Modeling Approaches for Considering Climate Change

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2022 National Training Workshop on Water Quality Data, Assessment, and Plans

Building on 50 Years of Change, Resilience, and Progress

May 31 – June 3, 2022

Background

- Kevin Kirsch, P.E.

  Wisconsin Dept. of Natural Resources

  Runoff Management Program and Water Evaluation Program

- BS and MS in Biological Systems Engineering, UW-Madison

- Watershed Modeler and Instructor (SWAT, WinSLAMM, RUSLE2)

- Models: SWAT, SnapPlus, RUSLE2, WinSLAMM, P8, “—”SWIMM, HEC-RAS, HEC-HMS, Flux, WiLMS, BATHTUB, QUAL2E, CE-QUAL-W2

Additional Modeling Tools

Developers: Aaron Fisch, Matt Diebel, and Alex Latzka

WHDPlus Viewer

(landcover, soils, streamflow, healthy watersheds, PRESTO and WILMS models)

https://devshinyint.dnr.wi.gov/int/wy/WHDPlus/

(Limited to Internal Only – switching to SQLite db)

PhosMER Model

Phosphorus Mixed Effects Regression

http://34.223.230.186:3838/latzka/TP_TSS_miniapp/

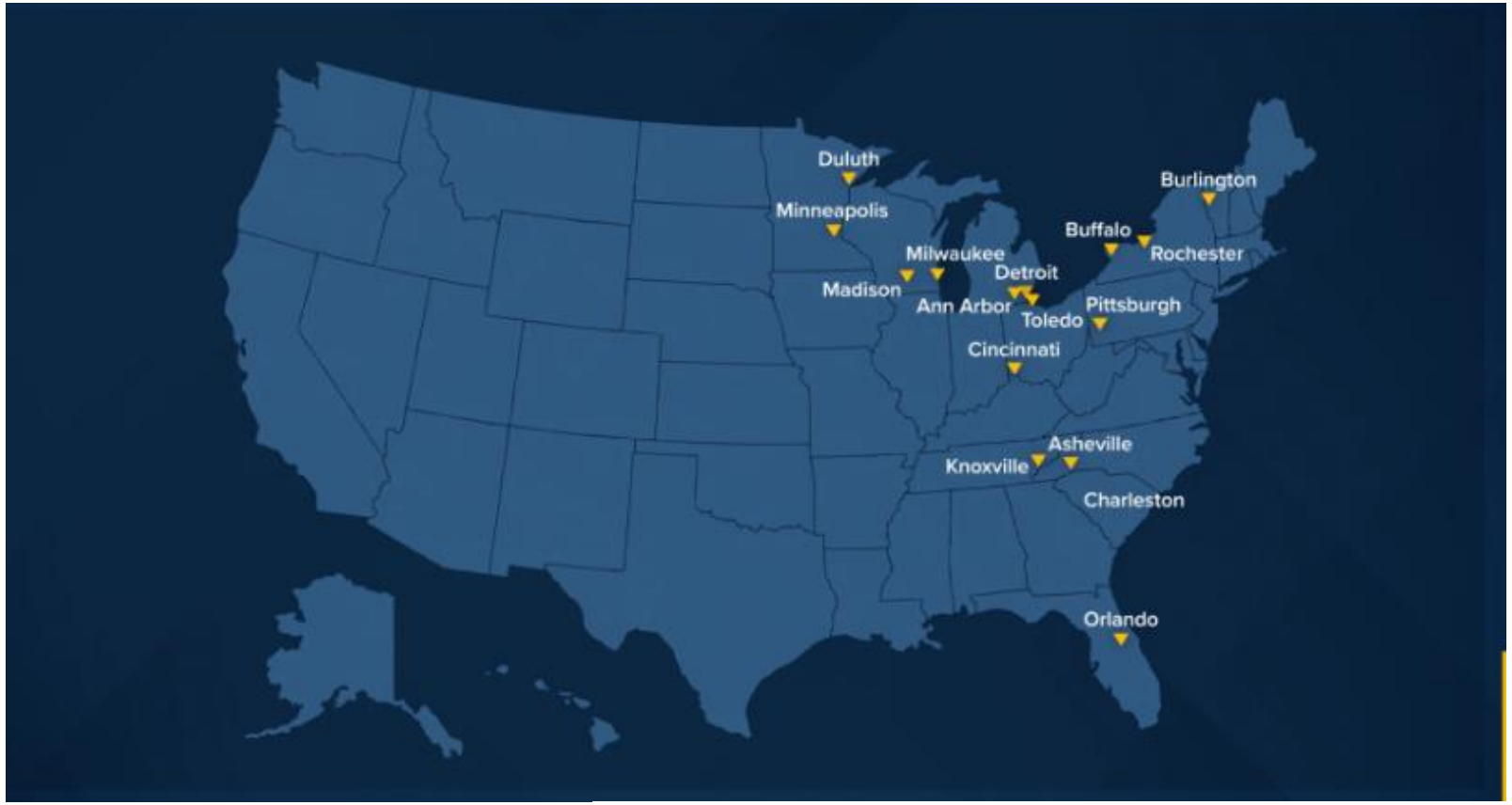
Long-term River Water Quality Trends in WI

https://wisconsindnr.shinyapps.io/riverwq/

Speaking to you from a Possible Climate Haven

Millions of Americans are living in communities with precarious climate conditions.

Climate havens or climate destinations are situated in places that avoid the worst effects of natural disasters and have the infrastructure to support a larger population.



CNBC Americans are fleeing climate change — here's where they can go

The Climate Crisis

"People do not understand the magnitude of what is going on," she said. "This will be greater than anything we have ever seen in the past. This will be unprecedented. Every living thing will be affected."

We cannot adapt our way out of climate crisis, warns leading scientist

Katharine Hayhoe says the world is heading for dangers people have not seen in 10,000 years of civilisation

theguardian

June 1,2022 Fiona Harvey, Correspondent

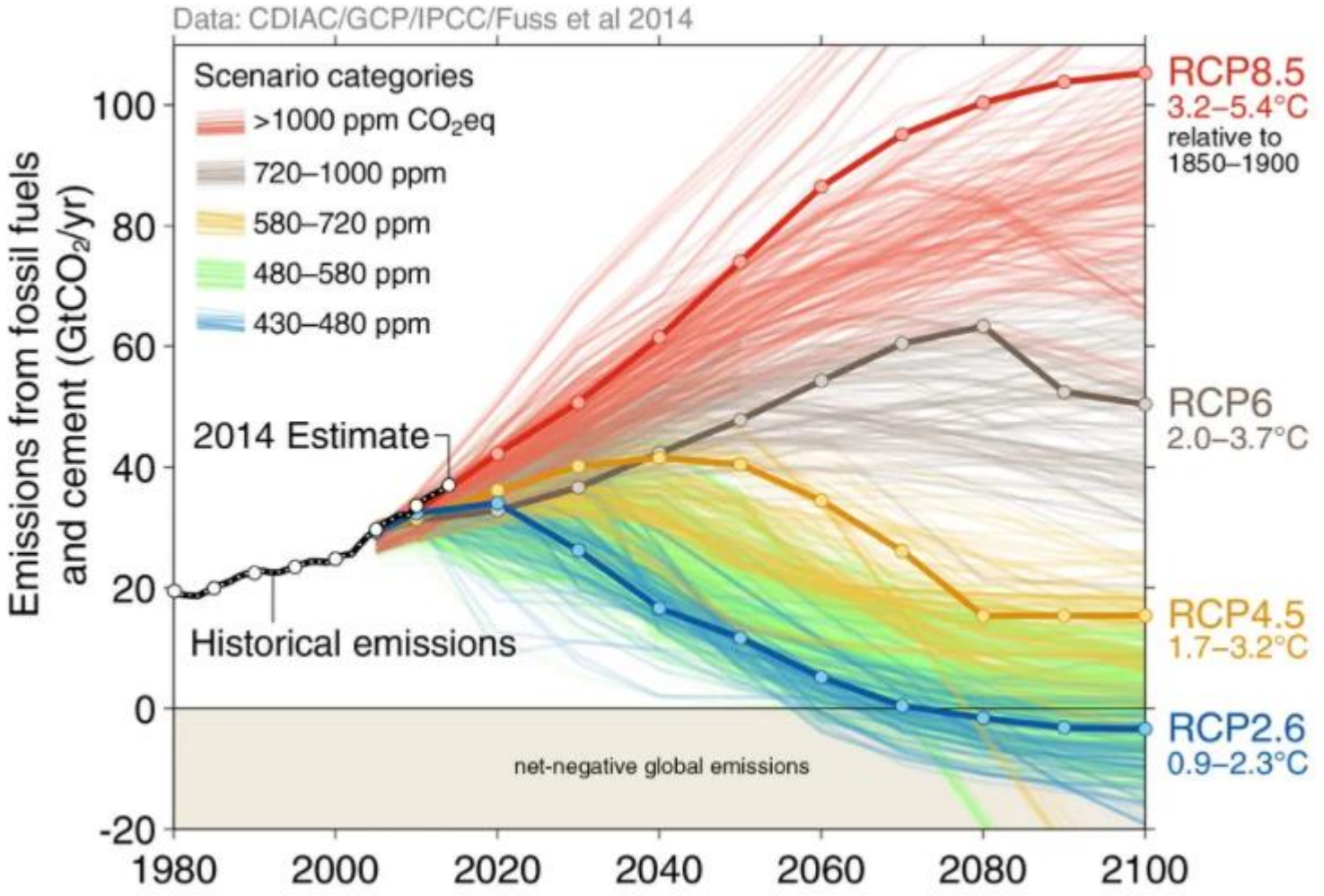
"We really think that drought is one of the greatest risks in terms of climate change to the stability of the Colorado River Basin," said Katrina Bennett, a member of the Los Alamos team that published the results of that modeling in the journal *Earth and Space Science*.

All Politics. All New Mexico. NMPOLITICALREPORT

May 24,2022 Hannah Grover, Correspondent

Climate Extremes: "This is not supposed to be underwater" – AEK, 08/2018

Climate Change Scenarios



Pre-Paris Projections or Status Quo

The IPCC reports that "*Scenarios without additional efforts to constrain emissions ('baseline scenarios') lead to pathways ranging between RCP6.0 and RCP8.5.*"

Current Progress and Policies

The question is not whether 2°C scenarios violate laws of physical science, but whether they are reasonable given what we know about human behavior.

