Wisconsin Lakes PreConvention Workshop

Lake Eutrophication Modeling and WiLMS

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Center for Watershed Science & Education

UW-Stevens Point

Tentative Outline/Approach

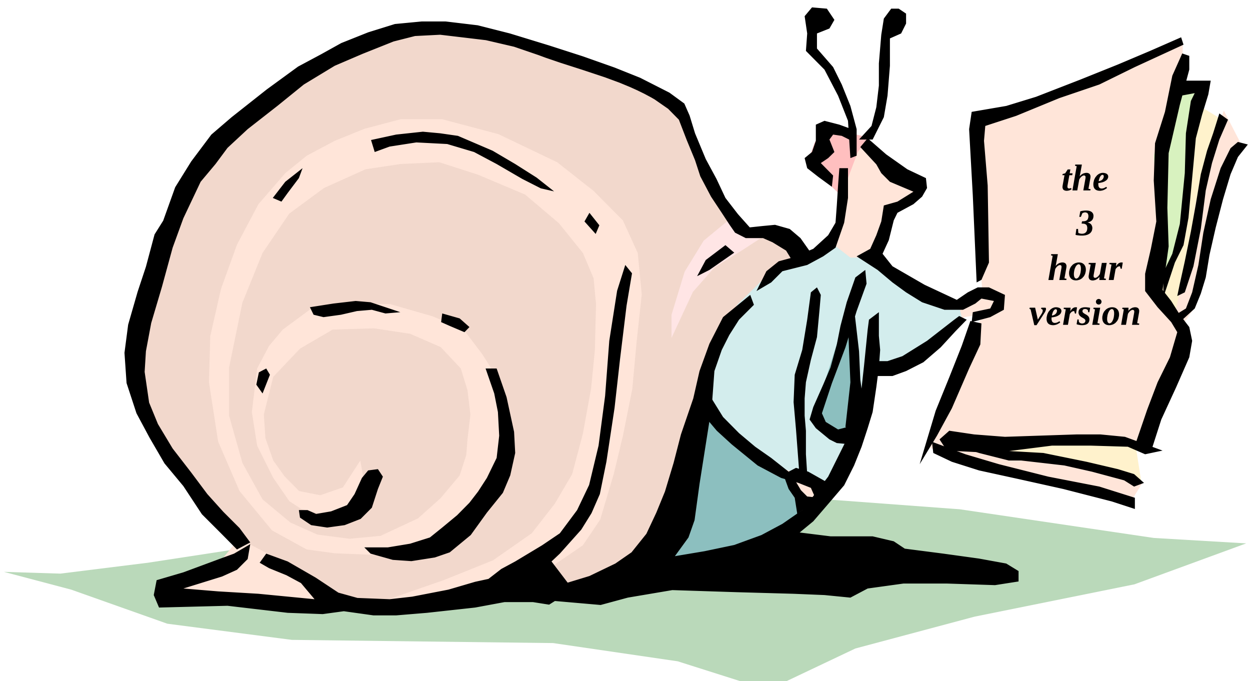
- **Introductions**
- ***Brief Overview – Eutrophication***
- ***QuickStart with WiLMS***
- **Introduce & discuss additional details as we work through a few examples**
- ***Other Models***
- **Time for your projects**

- ***Please question / interrupt / stop us!***
- ***Couple of Breaks (but feel free to move around!)***

Acknowledgements

- ***John Panuska, WDNR / now UW-Extension***
- ***Jeff Kreider, WDNR***
- ***DNR & UW Researchers***
- ***Matt Diebel and Aaron Ruesch***
- ***Many Lake Associations, WDNR, USGS, staff and students in the College of Natural Resources at UW-SP***

- <u>This is only a few hours / new workshop</u>
- *We aren't discussing everything…*
- Some background /Use WiLMS
- *Context with respect to other models*
- Learn more about your needs / suggestions for developing this course



Introductions

- *Name / Affiliation / Lake or Project etc*
- What do you hope to get out of the next few hours?
- How might / do you use eutrophication modeling?

Eutrophication

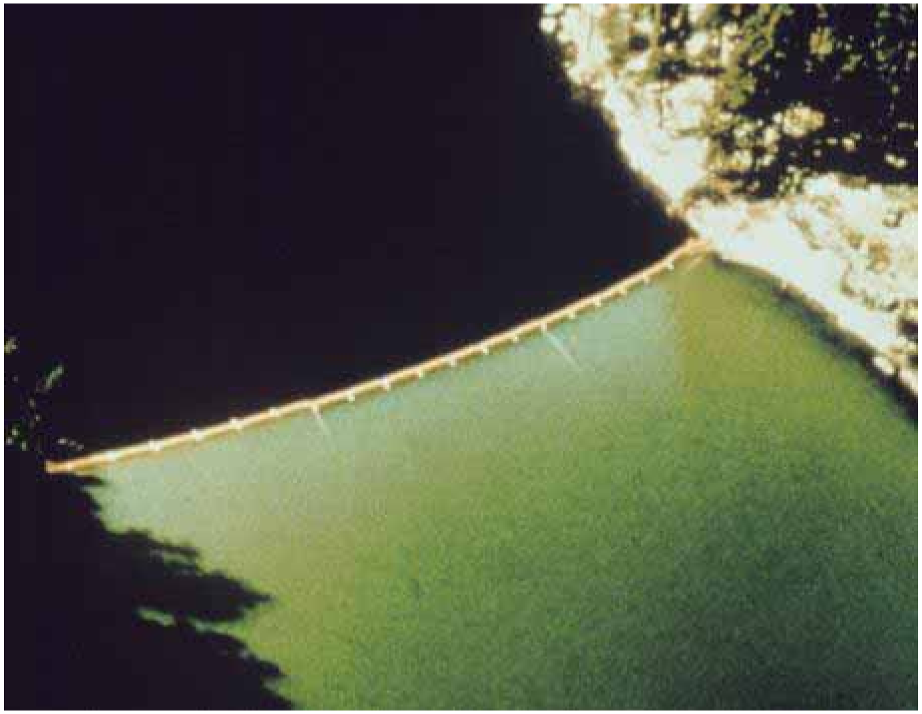
- “Process of an ecosystem becoming more productive by nutrient enrichment stimulating primary producers”
  - Walter Dodds, *Freshwater Ecology*

- Cultural eutrophication- nutrient input increased by humans

Trophic State

- Level of ecosystem productivity

- Oligotrophic - "few" "foods"
- Eutrophic – "many" "foods"



Algae's lake effect reveals pea green disaster

Rapid deterioration creates concern for Toledo community

BY TOM HENRY
BLADE STAFF WRITER

Shane Gaghen of Oregon holds a glass of algae filled Lake Erie water near the Toledo water intake crib on Sunday. The National Wildlife Federation conducted a media boat tour of the area.
THE BLADE/DAVE ZAPOTOSKY Enlarge | Buy This Photo

The most telling sign of western Lake Erie's sickness comes from an up-close view of the putrid, bright green algae surrounding Toledo's water-intake crib, not from the multiple updates provided by public officials in front of television cameras outside of the Lucas County Emergency Services Building.

The lake's rapid deterioration 2 miles off the Toledo shoreline created a gripping sight on Sunday for about 20 people — a combination of journalists, elected officials, and environmentalists — aboard a vessel

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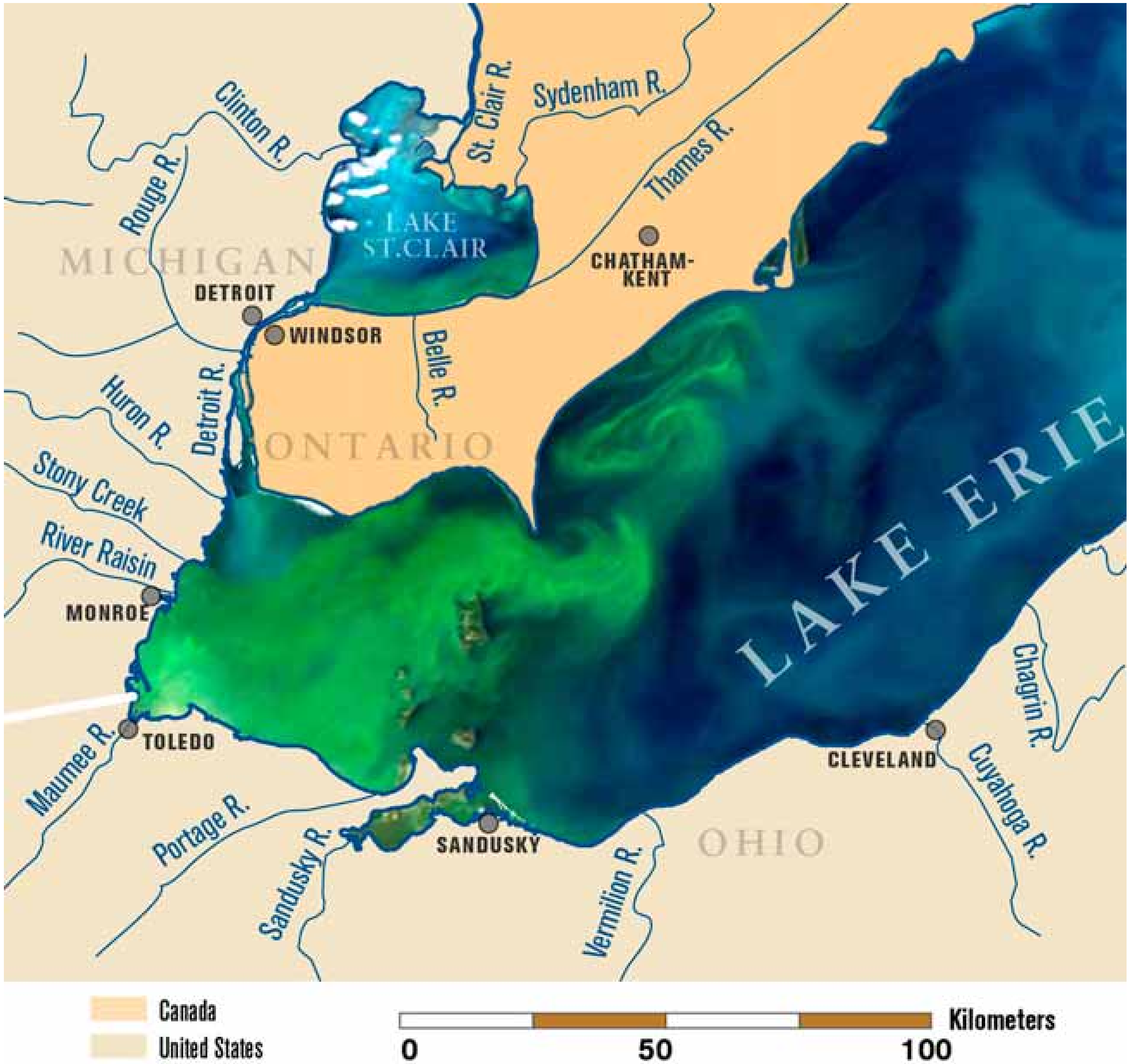
CURRENT WEATHER
46°
Sunny
Complete Forecast→
THE BLADE
One of America's Great Newspapers

NEWS | SPORTS | A & E | BUSINESS | OPINION | OUR TOWN



Sept 3, 2011 MODIS Satellite Image on Map

But you don’t have to go to Toledo to see algae

Implications of Trophic State

- Biomass quantity
- Types of organisms
- Light penetration
- Dissolved oxygen
- Algal toxins

Measures of Trophic State

- Fish Biomass
- Algal Concentration
- Nutrient Concentrations
  - Phosphorus

Note Units mg/m^3 = $\mu g/liter$

Table 1. Completed trophic state index and its associated parameters.

TSI	Secchi disk (m)	Surface phosphorus (mg/m^3)	Surface chlorophyll (mg/m^3)
0	64	0.75	0.04
10	32	1.5	0.12
20	16	3	0.34
30	8	6	0.94
40	4	12	2.6
50	2	24	6.4
60	1	48	20

http://www.secchidipin.org/trophic_state.htm

Eutrophication Modeling

- Why?
  - *Understand controls over the trophic condition*
  - *Evaluate alternatives that influence trophic status*

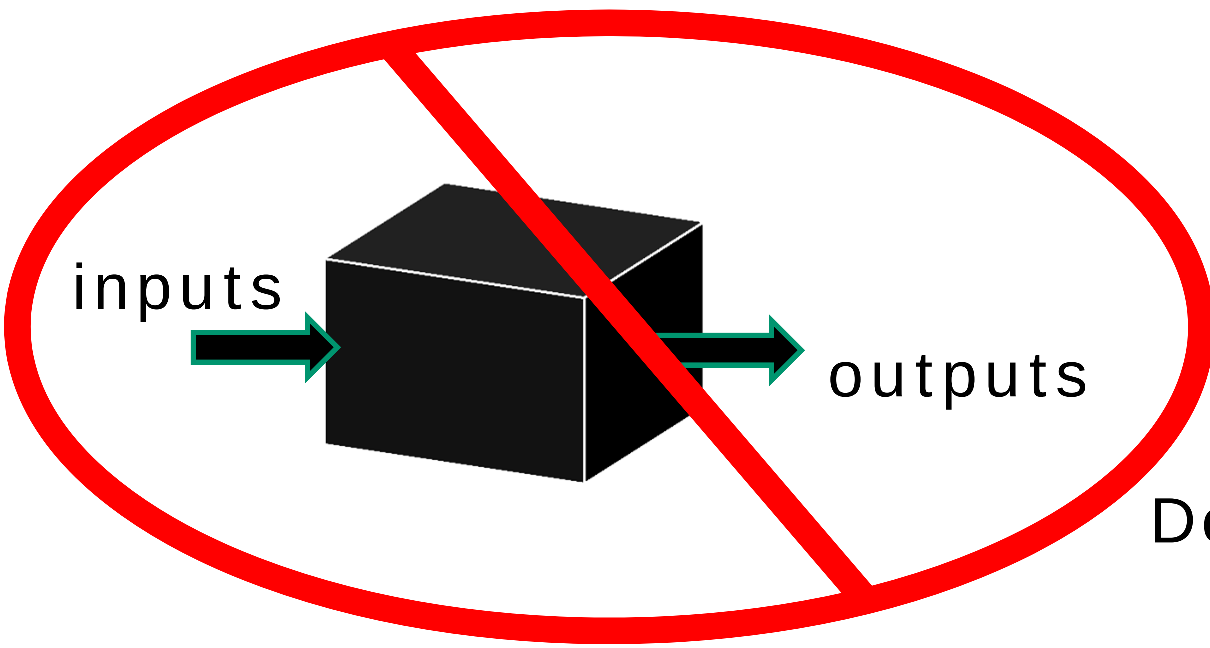
Models

- A mathematical description to help visualize something

- "All models are wrong but some are useful" -- George Box

Models

- A mathematical description to help visualize something
-



Our
Goal!
Demystify the
model...

Our First Model

- Goal– predict the P concentration

Given

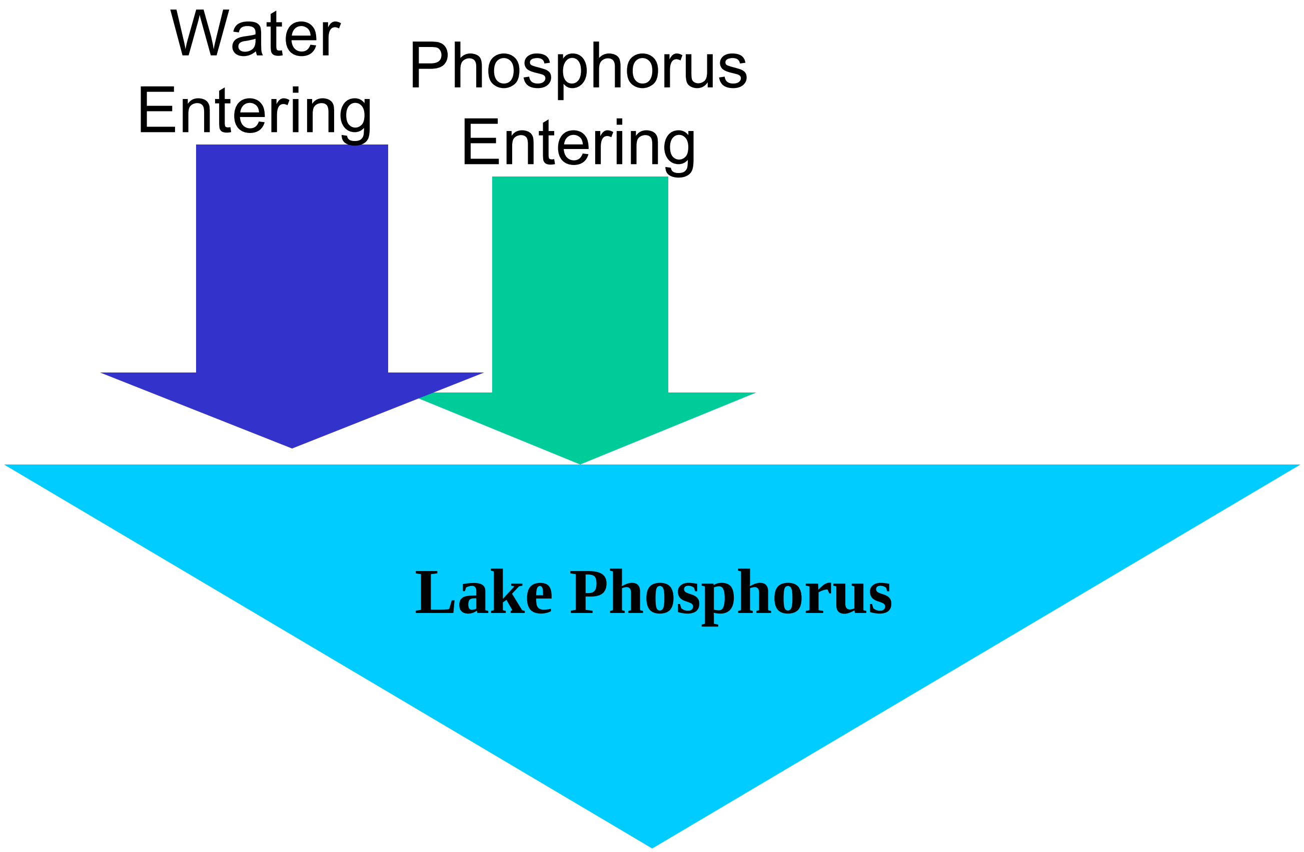
- Lake characteristics
- Watershed characteristics

Model I

- Lake
  - Walworth Co
  - 5000 acres, Mean Depth 60 feet
- Watershed
  - 10,000 acres, 50% Mixed Ag (Pasture & Row Crops), 50% Forest

- Estimate lake phosphorus concentration

How?

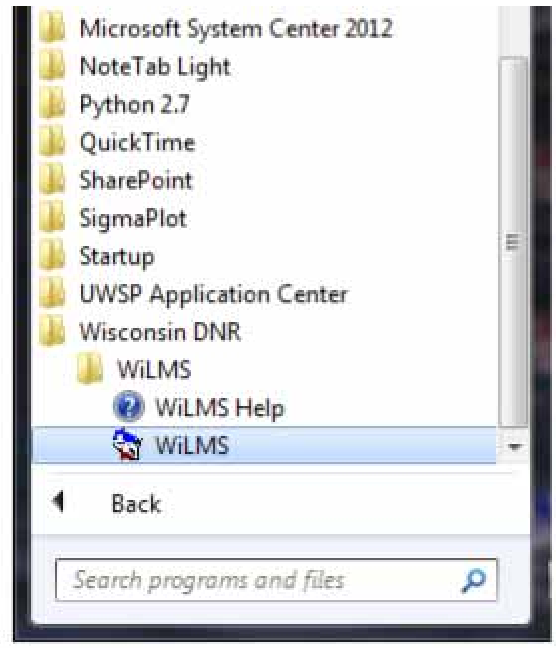


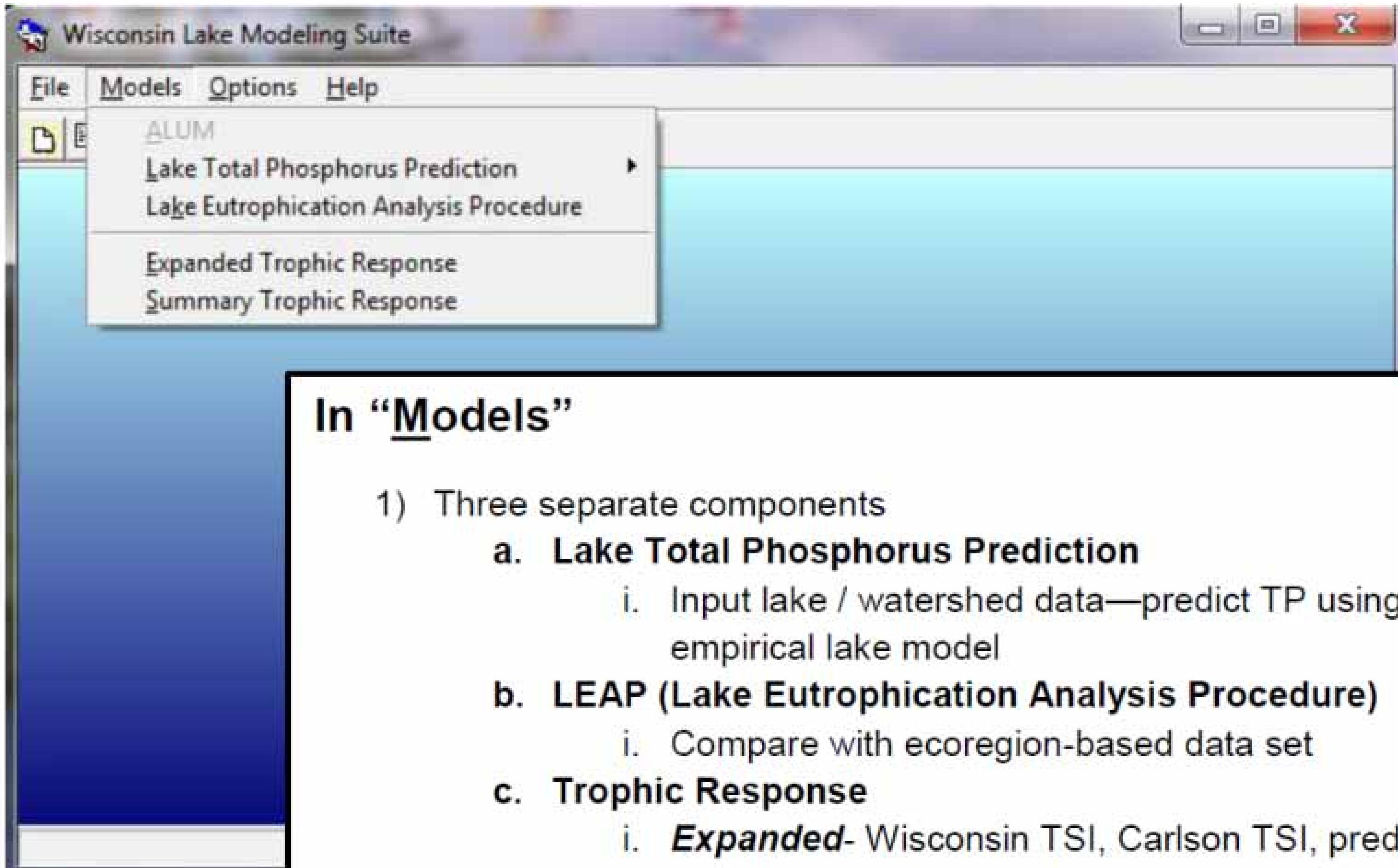
Brings us to WiLMS

- A Lake Eutrophication Model
- Combine **Lake** & **Watershed** to **Estimate** lake P concentration

WiLMS

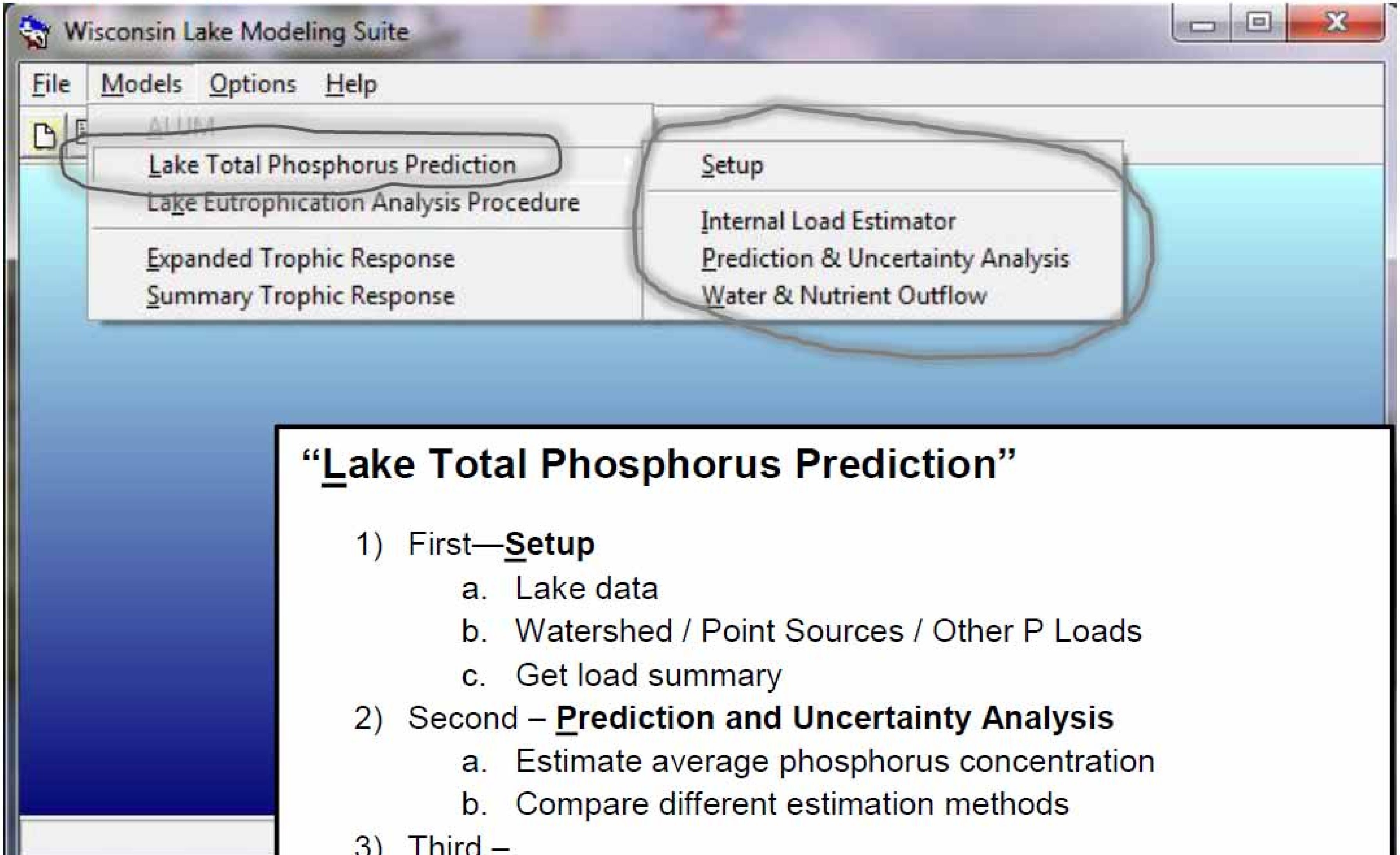
1. Download from WDNR **http://dnr.wi.gov/lakes/model/**
2. Installed – usually in
   a. "All Programs"
      i. "Wisconsin DNR"
         1. WiLMS





In "Models"

1) Three separate components
   a. **Lake Total Phosphorus Prediction**
      i. Input lake / watershed data—predict TP using empirical lake model
   b. **LEAP (Lake Eutrophication Analysis Procedure)**
      i. Compare with ecoregion-based data set
   c. **Trophic Response**
      i. ***Expanded***- Wisconsin TSI, Carlson TSI, predictive equations for Secchi and Chlorophyll
      ii. ***Summary*** – Wisconsin TSI and predictive

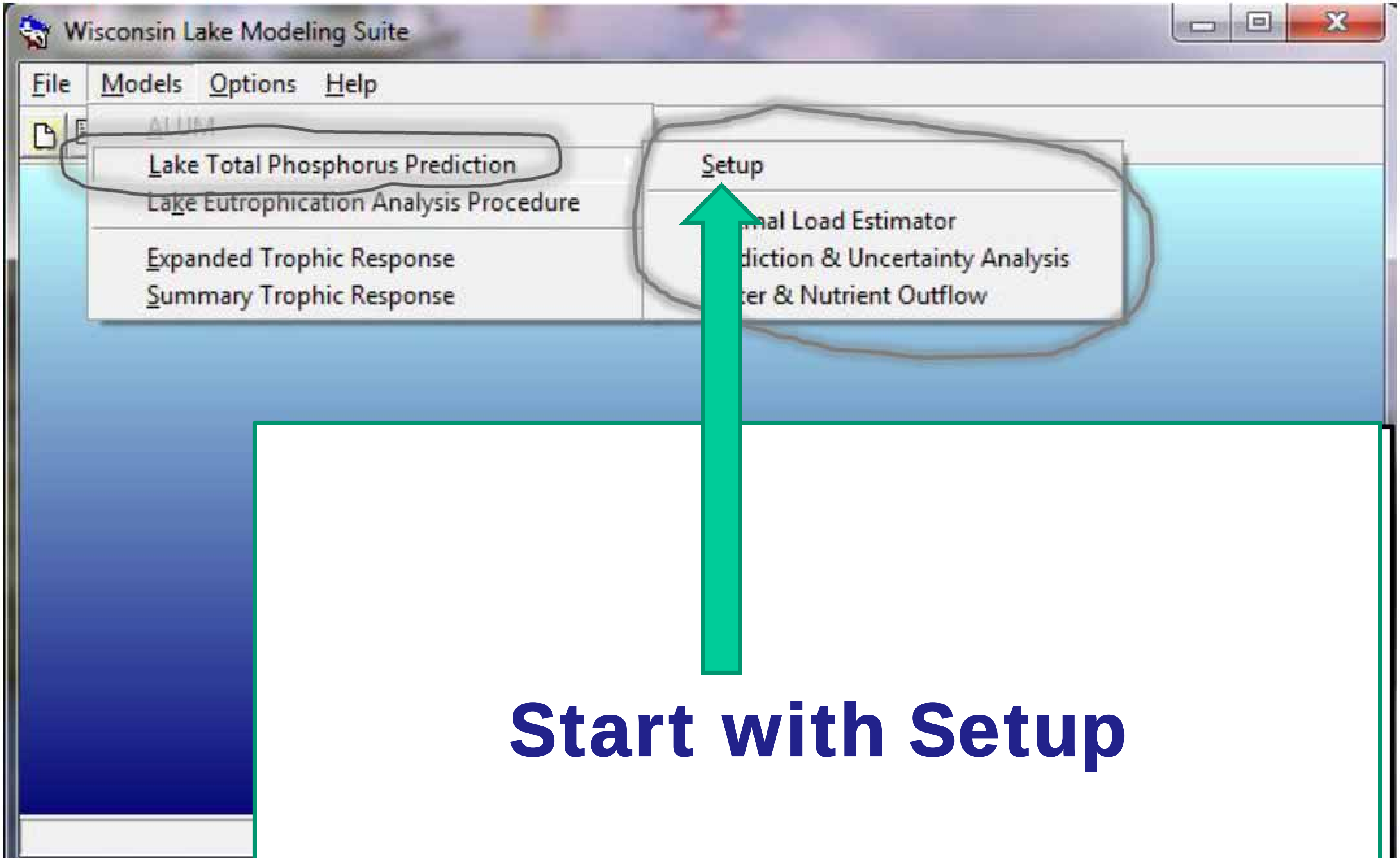


"Lake Total Phosphorus Prediction"

1) First—**Setup**
    a. Lake data
    b. Watershed / Point Sources / Other P Loads
    c. Get load summary
2) Second – **Prediction and Uncertainty Analysis**
    a. Estimate average phosphorus concentration
    b. Compare different estimation methods
3) Third –
    a. Explore sensitivity to load reductions
    b. Maybe use **Internal Load Estimator**
    c. Possibly use **Water & Nutrient Outflow**

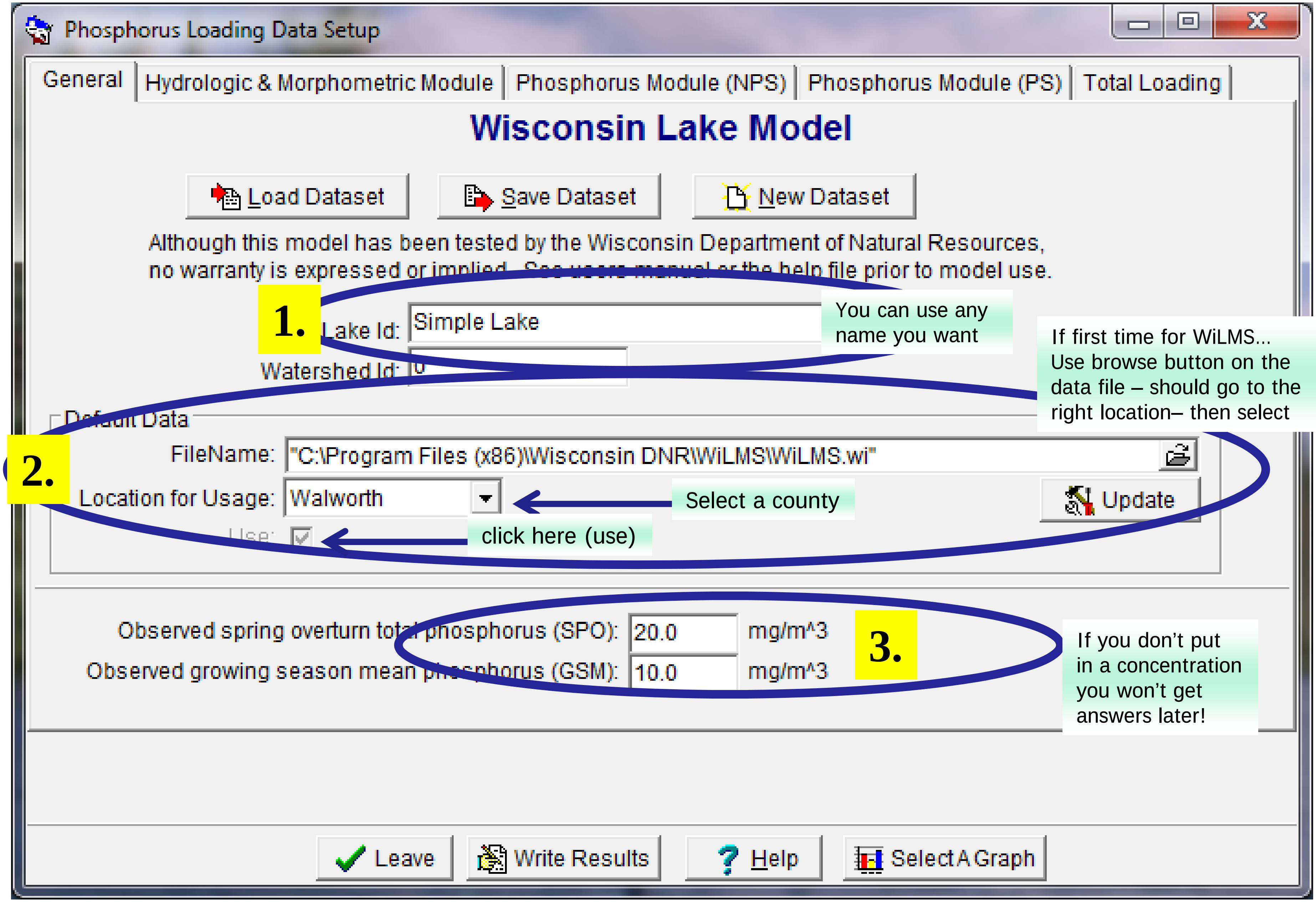
Model I

- Lake
  - Walworth Co
  - 5000 acres, Mean Depth 60 feet
- Watershed
  - 10,000 acres, 50% Mixed Ag (Pasture & Row Crops), 50% Forest
- Estimate lake phosphorus concentration

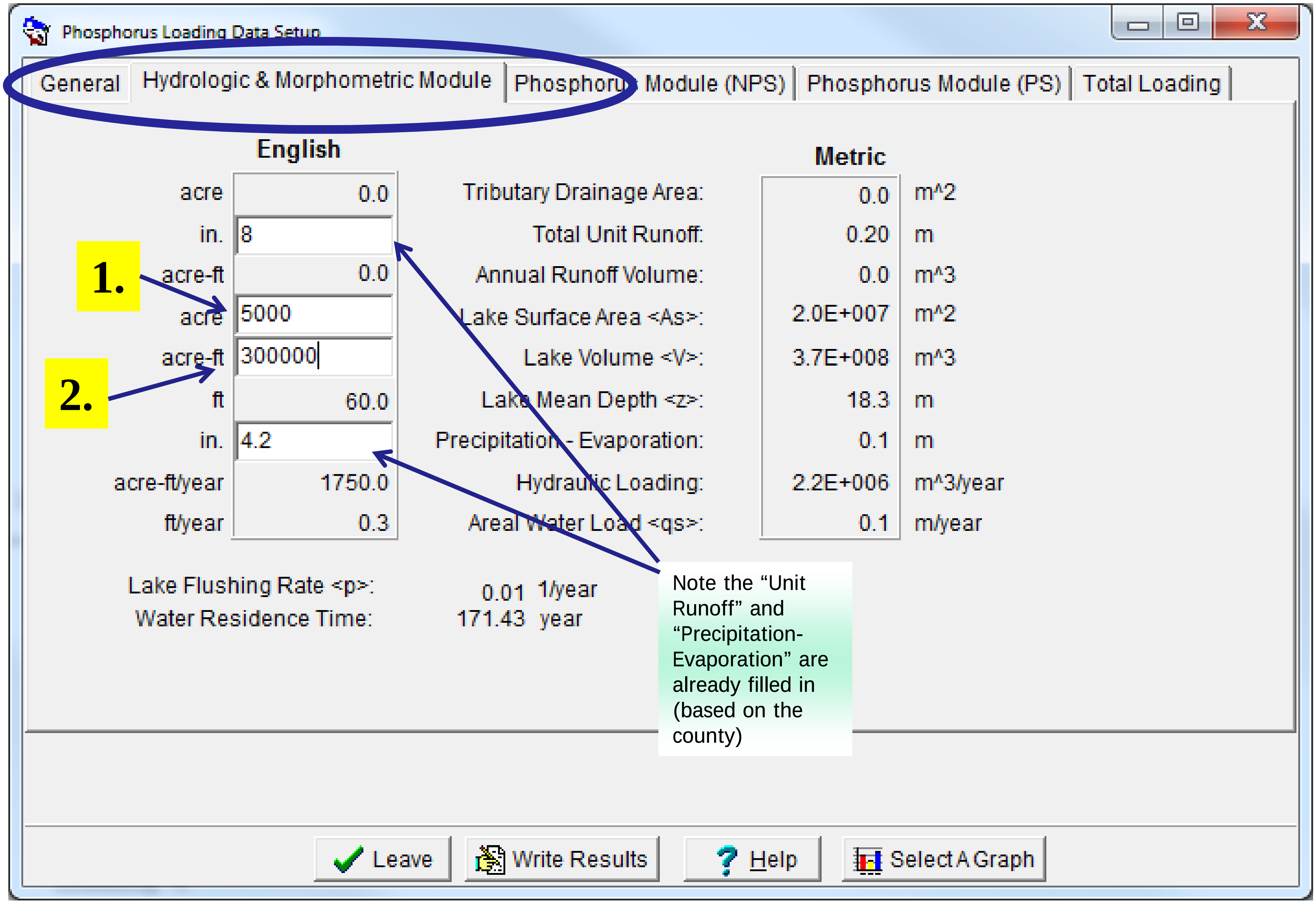


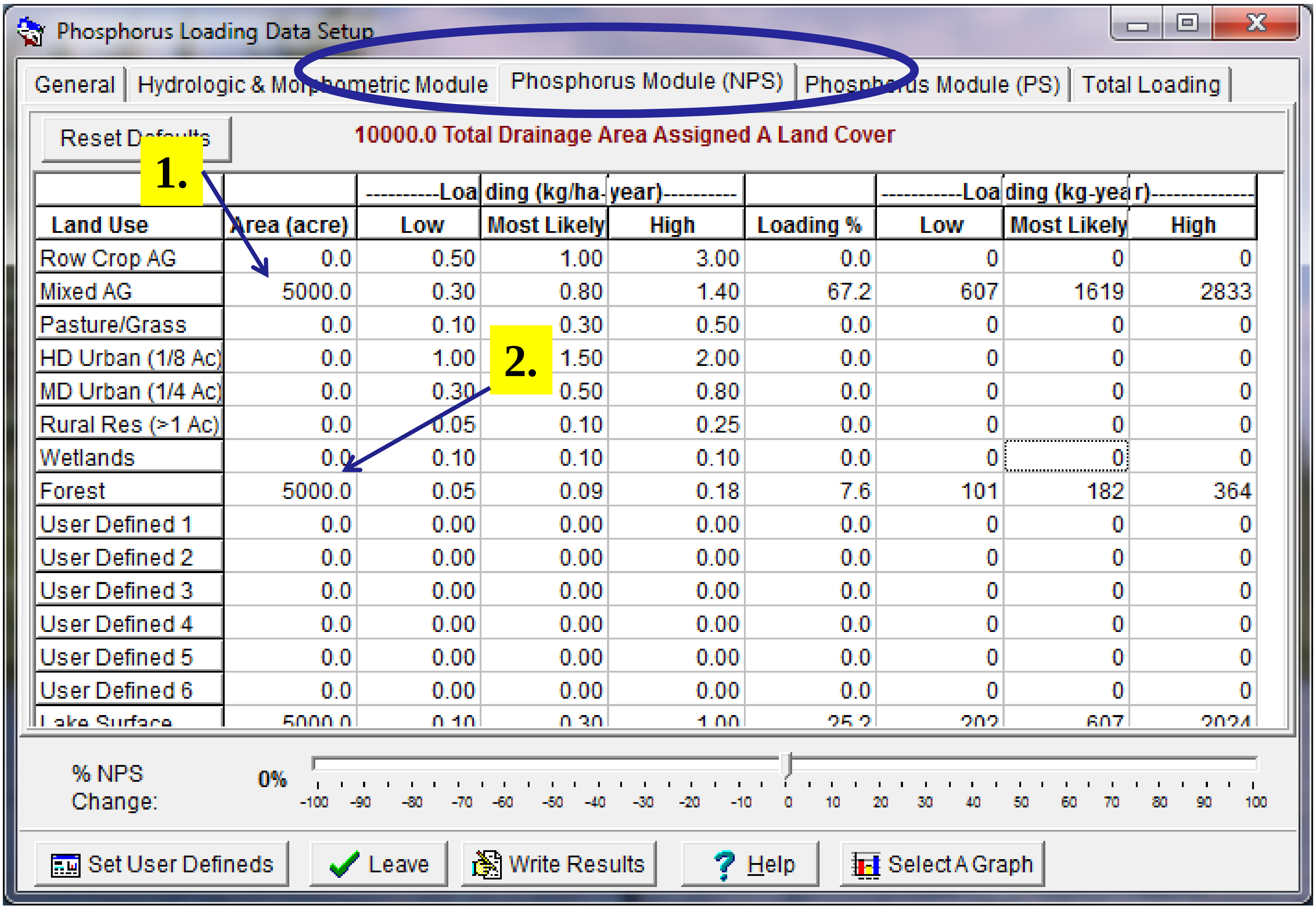
Start with Setup

General Tab


Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
Wisconsin Lake Model
Load Dataset
Save Dataset
New Dataset
Although this model has been tested by the Wisconsin Department of Natural Resources,
1.
Lake Id:
Simple Lake
You can use any name you want
Watershed Id:
If first time for WiLMS... Use browse button on the data file – should go to the right location– then select
2.
FileName:
"C:\Program Files (x86)\Wisconsin DNR\WiLMS\WiLMS.wi"
Location for Usage:
Walworth
Select a county
Update
click here (use)
Observed spring overturn total phosphorus (SPO):
20.0
mg/m^3
Observed growing season mean phosphorus (GSM):
10.0
mg/m^3
3.
If you don't put in a concentration you won't get answers later!
Leave
Write Results
Help
Select A Graph

