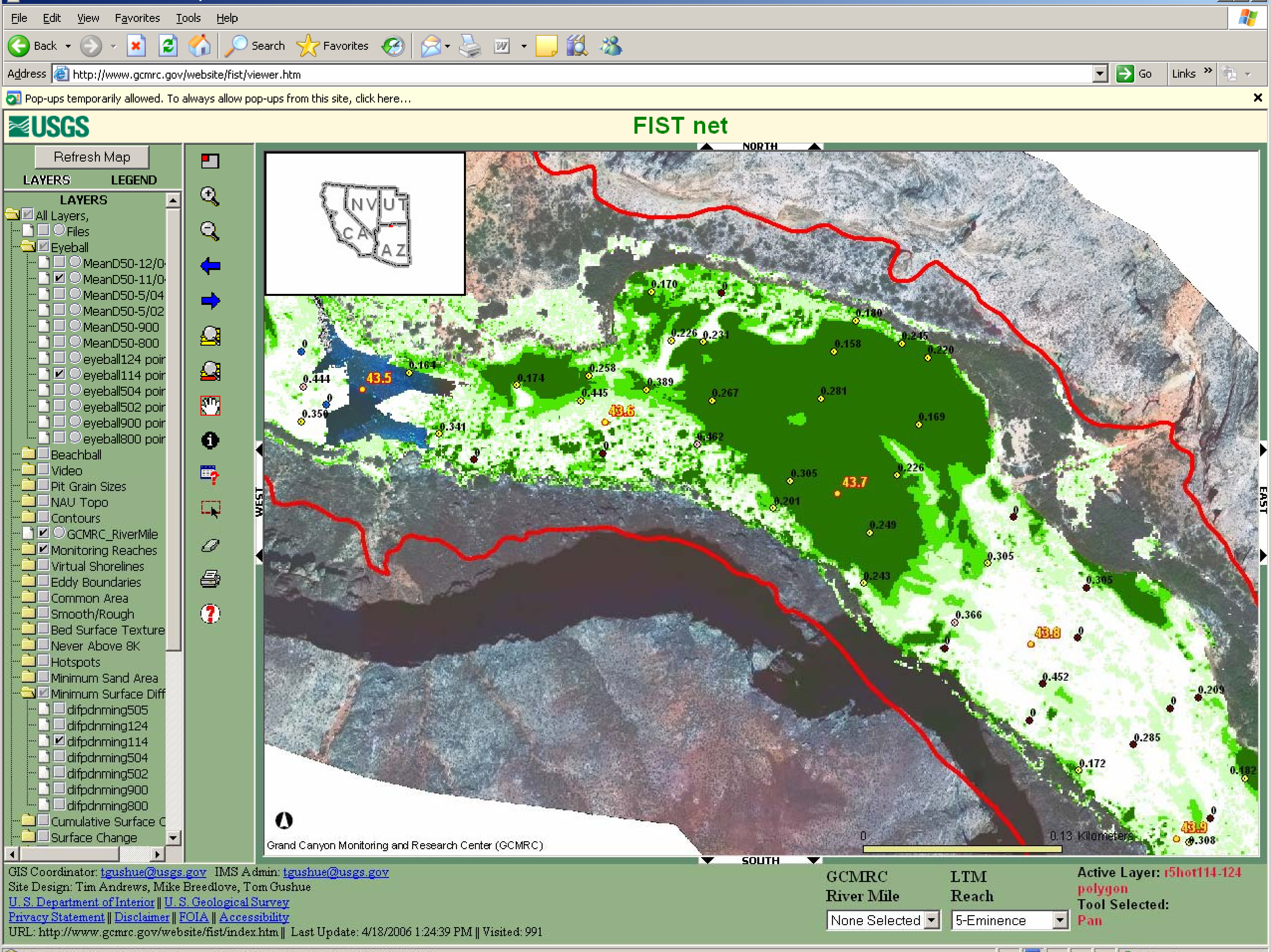
Mass balance project products/outcomes

- Streamflow (discharge and stage), and suspended-sediment concentration and grain-size time series at multiple mainstem sites and at the mouths of major tributaries
- Sediment budgets for five reaches of the CRE: upper Marble Canyon, lower Marble Canyon, eastern Grand Canyon, central Grand Canyon, and western Grand Canyon
- Annual peer-reviewed USGS report documenting results of the monitoring project
- Contribution to other research-related peer-reviewed publications (such as models)
- Biannual presentations at GCDAMP meetings

Challenges to geomorphic monitoring (i.e., key FIST results)

- More than 90% of the fine sediment in the CRE is stored at elevations lower than the stage associated with a discharge of 8,000 cfs --- this is referred to as the fine-sediment "bank account"