Pledges and Promises on Paper

Projections needed to avoid Risks

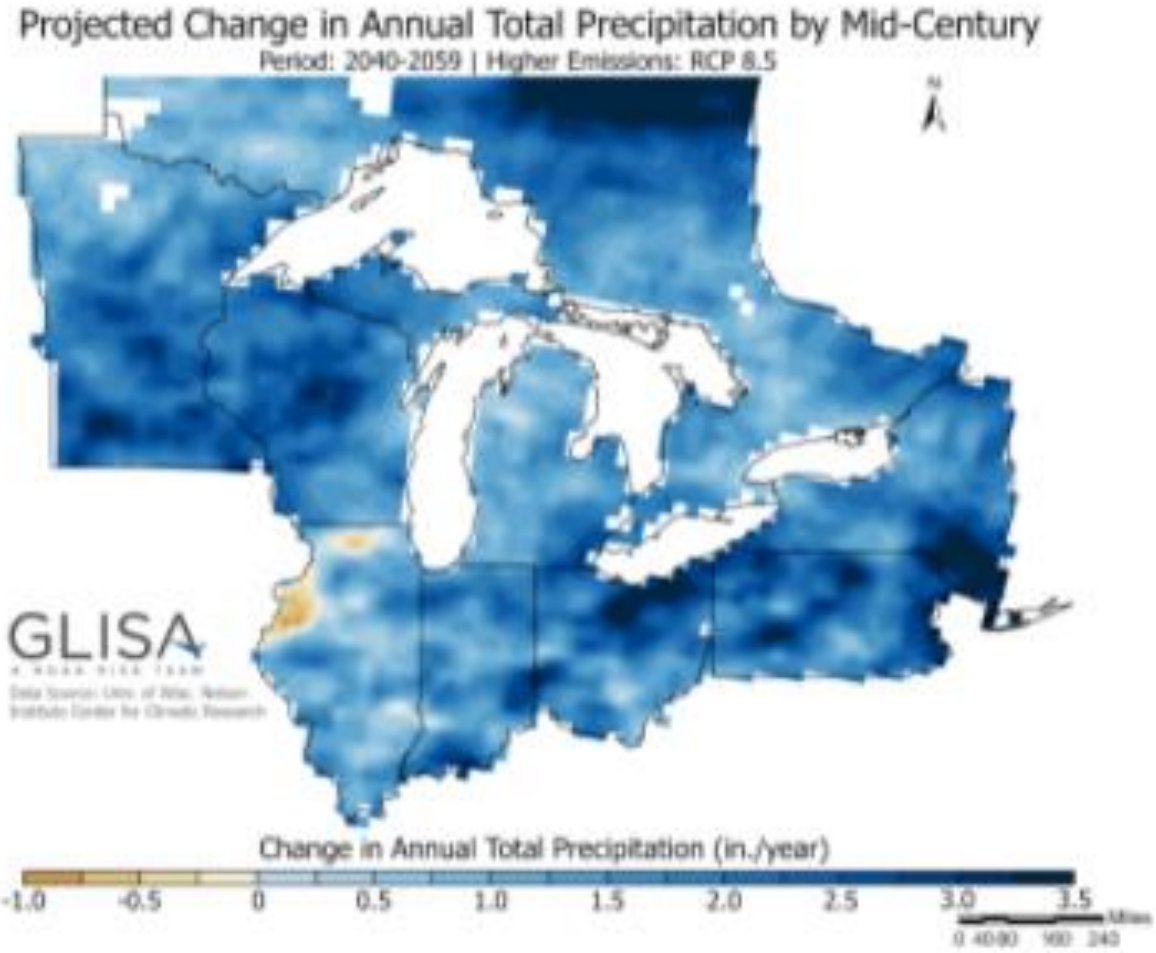
Requires human beings to quickly and fundamentally change their collective behavior and is unlikely, given what we know about human behavior, path dependence, and political dysfunction.

Updated GLISA/NOAA Predictions

(Assumes High Emissions Scenario RCP8.5)

Projections of precipitation are highly variable by location, individual model, and the timeframe considered for the projections.

The ensemble projection suggests more annual precipitation but with precipitation patterns shifting toward drier summers and wetter springs and falls accompanied overall with more intense storm events.



Source: The Great Lakes Integrated Sciences and Assessments (GLISA) is a collaboration between the University of Michigan and Michigan State University supported by the National Oceanic and Atmospheric Administration (NOAA)

Updated GLISA/NOAA Predictions

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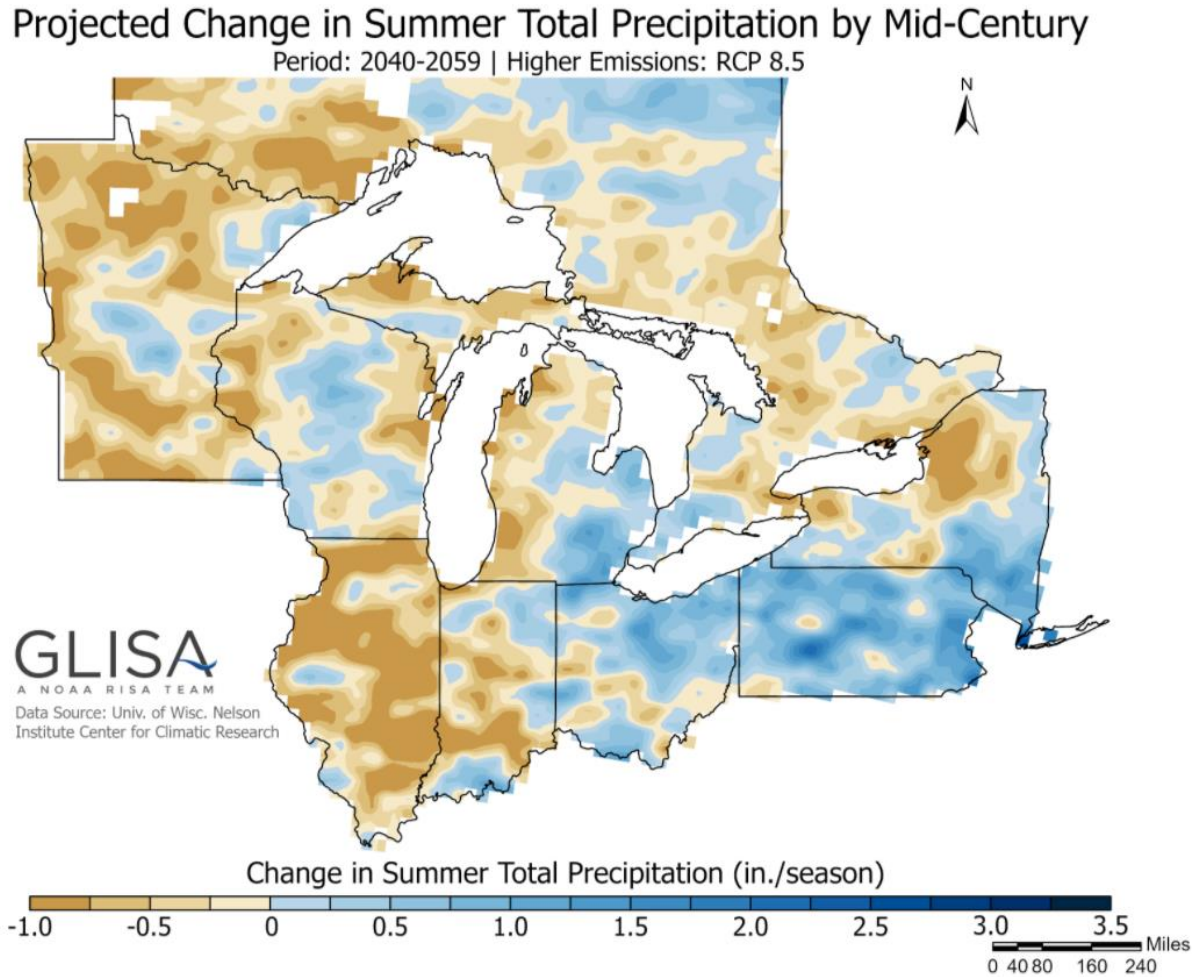