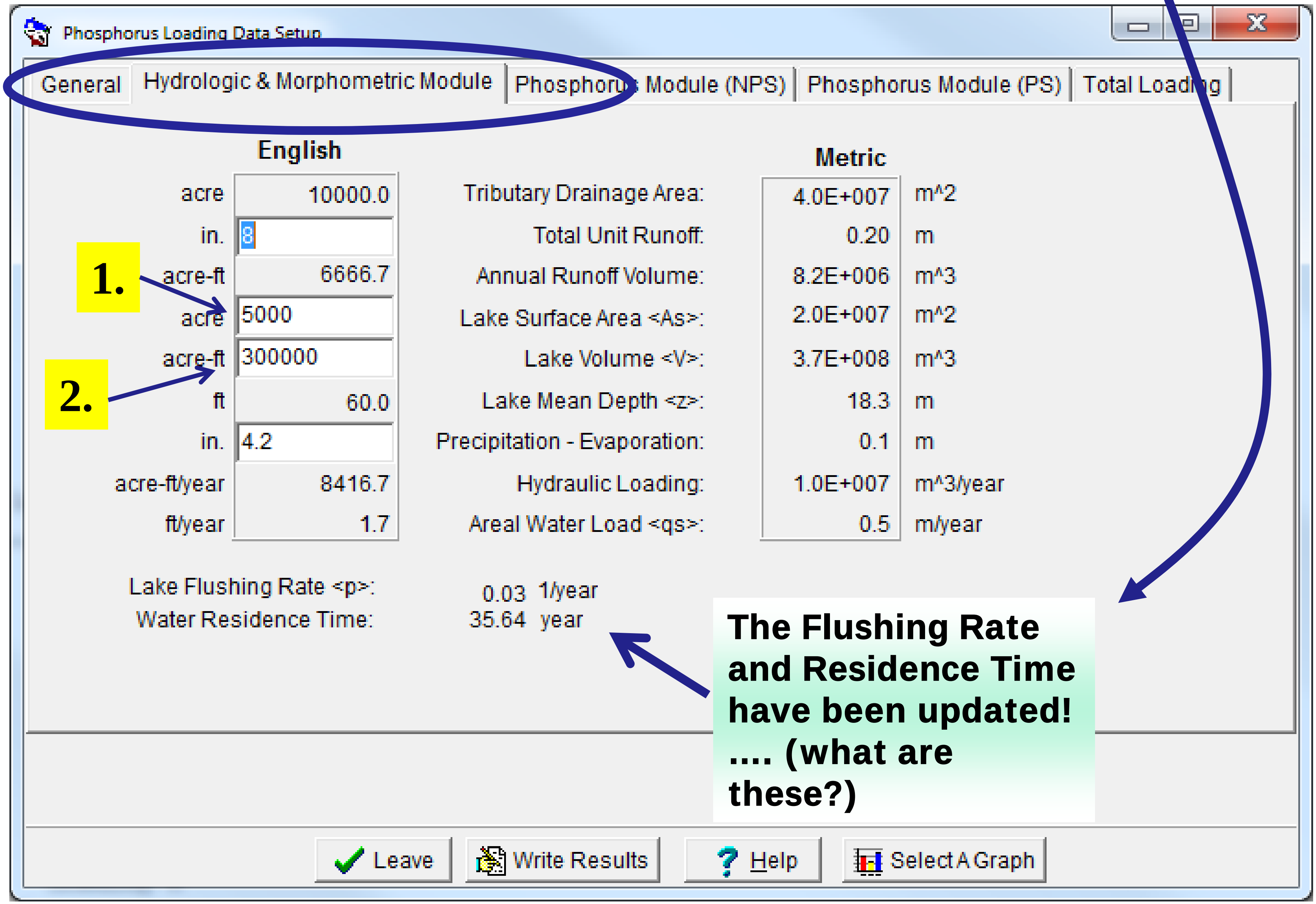
Hydrologic and Morphometric Tab





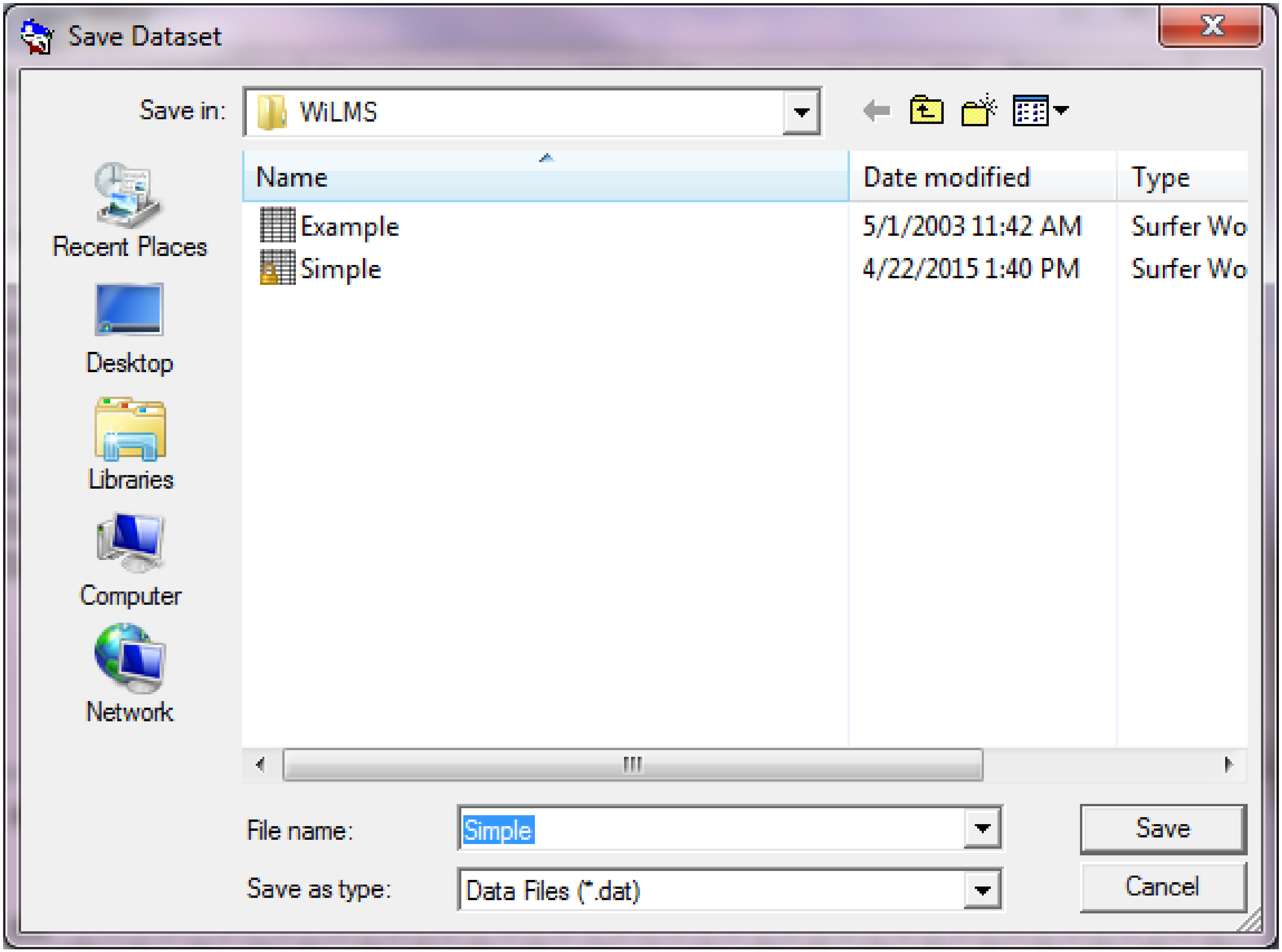
		----------Loading (kg/ha-year)----------				----------Loading (kg-year)----------		
Land Use	Area (acre)	Low	Most Likely	High	Loading %	Low	Most Likely	High
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0
Mixed AG	5000.0	0.30	0.80	1.40	67.2	607	1619	2833
Pasture/Grass	0.0	0.10	0.30	0.50	0.0	0	0	0
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	0.0	0.05	0.10	0.25	0.0	0	0	0
Wetlands	0.0	0.10	0.10	0.10	0.0	0	0	0
Forest	5000.0	0.05	0.09	0.18	7.6	101	182	364
User Defined 1	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 2	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 3	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 4	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 5	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 6	0.0	0.00	0.00	0.00	0.0	0	0	0
Lake Surface	5000.0	0.10	0.30	1.00	25.2	202	607	2024

Now Go Back to Hydrologic and Morphometric Tab

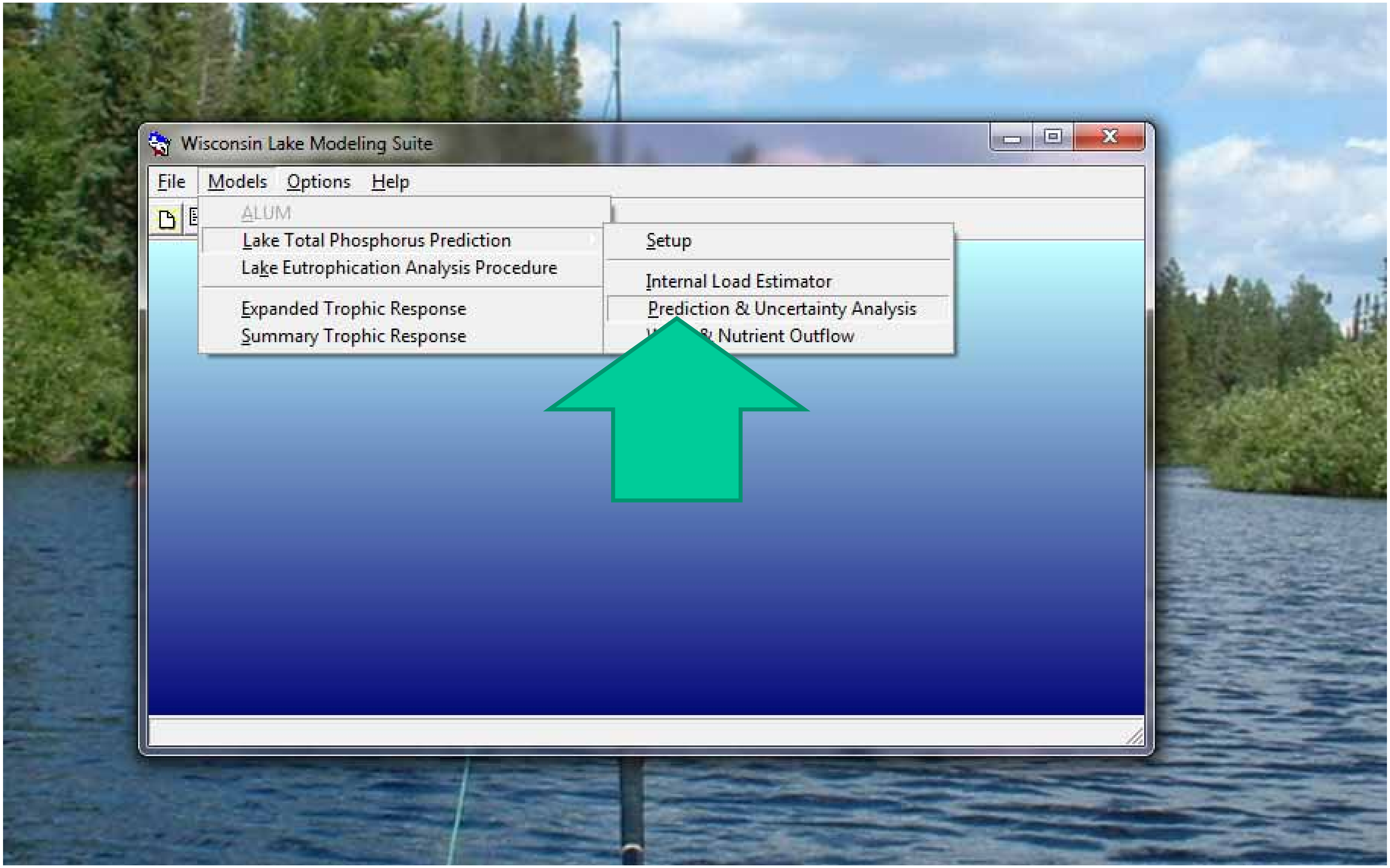


The Flushing Rate and Residence Time have been updated! …. (what are these?)

Leave... Save



Save Dataset
Save in:
WiLMS
Recent Places
Desktop
Libraries
Computer
Network
Name
Date modified
Type
Example
5/1/2003 11:42 AM
Surfer Wo
Simple
4/22/2015 1:40 PM
Surfer Wo
File name:
Simple
Save as type:
Data Files (*.dat)
Save
Cancel


Wisconsin Lake Modeling Suite
File
Models
Options
Help
ALUM
Lake Total Phosphorus Prediction
Lake Eutrophication Analysis Procedure
Expanded Trophic Response
Summary Trophic Response
Setup
Internal Load Estimator
Prediction & Uncertainty Analysis
Nutrient Outflow

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 20.0 mg/m^3

Observed growing season mean phosphorus (GSM): 10.0 mg/m^3

Back calculation for SPO total phosphorus: 0.0 mg/m^3

Back calculation GSM phosphorus: 0.0 mg/m^3

Nurnberg Model Input -
Est. Gross Int. Loading: 0 kg

% Confidence Range: 70

Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound	Confidence Upper Bound	Parameter Fit?	Back Calculation (kg/year)	Model Type
Walker, 1987 Reservoir	11	30	65	20	200	16	54	Tw	0	GSM
Canfield-Bachmann, 1981 Natural Lake	9	16	25	6	60	5	46	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	11	18	25	8	80	6	52	FIT	1	GSM
Rechow, 1979 General	4	10	21	0	0	5	18	qs	0	GSM
Rechow, 1977 Anoxic	12	32	70	22	220	17	57	FIT	0	GSM
Rechow, 1977 water load<50m/year	4	10	21	0	0	5	18	FIT	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	17	45	97	25	125	20	86	FIT	0	SPO
Vollenweider, 1982 Combined OECD	12	27	52	12	80	12	51	FIT	0	ANN
Dillon-Rigler-Kirchner	20	54	117	34	170	29	97	P qs p	0	SPO
Vollenweider, 1982 Shallow Lake/Res.	9	22	44	7	47	10	42	FIT	0	ANN
Larsen-Mercier, 1976	13	33	72	13	65	19	59	P Pin	0	SPO
Nurnberg, 1984 Oxic	17	[illegible]	95	34	340	21	83	FIT	0	ANN

Finished | Write Results | Display Parameter Values | Help

Eutrophication Models

1) This is a “Mass Balance” or “Empirical Regression” –Type Eutrophication Model

2) ***Not…*** *simulating daily / weekly / monthly / year-to-year variations in watershed or lake P*
3) ***Not…*** *simulating water movement within lake, sediment resuspension*
4) ***Not…*** *simulating algae growth, zooplankton, fish*

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3) Not… *simulating water movement within lake, sediment resuspension*

4) Not… *simulating alga*

Dynamic Models, Short Time Step Models (e.g., SWAT)

Eutrophication Models

1) This is a "Mass Balance" or "Empirical Regression" –Type Eutrophication Model

2) Not... *simulating daily / weekly / monthly / year-to-year variations in watershed or lake P*

3) Not... *simulating water movement within lake, sediment resuspension*

Hydrodynamic Models (CEQUAL), Shallow Lake Models (PCLake)

4) Not... *simulating algae gr*

Eutrophication Models

1) This is a “Mass Balance” or “Empirical Regression” –Type Eutrophication Model

2) Not... *simulating daily / ... r-to-year variations in w...*

3) Not... *simulating water ... e, sediment resuspension*

4) Not... *simulating algae growth, zooplankton, fish*

AQUATOX, CE-QUAL-W2,
HEC-RAS/NSM etc.

Let’s take a closer look at these “Steady-State Mass Balance” “Empirical Regression” Type Models

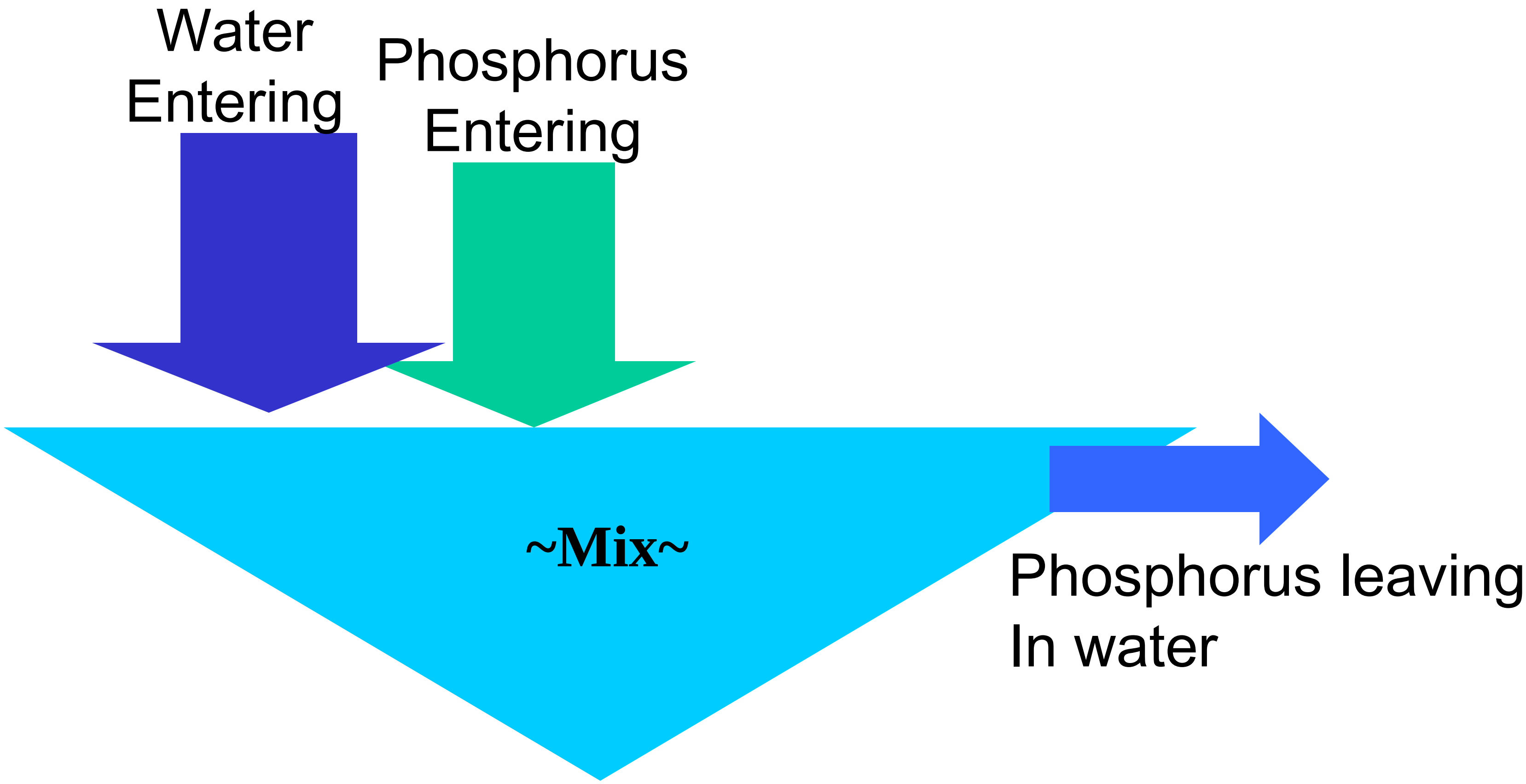
Backup….Model 0

- Goal– predict the P concentration

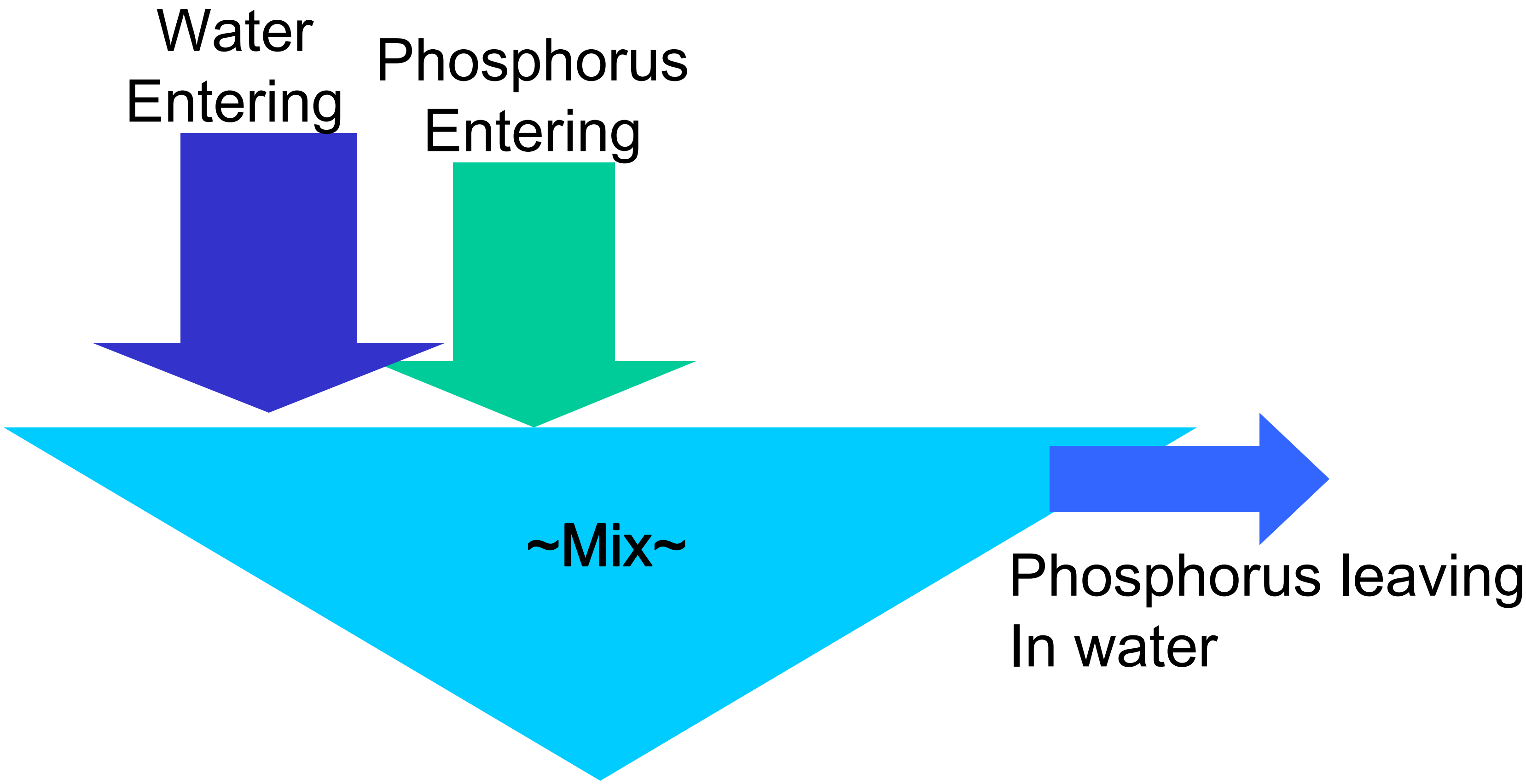
Given

- The amount of P entering the lake
- The amount of water entering the lake

Schematic View



How does this calculate concentration?



Concentration of P = C_P =

= Mass of Phosphorus divided by the Volume of Water

Let’s give this another try

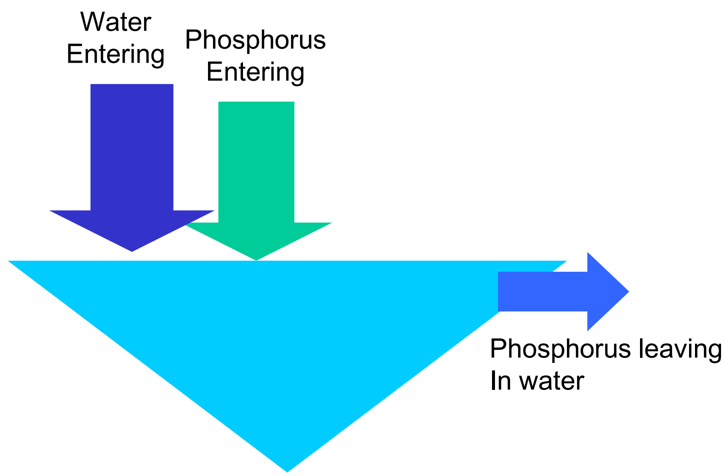
- 10,000 acre lake
- 150,000 acre watershed

Assume (more on this later)

- 34,000 kg/year P
- 150,000,000 m3/year water

Let’s give this a try

- 10,000 acre lake
- 150,000 acre watershed



Assume (more on this later)

- 34,000 kg/year P
- 150,000,000 m3/year water

“Simple Model 0”

- C_P = Concentration of P

- $C_P = \frac{Mass\ of\ P}{Volume\ of\ Water}$

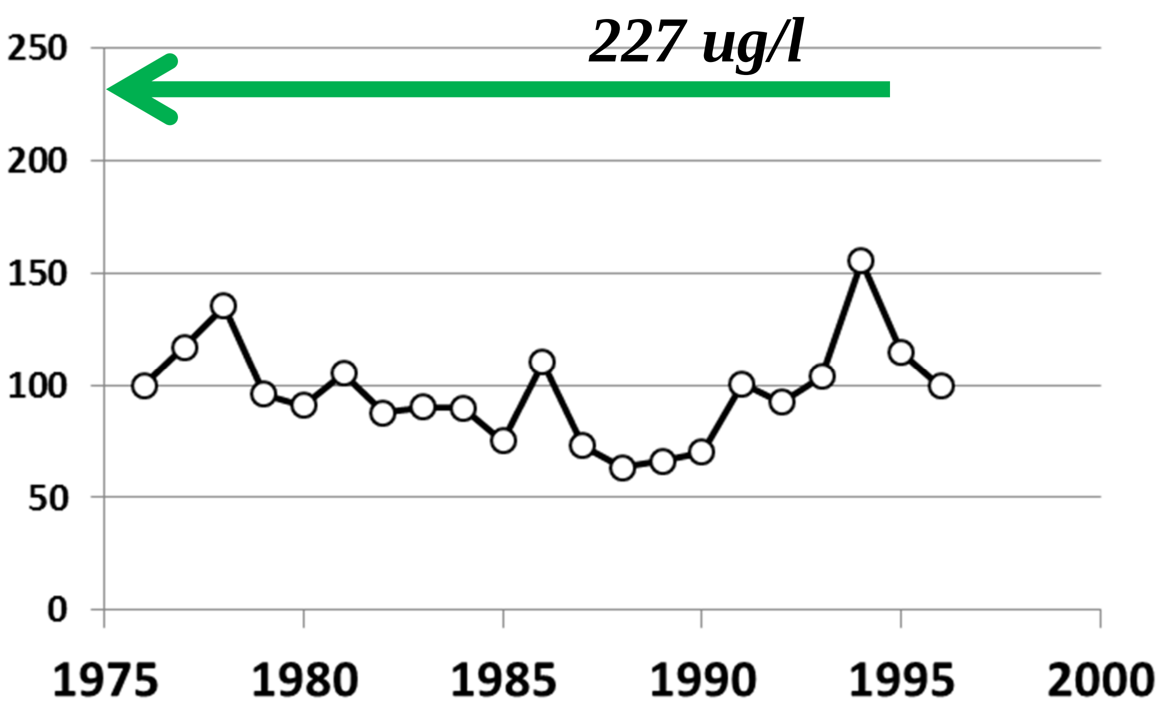
- $C_P = \frac{34{,}000\ kg\ P/yr}{150{,}000{,}000\ m3/yr}$

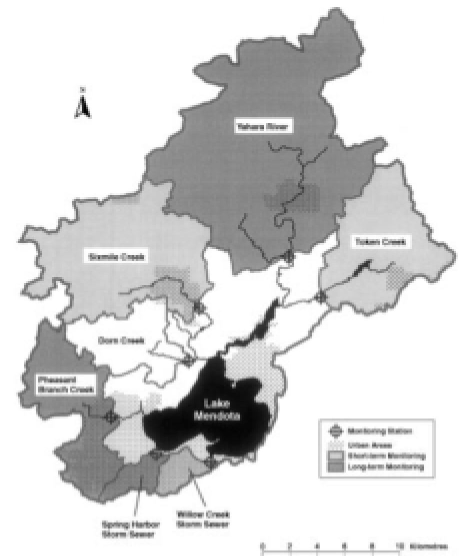
"Simple Model 0"

- C_P = Concentration of P

- $C_P = \frac{34{,}000\ kg\ P/yr}{150{,}000{,}000\ m3/yr}$
- $C_P = 0.0002\ \frac{kg}{m3} = 227\ \frac{mg}{m3} = 227\ \frac{ug}{liter}$

Not a very good model!
Take a look at some data





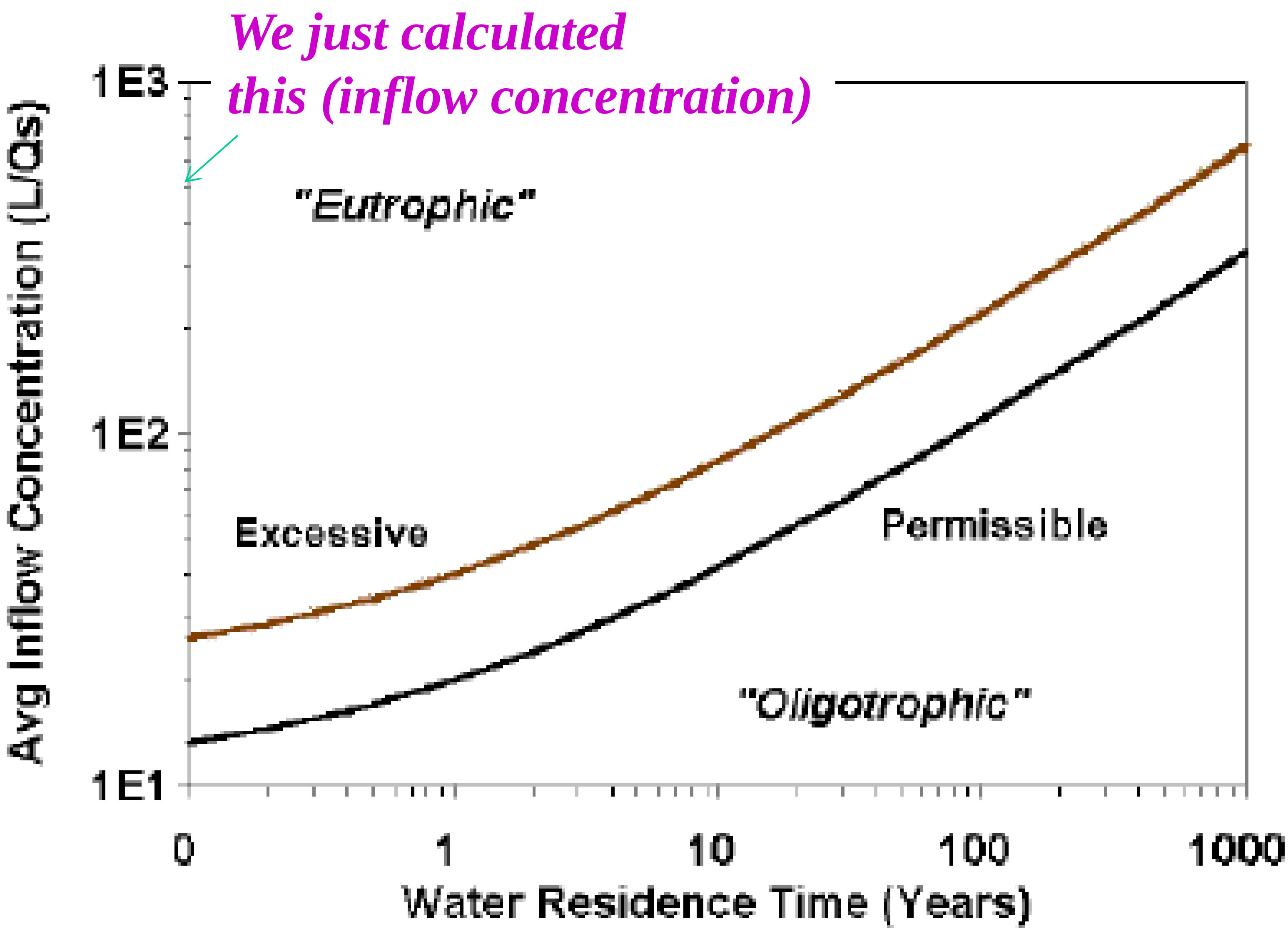
Lathrop and Panuska 1998

Revisit Assumptions

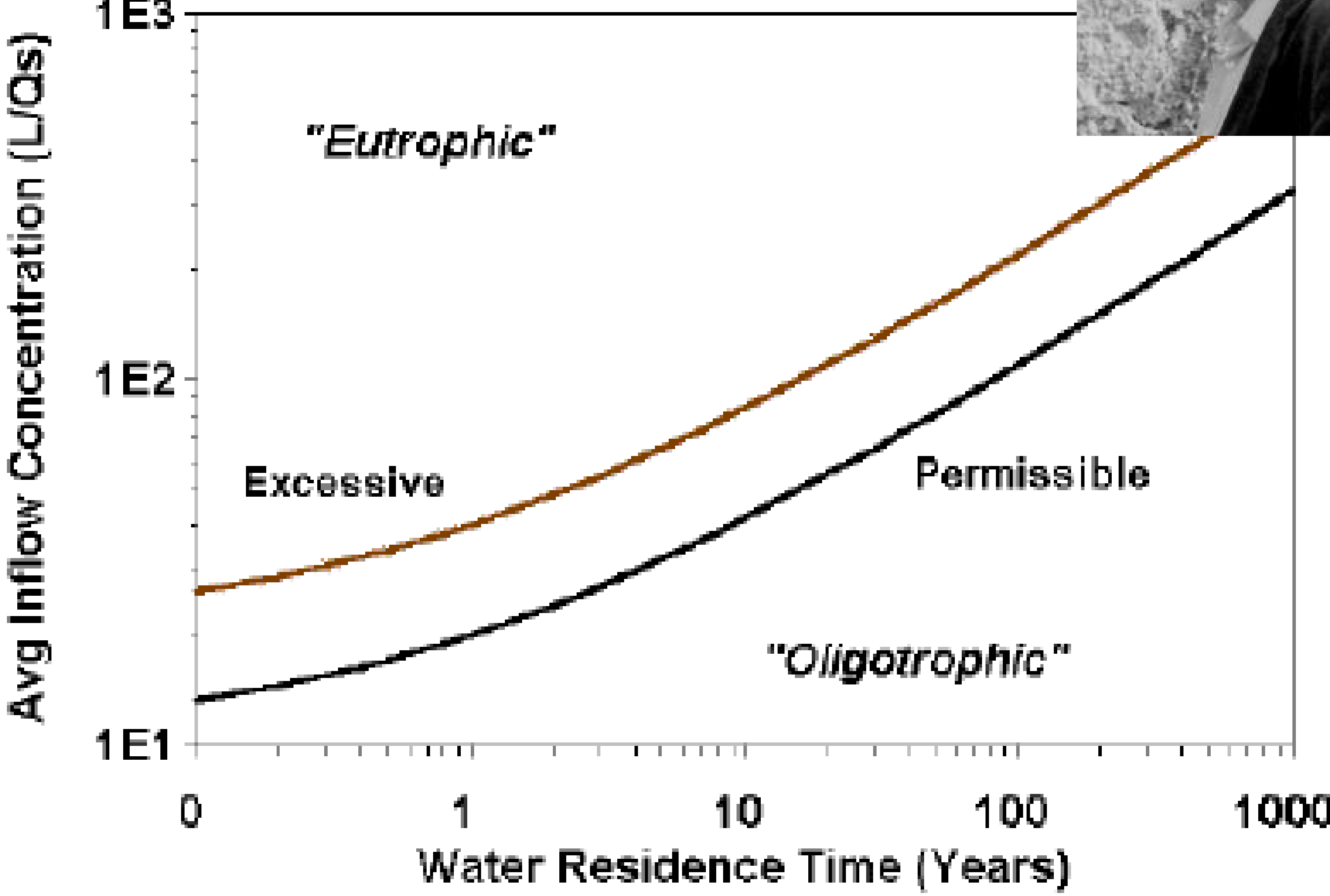
- **Completely Mixed**
- **Steady Conditions**
  - The P concentration doesn't change with time
  - The amount of P in the lake is constant

- ***P going into the lake is equal to what flows out***

Historical Note– 1960s… higher "Inflow P Conc" OK if you have a longer residence time



“Vollenweider Plots”

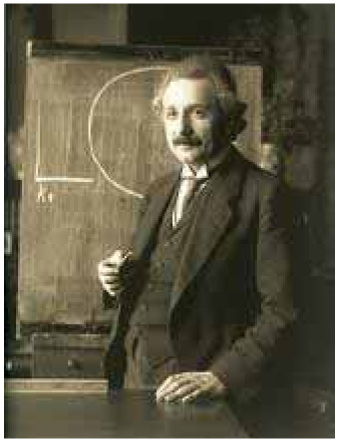


Not a very good model

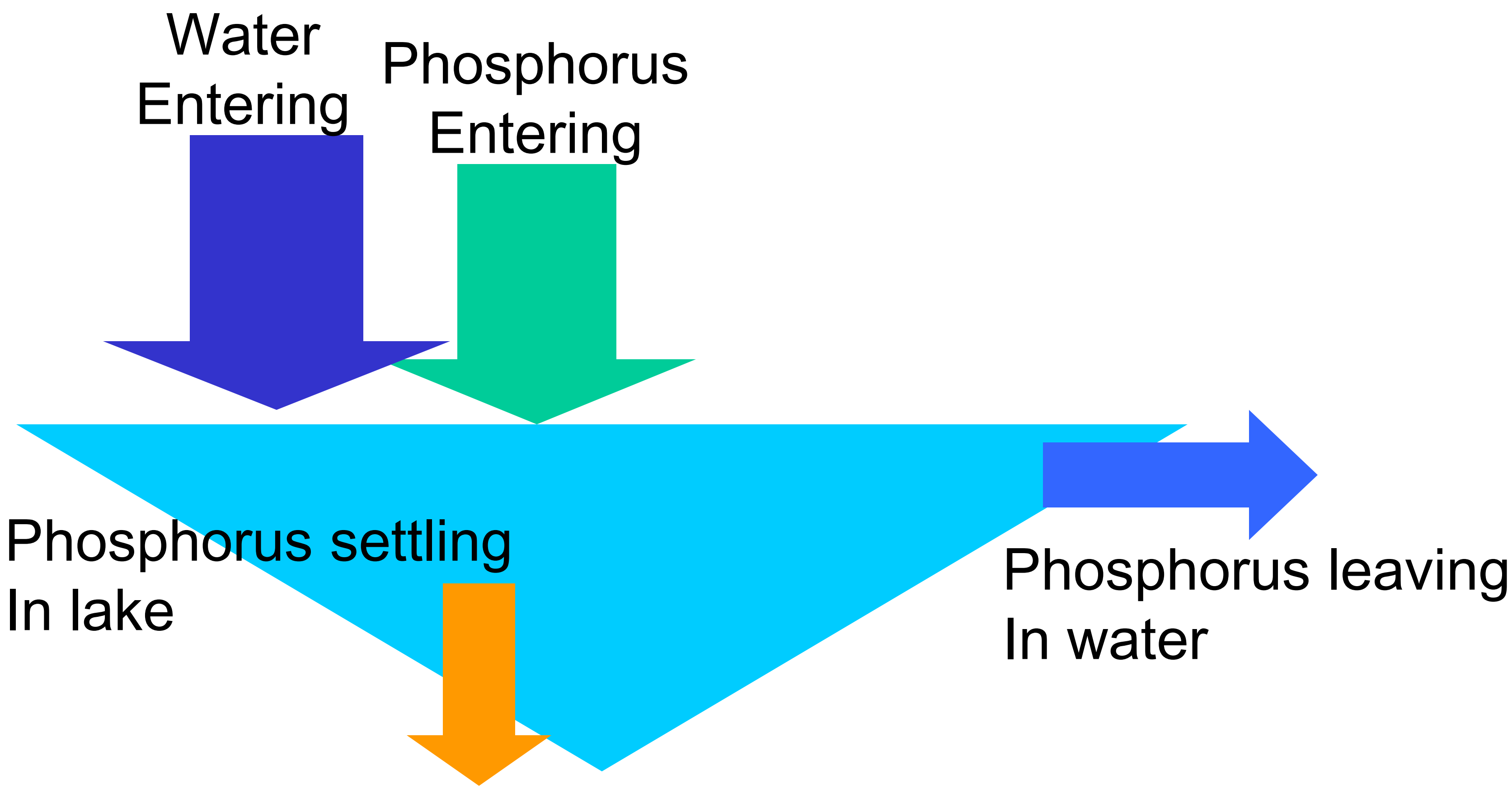
- Why?