- Extrapolation of FIST reach-based data to longer river segments is impossible. Thus, monitoring of the status of this bank account is best done over long river segments that equate to mass-balance reaches and are therefore constrained by mass-balance sediment budgeting.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Pit Grain Sizes
NAU Topo
Contours
GCMRC_RiverMile
Monitoring Reaches
Virtual Shorelines
Eddy Boundaries
Common Area
Smooth/Rough
Bed Surface Texture
Never Above 8K
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Minimum Sand Area
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Grand Canyon Monitoring and Research Center (GCMRC)
GIS Coordinator: tgushue@usgs.gov IMS Admin: tgushue@usgs.gov
Site Design: Tim Andrews, Mike Breedlove, Tom Gushue
U.S. Department of Interior || U.S. Geological Survey
Privacy Statement || Disclaimer || FOIA || Accessibility
URL: http://www.gcmrc.gov/website/fist/index.htm || Last Update: 4/18/2006 1:24:39 PM || Visited: 991
GCMRC River Mile
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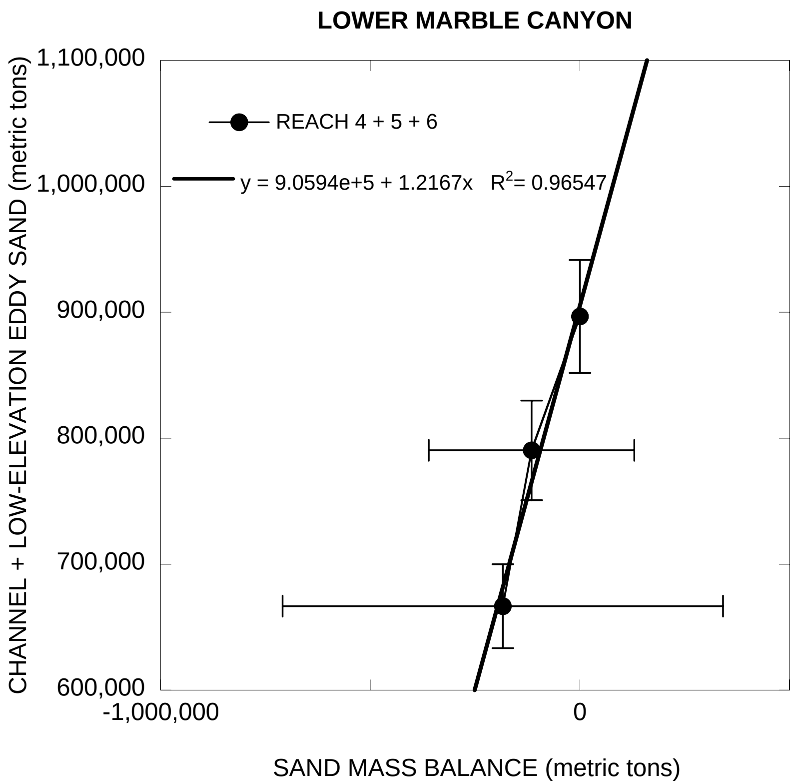
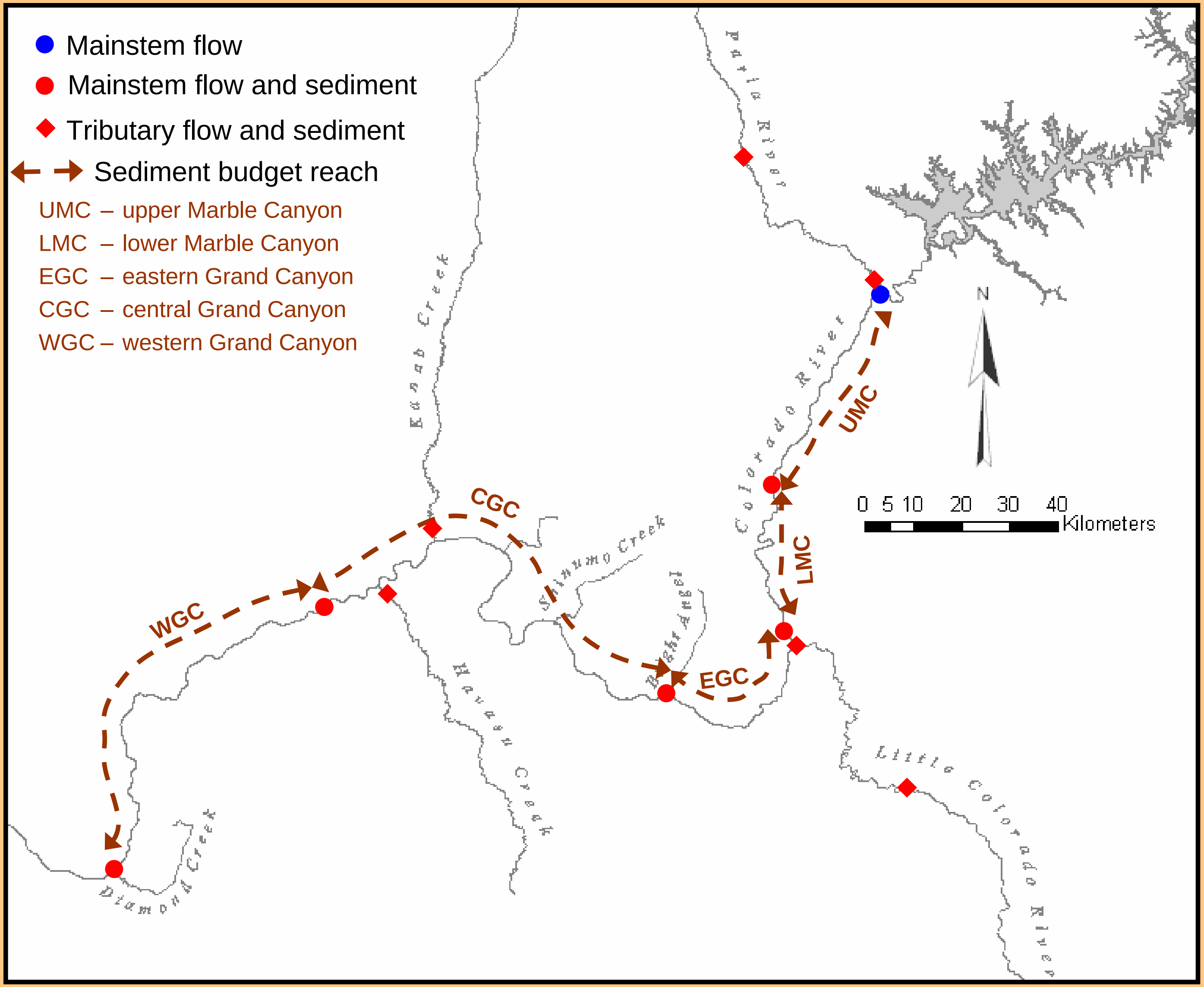
Sediment budgets cannot be extrapolated from FIST-reach data



