



# ESTIMATING SSC USING DOWNLOOKING ADCPS: MISSOURI RIVER EXAMPLE

MOLLY WOOD, P.E.

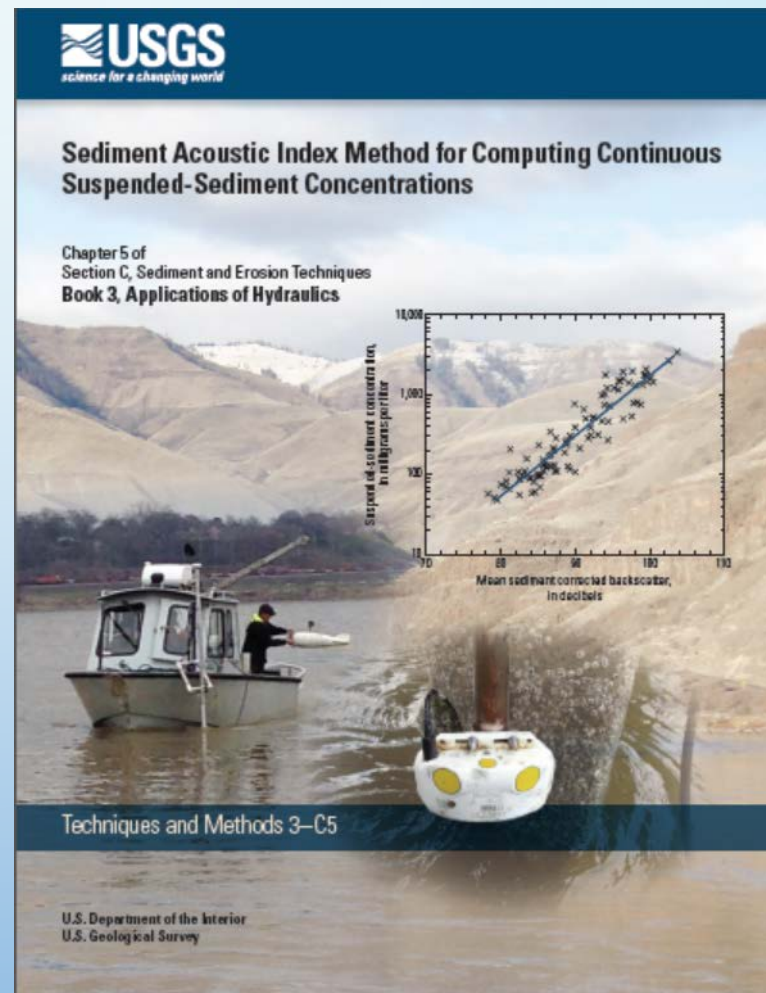
NATIONAL SEDIMENT SPECIALIST, OSW

REGIONAL WATER DATA CONFERENCE 2017



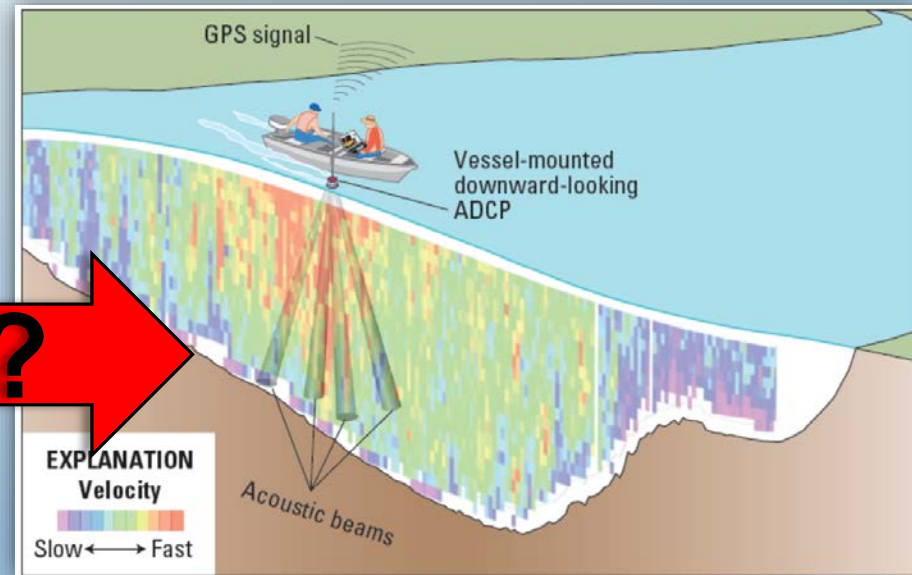
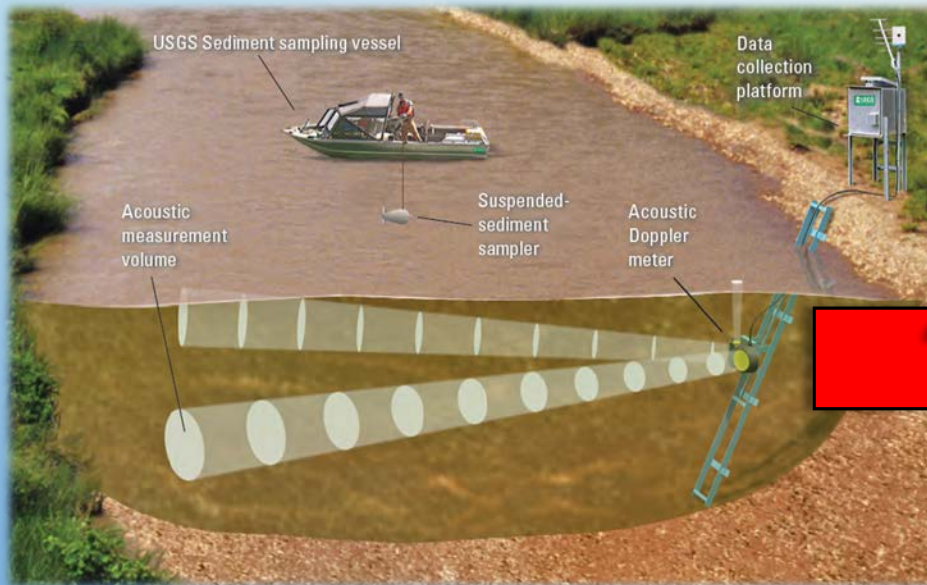
# BACKGROUND

- WE NOW HAVE THIS (TM3-C5):



# BACKGROUND

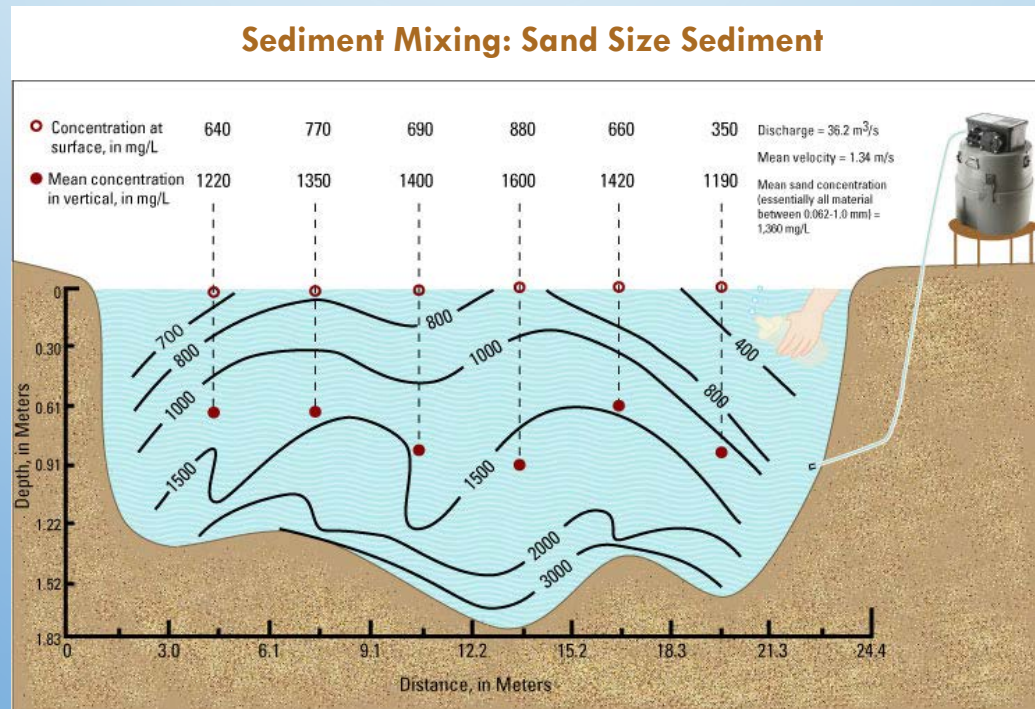
- CAN WE USE THE SAME METHOD FOR DOWNLOOKING ADCPS?