- What happens to P in a lake?

- Another observation on modeling
  - “Everything should be made as simple as possible, but no simpler”
    A. Einstein



Model II



"mean total P concentration is amount of phosphorus divided by volume of water and diminished by retention term as P apparently lost to sediments" (Nurnberg, 1984)

– ***Now….What goes in must be equal to what goes out but "out" can be the outflow and loss to the sediment!***

P Into Lake	=	P Flowing Out of Lake	+	P Lost To "Settling"

– ***Now….What goes in must be equal to what goes out but "out" can be the outflow and loss to the sediment!***

P Into Lake = P Flowing Out of Lake + P Lost To "Settling"

Note: Both Depend On P Conc

This looks a lot like our simple model...

Phosphorus Concentration in Lake

Mass of Phosphorus per year entering lake

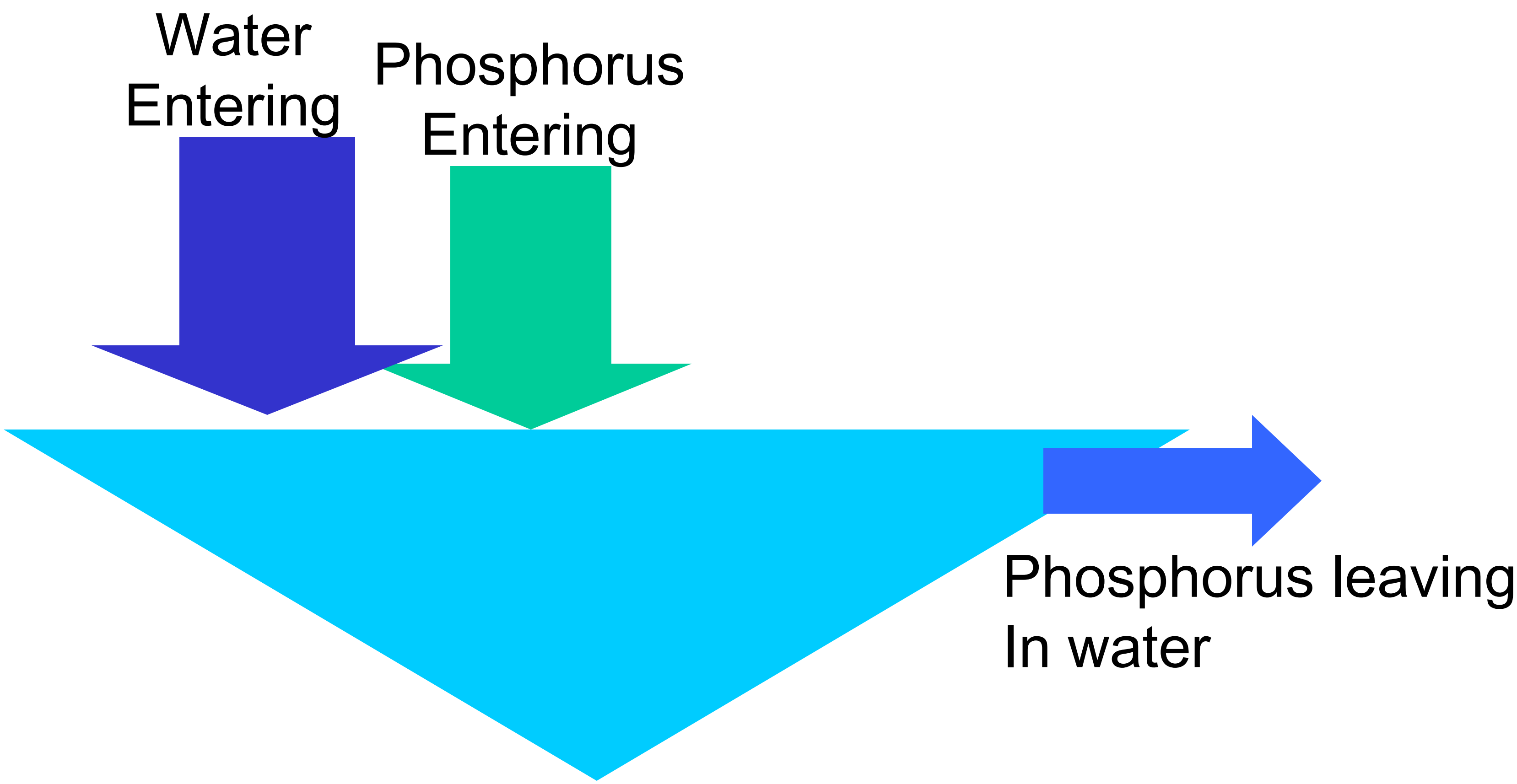
$$C_P = \frac{M}{Q + vA}$$

Amount of water Entering lake in a year

*Settling term (“settling velocity” * Area*

With this added

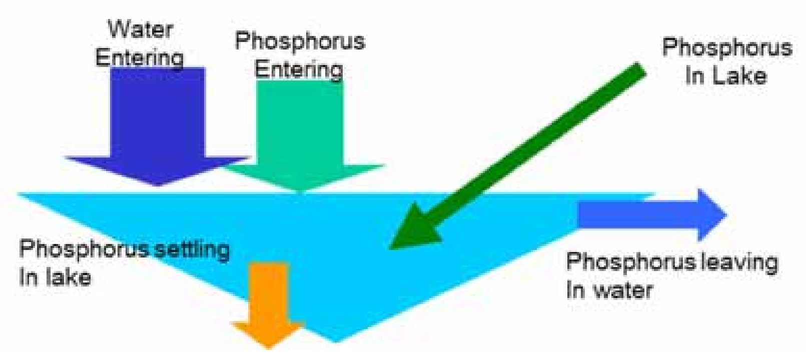
Model II



“mean total P concentration is amount of phosphorus divided by volume of water and diminished by retention term as P apparently lost to sediments” (Nurnberg, 1984)

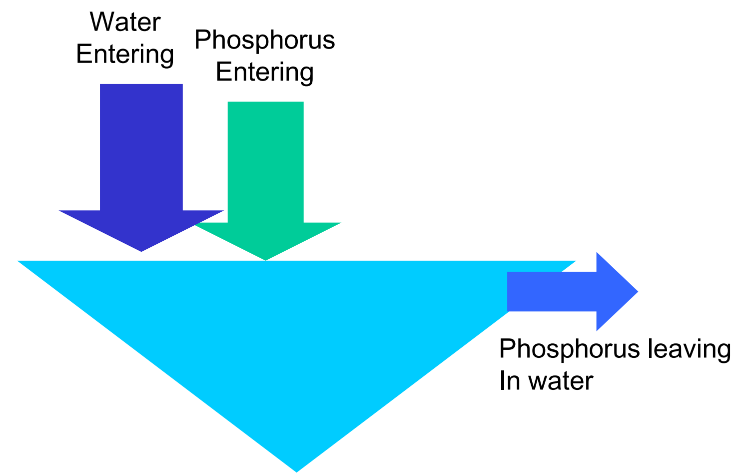
…just make a few assumptions

- Lake completely mixed
- Outflow conc. same as lake conc.
- Uniform conditions ("steady-state")
- <u>Sedimentation proportional to lake conc.</u>



Let's give this a try

- 10,000 acre lake
- 150,000 acre watershed



Assume

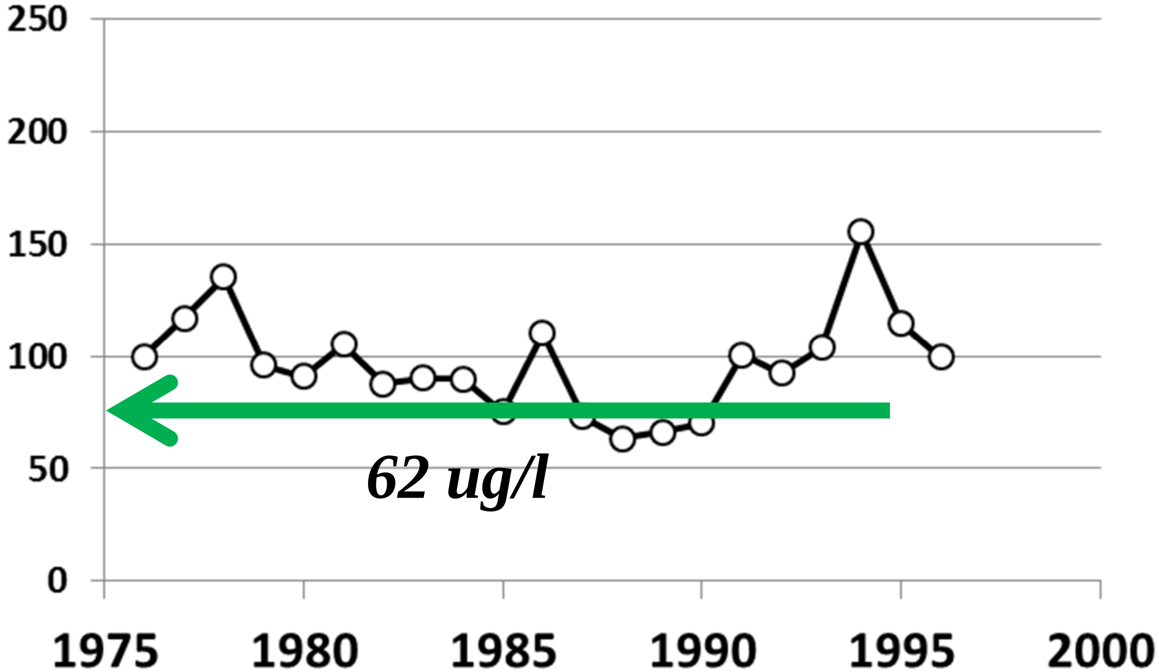
- 34,000 kg/year P
- 150,000,000 m3/year water
- 40,500,000 m2 lake surface
- 10 meter/year settling velocity

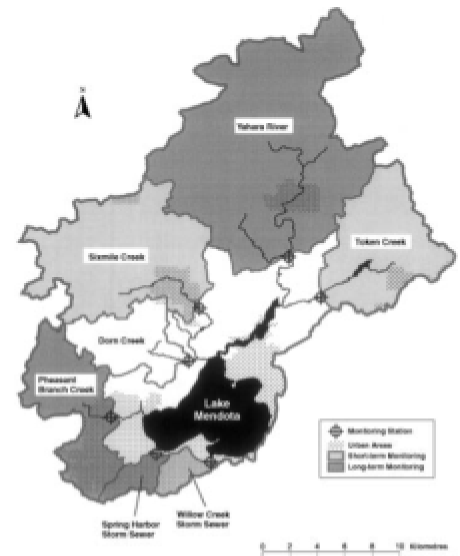
"New & Improved Simple Model"

"Settling Velocity" x Lake Area

- C_P = Concentration of P
- $$C_P = \frac{34{,}000\ kg\ P/yr}{150{,}000{,}000\frac{m3}{yr} + 405{,}000{,}000\frac{m3}{yr}}$$
- $$C_P = 0.00006\ \frac{kg}{m3} = 62\ \frac{mg}{m3} = 62\ \frac{ug}{liter}$$

Better?





Lathrop and Panuska 1998

What does this have to do with WiLMS?

- WiLMS uses “empirical models”
- “Empirical Models” were developed by fitting a group of lakes with different equations
- Most started similar to the simple steady-state mass balance method... then fit with some adjustment factors

- For example, our second model is similar to:

$$C_P = \frac{L}{q_s + v_s}$$

- Reckhow Natural Lake Model

$$C_P = \frac{L}{1.2q_s + 11.6}$$

Or Canfield Bachmann Model

This study with

$$TP = \frac{0.8L}{z(0.0942(L/z)^{0.422} + \rho)}$$

for natural lakes and

- L is P loading rate mg/m2-yr
- Z is mean depth
- Rho is water flushing rate

Prediction of Total Phosphorus Concentrations, Chlorophyll *a*, and Secchi Depths in Natural and Artificial Lakes[1]

DANIEL E. CANFIELD JR.,[2] AND ROGER W. BACHMANN

Department of Animal Ecology, Iowa State University, Ames, IA 50011, USA

CANFIELD, D. E. JR., AND R. W. BACHMANN. 1981. Prediction of total phosphorus concentrations, chlorophyll *a*, and Secchi depths in natural and artificial lakes. Can. J. Fish. Aquat. Sci. 38: 414–423.

These are not perfect fits…

Prediction of Total Phosphorus Concentrations, Chlorophyll *a*, and Secchi Depths in Natural and Artificial Lakes[1]

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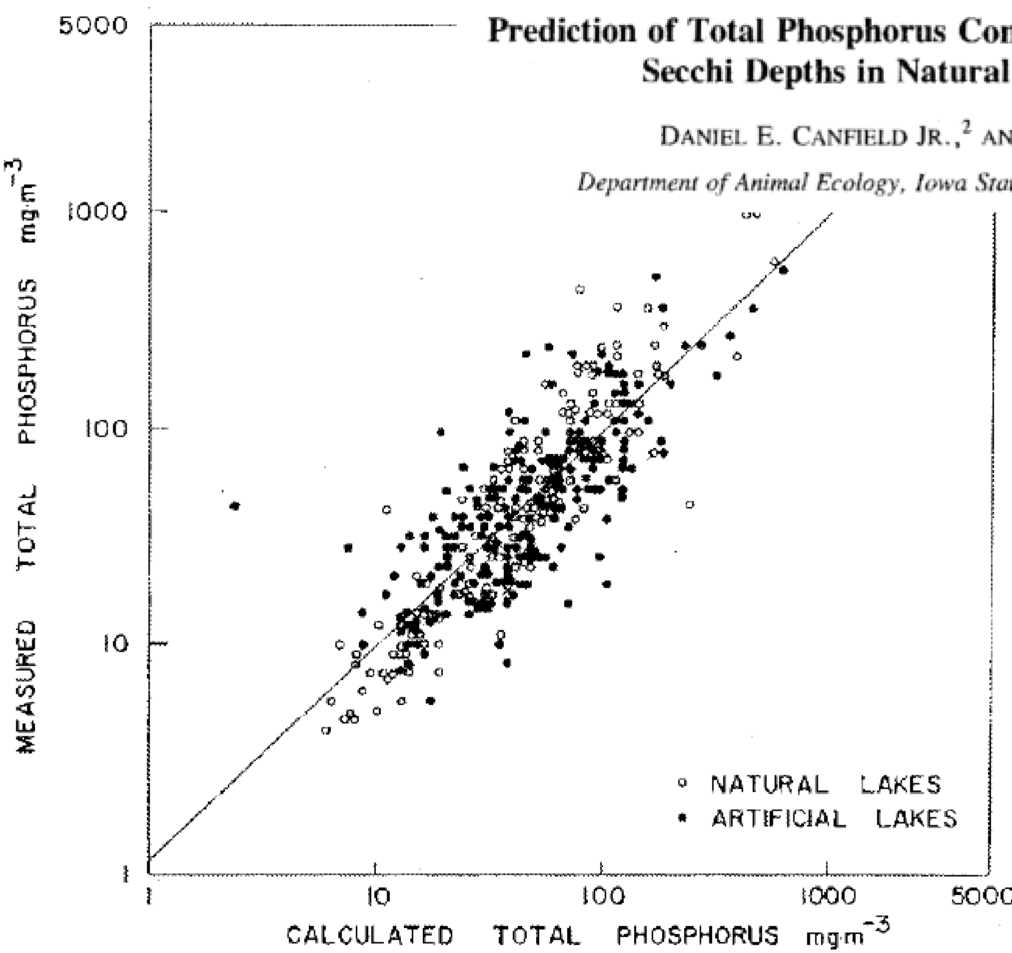

FIG. 2. Relationship between measured total phosphorus and total phosphorus calculated with equations 1, 5, and 6 of this study. The best-fit linear regression line is shown.

These are not perfect fits...

Prediction of Total Phosphorus Concentrations, Chlorophyll *a*, and Secchi Depths in Natural and Artificial Lakes[1]

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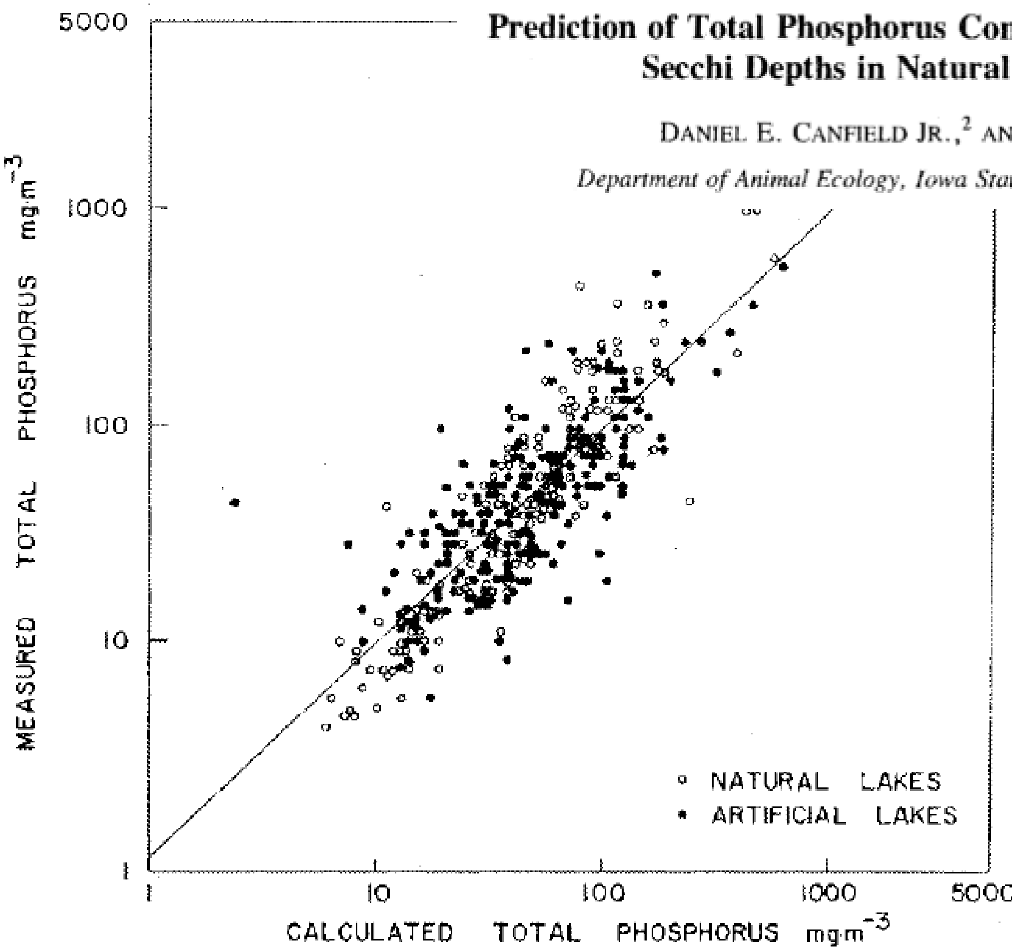


FIG. 2. Relationship between measured total phosphorus and total phosphorus calculated with equations 1, 5, and 6 of this study. The best-fit linear regression line is shown.

Note Units mg/m^3 = μg/liter

These are pretty simple models

- Shortcomings
  - Scatter, prediction error
  - Heterogeneous databases of lakes
  - Little mechanistic insight

- “in spite of these shortcomings, empirically derived loading models often provide useful order-of-magnitude estimates. As such, they provide a quick way to “see the big picture.”

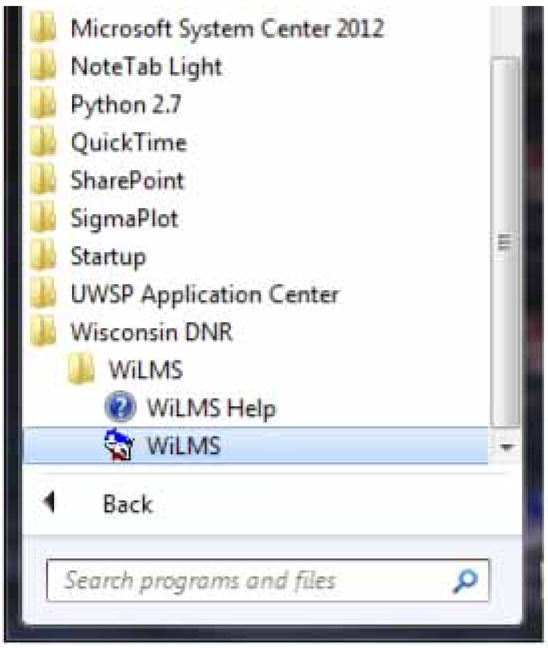
- (Professor Steven Chapra in “Surface Water Quality Modeling”)

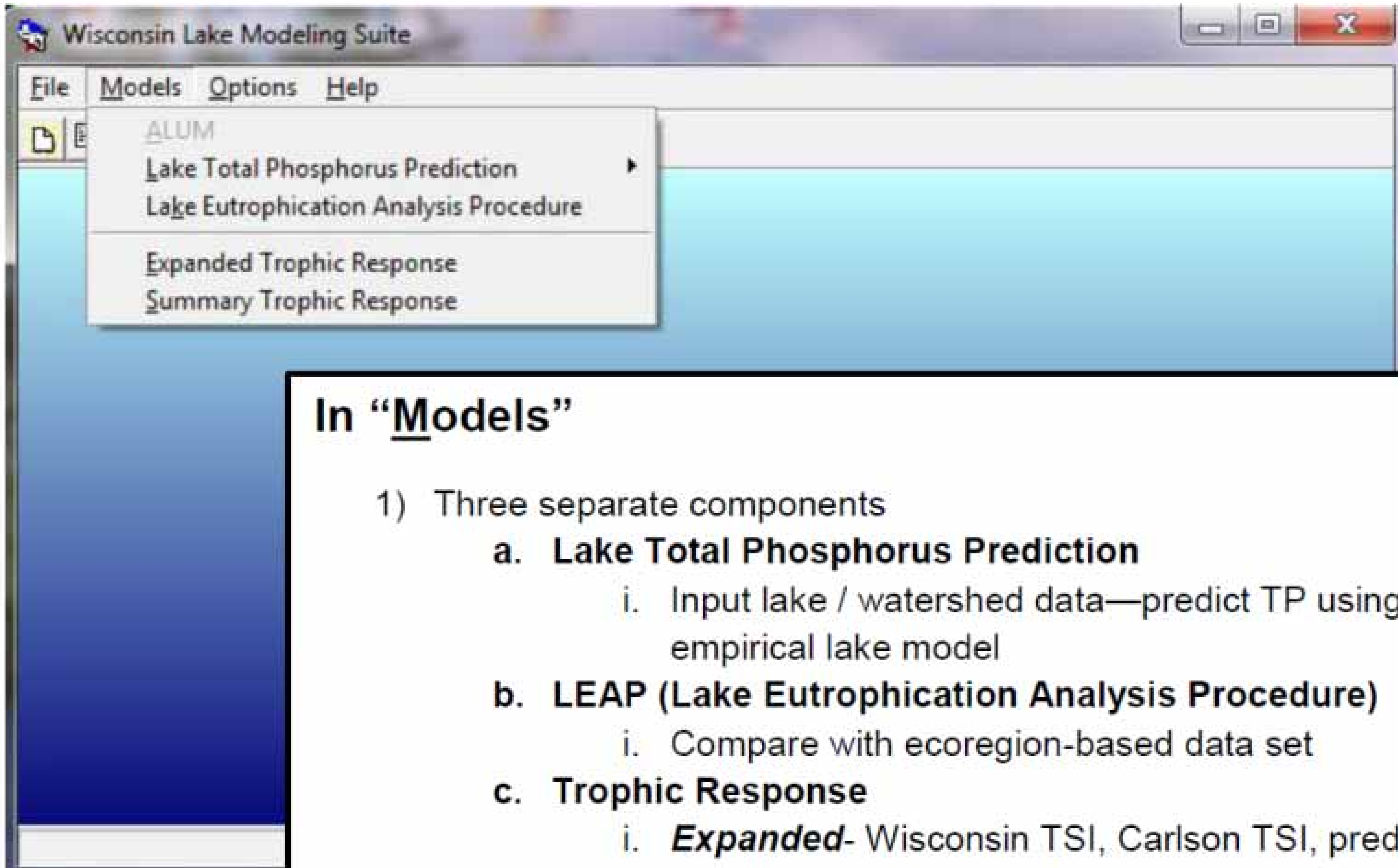
Two Pieces to Eutrophication Modeling in WiLMS

- Combine **watershed export** model & **lake response** tool
- Estimate lake P concentration with knowledge of lake and P loading (external loads)
- Annual time-step

WiLMS

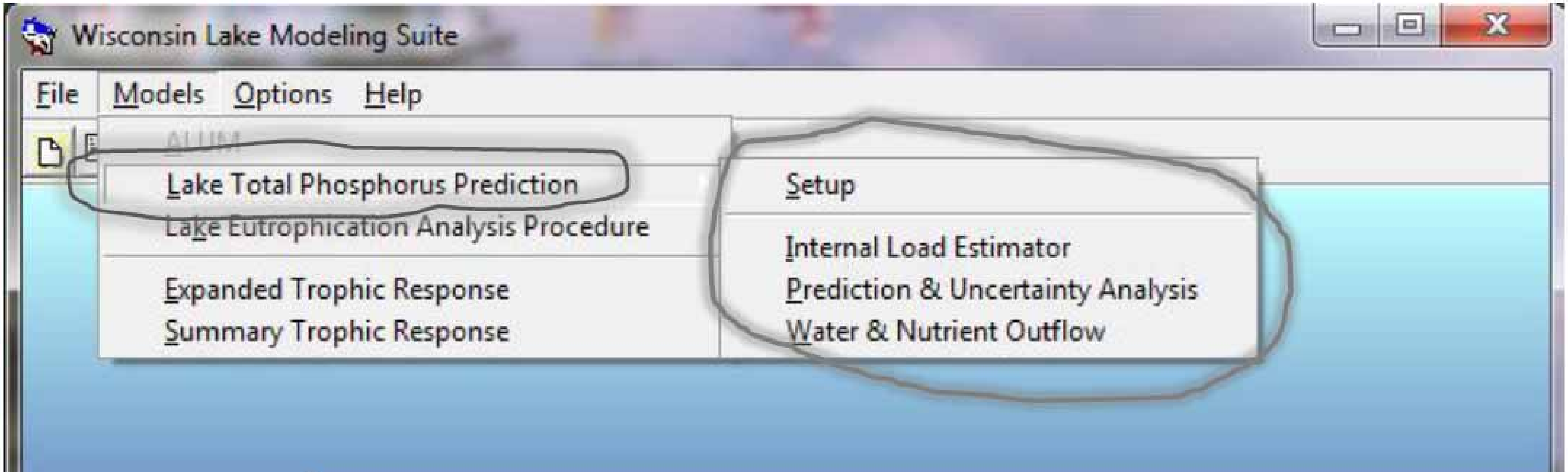
1. Download from WDNR **http://dnr.wi.gov/lakes/model/**
2. Installed – usually in
    a. "All Programs"
        i. "Wisconsin DNR"
            1. WiLMS





In "Models"

1) Three separate components
   a. **Lake Total Phosphorus Prediction**
      i. Input lake / watershed data—predict TP using empirical lake model
   b. **LEAP (Lake Eutrophication Analysis Procedure)**
      i. Compare with ecoregion-based data set
   c. **Trophic Response**
      i. ***Expanded***- Wisconsin TSI, Carlson TSI, predictive equations for Secchi and Chlorophyll
      ii. ***Summary*** – Wisconsin TSI and predictive



"Lake Total Phosphorus Prediction"

1) First—**Setup**
   a. Lake data
   b. Watershed / Point Sources / Other P Loads
   c. Get load summary
2) Second – **Prediction and Uncertainty Analysis**
   a. Estimate average phosphorus concentration
   b. Compare different estimation methods
3) Third –
   a. Explore sensitivity to load reductions
   b. Maybe use **Internal Load Estimator**
   c. Possibly use **Water & Nutrient Outflow**

WiLMS now w/ Model II

Setup / General & Hydrologic/Morphometric Module

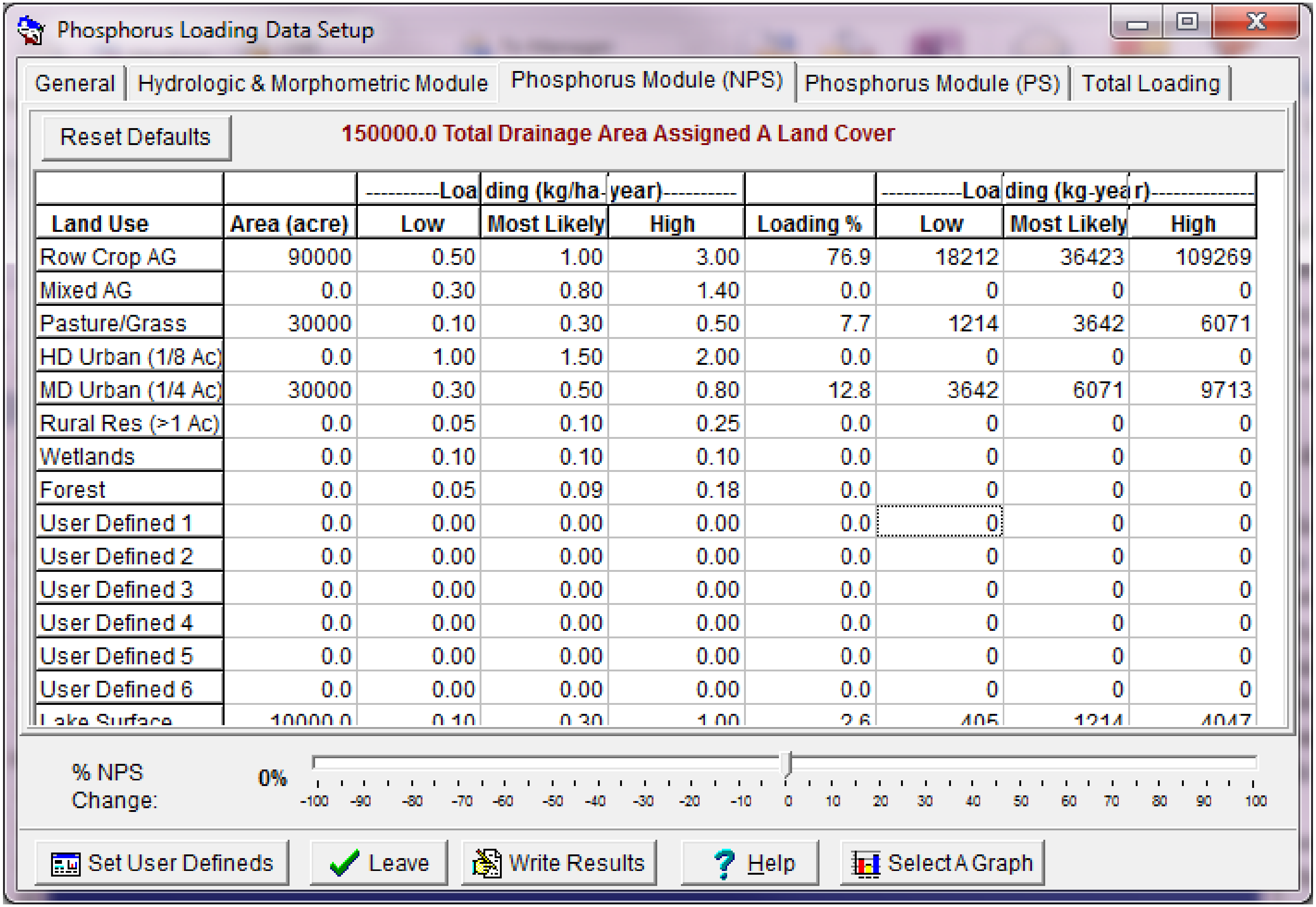
- Dane Co
- SPO: 75 mg/m3; GSM: 90 mg/m3
- 10,000 acre lake
- 420,000 acre feet lake volume
  - Check mean depth ~42 feet?

acre	10000	Lake Surface Area <As>:	4.0E+007	m^2
acre-ft	420000	Lake Volume <V>:	5.2E+008	m^3
ft	42.0	Lake Mean Depth <z>:	12.8	m
in.	2.6	Precipitation - Evaporation:	0.1	m

Model II

Phosphorus Module (NPS)

- Row Crop 90,000 acres
- Pasture Grass 30,000 acres
- MD Urban 30,000 acres
- *Note that lake surface is already entered*
- *Note loading in kg/ha-year “export rates”*

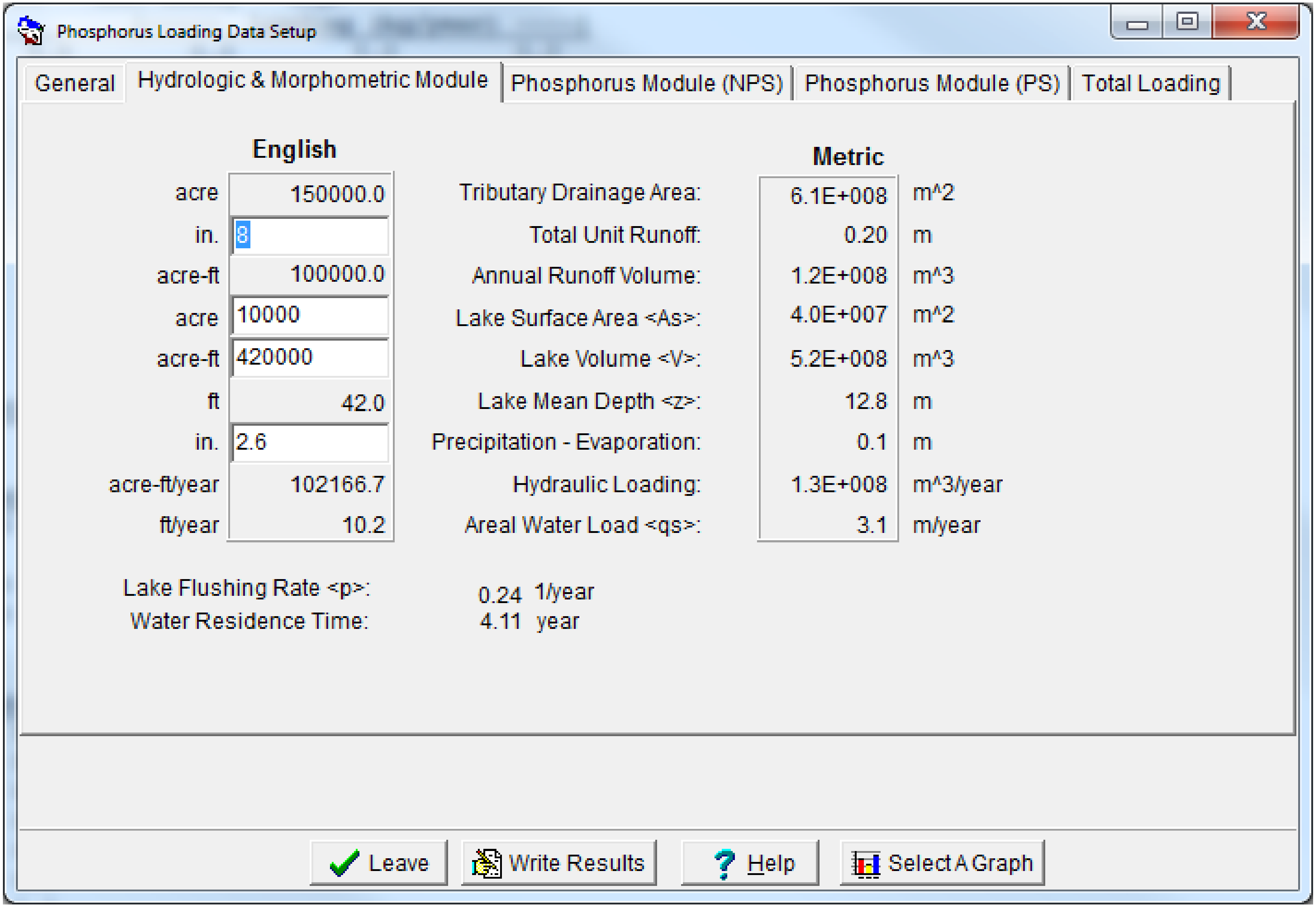


		----------Loading (kg/ha-year)----------				----------Loading (kg-year)----------		
Land Use	Area (acre)	Low	Most Likely	High	Loading %	Low	Most Likely	High
Row Crop AG	90000	0.50	1.00	3.00	76.9	18212	36423	109269
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0
Pasture/Grass	30000	0.10	0.30	0.50	7.7	1214	3642	6071
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	30000	0.30	0.50	0.80	12.8	3642	6071	9713
Rural Res (>1 Ac)	0.0	0.05	0.10	0.25	0.0	0	0	0
Wetlands	0.0	0.10	0.10	0.10	0.0	0	0	0
Forest	0.0	0.05	0.09	0.18	0.0	0	0	0
User Defined 1	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 2	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 3	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 4	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 5	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 6	0.0	0.00	0.00	0.00	0.0	0	0	0
Lake Surface	10000.0	0.10	0.30	1.00	2.6	405	1214	4047

WiLMS now w/ Model II

Setup / General & Hydrologic/Morphometric Module

- Dane Co
- SPO: 75 mg/m3; GSM: 90 mg/m3
- 10,000 acre lake
- 420,000 acre feet lake volume
  - Check mean depth ~42 feet?
  - Check q_s... about 10 ft/year? *(what's that?)*
  - What is water residence time? *(what's that?)*
  - What is the lake flushing rate? *(what's that?)*


Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
English
Metric
acre 150000.0 Tributary Drainage Area: 6.1E+008 m^2
in. 8 Total Unit Runoff: 0.20 m
acre-ft 100000.0 Annual Runoff Volume: 1.2E+008 m^3
acre 10000 Lake Surface Area <As>: 4.0E+007 m^2
acre-ft 420000 Lake Volume <V>: 5.2E+008 m^3
ft 42.0 Lake Mean Depth <z>: 12.8 m
in. 2.6 Precipitation - Evaporation: 0.1 m
acre-ft/year 102166.7 Hydraulic Loading: 1.3E+008 m^3/year
ft/year 10.2 Areal Water Load <qs>: 3.1 m/year
Lake Flushing Rate <p>: 0.24 1/year
Water Residence Time: 4.11 year
Leave
Write Results
Help
Select A Graph

