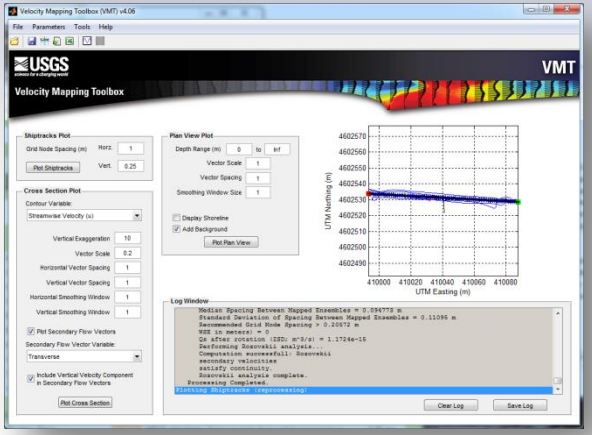
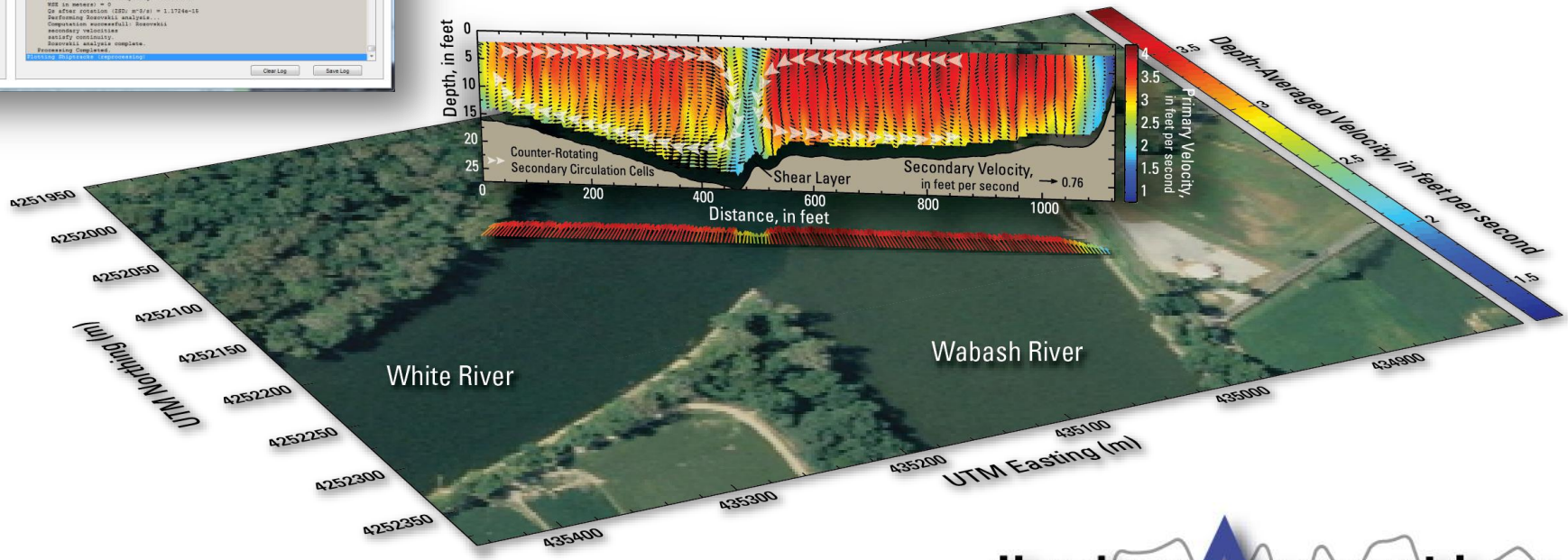
Hydrologic Workshop 2014

The Velocity Mapping Toolbox (VMT)



Justin Boldt

6/10/2014



HydroAcoustics
USGS

What is VMT?

- MATLAB-based ADCP data processing and visualization code (GUI)
- A quick look at VMT
  - Reads ADCP data files (multiple transects)
  - Averages to one mean cross section
  - Quickly allows for robust visualization
    - mean velocity
    - velocity components
    - contour plots
    - plan view plots show depth- or layer-averaged velocities
  - Export capabilities
    - Excel, ArcGIS, Google Earth, TecPlot, iRIC

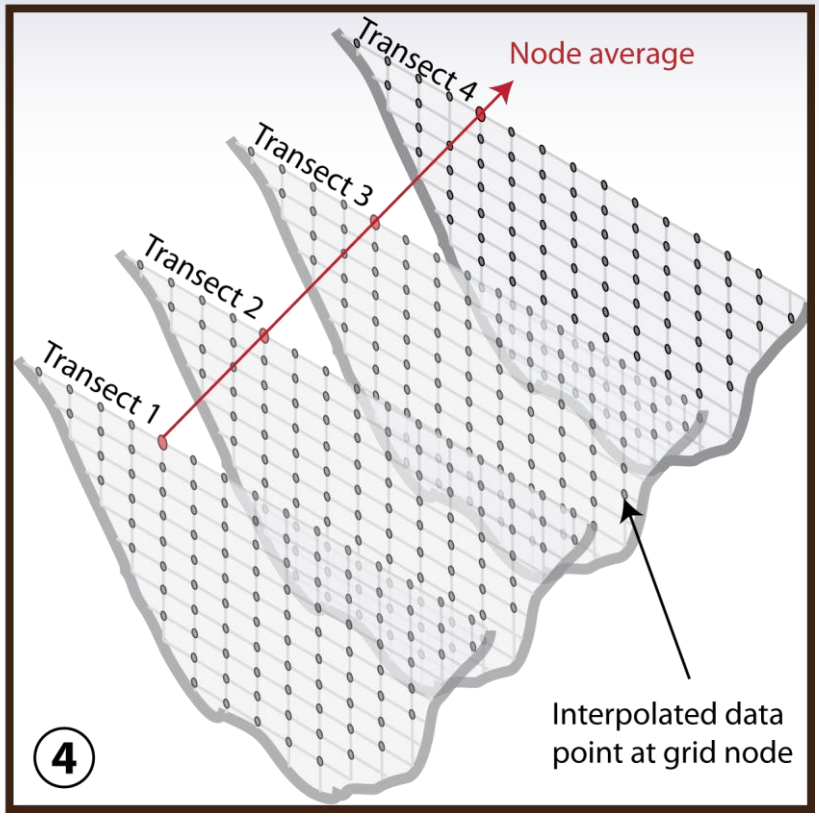
VMT: Beyond Discharge

Mapping velocity fields using ADCPs has gained popularity in recent years due to:

- **Advancements in technology (GPS, improved instrument accuracy, etc.)**
- **The need for higher-order (2-D and 3-D) model calibration and validation data**
- **Exposure in the literature**
- **Availability of data visualization software**

Average Multiple Transects

- Averages basic variables at each node
  - Velocity Components (East, North, Vertical, Error)
  - Backscatter & Depth
  - Velocity magnitude & direction are recomputed from averaged components



Example Applications of VMT

Geomorphology

- Morphodynamics of large river meanders
- Fluvial dynamics of stream confluences/bifurcations
- Sediment transport

Hydrodynamics near Structures

- Hydrodynamics near locks and dams and bypass structures
- Pier scour
- Characterization of flow/bathymetry near channel training structures

Contaminant Transport

- Plume tracking
- Mixing characterization

Limnology & Nearshore Circulation

- Rivermouth hydrodynamics and mixing
- Secondary flows in submarine bends
- Nearshore circulation

Biological/Ecological Studies

- Hydrodynamic requirements for fish spawning
- Habitat characterization

Gaging

- Evaluation of flow structure and secondary flows at index velocity gages
- Locating surface radar gages

Modeling

- Collection of model calibration/validation data
- Model development (bathymetric mapping)

Geomorphology

Wabash-Vermillion Confluence

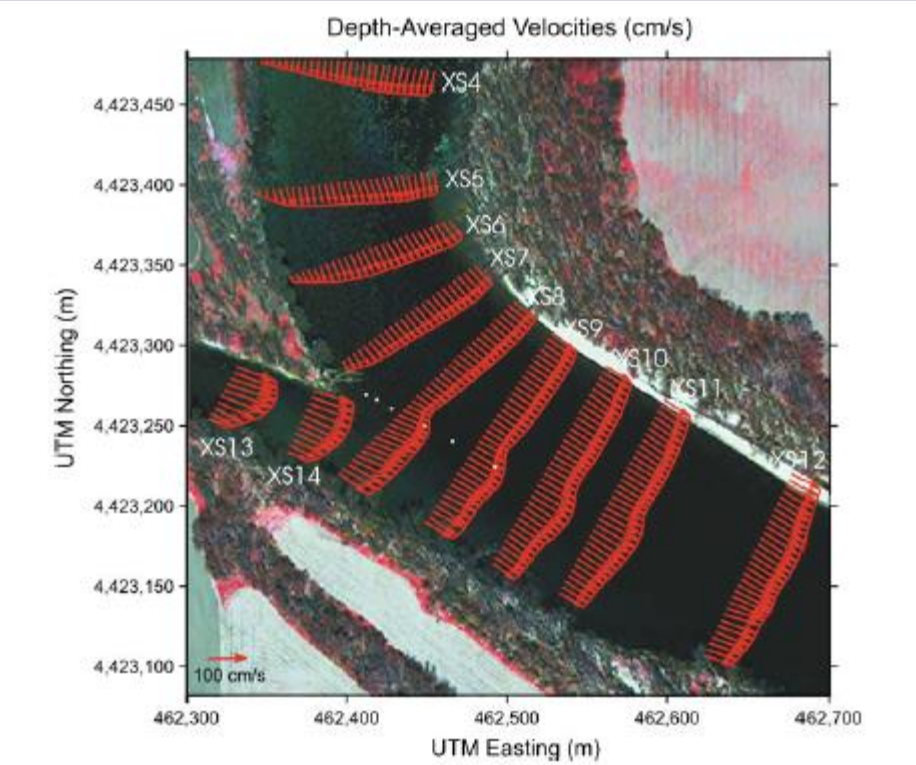


Fig. 18 Depth-averaged streamwise velocities at Wab–Verm. Locations of stationary measurements shown as *white dots*

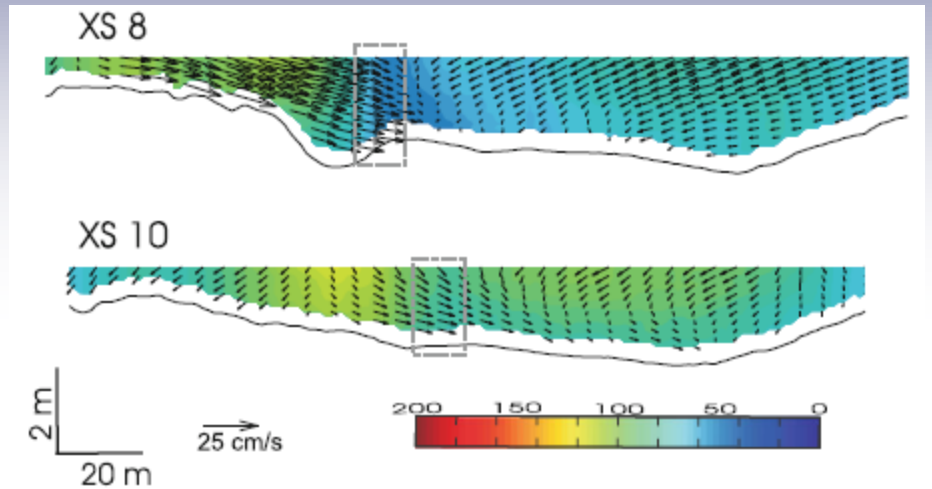


Fig. 15 Primary (contours) and secondary (vectors) velocity components using a zero net discharge frame of reference for cross sections at Wab–Verm confluence (looking upstream). *Grey boxes* indicates approximate locations of stationary ADCP within the mixing interface

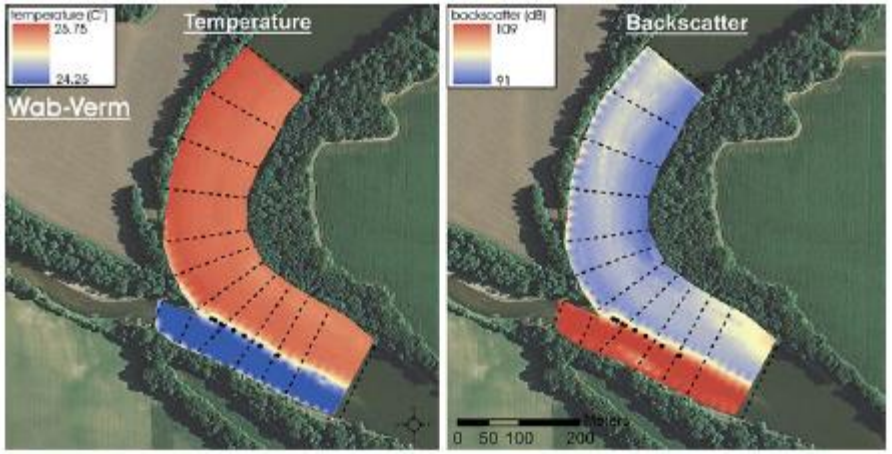


Fig. 20 Patterns of temperature and depth-averaged backscatter intensity at Wab–Verm (*top*) and Wab–Whi (*bottom*). Locations of stationary measurements shown as *dots*

Konsoer, K. M., & Rhoads, B. L. (2011). Spatial-temporal structure of mixing interface turbulence at two large river confluences. *Environmental Fluid Mechanics*, 1-28.

