Application of Wisconsin Lake Modeling Suite (WiLMS) for the Upper Fox-Wolf Basins TMDL

Summer 2016 Update

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The Cadmus Group

UFWB TMDL Stakeholder Meeting

June 15, 2016

- Phosphorus TMDLs to be developed for 25 lakes in UFWB

Name	County	WBIC	Surface Area (acres)	Mean Depth (ft.)
Mason Lake	Adams, Marquette	175700	856	7
Park Lake	Columbia	180300	312	7
Swan Lake	Columbia	179800	406	32
Lake Emily	Dodge	161600	270	5
Crane Lake	Forest	388500	337	12
Pine Lake	Forest	406900	1,692	11
Big Twin Lake	Green Lake	146500	78	16
Green Lake	Green Lake	146100	7,346	104
Little Green Lake	Green Lake	162500	466	10
Upper Post Lake	Langlade, Oneida	399200	757	6
Buffalo Lake	Marquette	168000	2,210	5
Puckaway Lake	Marquette, Green Lake	158700	5,039	3
Black Otter Lake	Outagamie	315600	75	5
Collins Lake	Portage	270200	42	25
Spring Lake	Portage	267200	37	8
Tree Lake	Portage	289400	74	14
Long Lake	Shawano	321300	86	19
Shawano Lake	Shawano	322800	6,063	9
White Clay Lake	Shawano	326400	234	14
Old Taylor Lake	Waupaca	195000	55	5
School Section Lake	Waupaca	283600	37	19
Lake Poygan	Winnebago, Waushara	242800	14,024	7
Lake Winneconne	Winnebago	241600	4,553	5
Lake Butte des Morts	Winnebago	139900	8,581	9
Lake Winnebago	Winnebago, Calumet, Fond du Lac	131100	131,939	16

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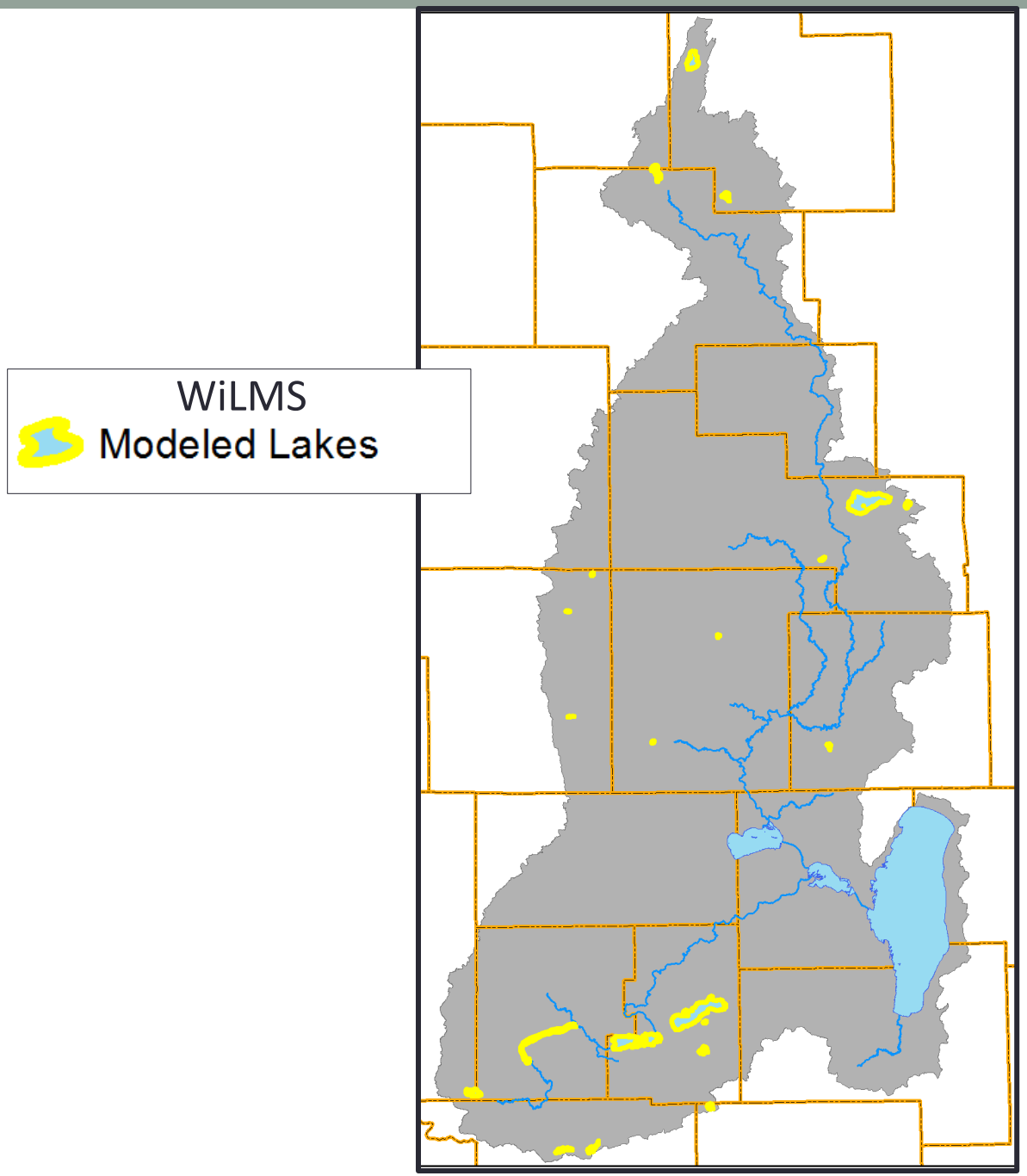
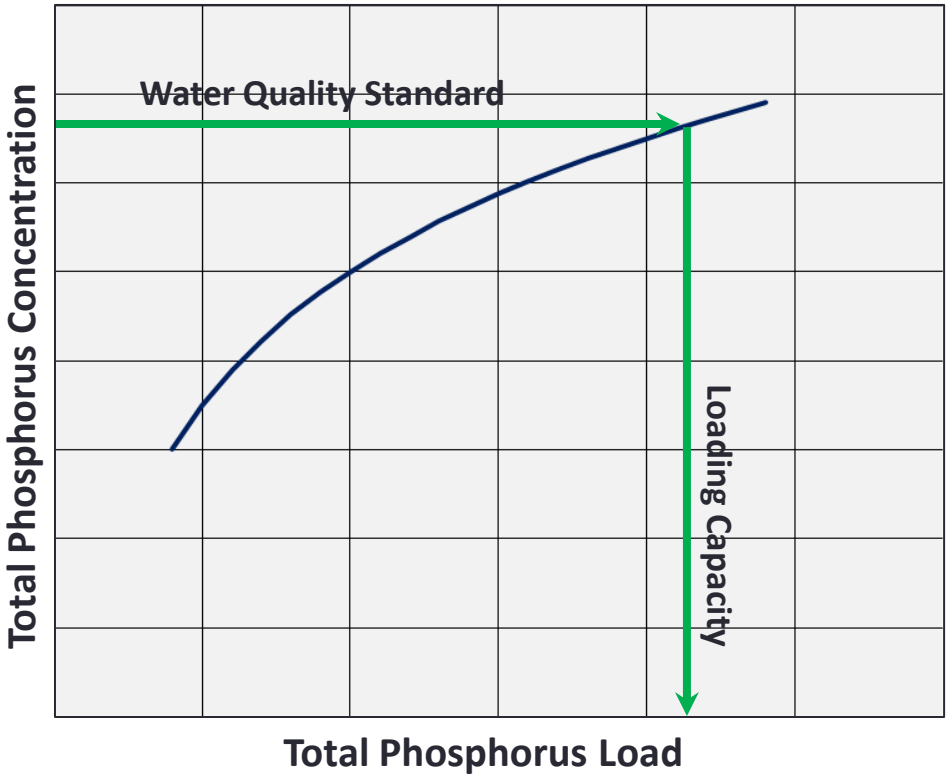
Wisconsin Lake Modeling Suite (WiLMS)