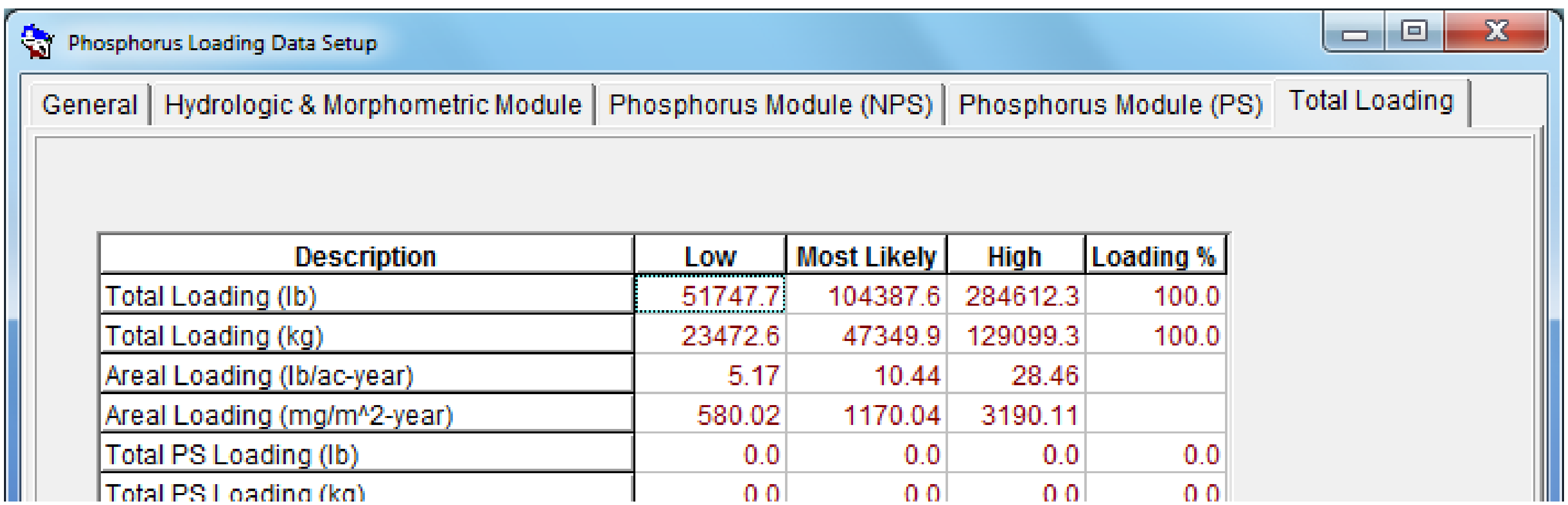
Example 1
Phosphorus Module (PS)

- Don’t enter anything here
  - *Point sources and septic tank stuff*

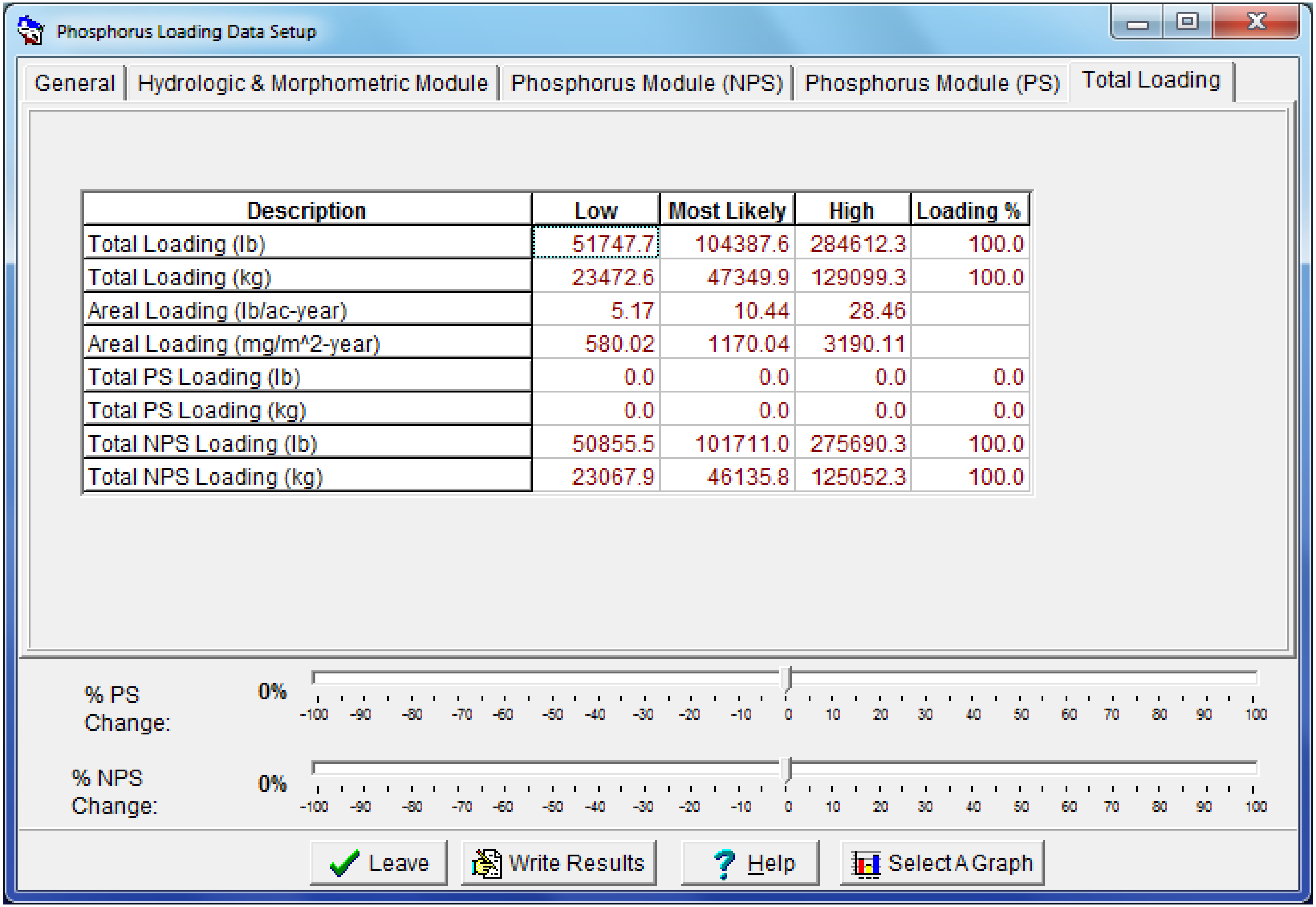
Example 1

(Total Loading)

- Nothing to enter here…
  - *Review*
    - *Total loading in lbs…. Around 100,000?*
    - *Should be all NPS… right?*
  - *Leave – save as something (“Dane1”?)*



Description	Low	Most Likely	High	Loading %
Total Loading (lb)	51747.7	104387.6	284612.3	100.0
Total Loading (kg)	23472.6	47349.9	129099.3	100.0
Areal Loading (lb/ac-year)	5.17	10.44	28.46	
Areal Loading (mg/m^2-year)	580.02	1170.04	3190.11	
Total PS Loading (lb)	0.0	0.0	0.0	0.0
Total PS Loading (kg)	0.0	0.0	0.0	0.0



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Total PS Loading (lb)	0.0	0.0	0.0	0.0
Total PS Loading (kg)	0.0	0.0	0.0	0.0
Total NPS Loading (lb)	50855.5	101711.0	275690.3	100.0
Total NPS Loading (kg)	23067.9	46135.8	125052.3	100.0

Model II– P Results

(Models – Lake Total Phosphorus Prediction – Prediction & Uncertainty Analysis)

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 75.0 mg/m^3

Observed growing season mean phosphorus (GSM): 90.0 mg/m^3

Back calculation for SPO total phosphorus: 0.0 mg/m^3

Back calculation GSM phosphorus: 0.0 mg/m^3

Nurnberg Model Input - Est. Gross Int. Loading: 0 kg

% Confidence Range: 70

Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound	Confidence Upper Bound	Parameter Fit?	Back Calculation (kg/year)	Model Type
Walker, 1987 Reservoir	25	50	135	-40	-44	29	105	Tw	0	GSM
Canfield-Bachmann, 1981 Natural Lake	39	60	110	-30	-33	19	173	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	34	49	78	-41	-46	15	141	FIT	1	GSM
Rechow, 1979 General	38	76	208	-14	-16	43	162	FIT	0	GSM
Rechow, 1977 Anoxic	102	205	560	115	128	123	432	FIT	0	GSM
Rechow, 1977 water load<50m/year	43	87	236	-3	-3	50	184	P Pin	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	73	146	399	71	95	73	322	FIT	0	SPO
Vollenweider, 1982 Combined OECD	45	81	184	-2	-2	40	164	FIT	0	ANN
Dillon-Rigler-Kirchner	50	100	273	25	33	59	211	P	0	SPO
Vollenweider, 1982 Shallow Lake/Res.	38	71	172	-12	-15	35	148	FIT	0	ANN
Larsen-Mercier, 1976	62	124	338	49	65	76	259	P Pin	0	SPO
Nurnberg, 1984 Oxic	54	109	297	19	21	57	237	P	0	ANN

Finished | Write Results | Display Parameter Values | Help

- *13 empirical equations*
- *TP Predictions*
- *Difference from observed– that was input in the “Setup” screen (note that if both GSM and SPO– the average will be used for ANN)*
- *Uncertainty bounds - set confidence range*
- *Parameter fit?– checks to see if the input fits within the model data set – if not it indicates where it differs (N/A means it didn’t calculate) … (more in WiLMS Manual)*

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 75.0 mg/m^3

Observed growing season mean phosphorus (GSM): 90.0 mg/m^3

Back calculation for SPO total phosphorus: 0.0 mg/m^3

Back calculation GSM phosphorus: 0.0 mg/m^3

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Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound	Confidence Upper Bound	Parameter Fit?	Back Calculation (kg/year)	Model Type
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Rechow, 1977 Anoxic	102	205	560	115	128	123	432	FIT	0	GSM
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Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	73	146	399	71	95	73	322	FIT	0	SPO
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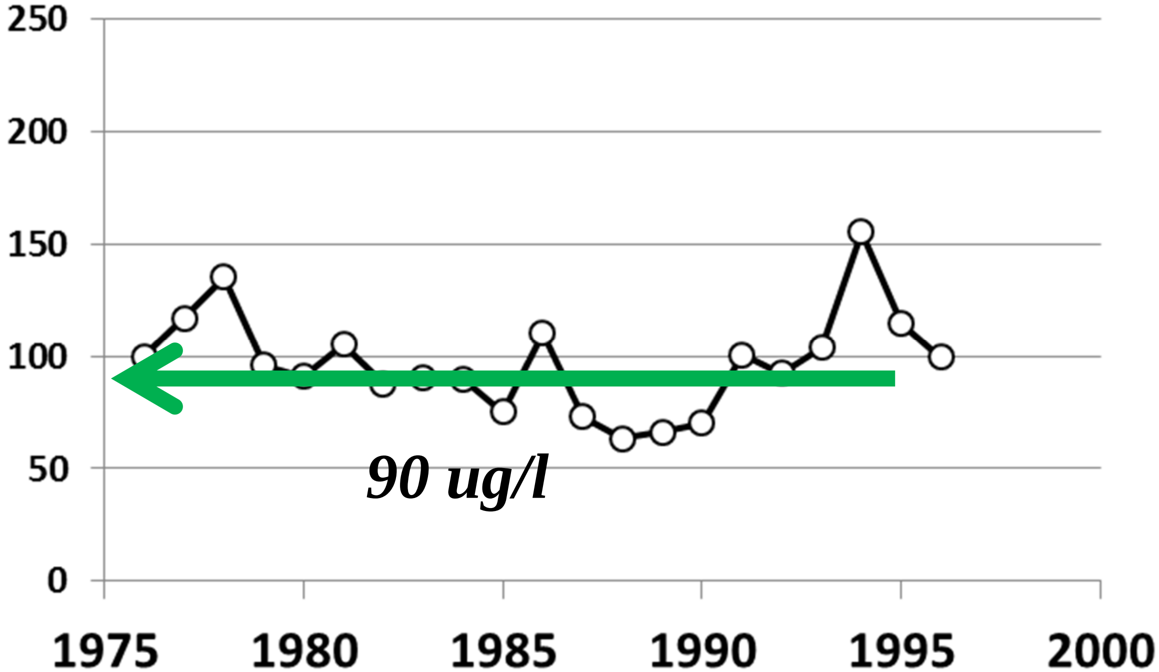
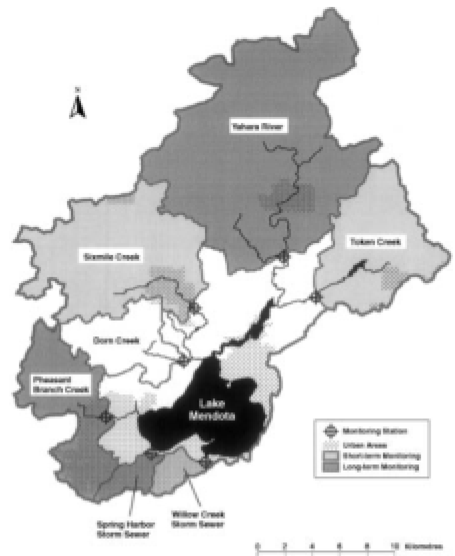
Finished | Write Results | Display Parameter Values | Help

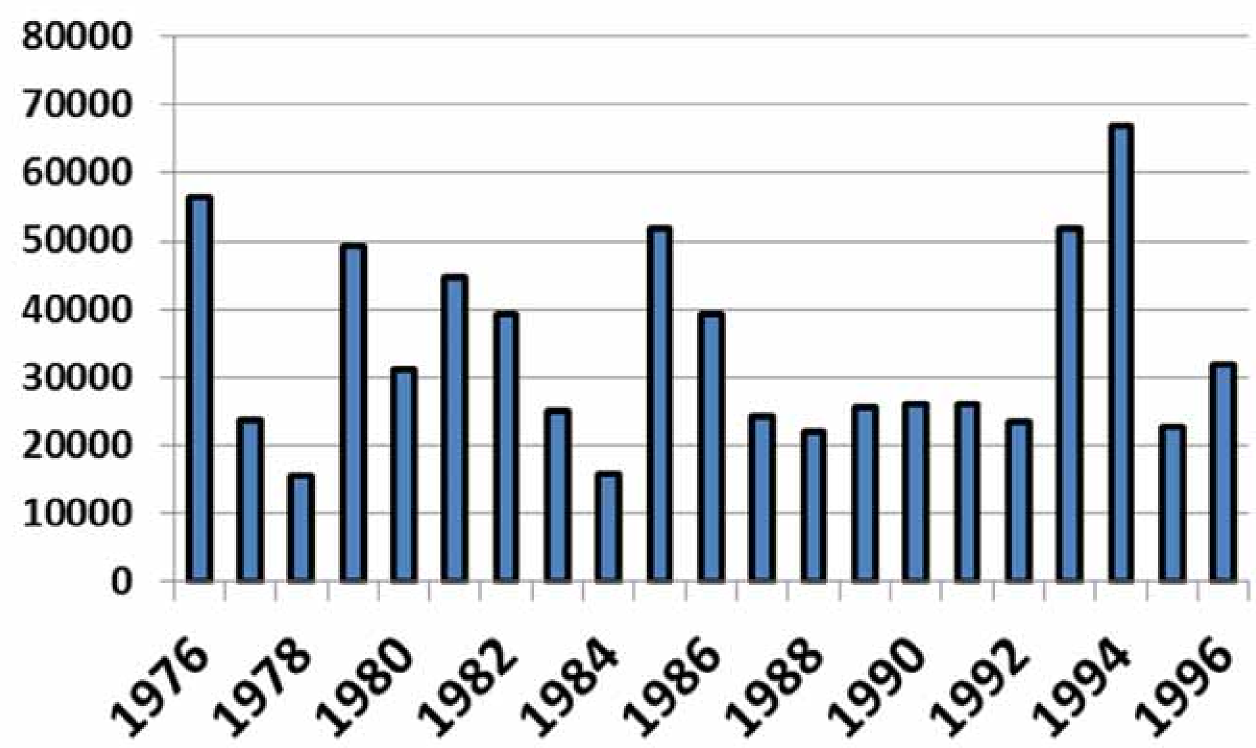
Discuss





Lathrop and Panuska 1998

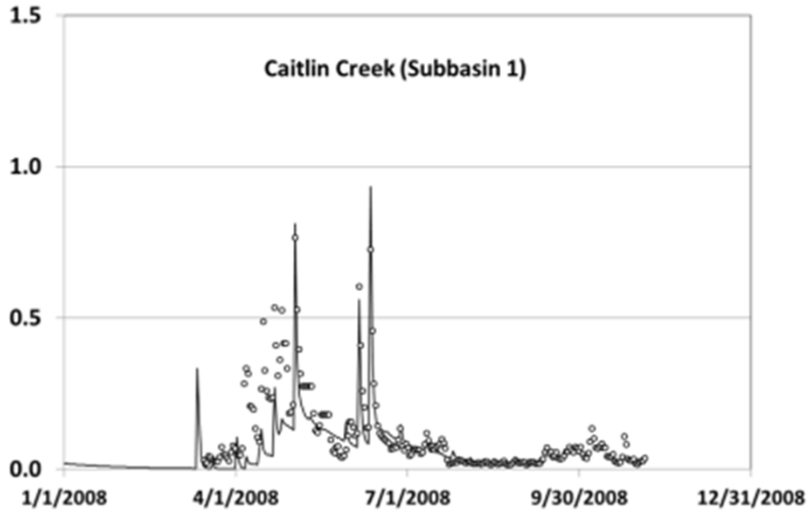
Challenges: Annual Variations in Phosphorus Load… (how does the model handle this?)



- **P Load (kg) to Lake** **(Lathrop and Panuska)**

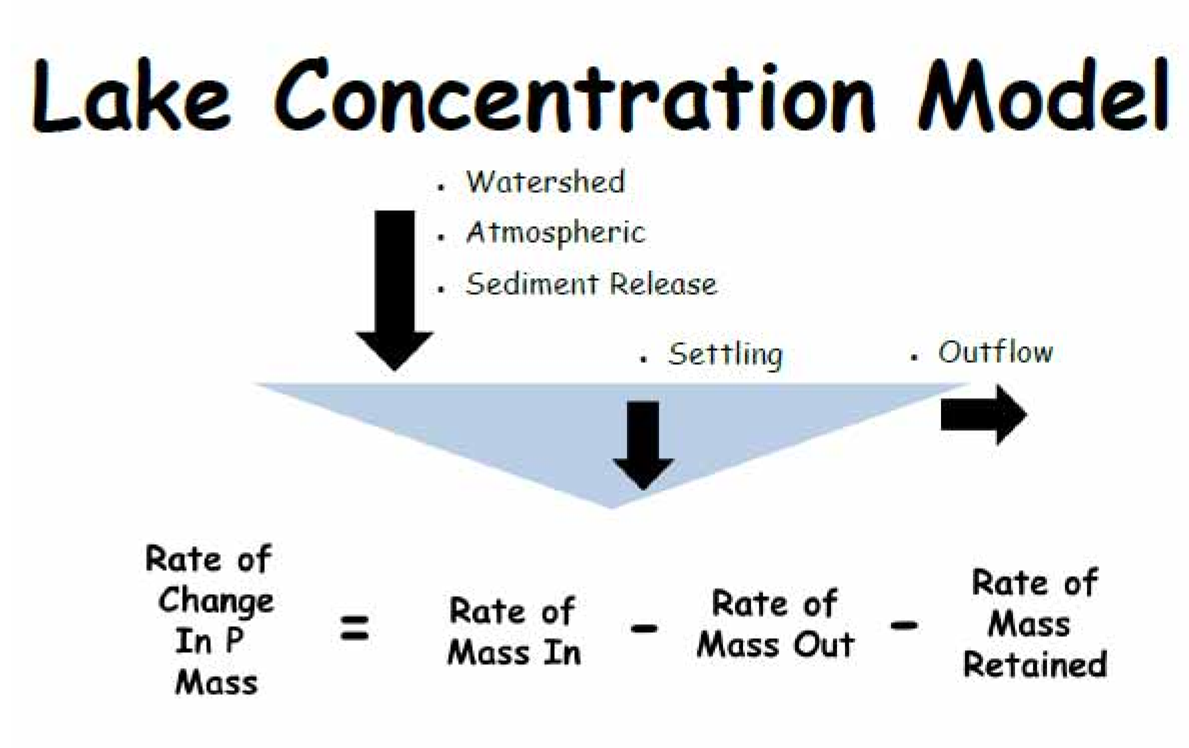
What if you wanted to model concentration variation over time?

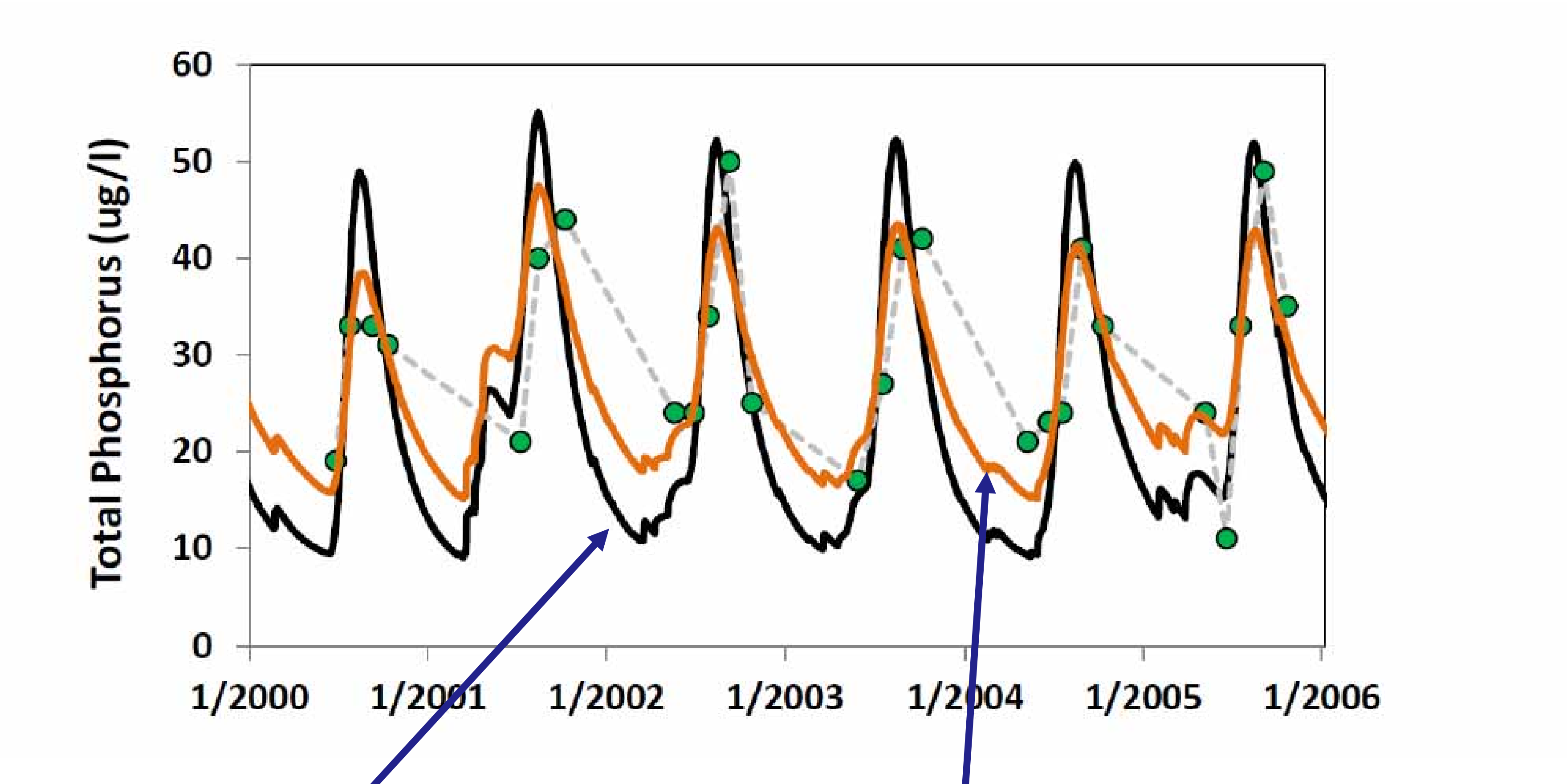
- Year to Year?
- Within Year?



Measured (symbols) and SWAT simulated (line) flow over time at one of the sub-watersheds draining to the lake.

One approach... similar method but daily time step



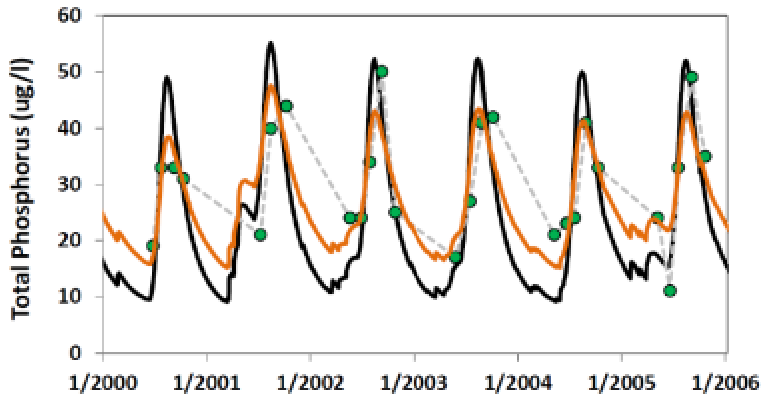


Peak (temp dependent) sediment release of 3 mg/m^2-d (orange) and 6 mg/m^2-d (black).

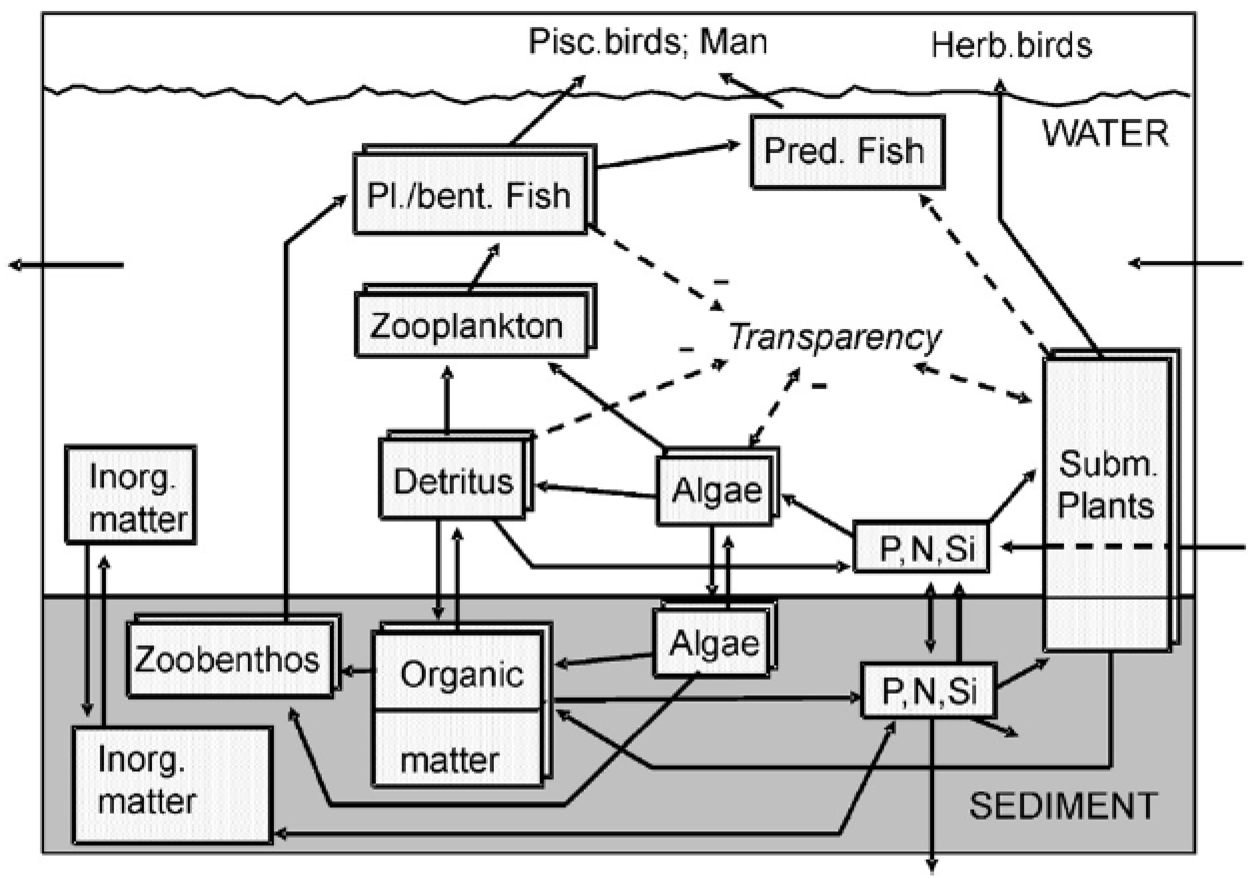
Corresponding settling rates are 11 m/year and 18 m/year.

Upper St. Croix Lake Example

- The Upper St. Croix Lake model accounts for inflow, sediment release, “settling” and outflow
- These models could be quite a bit more complicated...



PCLake Model Structure



Other Models!

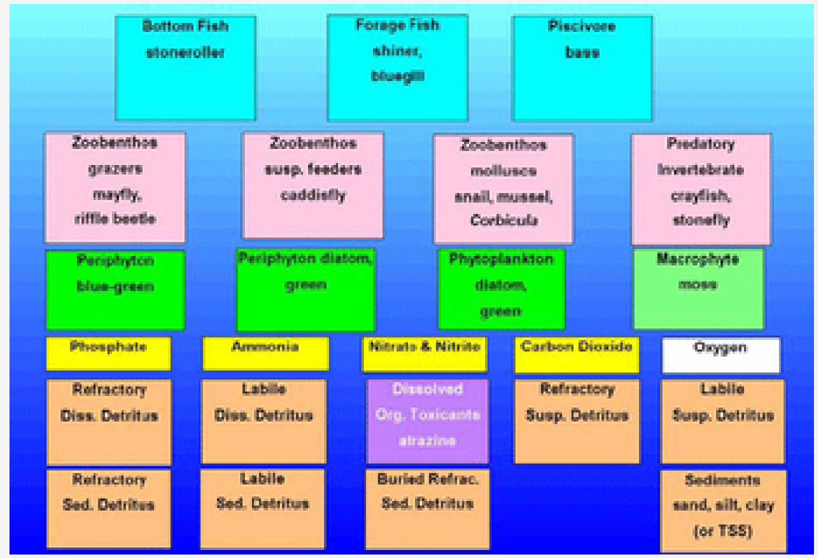
Critical phosphorus loading of different types of shallow lakes and the consequences for management estimated with the ecosystem model PCLake

Jan H. Janse[a], Lisette N. De Senerpont Domis[b], Marten Scheffer[c], Lambertus Lijklema[c], Lowie Van Liere[a], Marcel Klinge[d], Wolf M. Mooij[b,*]

AQUATOX (USEPA)

Ecological components simulated by AQUATOX

AQUATOX can model numerous inter-related components in aquatic ecosystems, known as the **state variables**.



An Example of AQUATOX State Variables for a Stream

- Phytoplankton (multiple species)
- Periphyton and submerged aquatic vegetation (multiple species)
- Planktonic and benthic invertebrates (multiple species)
- Forage, game, and bottom fish (multiple species)
- Nutrients and dissolved oxygen
- Organic and inorganic sediments
- Toxic organic chemicals (up to 20 different chemicals simultaneously)
- Perfloroalkylated Surfactants (bioaccumulation only)

AQUATOX is not intended to include every species of plant or animal that can exist in an aquatic habitat or every ecological process, but attempts to characterize the significant factors that determine the functioning of the ecosystem.

Tradeoffs

Ken Reckhow's Water Quality Wire

Some thoughts and observations on the science, engineering, and policy analysis of water quality assessment and management.

Friday, August 8, 2014

Is There A Disconnect Between Mechanistic and Statistical Water Quality Modelers?

In overly simple terms, the surface water quality modeling community can be divided into two camps – mechanistic and statistical. In much of my recent work, I have sought a middle ground that is loyal to process understanding yet yields a measure of uncertainty in predictions. I have argued for years that we should not provide decision makers with predictions of the impact of management actions without an estimate of the confidence we have in those predictions. To me, this point is irrefutable, and it continues to dismay me that EPA and other agencies largely ignore this point in the water quality models they support.

My mechanistic modeling colleagues have tended to stress large elaborate models that are generally motivated by the assumption that models must be sufficiently detailed so the modelers can "get the processes right." This is a goal that likely will never be achieved. The result is that these elaborate models are overparameterized; this condition, called "equifinality," is well-documented in the hydrologic sciences, but the concept rarely has been discussed in the water quality modeling literature. Among experienced hydrologic modelers, it is well-recognized that many "sets" of parameter values will fit large simulation models about equally well; unfortunately, this can create problems with the interpretation of sensitivity analyses, since different (equally well-fitting) parameter sets can lead to quite different causal conclusions about the effect of management actions.

There is a lot of terminology related to the P "settling"...

- Retention =fraction of the incoming P that is retained
  - » $R = 1- (C_{out}/C_{in})$
  - » See page 58, 68, 100 of notes
  - » Therefore
  - » Can show that $R=v_s/(v_s+q_s)$ and...
  - » $C_P=(L/q_s)(1-R)$
- Volumetric Removal...

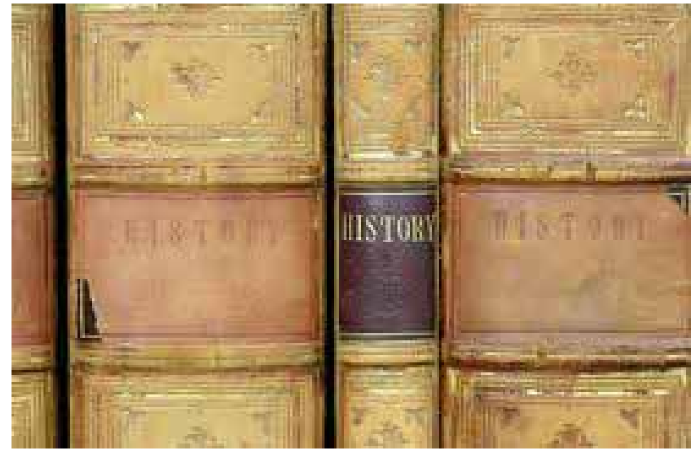
Or $kV_L = vA_s$

These are equivalent...

- For example... retention
  - Our example, 78% of the annual P is retained (is “stored”)
  - Our hydraulic loading is
    - 10 ft/year (that’s q_s)
  - Our P load could be expressed as
    - 1.12 g/(m^2 of lake surface – year) (that’s L)
  - Then could use $Cp = (L/q_s)(1-R) = 82$ ug/l

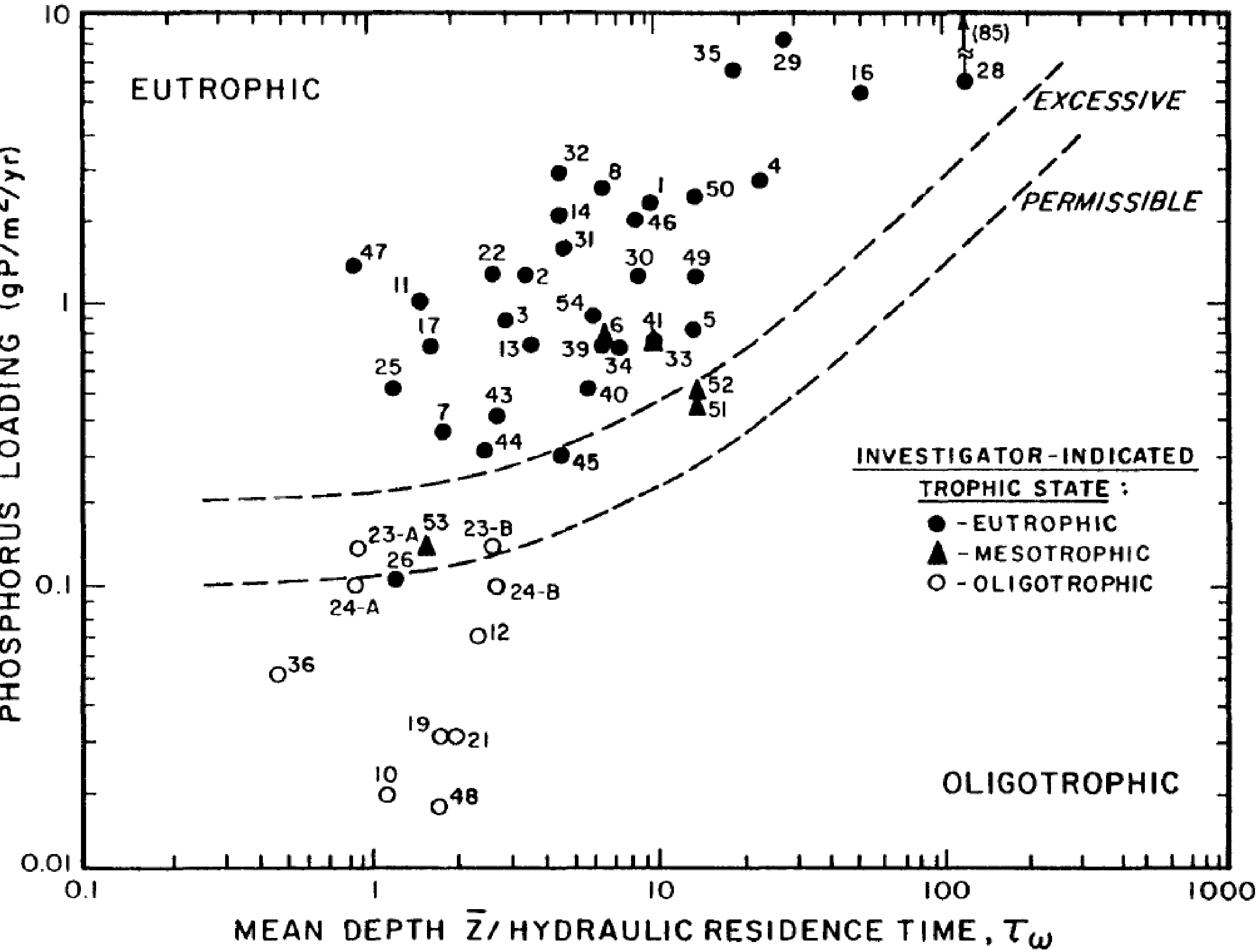
You want more of this… check out Reckhow and Chapra Book pages

Historical Note

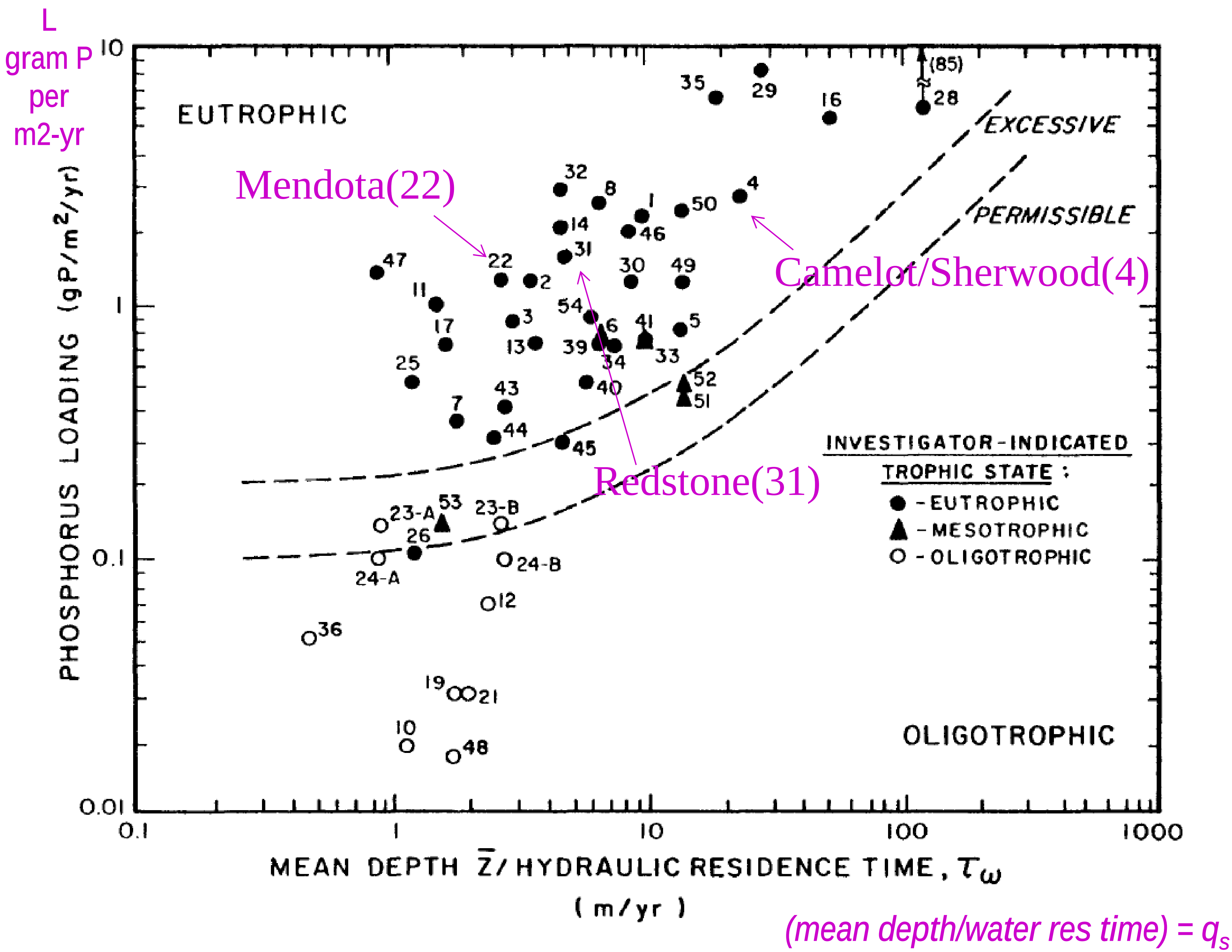


- 1960s/70s eutrophication / phosphorus
- OECD (Organization for Economic Cooperation and Development) Eutrophication Study (1970s)
  - 18 countries involved, in some, field studies were initiated
  - US used small grants to encourage reports on existing studies
  - Summarized in 1978 Report (Rast and Lee)

Phosphorus Load on Lake



Water Load on Lake



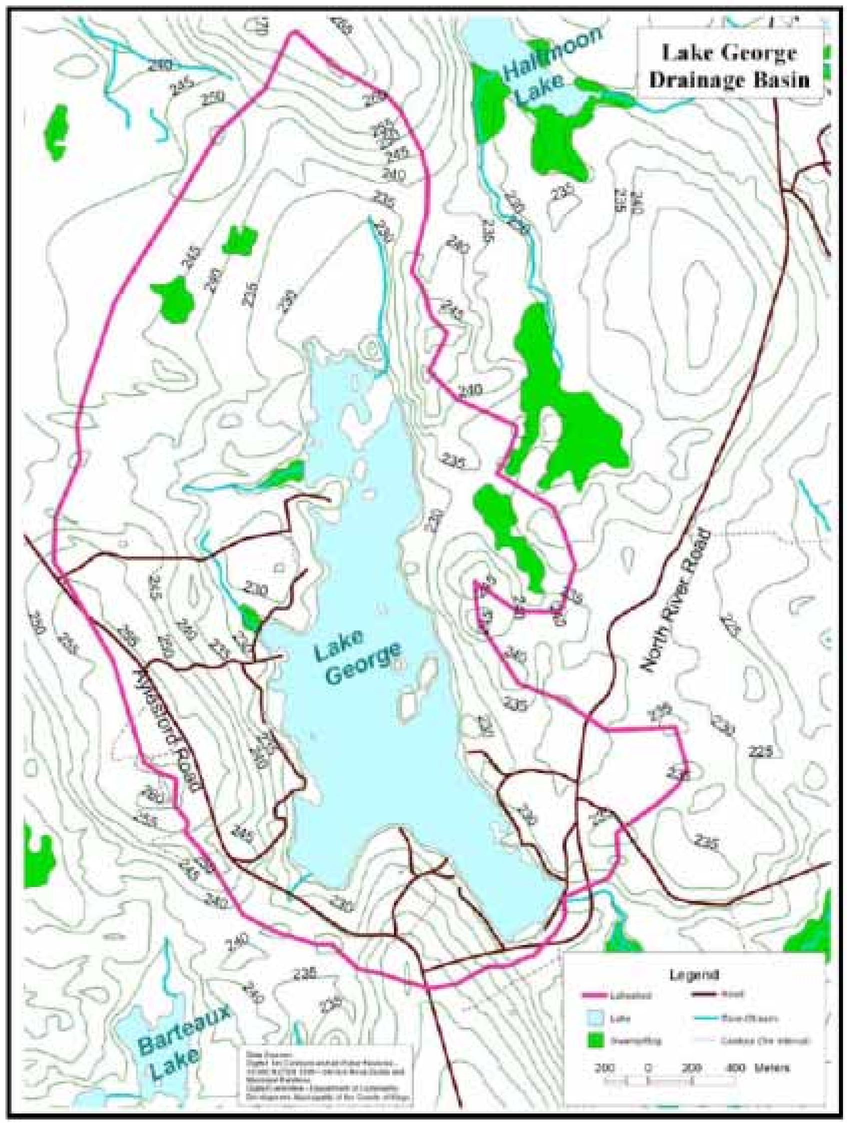
L
gram P
per
m2-yr
PHOSPHORUS LOADING (gP/m²/yr)
EUTROPHIC
EXCESSIVE
PERMISSIBLE
OLIGOTROPHIC
Mendota(22)
Camelot/Sherwood(4)
Redstone(31)
INVESTIGATOR-INDICATED
TROPHIC STATE :
- EUTROPHIC
- MESOTROPHIC
- OLIGOTROPHIC
(85)
10
1
0.1
0.01
0.1
1
10
100
1000
MEAN DEPTH Z̄/ HYDRAULIC RESIDENCE TIME, τ_ω
(m / yr)
(mean depth/water res time) = q_s

Now Let's Talk about Those Inputs

- Water Budget
  - Annual estimate for WiLMS
  - Need the total quantity of water entering the lake
  - What happens to precip on land & water?