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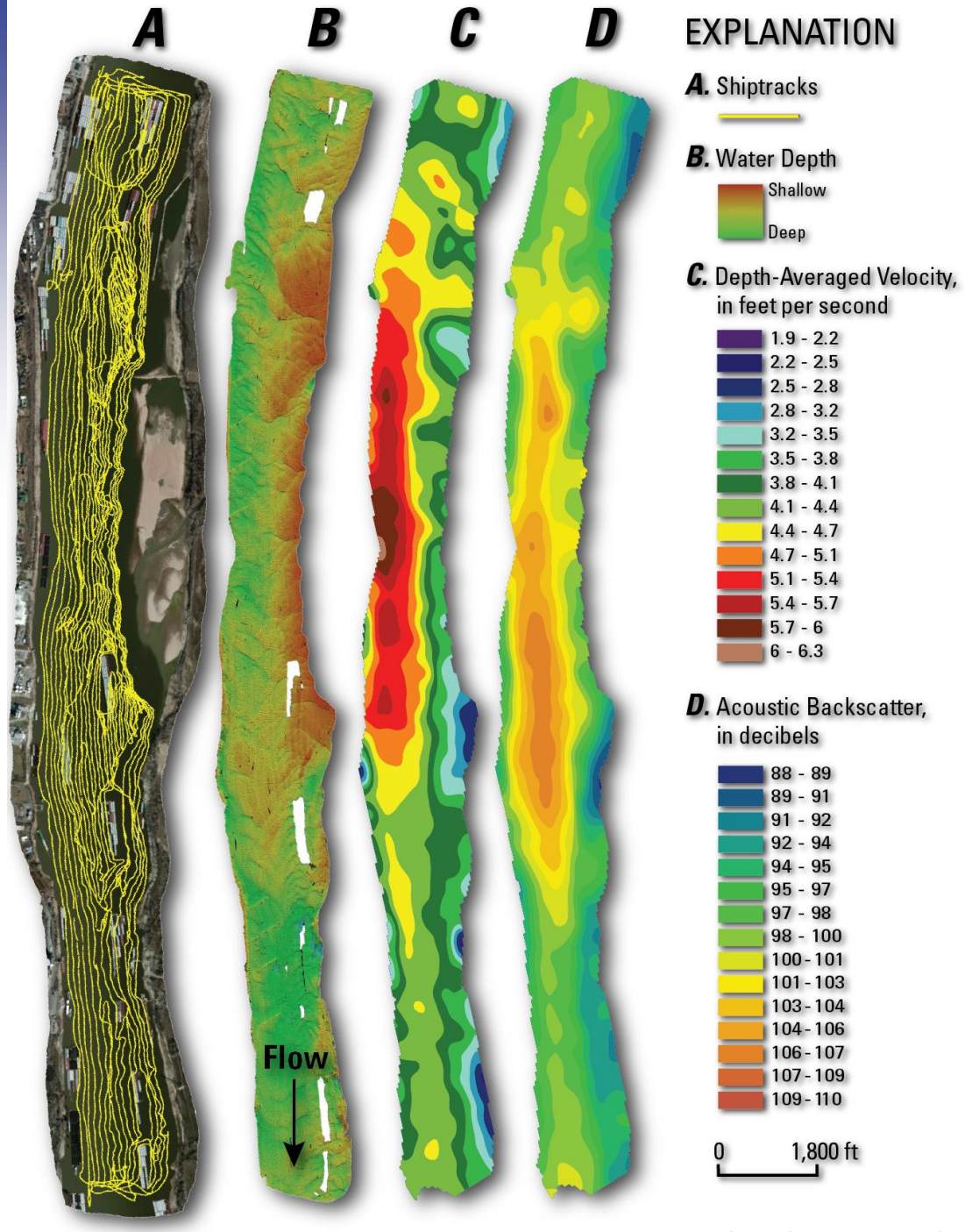
MBES / ADCP Survey

Mississippi River near St. Louis, MO

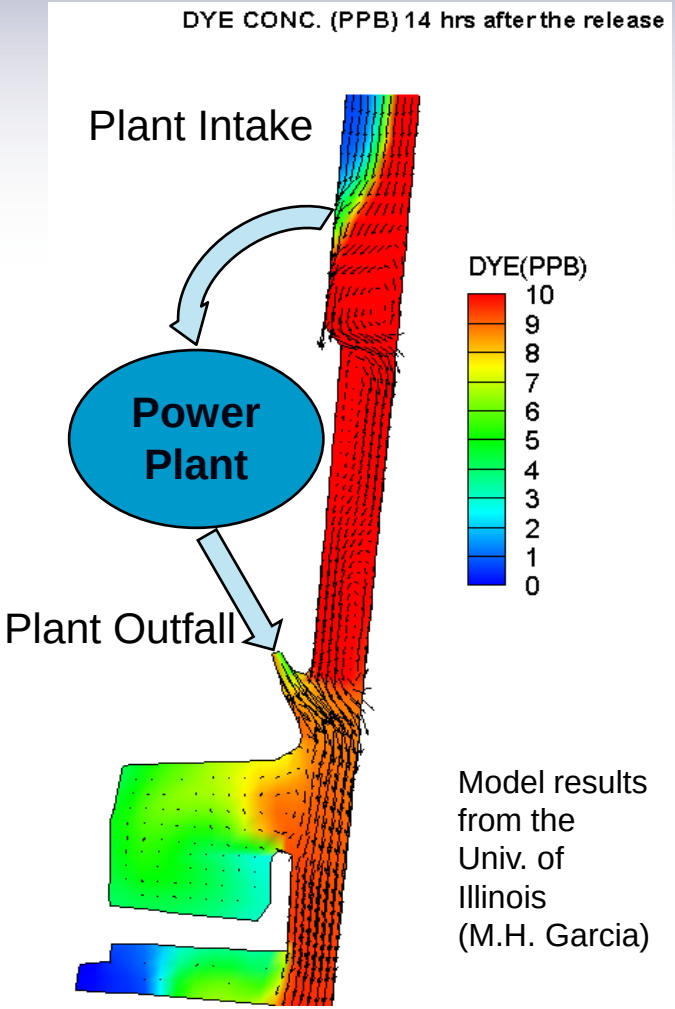
- Concurrent MBES and ADCP data collection
- 2 days in the field
- 127,000 depth-averaged data points
- Each point represents a 20-second average
- Exported from VMT and visualized in ArcGIS



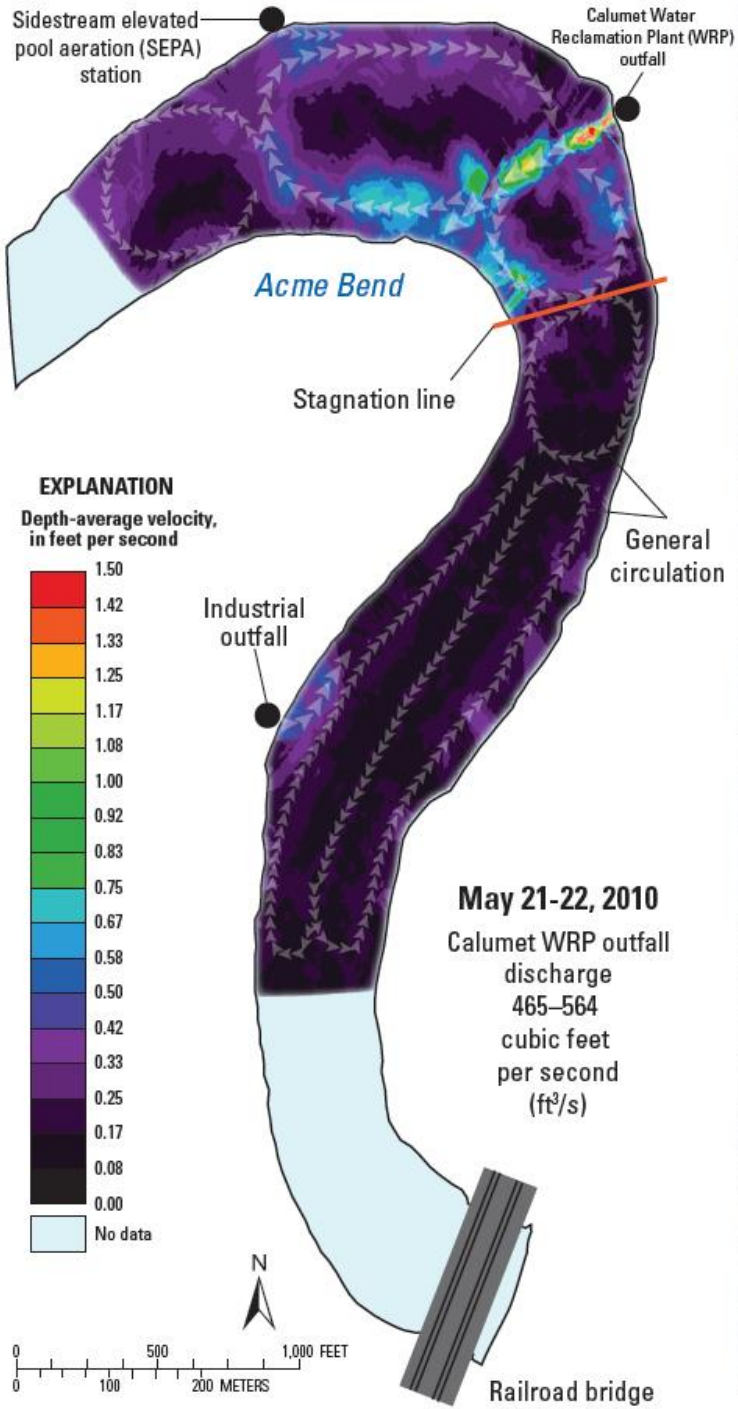
From Jackson (FS 2013-3028)

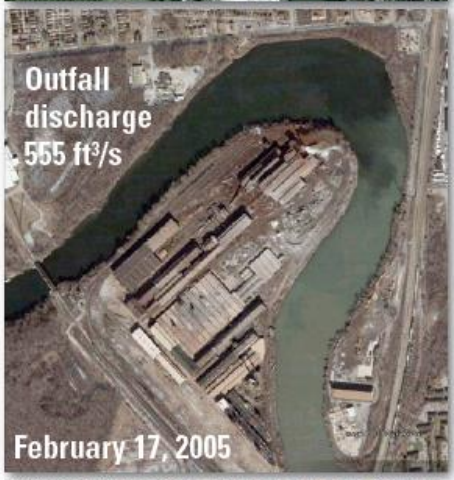
Contaminant Transport

Chicago Sanitary and Ship Canal



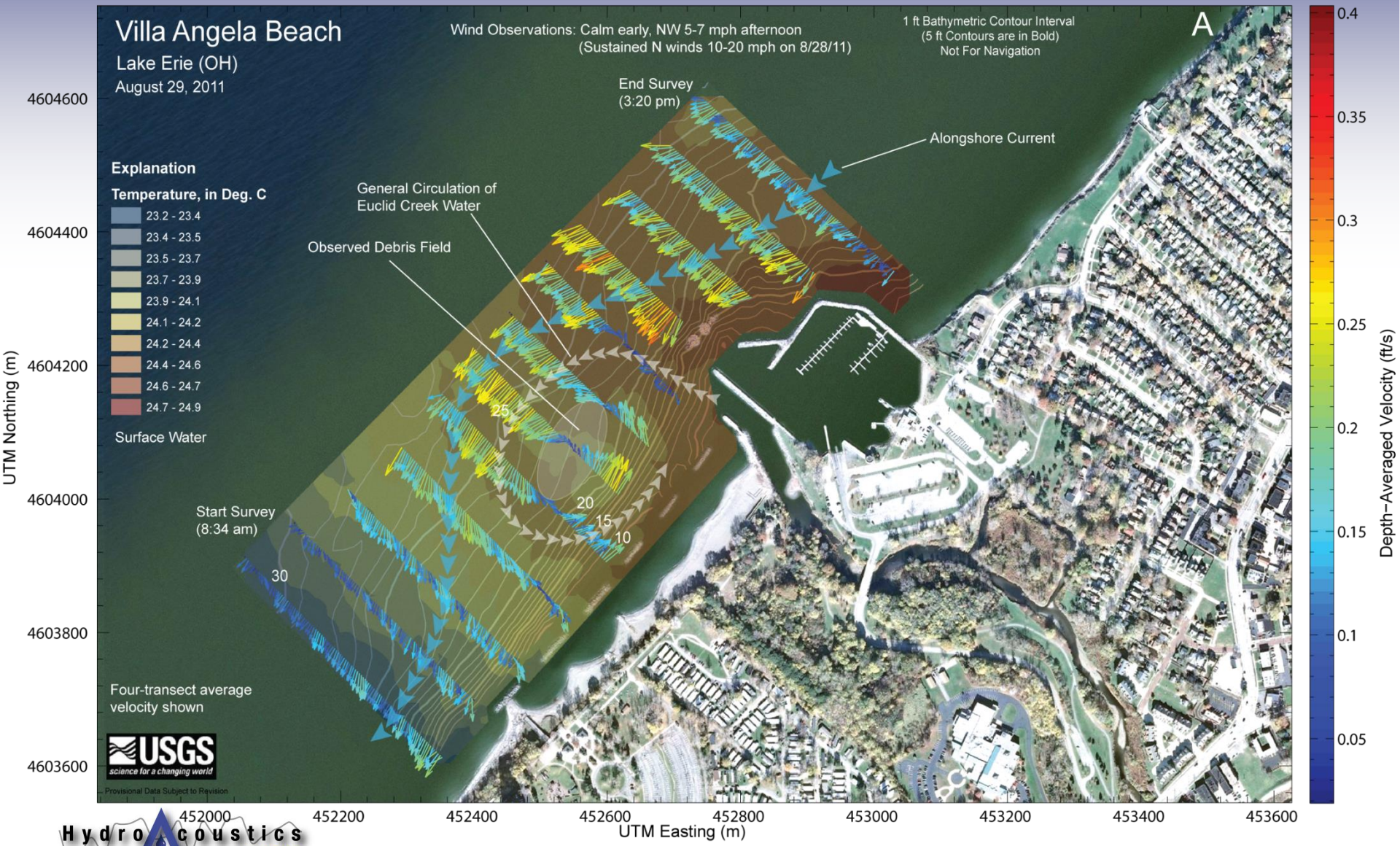
Model results from the Univ. of Illinois (M.H. Garcia)





Jackson, P.R., Lageman, J.D., 2014, Real-time piscicide tracking using Rh application, transport, and deactivation strategies in riverine environments: Investigations Report 2013–5211, 43 p., http://dx.doi.org/10.3133/sir20135