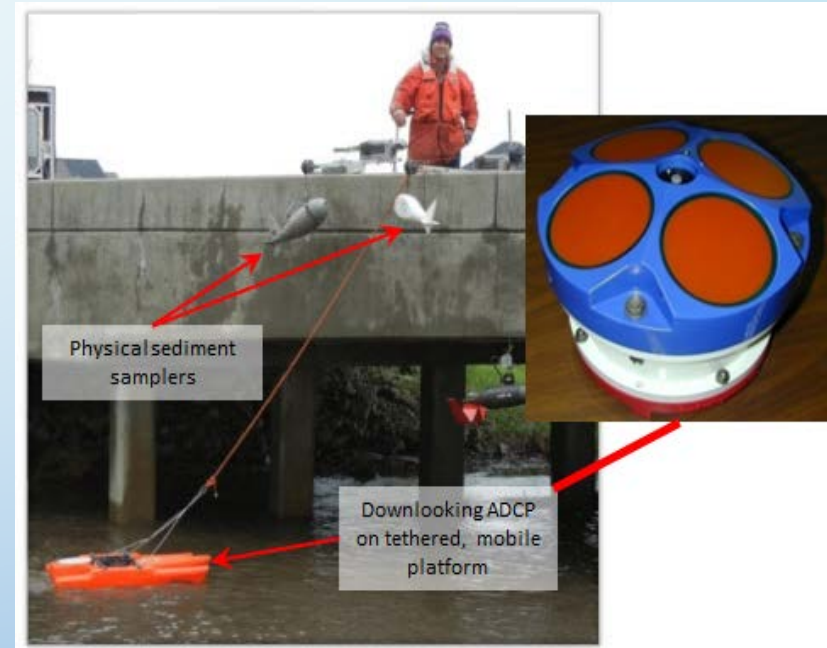
# BACKGROUND

- NOT EXACTLY! WHY?
  - A MAJOR ASSUMPTION OF THE SIDELOOKING METHOD IS SEDIMENT HOMOGENEITY WITH THE ACOUSTIC MEASUREMENT VOLUME (CONSTANT SEDIMENT ATTENUATION AT A TIME STEP)
  - THIS ASSUMPTION ALMOST NEVER VALID VERTICALLY IN SAND-BEDDED RIVERS



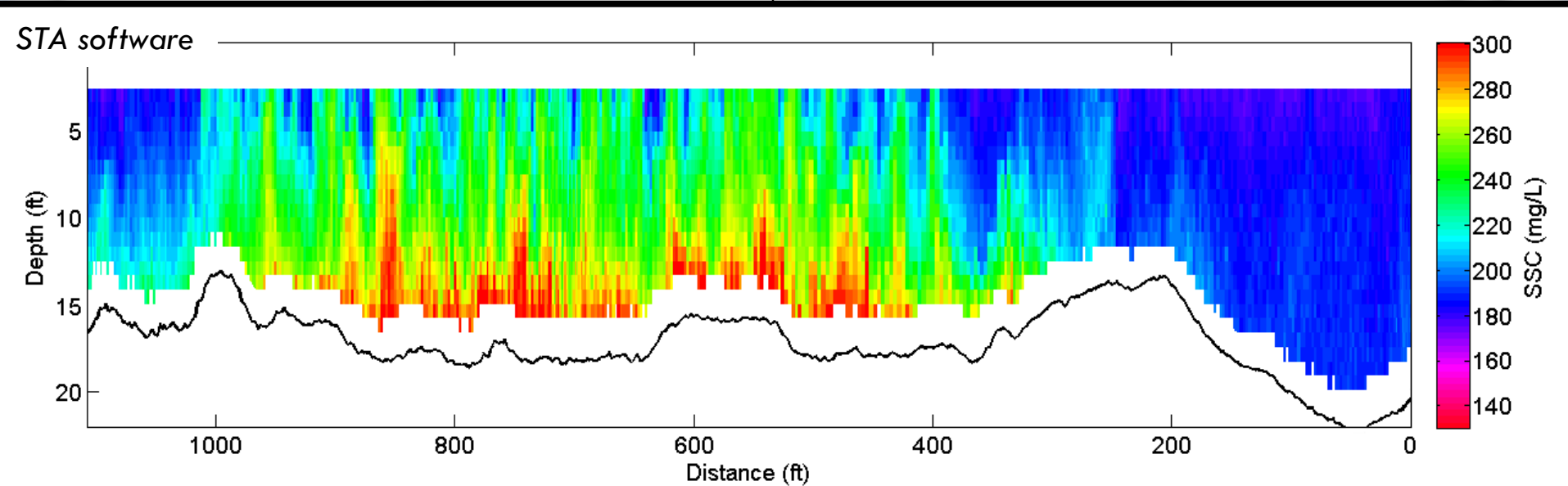
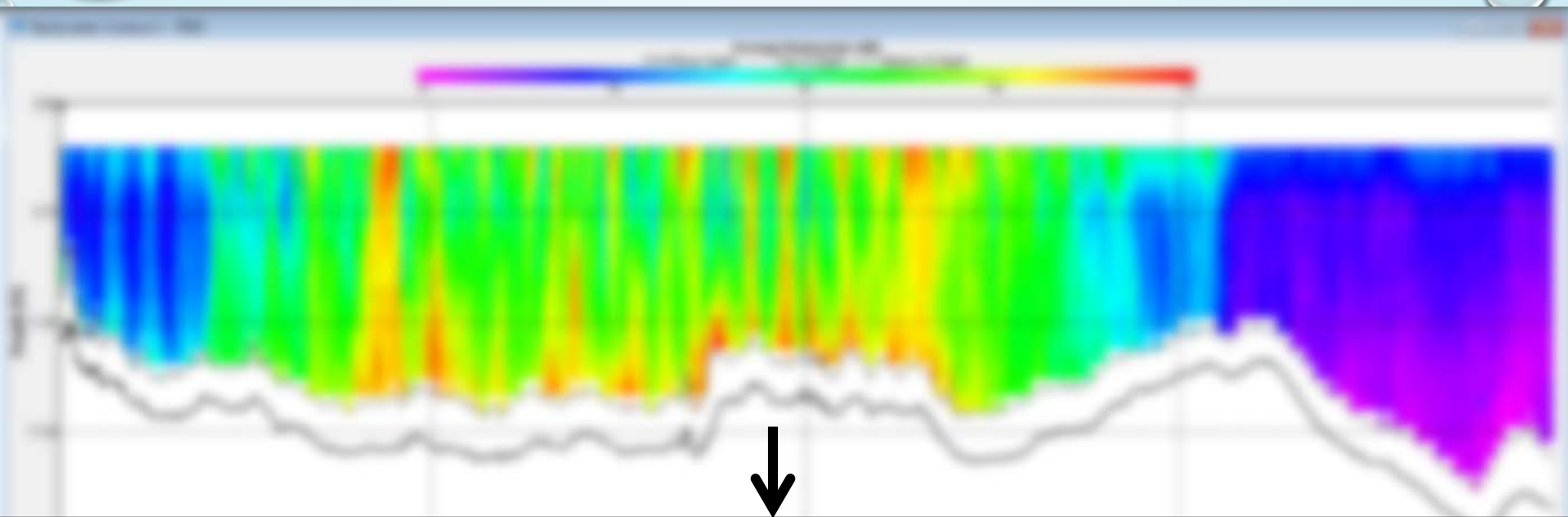
# MOTIVATION