- Phosphorus Loading

Watershed - *Water Budget*



Watershed - *Water Budget*

- **Hydrology…lots of pathways to the lake**
  - Precipitation = ET + “Runoff”
  - “Runoff” = baseflow + event flow
  - “Baseflow” = percolation to saturated zone (groundwater)
  - “Event flow” = surface runoff, saturation excess flow

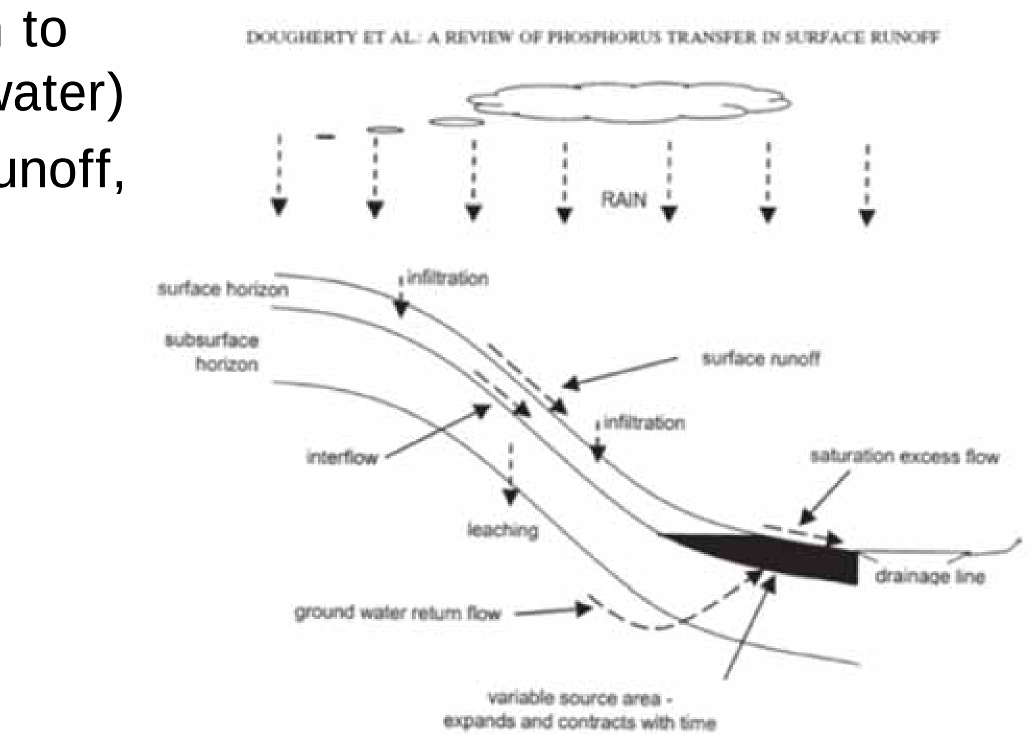
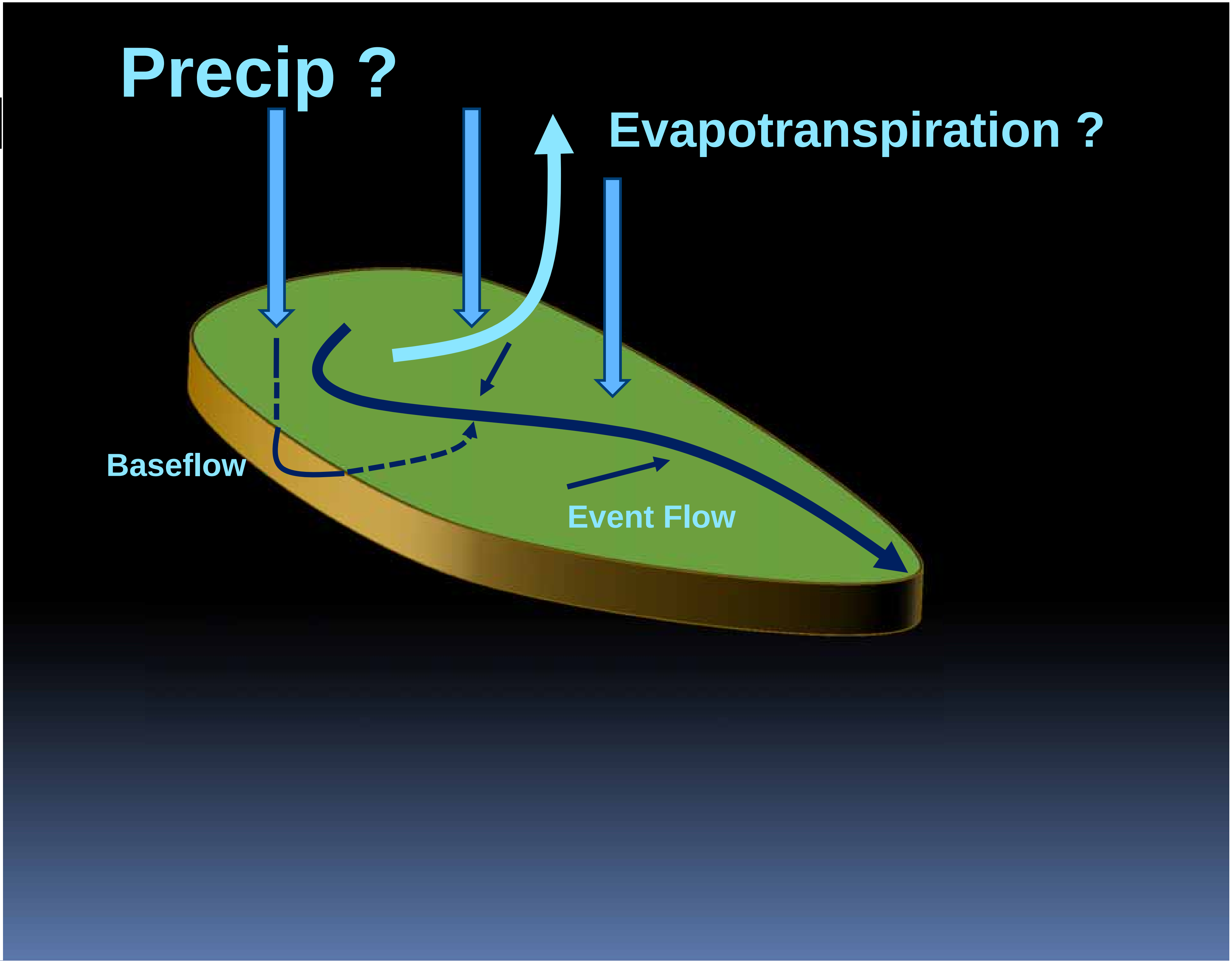
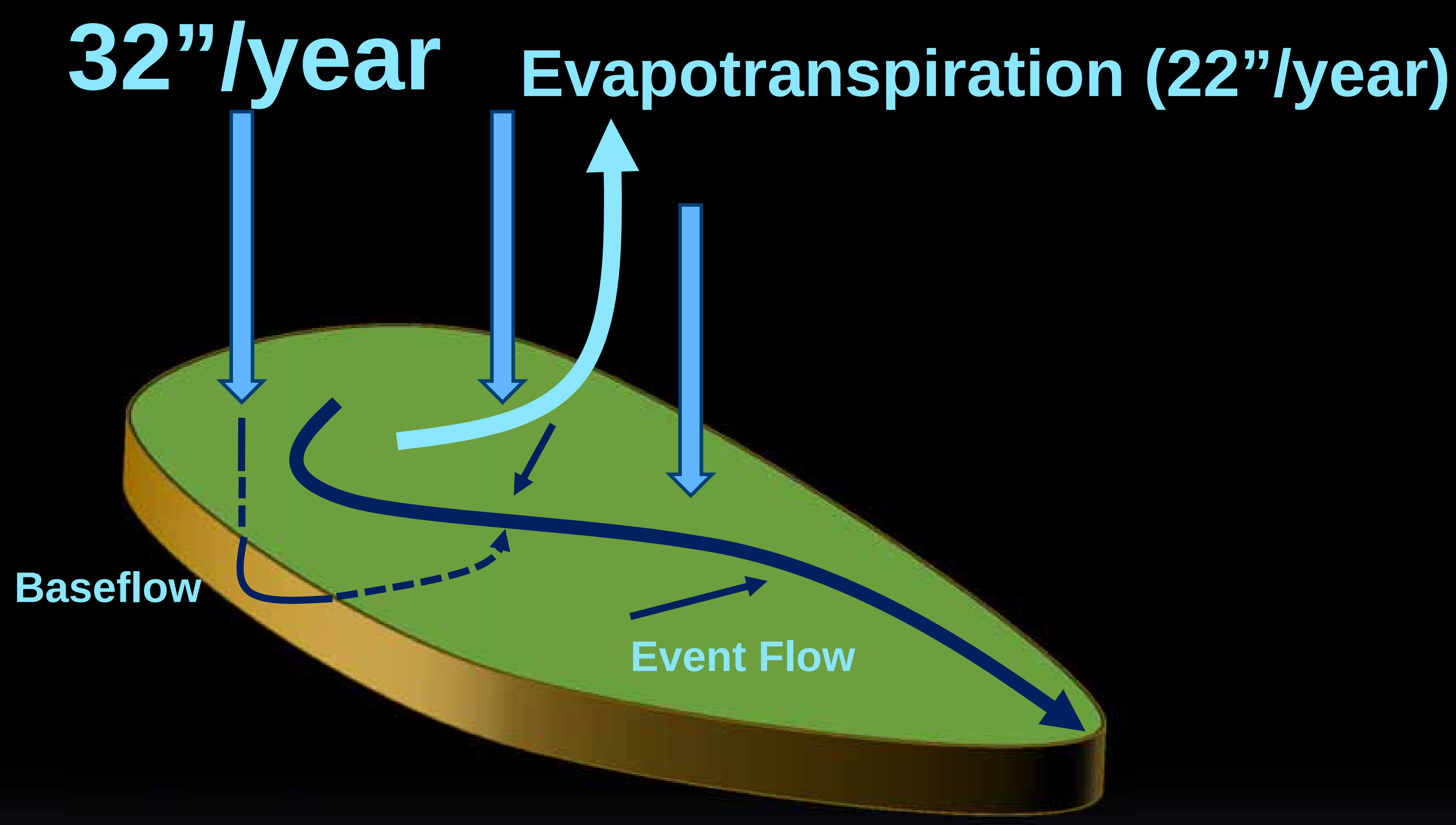


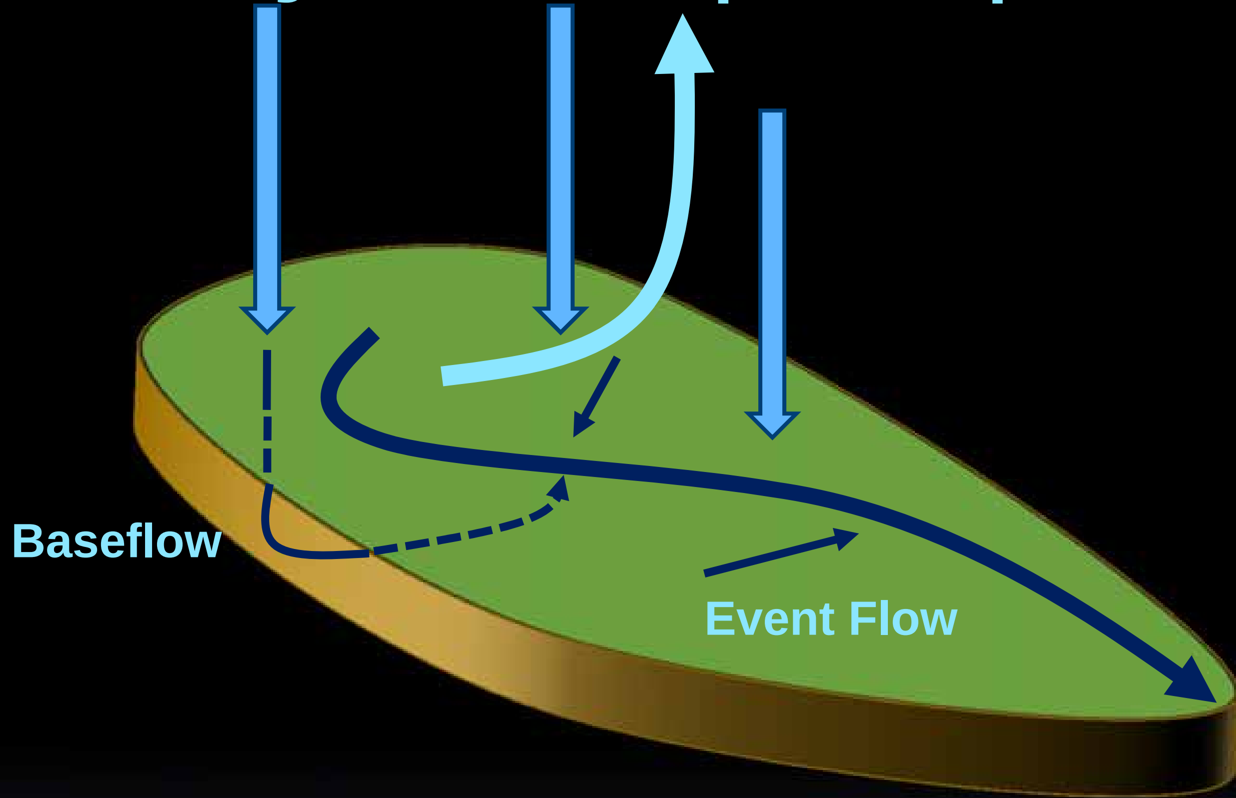
Fig. 4. Basic components of hillslope hydrology.


Precip ?
Evapotranspiration ?
Baseflow
Event Flow



Big Picture…

32”/year Evapotranspiration (22”/year)

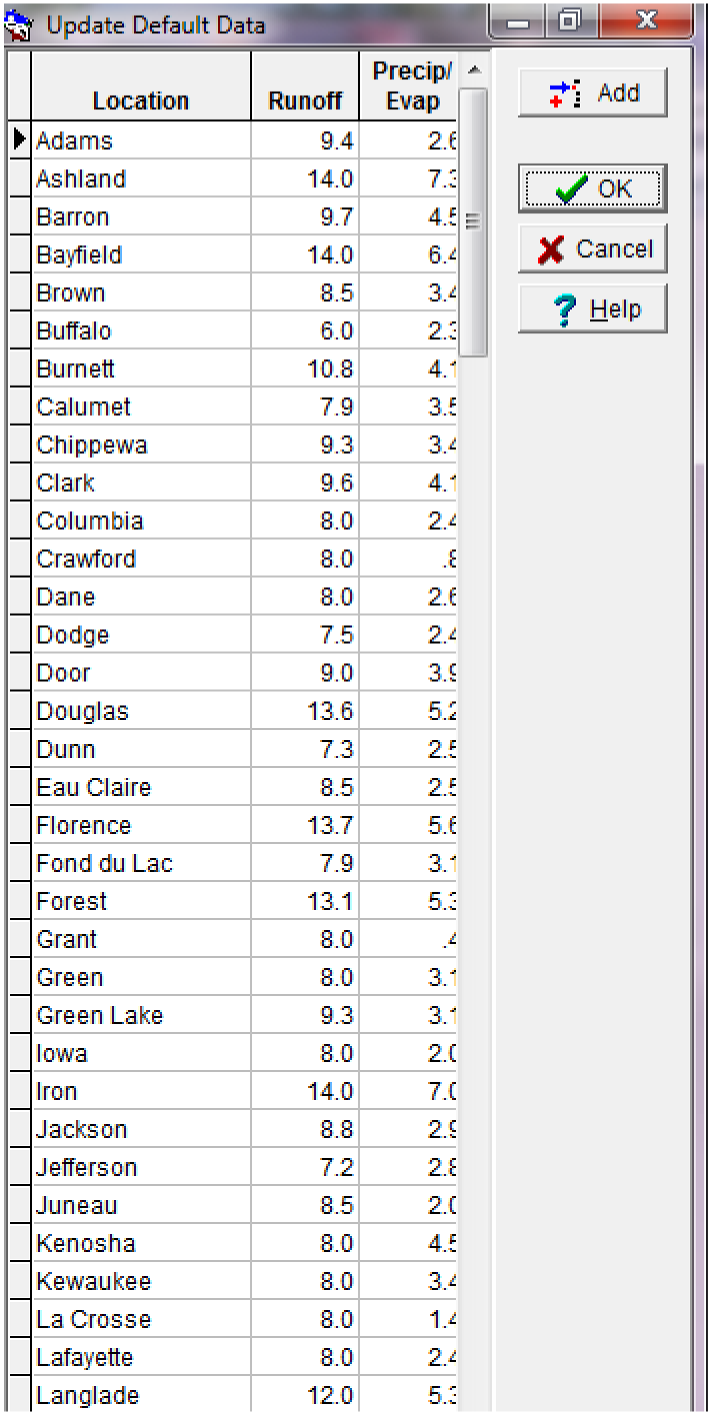


10 inches /year on 1 square mile…

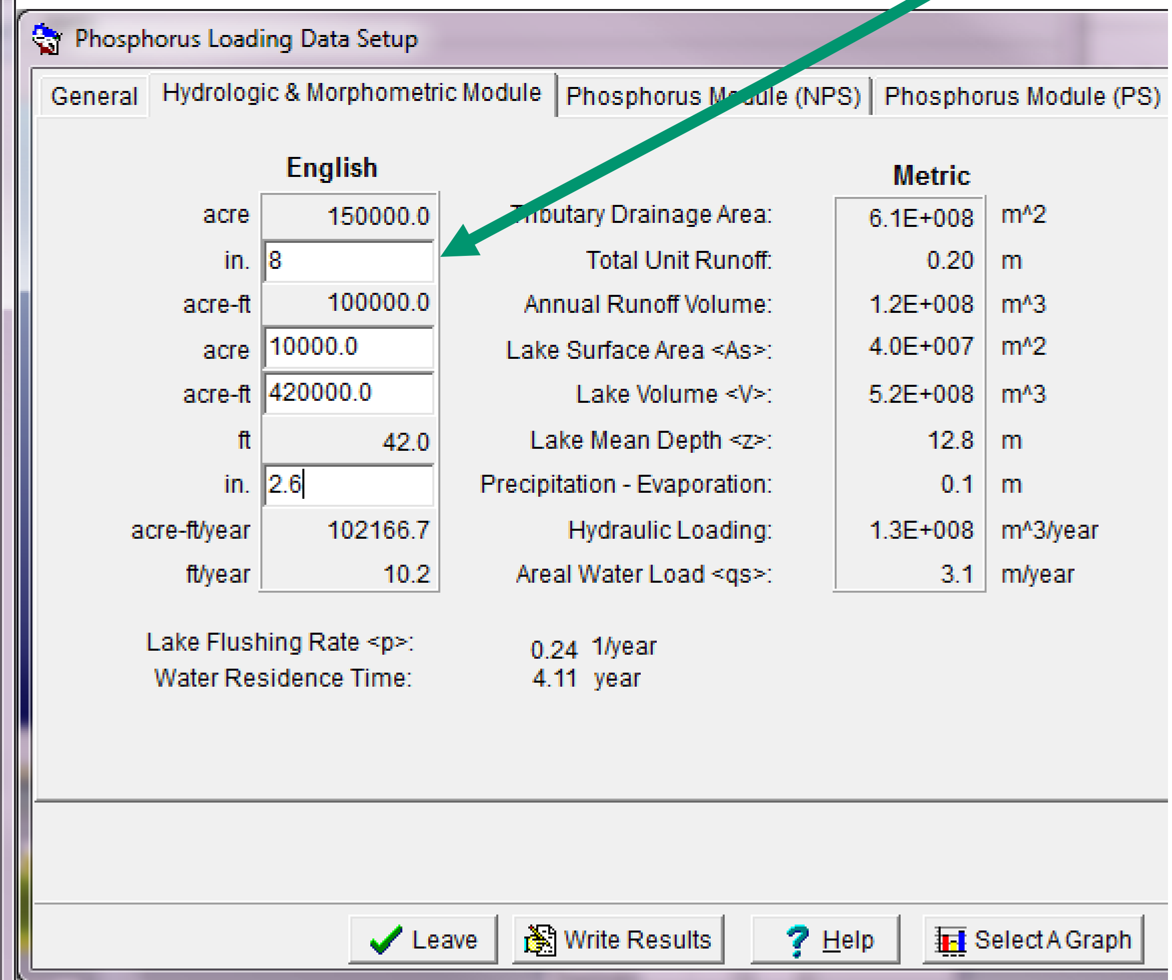
= 23,000,000 cubic feet /year

= 0.7 cubic foot every second

WiLMS



Location	Runoff	Precip/ Evap
Adams	9.4	2.6
Ashland	14.0	7.3
Barron	9.7	4.5
Bayfield	14.0	6.4
Brown	8.5	3.4
Buffalo	6.0	2.3
Burnett	10.8	4.1
Calumet	7.9	3.5
Chippewa	9.3	3.4
Clark	9.6	4.1
Columbia	8.0	2.4
Crawford	8.0	.8
Dane	8.0	2.6
Dodge	7.5	2.4
Door	9.0	3.9
Douglas	13.6	5.2
Dunn	7.3	2.5
Eau Claire	8.5	2.5
Florence	13.7	5.6
Fond du Lac	7.9	3.1
Forest	13.1	5.3
Grant	8.0	.4
Green	8.0	3.1
Green Lake	9.3	3.1
Iowa	8.0	2.0
Iron	14.0	7.0
Jackson	8.8	2.9
Jefferson	7.2	2.8
Juneau	8.5	2.0
Kenosha	8.0	4.5
Kewaukee	8.0	3.4
La Crosse	8.0	1.4
Lafayette	8.0	2.4
Langlade	12.0	5.3



Phosphorus Inputs

- Water Budget
- Phosphorus Loading
  - Sources include
    - Event flow
    - Baseflow
    - Atmospheric Deposition
    - Internal (eg sediments)
- Land is a concentrated sediment & nutrient source

WiLMS Watershed Inputs

- "Export"
  - Pounds/acre-yr
  - Kg/hectare-yr
  - Pounds/square mile-yr

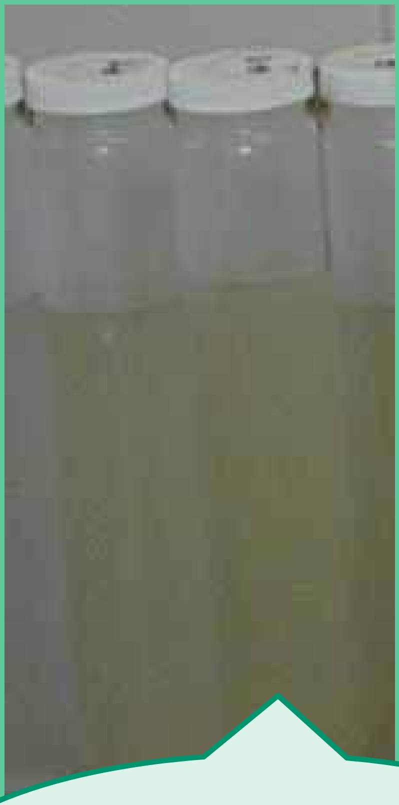
- Comment on unit conversions
  - pound/acre-yr is about the same as kilogram/ha-yr

- Watershed loading combines sources and transport
  - Quantity, availability
  - Interaction with water & transport

Phosphorus Export Coefficients

- Panuska and Lillie (p 29)
- Corsi et al. (p 37)
- Summary from PRESTO (p 41)
- Sparrow
- Hubbard Brook (p 52)
- Ontario LCM (p 119)

Total Suspended Solids…



0.01 gram/l

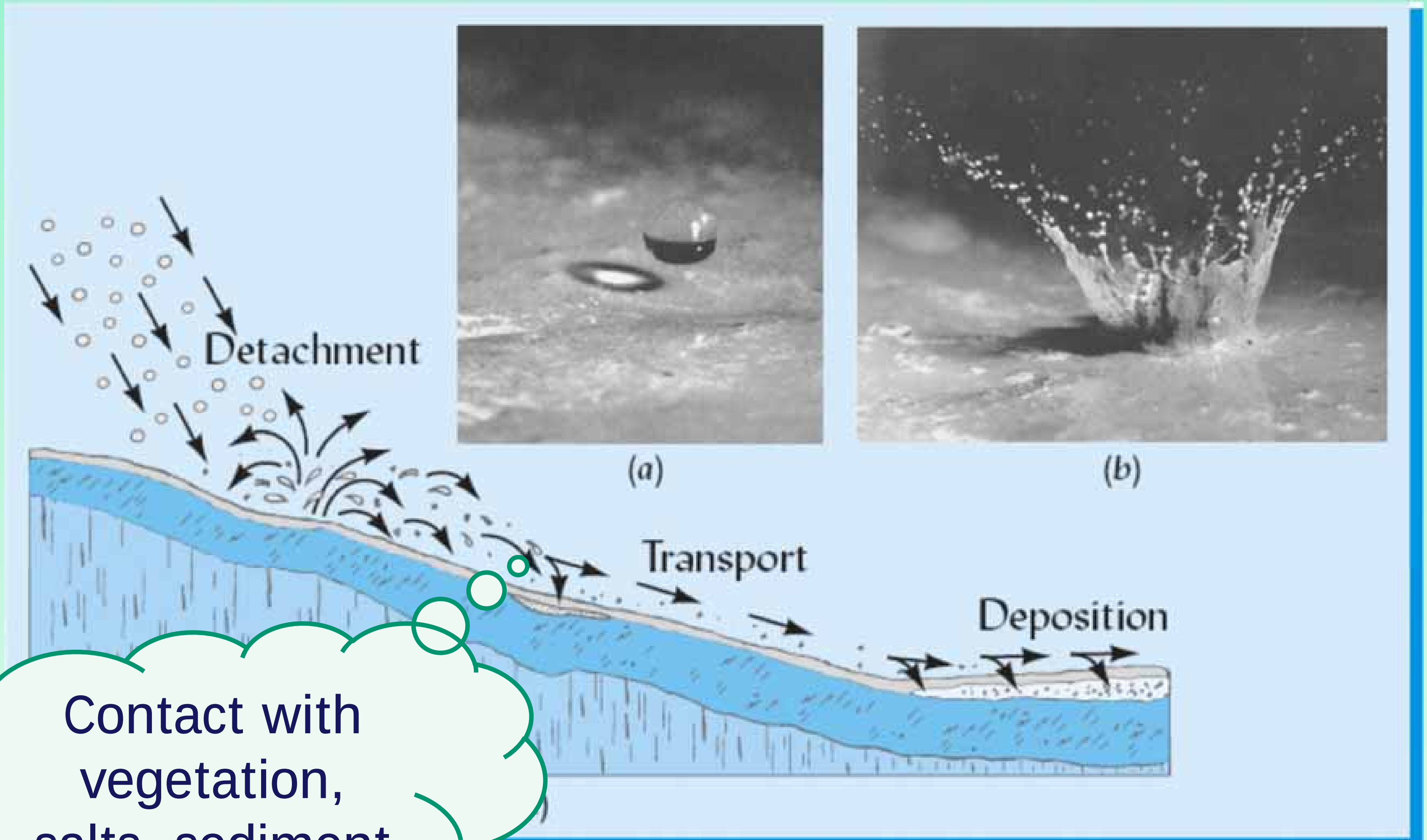
1,500 gram/l

Phosphorus

300,000 microgram P / liter

40 microgram P / liter

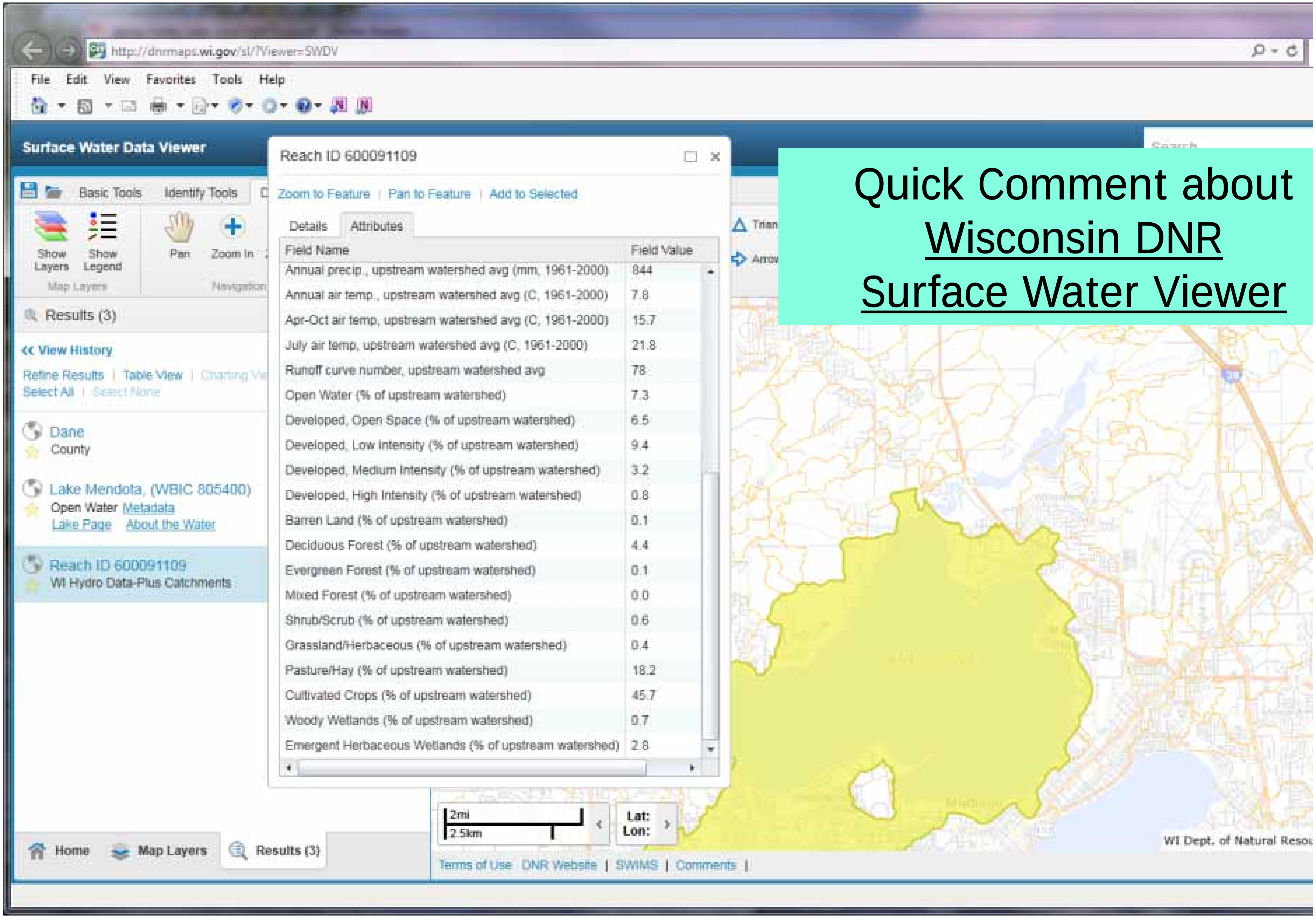
Add Energy & Opportunity

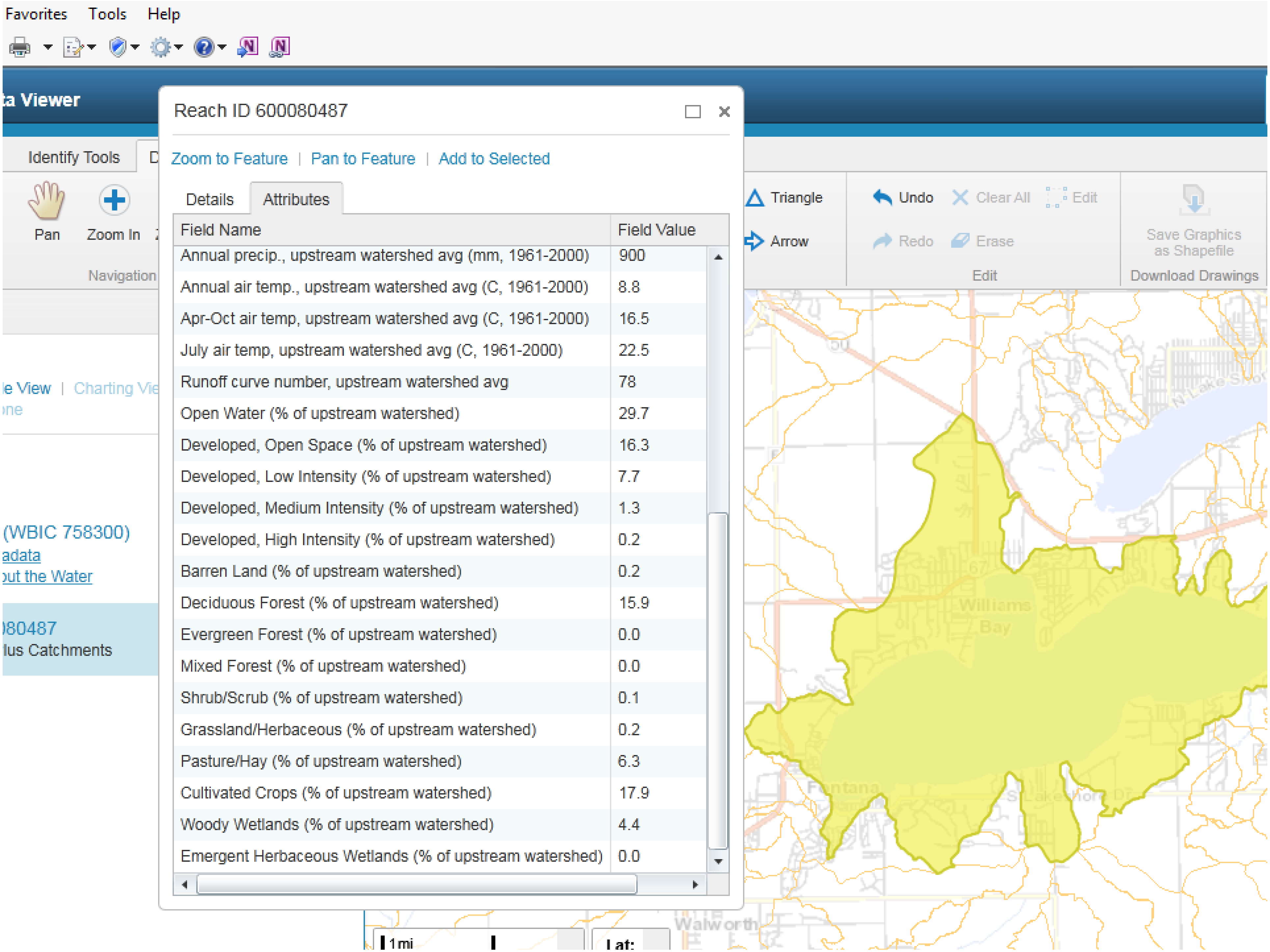


Contact with vegetation, salts, sediment

Nyle Brady and Raymond Weil 3/e

Quick Comment about [Wisconsin DNR Surface Water Viewer]