BATHTUB & Jensen Lake Models


WiLMS
Modeled Lakes

WiLMS Lake Modeling Purpose

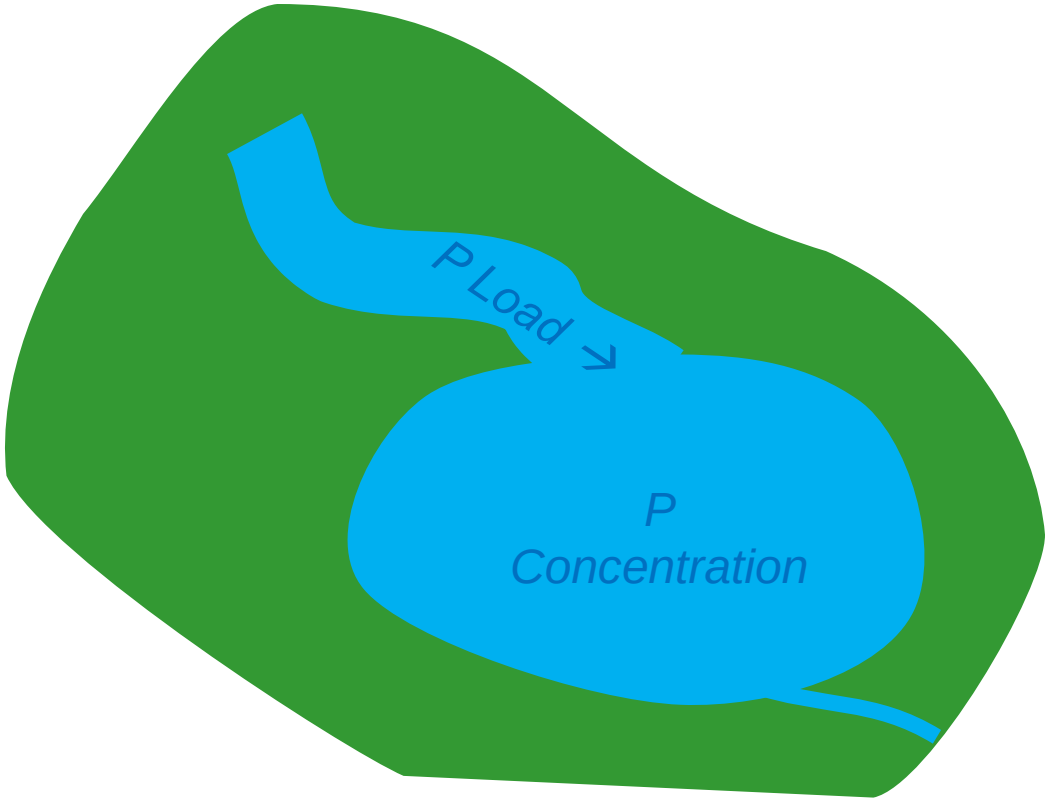
- Evaluate phosphorus loading capacity for impaired UFWB lakes (other than Winnebago pool lakes).
- Output used for TMDL allocation analysis.



Wisconsin Lake Modeling Suite (WiLMS)

Empirically-Based

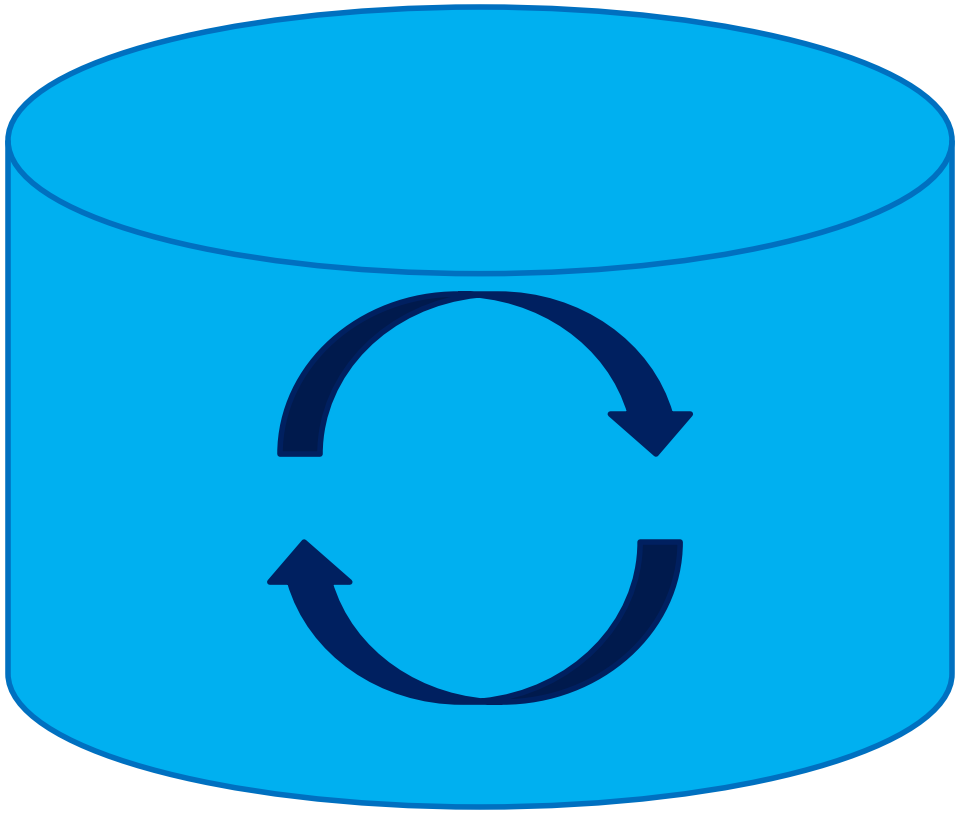
- Regression models relate phosphorus loading to in-lake phosphorus concentration
  - Derived from phosphorus measurements in lakes across the US.



Wisconsin Lake Modeling Suite (WiLMS)

Completely Mixed (Zero-Dimensional)

- Lake modeled as a single basin.
- No horizontal or vertical variability.



Inputs

Lake Dimensions (Surface Area, Volume)
Phosphorus Load Into Lake
Water Volume Into Lake
Net Precipitation

$$P = \frac{L}{z(0.162(L/z)^{0.458} + p)}$$

Canfield-Bachmann (1981)

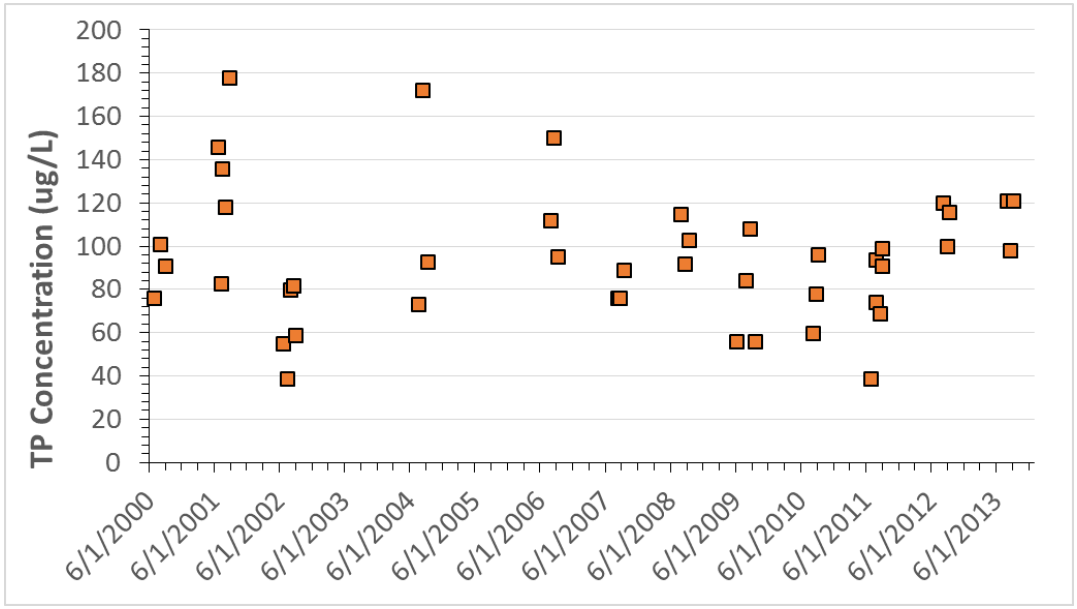
P = Growing Season Mean Total Phosphorus Concentration
L = Annual Total Phosphorus Load
p = Hydraulic Flushing Rate
z = Average Lake Depth