- OTHER RESEARCHERS HAVE INVESTIGATED USE OF DOWNLOOKING ADCPS FOR SEDIMENT TO ANSWER SPECIFIC QUESTIONS....
- WE USE ADCPS FOR STREAMFLOW MEASUREMENTS AT THOUSANDS OF GAGES ACROSS U.S.....
- NEED FOR OPERATIONAL METHOD, LEVERAGING ADCP USE, THAT COULD BE USED AT MANY LOCATIONS
- COULD REVOLUTIONIZE SEDIMENT MONITORING



# MOTIVATION

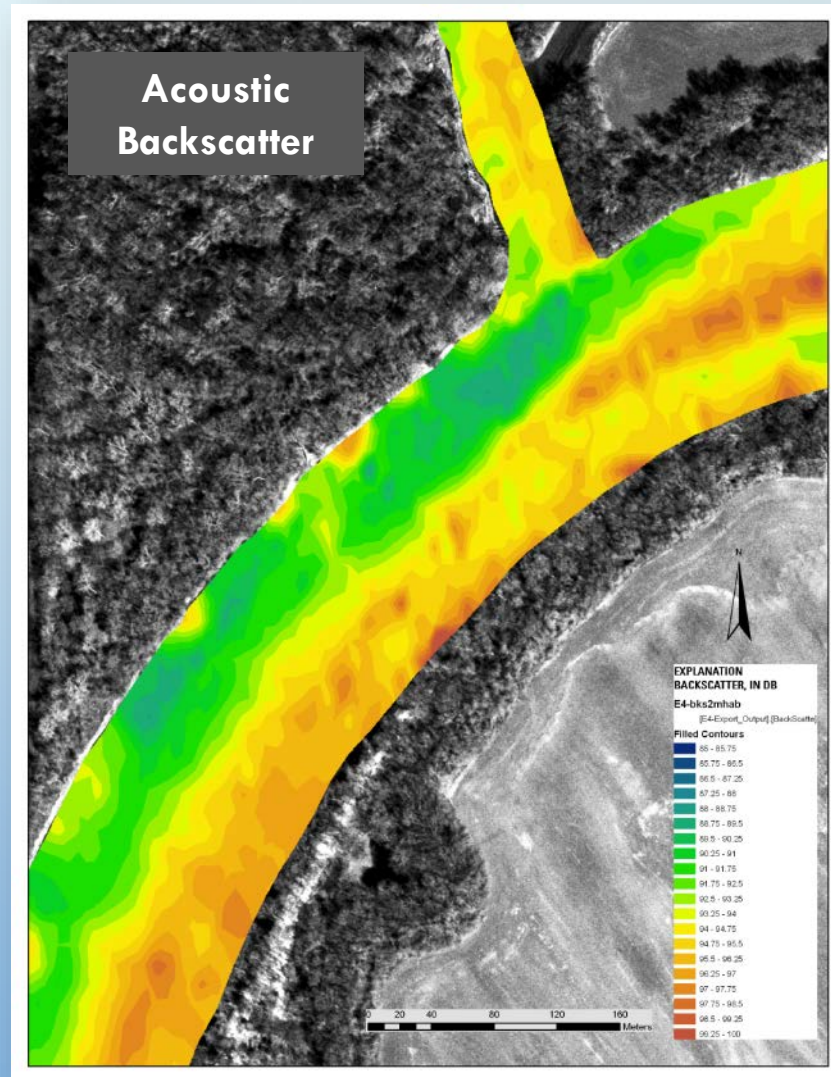
Source: Justin Boldt, USGS





# MOTIVATION

*Future:  
Reach-Scale,  
Rapid  
Sediment  
Mapping*



Source: Ryan Jackson, USGS

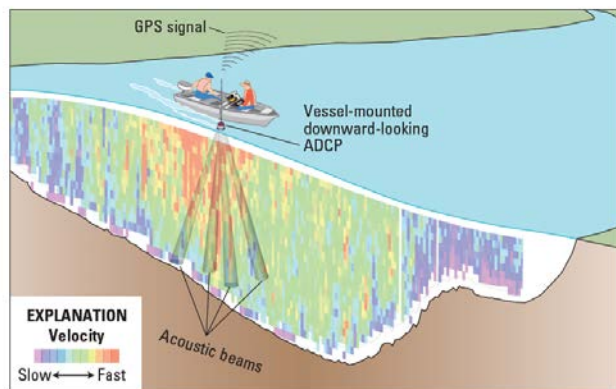


# OVERVIEW

- DATA REQUIREMENTS
- CALIBRATION METHOD (STA SOFTWARE)
- DATA DISPLAY
- EFFORTS TO DATE FOR DEVELOPING OPERATIONAL METHOD – MISSOURI RIVER FOCUS



# DATA REQUIREMENTS



## INPUTS

**Stationary  
ADCP**

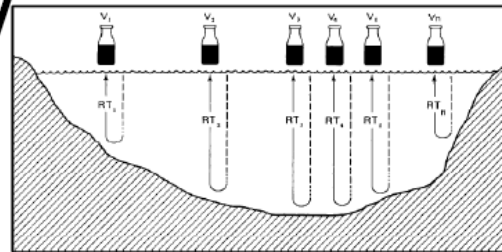
**Sediment  
point  
samples**

**ADCP cross  
section(s)**

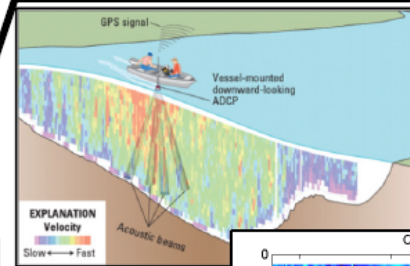
**MATLAB-  
based tool  
(called STA)**

Level 3: Validate calibration with EDI sample

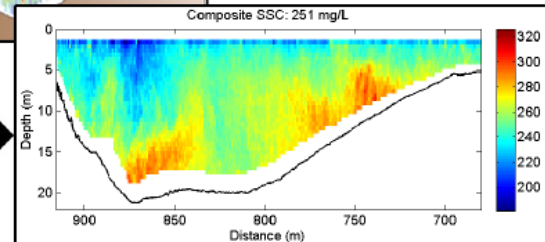
EDI sediment sample



Level 2: Apply calibration to cross section

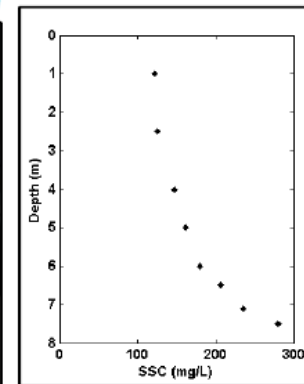
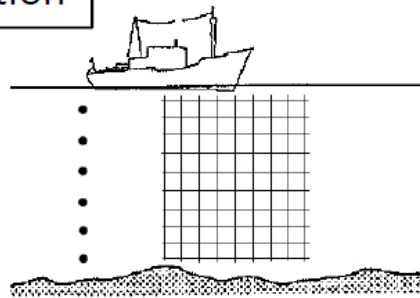


ADCP  
transect



Level 1:  
Develop a  
calibration

**Concurrent** measurements of acoustic backscatter  
(stationary profile) and suspended sediment  
concentration (point samples)