- Approximately 120% of the change in sand volume in lower Marble Canyon occurred in only the 30% of this river segment surveyed by FIST
- Sand budget in other 70% of lower Marble Canyon must have had OPPOSITE SIGN and LARGER MAGNITUDE of change



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Little Colorado River
UMC
LMC
EGC
CGC
WGC
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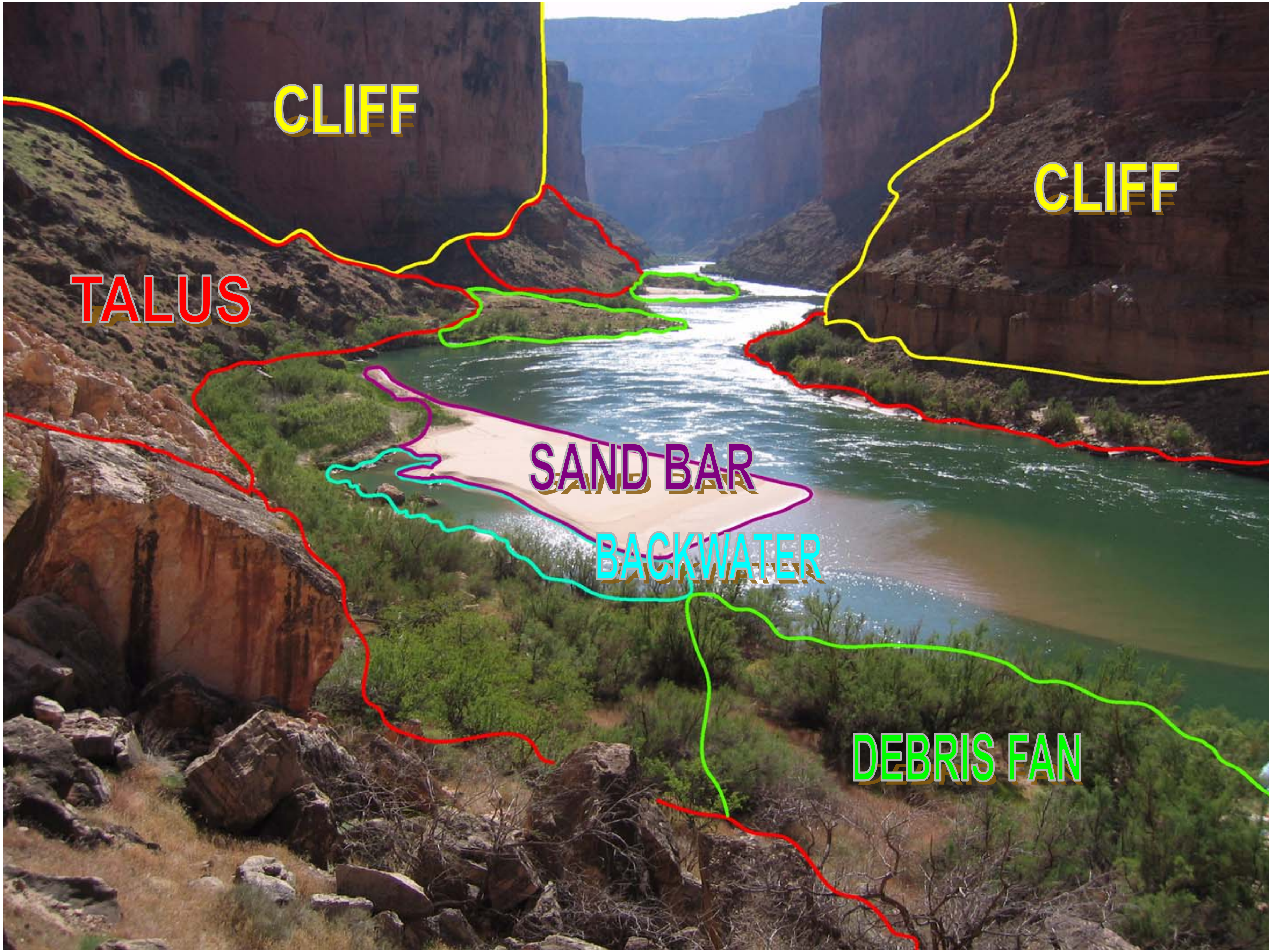
0 5 10 20 30 40
Kilometers