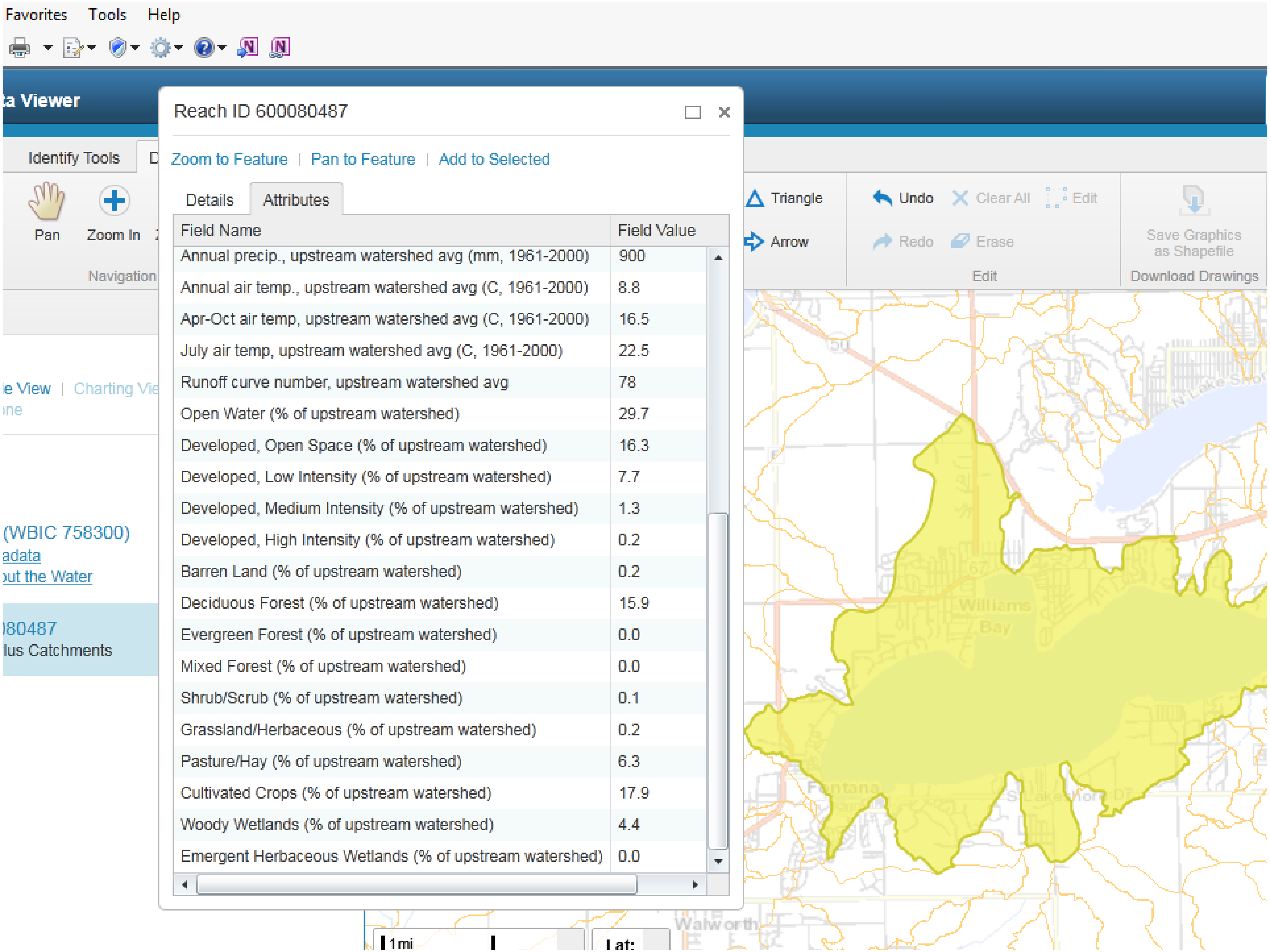




Field Name	Field Value
Annual precip., upstream watershed avg (mm, 1961-2000)	900
Annual air temp., upstream watershed avg (C, 1961-2000)	8.8
Apr-Oct air temp, upstream watershed avg (C, 1961-2000)	16.5
July air temp, upstream watershed avg (C, 1961-2000)	22.5
Runoff curve number, upstream watershed avg	78
Open Water (% of upstream watershed)	29.7
Developed, Open Space (% of upstream watershed)	16.3
Developed, Low Intensity (% of upstream watershed)	7.7
Developed, Medium Intensity (% of upstream watershed)	1.3
Developed, High Intensity (% of upstream watershed)	0.2
Barren Land (% of upstream watershed)	0.2
Deciduous Forest (% of upstream watershed)	15.9
Evergreen Forest (% of upstream watershed)	0.0
Mixed Forest (% of upstream watershed)	0.0
Shrub/Scrub (% of upstream watershed)	0.1
Grassland/Herbaceous (% of upstream watershed)	0.2
Pasture/Hay (% of upstream watershed)	6.3
Cultivated Crops (% of upstream watershed)	17.9
Woody Wetlands (% of upstream watershed)	4.4
Emergent Herbaceous Wetlands (% of upstream watershed)	0.0

Spreadsheet Tool for Watershed Information

- Adapted from the Surface Water Data Viewer
- In your Precon folder as "DEMOVersion"
- An Excel Spreadsheet
- Let's try it



Field Name	Field Value
Annual precip., upstream watershed avg (mm, 1961-2000)	900
Annual air temp., upstream watershed avg (C, 1961-2000)	8.8
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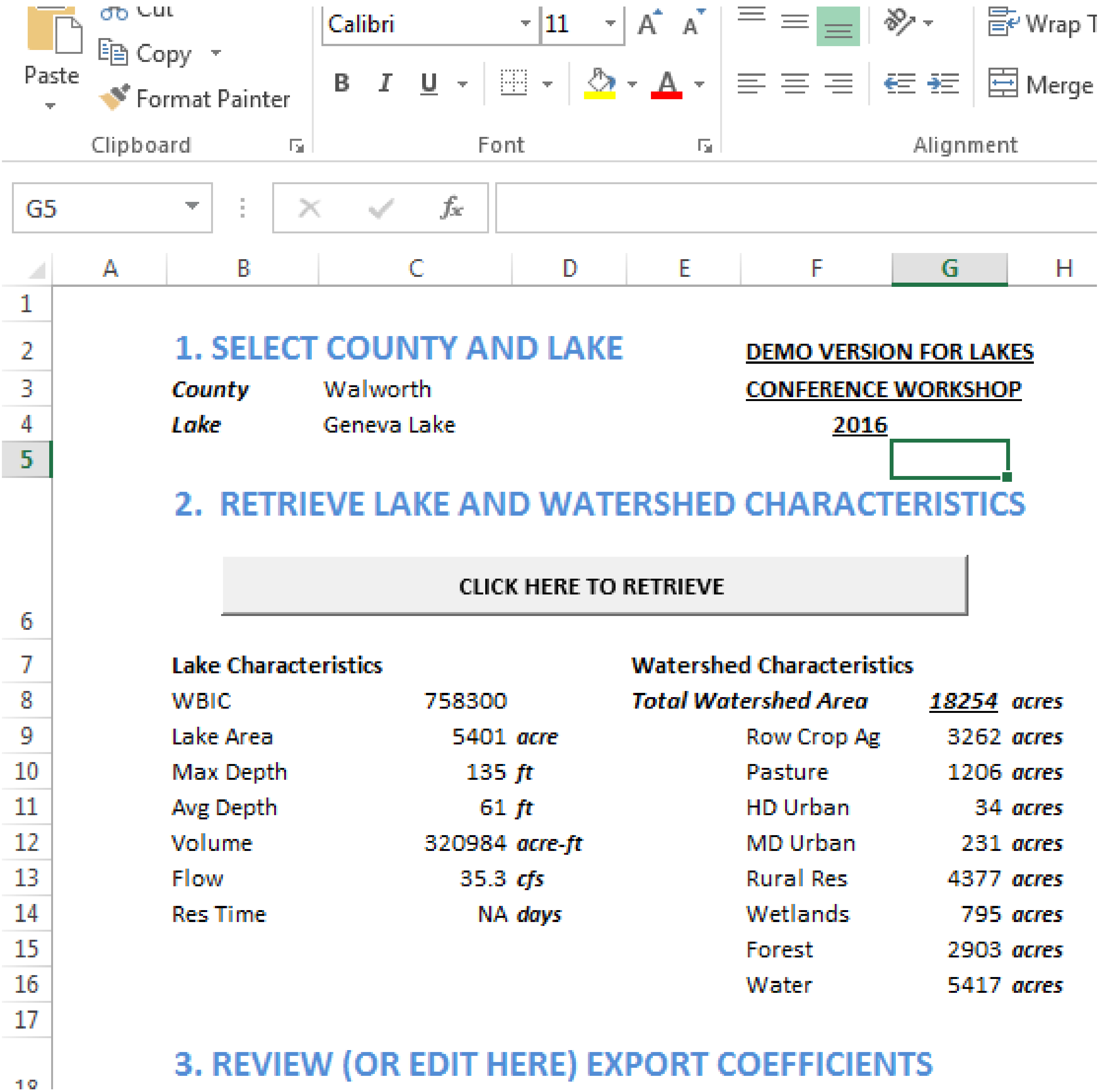
Grassland/Herbaceous (% of upstream watershed)	0.2
Pasture/Hay (% of upstream watershed)	6.3
Cultivated Crops (% of upstream watershed)	17.9
Woody Wetlands (% of upstream watershed)	4.4
Emergent Herbaceous Wetlands (% of upstream watershed)	0.0


Paste
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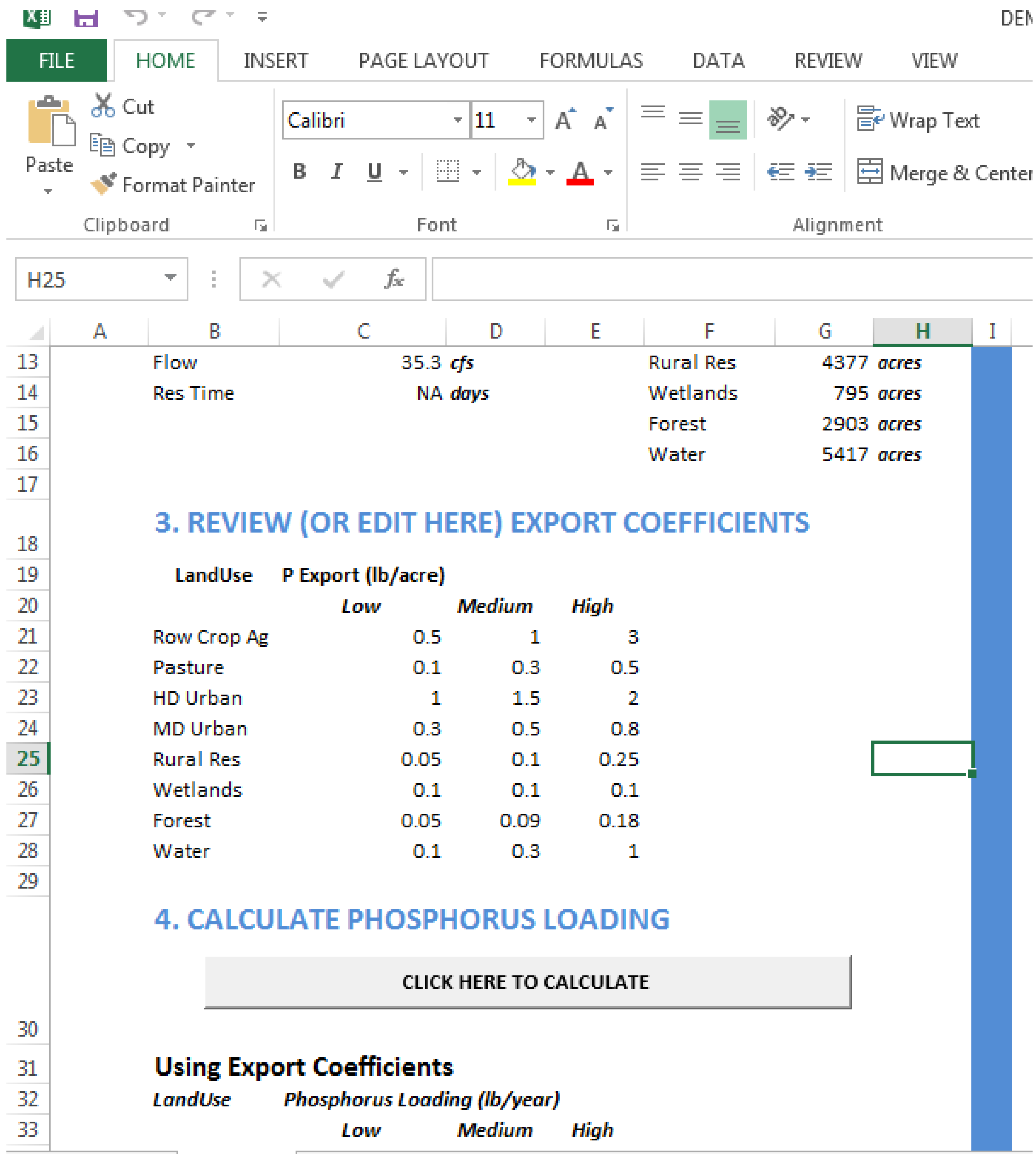
1. SELECT COUNTY AND LAKE
County Walworth
Lake Geneva Lake
DEMO VERSION FOR LAKES
CONFERENCE WORKSHOP
2016
2. RETRIEVE LAKE AND WATERSHED CHARACTERISTICS
CLICK HERE TO RETRIEVE
Lake Characteristics
WBIC 758300
Lake Area 5401 acre
Max Depth 135 ft
Avg Depth 61 ft
Volume 320984 acre-ft
Flow 35.3 cfs
Res Time NA days
Watershed Characteristics
Total Watershed Area 18254 acres
Row Crop Ag 3262 acres
Pasture 1206 acres
HD Urban 34 acres
MD Urban 231 acres
Rural Res 4377 acres
Wetlands 795 acres
Forest 2903 acres
Water 5417 acres
3. REVIEW (OR EDIT HERE) EXPORT COEFFICIENTS



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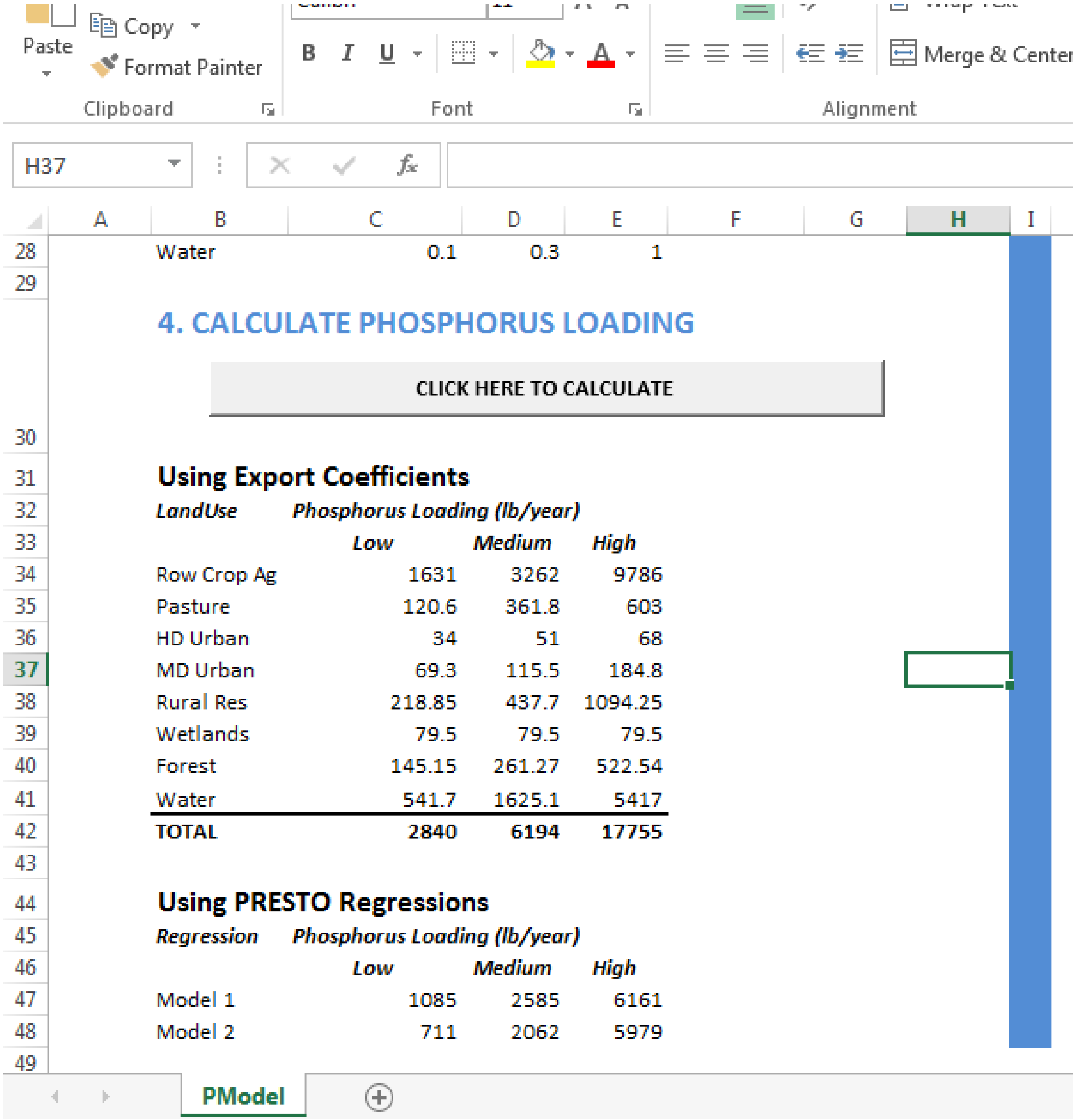
H25
Flow 35.3 cfs
Res Time NA days
Rural Res 4377 acres
Wetlands 795 acres
Forest 2903 acres
Water 5417 acres
3. REVIEW (OR EDIT HERE) EXPORT COEFFICIENTS
LandUse P Export (lb/acre)
Low Medium High
Row Crop Ag 0.5 1 3
Pasture 0.1 0.3 0.5
HD Urban 1 1.5 2
MD Urban 0.3 0.5 0.8
Rural Res 0.05 0.1 0.25
Wetlands 0.1 0.1 0.1
Forest 0.05 0.09 0.18
Water 0.1 0.3 1
4. CALCULATE PHOSPHORUS LOADING
CLICK HERE TO CALCULATE
Using Export Coefficients
LandUse Phosphorus Loading (lb/year)
Low Medium High



Water	0.1	0.3	1

4. CALCULATE PHOSPHORUS LOADING

CLICK HERE TO CALCULATE

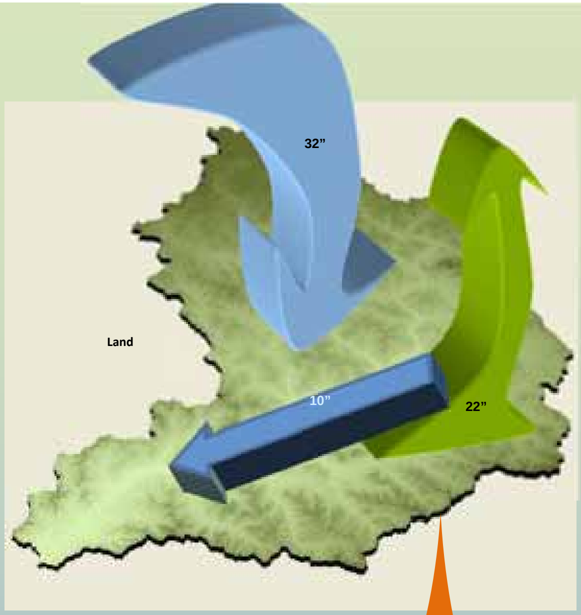
Using Export Coefficients

LandUse	*Phosphorus Loading (lb/year)*		
	Low	*Medium*	*High*
Row Crop Ag	1631	3262	9786
Pasture	120.6	361.8	603
HD Urban	34	51	68
MD Urban	69.3	115.5	184.8
Rural Res	218.85	437.7	1094.25
Wetlands	79.5	79.5	79.5
Forest	145.15	261.27	522.54
Water	541.7	1625.1	5417
TOTAL	**2840**	**6194**	**17755**

Using PRESTO Regressions

Regression	*Phosphorus Loading (lb/year)*		
	Low	*Medium*	*High*
Model 1	1085	2585	6161
Model 2	711	2062	5979

Export Coefficients are a very simple way to model the land



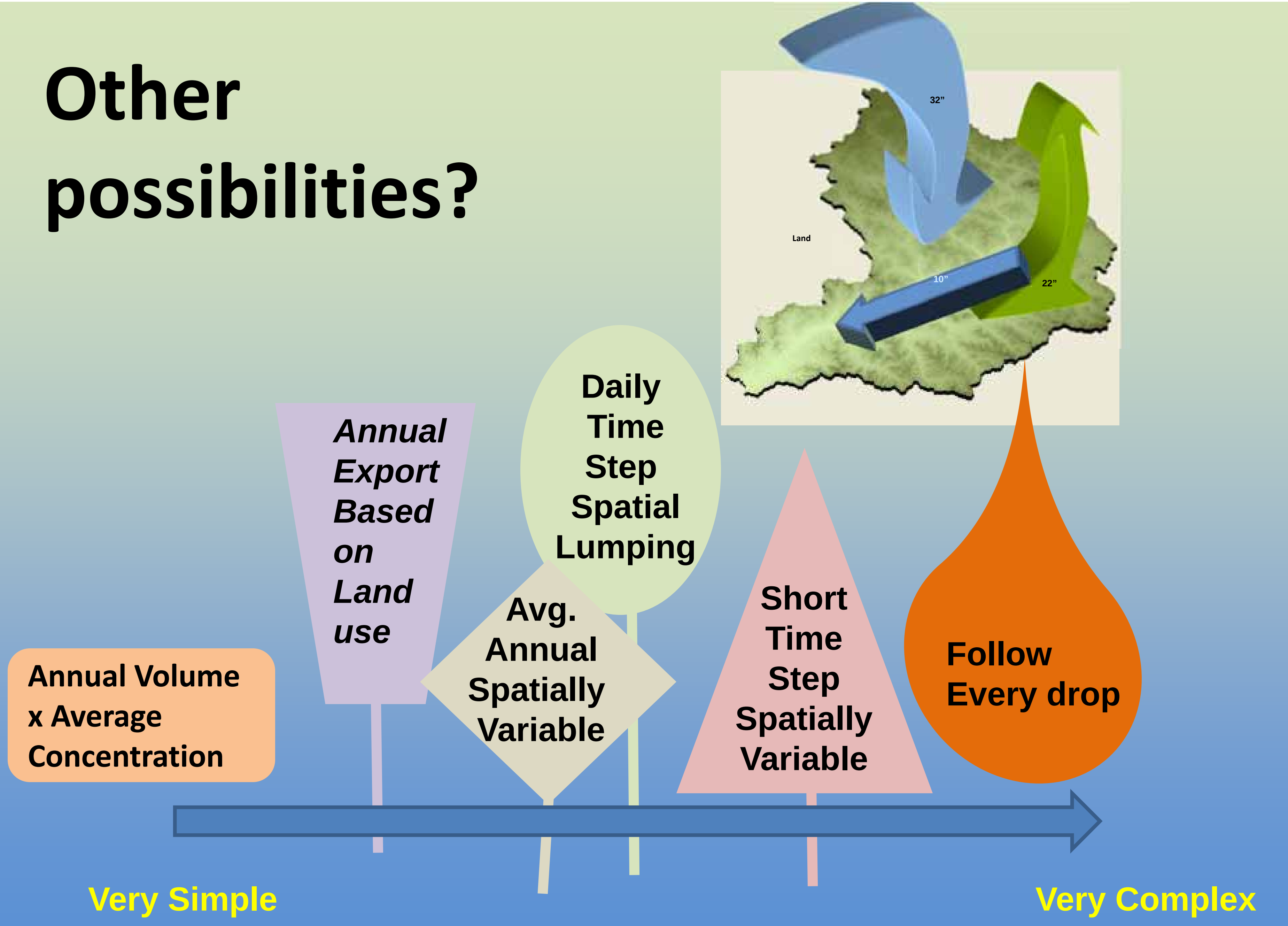
Annual Volume x Average Concentration

Follow Every drop

Very Simple

Very Complex

Other possibilities?



Watersheds

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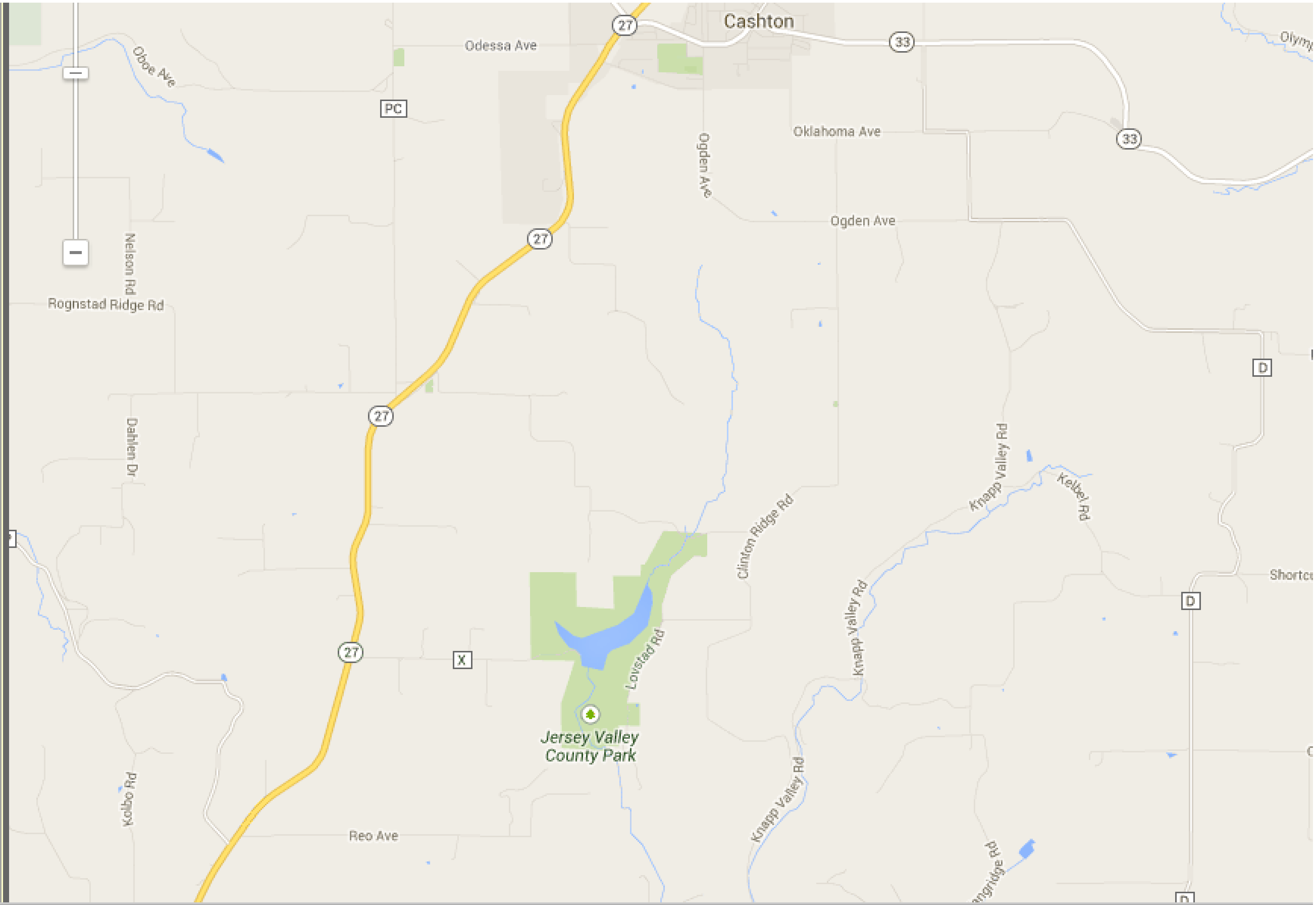


https://engineering.purdue.edu/mapserve/LTHIAWD/wi/wgen_huc10.cgi

File Edit View Favorites Tools Help

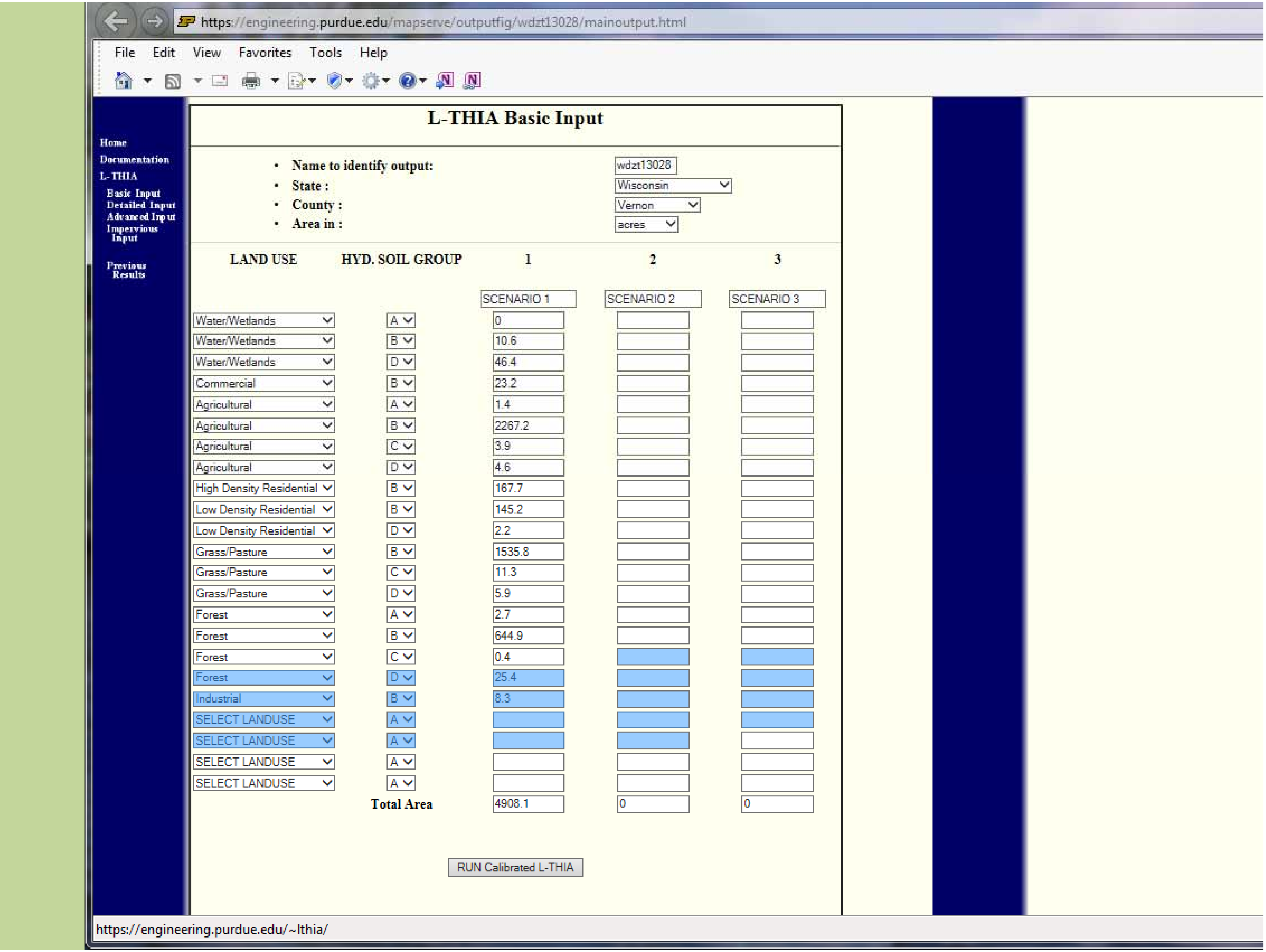
Watershed spatial data number for 10-digit watershed: **0707000602**

Watershed spatial data number for 8-digit watershed: **w07070006**

Watershed spatial data name for 12-digit watershed: **West Fork Kickapoo River**

coordinates you selected in meters: **X=193909.64978062932 and Y=4844300.413064256**

Land use	Soil group	Area(acres)
Water	A	0
Water	B	10.6
Water	D	46.4
Commercial	B	23.2
Agriculture	A	1.4
Agriculture	B	2267.2
Agriculture	C	3.9
Agriculture	D	4.6
HD-Residential	B	167.7
LD-Residential	B	145.2
LD-Residential	D	2.2
Grass/Pasture	B	1535.8
Grass/Pasture	C	11.3
Grass/Pasture	D	5.9
Forest	A	2.7
Forest	B	644.9
Forest	C	0.4
Forest	D	25.4
Industrial	B	8.3
Total Area		4907.1



https://engineering.purdue.edu/mapserve/outputfig/wdzt13028/mainoutput.html

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Home
Documentation
L-THIA
Basic Input
Detailed Input
Advanced Input
Impervious Input
Previous Results

L-THIA Basic Input

- Name to identify output: wdzt13028
- State : Wisconsin
- County : Vernon
- Area in : acres

LAND USE	HYD. SOIL GROUP	1	2	3
		SCENARIO 1	SCENARIO 2	SCENARIO 3
Water/Wetlands	A	0		
Water/Wetlands	B	10.6		
Water/Wetlands	D	46.4		
Commercial	B	23.2		
Agricultural	A	1.4		
Agricultural	B	2267.2		
Agricultural	C	3.9		
Agricultural	D	4.6		
High Density Residential	B	167.7		
Low Density Residential	B	145.2		
Low Density Residential	D	2.2		
Grass/Pasture	B	1535.8		
Grass/Pasture	C	11.3		
Grass/Pasture	D	5.9		
Forest	A	2.7		
Forest	B	644.9		
Forest	C	0.4		
Forest	D	25.4		
Industrial	B	8.3		
SELECT LANDUSE	A			
SELECT LANDUSE	A			
SELECT LANDUSE	A			
SELECT LANDUSE	A			
	Total Area	4908.1	0	0

RUN Calibrated L-THIA

https://engineering.purdue.edu/~lthia/

om and Click

our location

igit HUC

Zoom-in to your area.

Search

ate" button and click
whose watershed you
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engine and the
that point is calculated;
run L-THIA model on it
off.

ecific latitude- longitude
n" button below ,
minus sign must be
00 to -87.00000 and
46.90000 to 42.00000

one16 N coordinates
ge of X should be
o 490000 and Y within
200000

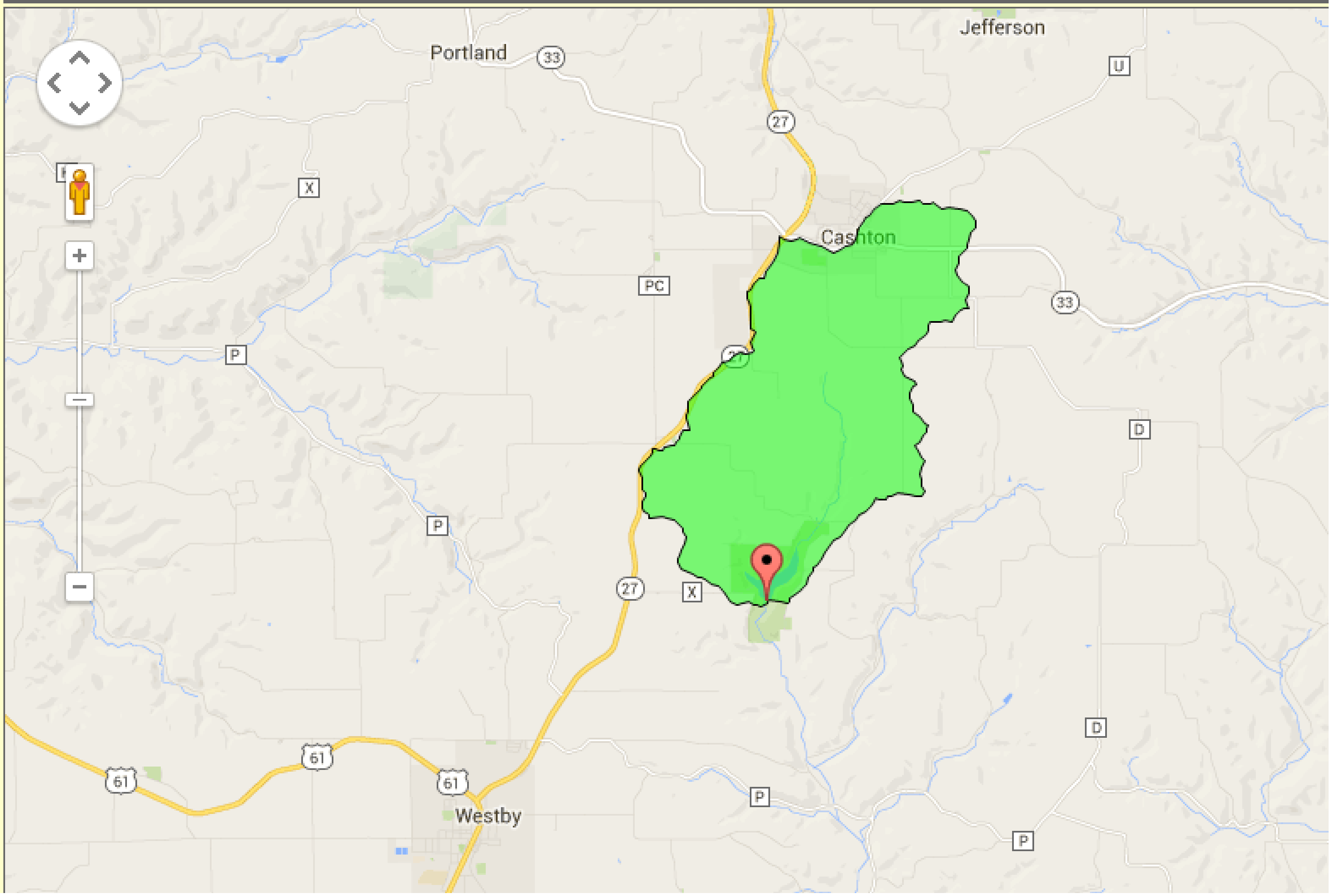
one

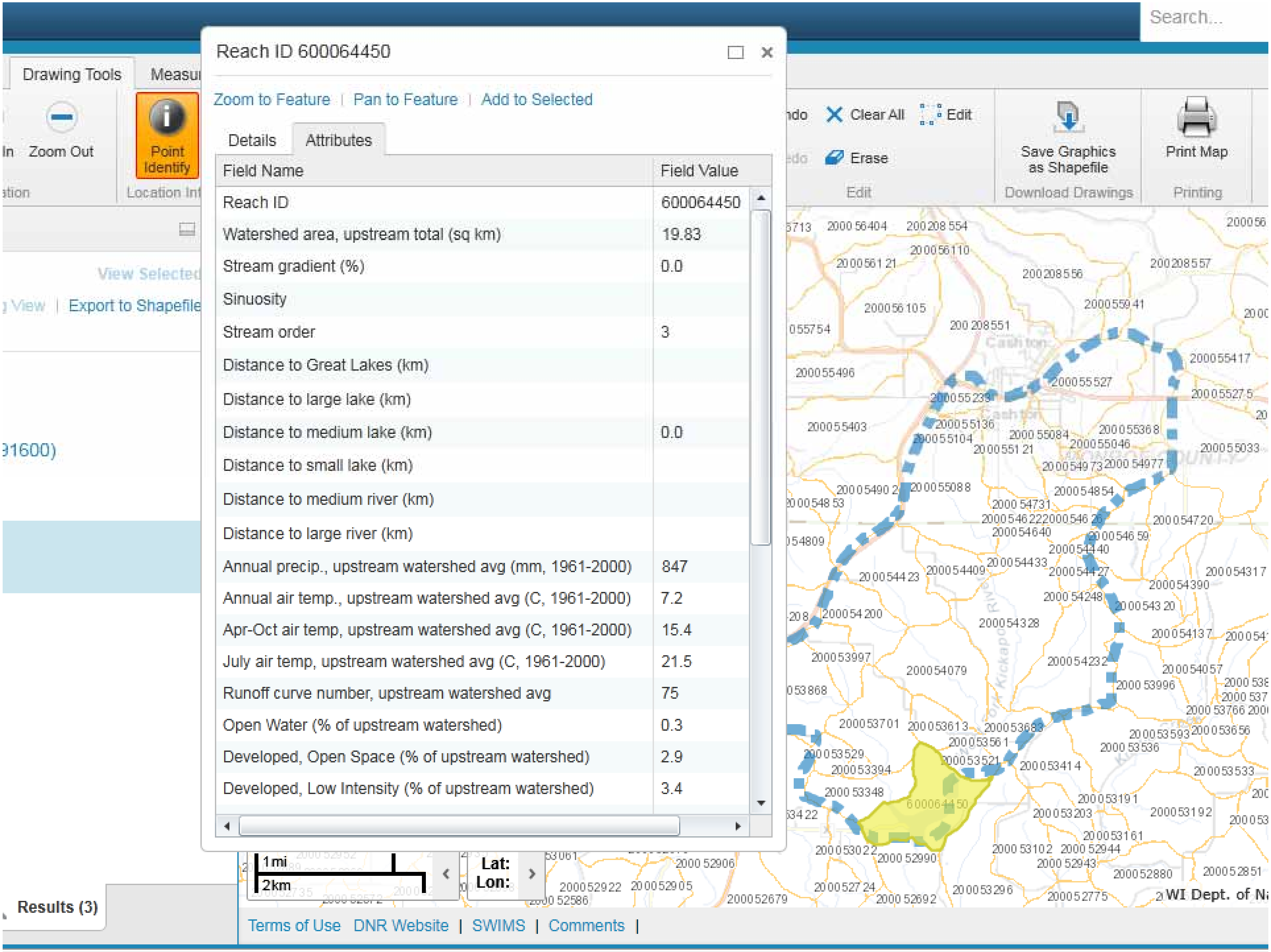
Download KML

Check the checkbox to display streaming WMS layer

☑ Streaming Layer ☐ HIT Sediment ☐ HIT Erosion ☐ Wisconsin HUC 8, 10, and 12 ☐ NHD water layer