# CALIBRATION METHOD

$$SCB = K_c * RB + 20 * \log_{10}(\psi R) + 2\alpha_w R + 2\alpha_s R$$

$K_c$  = instrument  
echo intensity scale  
factor



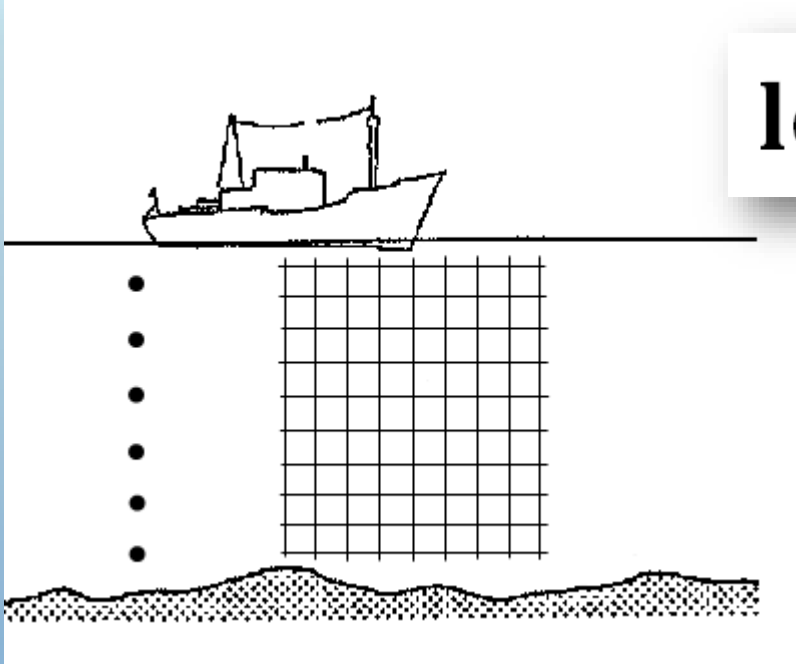
$\psi$  = near-field  
correction (Downing  
et al., 1995)

$R$  = range  
along beam

$\alpha_w$  = sound  
absorption  
coefficient (Schulkin  
and March, 1962)

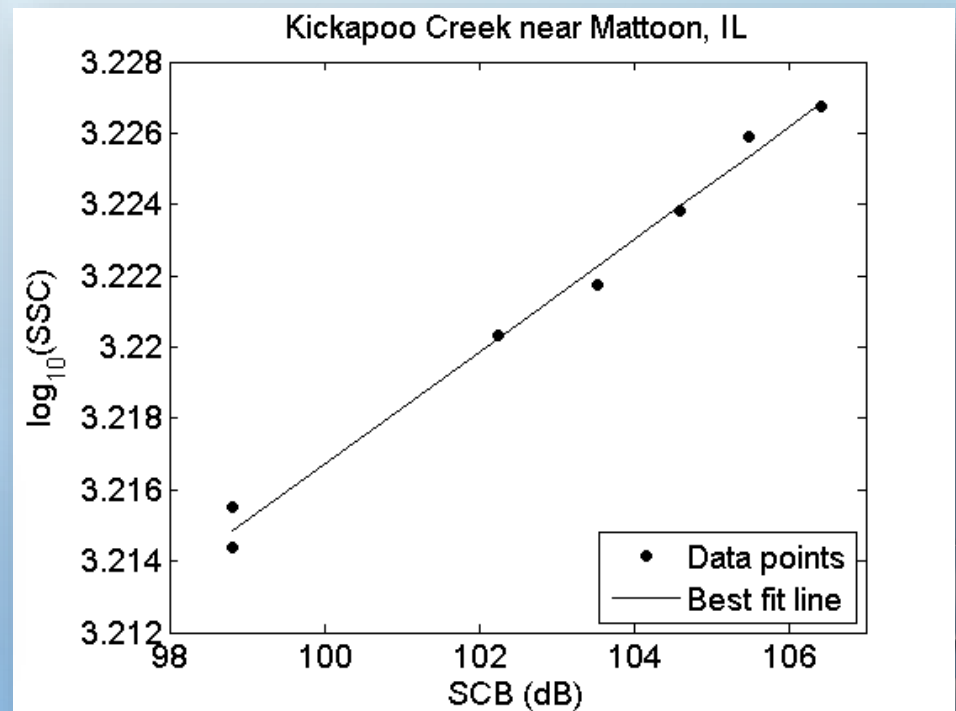
$\alpha_s$  = sediment  
attenuation  
coefficient  
(Wright et al.,  
2010 & Landers,  
2010)

# CALIBRATION METHOD



$$\log_{10} SSC = a * SCB + b$$

$$SSC = 10^{(a*SCB+b)}$$





# Stationary Time-Series Analysis (STA)

A standalone utility to Velocity Mapping Toolbox (VMT)

v. 2.0 beta

Disclaimer

## Select method - Shear velocity (cm/s)

- ☐ Log law - bottom 50%  
☐ Log law - middle 50%  
☐ Log law - top 50%  
☐ Log law - entire profile  
☐ Reynolds shear stress ( $u'w'$ )

Ensemble start

Ensemble end

☐ Force Fill

## Bed shear stress (N/m<sup>2</sup>)

tau0L:  
 tau0S:  
 tau0ka:  
 tau0ka2:  
 tau0kb:  
 tau0kb2:  
 tau0q:

## ADCP frequency

- ☐ 600 kHz  
☐ 1200 kHz

Load Stationary Data

File loaded:

## Select plots

Select All

Clear All

Close All

### Velocity

- ☐ Time-averaged velocity  
☐ Time-averaged velocity with RMS  
☐ Normalized velocity  
☐ Depth-averaged streamwise velocity  
☐ Cumulative U  
☐ Cumulative U at depths

### Backscatter

- ☐ Time-averaged backscatter  
☐ Depth-averaged backscatter  
☐ Contour plot with Q2 and Q4

☐ Velocity and backscatter time series

### Ship Track (requires GPS)

☐ Ship track

Output KML file (Google Earth)

### Turbulence

- ☐ Normalized turbulence intensity  
     ☐ with semi-theoretical curves  
☐ Turbulence intensity ratios  
     ☐ with semi-theoretical curves  
☐ Normalized turbulent kinetic energy  
     ☐ with semi-theoretical curves

### Reynolds Shear Stress

- ☐ Time-averaged Reynolds shear stress  
☐ Shear velocity from  $u'w'$

## Dashboard

No. of ens:  
 No. of bins:  
 Duration (sec):  
 Bin size (cm):  
 Avg. depth (m):  
 Mean flow direction (deg):  
 Froude No.:  
 Reynolds No.:  
 Equivalent bed roughness (m):  
 Friction coefficient 1:  
 Friction coefficient 2:

## Sediment Analysis

☒ Sediment Analysis

Select an option

- ☐ Obtain a calibration  
☐ Apply a calibration

$SSC = 10^a(a * SCB + b)$

a =

b =

Inputs

Select beam(s)

Echo intensity scale factor:

Beam 1

Beam 2

Beam 3

Beam 4

Sediment attenuation method

☐ Topping & Wright

from to

(0 = top, 100 = bottom)

☐ Urick Sheng Hay

Sediment density: g/cm<sup>3</sup>

Mean sediment dia: microns

☐ Manual Input

alphaS: dB/m

Calibrate with

- ☐ Total SSC  
☐ Sands  
☐ Fines

Load SSC Data

## Dashboard

alphaW: dB/m

alphaS: dB/m

☐ Reverse

Select plots

- ☐ MB,WCB,SCB vs R  
☐ log10(SSC) vs SCB  
☐ Calibrated SSC profile  
☐ Calibrated SSC profile with range