- The main channel below 8,000 cfs is the most important fine-sediment storage bin downstream from tributaries, eddies below 8,000 cfs are the most important fine-sediment storage bin farther downstream. Both channel and eddy environments must therefore be monitored.

- Data collection on the geometries of backwaters (i.e., eddy return-current channels) requires topographic data collection below 8,000 cfs.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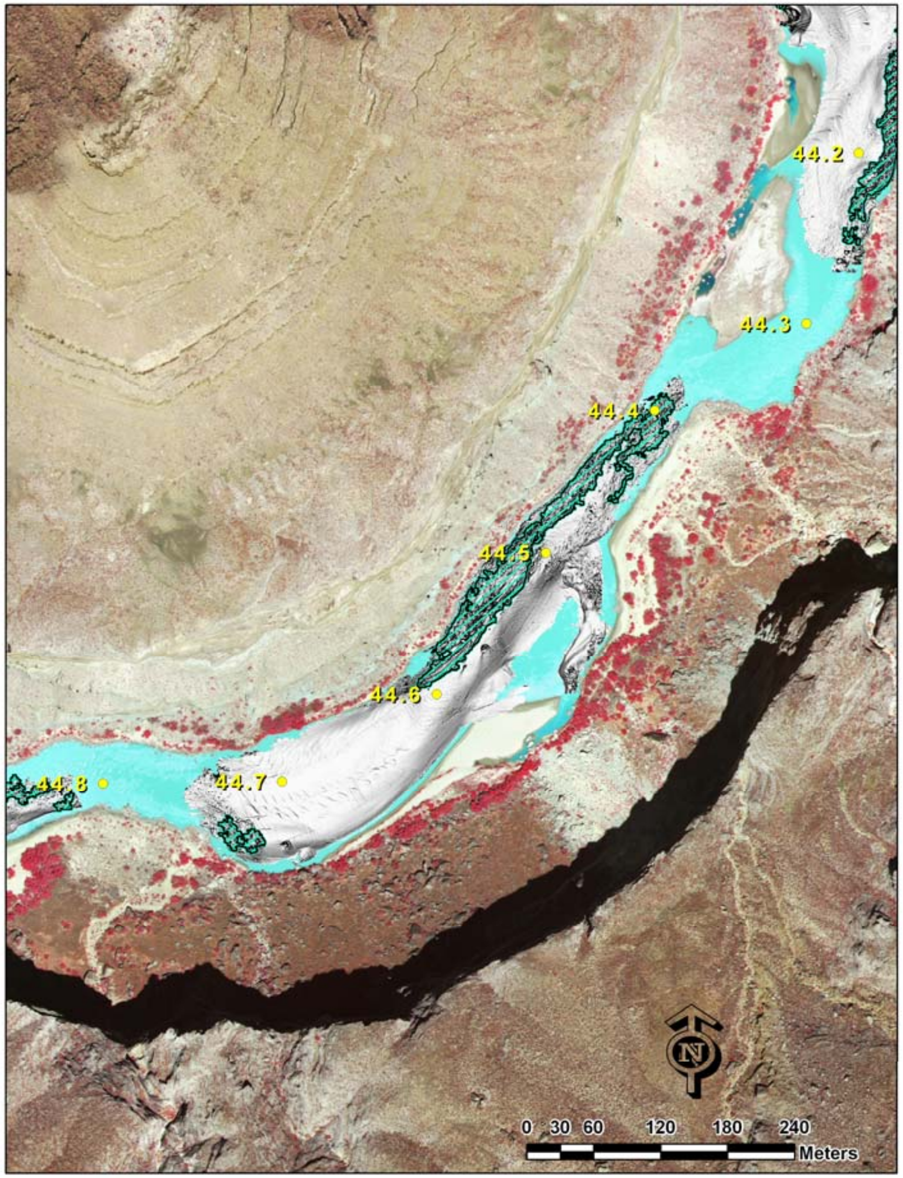
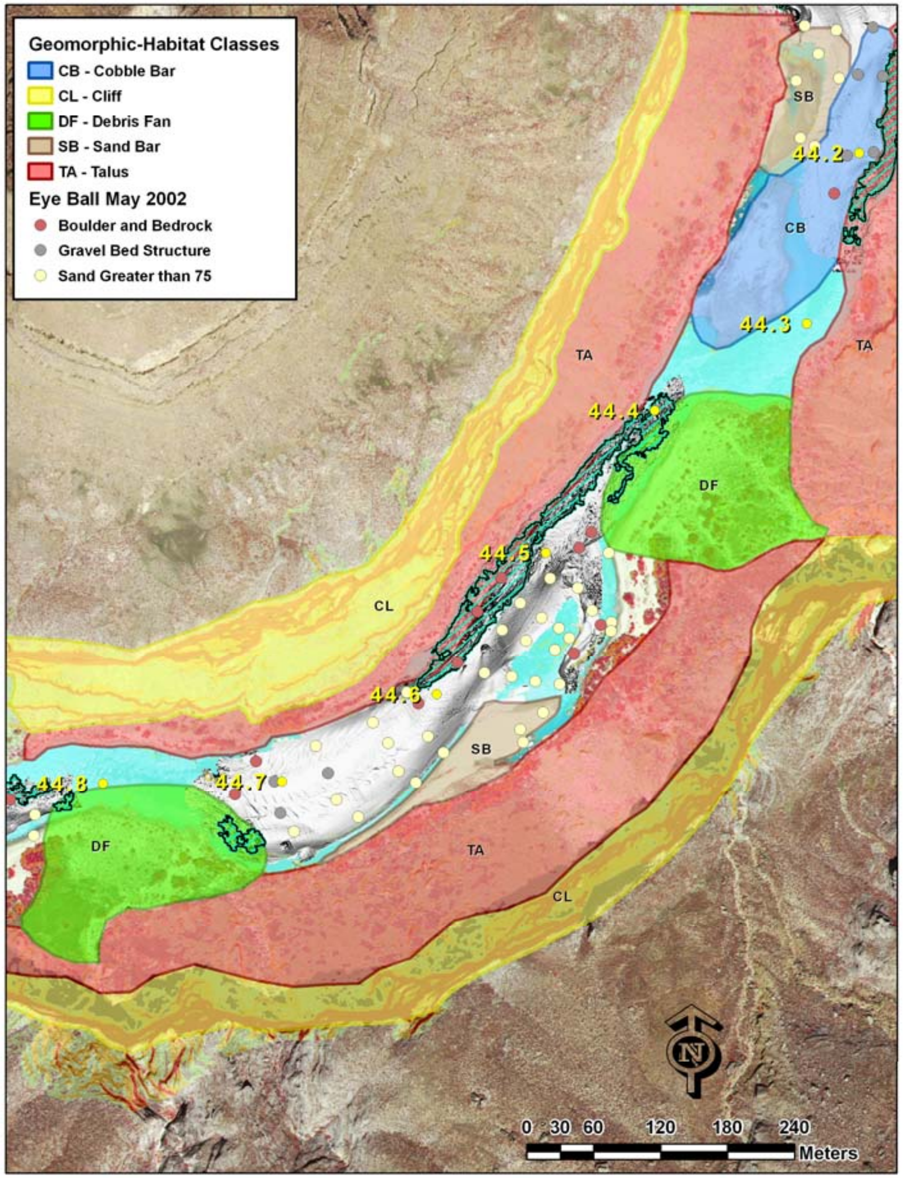
CLIFF
TALUS
SAND BAR
BACKWATER
DEBRIS FAN