Limnology and Nearshore Circulation



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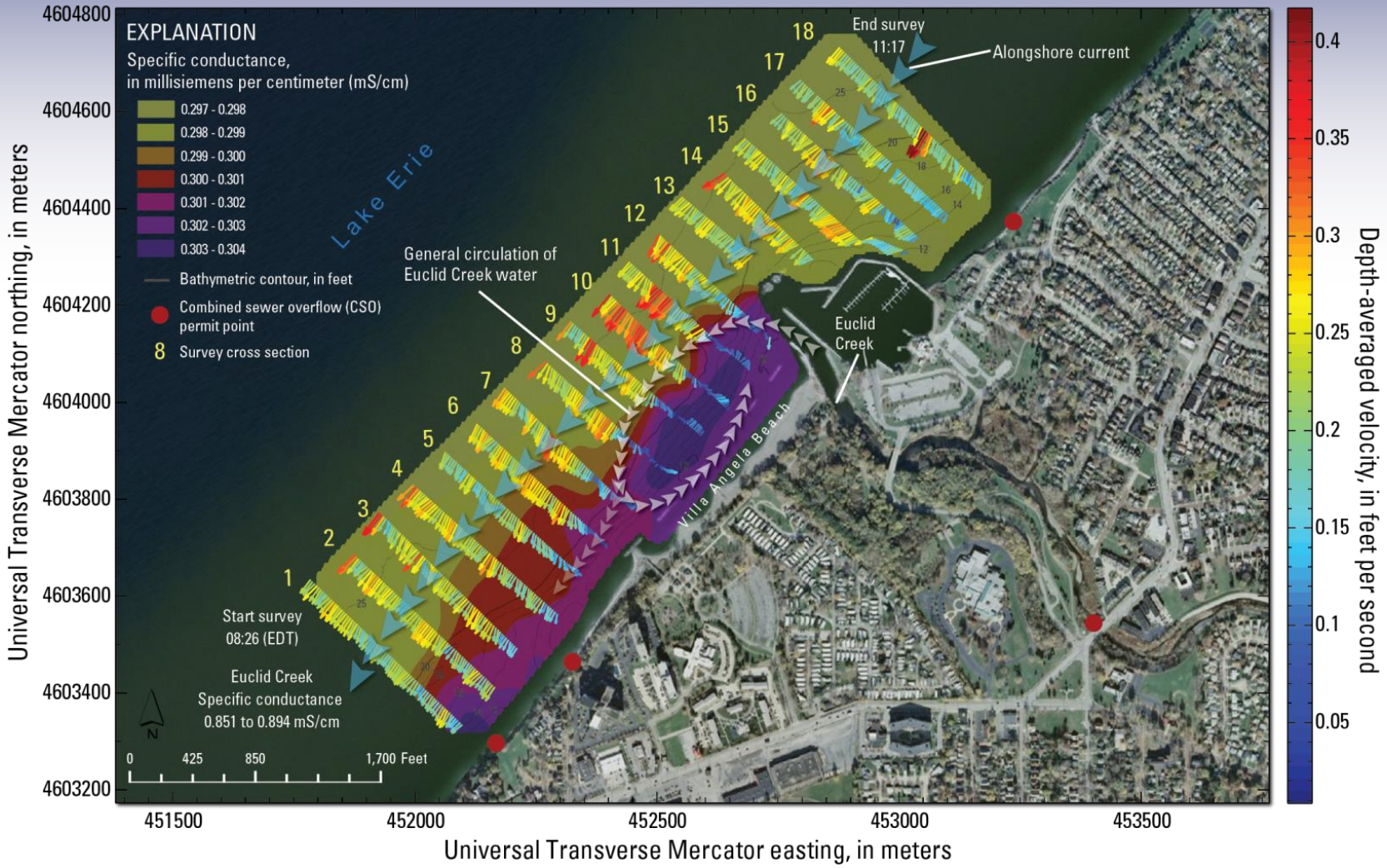
Limnology and Nearshore Circulation



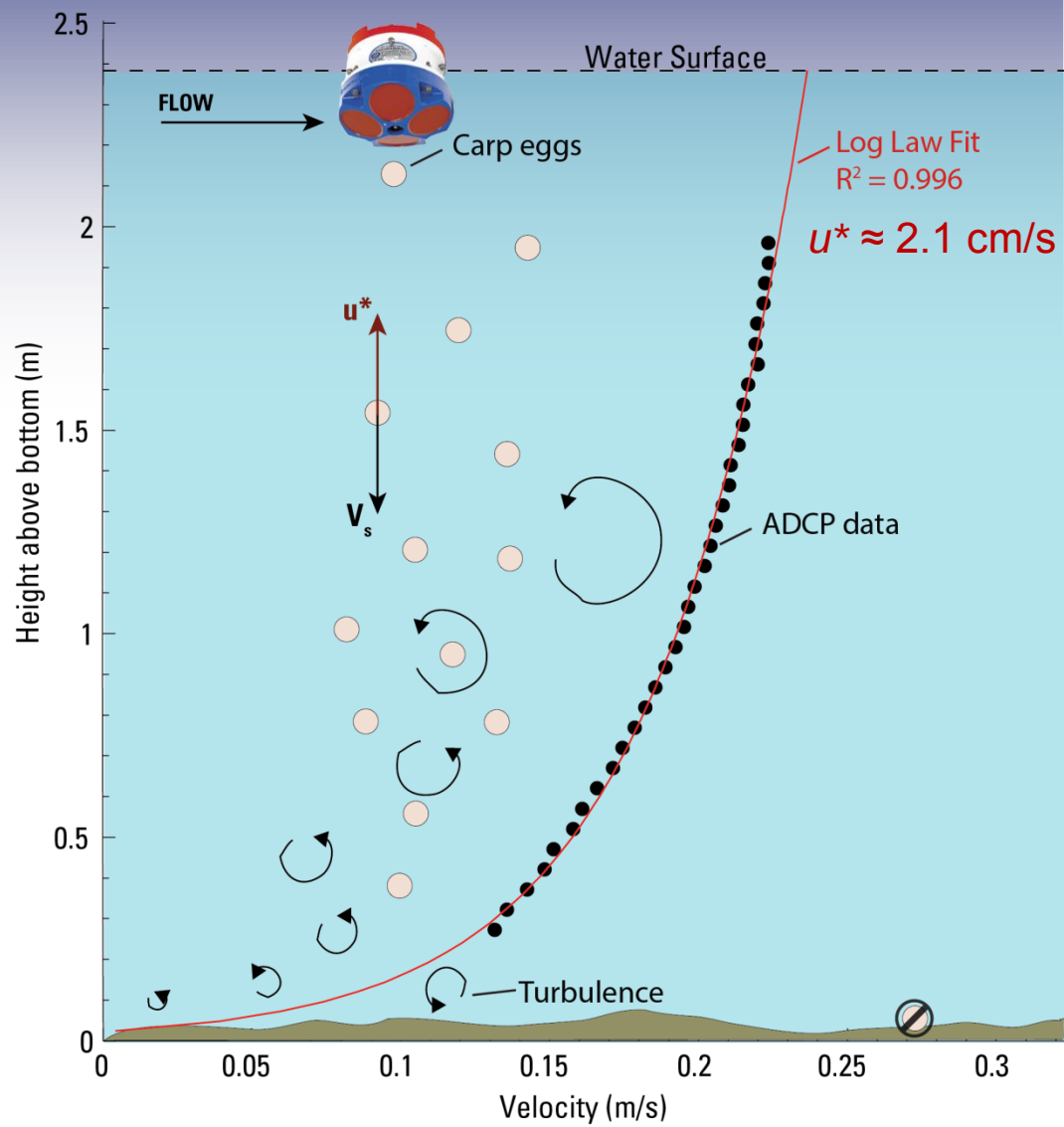
Jackson, P.R., 2013, Circulation, mixing, and transport in nearshore Lake Erie in the vicinity of Villa Angela Beach and Euclid Creek, Cleveland, Ohio, September 11–12, 2012: U.S. Geological Survey Scientific Investigations Report 2013–5198, 34 p., http://dx.doi.org/10.3133/sir20135198.

Biological Studies

V_s = settling velocity
u^* = shear velocity

If $u^* > V_s$, eggs should remain in suspension

Eggs that settle on the bottom are thought to perish



Biological Studies

Velocity magnitude

Vertical velocity

Shear velocity

Depth

Temperature

Specific conductance

Dissolved oxygen

pH

Turbidity

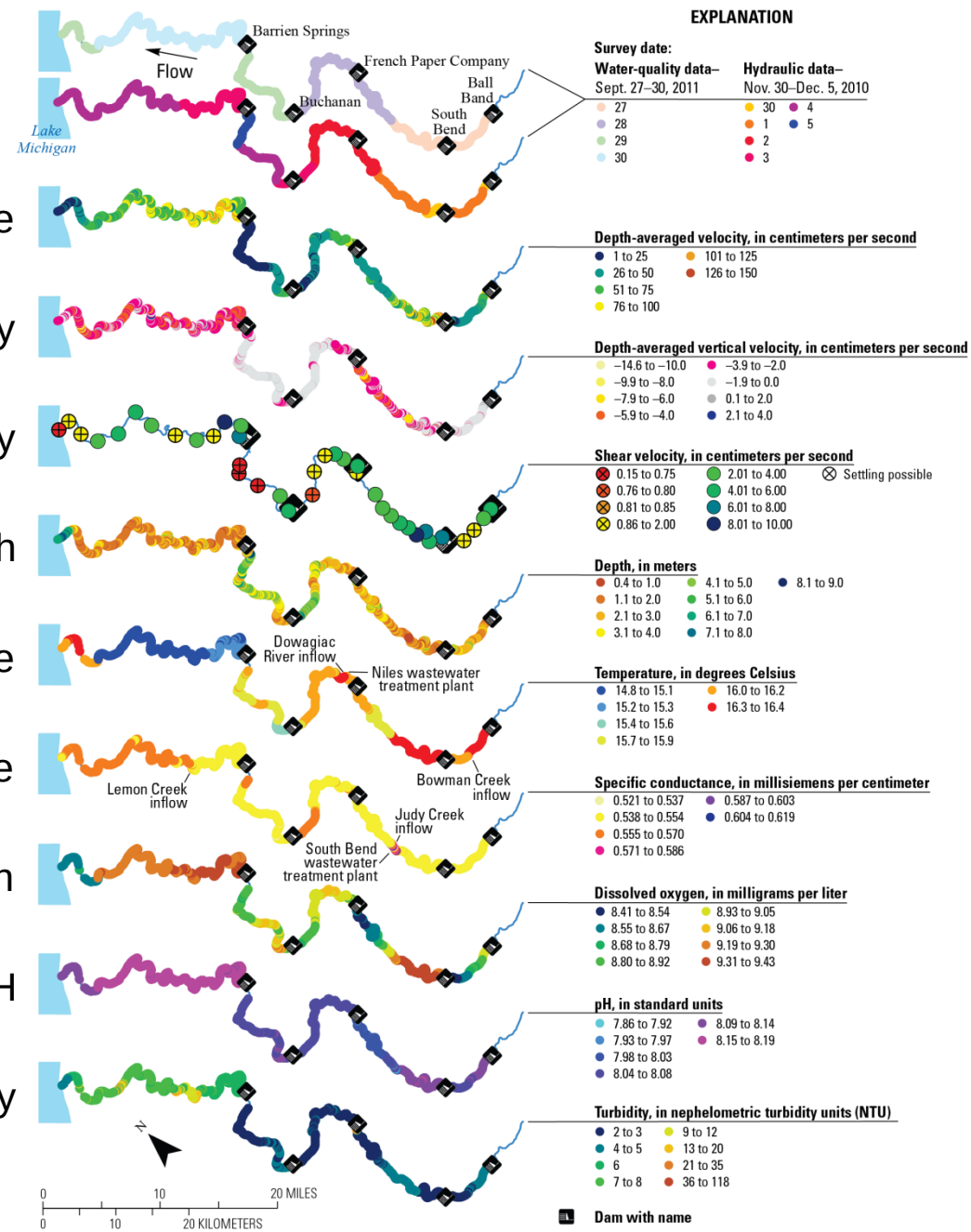


Figure 10. Hydraulic and water-quality data for the St. Joseph River, Michigan and Indiana, November 30–December 5, 2010 (hydraulic data), and September 27–30, 2011 (water-quality data).

Murphy, E.A., and Jackson, P.R., 2013, Hydraulic and water-quality data collection for the investigation of Great Lakes tributaries for Asian carp spawning and egg-transport suitability: U.S. Geological Survey Scientific Investigations Report 2013–5106, 30 p., http://pubs.usgs.gov/sir/2013/5106/.