Plot

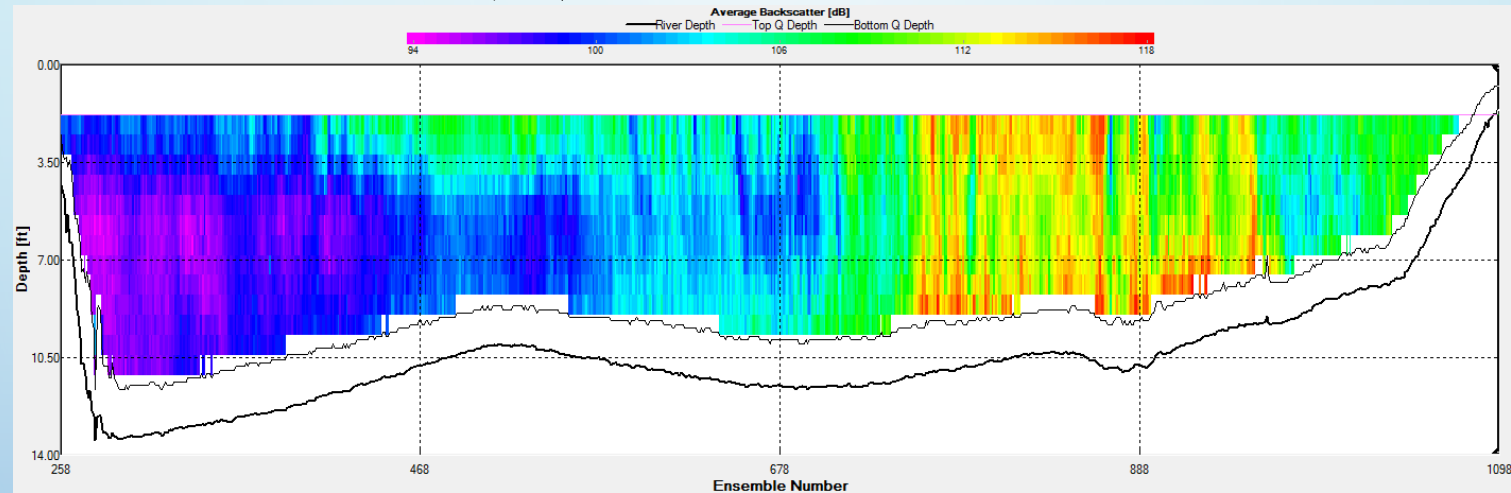
Export

XS Calibration

Plot

# DATA DISPLAY

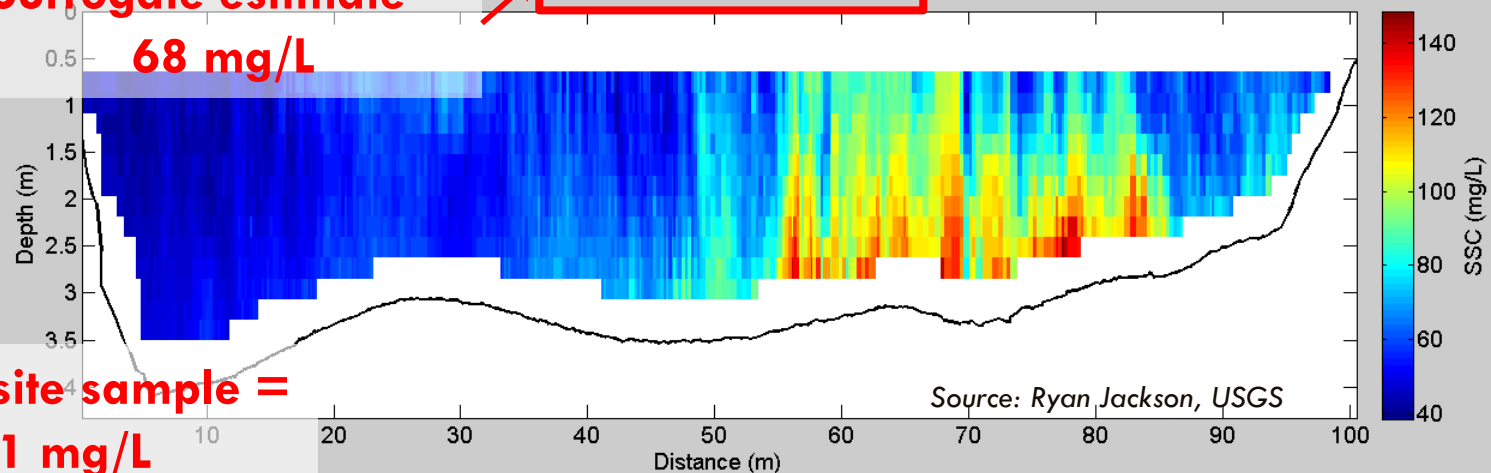
## Measured Acoustic Backscatter (dB)



## Suspended Sediment Concentration (mg/L)

Surrogate estimate = Composite SSC: 68 mg/L

68 mg/L



Composite sample =  
71 mg/L

Source: Ryan Jackson, USGS

# 2016 ADCP~SSC “SUMMIT”

- JULY 18-22, 2016 IN URBANA, IL AND ST. LOUIS, MO
- DISCUSSED STEPS TO ADVANCE USE OF DOWN-LOOKING ADCPS FOR SUSPENDED SEDIMENT
- FIELD EFFORT
- PARTICIPANTS: USGS - JUSTIN BOLDT, MARK LANDERS, AMANDA MANASTER, KEVIN OBERG, TIM STRAUB, MOLLY WOOD, RYAN BEAULIN, GARY JOHNSON, BEN RIVERS. UNIVERSIDAD NACIONAL DE LITORAL (ARGENTINA) - RICARDO SZUPIANY



