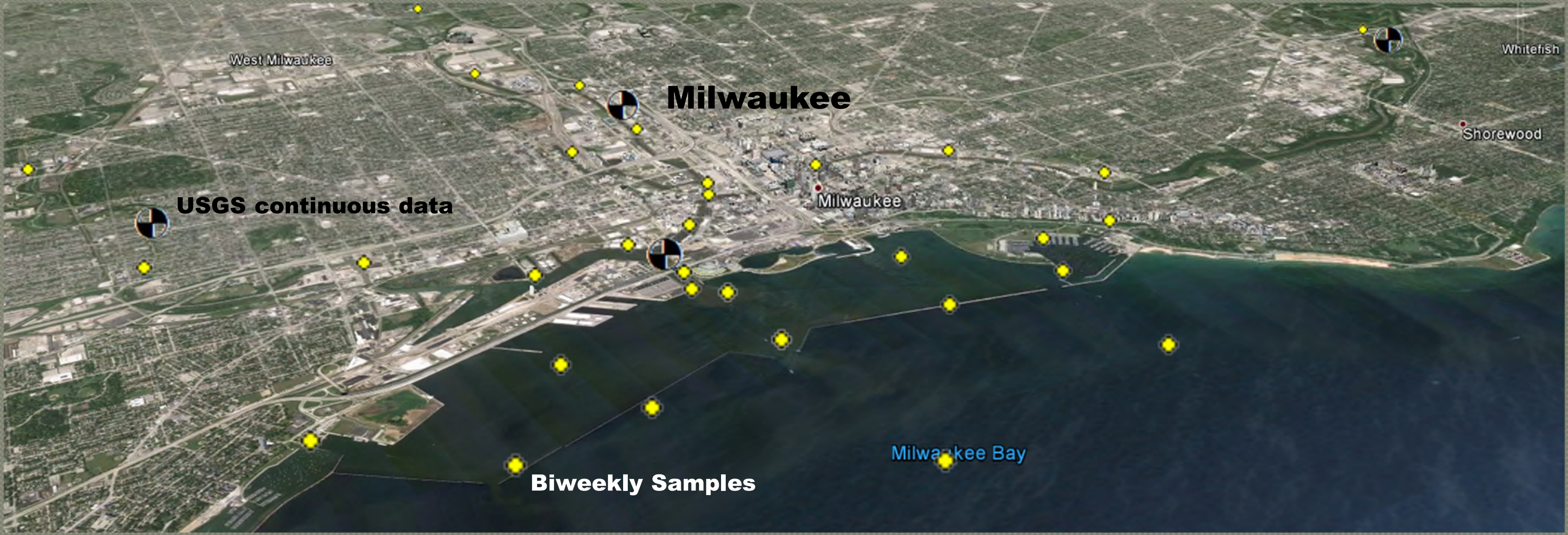
Results from a National Monitoring Network Lake Michigan Pilot Study:

Integrated surveys of water quality and hydrodynamics in rivermouth mixing zones using an autonomous underwater vehicle



P. Ryan Jackson
USGS Illinois Water Science Center
Paul Reneau
USGS Wisconsin Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

National Monitoring Network Lake Michigan Pilot Study

Objectives:

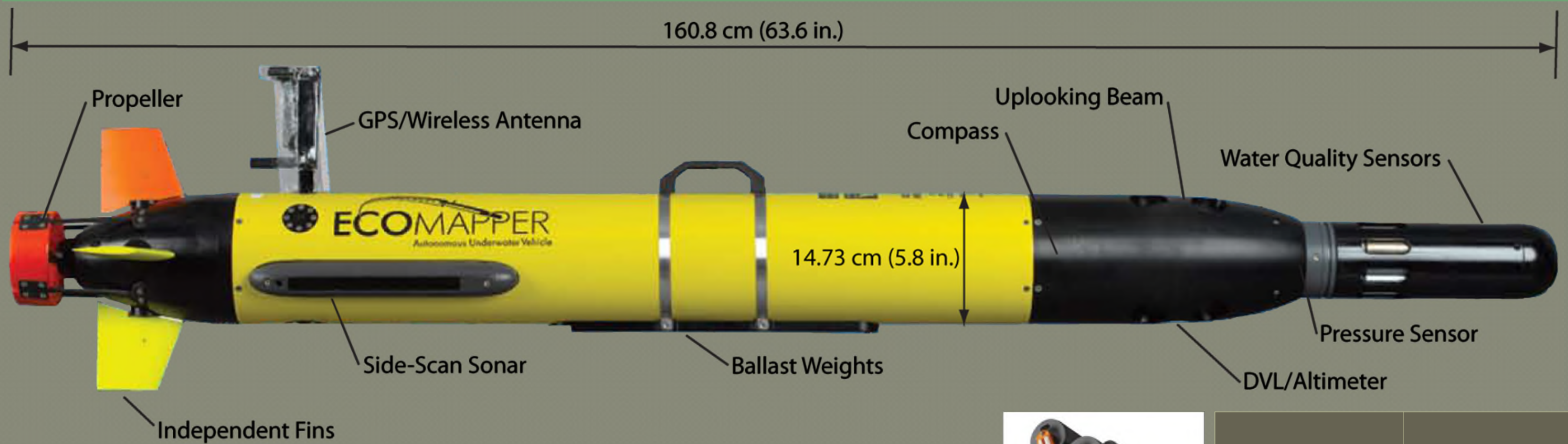
- Collect continuous water-quality data from the fluvial to the lacustrine zones of a rivermouth
- Bridge the gap between the last gage on a tributary and the nearshore sampling stations
- Examine the mixing, dispersion, and hydrodynamics within rivermouths
- Determine if synoptic surveys can be beneficial to continuous water-quality monitoring programs & modelers

Lake Michigan shoreline near Burns Ditch and Burns Harbor, Indiana

USGS

New Tools for Synoptic Mapping:

The Autonomous Underwater Vehicle (AUV)



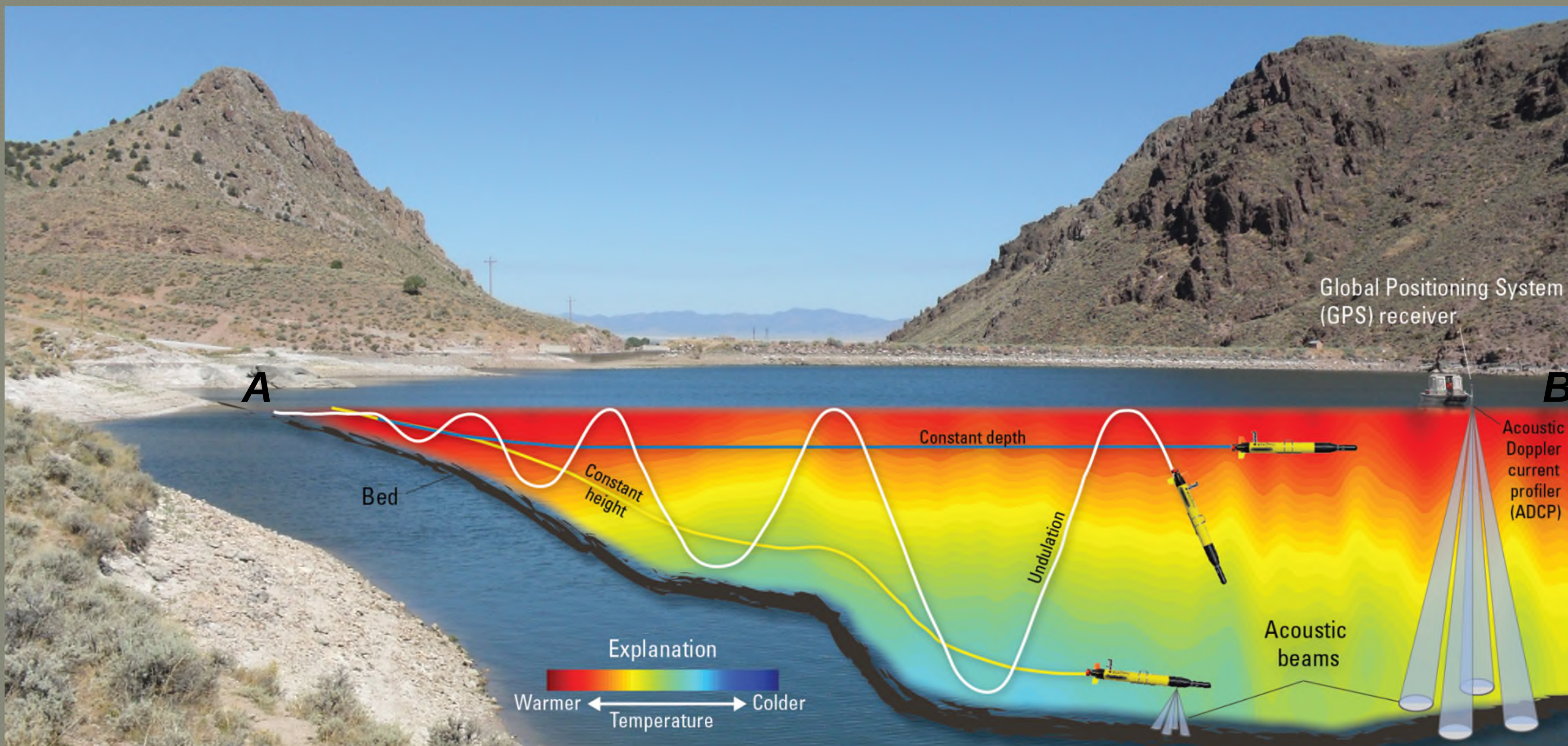
- 200 ft dive capability
- Full suite of water-quality sensors (right)
- 6-beam DVL/ADCP
  - Bottom tracking
  - Echo sounder
  - Current profiling
- Dual pressure sensors, multi-axis compass
- Imagenex 330/800 kHz side scan sonar
- Differential GPS