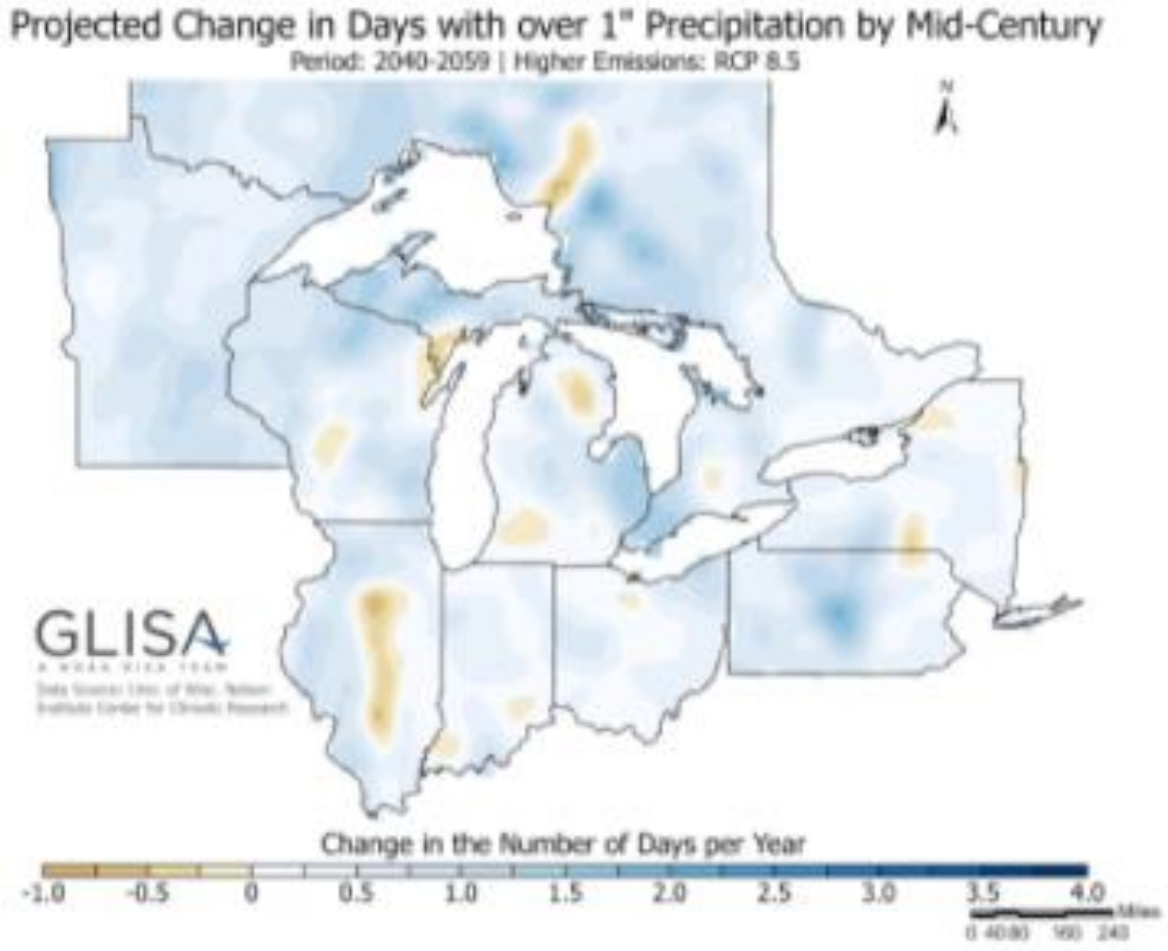

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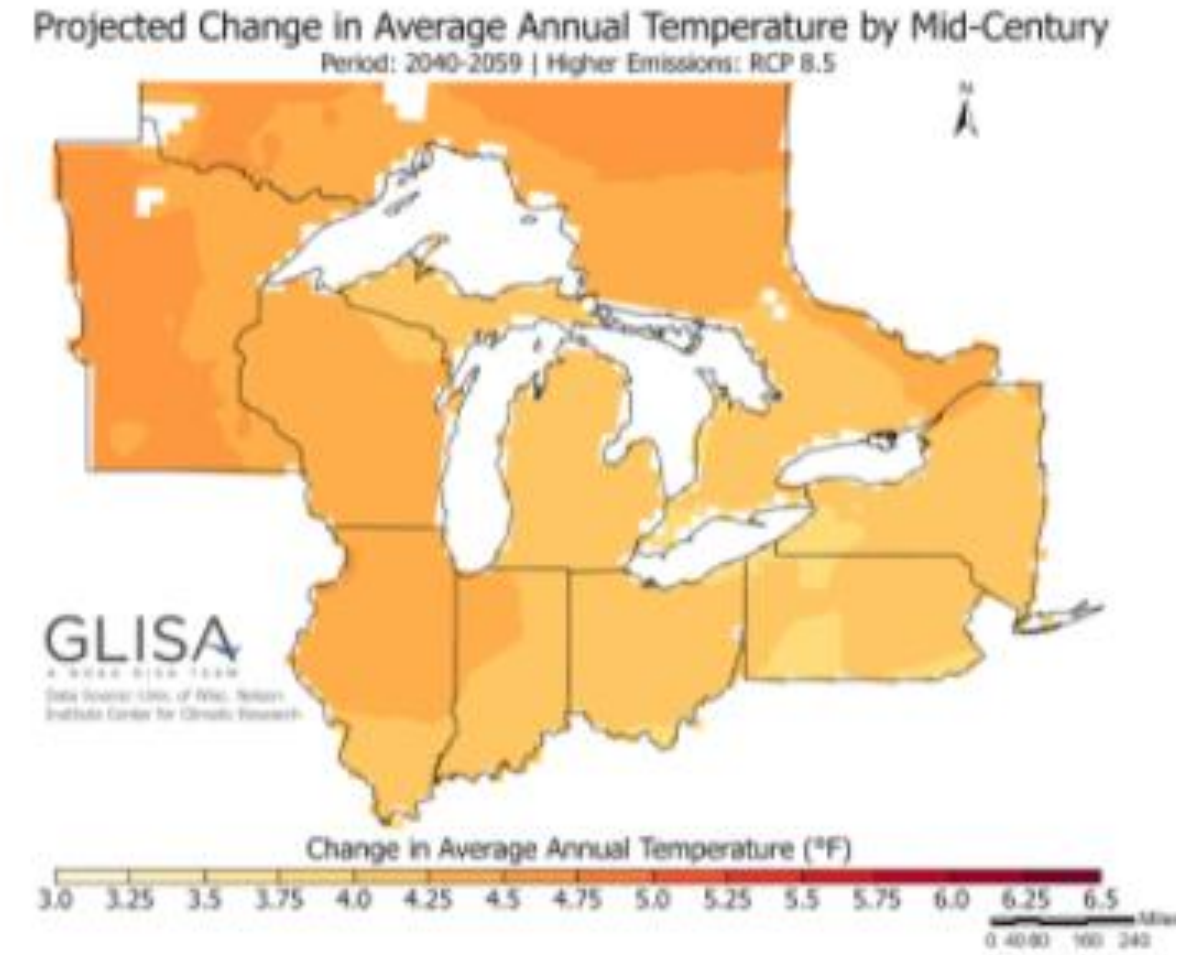
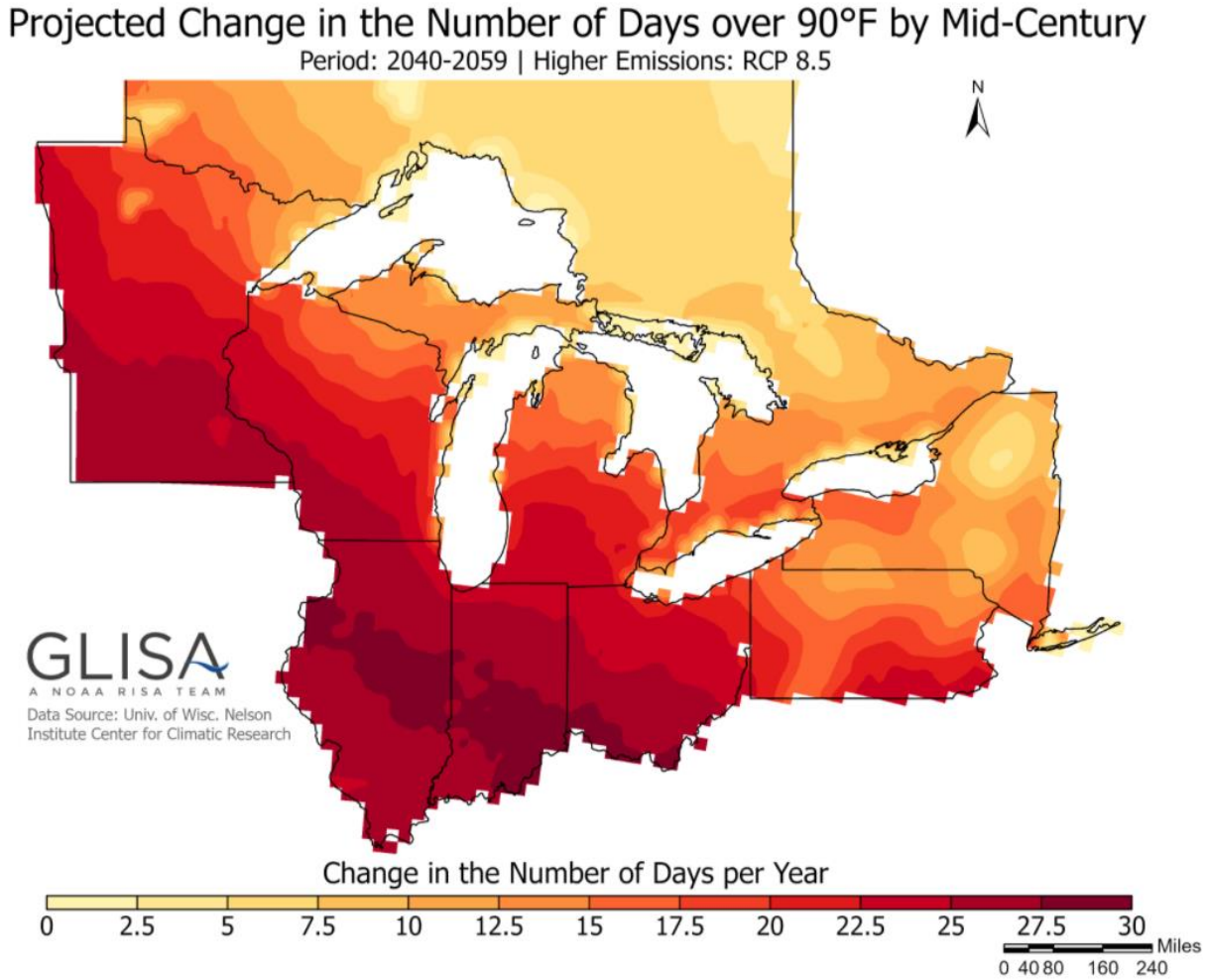




Climate Change Impacts to 303(d) Program

Water Quality Criteria and Standards

Monitor and Assess Waters

Develop Protection and Restoration Plans

Implementation and reduction in pollutants

1. Climate change is very complicated, and it impacts all aspects of the 303(d) program.

2. The rate at which climate change impacts are being observed as well as the variability and uncertainty around the impacts makes it challenging to account for in models and protection/restoration plans.

Poll Question: Is it best to use projections from the high emissions scenario, a different scenario, or multiple scenarios? Maybe none of the above?

Monitoring to Support Modeling Will Take More Effort

Water Quality Criteria and Standards

Monitor and Assess Waters

Develop Protection and Restoration Plans

Implementation and reduction in pollutants

1. Ecosystems no longer “static” relative to the rapid alterations occurring due to climate change making the use of biological indicators and other metrics more complex and perhaps requiring more frequent assessments.

2. Monitoring will become more challenging due to the higher variability in flows requiring more strategic placement of monitoring equipment, more robust monitoring equipment, collection of more data/sampling events, and better statistical assessment packages to evaluate data.

Climate Change Challenges in Modeling

Water Quality Criteria and Standards

Monitor and Assess Waters

Develop Protection and Restoration Plans

Implementation and reduction in pollutants

- More uncertainty and challenging to simulate with models; however, the use of current and representative climate data to address critical conditions (wet, dry, and average years) will help.
- Run models under different scenarios and under variable climate scenarios to ensure that model parameters are correctly simulating processes and help capture the necessary extreme events.
- Evaluate model calibration and validation at the low and high flow events; if the model is not properly representing these events the results under future climate projections are likely not representative nor predictive.
- The shelf life of restoration plans likely shorter requiring more updates during the typical implementation time period and may require more adaptive approaches.