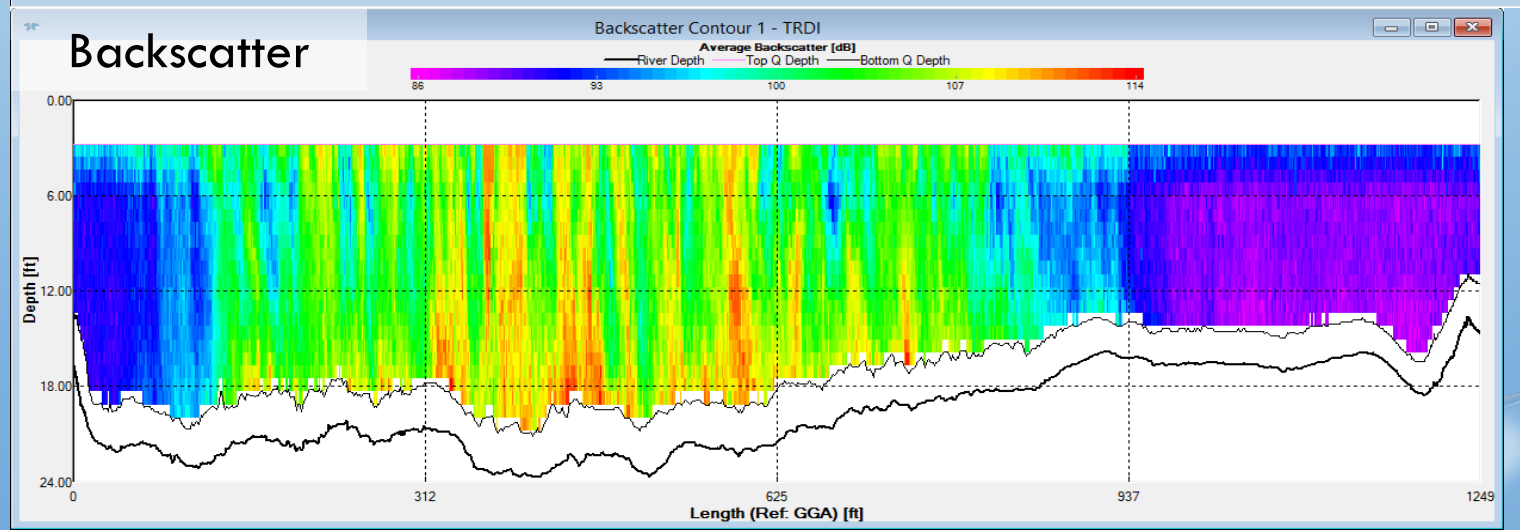
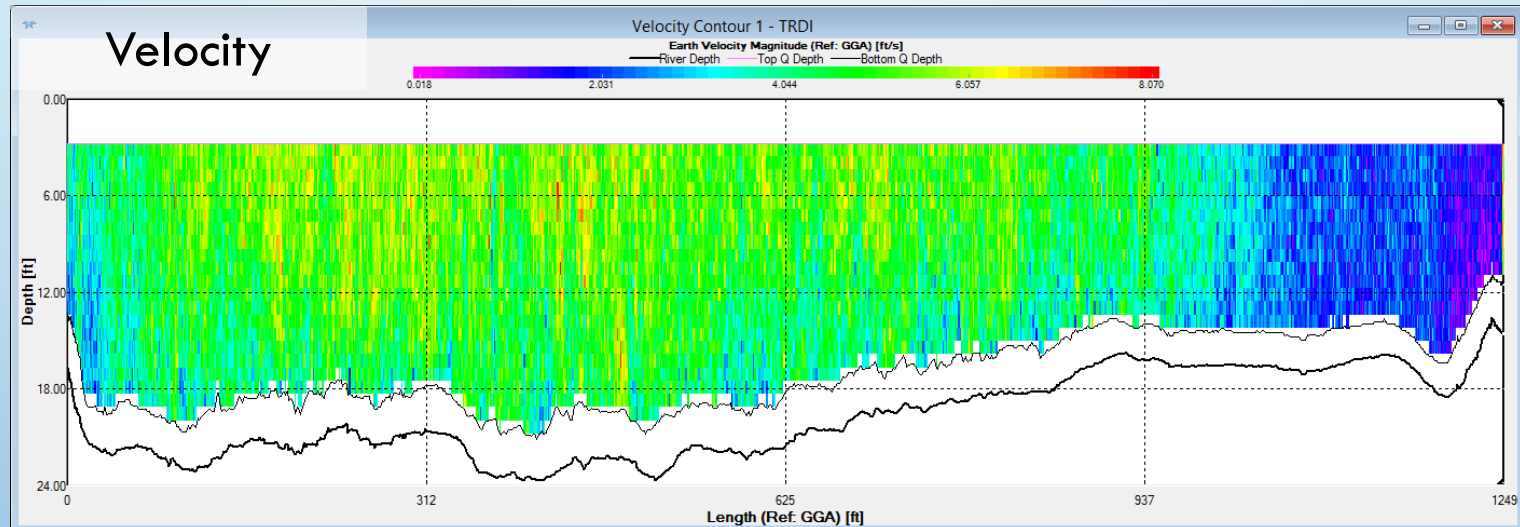
# MISSOURI RIVER FIELD EFFORT

- INSTRUMENTS USED:
  - 600 AND 1200KHZ TRDI RIO GRANDE
  - 1200KHZ TRDI RIVERPRO
  - MULTIFREQUENCY SONTEK M9
  - SEQUOIA LISST-ABS
  - YSI 6920 SONDE W/ TURBIDITY PROBE
  - P-6 POINT SEDIMENT SAMPLER
  - BM-54 BED MATERIAL SAMPLER