Water-quality sensor suite

Sensor	YSI #
Conductivity	6560FR
Temperature	6560FR
Depth	
Blue-green Algae	6131
Chlorophyll Fluorescence	6025
Dissolved Oxygen	6150FR
pH	6589FR
Rhodamine	6130
Turbidity	6136

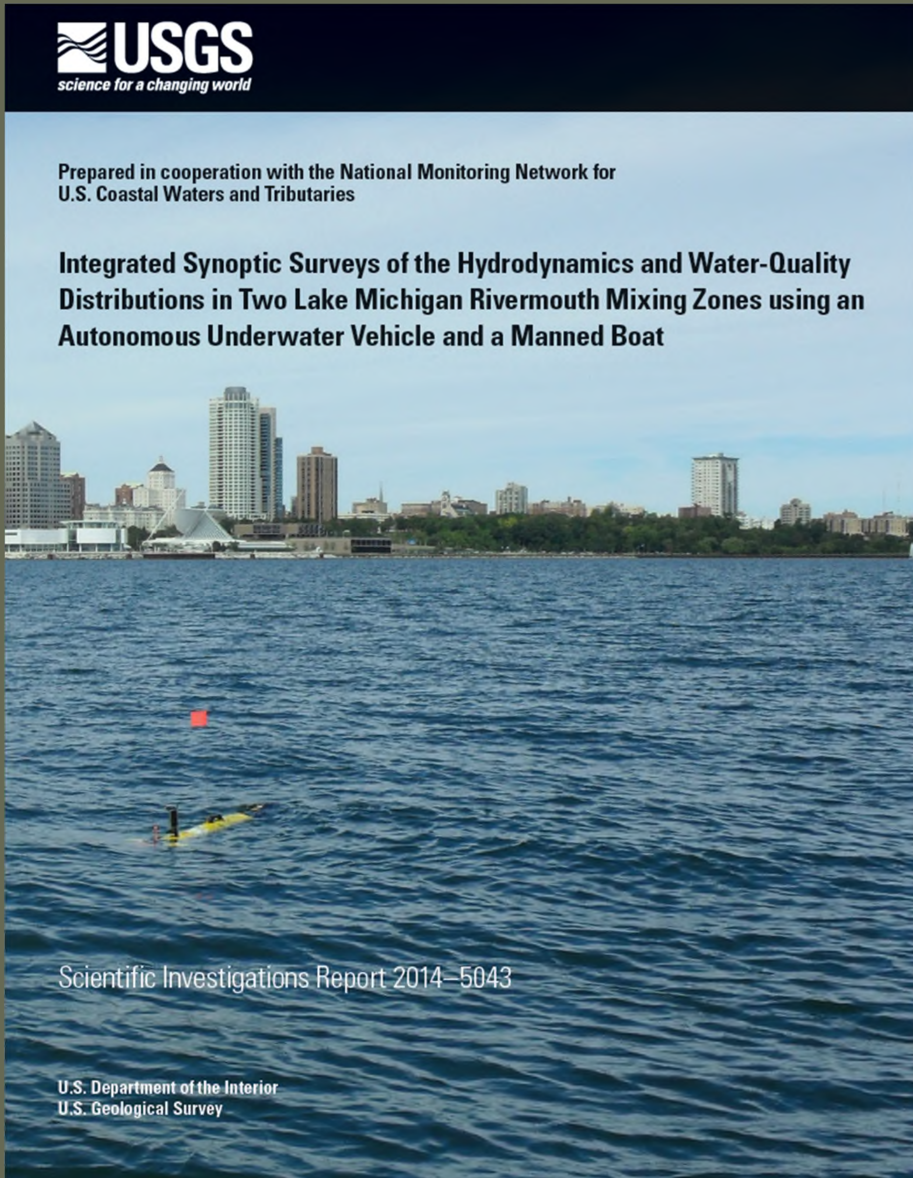
USGS

AUV Survey Methods



Newcastle Reservoir, Utah

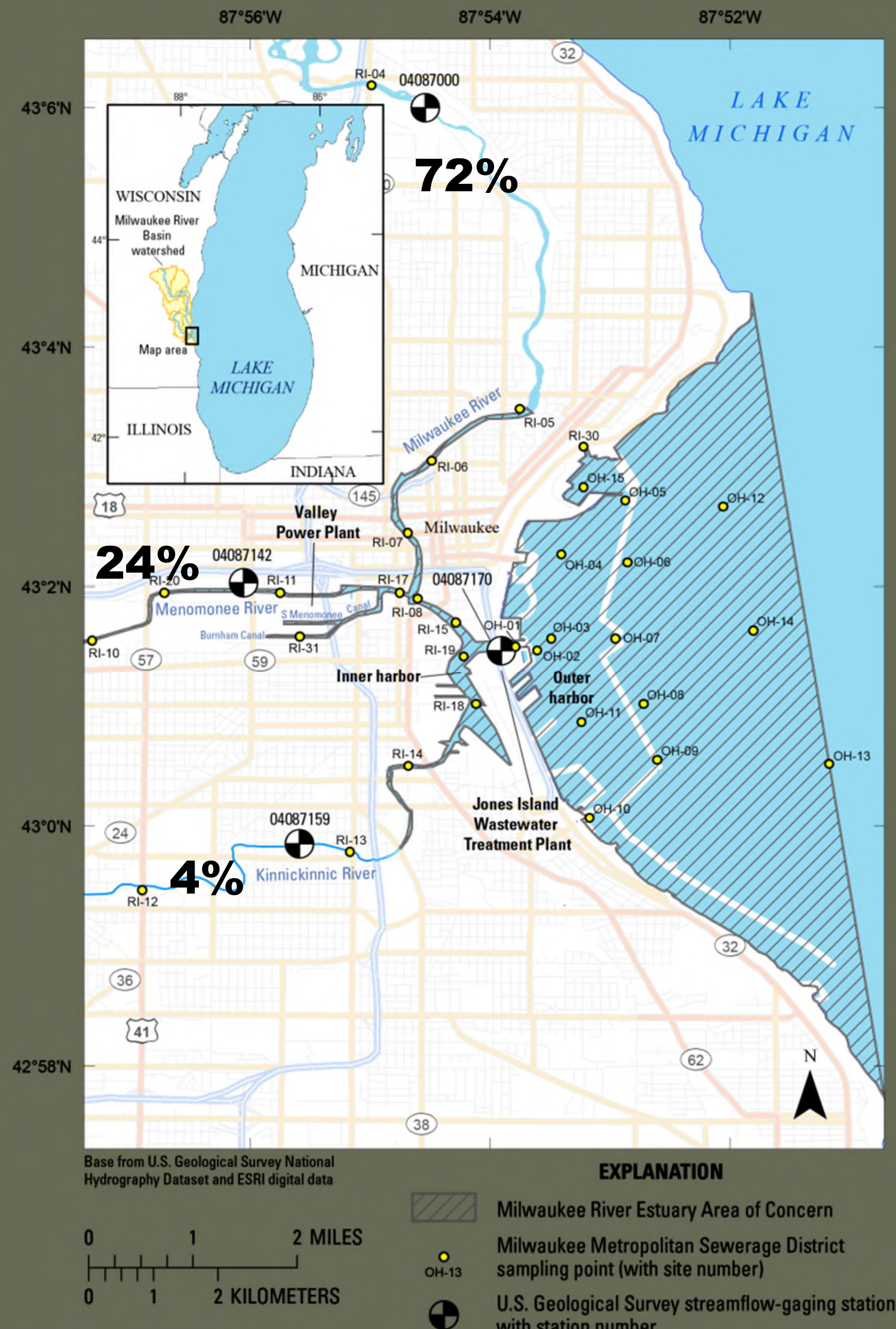
USGS



USGS Scientific Investigations Report 2014-5043

Application: Milwaukee River Estuary and AOC (WI)