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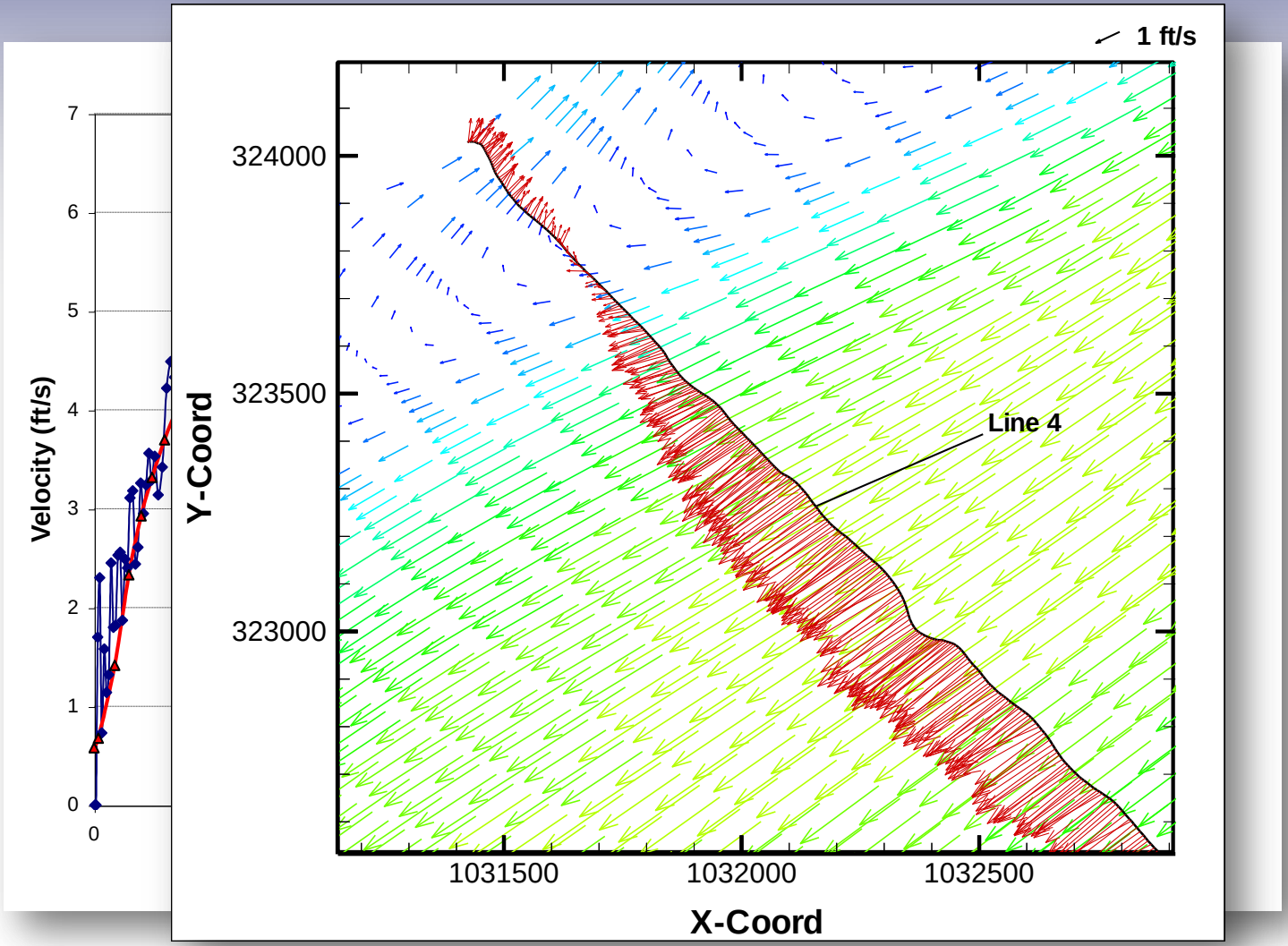
Model Calibration / Validation



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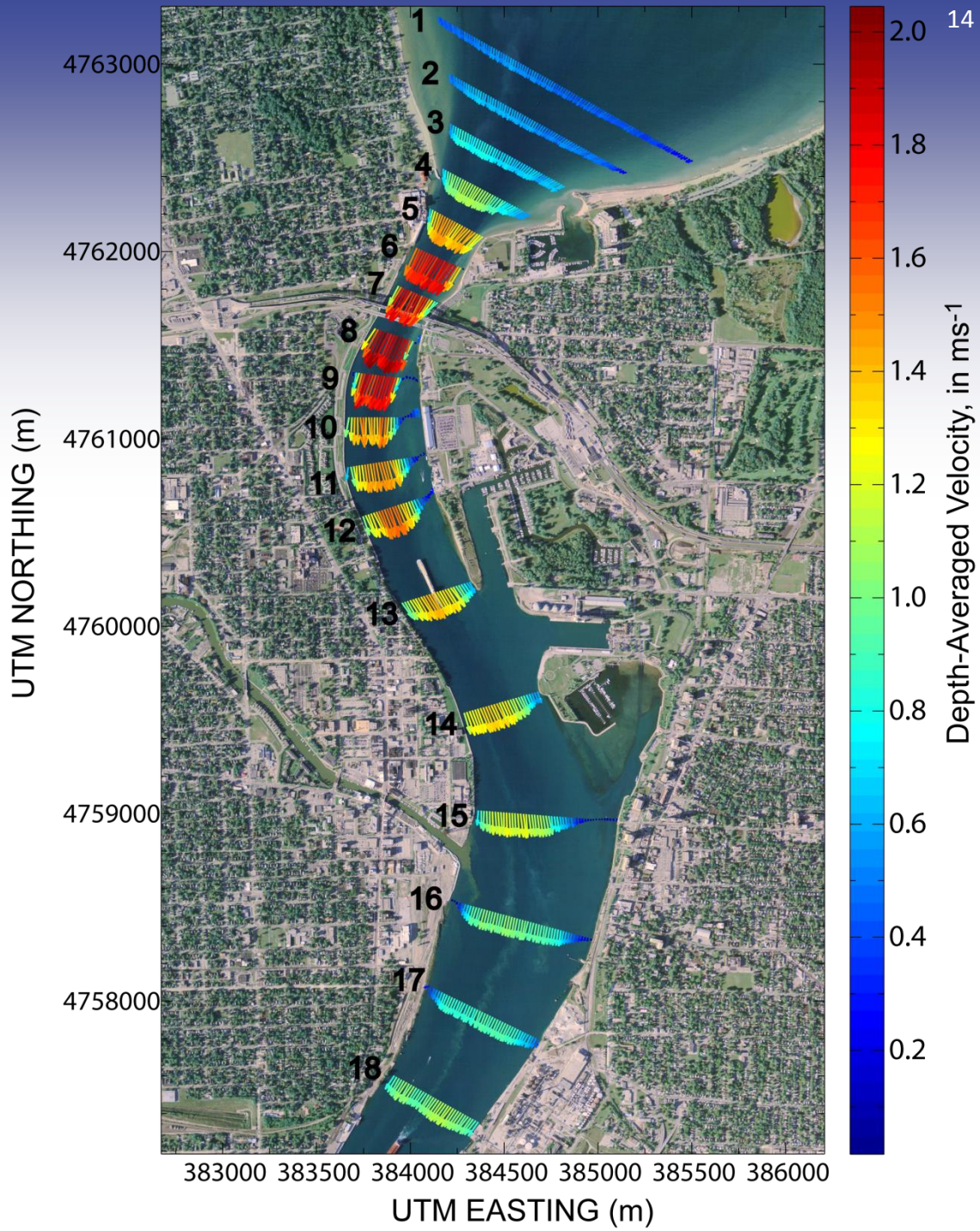
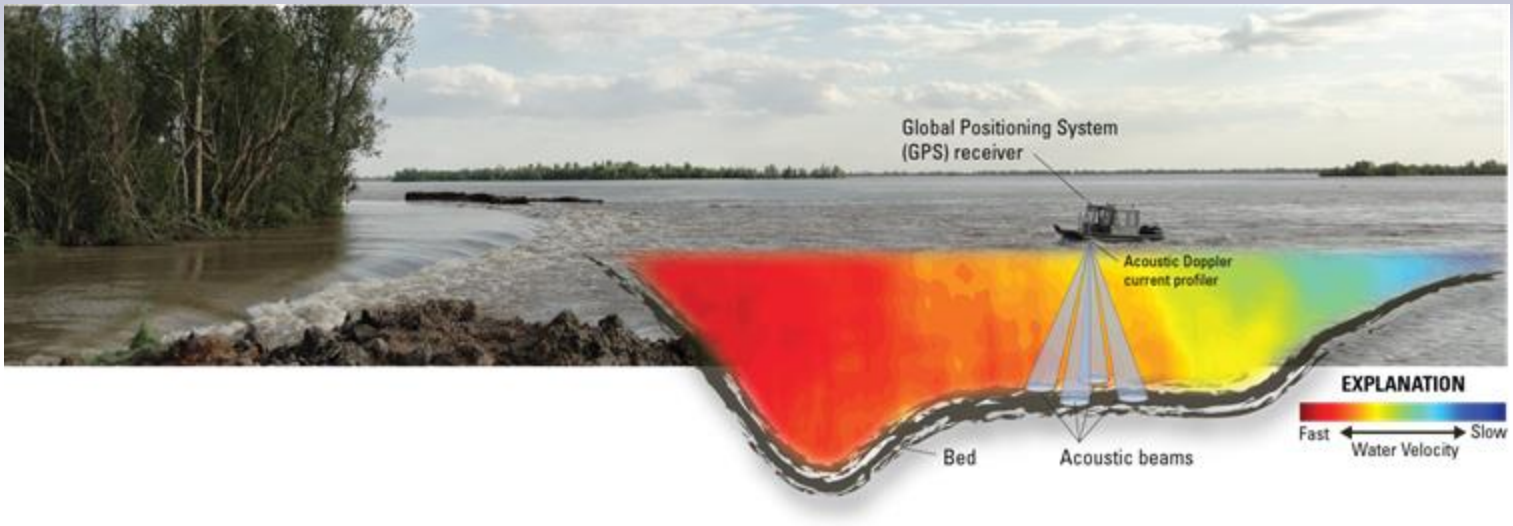
General Flow Visualization

- For navigation
- For sediment transport
- For contaminant transport
- For public safety
- For structure evaluation/location
- For biological/ecological studies
- For gage site evaluation
- For model development
- For understanding