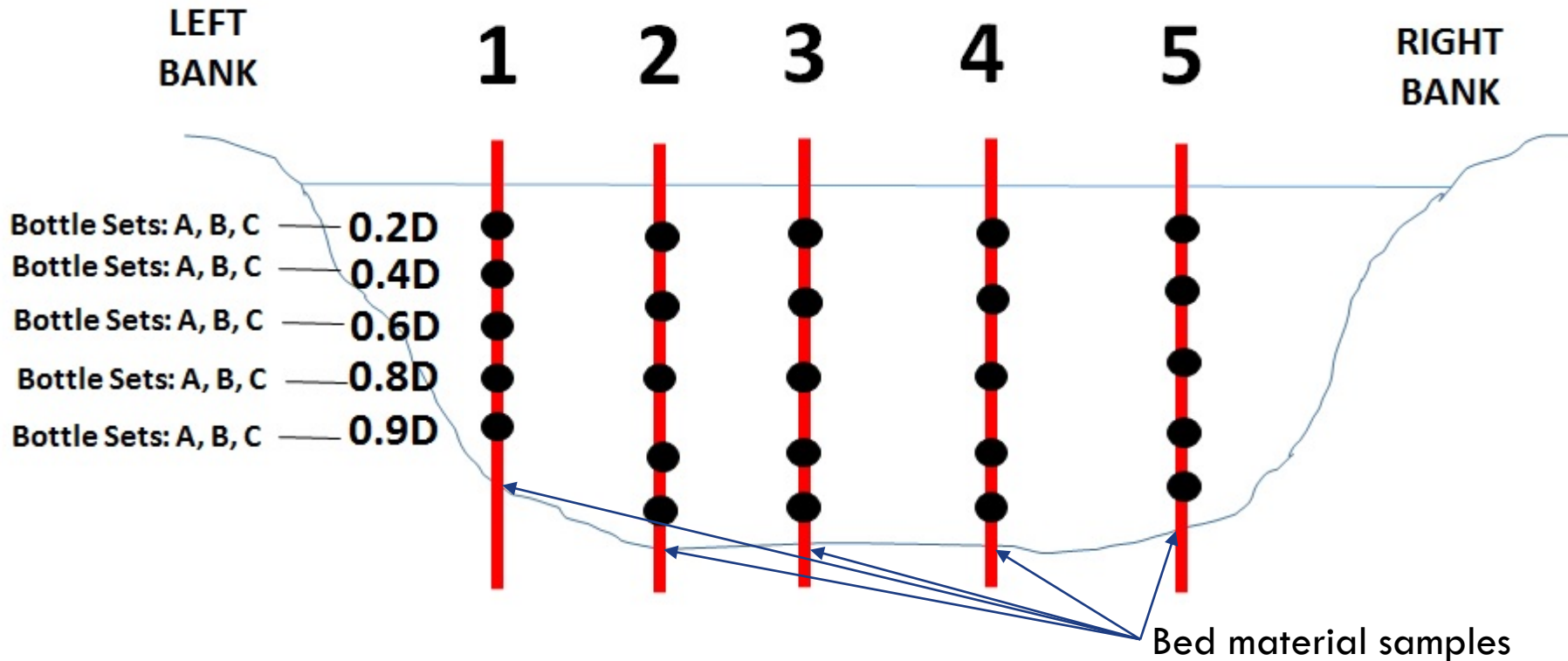


# EXAMPLE CONTOURS FROM 1200KHZ RIO GRANDE



# SAMPLING SCHEME

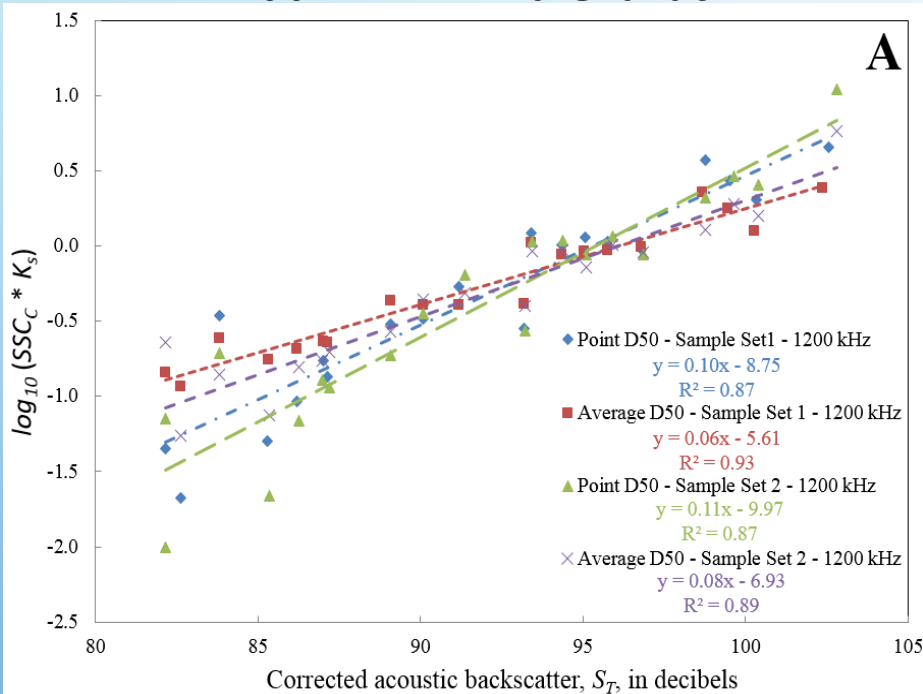
## EDI STATIONS



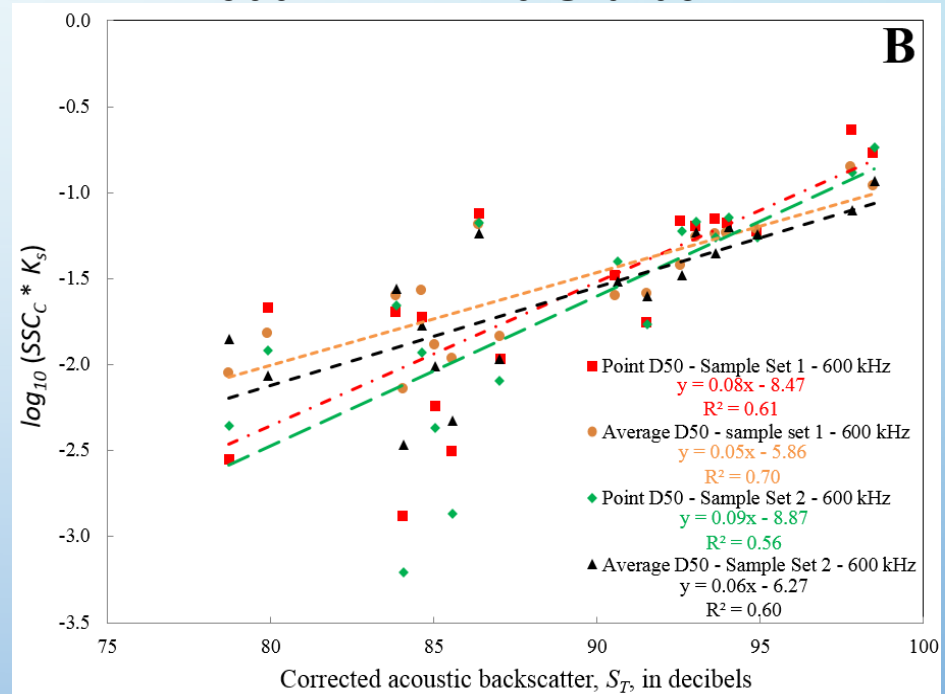
***W/ concurrent ADCP data collection***

# CALIBRATIONS FOR SAND CONCENTRATIONS

1200kHz TRDI Rio Grande:

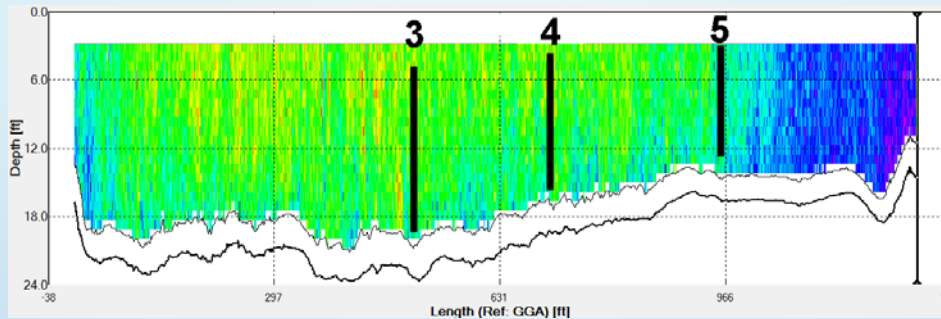


600kHz TRDI Rio Grande:

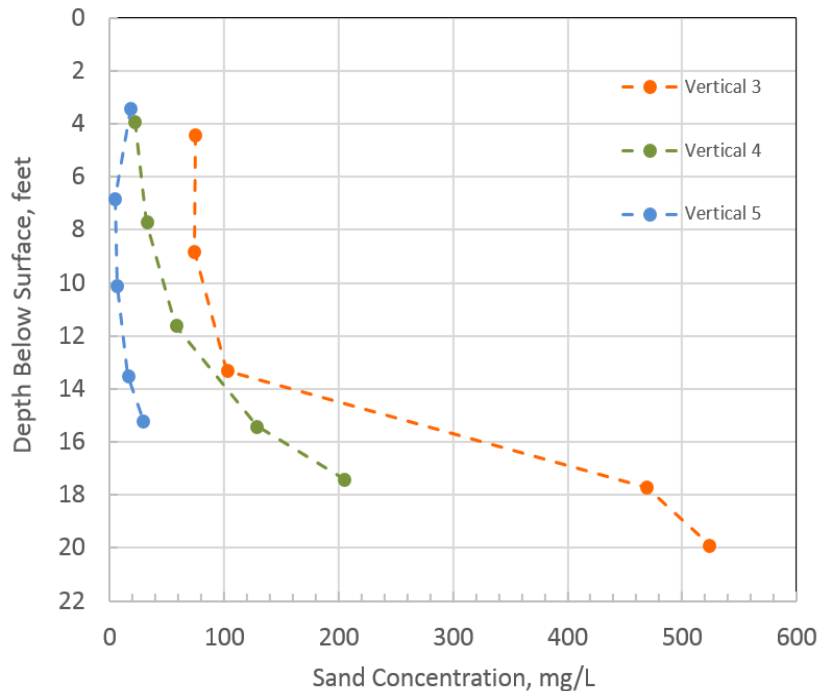


- HIGHER SCATTER NEAR SURFACE
- POORER CALIBRATION WITH 600KHZ
- SOURCES OF NOISE?

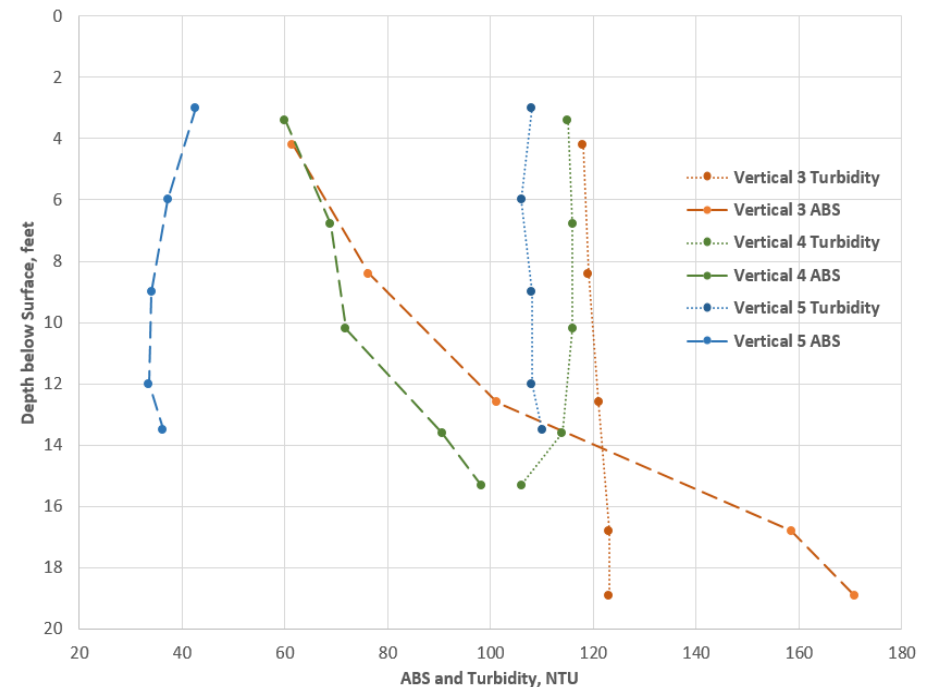
# SAND, TURBIDITY, AND LISST-ABS PROFILES