Output

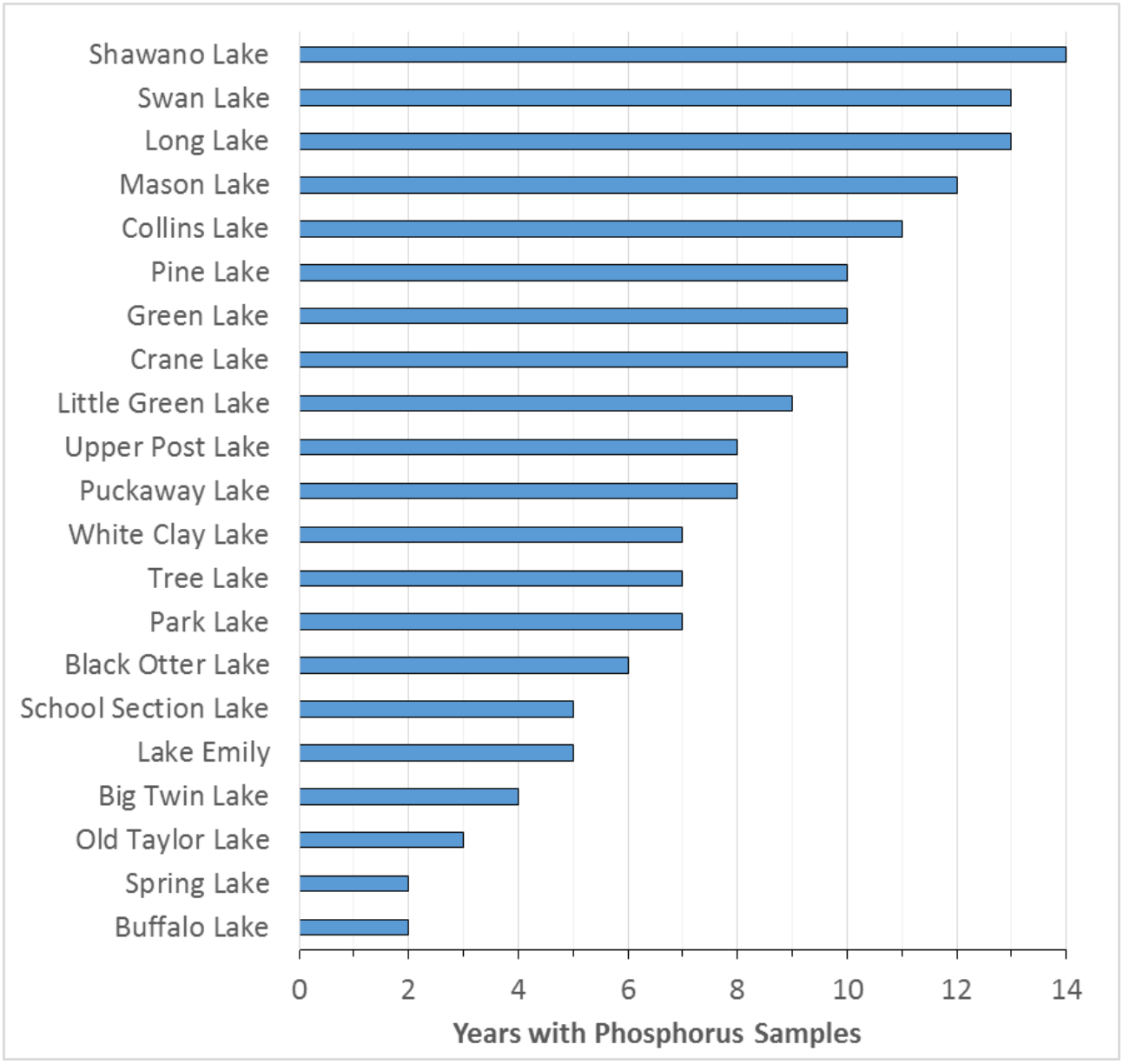
Predicted Growing Season Total Phosphorus Concentration

Phosphorus Monitoring Data

- DNR Citizen Lake Monitoring Network, SWIMS database
- Used for model calibration and validation
- Selected years since 2000 with at least 2 growing season months sampled (June-Sept.)