Metadata

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Drawing Tools
Zoom Out
Point Identify
Reach ID 600064450
Zoom to Feature | Pan to Feature | Add to Selected
Details
Attributes
Field Name | Field Value
Reach ID | 600064450
Watershed area, upstream total (sq km) | 19.83
Stream gradient (%) | 0.0
Sinuosity
Stream order | 3
Distance to Great Lakes (km)
Distance to large lake (km)
Distance to medium lake (km) | 0.0
Distance to small lake (km)
Distance to medium river (km)
Distance to large river (km)
Annual precip., upstream watershed avg (mm, 1961-2000) | 847
Annual air temp., upstream watershed avg (C, 1961-2000) | 7.2
Apr-Oct air temp, upstream watershed avg (C, 1961-2000) | 15.4
July air temp, upstream watershed avg (C, 1961-2000) | 21.5
Runoff curve number, upstream watershed avg | 75
Open Water (% of upstream watershed) | 0.3
Developed, Open Space (% of upstream watershed) | 2.9
Developed, Low Intensity (% of upstream watershed) | 3.4
Clear All
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Download Drawings
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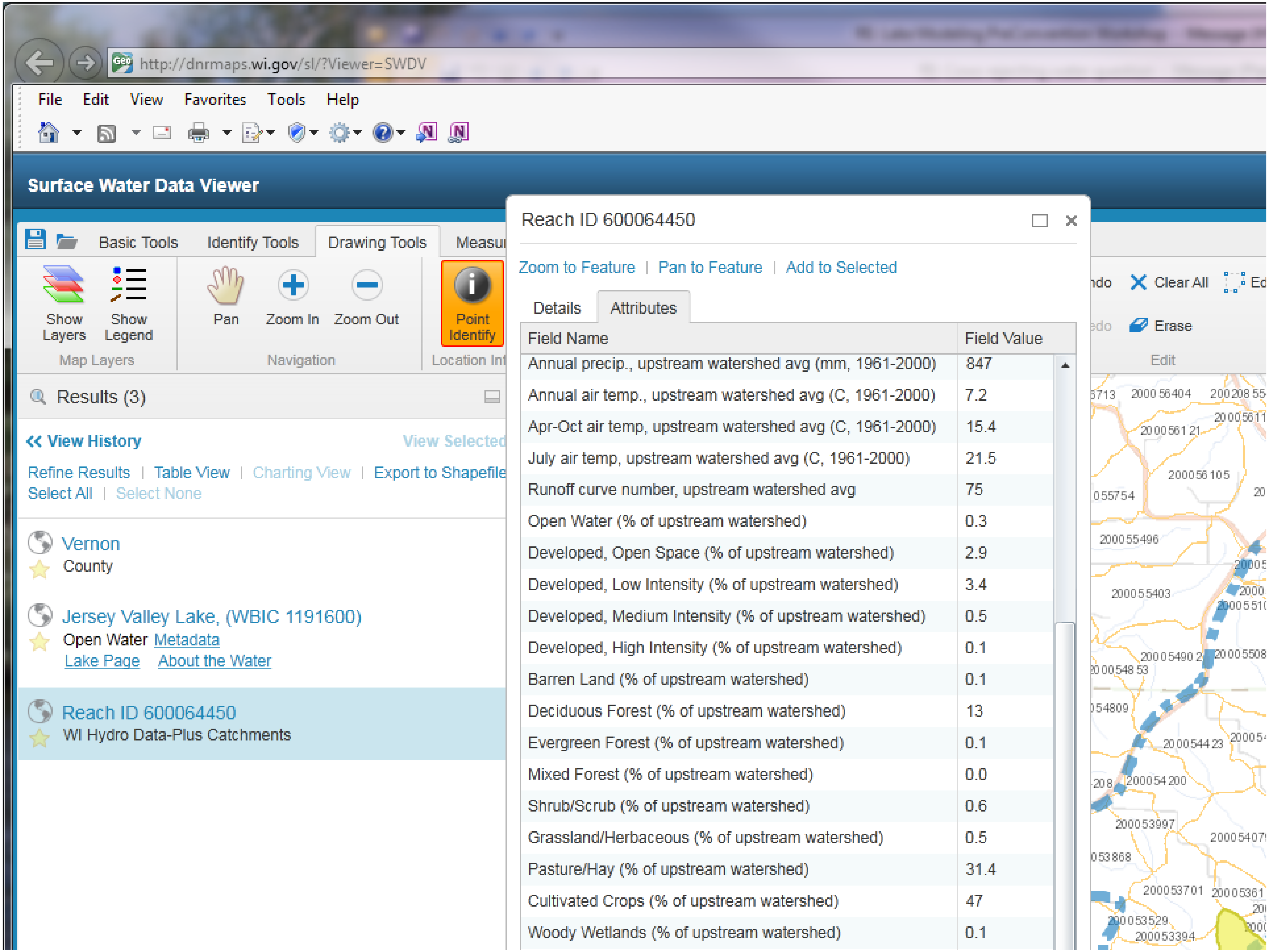
http://dnrmaps.wi.gov/sl/?Viewer=SWDV
File Edit View Favorites Tools Help
Surface Water Data Viewer
Basic Tools
Identify Tools
Drawing Tools
Show Layers
Show Legend
Map Layers
Pan
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Navigation
Point Identify
Results (3)
View History
View Selected
Refine Results | Table View | Charting View | Export to Shapefile
Select All | Select None
Vernon
County
Jersey Valley Lake, (WBIC 1191600)
Open Water Metadata
Lake Page About the Water
Reach ID 600064450
WI Hydro Data-Plus Catchments
Reach ID 600064450
Zoom to Feature | Pan to Feature | Add to Selected
Details
Attributes
Field Name
Field Value
Annual precip., upstream watershed avg (mm, 1961-2000) 847
Annual air temp., upstream watershed avg (C, 1961-2000) 7.2
Apr-Oct air temp, upstream watershed avg (C, 1961-2000) 15.4
July air temp, upstream watershed avg (C, 1961-2000) 21.5
Runoff curve number, upstream watershed avg 75
Open Water (% of upstream watershed) 0.3
Developed, Open Space (% of upstream watershed) 2.9
Developed, Low Intensity (% of upstream watershed) 3.4
Developed, Medium Intensity (% of upstream watershed) 0.5
Developed, High Intensity (% of upstream watershed) 0.1
Barren Land (% of upstream watershed) 0.1
Deciduous Forest (% of upstream watershed) 13
Evergreen Forest (% of upstream watershed) 0.1
Mixed Forest (% of upstream watershed) 0.0
Shrub/Scrub (% of upstream watershed) 0.6
Grassland/Herbaceous (% of upstream watershed) 0.5
Pasture/Hay (% of upstream watershed) 31.4
Cultivated Crops (% of upstream watershed) 47
Woody Wetlands (% of upstream watershed) 0.1
Clear All
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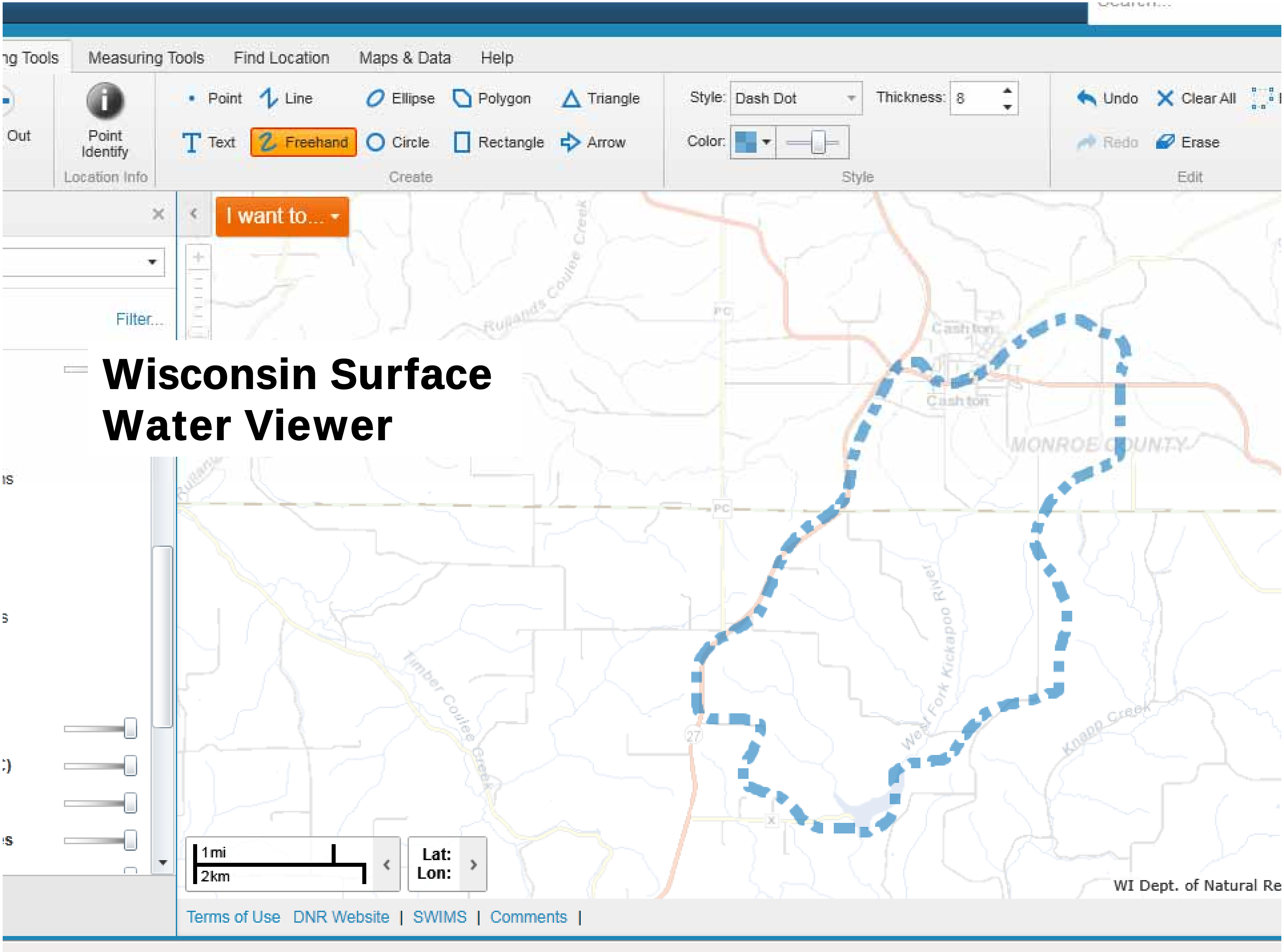
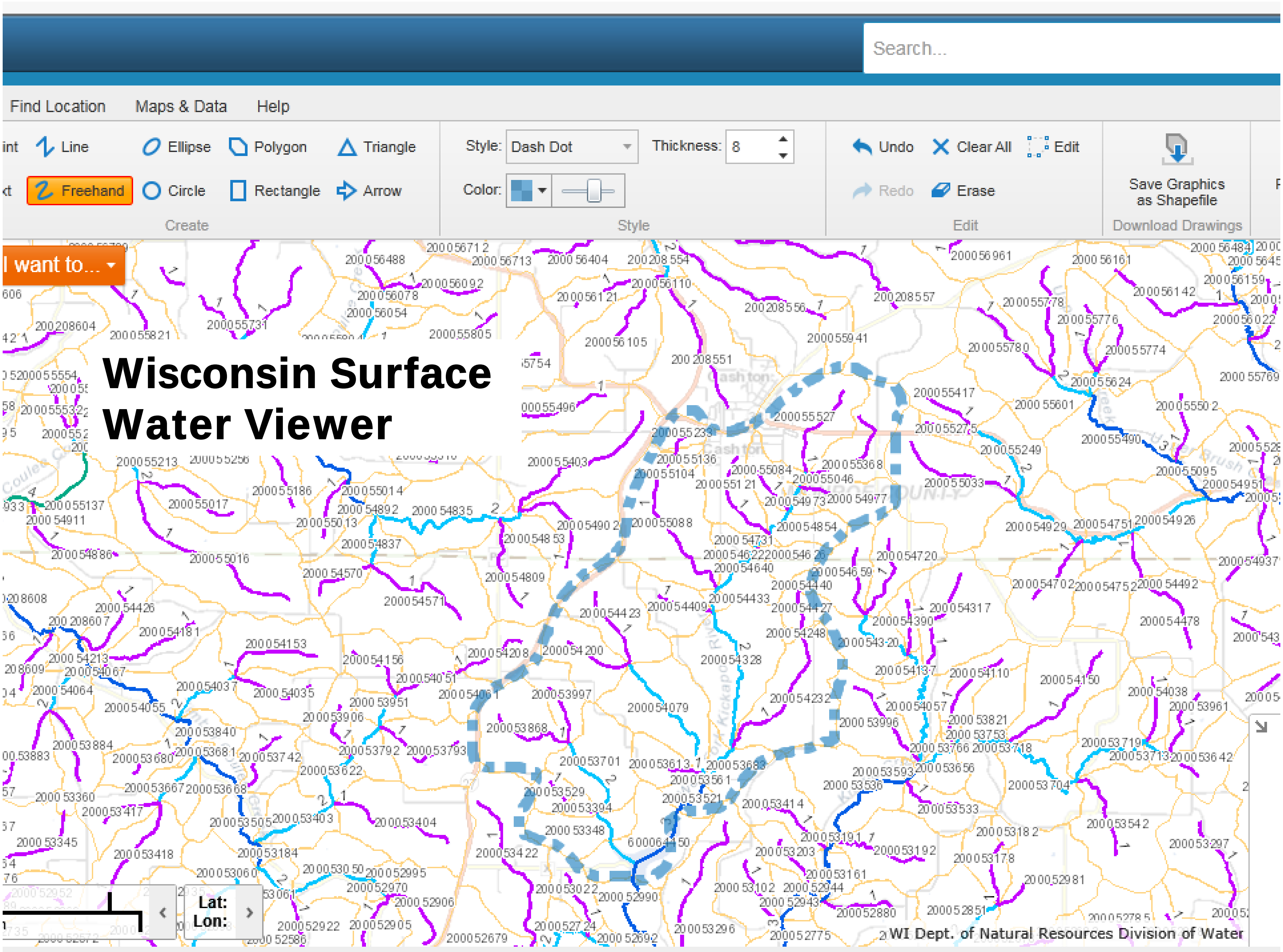
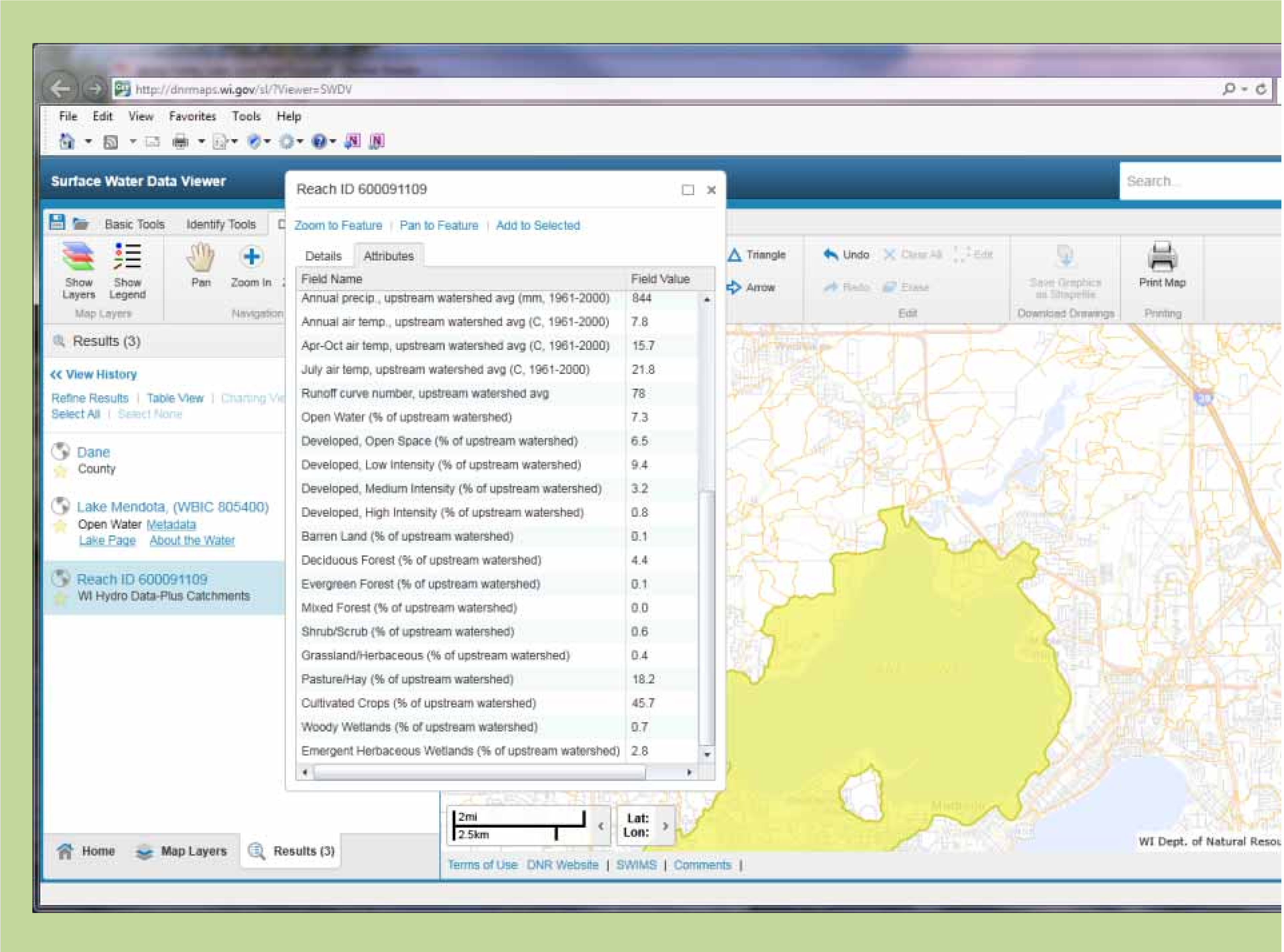
Wisconsin Surface Water Viewer



Wisconsin Surface Water Viewer





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File Edit View Favorites Tools Help
Surface Water Data Viewer
Search...
Basic Tools
Identify Tools
Show Layers
Show Legend
Map Layers
Pan
Zoom In
Navigation
Reach ID 600091109
Zoom to Feature | Pan to Feature | Add to Selected
Details
Attributes
Field Name
Field Value
Annual precip., upstream watershed avg (mm, 1961-2000) 844
Annual air temp., upstream watershed avg (C, 1961-2000) 7.8
Apr-Oct air temp, upstream watershed avg (C, 1961-2000) 15.7
July air temp, upstream watershed avg (C, 1961-2000) 21.8
Runoff curve number, upstream watershed avg 78
Open Water (% of upstream watershed) 7.3
Developed, Open Space (% of upstream watershed) 6.5
Developed, Low Intensity (% of upstream watershed) 9.4
Developed, Medium Intensity (% of upstream watershed) 3.2
Developed, High Intensity (% of upstream watershed) 0.8
Barren Land (% of upstream watershed) 0.1
Deciduous Forest (% of upstream watershed) 4.4
Evergreen Forest (% of upstream watershed) 0.1
Mixed Forest (% of upstream watershed) 0.0
Shrub/Scrub (% of upstream watershed) 0.6
Grassland/Herbaceous (% of upstream watershed) 0.4
Pasture/Hay (% of upstream watershed) 18.2
Cultivated Crops (% of upstream watershed) 45.7
Woody Wetlands (% of upstream watershed) 0.7
Emergent Herbaceous Wetlands (% of upstream watershed) 2.8
Triangle
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Results (3)
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Dane
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Lake Mendota, (WBIC 805400)
Open Water Metadata
Lake Page About the Water
Reach ID 600091109
WI Hydro Data-Plus Catchments
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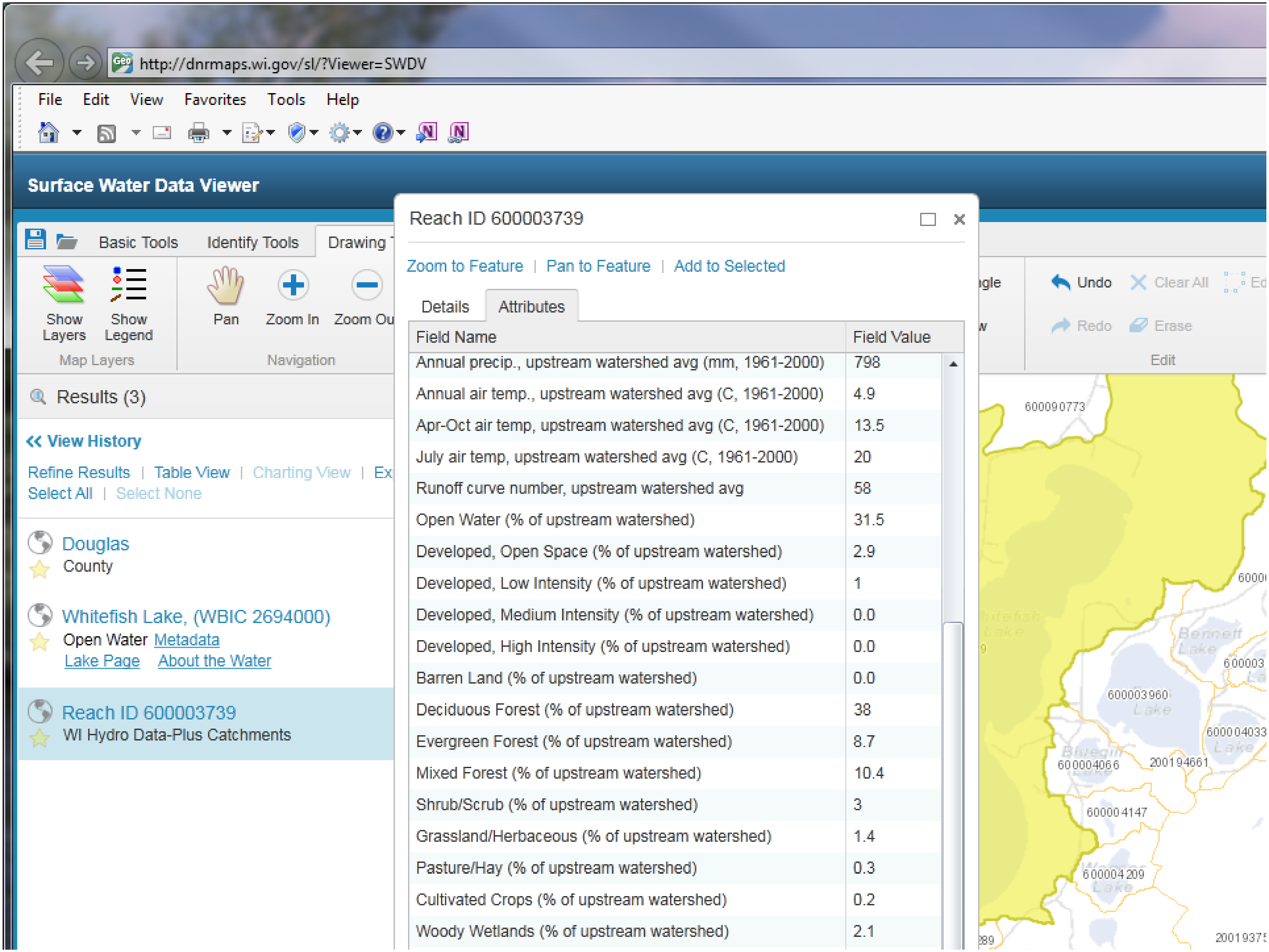
http://dnrmaps.wi.gov/sl/?Viewer=SWDV
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View History
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Select All | Select None
Douglas
County
Whitefish Lake, (WBIC 2694000)
Open Water Metadata
Lake Page About the Water
Reach ID 600003739
WI Hydro Data-Plus Catchments
Reach ID 600003739
Zoom to Feature | Pan to Feature | Add to Selected
Details
Attributes
Field Name
Field Value
Annual precip., upstream watershed avg (mm, 1961-2000)
798
Annual air temp., upstream watershed avg (C, 1961-2000)
4.9
Apr-Oct air temp, upstream watershed avg (C, 1961-2000)
13.5
July air temp, upstream watershed avg (C, 1961-2000)
20
Runoff curve number, upstream watershed avg
58
Open Water (% of upstream watershed)
31.5
Developed, Open Space (% of upstream watershed)
2.9
Developed, Low Intensity (% of upstream watershed)
1
Developed, Medium Intensity (% of upstream watershed)
0.0
Developed, High Intensity (% of upstream watershed)
0.0
Barren Land (% of upstream watershed)
0.0
Deciduous Forest (% of upstream watershed)
38
Evergreen Forest (% of upstream watershed)
8.7
Mixed Forest (% of upstream watershed)
10.4
Shrub/Scrub (% of upstream watershed)
3
Grassland/Herbaceous (% of upstream watershed)
1.4
Pasture/Hay (% of upstream watershed)
0.3
Cultivated Crops (% of upstream watershed)
0.2
Woody Wetlands (% of upstream watershed)
2.1
Undo
Clear All
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Edit
600090773
Bennett Lake
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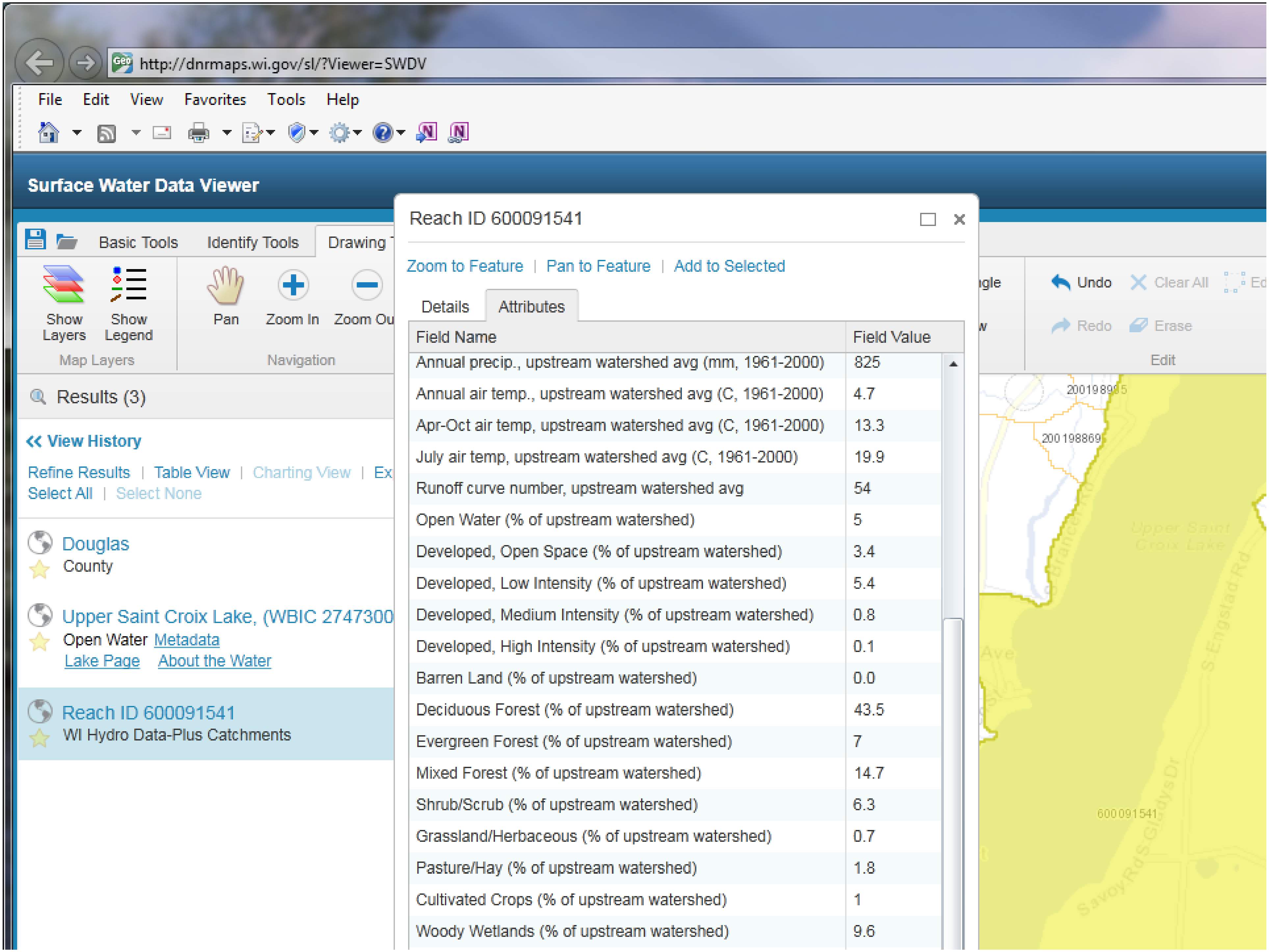
Lake


http://dnrmaps.wi.gov/sl/?Viewer=SWDV
File
Edit
View
Favorites
Tools
Help
Surface Water Data Viewer
Basic Tools
Identify Tools
Drawing
Show Layers
Show Legend
Map Layers
Pan
Zoom In
Zoom Ou
Navigation
Results (3)
View History
Refine Results | Table View | Charting View | Ex
Select All | Select None
Douglas
County
Upper Saint Croix Lake, (WBIC 2747300
Open Water Metadata
Lake Page About the Water
Reach ID 600091541
WI Hydro Data-Plus Catchments
Reach ID 600091541
Zoom to Feature | Pan to Feature | Add to Selected
Details
Attributes
Field Name
Field Value
Annual precip., upstream watershed avg (mm, 1961-2000)
825
Annual air temp., upstream watershed avg (C, 1961-2000)
4.7
Apr-Oct air temp, upstream watershed avg (C, 1961-2000)
13.3
July air temp, upstream watershed avg (C, 1961-2000)
19.9
Runoff curve number, upstream watershed avg
54
Open Water (% of upstream watershed)
5
Developed, Open Space (% of upstream watershed)
3.4
Developed, Low Intensity (% of upstream watershed)
5.4
Developed, Medium Intensity (% of upstream watershed)
0.8
Developed, High Intensity (% of upstream watershed)
0.1
Barren Land (% of upstream watershed)
0.0
Deciduous Forest (% of upstream watershed)
43.5
Evergreen Forest (% of upstream watershed)
7
Mixed Forest (% of upstream watershed)
14.7
Shrub/Scrub (% of upstream watershed)
6.3
Grassland/Herbaceous (% of upstream watershed)
0.7
Pasture/Hay (% of upstream watershed)
1.8
Cultivated Crops (% of upstream watershed)
1
Woody Wetlands (% of upstream watershed)
9.6
Undo
Clear All
Redo
Erase
Edit
200198905
200198869
600091541

WiLMS Example III

Input this...

- Mercer Lake, Iron Co
- Area = 179 acres
- Volume = 1793 acre-feet
- P GSM=20 ug/l

WiLMS Example III

Input this...

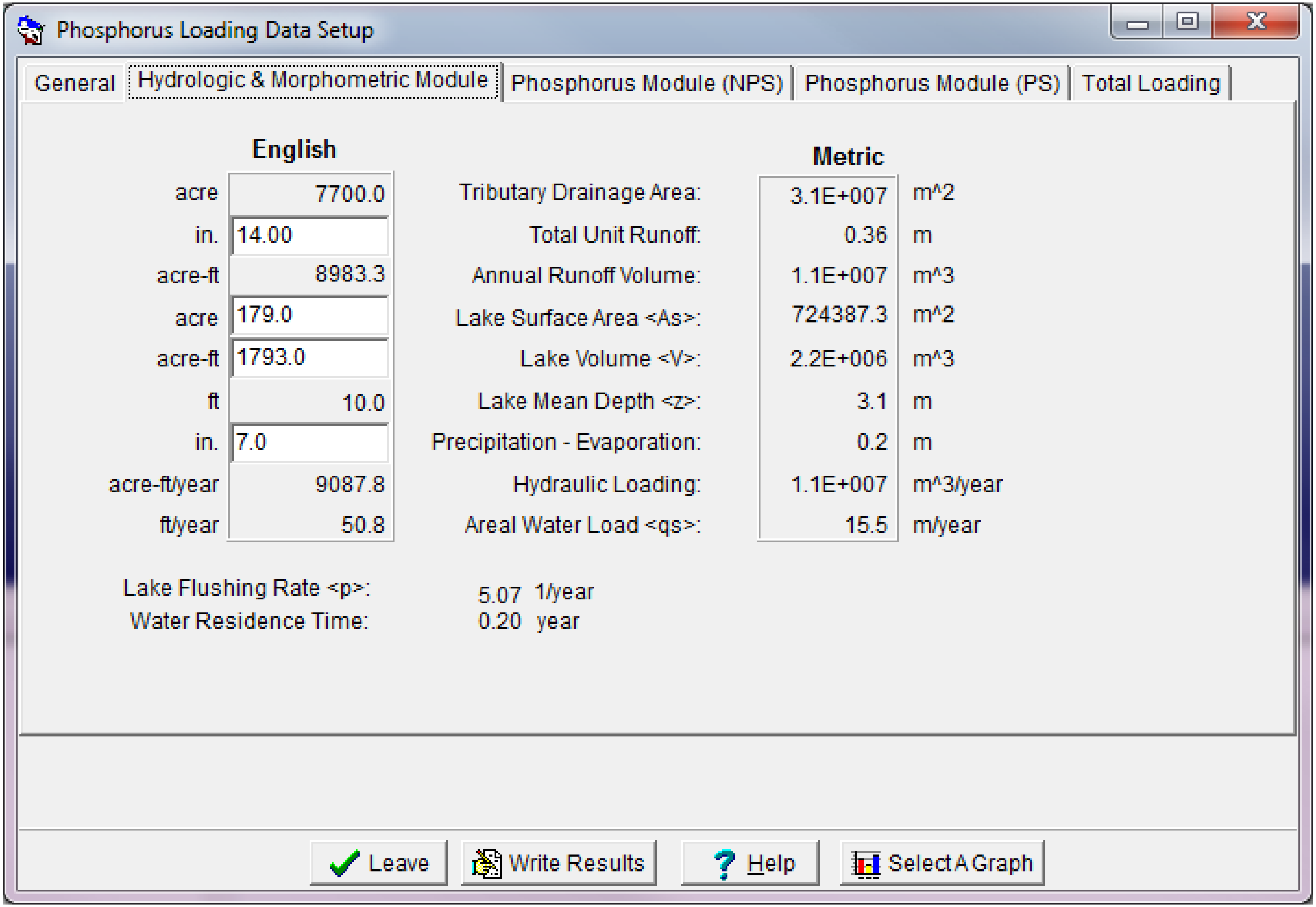
- Mercer Lake, Iron Co
- Area = 179 acres
- Volume = 1793 acre-feet
- P GSM=20 ug/l

- Watershed

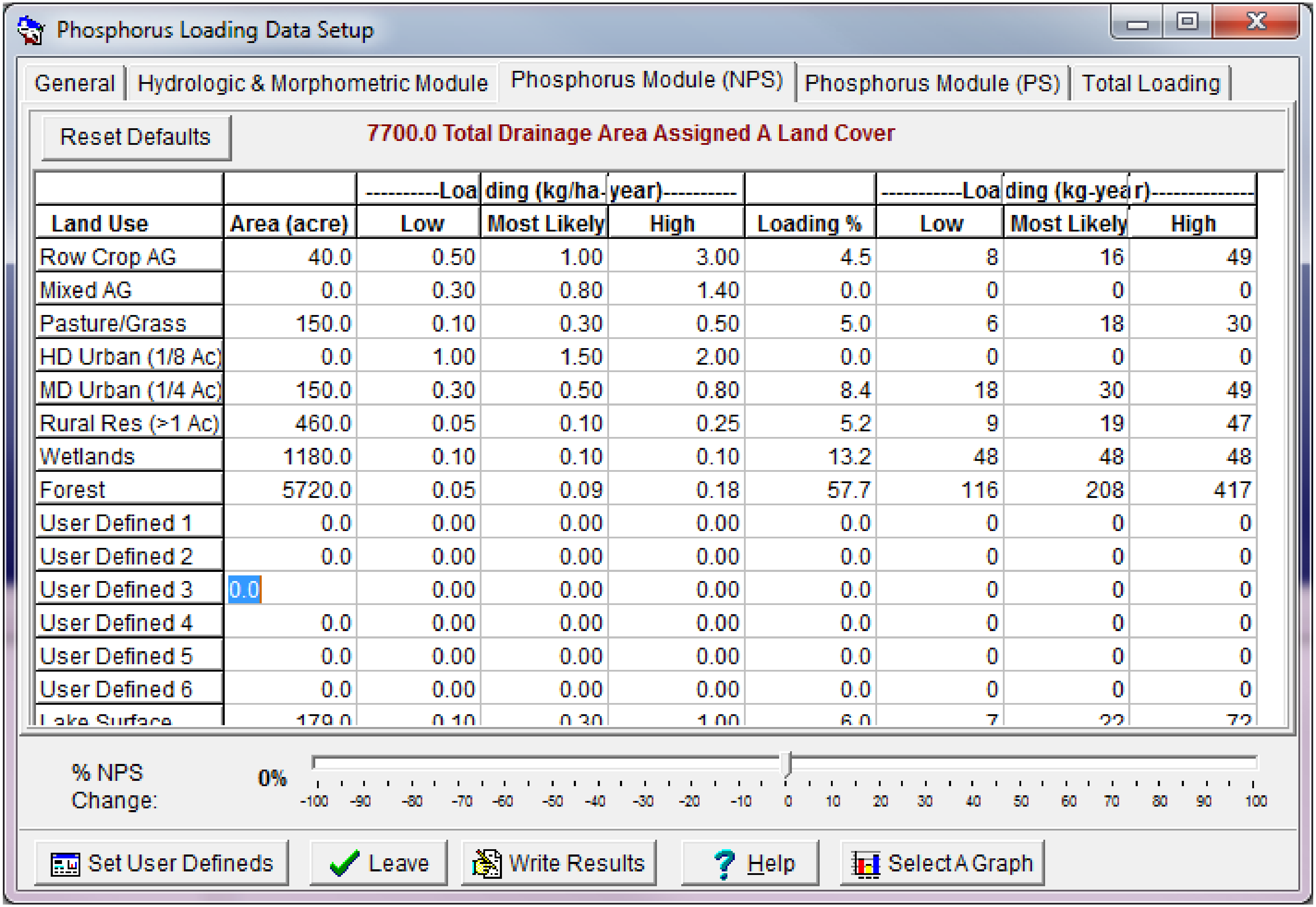
Land Use	Acres
Agriculture	40
Low Den Residential	460
Med Den Residential	150
Grassland	150
Water/Wetlands	1180
Forest	5720

Find this...