Set A - Sand Concentrations by Depth



LISST-ABS and Turbidity Profiles





# NEXT STEPS – MISSOURI RIVER DATASET

- PROCESS REMAINDER OF ADCP DATASETS
- DEVELOP CALIBRATIONS IN STA AND APPLY TO CROSS-SECTION BACKSCATTER
- INVESTIGATE SOURCES OF SURFACE SCATTER AND NOISE
- LOOK FOR COMMONALITIES WITH OTHER DATASETS

*More Information:*

*Conference paper by Wood and others (2017): <http://www.rioacoustics.org/>*

# OSW NOTE 2016.33

- DESCRIBED 2016 ADCP~SSC SUMMIT AND MISSOURI RIVER WORK
- SOLICITED HELP FROM WSCS FOR COLLECTION OF TEST DATASETS

*OSW Informational and Technical Note 2016.33*

*September 8, 2016*

**SUBJECT:** Announcement of OSW Summit to Advance the Use of ADCPs to Estimate Suspended Sediment

The purpose of this OSW Note is to announce an initiative coordinated by OSW to advance the use of down-looking acoustic Doppler current profilers (ADCPs) to estimate suspended-sediment transport in rivers. This Note presents 1) a summary of a recent OSW Summit to strategize and collect a test dataset and 2) an invitation for USGS Water Science Centers to collaborate with OSW on the collection of future test datasets.

## **Background**

Various OSW and Water Science Center initiatives have advanced the use of side-looking acoustic Doppler velocity meters (ADVMS) to estimate suspended-sediment concentrations, resulting in the publication of the [Techniques and Methods Report 3-C5](#) (Landers and others, 2016). A key assumption in the successful application of the methods described in [T&M 3-C5](#) is that sediment characteristics (particularly grain size distribution) do not substantially vary across the measurement volume encompassed by the ADVMS. This assumption is almost never met in the measurement volume encompassed by a down-looking ADCP because sediment concentration and grain size commonly vary with depth in a river channel (García, 2008). The use of ADCPs to estimate suspended sediment has been investigated (Boldt and others, 2012; Latosinski, 2014; Boldt, 2015; Szupiany and others, 2016) but is not yet considered an operational technique. Additional datasets are needed to define methods that are appropriate for a wide range of sediment and hydrologic conditions and that account for sediment variations with depth in acoustic data corrections. OSW staff in the Hydroacoustics and Sediment programs has recognized the need to advance this technique, which would greatly leverage and provide value to existing sediment monitoring programs where ADCPs are used to measure streamflow.

## **OSW Summit**

OSW staff held an "ADCP Sediment Summit" during the week of July 18-22, 2016, in Urbana, Illinois, and St. Louis, Missouri, to discuss steps for advancing the use of down-looking ADCPs for estimating suspended-sediment transport. The summit included a series of meetings and seminars in Urbana and a comprehensive field data collection effort on the Missouri River near St. Louis. Summit participants included Justin Boldt (Indiana-Kentucky WSC), Mark Landers (OSW), Amanda Manaster (Illinois-Iowa WSC), Kevin Oberg (OSW), Tim Straub (Illinois-Iowa WSC), Molly Wood (OSW), and Ricardo Szupiany (Universidad Nacional de Litoral in Santa Fe, Argentina). Ryan Beaulin (Illinois-Iowa WSC), Gary Johnson (Illinois-Iowa WSC), and Ben Rivers (Missouri WSC) also participated in the field data collection effort on the Missouri River. The Missouri River dataset included the collection of three replicate sets of point suspended-sediment samples at 25 locations in the river, bed material samples, backscatter profiles at five locations using four ADCPs with differing frequencies, and backscatter and turbidity profiles using fixed-point monitoring sensors.

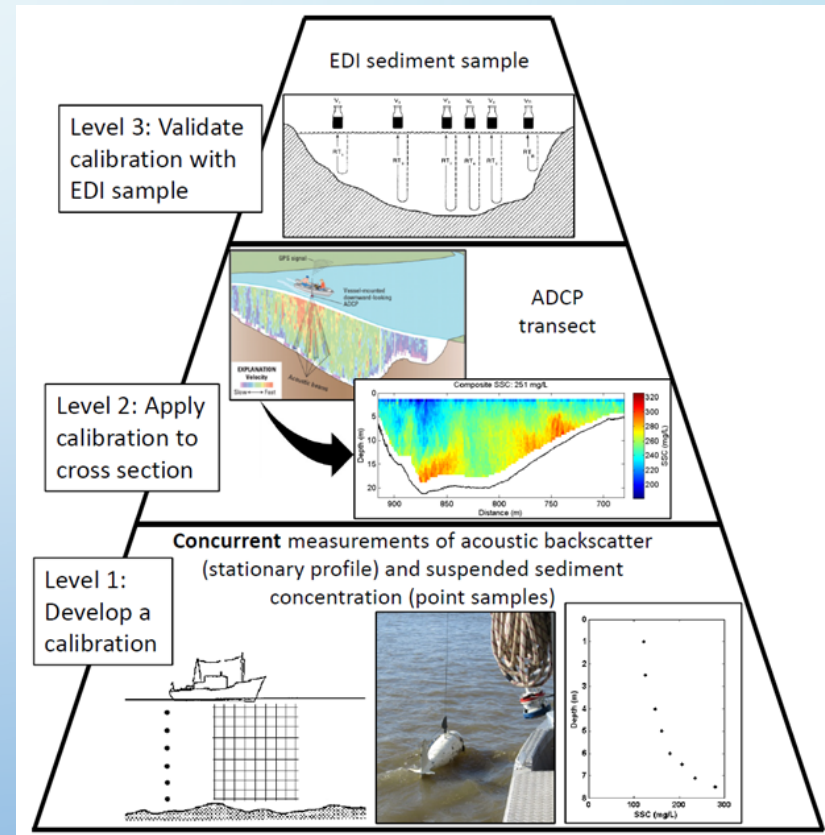
# ADCP~SSC TEST DATASETS COLLECTED 2016-17

- MISSOURI RIVER AT ST. CHARLES, MO
- SACRAMENTO RIVER AT FREEPORT, CA
- ILLINOIS RIVER AT FLORENCE, IL
- MISSOURI RIVER AT NEBRASKA CITY, NE



# YOU CAN HELP US!

- FUNDS MAY BE AVAILABLE IN FY18 TO AUGMENT EXISTING MONITORING
- POINT, ISOKINETIC SAMPLES
  - INDIVIDUAL ANALYSIS
  - SOME LEVEL OF FULL PARTICLE SIZE INFORMATION NEEDED
- CONCURRENT ADCP PROFILES AT EACH VERTICAL
- MOVING-BOAT ADCP MEASUREMENTS
- DEPTH-INTEGRATED EDI SAMPLES







# QUESTIONS?

**YOUR FRIENDLY NEIGHBORHOOD OSW/OSD SEDIMENT TEAM....  
MARK AND MOLLY**