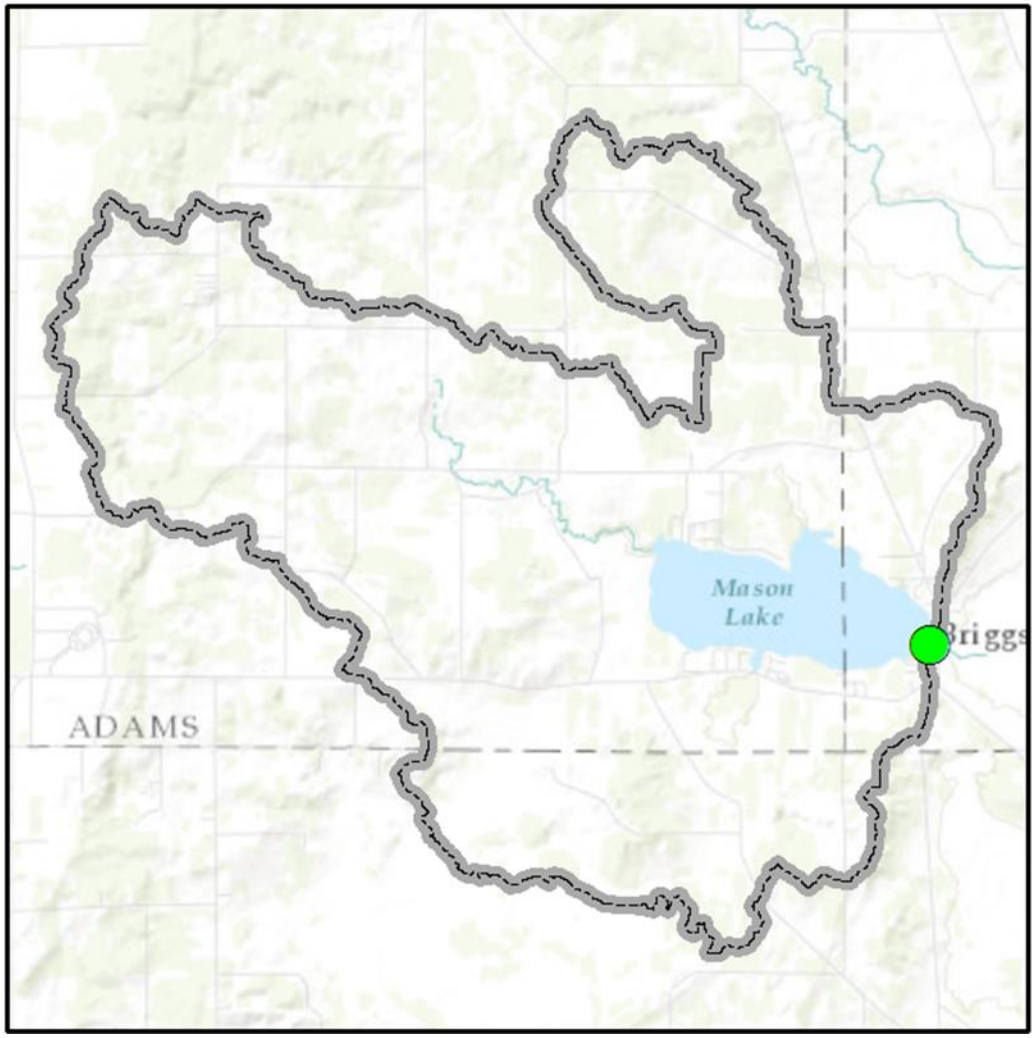


Number of Years with Phosphorus Samples

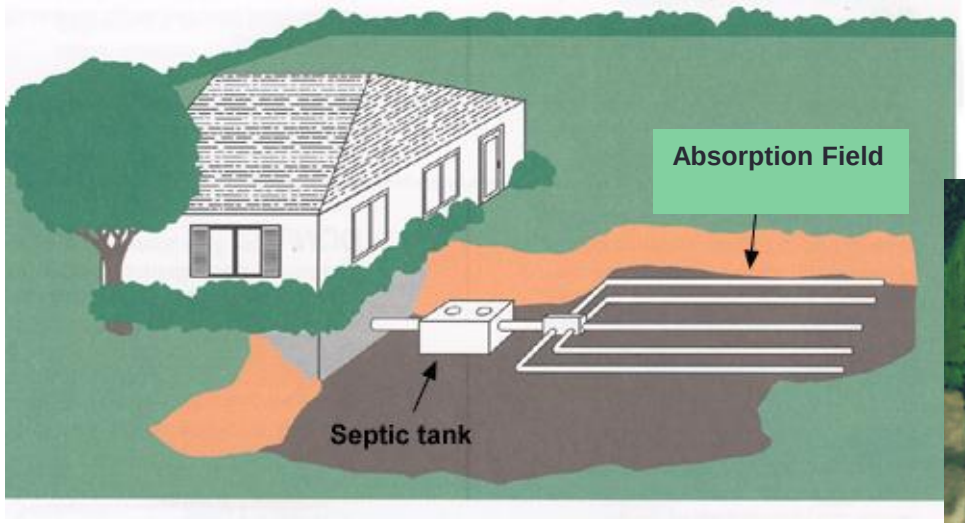


Water and Phosphorus Inflows

Tributary phosphorus loads and runoff volumes estimated from UFWB SWAT model



Nearshore Septic Systems

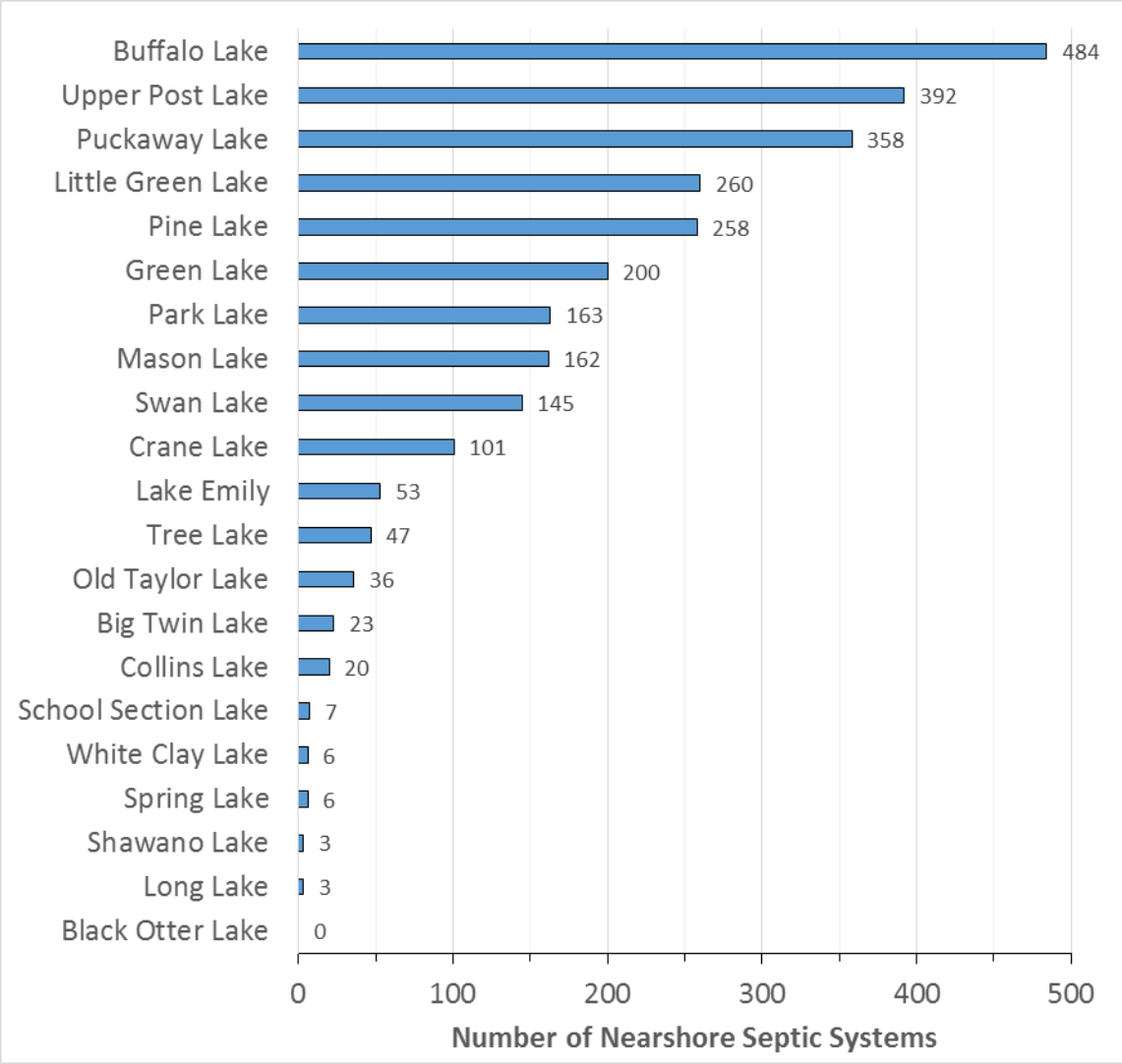


Defined as residences with septic systems within 500 feet of shoreline.

Counts estimated from land parcel boundaries, aerial photos, and centralized sewer system information.

Initial estimates shared with county planning departments in Fall 2014 and refined with county feedback.

Nearshore Septic Systems



- Septic system phosphorus loads estimated from:
  - Number of Nearshore Septic Systems
  - Number of Residents per Septic System (County Census records)
  - Per Capita Phosphorus Export Rate (1.8 Pounds/Person/Year)
  - Soil Retention Coefficient (SSURGO soils database)