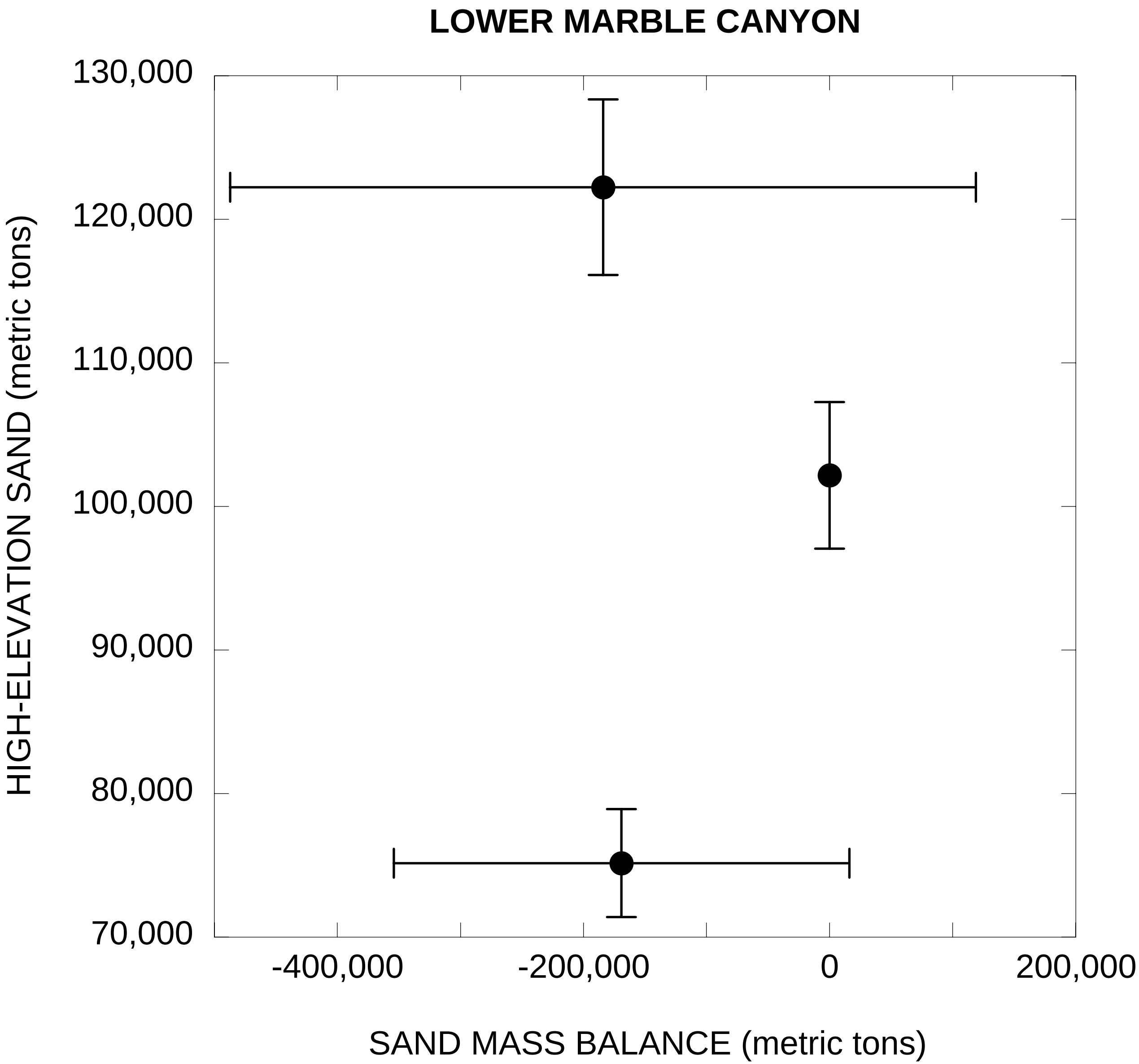
Digitizing Geomorphic Classes in GIS: Below 8,000 CFS





- No relation between the sediment budget and the amount of sand above 8,000 cfs currently exists because less than 10% of the fine-sediment in the CRE occurs at these higher elevations.

WARNING: Only monitoring high-elevation sand will not provide information on the overall sediment budget and will not allow prediction of the long-term fate of sediment-related resources. YOU CAN'T PREDICT THE FUTURE BASED ON NOISE


LOWER MARBLE CANYON
130,000
120,000
110,000
100,000
90,000
80,000
70,000
HIGH-ELEVATION SAND (metric tons)
-400,000
-200,000
0
200,000
SAND MASS BALANCE (metric tons)