National Monitoring Network
Lake Michigan Pilot Study



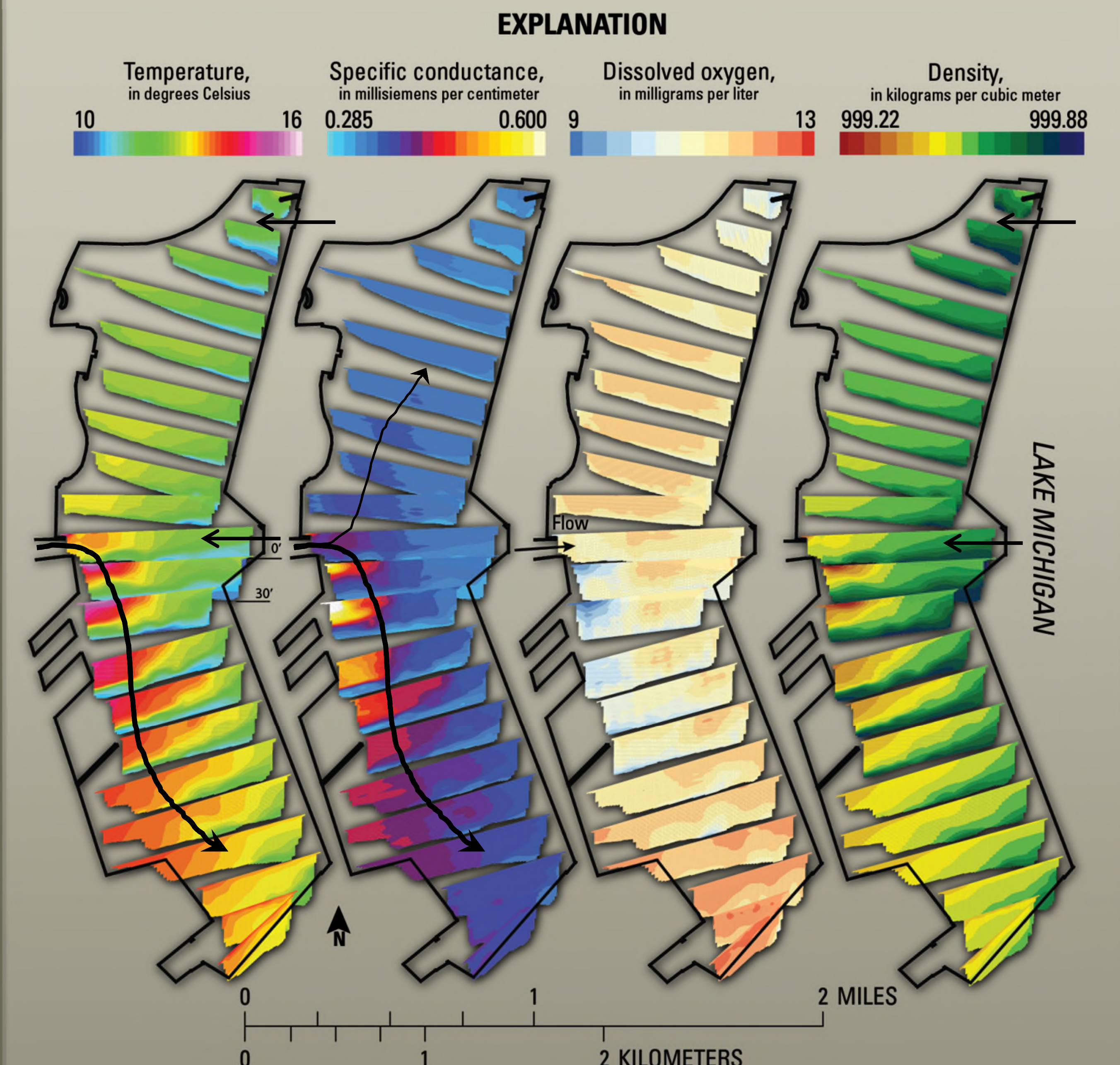
Milwaukee AOC

- 850 mi^2 drainage area
- Most populated basin that flows directly into Lake Michigan
- Three rivers converge
  - Milwaukee River (2010 AM 641 cfs)
  - Menomonee River (2010 AM 215.4 cfs)
  - Kinnickinnic River (2010 AM 32.5 cfs)
- Designated an Area of Concern (AOC) in 1987
  - Conventional contaminants (phosphorous and suspended solids)
  - Toxic contaminants (metals and organic chemicals)
- Industrial point sources
  - Valley Power Plant (~250 cfs)
  - Jones Island Wastewater Treatment Plant (~230 cfs)
- Subject to combined sewer overflows

USGS

Data Collection

- September 7-9, 2010
- Inner and outer harbors surveyed with the AUV in undulation mode
- Rivers surveyed with the manned boat
  - Profiles and discharge measurements at 16 stations
- All data compiled into an integrated dataset



Milwaukee Harbor, Milwaukee, WI

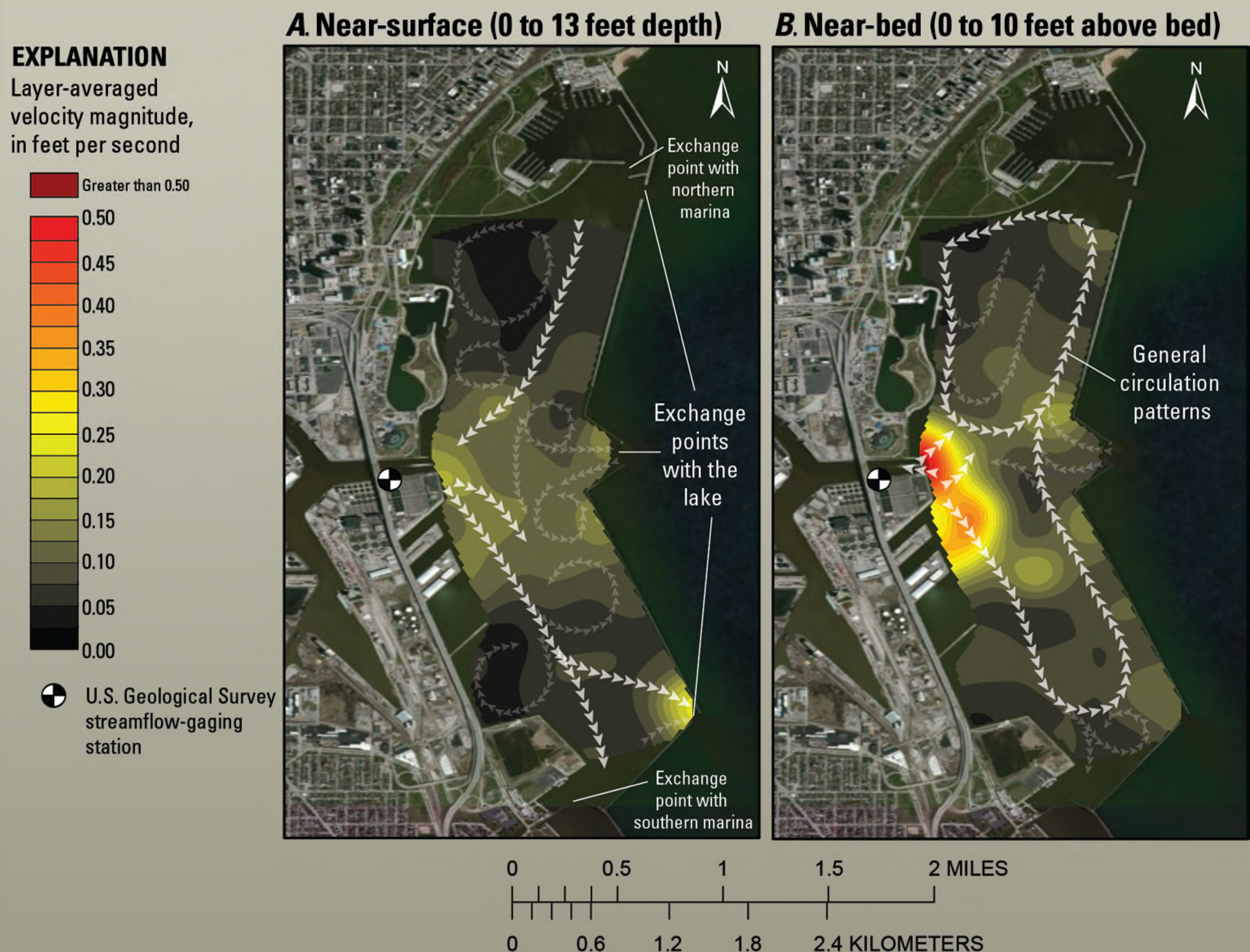
AUV survey September 9, 2010

Processed with custom Matlab® scripts and visualized in Tecplot®

Milwaukee Harbor, Milwaukee, WI

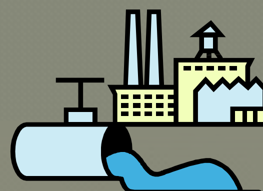
AUV and manned boat survey September 7-9, 2010