Empirical Model Selection

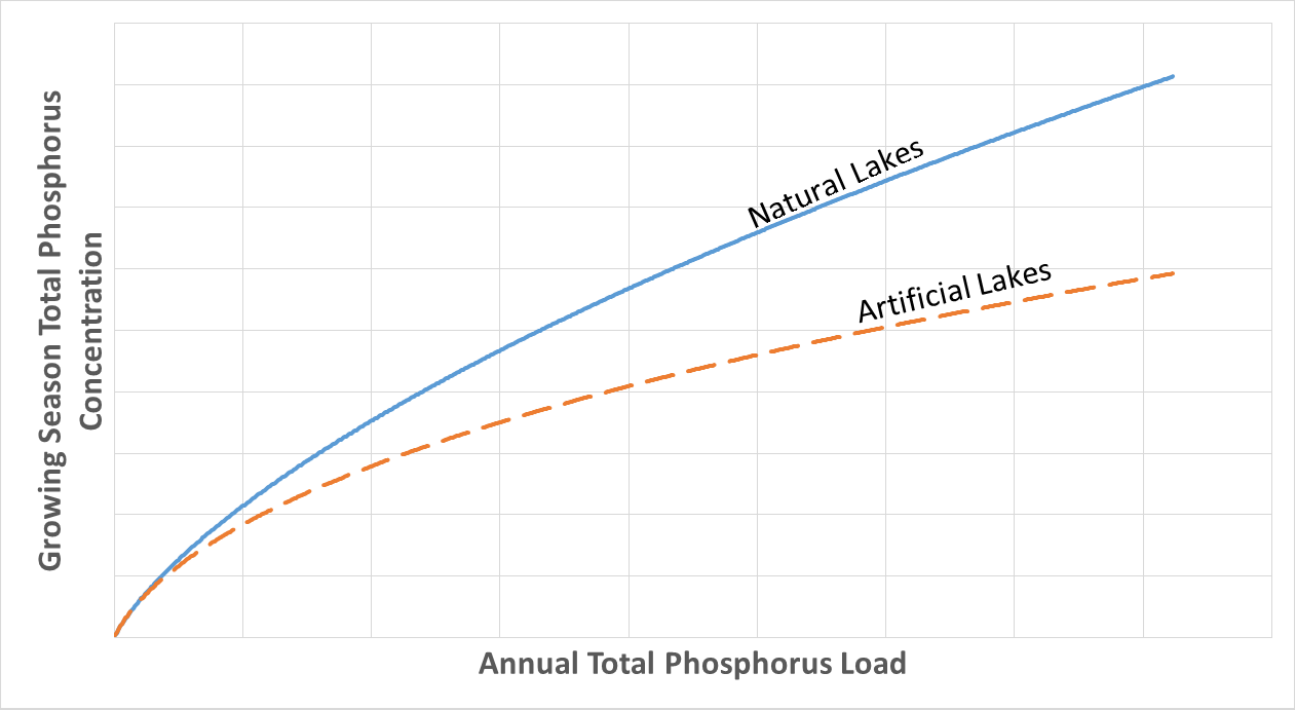
- Canfield-Bachmann Natural Lake Model

$$P = \frac{L}{z(0.162(L/z)^{0.458} + p)}$$

- Canfield-Bachmann Artificial Lake Model

$$P = \frac{L}{z(0.114(L/z)^{0.589} + p)}$$

P = Growing Season Mean Total Phosphorus Concentration
L = Annual Total Phosphorus Load
p = Hydraulic Flushing Rate
z = Average Lake Depth



- Selection of natural vs. artificial model based on profile of natural vs. artificial lakes in the Canfield-Bachmann dataset.

- Natural lakes:
  - Longer Residence Time
  - Deeper
  - Lower TP Load
  - Higher TP Concentration

Natural Lakes
Residence Time = 0.2 years
Depth = 42 feet
TP Load = 25 pounds/acre
TP Concentration = 120 µg/L

Artificial Lakes
Residence Time = 0.03 years
Depth = 30 feet
TP Load = 134 pounds/acre
TP Concentration = 78 µg/L

Lake Name	County	Natural Lake Model	Artificial Lake Model
Big Twin Lake	Green Lake	✓	
Black Otter Lake	Outagamie		✓
Buffalo Lake	Marquette	✓	
Collins Lake	Portage	✓	
Crane Lake	Forest	✓	
Green Lake	Green Lake	✓	
Lake Emily	Dodge	✓	
Little Green Lake	Green Lake	✓	
Long Lake	Shawano	✓	
Mason Lake	Adams, Marquette	✓	
Old Taylor Lake	Waupaca	✓	
Park Lake	Columbia		✓
Pine Lake	Forest	✓	
Puckaway Lake	Marquette, Green Lake	✓	
School Section Lake	Waupaca	✓	
Shawano Lake	Shawano	✓	
Spring Lake	Portage	✓	
Swan Lake	Columbia	✓	
Tree Lake	Portage	✓	
Upper Post Lake	Langlade, Oneida	✓	
White Clay Lake	Shawano	✓	