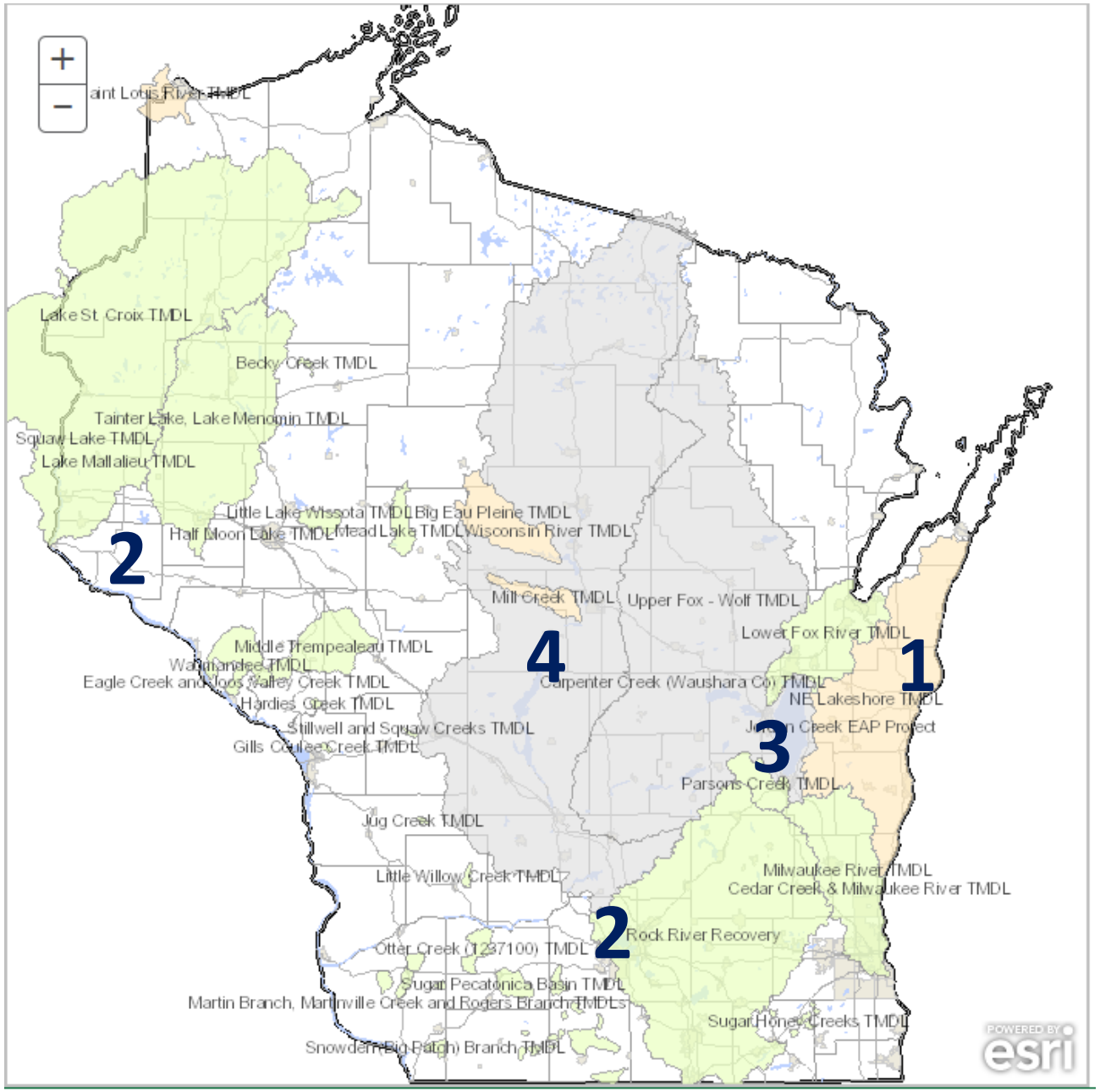
Some Things to Consider:

1. Impact of Extreme Events
   NE Lakeshore TMDL

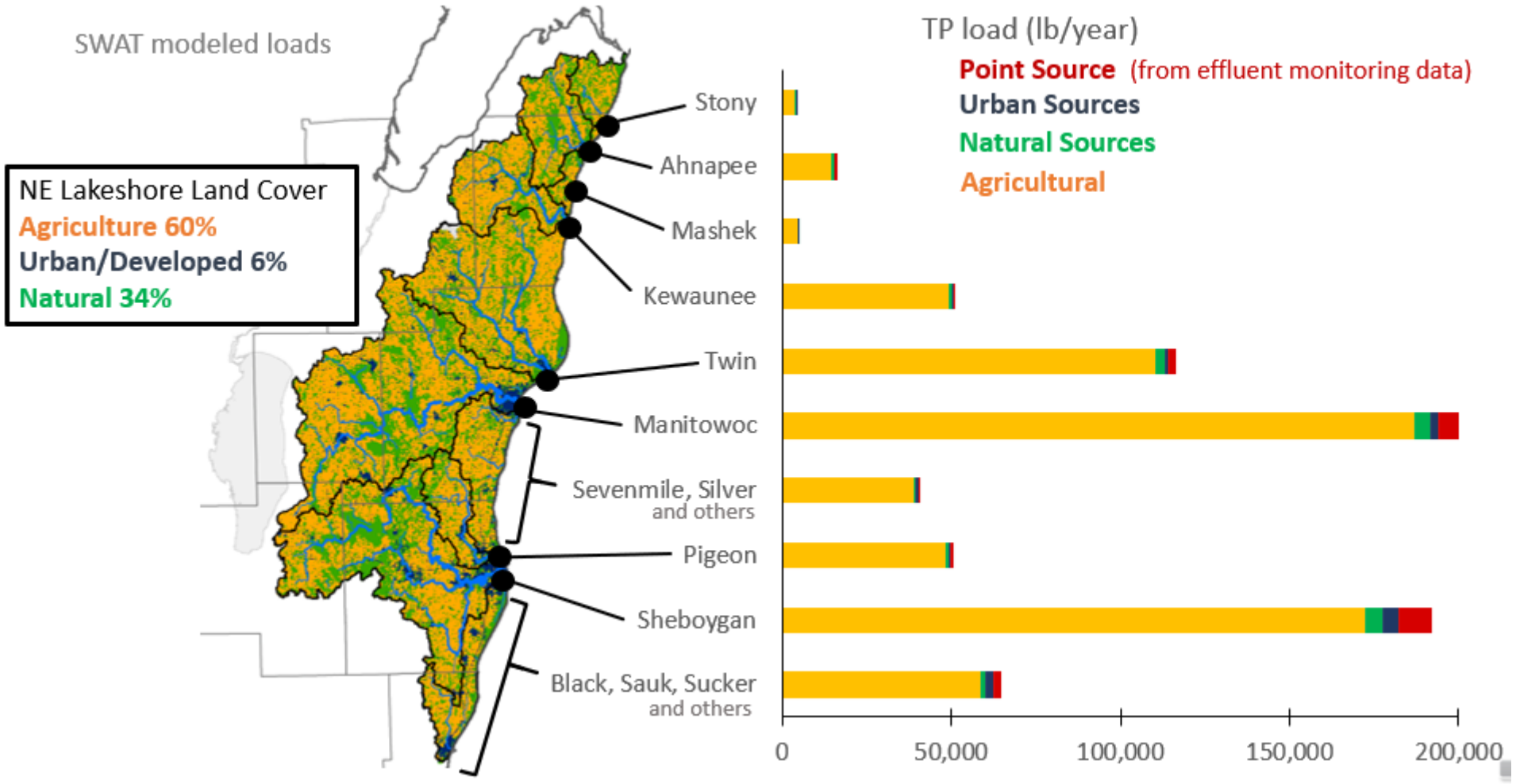
2. System Sensitivity
   Lake Pepin TMDL and Rock River TMDL