Currents

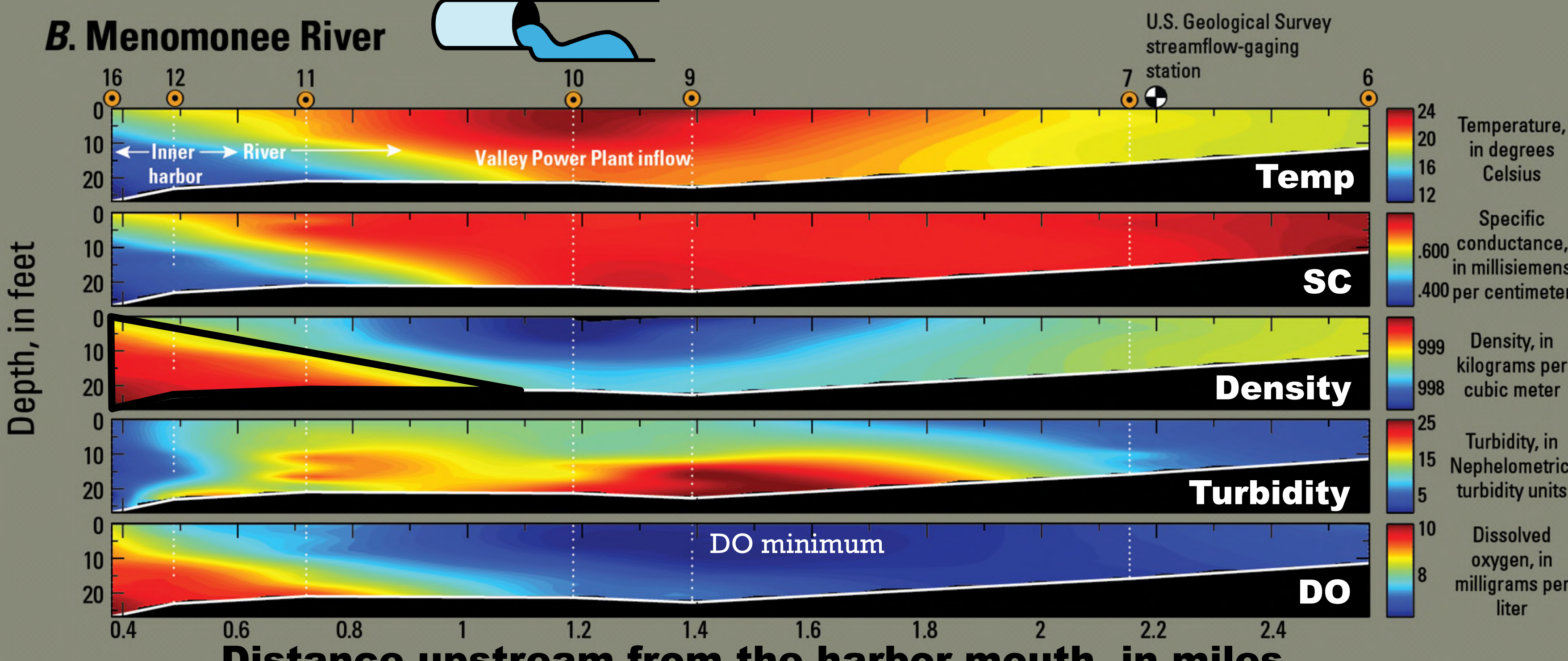


USGS

Menomonee River Section



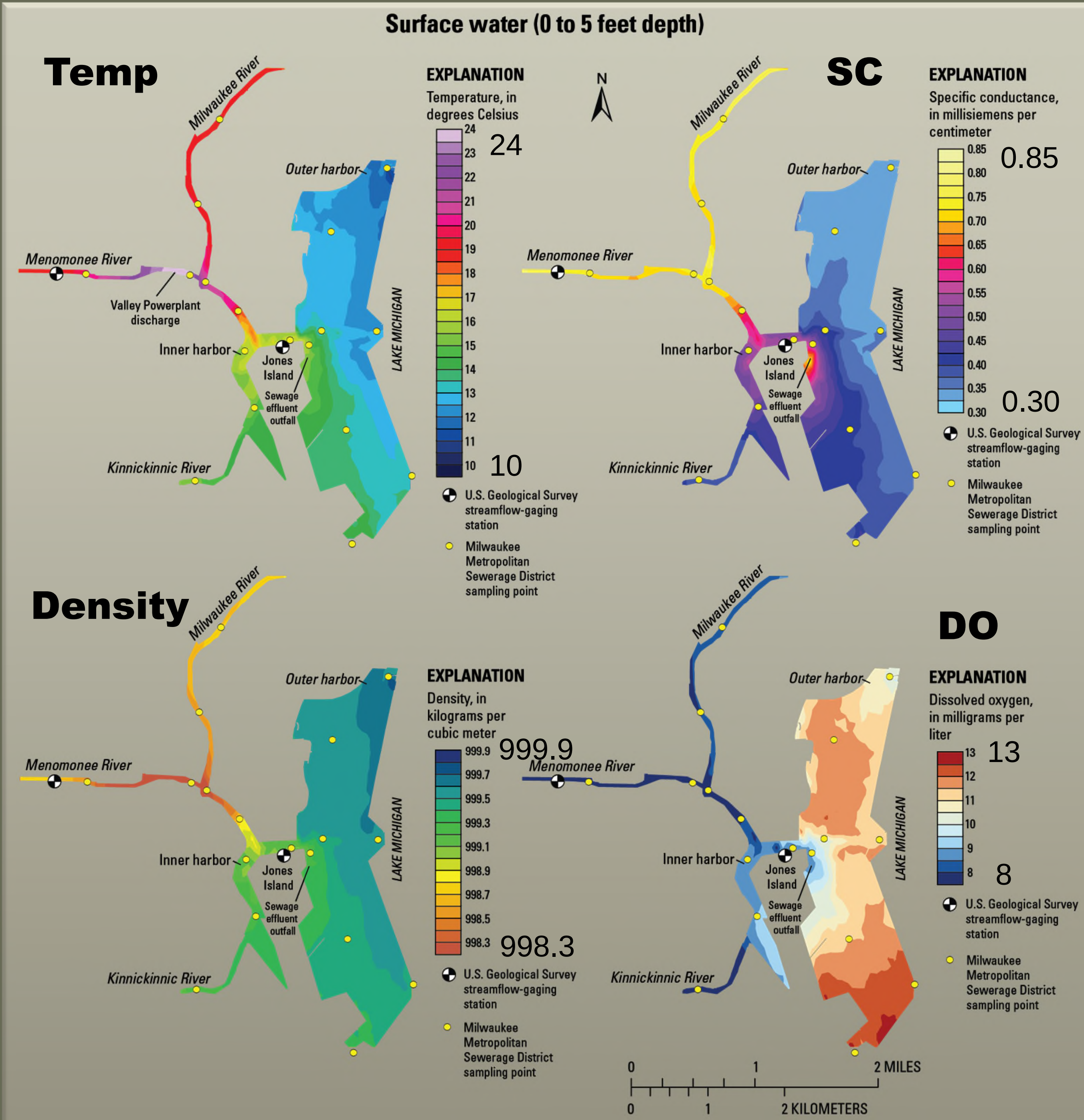
B. Menomonee River



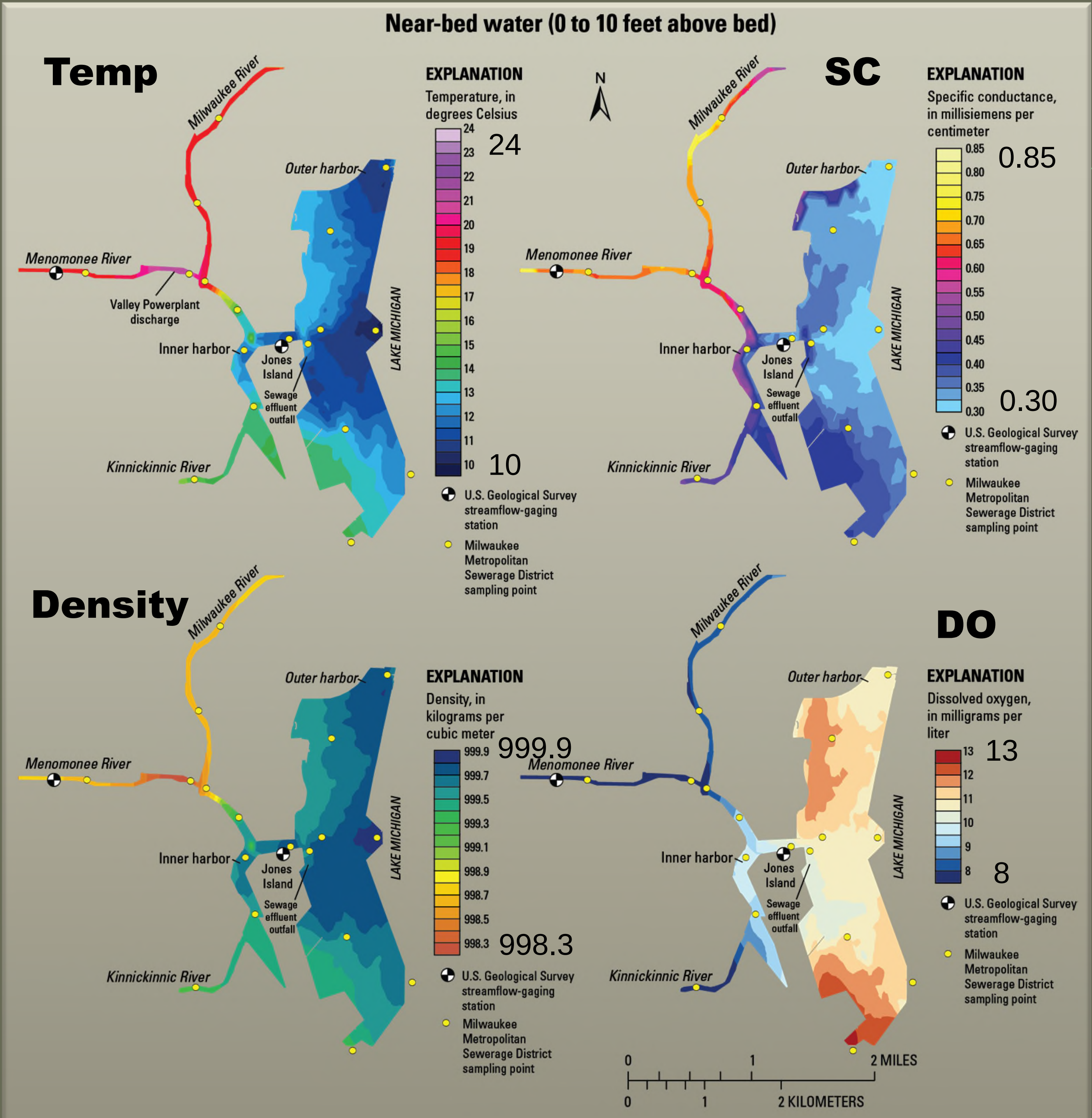
Lake water → **← River inflow**

Milwaukee River Estuary, Milwaukee, WI

AUV and manned boat survey September 7-9, 2010



Surface Water (0 – 5 ft)