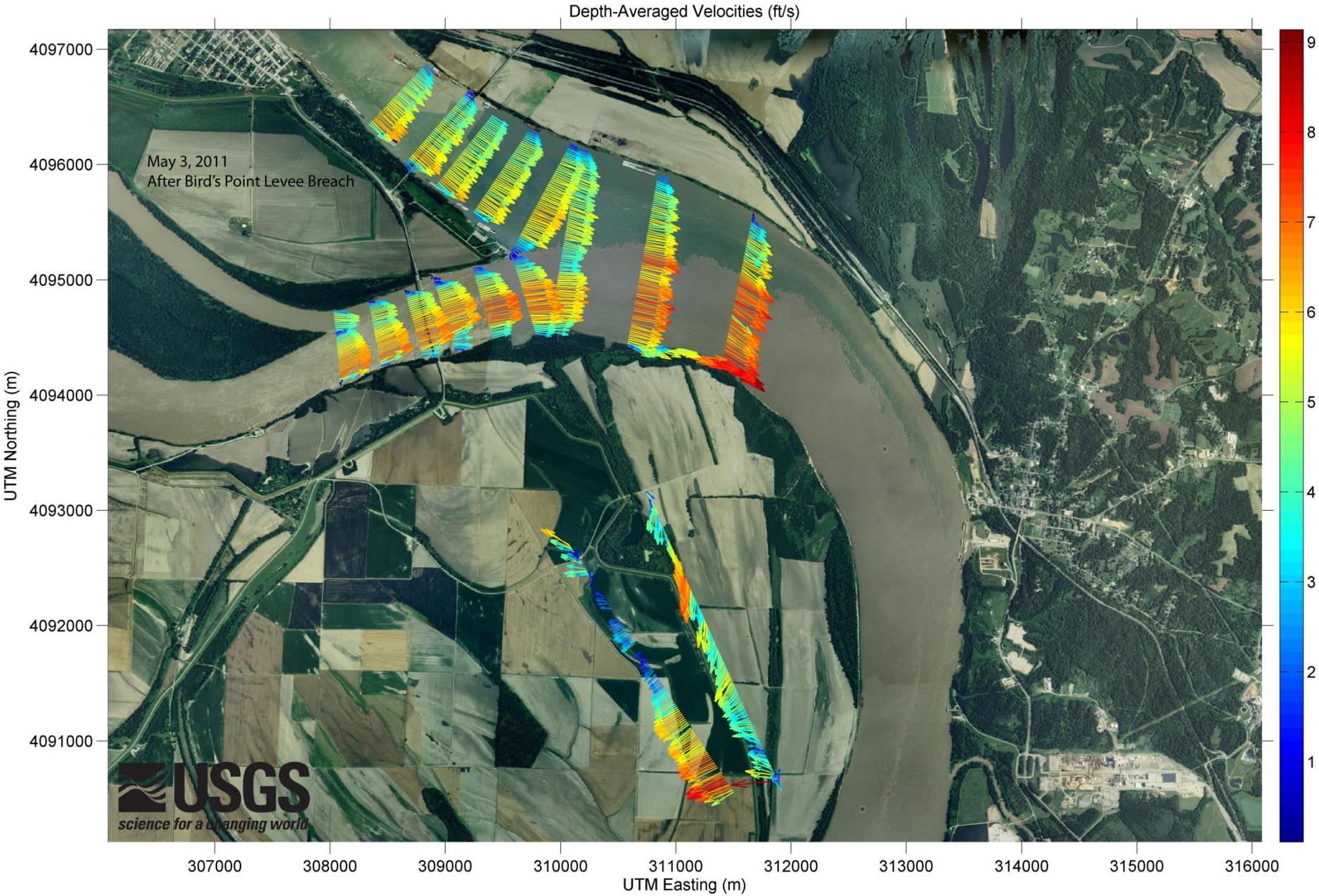


Hydro Acoustics USGS

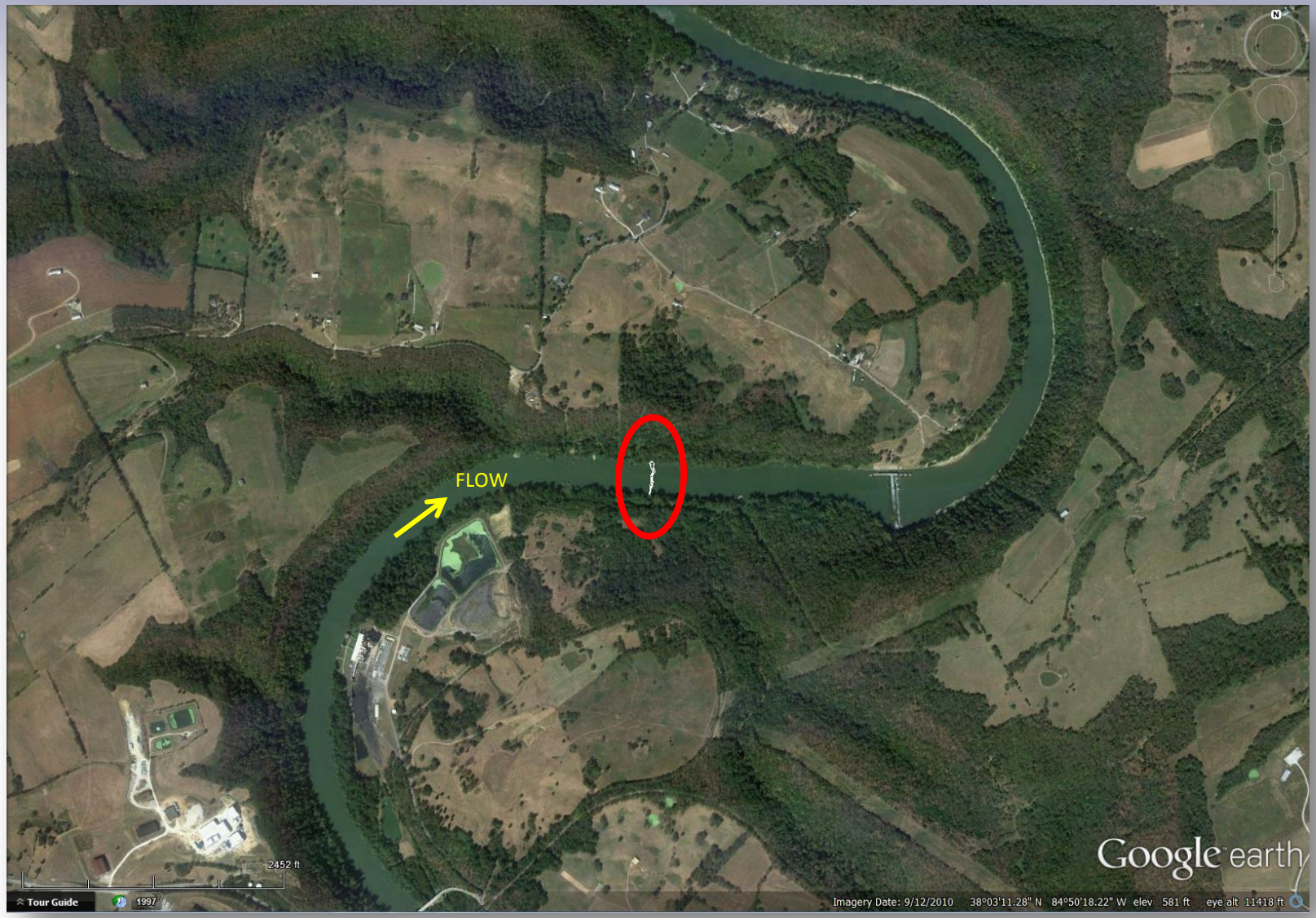


Velocity Mapping

More Example Applications


Depth-Averaged Velocities (ft/s)
May 3, 2011
After Bird's Point Levee Breach
UTM Northing (m)
4097000
4096000
4095000
4094000
4093000
4092000
4091000
UTM Easting (m)
307000
308000
309000
310000
311000
312000
313000
314000
315000
316000
9
8
7
6
5
4
3
2
1
USGS
science for a changing world

Example #2: USGS 03287250 Kentucky River at Lock 5 near Tyrone, KY

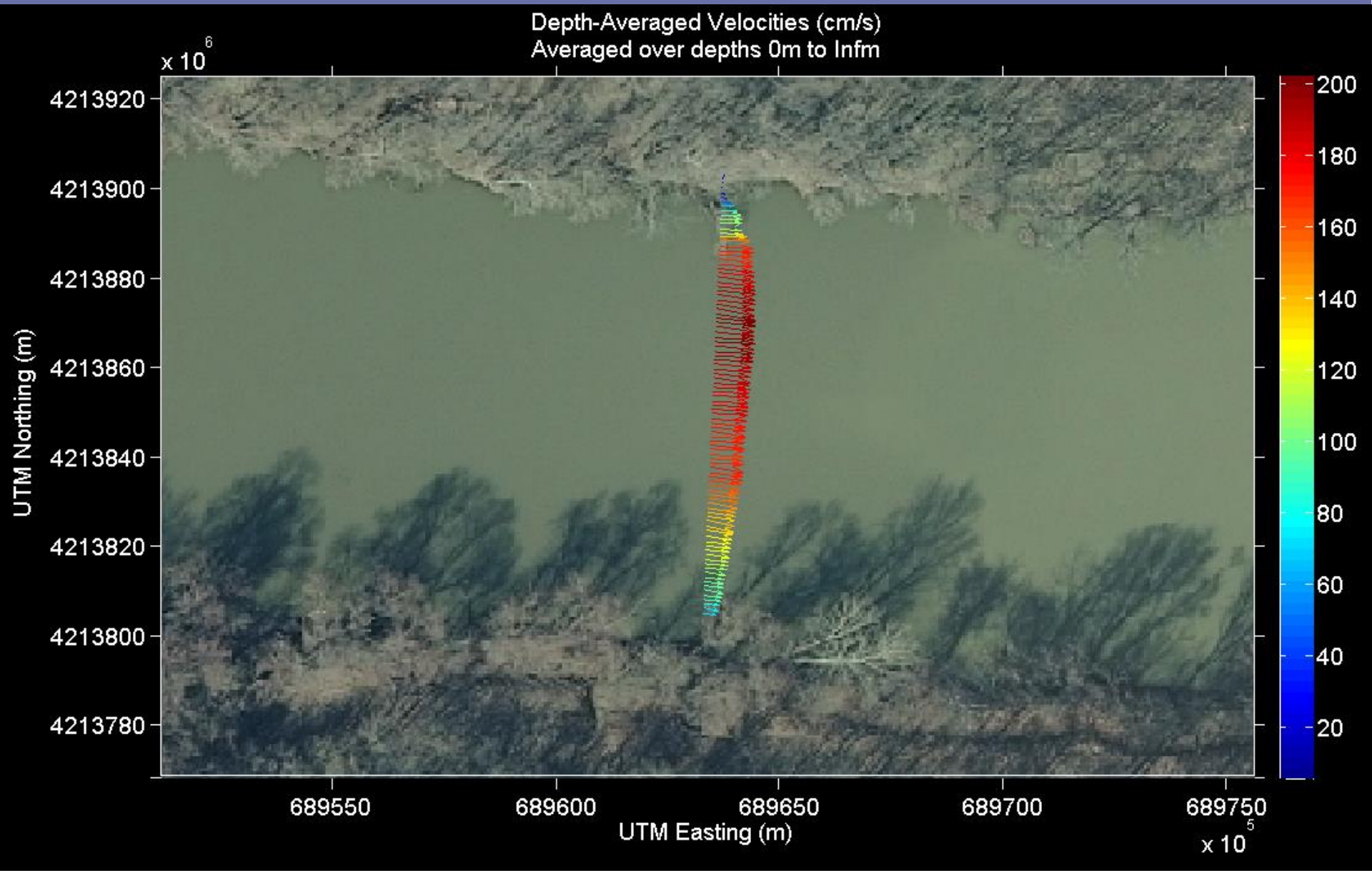


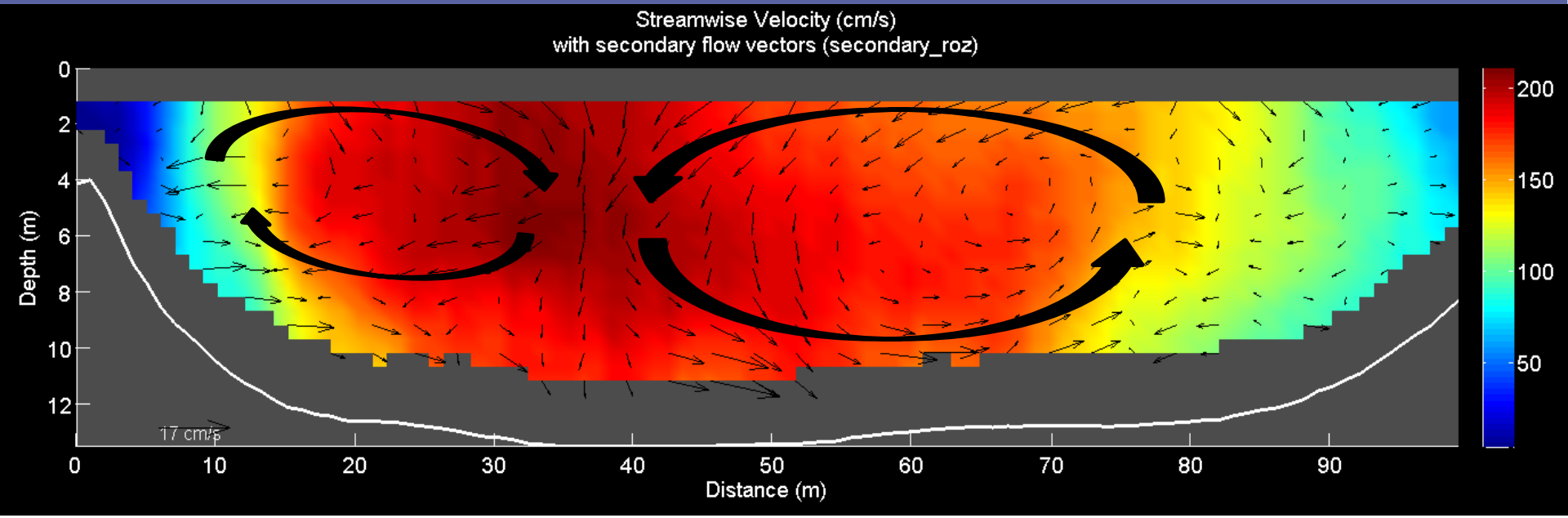
February 2, 2014

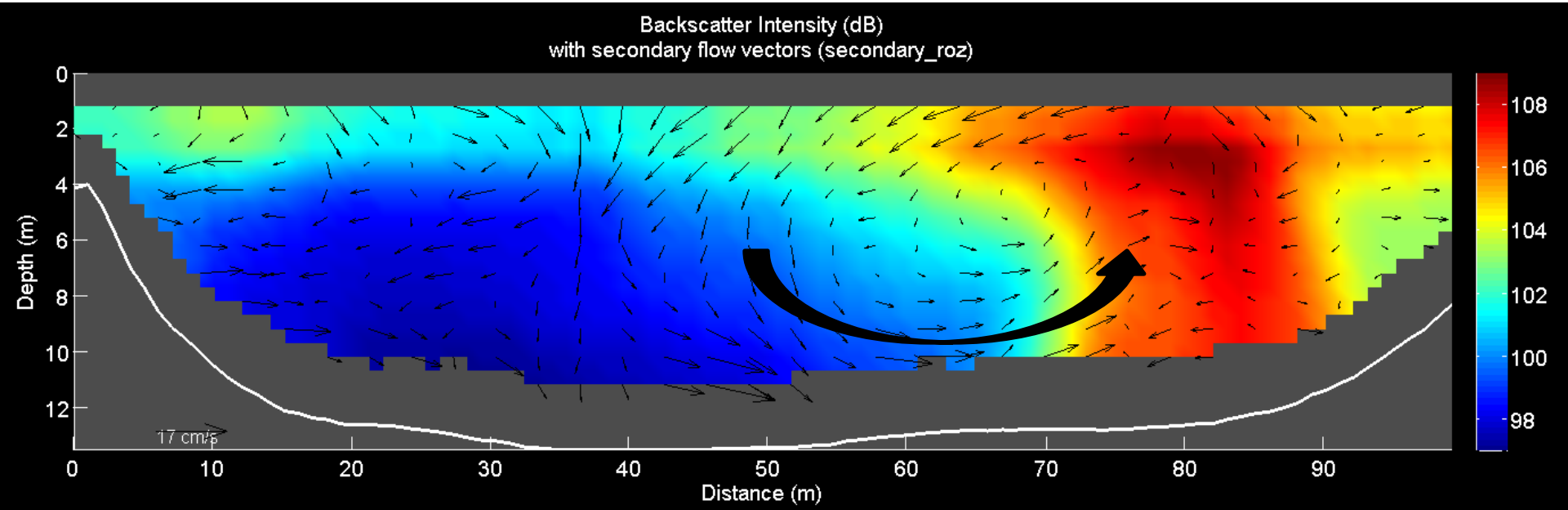
Qm = 63,100 cfs (very high flow)

Measurement section in a straight reach between two meander bends.