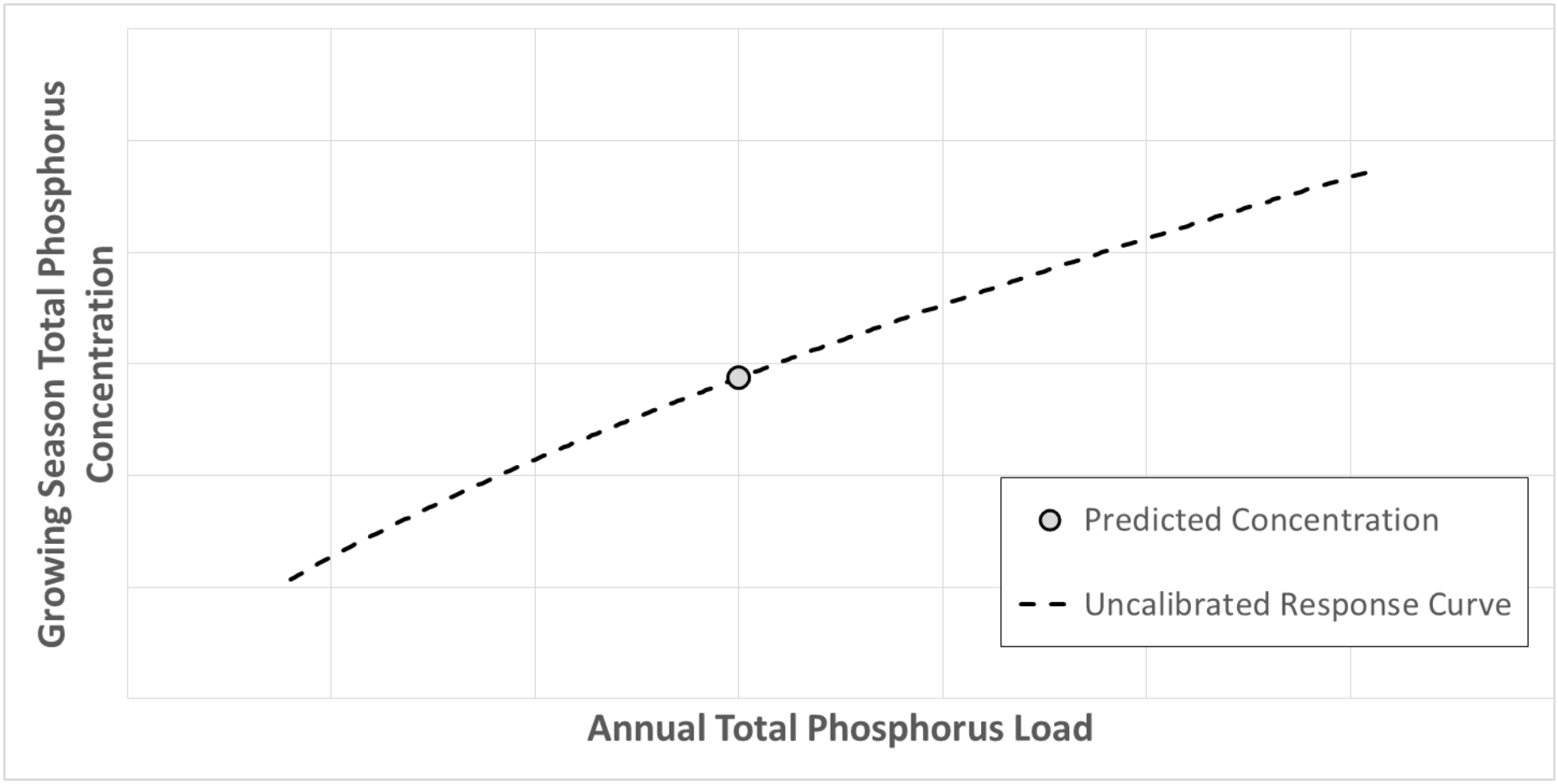
Model Calibration

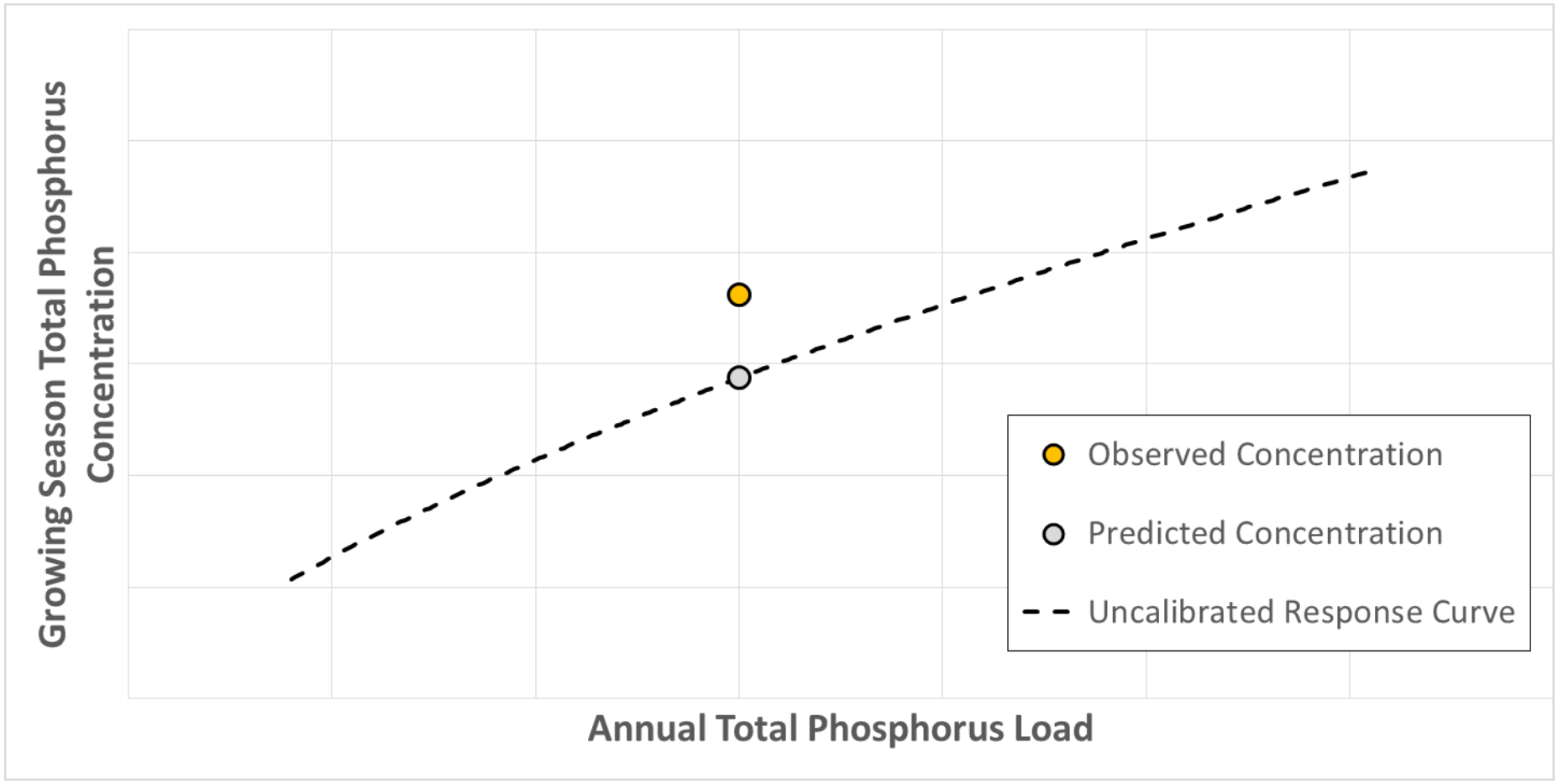
- Step 1) Predict growing season TP concentration for calibration period

- Step 2) Compare predicted and observed TP concentrations

- Step 3) Calculate adjustment factor to account for difference between predicted and observed concentrations.

$$Adjustment\ Factor = \frac{Observed\ TP\ Concentration}{Predicted\ TP\ Concentration}$$


Growing Season Total Phosphorus Concentration
Annual Total Phosphorus Load
Predicted Concentration
Uncalibrated Response Curve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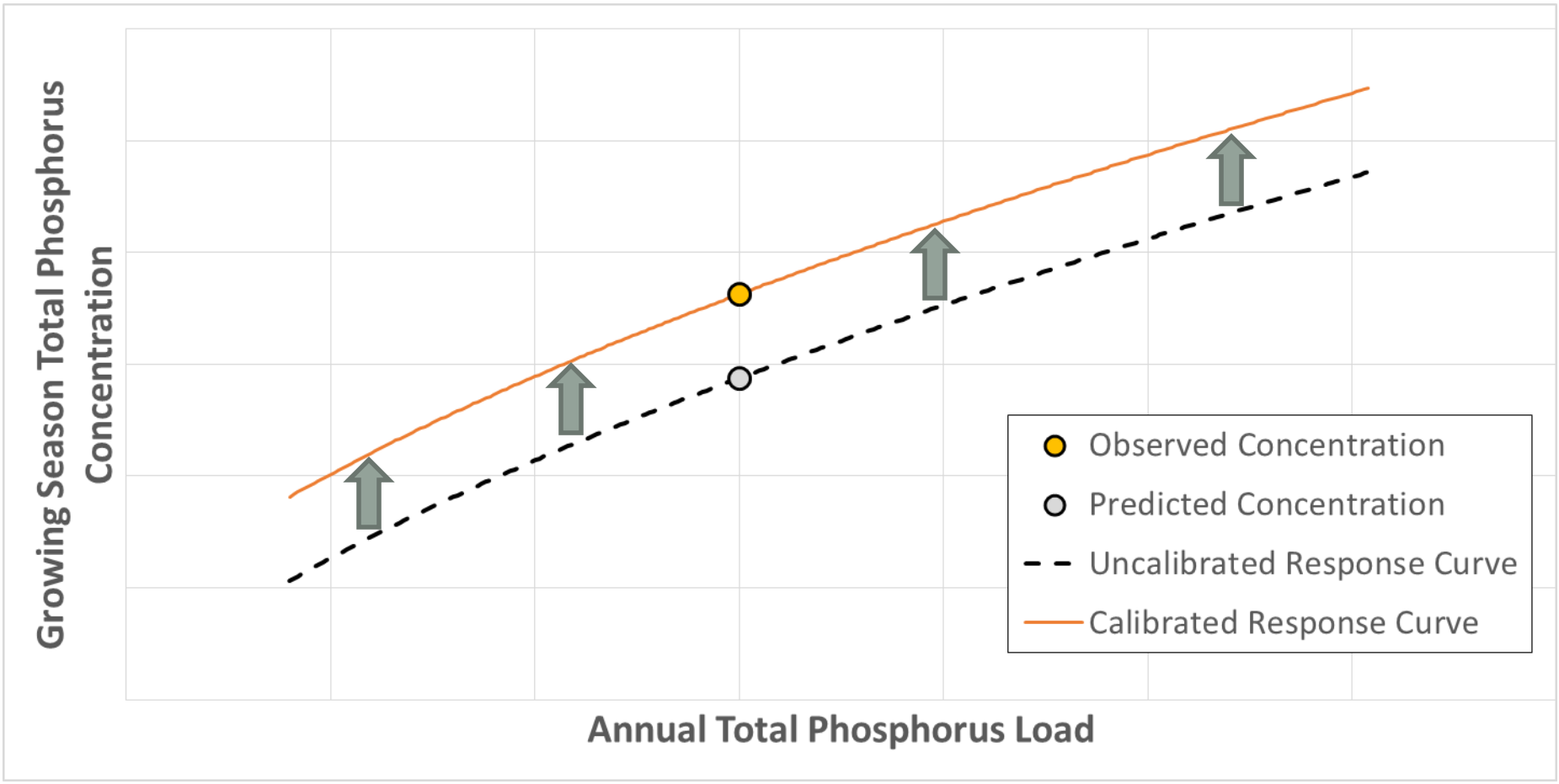
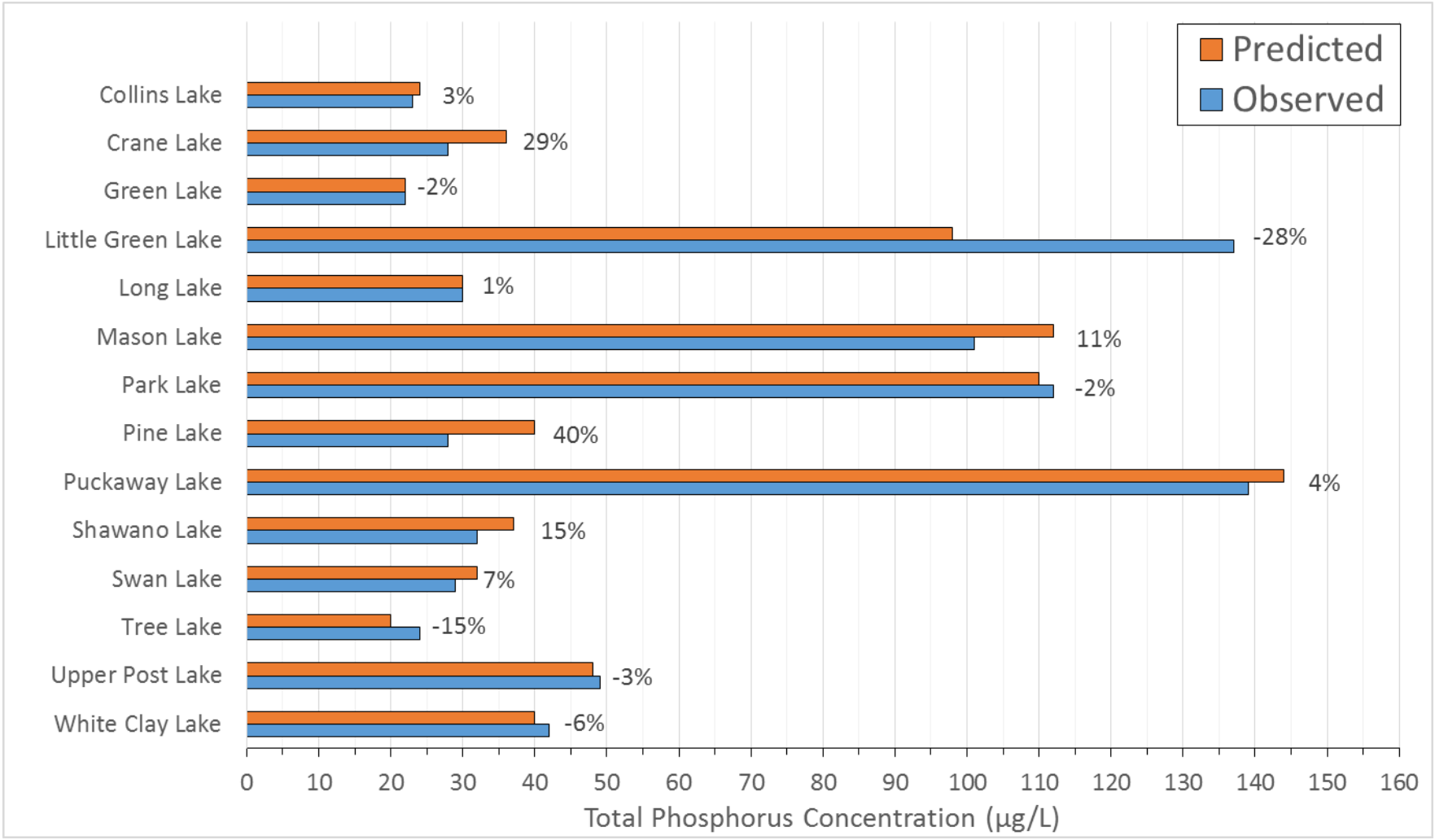