3. Adaptive Approaches
   Upper Fox-Wolf Basin TMDL

4. Implementation Approaches
   Wisconsin River Basin TMDL



Impact of Extreme Precipitation Events

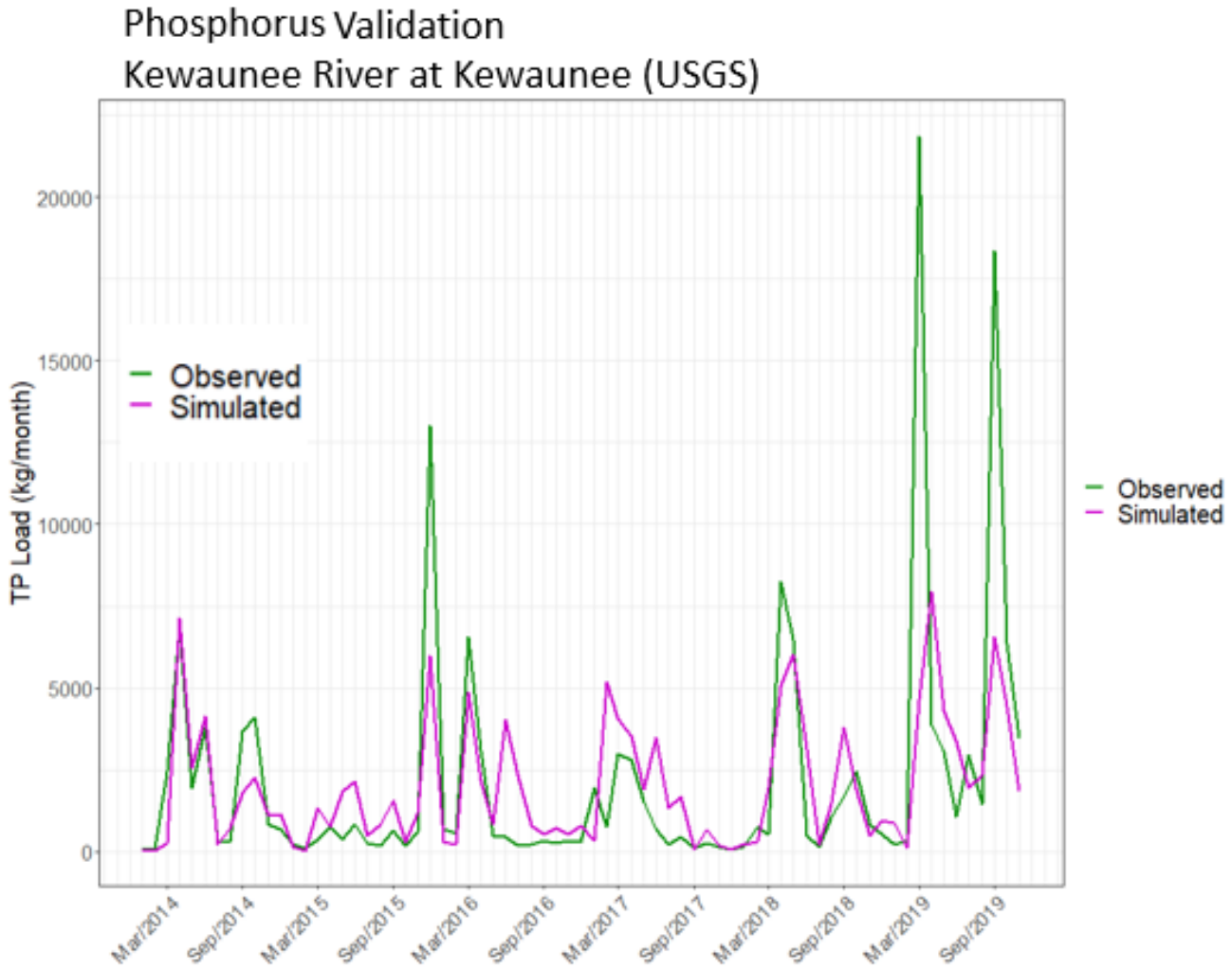


Impact of Extreme Precipitation Events

NE Lakeshore TMDL

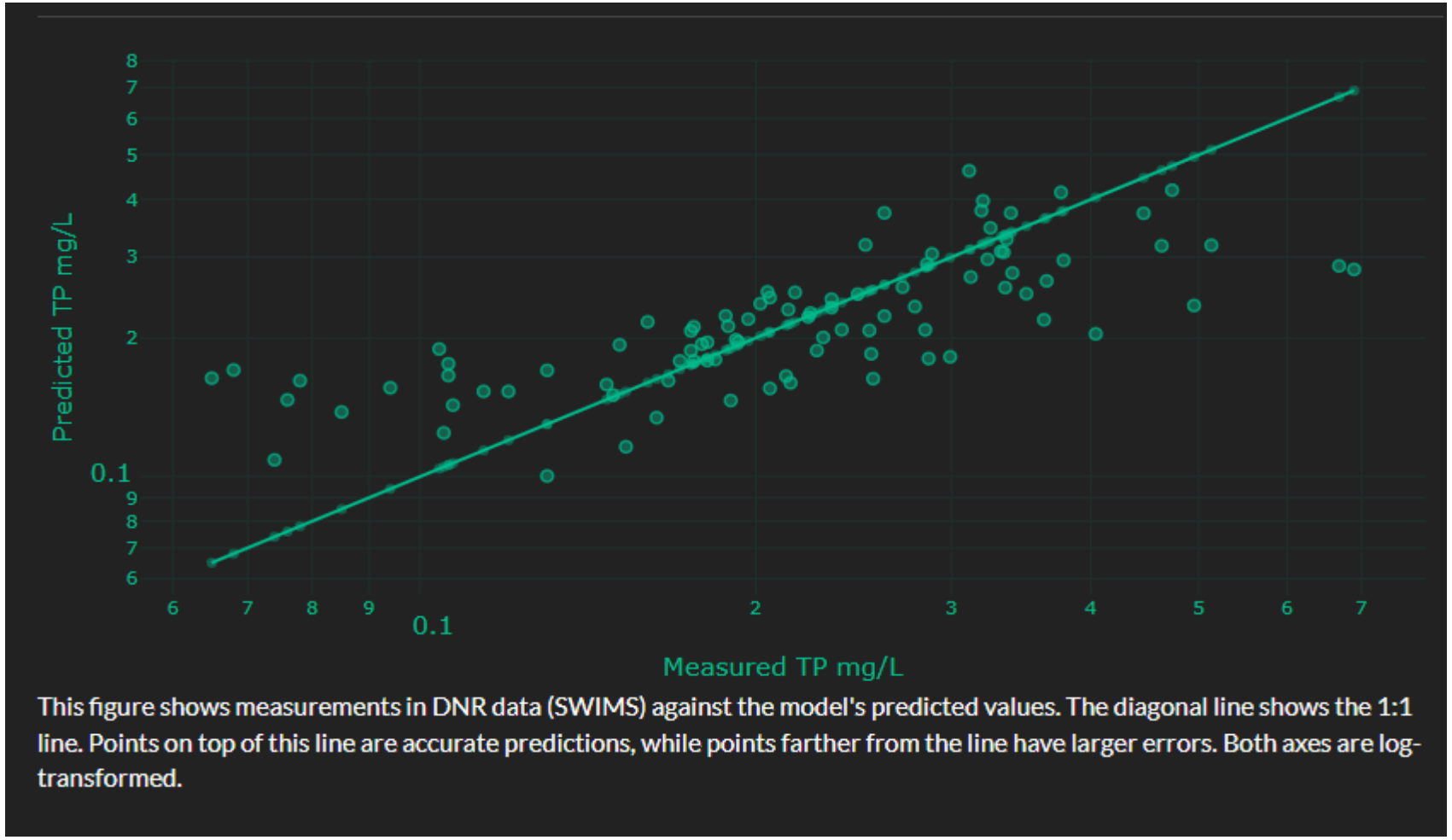
SWAT modeling and stream monitoring show episodic loadings

- On average, 50% of the phosphorus load comes from 10 or less events.
- On average, 40% of annual load occurs in the Spring.



Impact of Extreme Precipitation Events

PhosMER Model: Measured Vs Predicted TP Concentrations (mg/L)



This figure shows measurements in DNR data (SWIMS) against the model's predicted values. The diagonal line shows the 1:1 line. Points on top of this line are accurate predictions, while points farther from the line have larger errors. Both axes are log-transformed.

- Models are often calibrated to average conditions.
- Models can only be calibrated and validated against existing data making it challenging to use for future projections.
- Important to look at the tails when extreme events drive the loads and loading capacity.

Considerations:

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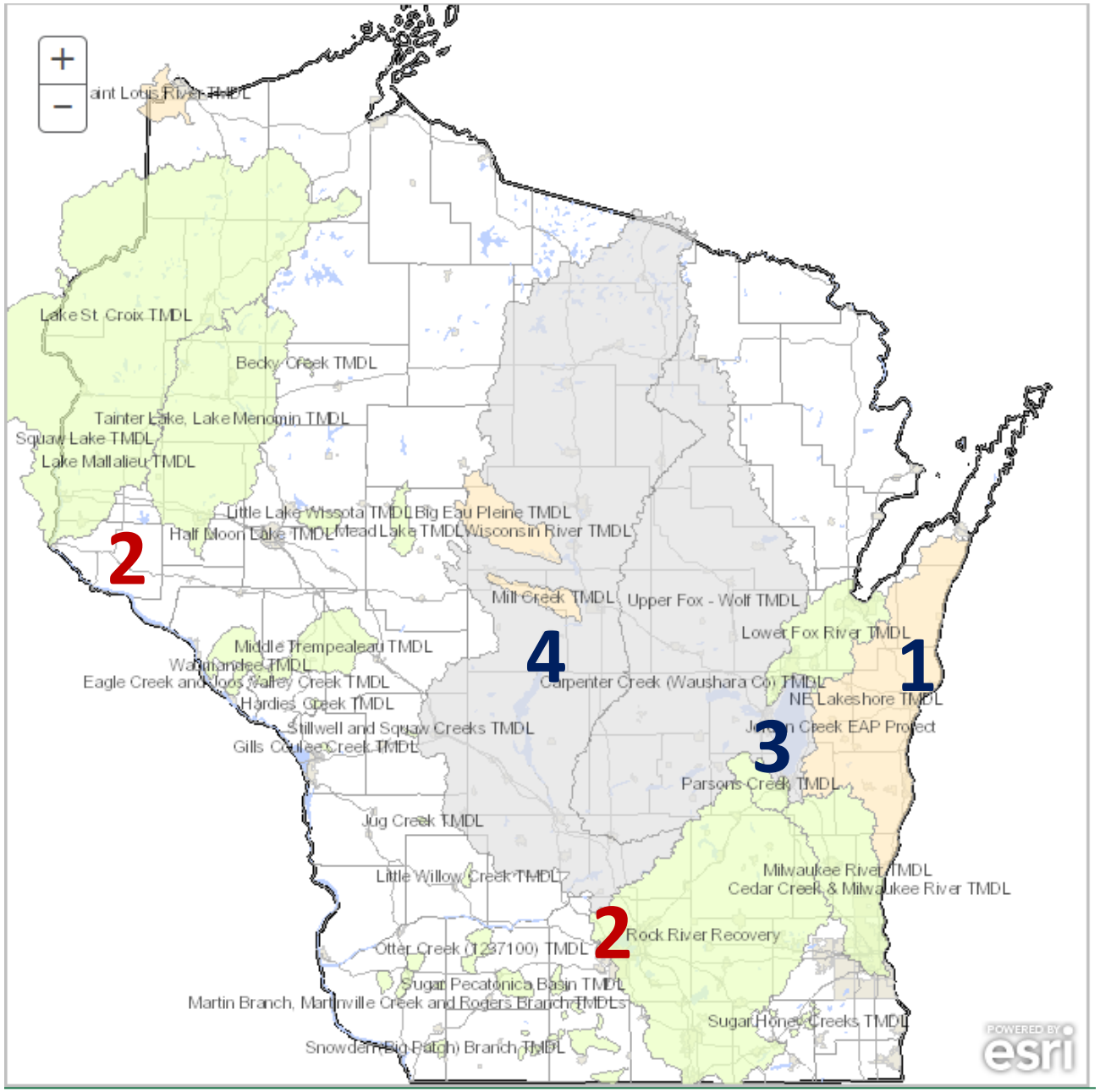


System Sensitivity (Precipitation and Temperature)

Stream Phosphorus and Sediment dynamics | Interactive map & site selection | Site-level daily model results

PhosMER Model:

Distribution

Observed vs. Predicted

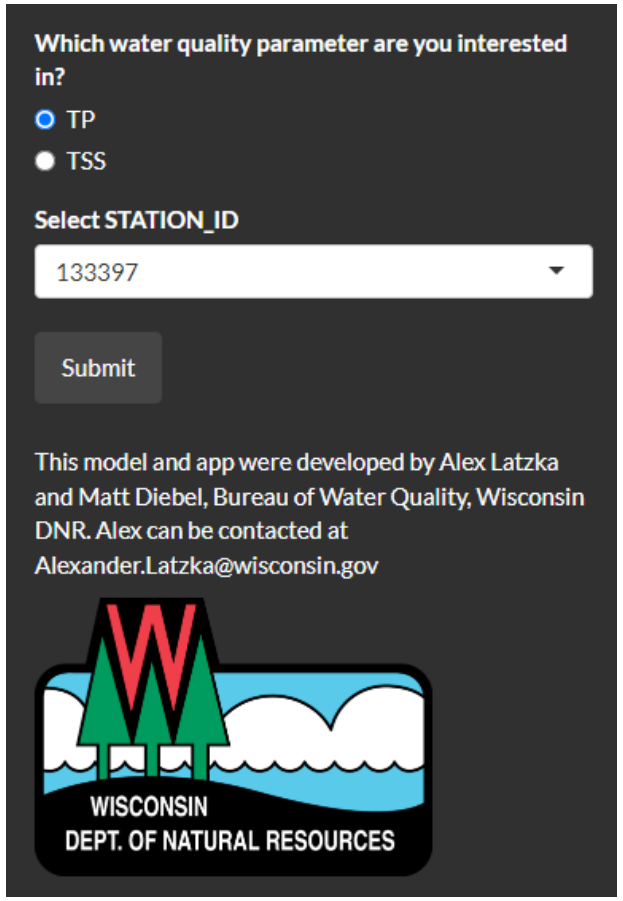
Time Series

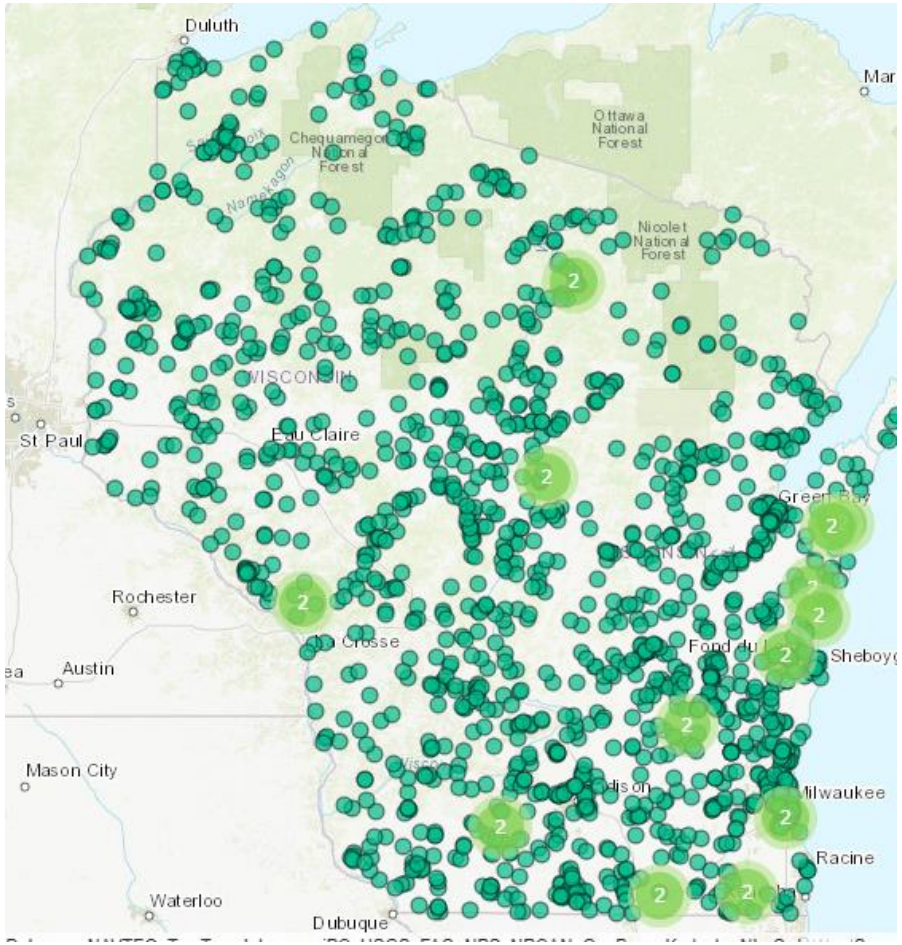
Water Quality Drivers

Test for Change

Statistically Significant Reductions

Monitoring Needs

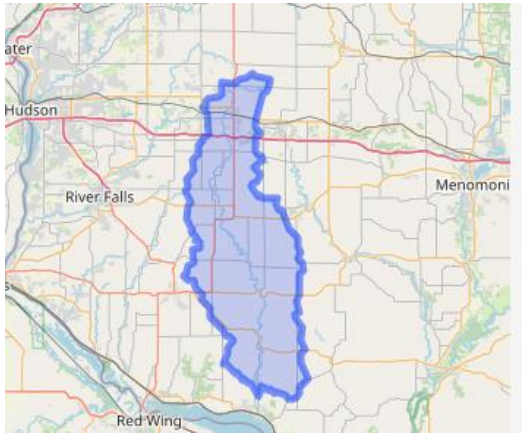




System Sensitivity (Precipitation and Temperature)

Rush River
Lake Pepin TMDL

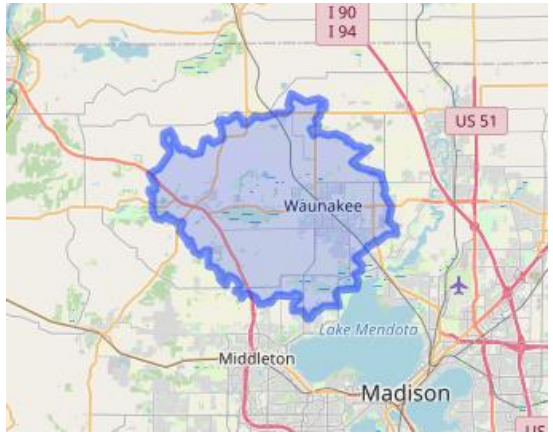
- 203 sq. miles
- Driftless Area (hilly)
- 1 WWTF



Land use predominately agricultural (PRESTO Model Results)
Avg annual nonpoint TP load: 139,077 (70,378-274,837) lbs.
Avg annual point source TP load: 3,702 lbs.

Sixmile Creek
Rock River TMDL

- 62 sq. miles
- WI Till Plains

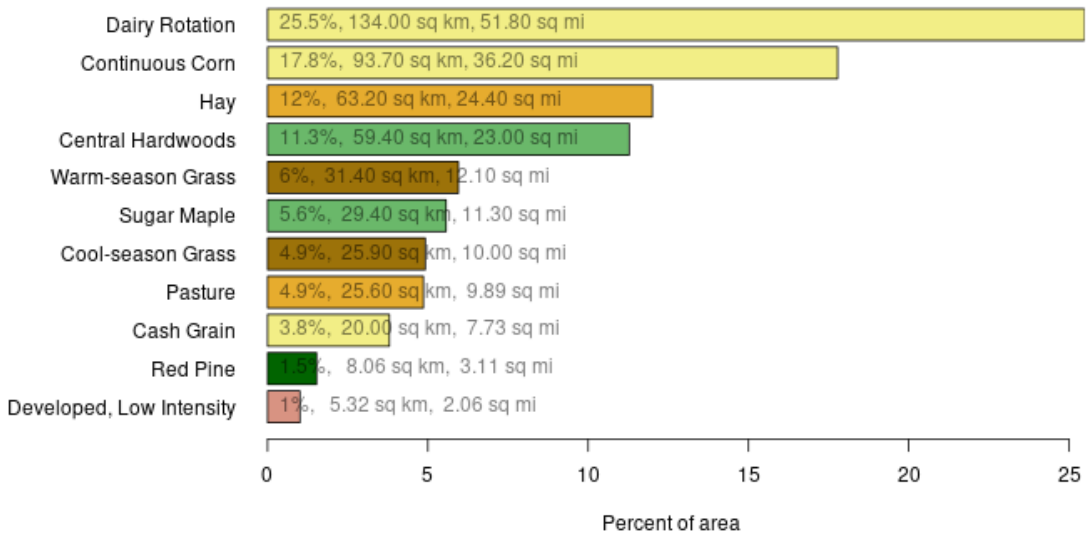


Land use predominately agricultural (PRESTO Model Results)
Avg annual nonpoint TP load: 43,662 (22,025 – 86,555) lbs.
Avg annual point source TP load: 0 lbs.

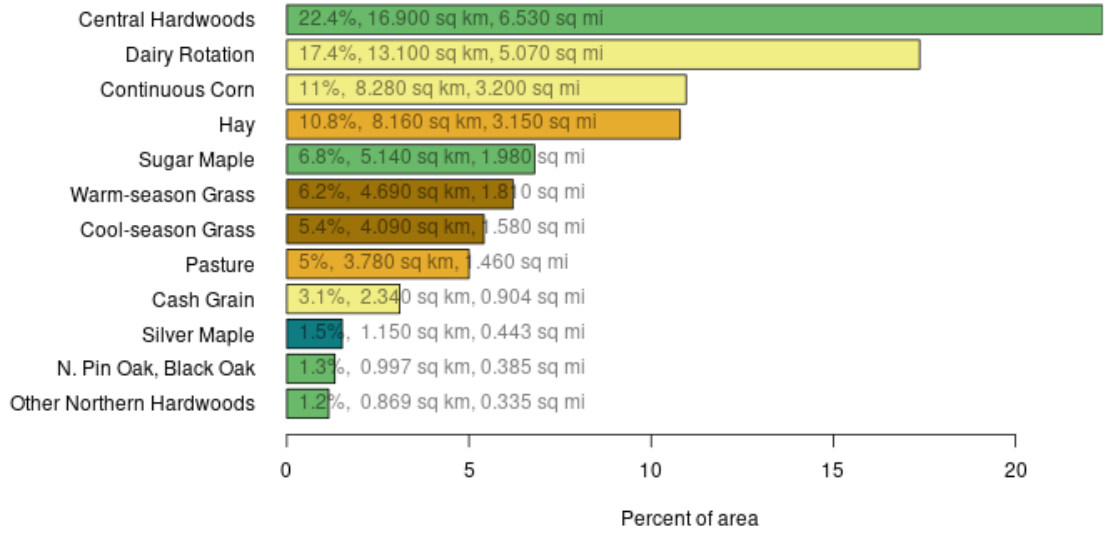
System Sensitivity (Precipitation and Temperature)

Lake Pepin TMDL – Rush River

Watershed Landcover (WHDPlus)



Riparian Landcover (WHDPlus)



System Sensitivity (Precipitation and Temperature)

Lake Pepin TMDL – Rush River

PhosMER Water Quality Drivers:

<u>Precipitation</u>: Highly sensitive to precipitation events with larger precipitation events having a much greater proportional influence on total phosphorus loading.

<u>Temperature</u>: Temperature fluctuations have a very small influence on phosphorus cycling in the system.