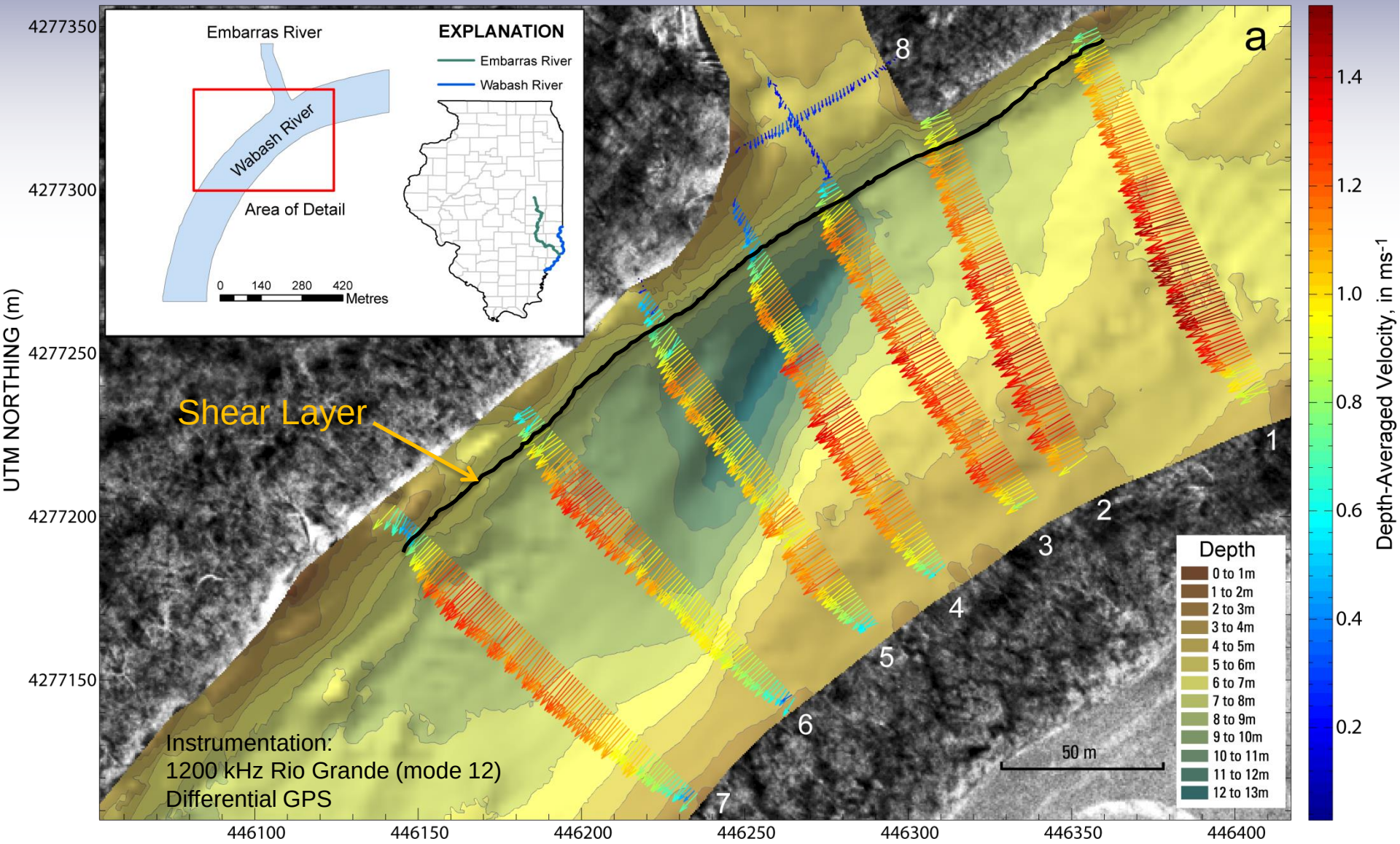
FLOW

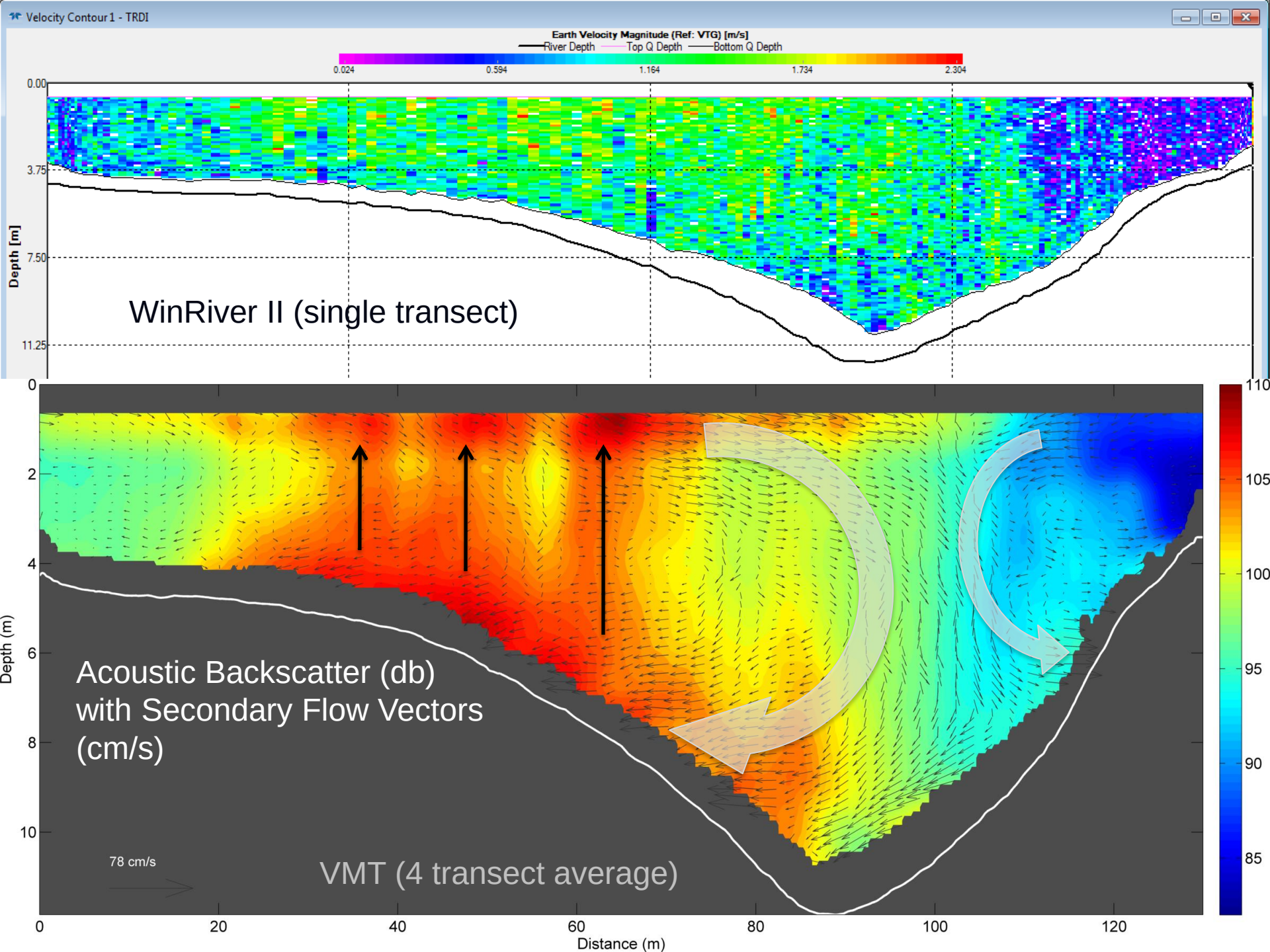

Depth-Averaged Velocities (cm/s)
Averaged over depths 0m to Infm
x 10^6
4213920
4213900
4213880
4213860
4213840
4213820
4213800
4213780
UTM Northing (m)
689550
689600
689650
689700
689750
UTM Easting (m)
x 10^5
200
180
160
140
120
100
80
60
40
20

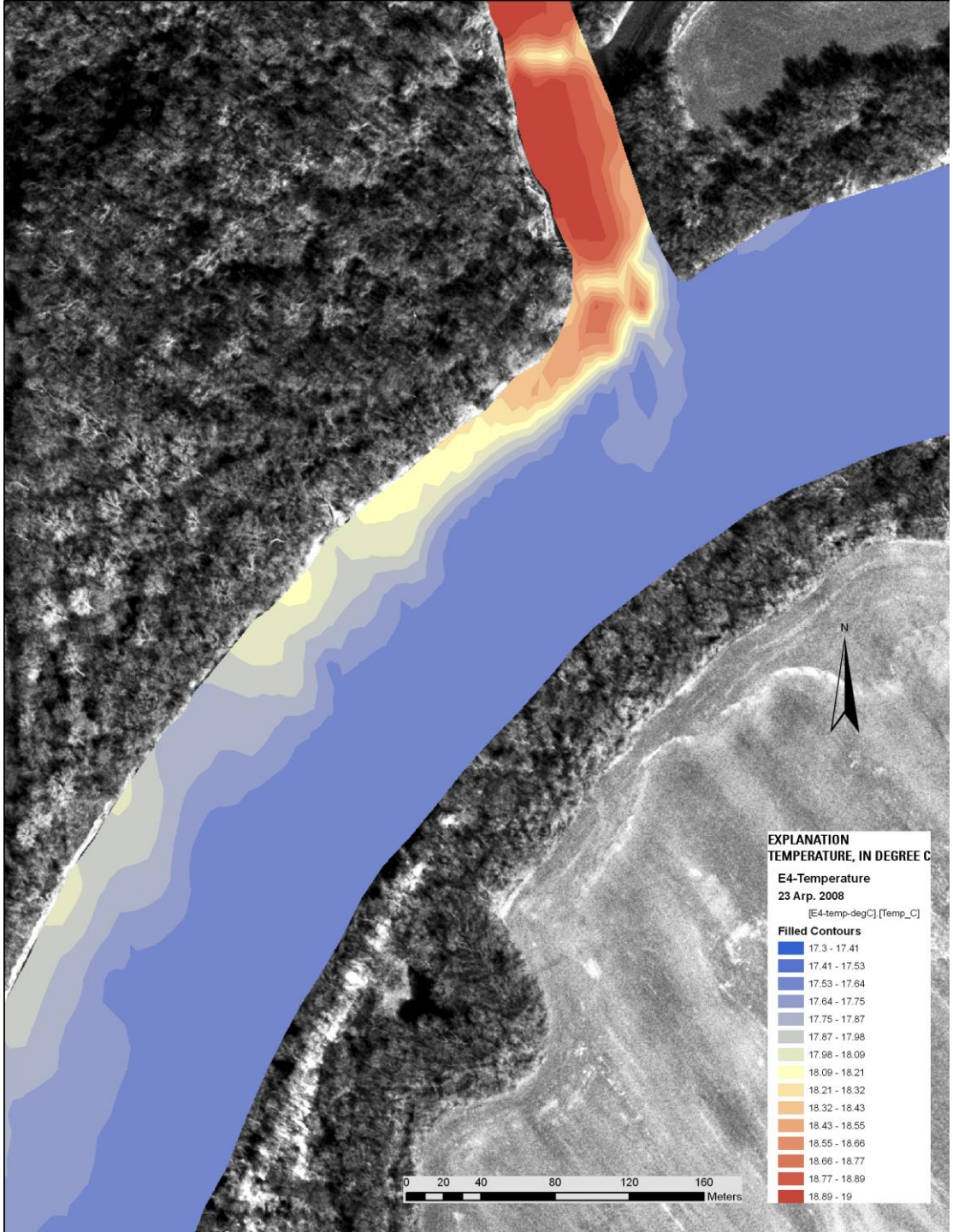

Streamwise Velocity (cm/s)
with secondary flow vectors (secondary_roz)
Depth (m)
Distance (m)
17 cm/s
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
200
150
100
50


Backscatter Intensity (dB)
with secondary flow vectors (secondary_roz)
Depth (m)
Distance (m)
17 cm/s
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
108
106
104
102
100
98

Example #3: Wabash-Embarras Confluence



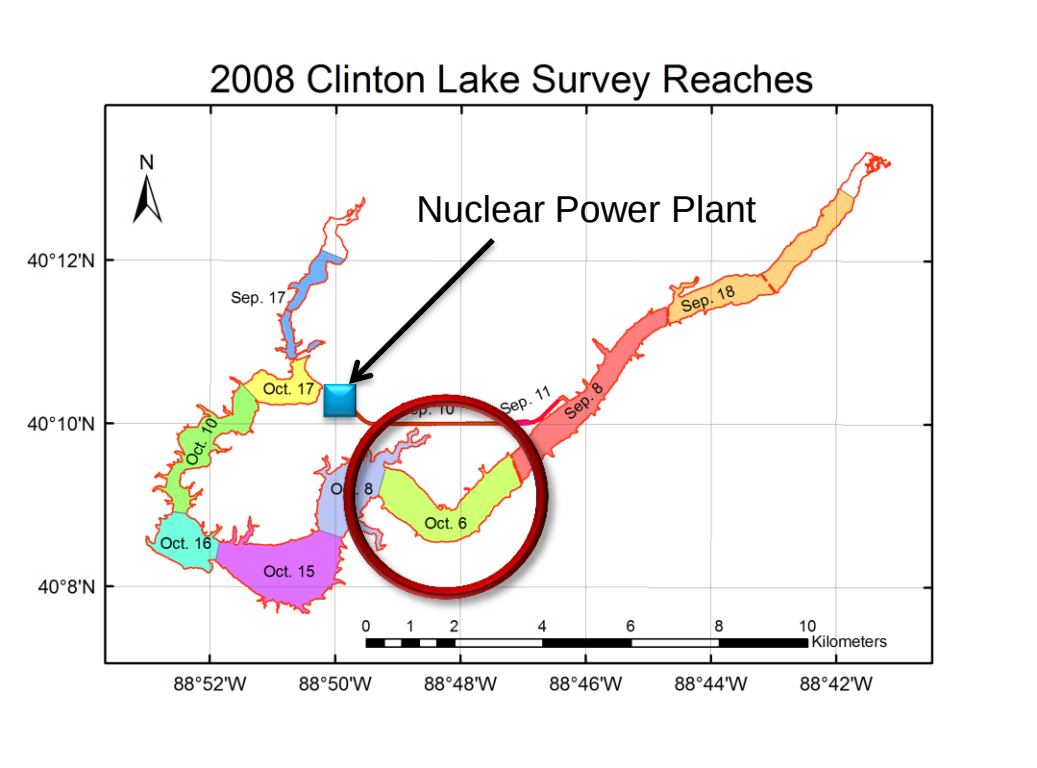

Velocity Contour 1 - TRDI
Earth Velocity Magnitude (Ref: VTG) [m/s]
River Depth
Top Q Depth
Bottom Q Depth
0.024
0.594
1.164
1.734
2.304
Depth [m]
0.00
3.75
7.50
11.25
WinRiver II (single transect)
Depth (m)
Distance (m)
Acoustic Backscatter (db)
with Secondary Flow Vectors
(cm/s)
78 cm/s
VMT (4 transect average)


N
EXPLANATION
TEMPERATURE, IN DEGREE C
E4-Temperature
23 Arp. 2008
[E4-temp-degC].[Temp_C]
Filled Contours
17.3 - 17.41
17.41 - 17.53
17.53 - 17.64
17.64 - 17.75
17.75 - 17.87
17.87 - 17.98
17.98 - 18.09
18.09 - 18.21
18.21 - 18.32
18.32 - 18.43
18.43 - 18.55
18.55 - 18.66
18.66 - 18.77
18.77 - 18.89
18.89 - 19
0 20 40 80 120 160
Meters