Growing Season Total Phosphorus Concentration
Annual Total Phosphorus Load
Observed Concentration
Predicted Concentration
Uncalibrated Response Curve
Calibrated Response Curve

Lake Name	County	Calibration Years	Observed TP (µg/L)	Adjustment Factor
Big Twin Lake	Green Lake	2004-2006; 2009	43	0.49
Black Otter Lake	Outagamie	2002; 2009-2013	100	0.57
Buffalo Lake	Marquette	2000-2001	135	1.83
Collins Lake	Portage	2009-2013	27	1.47
Crane Lake	Forest	2009-2013	32	1.99
Green Lake	Green Lake	2009-2013	17	0.98
Lake Emily	Dodge	2005-2006; 2011-2013	64	0.98
Little Green Lake	Green Lake	2011-2013	96	2.66
Long Lake	Shawano	2008-2013	35	0.71
Mason Lake	Adams, Marquette	2008-2013	125	1.68
Old Taylor Lake	Waupaca	2003-2005	49	2.07
Park Lake	Columbia	2009; 2011-2013	106	1.06
Pine Lake	Forest	2009-2013	37	2.07
Puckaway Lake	Marquette, Green Lake	2009; 2011-2013	142	1.70
School Section Lake	Waupaca	2009-2013	35	0.46
Shawano Lake	Shawano	2007-2013	44	1.67
Spring Lake	Portage	2012-2013	30	0.31
Swan Lake	Columbia	2006-2007; 2009-2013	30	0.37
Tree Lake	Portage	2010-2013	24	0.82
Upper Post Lake	Langlade, Oneida	2010-2013	46	1.22
White Clay Lake	Shawano	2010-2013	39	1.37

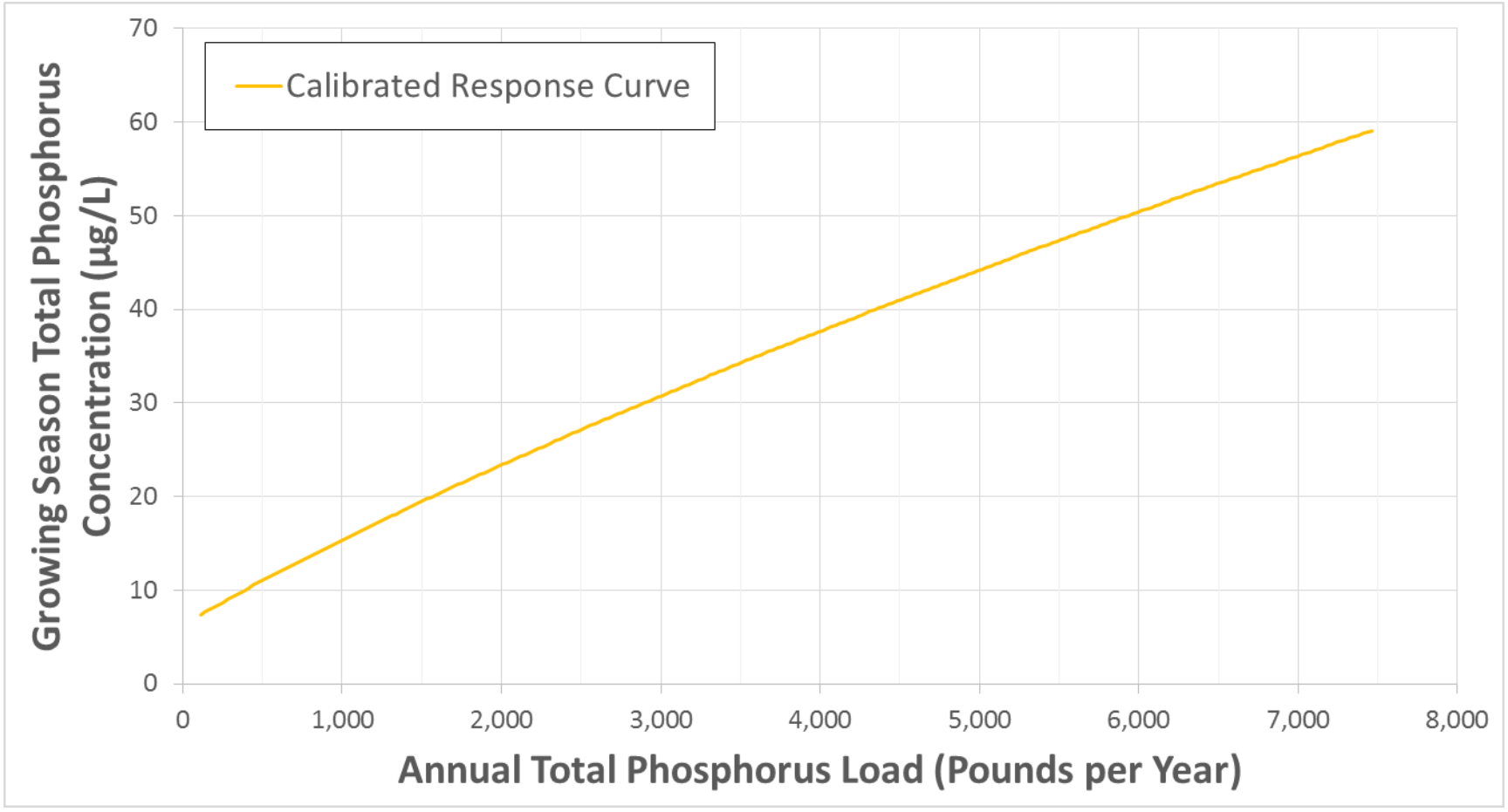
Model Validation

- Step 1) Predict growing season TP concentration for validation period.
- Step 2) Apply adjustment factor to predicted TP concentration.
- Step 3) Compare predicted and observed TP concentrations.
- Not applied to Big Twin Lake, Black Otter Lake, Buffalo Lake, Lake Emily, Old Taylor Lake, School Section Lake, or Spring Lake
  - ≤6 years of monitoring data; all years used for calibration.