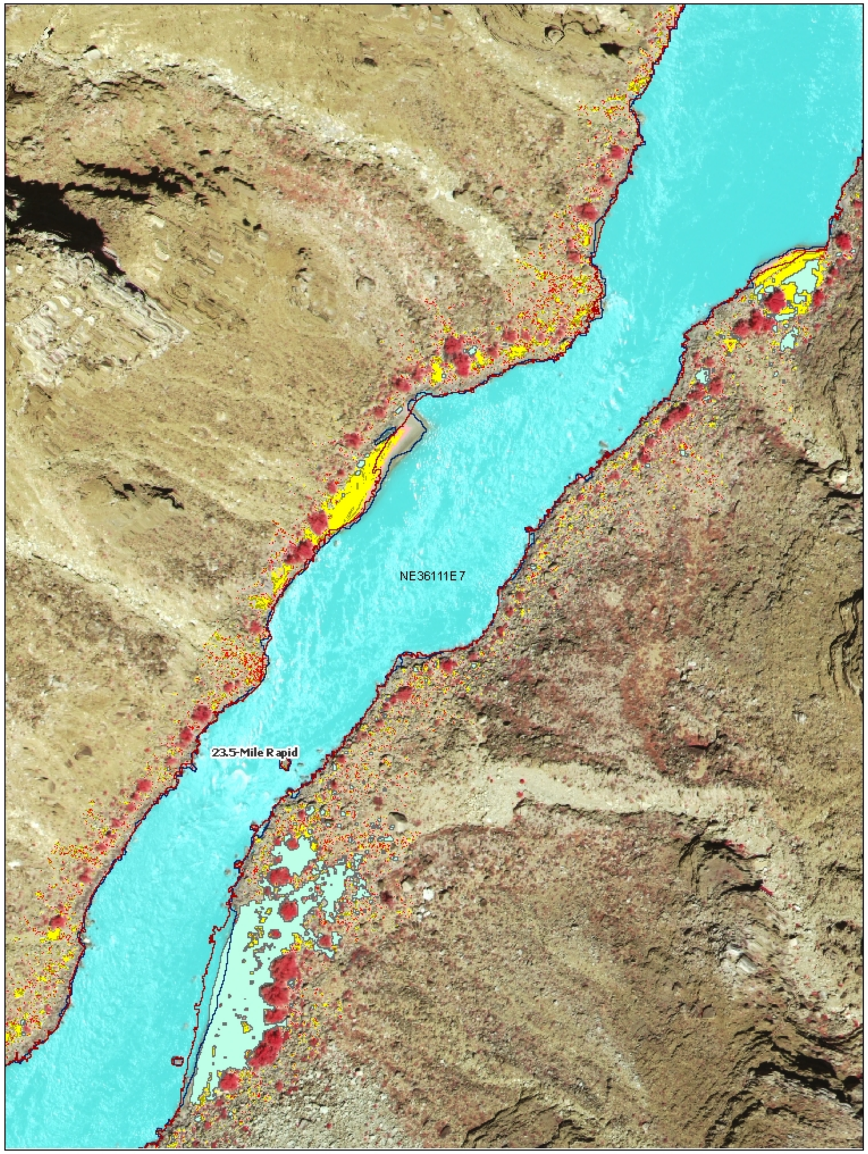
- The sandbars monitored as part of the NAU time series are sufficient to detect trends in the area of sand above 8,000 cfs (Schmidt and others, 2004). This is because high-elevation fine sediment is least sensitive to dam operations. These data only provide information on the effectiveness of past dam operations in maintaining fine sediment at high elevations.

- There is not a unique relation between fine-sediment volume and area (owing to changes in deposit convexity/concavity in cross-section). This observation requires that both area and volume of fine sediment be monitored.

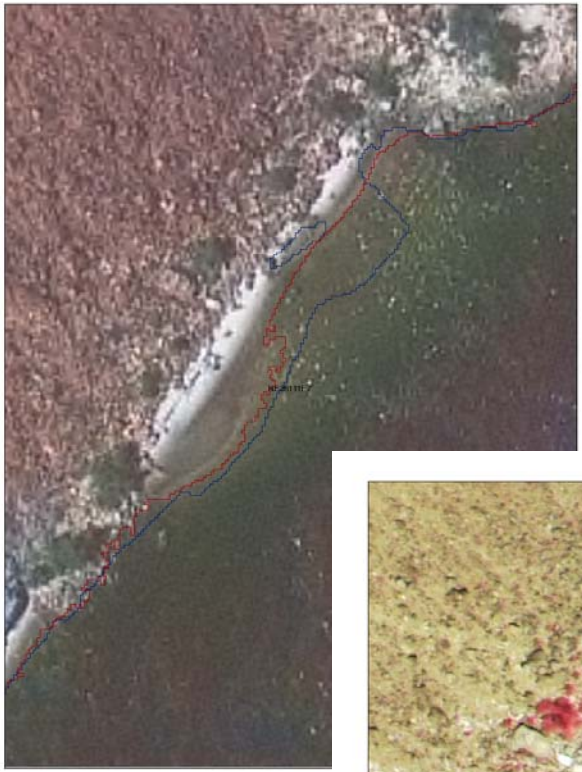
- Although remote-sensing data are least needed for monitoring of only high-elevation sand, they do provide CRE-wide information and are required to address multiple resource areas: i.e., interfaces between goals 8, 9, 11, 1, 2, and 6

Surface Change

Dry, Fine Sediment: 5/02 & 5/05



Blowup May, 2002



Blowup
May, 2005

SED TREND project linkages

- Provides the data showing whether dam operations continue to mine the long-term fine sediment "bank account" stored at elevations below 8,000 cfs

  TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

- Provides data (i.e, the maps showing the topography and distribution of sediment types over ~30-mile reaches of the river) that is essential to the development and testing of numerical predictive models of discharge, stage, sediment transport, and sandbar morphology.

  TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

- Supports science activities in the fisheries program by providing the data (as part of the long ~30-mile data collection effort described under Task 3) to characterize the locations and geometries of backwaters thought to be important habitat for native fish.

  TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

- Provides the data used to evaluate the effectiveness of dam operations (including BHBFs) on rebuilding and maintaining sandbars in the CRE.

  TASK 1: *NAU SANDBAR TIME SERIES* ; TASK 2: *CRE-WIDE REMOTE-SENSING DATA*; BHBF SCIENCE PLAN PROJECT 1C

- Supports the campsite inventories conducted under Goal 9 by characterizing the status and trends of a sample of the sandbars used as campsites.

  TASK 1: *NAU SANDBAR TIME SERIES* ; TASK 2: *CRE-WIDE REMOTE-SENSING DATA*; BHBF SCIENCE PLAN PROJECT 1C

- Supports Goal 11 by characterizing the status of fine-sediment at higher elevations in and around cultural sites, and by characterizing the amount of open dry sand available to be transported by the wind into some of these cultural sites.

  TASK 2: *CRE-WIDE REMOTE-SENSING DATA*; BHBF SCIENCE PLAN PROJECT 1C

- Supports new research focused on the food web of the CRE by providing data on the input of new gravel from tributaries, and the accumulation and redistribution of gravel used as a substrate by the aquatic food web.

  TASK 2: *CRE-WIDE REMOTE-SENSING DATA*; TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

- Provides information on the distribution of the fine-sediment deposits that form the substrate for the riparian ecology.

  TASK 2: *CRE-WIDE REMOTE-SENSING DATA*; TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

SED TREND project products/outcomes

- Topographic maps of the CRE in five long reaches: upper Marble Canyon, lower Marble Canyon, eastern Grand Canyon, central Grand Canyon, and western Grand Canyon. These maps will be produced 1-2 times per decade for each reach on average. These maps will characterize the geometries of the backwaters in each ~30-mile reach.
- Decadal-timescale sediment budgets for these five reaches of the CRE. These data will provide managers information on the long-term status of the fine-sediment "bank account."
- These sediment budgets will be compared to the sediment budgets computed for these reaches under the complimentary mass balance project. This comparison will help evaluate the uncertainties associated with the SED TREND monitoring and mass-balance approaches.
- Where possible, data collected in upper Marble Canyon in FY 2008 will be compared with earlier multibeam-sonar data collected in 2000, 2001 and as part of the 2002–04 FIST project to evaluate volume changes in the fine-sediment bank account (2000 vs. 2008).
- Annual updates of the NAU sandbar time series showing trends in the area and volume of the high-elevation parts of sandbars
- Maps and analyses of the systemwide area and volume of fine sediment at high elevations as determined by digital aerial photography and LiDAR
- Annual peer-reviewed USGS data reports documenting results of the monitoring project
- Contribution to other research-related peer-reviewed publications (such as models)
- Biannual presentations at GCDAMP meetings

Annual costs

- MASS BALANCE PROJECT

  $700,000 to $1,045,000 depending on number of mainstem and tributary gaging stations; FY 2008 cost for stage, discharge, and sediment components of this project is $700,000 (an additional $183,000 in FY 2008 is for other water-quality parameters, i.e., temperature, conductivity)

- SED TREND TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

  $200,000 but deferred during years with BHBF tests resulting in SAVINGS that could be rolled into experimental fund; FY 2008 cost is $200,000

- SED TREND TASK 1: *NAU SANDBAR TIME SERIES*

  $95,000 (see FY 2008 draft work plan description for Project REC 9.R1.07/PHYS 8.M2/07)

- SED TREND TASK 2: *CRE-WIDE REMOTE-SENSING DATA*

  Scope of analyses and cost are yet to be fully determined but deferred during years with BHBF tests; refer to FY 2008 and 2009 DASA project descriptions for Goal #12, Remote Sensing and Analysis.

Risks to knowledge and resource if not implemented

- MASS-BALANCE PROJECT

  No information on stage, flow, sediment flux in CRE; No information on < 2-year sediment budgets; No information for BHBF triggers

- SED TREND TASK 3: *FINE-SEDIMENT BANK ACCOUNT*

  No ability to predict future condition of fine-sediment resource; No information on locations and geometries (areas plus depths) of backwaters

  $200,000 is minimum required to survey sufficiently long reaches, shorter reaches are not worth surveying

- SED TREND TASK 1: *NAU SANDBAR TIME SERIES*

  No information on effectiveness of past dam operations on maintaining high-elevation fine sediment; No information on annual status of campsites

- SED TREND TASK 2: *CRE-WIDE REMOTE-SENSING DATA*

  No information on CRE-wide distribution of high-elevation fine sediment; No ability to interface with other GCDAMP goals, especially goals 1, 6, and 11