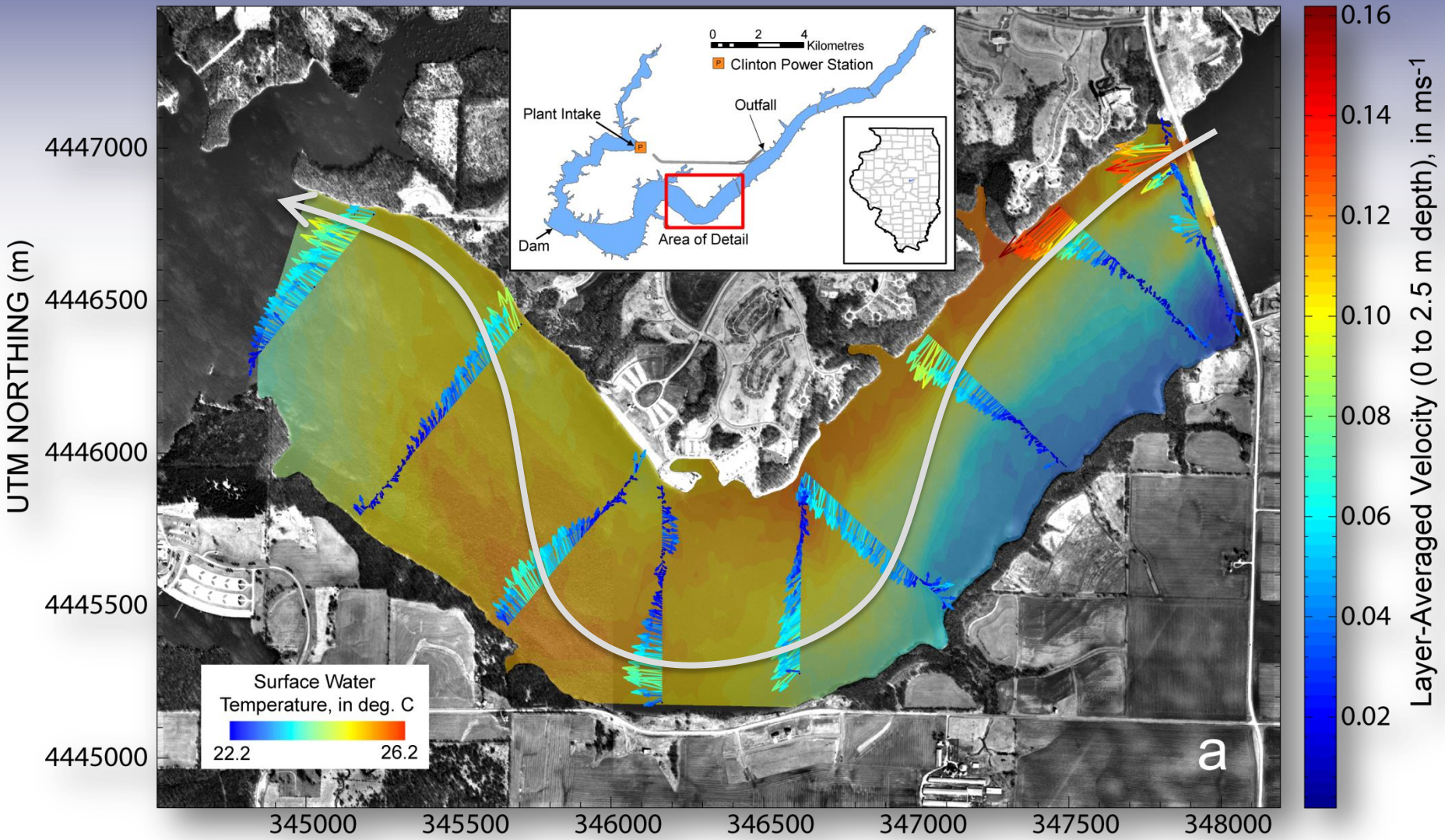
Example #4: Lake Circulation

Clinton Lake

- 5,000 acre cooling reservoir for a nuclear power plant
- 2008 survey
  - Bathymetry
  - Velocity
  - Temperature



Clinton Lake (IL)



Instrumentation: 600 kHz Rio Grande ADCP
Mode 11
Differential GPS

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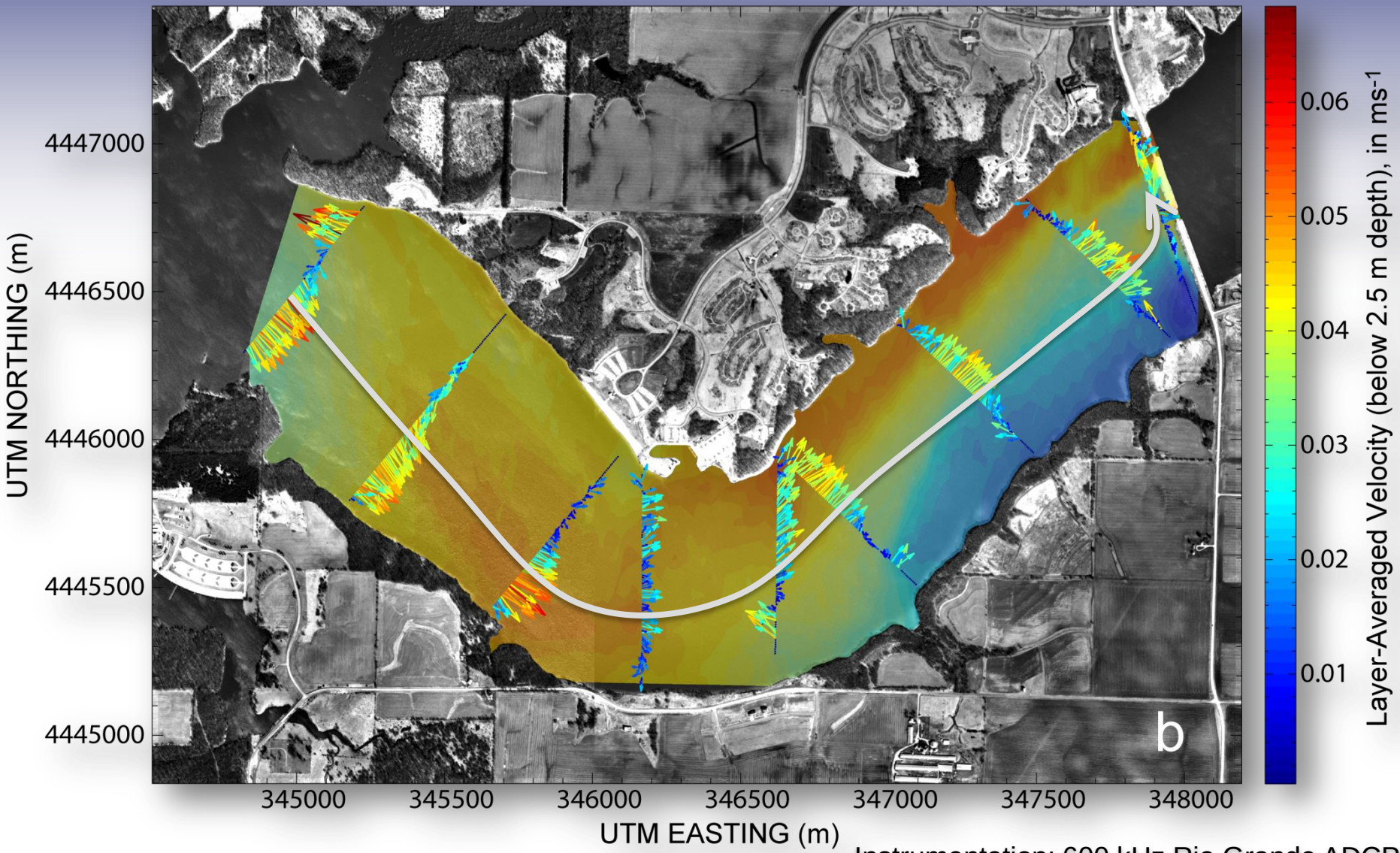
Clinton Lake (IL)



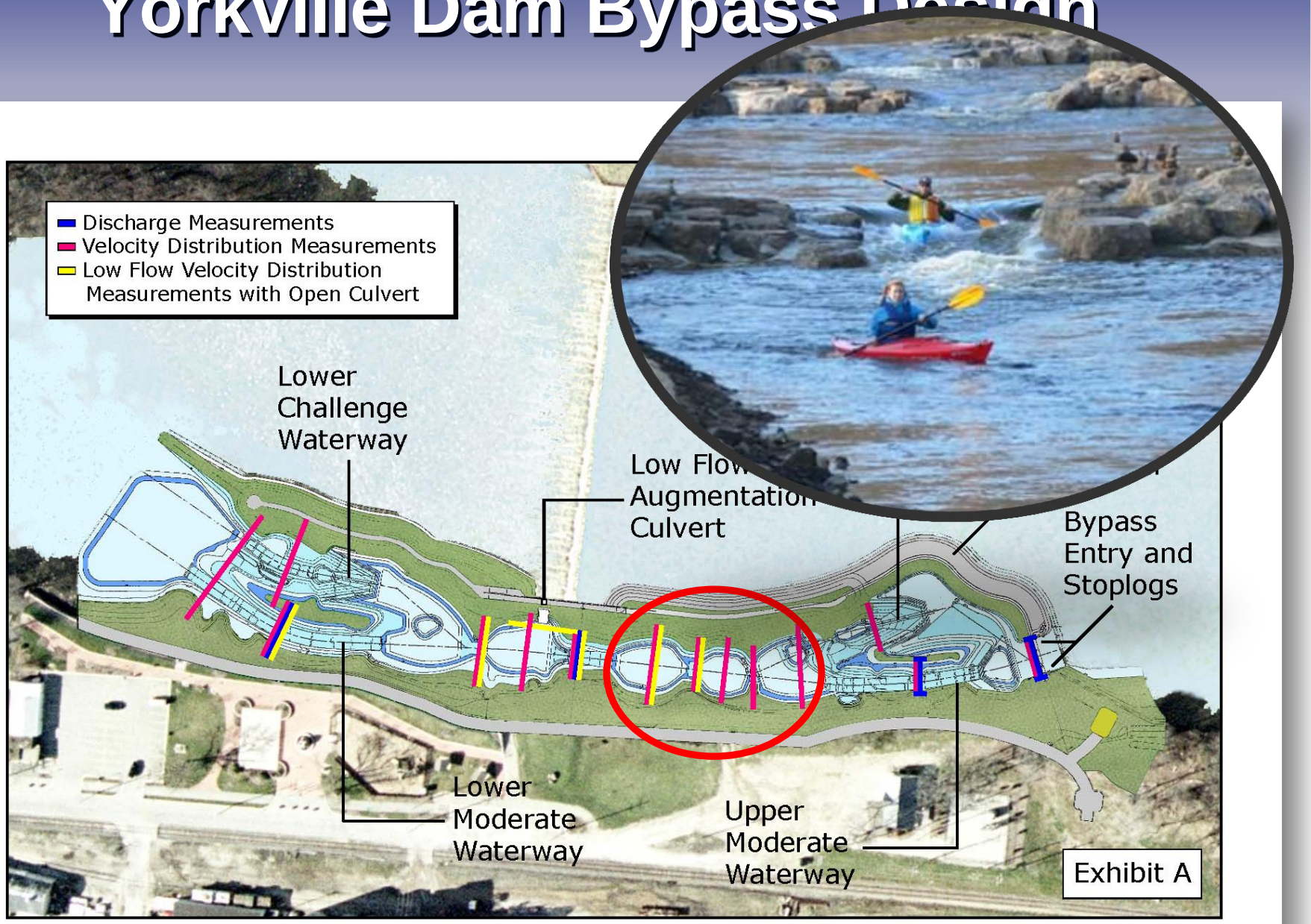
Instrumentation: 600 kHz Rio Grande ADCP
Mode 11
Differential GPS

Hydro Acoustics USGS

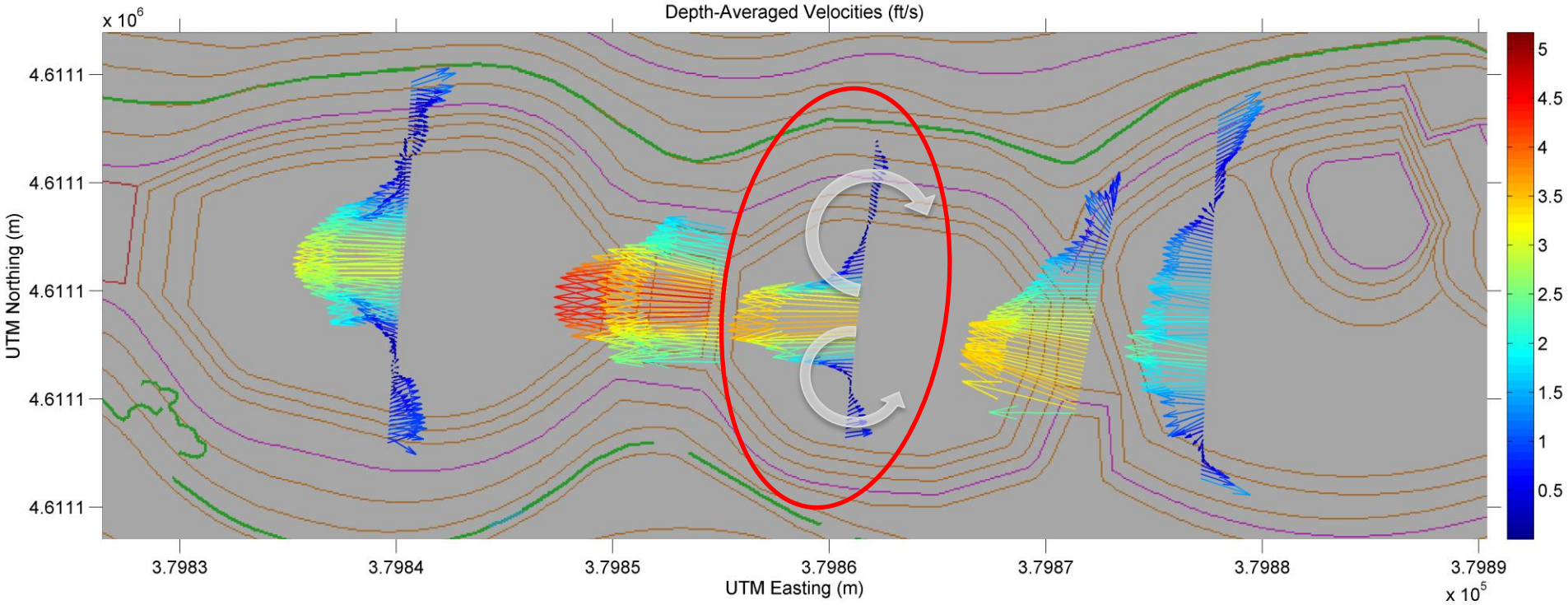
Example #5: Yorkville Bypass (Fox River, Illinois)