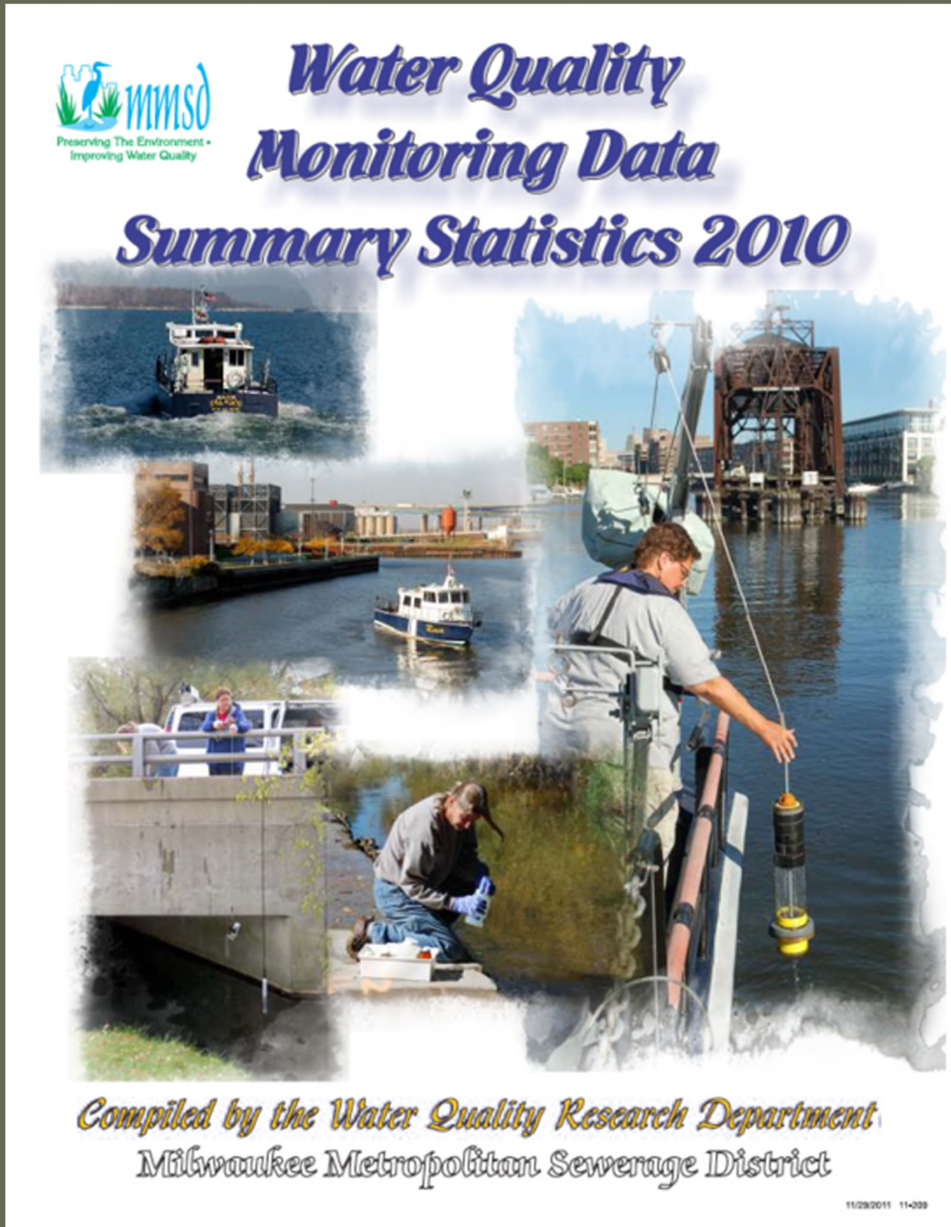


Milwaukee River Estuary, Milwaukee, WI

AUV and manned boat survey September 7-9, 2010

Bottom Water (0 – 10 ft above bed)

USGS



Can synoptic distributions help explain variations in point samples?

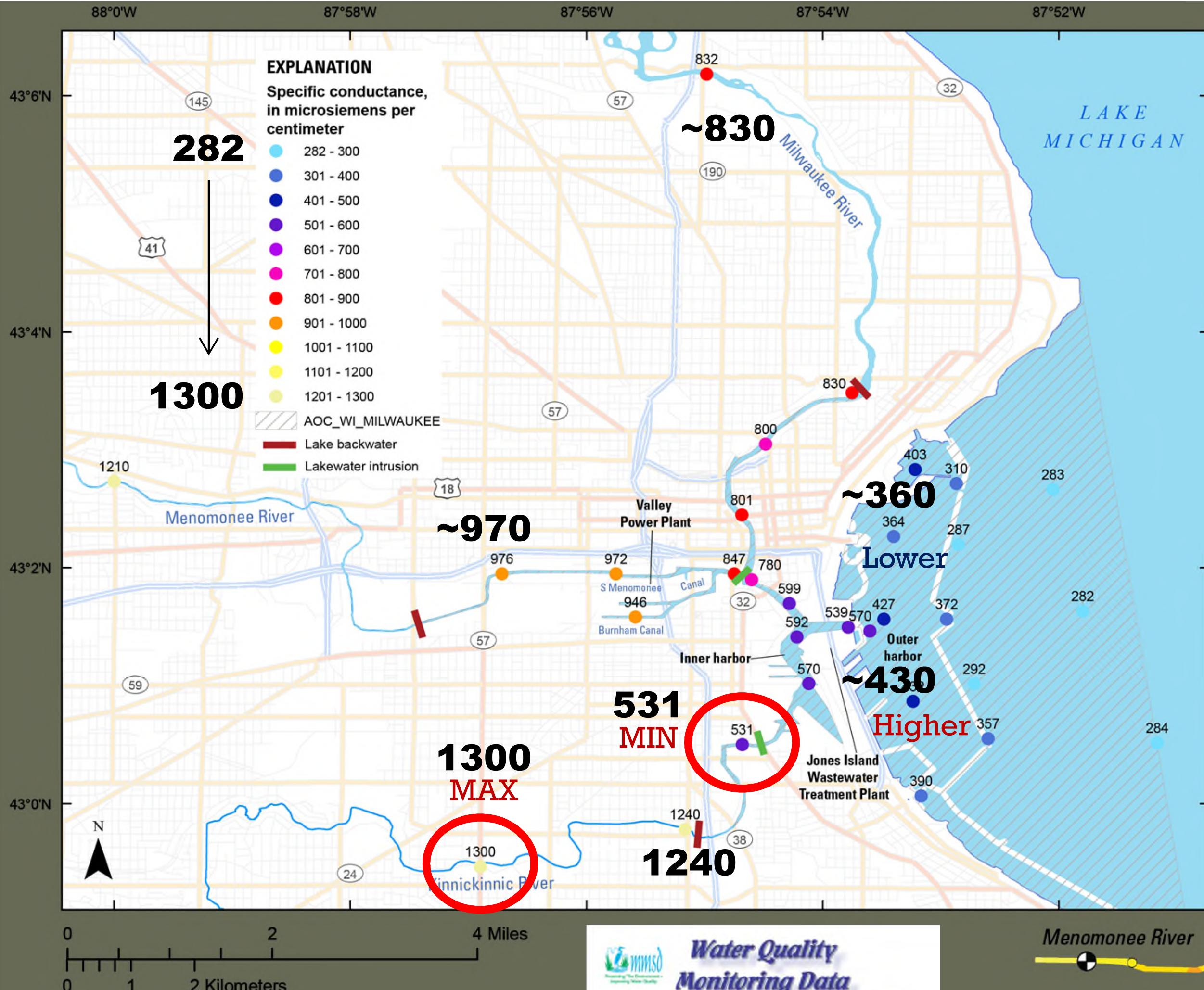
2010 Milwaukee Metropolitan Sewerage District monitoring data

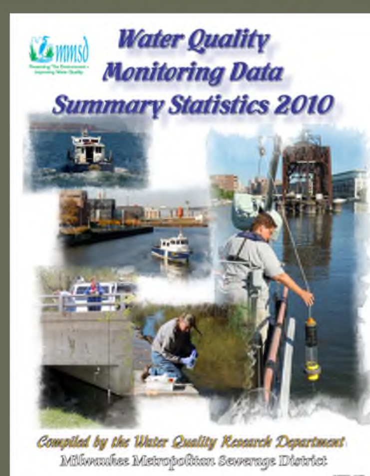
Yes.