Validation Results



Loading Capacity Analysis Example



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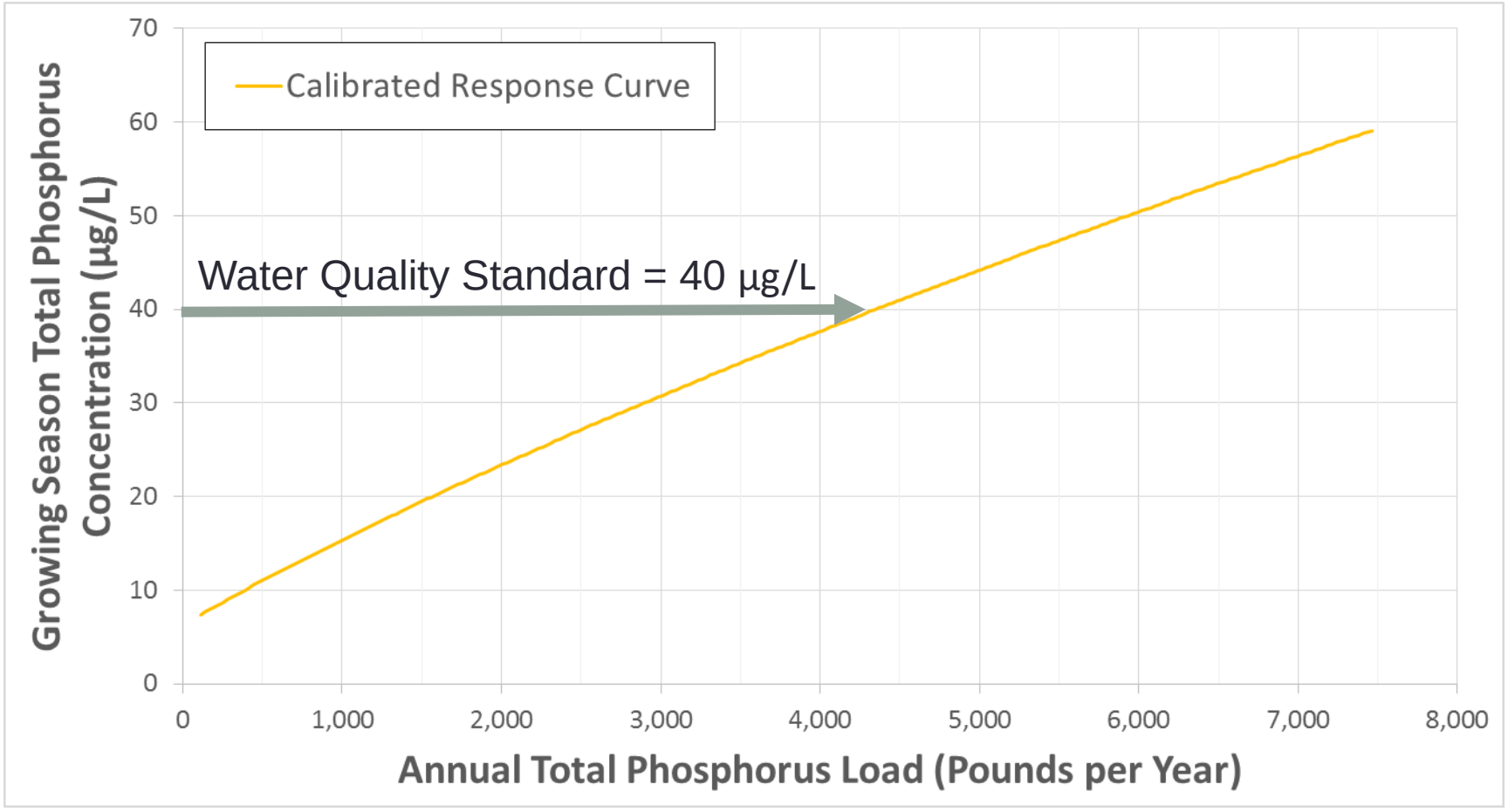

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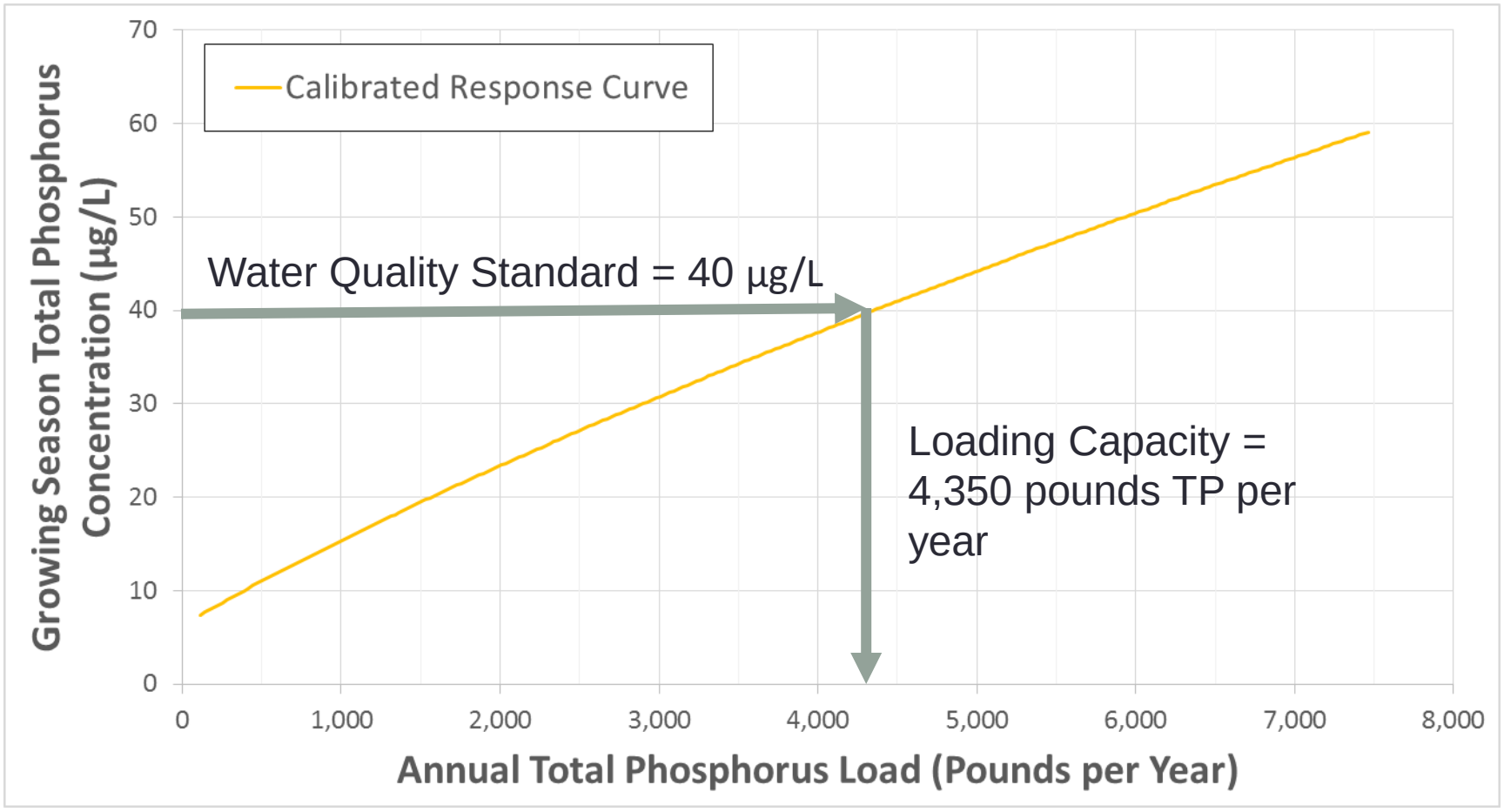

Questions?