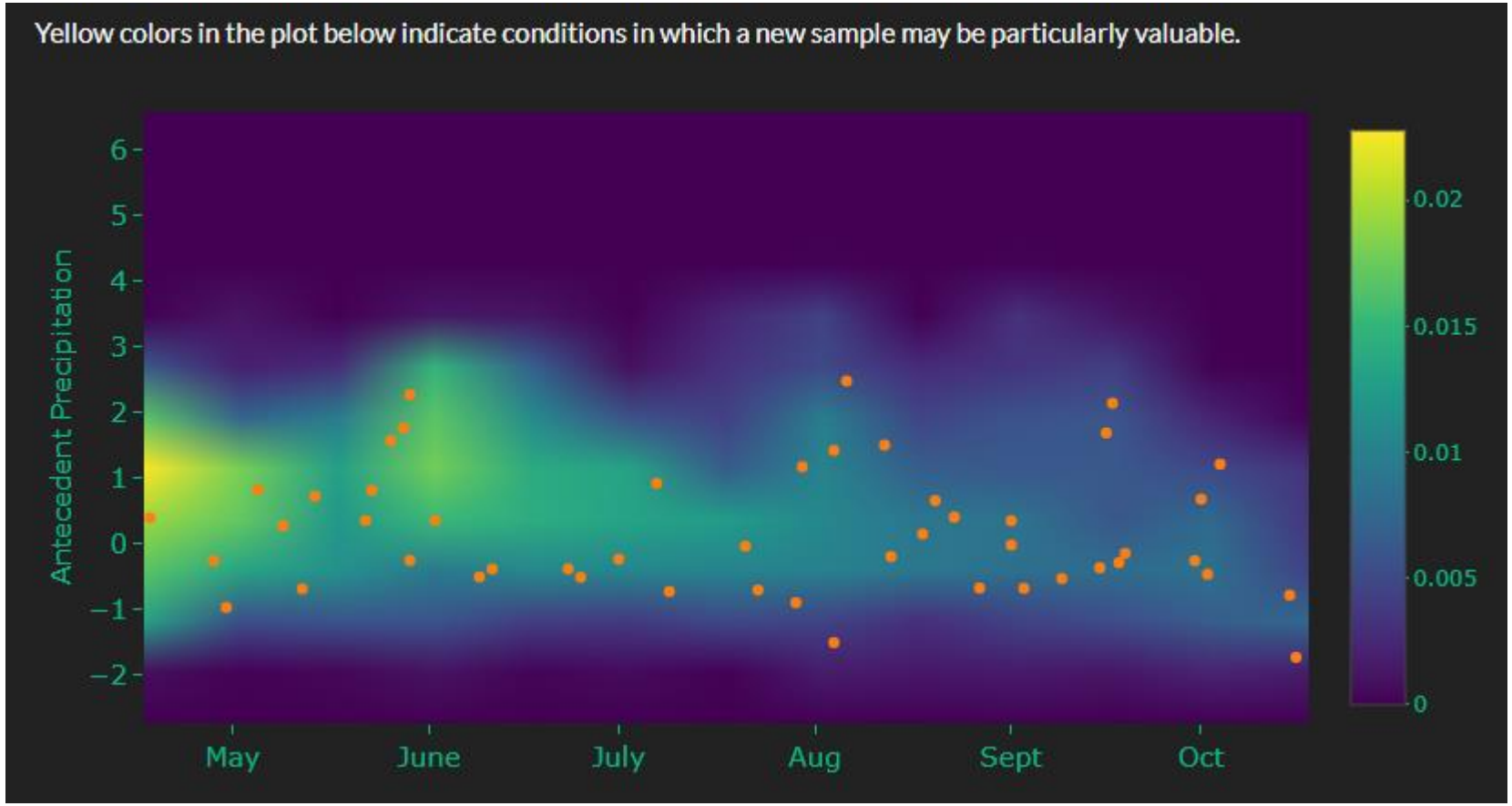
<u>Seasonal Variation</u>: Driven by precipitation patterns.

System Sensitivity (Precipitation and Temperature)

Lake Pepin TMDL – Rush River

PhosMER Monitoring Recommendations:

Additional sampling in the spring will be particularly valuable.



System Sensitivity (Precipitation and Temperature)

Rock River TMDL – Sixmile Creek

Precipitation: Highly sensitive to precipitation events with larger precipitation events having a much greater proportional influence on total phosphorus loading.

Temperature: Temperature fluctuations have a very large influence on phosphorus cycling in the system.

Seasonal Variation: In addition to precipitation events, total phosphorus concentrations are largely influenced by in-channel phosphorus cycling.

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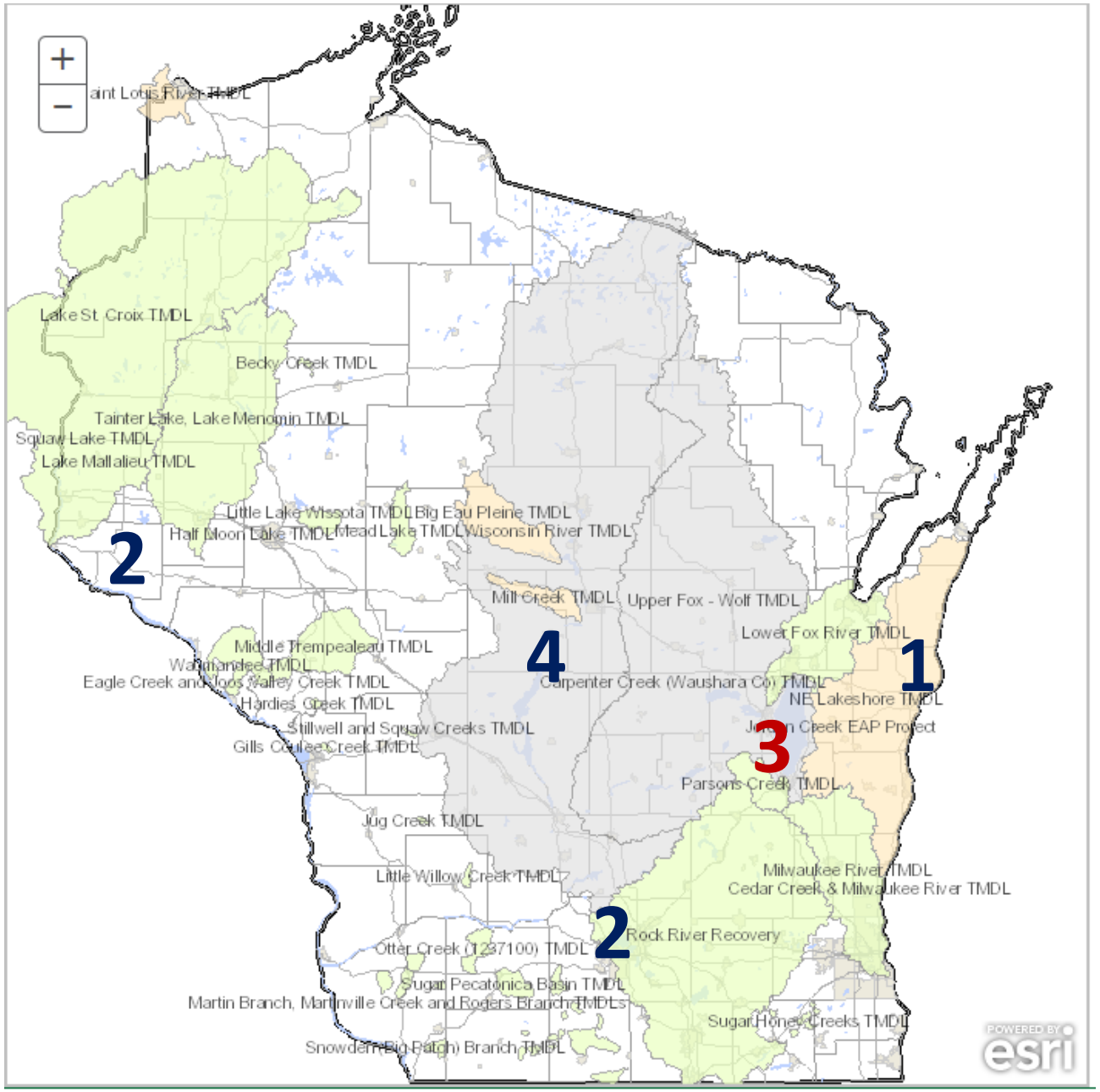


Adaptive Approaches

Upper Fox-Wolf Basin TMDL

Lake Winnebago is impaired for phosphorus and has seen significant alterations over the decades.


North End Winnebago Lake Aerial Photo

Drainage Area: 5,903 sq. miles

Adaptive Approaches

Upper Fox-Wolf Basin TMDL

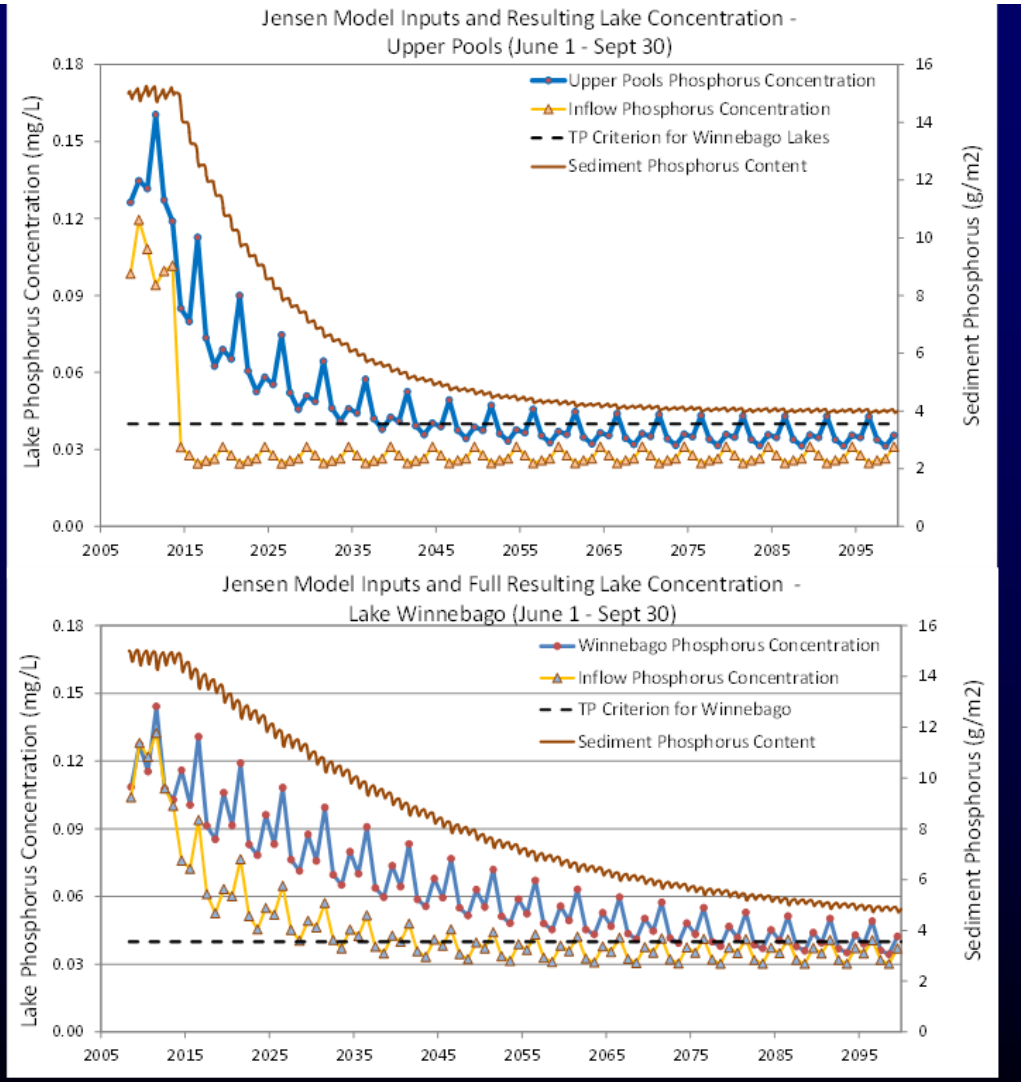
Two models were run to simulate phosphorus cycling in Lake Winnebago.