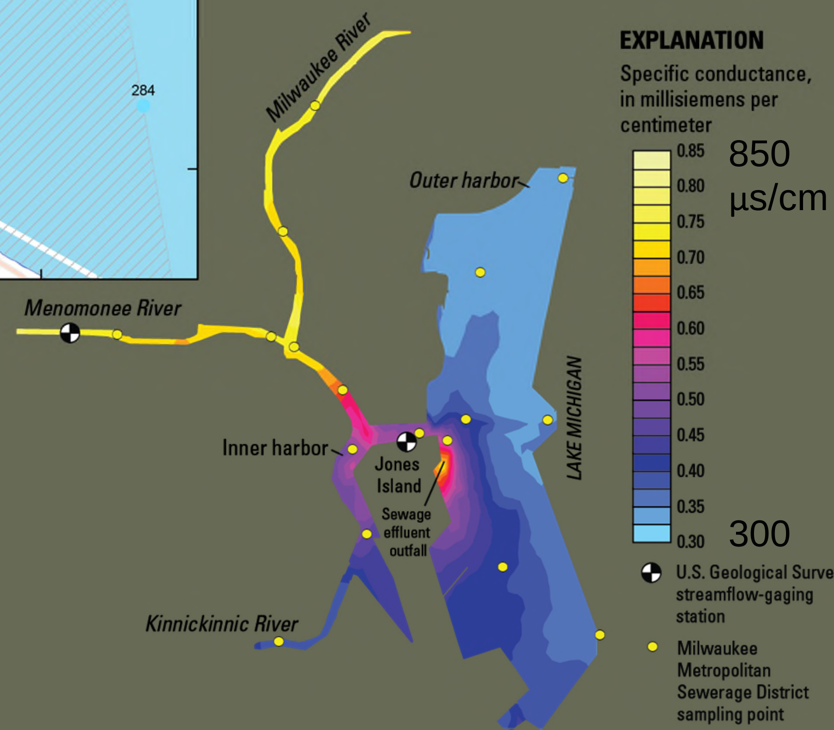
USGS

Specific Conductance

MMSD 2010 median vs. synoptic



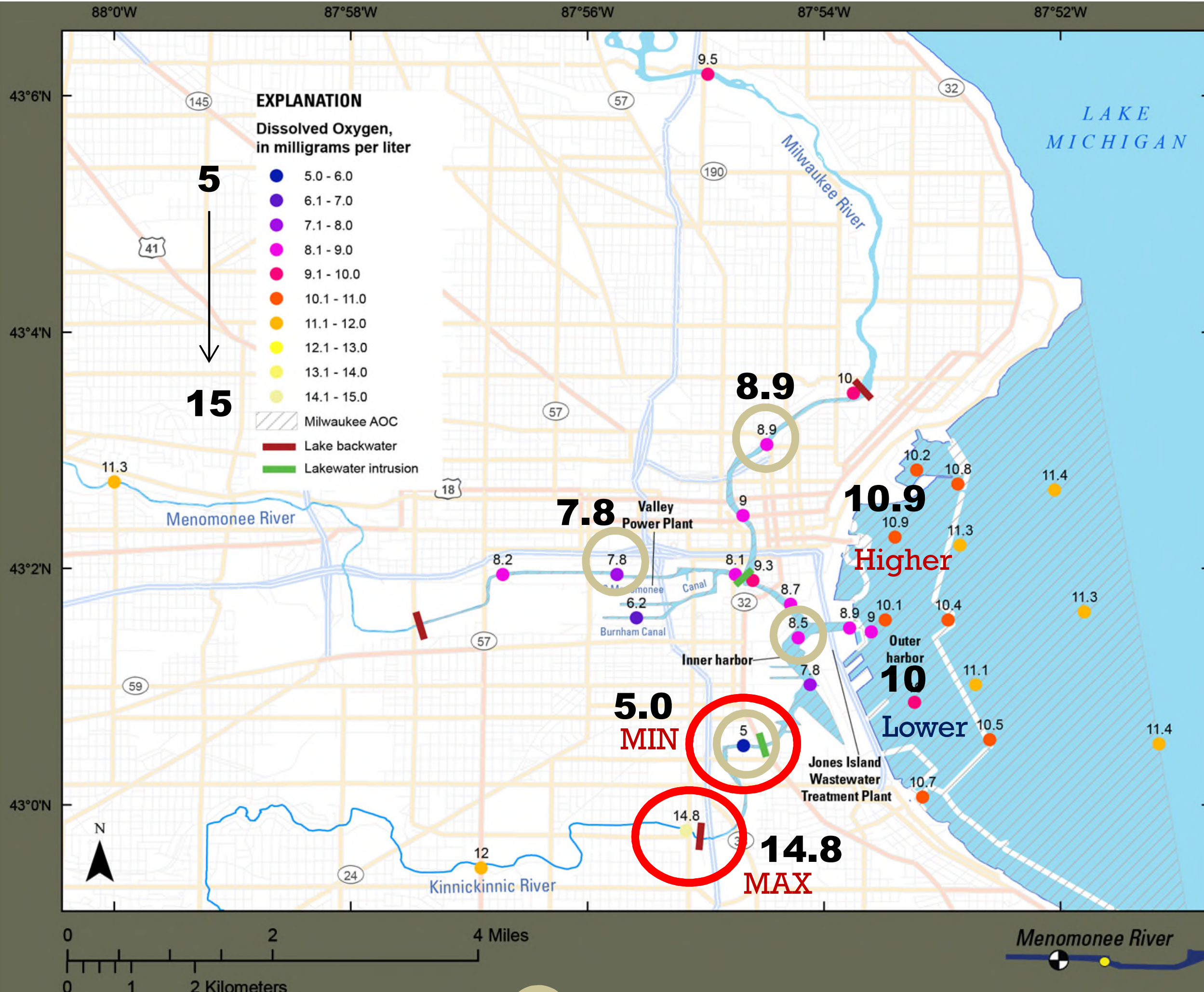




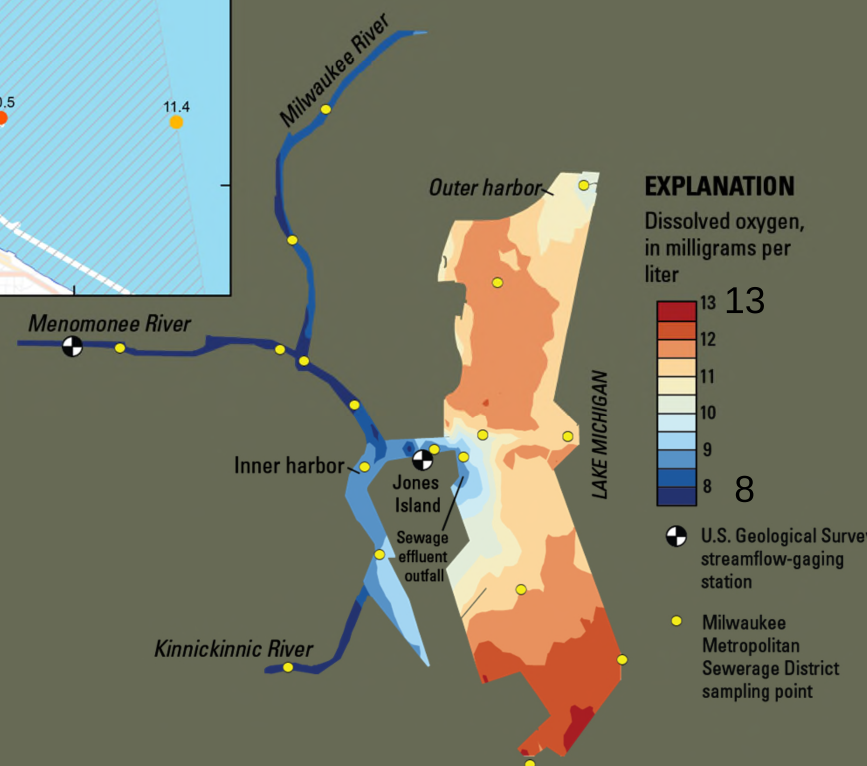
USGS

Dissolved Oxygen

MMSD 2010 median vs. synoptic



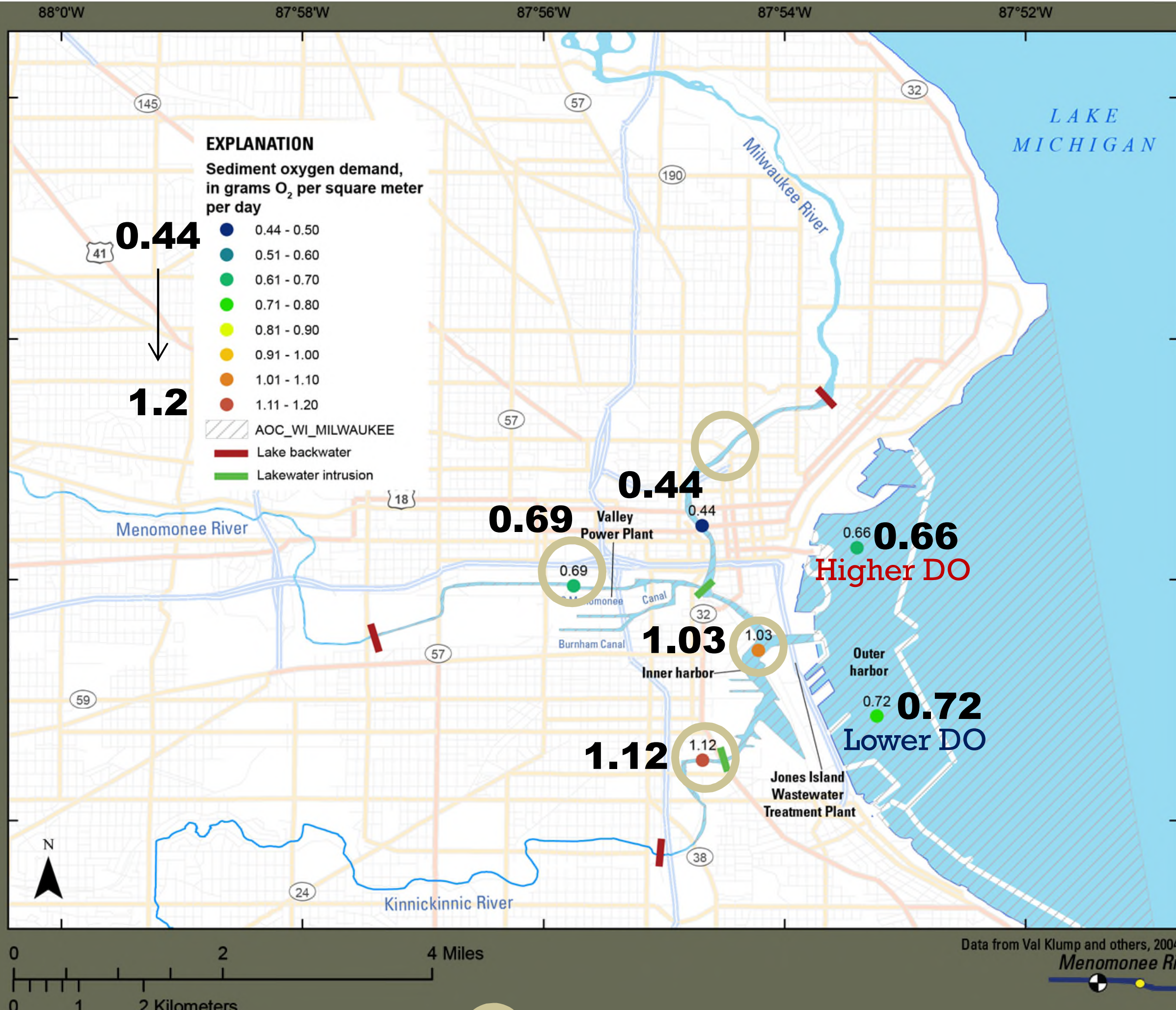
Local minima in DO



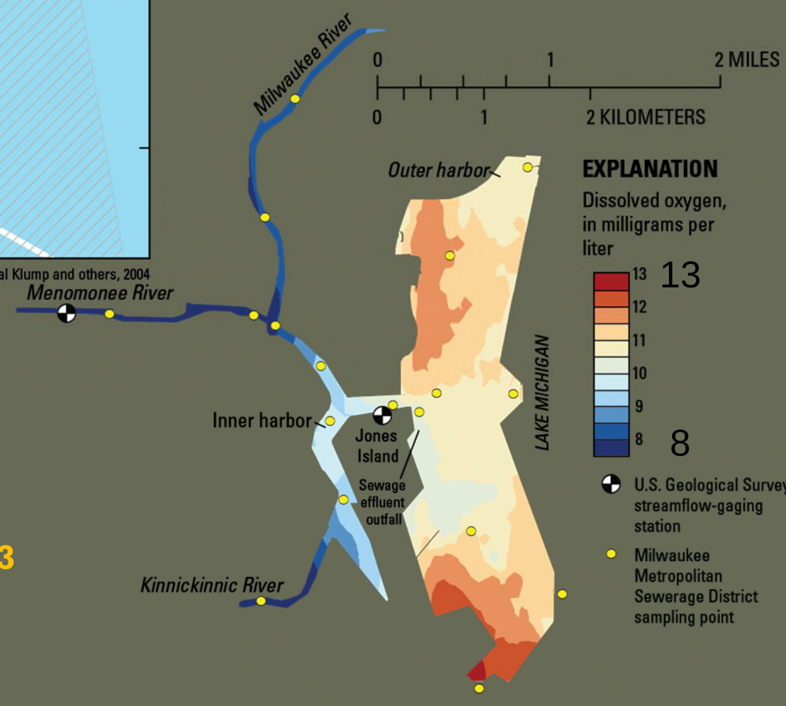
USGS

Sediment Oxygen Demand

Val Klump et al. (2004) data vs. 2010 synoptic DO



Local minima in DO

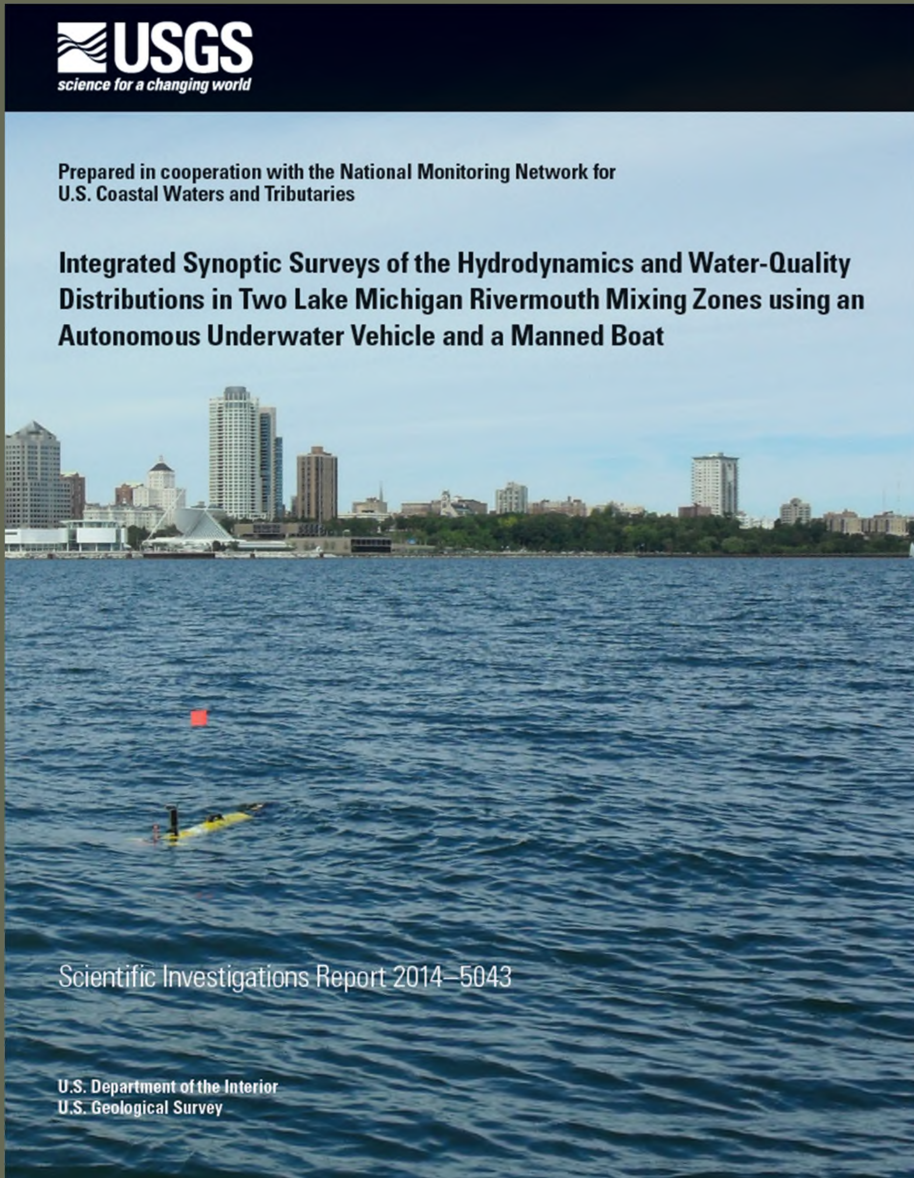


Near-bed water (0 to 10 feet above bed)

At an SOD of 1.12 g/m^2/day and mean depth of about 1 meter **DO decline is approximately 1.1 mg/L every day**.

To drop from 14.8 to 5 mg/L in 2 km **requires a velocity of about 3 mm/s**. We measured mean velocities of 5 mm/s.

USGS



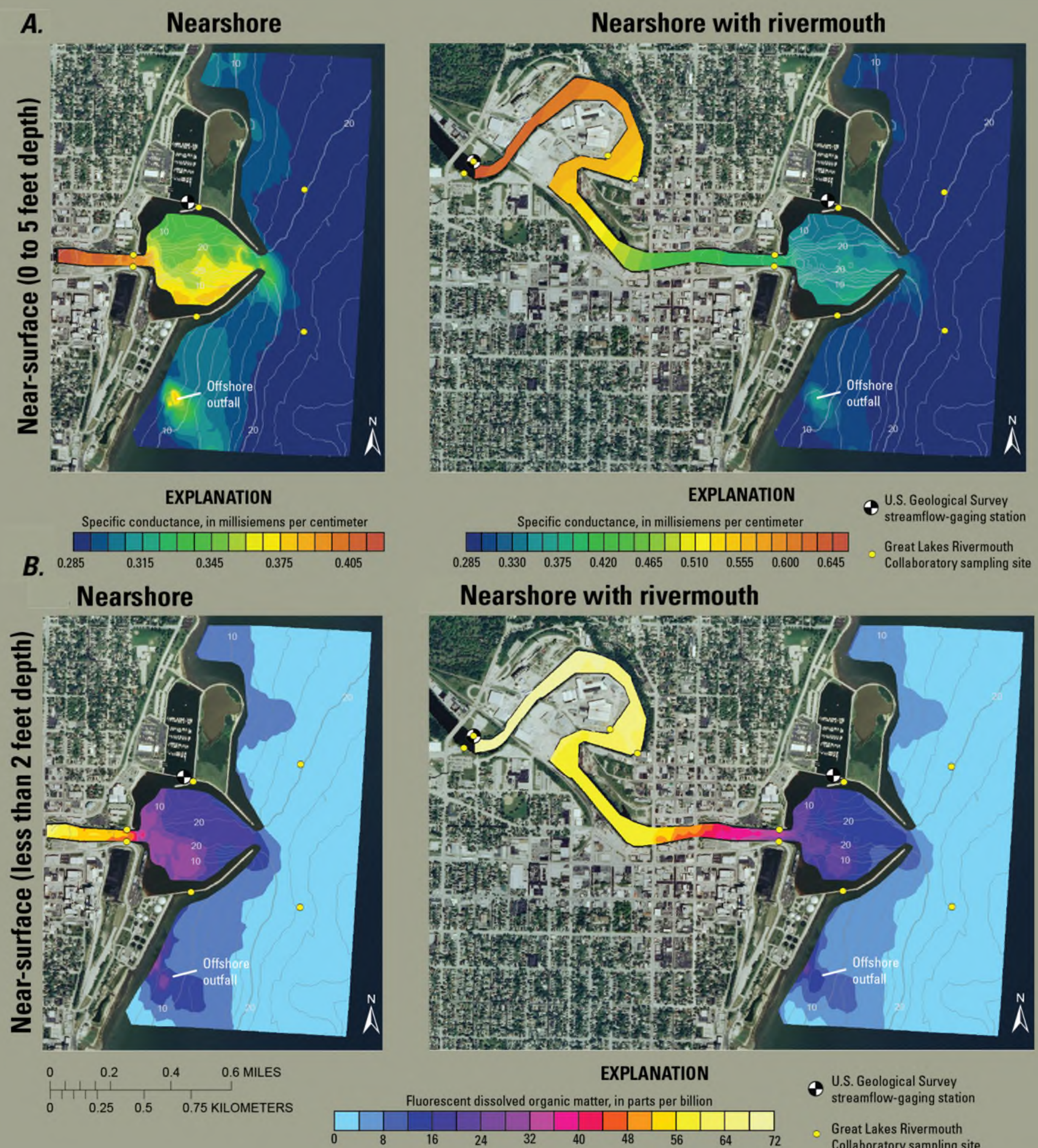
USGS Scientific Investigations Report 2014-5043

Application: Manitowoc Rivermouth (WI)

National Monitoring Network
Lake Michigan Pilot Study

TEASER

USGS



Manitowoc Rivermouth

September 19-20, 2011

Specific Conductance

Fluorescent Dissolved Organic Material (FDOM)

USGS

Overall Conclusions

- AUV technology is highly efficient
  - Rapid collection of water-quality data in relatively open water (harbors, nearshore, etc.)
  - Example: 600 profiles in 7 hr with the AUV compared to ~150 hours with traditional methods (Harbor)
- Synoptic surveys provide great insight into mixing and dispersion in highly unsteady mixing zones
- High resolution data can help explain variation in periodic point samples and assess point sampling strategies
  - Example: MMSD sampling points are well distributed to capture spatial variations
- High resolution synoptic datasets can provide modelers with valuable calibration and/or validation data
- AUVs are generally not designed for riverine surveys
  - should be integrated with manned boat measurements in rivers
- While manned boats can be equipped for synoptic mapping, it is generally less efficient and results in lower resolution data (towed instruments would be the exception)
- Velocity surveys are still most efficient and accurate using a manned boat

USGS

P. Ryan Jackson
pjackson@usgs.gov

Questions?