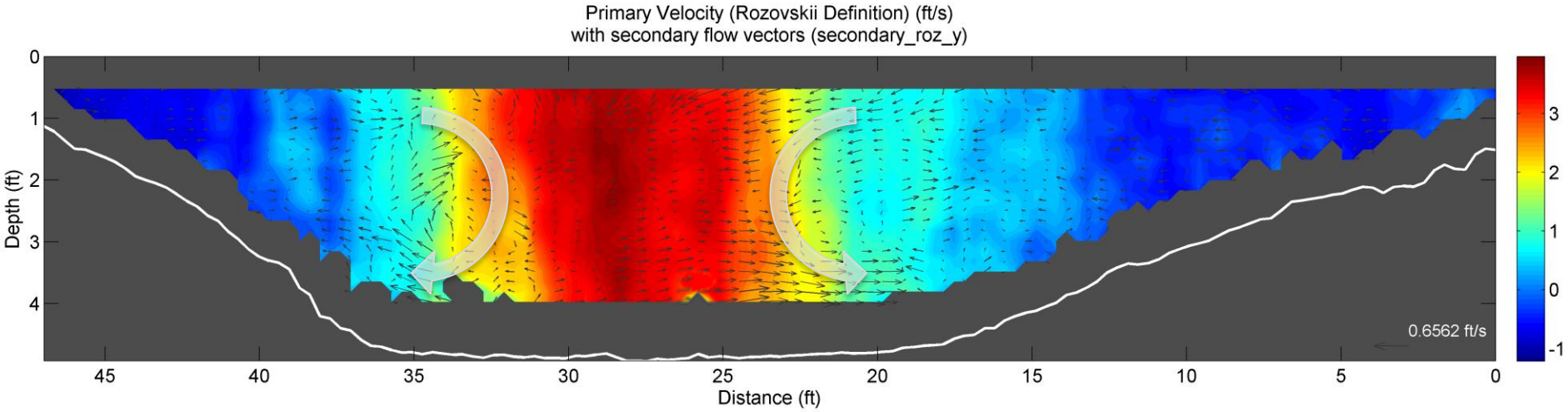
- Yorkville Dam Problems:
  - Public Safety
  - Fish Passage
  - Boat Passage

Yorkville Dam Bypass Design



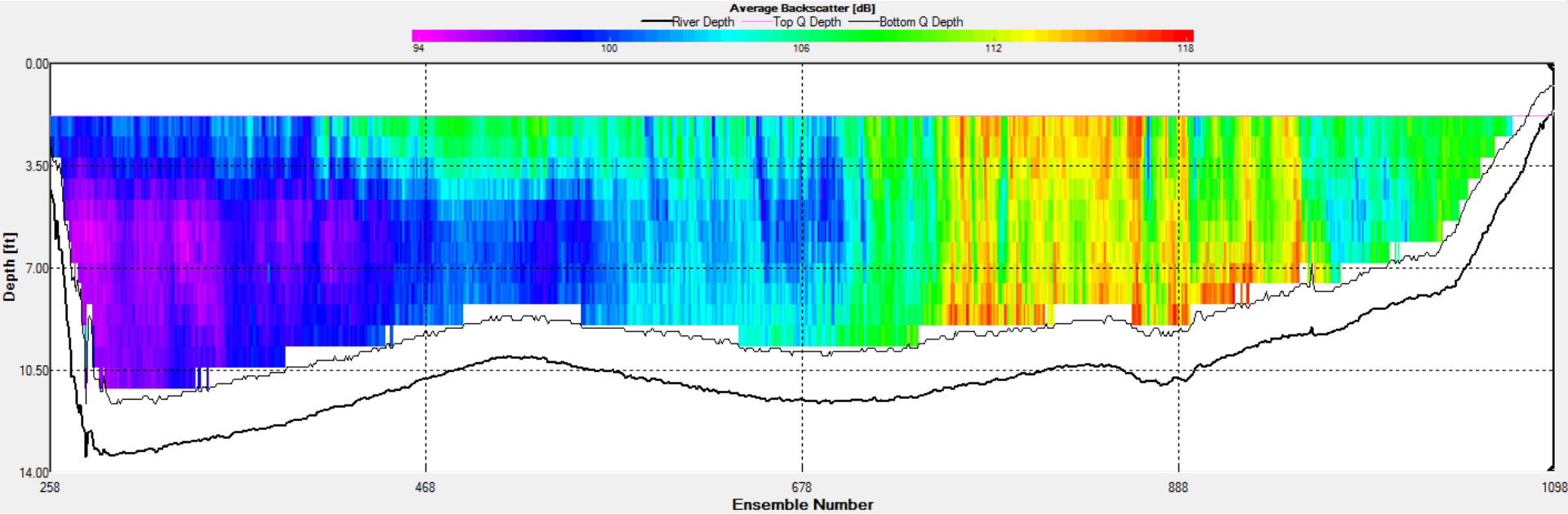
23 2:37 PM


Depth-Averaged Velocities (ft/s)
x 10^6
4.6111
4.6111
4.6111
4.6111
4.6111
UTM Northing (m)
3.7983
3.7984
3.7985
3.7986
3.7987
3.7988
3.7989
UTM Easting (m)
x 10^5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5


Primary Velocity (Rozovskii Definition) (ft/s)
with secondary flow vectors (secondary_roz_y)
Depth (ft)
0
1
2
3
4
45
40
35
30
25
20
15
10
5
0
Distance (ft)
0.6562 ft/s
3
2
1
0
-1

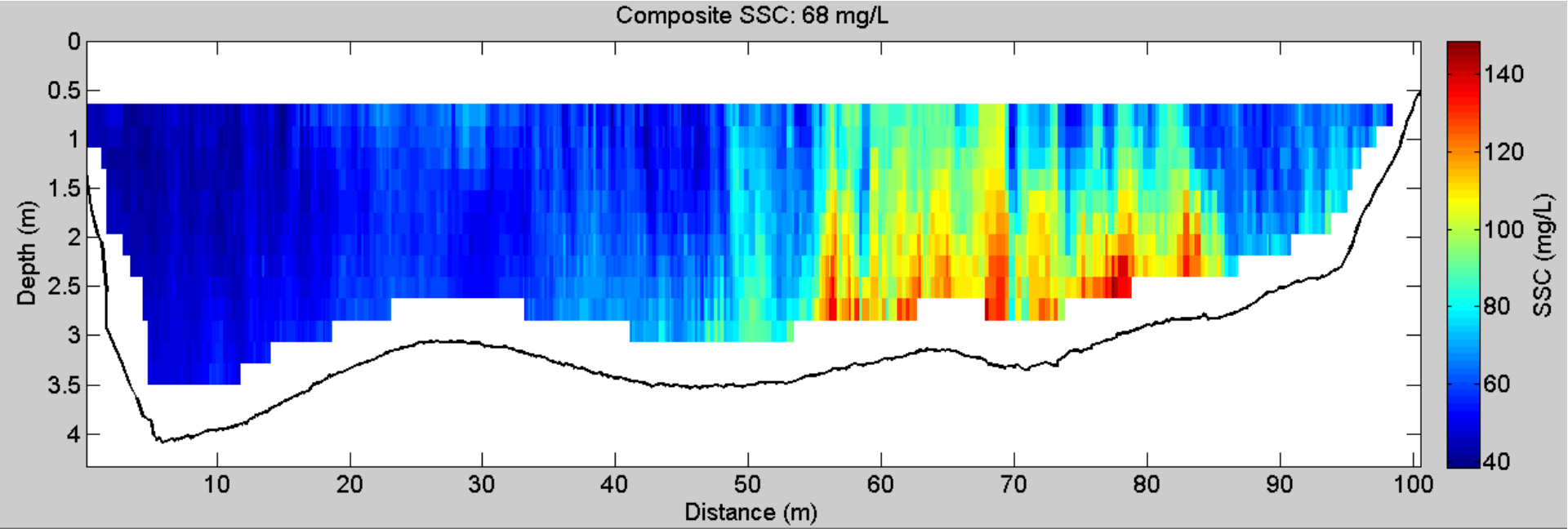
Cowlitz River at Castle Rock, WA – 3/24/2014

Measured Backscatter (dB)



Suspended Sediment Concentration (mg/L)

EDI = 71.4 mg/L



THANK YOU for being our cooperators!

Questions?

Contact Info:

Justin Boldt
U.S. Geological Survey
jboldt@usgs.gov
502-493-1931

An Incomplete List of Application Sites

1 Congo River (DRC, Africa)
2 Mississippi River (IL, MO, LA, MS)
3 Missouri River (MO)
4 Ohio River (IL, KY)
5 Chicago Sanitary and Ship Canal (IL)
6 Chicago Lakefront (Lake Michigan) (IL)
7 Lake Erie at Villa Angela Beach (OH)
8 Milwaukee River (WI)
9 Menomonee River (WI)
10 Kinnickinnic River (WI)
11 Green Bay (WI)
12 Manitowoc River (WI)
13 Sandusky River (OH)
14 Maumee River (OH)
15 Clinton Lake (IL)
16 Wonder Lake (IL)
17 Wabash River (IL, IN)
18 Embarras River (IL)
19 Hurunui River (New Zealand)
20 Clutha River (New Zealand)
21 Vermillion River (IL)
22 Boise River (ID)
23 Kootenai River (ID)
24 White River (IN)
25 Cal-Sag Channel (IL)
26 Lake Calumet (IL)
27 Yellow Sea (China)
28 Yellow River (China)
29 Parana River (Argentina)
30 Rio Coronda (Argentina)
31 Madeira River (Brazil)
32 Fox River (IL)
33 Arkansas River (AR)
34 Cowlitz River (WA)
35 Umqua River (OR)
36 St. Lawrence River (Canada)
37 Des Plaines River (IL)
38 Illinois River (IL)
39 Little Calumet River (IL)
40 Fraser River (BC, Canada)
41 St. Clair River (MI, Canada)
42 Big Muddy Creek (IL)
43 Little Wabash River (IL)
44 Yuma Canal (AZ)
45 Sacramento River (CA)
46 New Castle Reservoir (UT)
47 St. Marys River (MI, Canada)
48 Jordan River (UT)
49 All American Canal (AZ)
50 Coachella Canal (AZ)
51 Sangamon River (IL)
52 Columbia River (WA, OR)
53 Snake River (WA)
54 Shepaug River (CT)
55 Susquehanna River (CT)
56 Lake Lillinonah (CT)
57 Patoka Lake (KY)
58 Rasmussen Lake (IL)
59 Colastine River (Argentina)
60 Fire Island Breach (NY)
61 Sugar Creek (IL)

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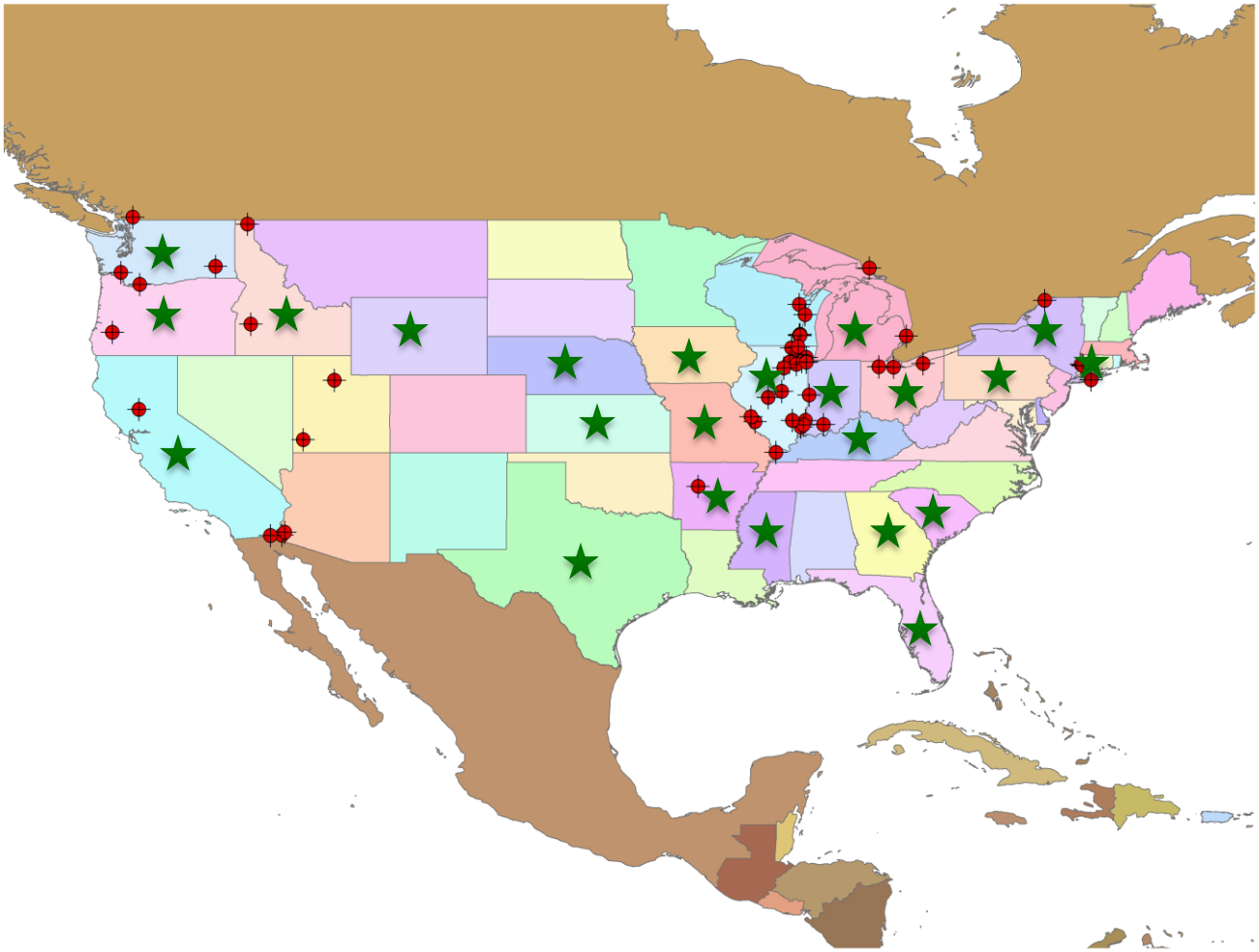
Known Applications in the U.S.



- ★ States with trained users (attended a class)
- ● Application Sites

Hydro Acoustics USGS