The Jensen model also allows estimates of response time based on internal loading.

Poll Question: What will the climate be in 25, 50, or 75 years and will that impact the overall response time?

Simulation of a 75% Reduction in all external loading to the Upper Fox/Wolf Basin

The BATHTUB model shows that a 73% reduction in external load is needed to meet 0.04mg/L.



Upper Pools need about a 70% Reduction in Loading & 40 yrs to Reach 0.04 mg/L
Winnebago needs about a 75% Reduction in Loading & 75 yrs to Reach 0.04 mg/L

Climate Change in TMDL Development
More uncertainty and challenging to simulate with models

"We are unsure of the impacts of changing temperatures and precipitation coupled with the impact of invasive species, but one thing is certain, you need to reduce the amount of phosphorus entering Lake Winnebago"

- UW-System Researcher Comment on Lake Winnebago

- The Upper Fox - Wolf Basin TMDL requires an 83% reduction in anthropogenic phosphorus loads to meet water quality criteria in Lake Winnebago.

- Factoring projected climate change into the percent reductions may only complicate messaging. Modeling to calculate allocations already uses a combination of critical conditions including wet, dry, and average rainfall years obtained from the current climate normal.

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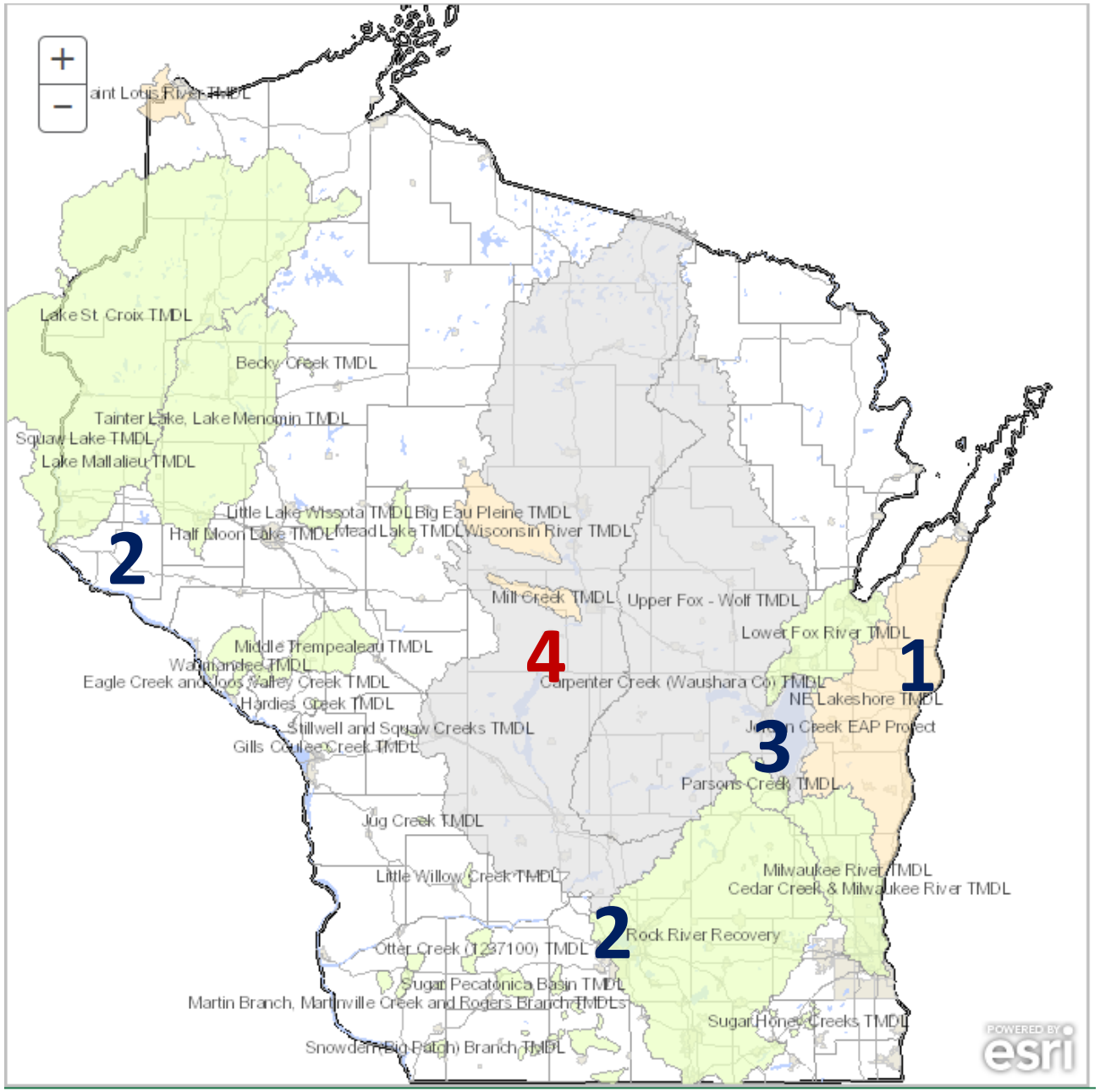


Implementation Approaches

Wisconsin River Basin TMDL

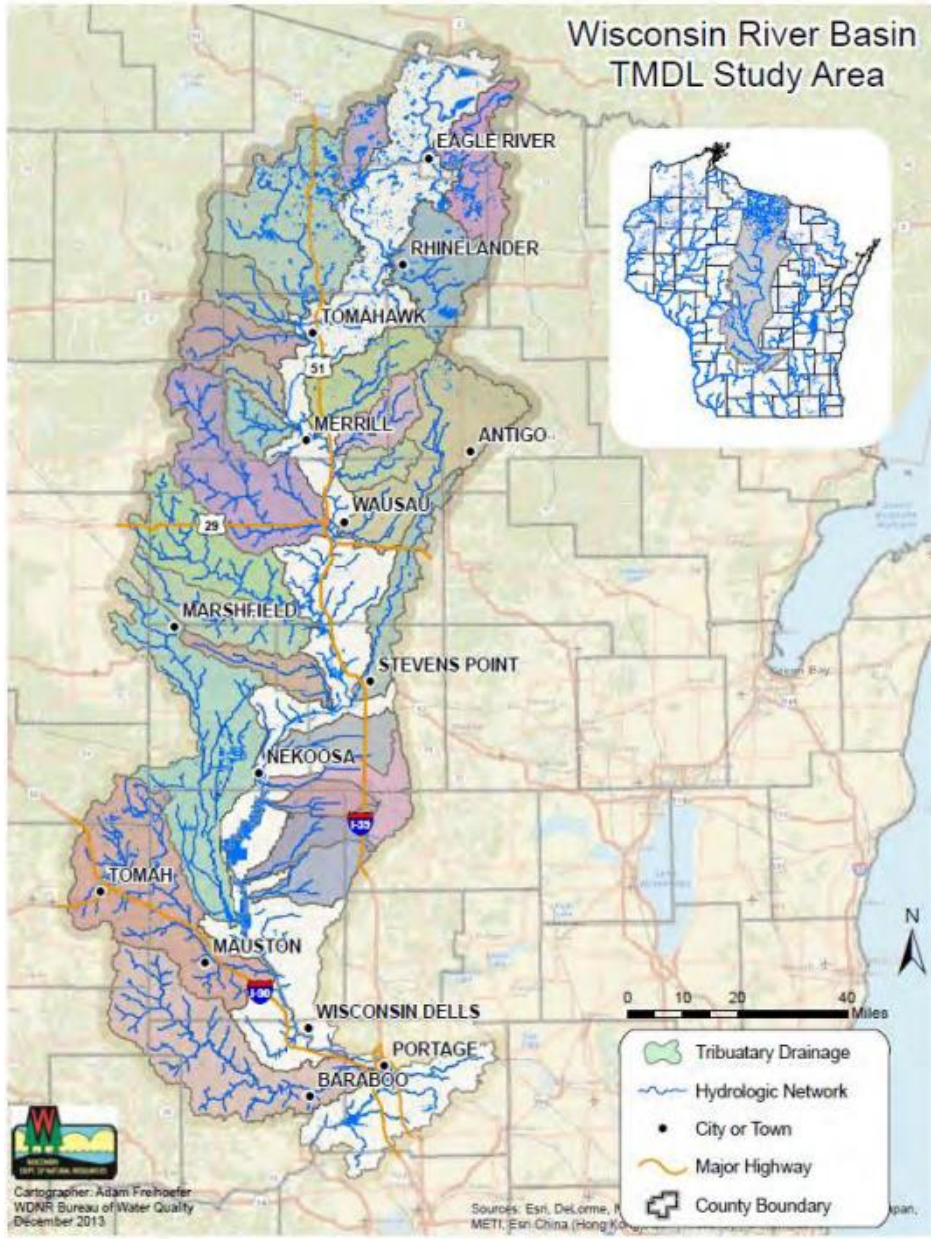
Agricultural Load Allocations Expressed as Edge of field targets (SnapPlus)

Translates TMDL allocations into a value that can easily be compared to nutrient management plans on a field scale.

Actual percent reductions will vary by field depending on the field's current conditions compared to the baseline condition specified in the TMDL.

SNAPPLUS
WISCONSIN'S NUTRIENT MANAGEMENT PLANNING SOFTWARE

https://snapplus.wisc.edu/



Implementation Approaches

Wisconsin River Basin TMDL

TMDL includes baseline and edge of field targets:

TMDL Subbasin	TP			TSS		
	Baseline (lbs./ac/yr)	% Reduction	Target (lbs./ac/yr)	Baseline (tons/ac/yr)	% Reduction	Target (tons/ac/yr)
1	1.68	88%	0.20	1.71	47%	0.91
2	2.74	79%	0.57	2.72	47%	1.45
3	3.41	79%	0.71	3.29	79%	0.69
4	2.10	88%	0.25	1.80	47%	0.96
5	3.14	74%	0.83	2.64	64%	0.96

Additional implementation scenarios selected based on pollutant loading drivers. Management practices included buffer strips, no-till and conservation tillage, grassed waterways, and cover crops.

SnapPlus can also be re-run and updated to account for the new climate normals allowing revaluation of baseline, target values, and implementation practices.

Summary:

- Climate change is not making our jobs easier and climate change impacts are highly variable.
- More uncertainty and challenging to simulate with models; however, the use of current and representative climate data to address critical conditions (wet, dry, and average years) will help.
- Run models under different scenarios and under variable climate scenarios to ensure that model parameters are correctly simulating processes and help capture the necessary extreme events.
- Look at model calibration and validation at the low and high flow events; if the model is not properly representing these events the results under future climate projections are likely not representative nor predictive.
- The shelf life of restoration plans likely shorter requiring updates during the typical implementation time period and may require more adaptive approaches.

Questions