Report online:
http://pubs.usgs.gov/sir/2014/5043/

Acknowledgements:
National Monitoring Network
USGS Office of Water Quality
Milwaukee Metropolitan Sewerage District
USGS Wisconsin WSC
- **Paul Reneau**
- Dan Sullivan
- Charlie Peters
- Peter Hughes

USGS Iowa WSC
- Kevin Richards

USGS Illinois WSC
- Ryan Beaulin

Great Salt Lake Dye Study
An investigation of freshwater and selenium inputs into a hypersaline lake

Lee Creek Freshwater Inflow Plume
Surveyed by the AUV and a manned boat
November 2, 2011
Photo courtesy of KSL News

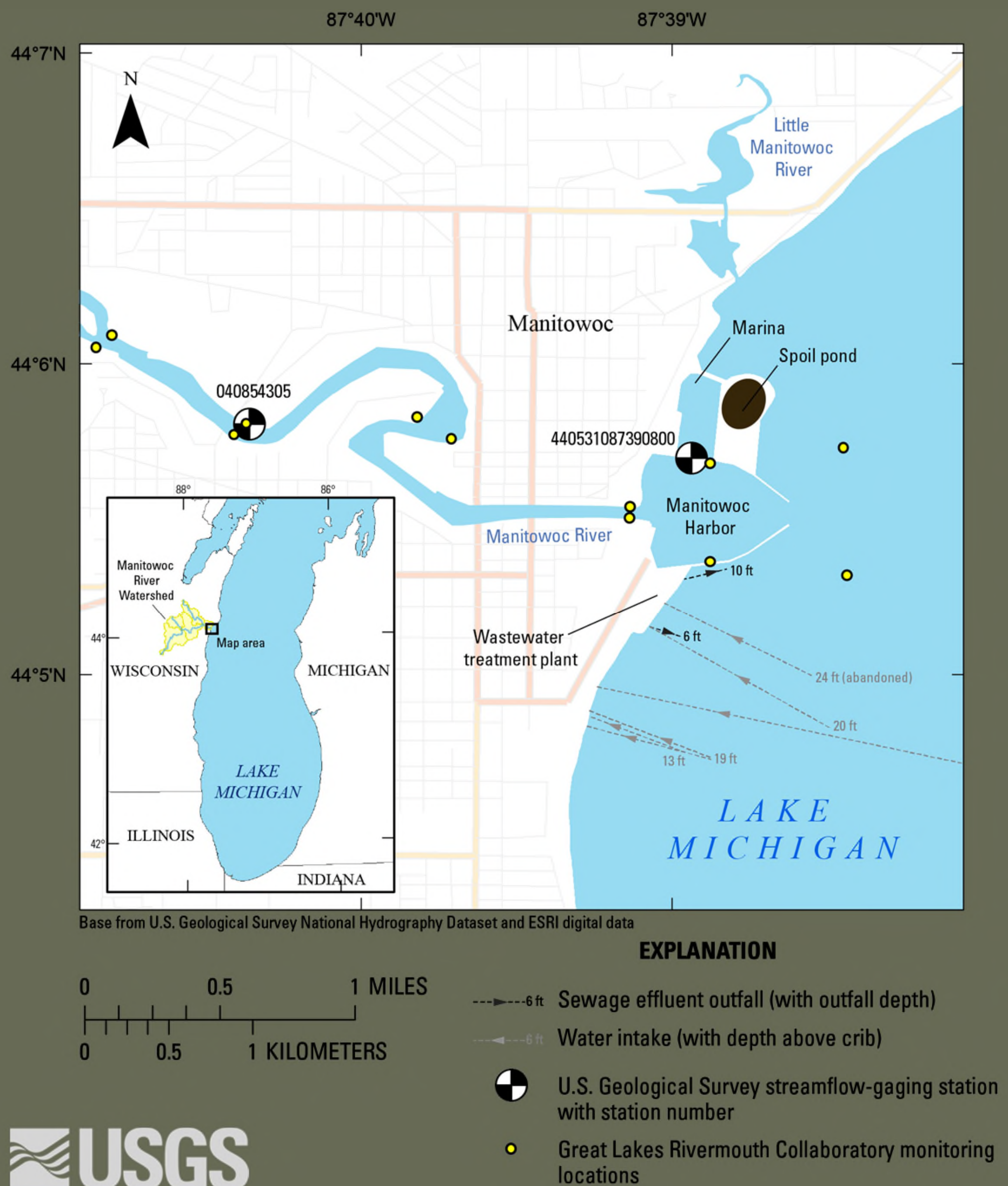
USGS

Extra Slides

Manitowoc Rivermouth

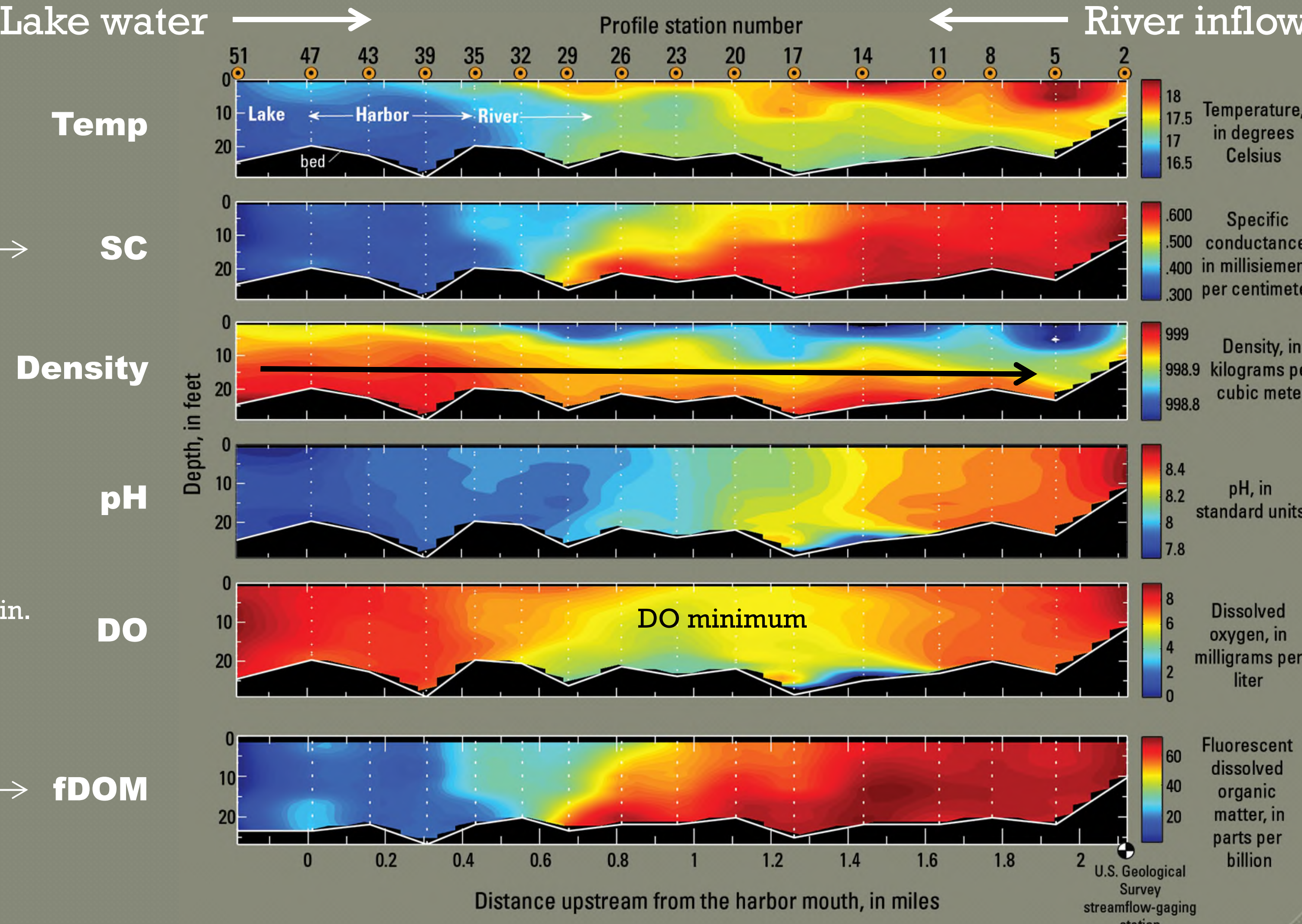
USGS

Manitowoc Rivermouth



- 526 mi^2 drainage area
- Impaired due to
  - Phosphorus
  - Sediment
  - Coliform bacteria
- Heavily agricultural watershed with cropland and dairy waste runoff
- Dredged navigation channel in lower 2 miles
- 2011 mean annual flow of 460 cfs
- Small 20-acre harbor
- Two offshore wastewater effluent outfalls and six offshore intakes south of the harbor
- 9-acre spoil pond north of the harbor
- Part of the Great Lakes Rivermouth Collaboratory study

Manitowoc River Section



NOTE: Lake water pushes 2 mi upstream

NOTE: Similar distributions

NOTE: DO min. (~ 0 mg/L near bed)

USGS

Dissolved Oxygen

September 19-20, 2011

USGS

Conclusions: Manitowoc Pilot Study

- The lower 1.5 miles of the Manitowoc River is the primary mixing zone and exhibits a significant DO minimum in this zone
- Point sources along the lakeshore both north (spoil pond, Little Manitowoc River) and south of the harbor (wastewater outfalls) combine with the river plume and affect nearshore distributions
- Offshore water intakes located south of the harbor can lie within the river and outfall plumes
- Bi-directional nearshore currents exist and surface water observations may not always predict river plume dynamics
- Specific conductance and FDOM are highly correlated and both provide good tracers for river plumes and wastewater effluent plumes
- Monitoring data from the GL Rivermouth Collaboratory is not yet available for comparison, but sampling points are few and far between and may not resolve the variability in the system

USGS