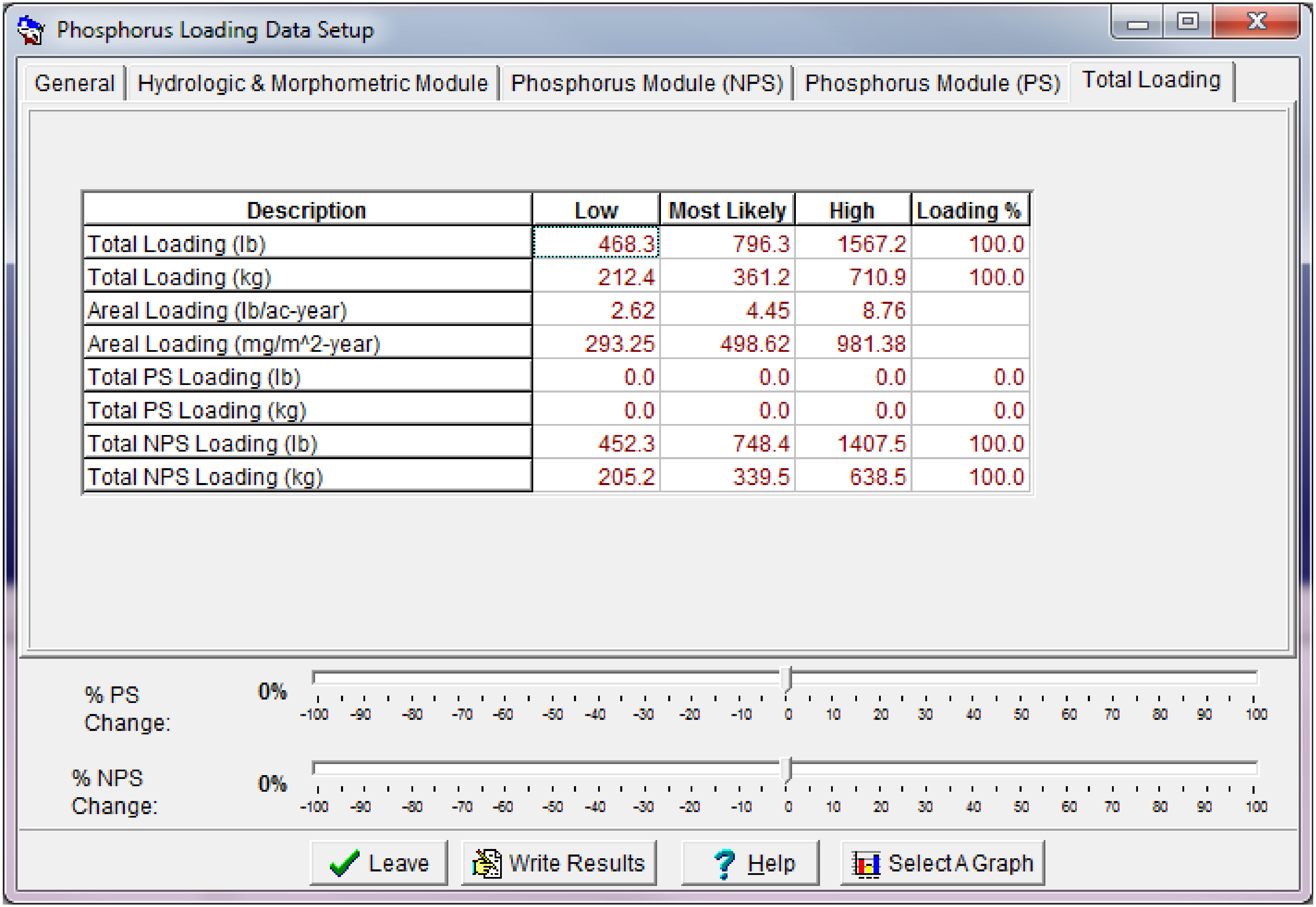
- What is water loading rate (feet/year)?
- What is water residence time (years)?
- What is your “most likely” P loading?
- What is P loading in mg/m2-year of lake surface?
- Compare your lake P prediction with the observed



Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
English
Metric
acre 7700.0
in. 14.00
acre-ft 8983.3
acre 179.0
acre-ft 1793.0
ft 10.0
in. 7.0
acre-ft/year 9087.8
ft/year 50.8
Tributary Drainage Area: 3.1E+007 m^2
Total Unit Runoff: 0.36 m
Annual Runoff Volume: 1.1E+007 m^3
Lake Surface Area <As>: 724387.3 m^2
Lake Volume <V>: 2.2E+006 m^3
Lake Mean Depth <z>: 3.1 m
Precipitation - Evaporation: 0.2 m
Hydraulic Loading: 1.1E+007 m^3/year
Areal Water Load <qs>: 15.5 m/year
Lake Flushing Rate <p>: 5.07 1/year
Water Residence Time: 0.20 year
Leave
Write Results
Help
Select A Graph



		Loading (kg/ha-year)				Loading (kg-year)		
Land Use	Area (acre)	Low	Most Likely	High	Loading %	Low	Most Likely	High
Row Crop AG	40.0	0.50	1.00	3.00	4.5	8	16	49
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0
Pasture/Grass	150.0	0.10	0.30	0.50	5.0	6	18	30
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	150.0	0.30	0.50	0.80	8.4	18	30	49
Rural Res (>1 Ac)	460.0	0.05	0.10	0.25	5.2	9	19	47
Wetlands	1180.0	0.10	0.10	0.10	13.2	48	48	48
Forest	5720.0	0.05	0.09	0.18	57.7	116	208	417
User Defined 1	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 2	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 3	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 4	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 5	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 6	0.0	0.00	0.00	0.00	0.0	0	0	0
Lake Surface	179.0	0.10	0.30	1.00	6.0	7	22	72



Description	Low	Most Likely	High	Loading %
Total Loading (lb)	468.3	796.3	1567.2	100.0
Total Loading (kg)	212.4	361.2	710.9	100.0
Areal Loading (lb/ac-year)	2.62	4.45	8.76	
Areal Loading (mg/m^2-year)	293.25	498.62	981.38	
Total PS Loading (lb)	0.0	0.0	0.0	0.0
Total PS Loading (kg)	0.0	0.0	0.0	0.0
Total NPS Loading (lb)	452.3	748.4	1407.5	100.0
Total NPS Loading (kg)	205.2	339.5	638.5	100.0

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3

Observed growing season mean phosphorus (GSM): 20.0 mg/m^3

Back calculation for SPO total phosphorus: 0.0 mg/m^3

Back calculation GSM phosphorus: 0.0 mg/m^3

Nurnberg Model Input - Est. Gross Int. Loading: 0 kg

% Confidence Range: 70

Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound	Confidence Upper Bound	Parameter Fit?	Back Calculation (kg/year)	Model Type
Walker, 1987 Reservoir	13	23	45	3	15	14	39	FIT	0	GSM
Canfield-Bachmann, 1981 Natural Lake	15	24	44	4	20	7	69	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	14	22	38	2	10	7	63	FIT	1	GSM
Rechow, 1979 General	10	17	33	-3	-15	10	29	FIT	0	GSM
Rechow, 1977 Anoxic	16	28	55	8	40	18	47	FIT	0	GSM
Rechow, 1977 water load<50m/year	12	21	41	1	5	13	36	FIT	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	13	20	34	10	100	10	36	FIT	0	ANN
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	10	16	28	6	60	8	29	FIT	0	ANN
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	10	18	35	-2	-10	10	32	FIT	0	ANN

Finished | Write Results | Display Parameter Values | Help

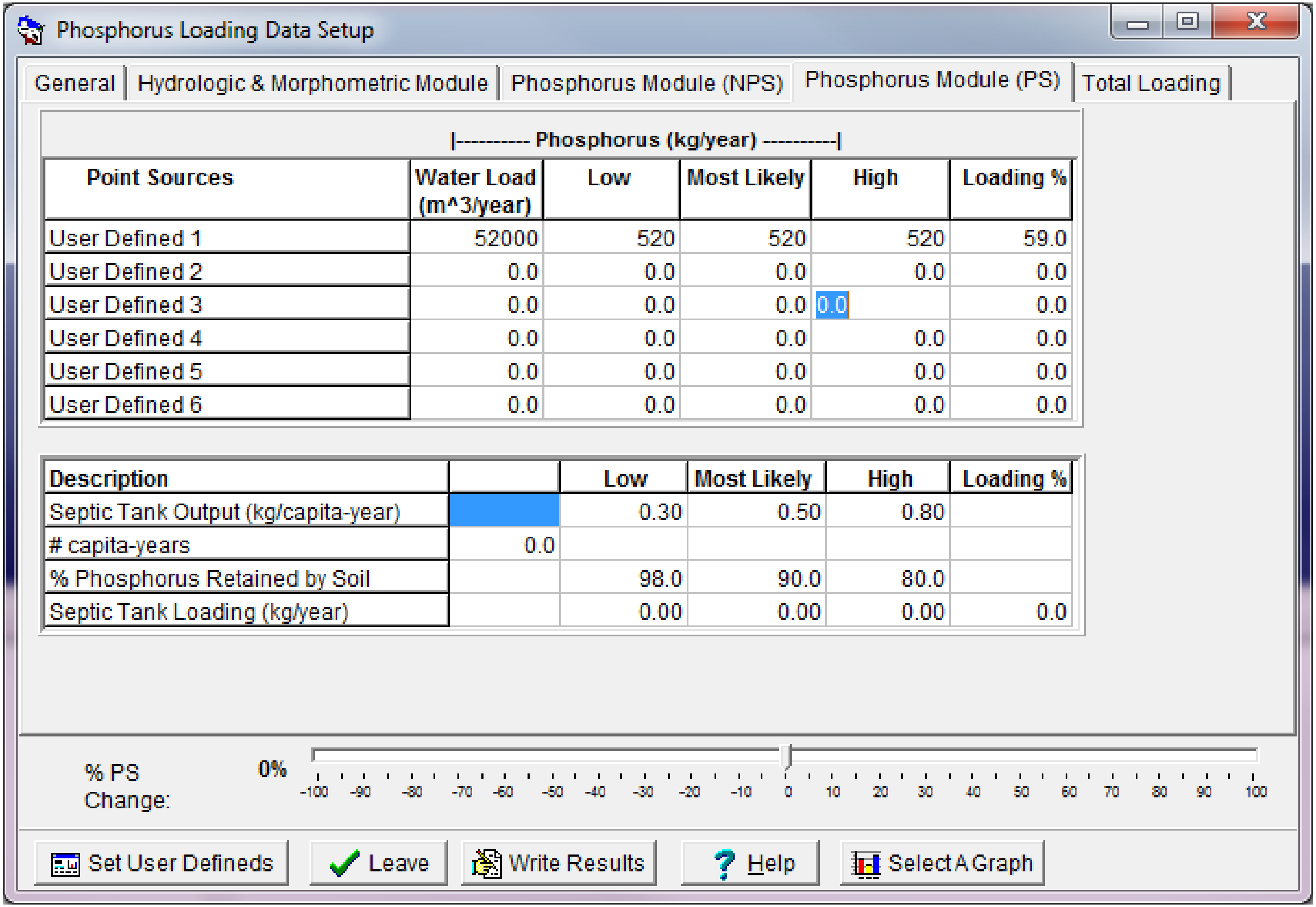
Water Quality, Hydrology, and Simulated Response to Changes in Phosphorus Loading of Mercer Lake, Iron County, Wisconsin, with Special Emphasis on the Effects of Wastewater Discharges

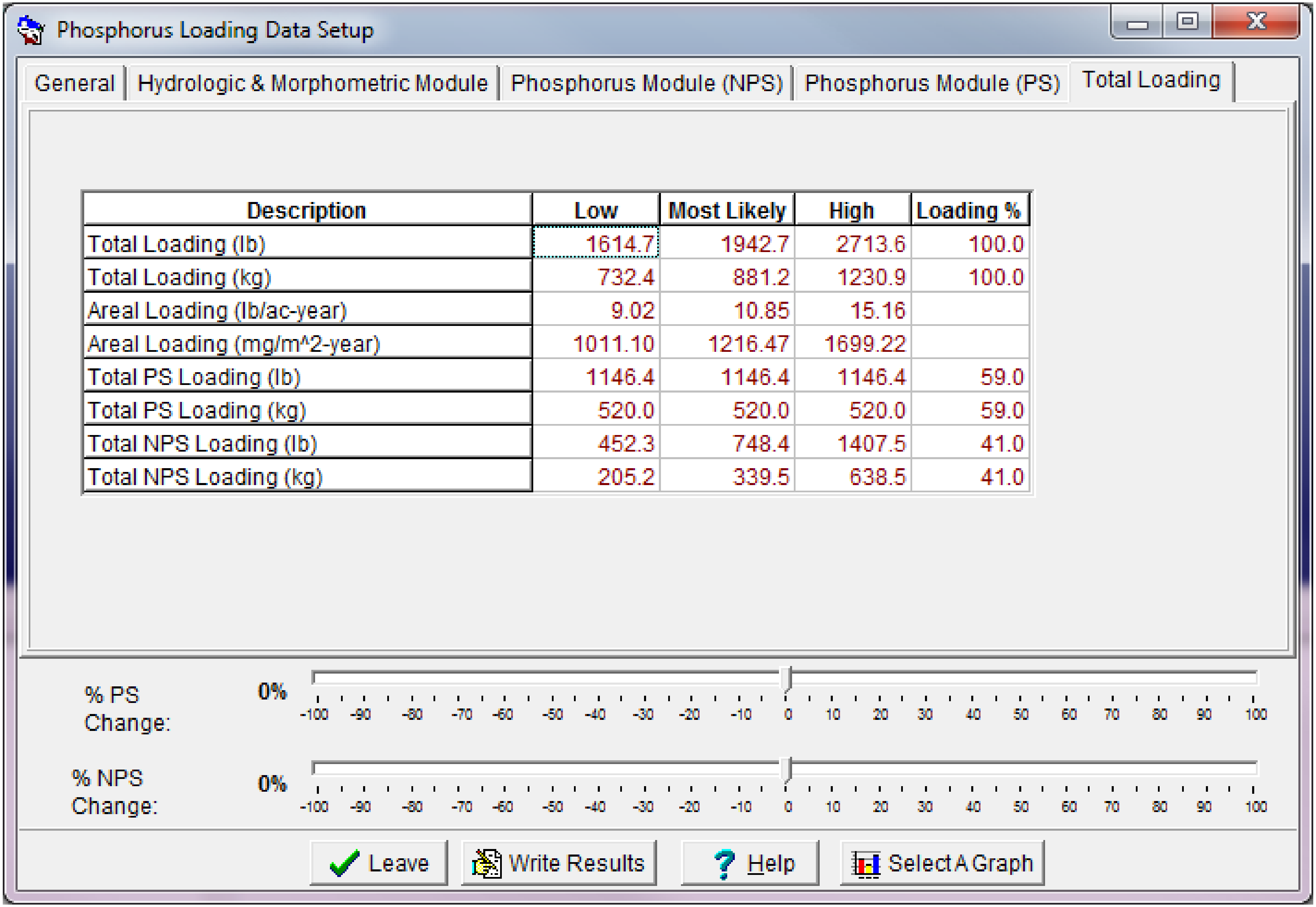
By Dale M. Robertson, Herbert S. Garn, William J. Rose, Paul F. Juckem, and Paul C. Reneau

Point Sources

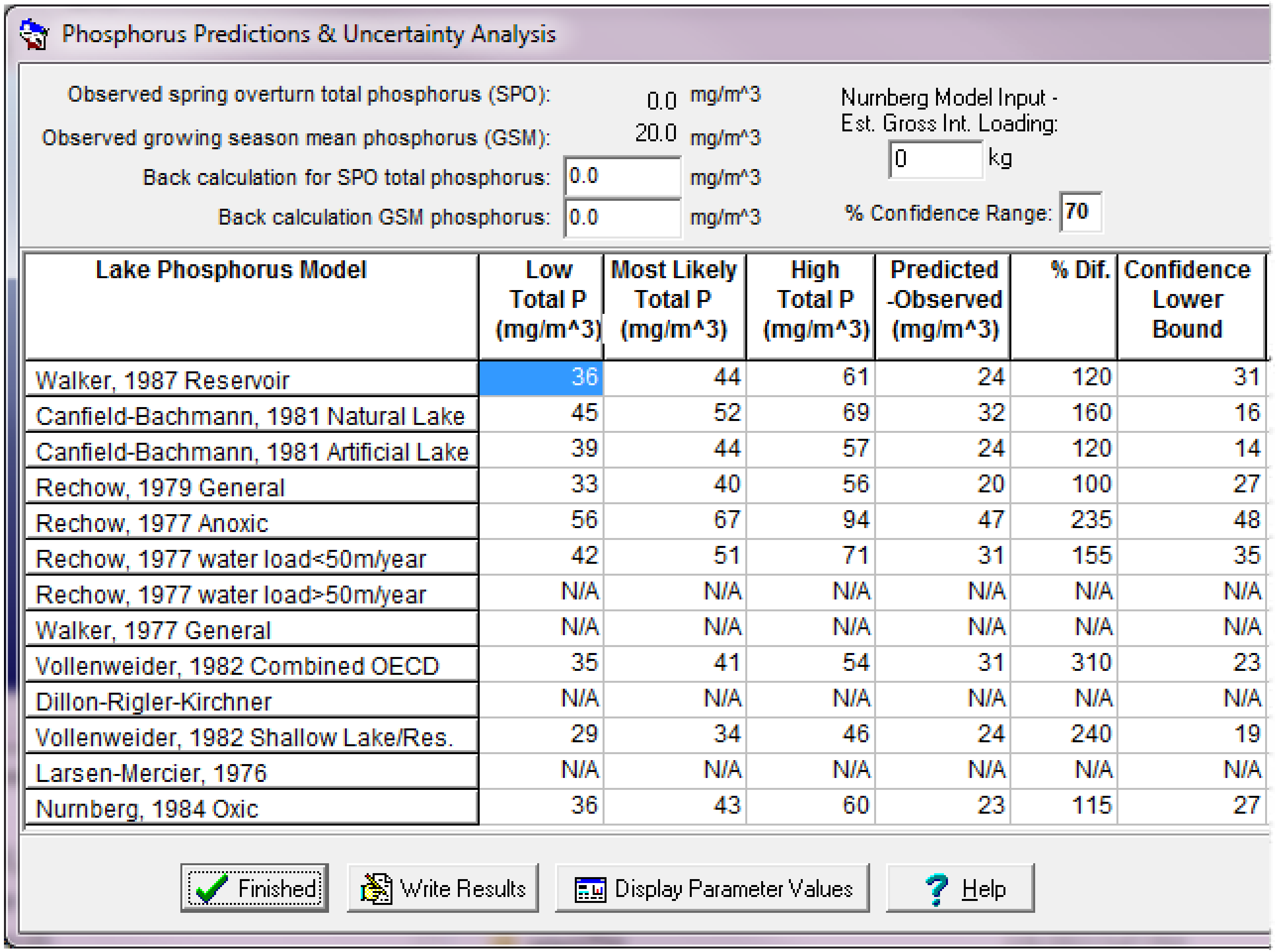
- Let's assume this lake had a WWTP discharge
  - 37,400 gallon/day
  - 10 mg/l P

- We'll need to do some math...
  - That's (37,400 gal/d)(365 d/yr)(1m3/264 gal)
  - **Or = 52,000 m3/year**
  - And, (52,000 m3/yr)(1000 liter/m3)(10mg/l)(1kg/1000000mg)
  - **Or = 520 kg/year**


Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
|---------- Phosphorus (kg/year) ----------|
Point Sources | Water Load (m^3/year) | Low | Most Likely | High | Loading %
User Defined 1 | 52000 | 520 | 520 | 520 | 59.0
User Defined 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
Description | | Low | Most Likely | High | Loading %
Septic Tank Output (kg/capita-year) | | 0.30 | 0.50 | 0.80 |
capita-years | 0.0 | | | |
% Phosphorus Retained by Soil | | 98.0 | 90.0 | 80.0 |
Septic Tank Loading (kg/year) | | 0.00 | 0.00 | 0.00 | 0.0
% PS Change:
0%
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
Set User Defineds
Leave
Write Results
Help
Select A Graph



Description	Low	Most Likely	High	Loading %
Total Loading (lb)	1614.7	1942.7	2713.6	100.0
Total Loading (kg)	732.4	881.2	1230.9	100.0
Areal Loading (lb/ac-year)	9.02	10.85	15.16	
Areal Loading (mg/m^2-year)	1011.10	1216.47	1699.22	
Total PS Loading (lb)	1146.4	1146.4	1146.4	59.0
Total PS Loading (kg)	520.0	520.0	520.0	59.0
Total NPS Loading (lb)	452.3	748.4	1407.5	41.0
Total NPS Loading (kg)	205.2	339.5	638.5	41.0



Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound
Walker, 1987 Reservoir	36	44	61	24	120	31
Canfield-Bachmann, 1981 Natural Lake	45	52	69	32	160	16
Canfield-Bachmann, 1981 Artificial Lake	39	44	57	24	120	14
Rechow, 1979 General	33	40	56	20	100	27
Rechow, 1977 Anoxic	56	67	94	47	235	48
Rechow, 1977 water load<50m/year	42	51	71	31	155	35
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	35	41	54	31	310	23
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	29	34	46	24	240	19
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	36	43	60	23	115	27

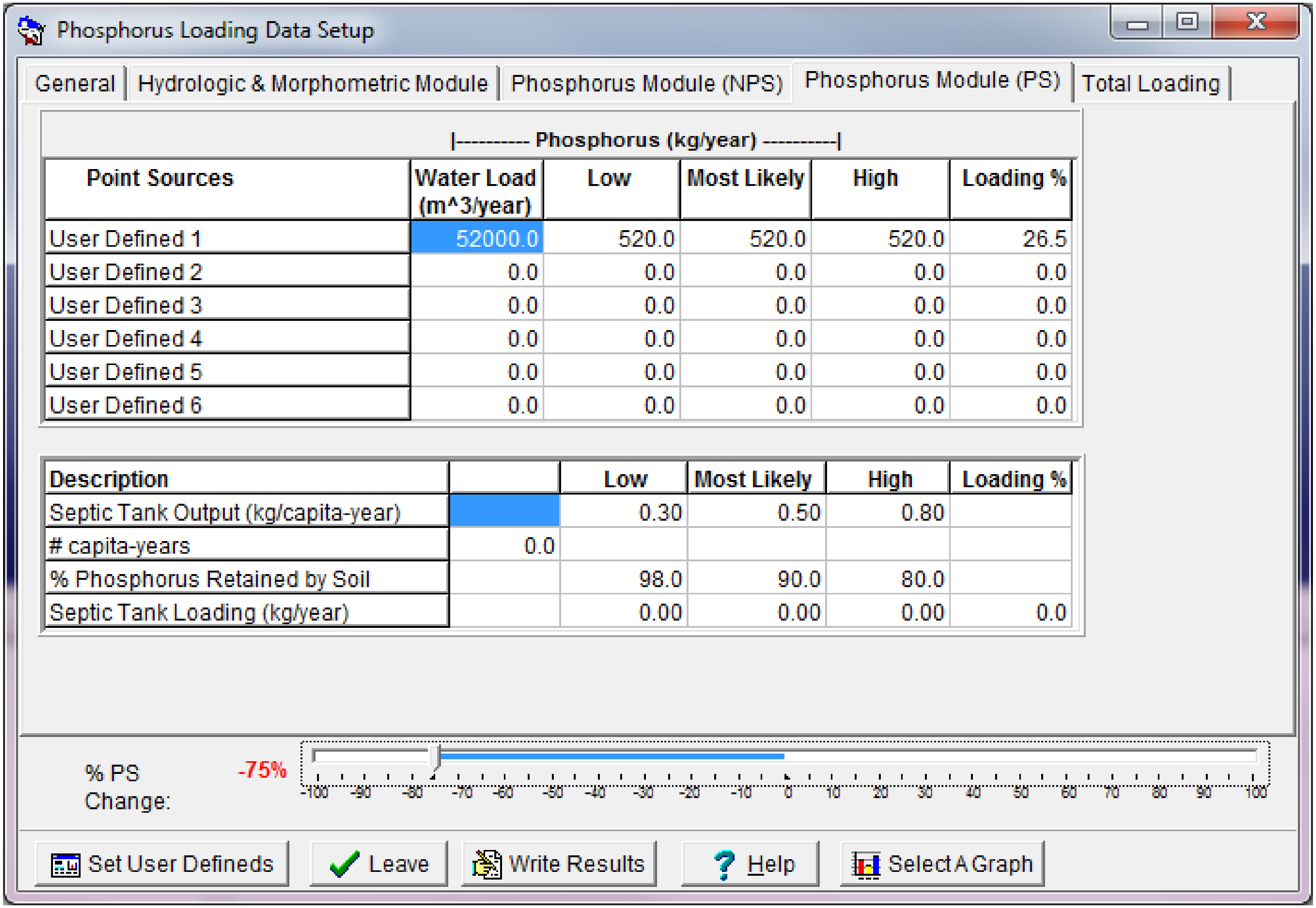
Table 5. Near-surface, summer-av
based on data from the East Basin c

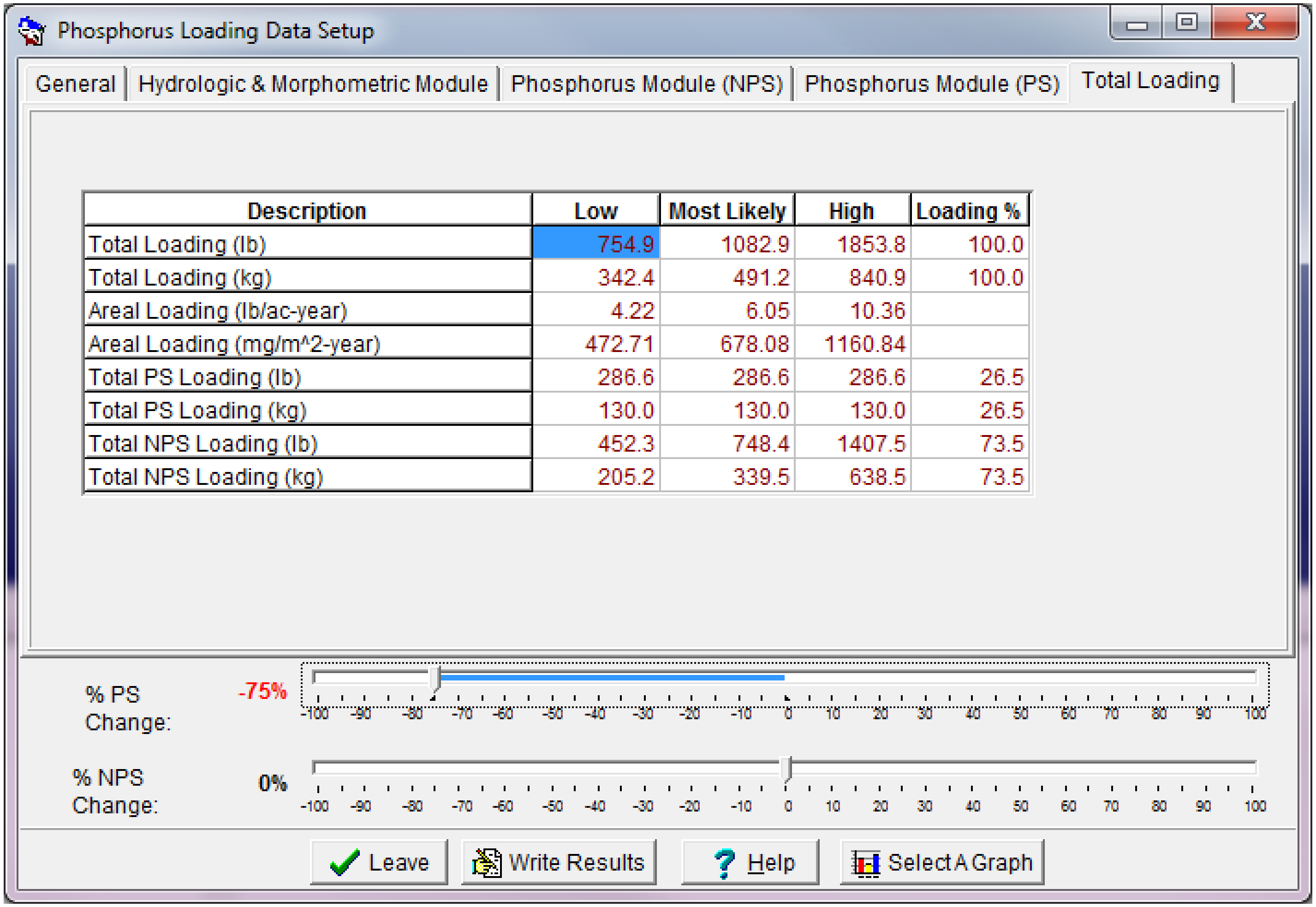
[mg/L, milligrams per liter; µg/L, microgr:

Year	Total phosphorus (mg/L)
1973	0.040
1974	0.030
1975	0.020
1976	0.030
1979	0.027
2000	0.015
2001	—
2002	0.018
2004	—
2005	—
2006	0.017
2007	0.017
2008	0.022
2009	0.024
2010	0.018
2011	0.019
Average 2006–10	0.019
Average	0.023

Slider Bar on Point Sources

- Return to Setup
- PS Tab (Phosphorus Module (PS))
- Do 75% reduction in point sources
- Then look at P prediction


Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
|---------- Phosphorus (kg/year) ----------|
Point Sources
Water Load (m^3/year)
Low
Most Likely
High
Loading %
User Defined 1 52000.0 520.0 520.0 520.0 26.5
User Defined 2 0.0 0.0 0.0 0.0 0.0
User Defined 3 0.0 0.0 0.0 0.0 0.0
User Defined 4 0.0 0.0 0.0 0.0 0.0
User Defined 5 0.0 0.0 0.0 0.0 0.0
User Defined 6 0.0 0.0 0.0 0.0 0.0
Description
Low
Most Likely
High
Loading %
Septic Tank Output (kg/capita-year) 0.30 0.50 0.80
capita-years 0.0
% Phosphorus Retained by Soil 98.0 90.0 80.0
Septic Tank Loading (kg/year) 0.00 0.00 0.00 0.0
% PS Change:
-75%
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
Set User Defineds
Leave
Write Results
Help
Select A Graph



Description	Low	Most Likely	High	Loading %
Total Loading (lb)	754.9	1082.9	1853.8	100.0
Total Loading (kg)	342.4	491.2	840.9	100.0
Areal Loading (lb/ac-year)	4.22	6.05	10.36	
Areal Loading (mg/m^2-year)	472.71	678.08	1160.84	
Total PS Loading (lb)	286.6	286.6	286.6	26.5
Total PS Loading (kg)	130.0	130.0	130.0	26.5
Total NPS Loading (lb)	452.3	748.4	1407.5	73.5
Total NPS Loading (kg)	205.2	339.5	638.5	73.5

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 0.0 mg/m^3

Observed growing season mean phosphorus (GSM): 20.0 mg/m^3

Back calculation for SPO total phosphorus: 0.0 mg/m^3

Back calculation GSM phosphorus: 0.0 mg/m^3

Nurnberg Model Input - Est. Gross Int. Loading: 0 kg

% Confidence Range: 70

Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound
Walker, 1987 Reservoir	20	29	49	9	45	19
Canfield-Bachmann, 1981 Natural Lake	23	32	50	12	60	10
Canfield-Bachmann, 1981 Artificial Lake	21	28	43	8	40	9
Rechow, 1979 General	16	22	38	2	10	14
Rechow, 1977 Anoxic	26	37	64	17	85	25
Rechow, 1977 water load<50m/year	20	28	49	8	40	18
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	N/A	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Combined OECD	19	25	39	15	150	14
Dillon-Rigler-Kirchner	N/A	N/A	N/A	N/A	N/A	N/A
Vollenweider, 1982 Shallow Lake/Res.	15	20	33	10	100	11
Larsen-Mercier, 1976	N/A	N/A	N/A	N/A	N/A	N/A
Nurnberg, 1984 Oxic	17	24	41	4	20	14

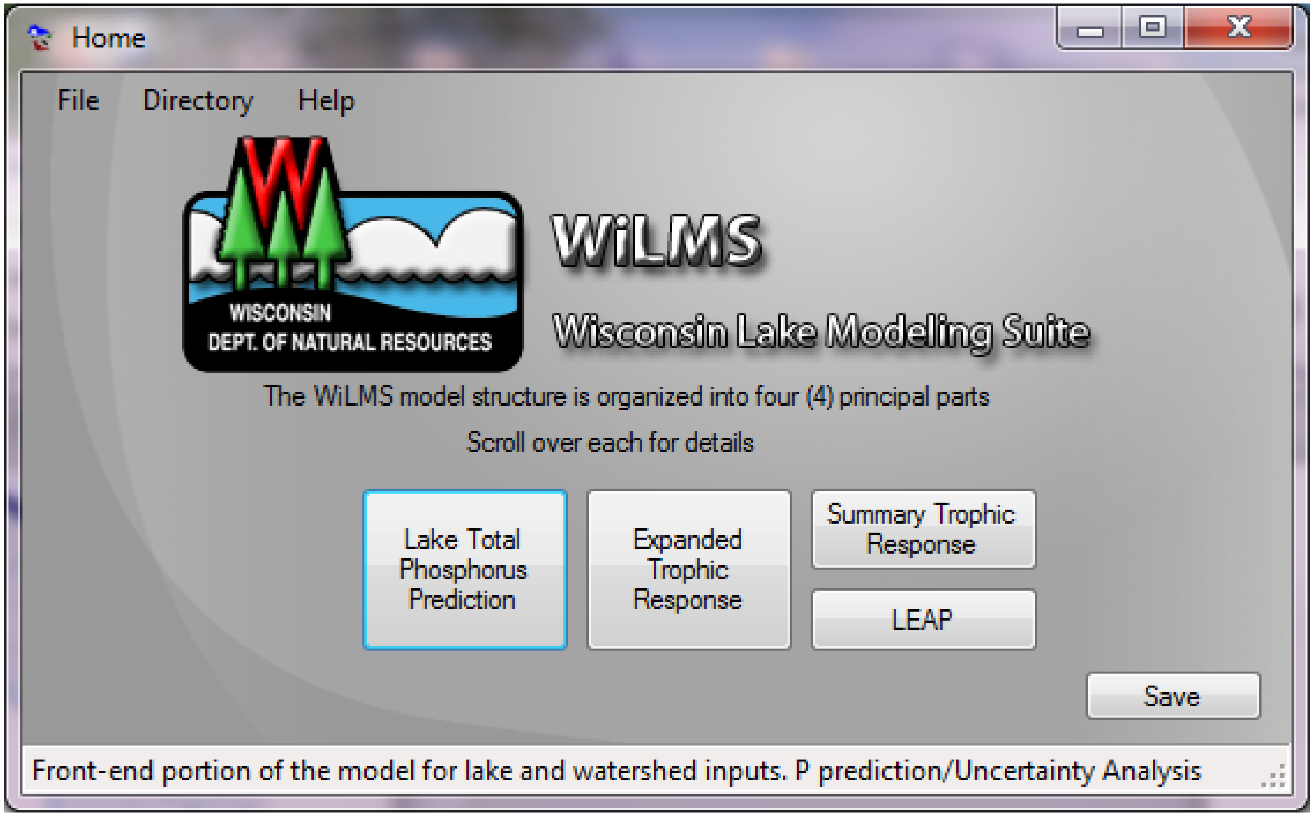
Finished | Write Results | Display Parameter Values | Help

Table 5. Near-surface, summer-aw
based on data from the East Basin c

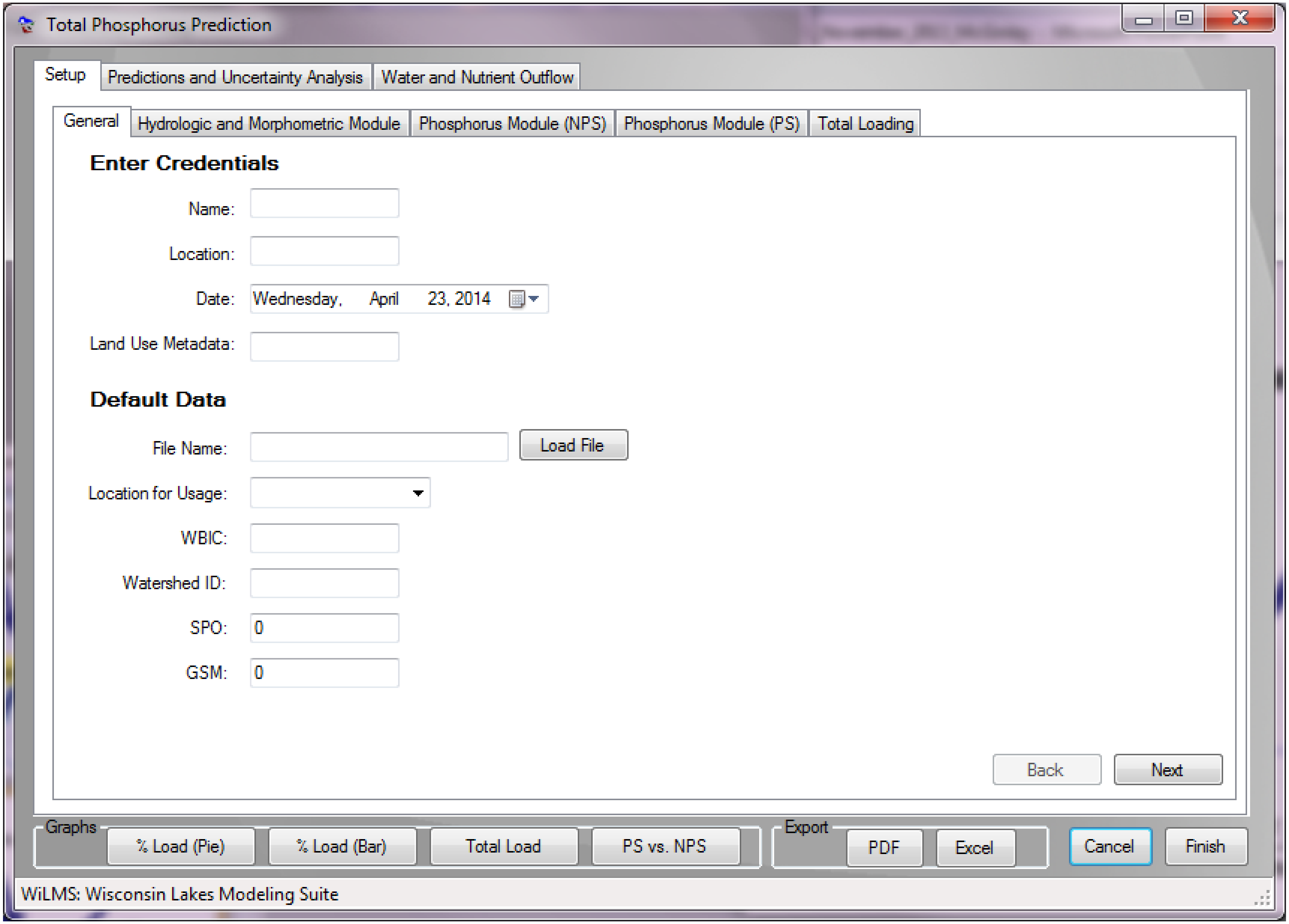
[mg/L, milligrams per liter; µg/L, microgr

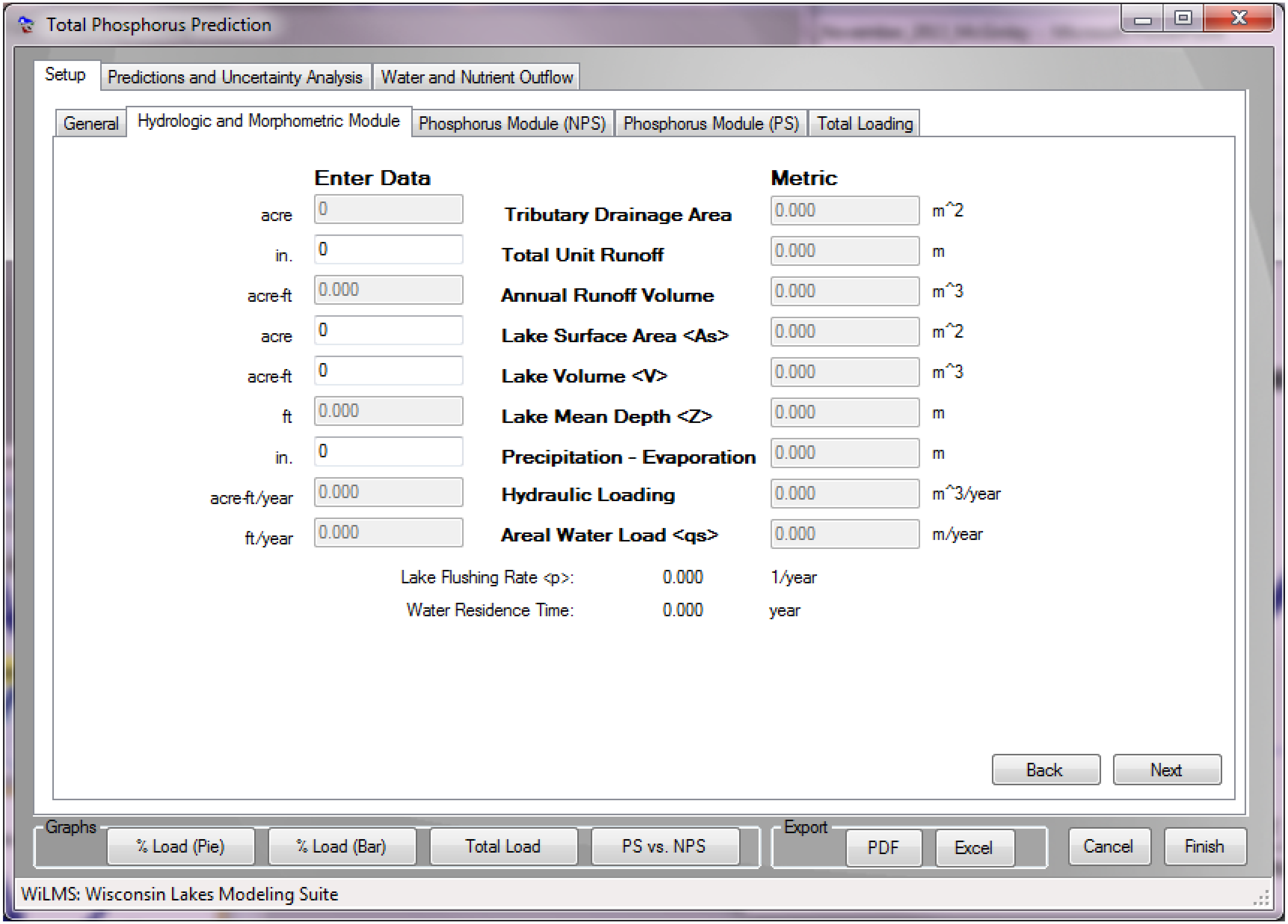
Year	Total phosphorus (mg/L)
1973	0.040
1974	0.030
1975	0.020
1976	0.030
1979	0.027
2000	0.015
2001	—
2002	0.018
2004	—
2005	—
2006	0.017
2007	0.017
2008	0.022
2009	0.024
2010	0.018
2011	0.019
Average 2006–10	0.019
Average 2008–09	0.023

- WiLMS History
  - 1990s– Spreadsheet
  - 2005 – Current Version
  - 2015 – Updated Version

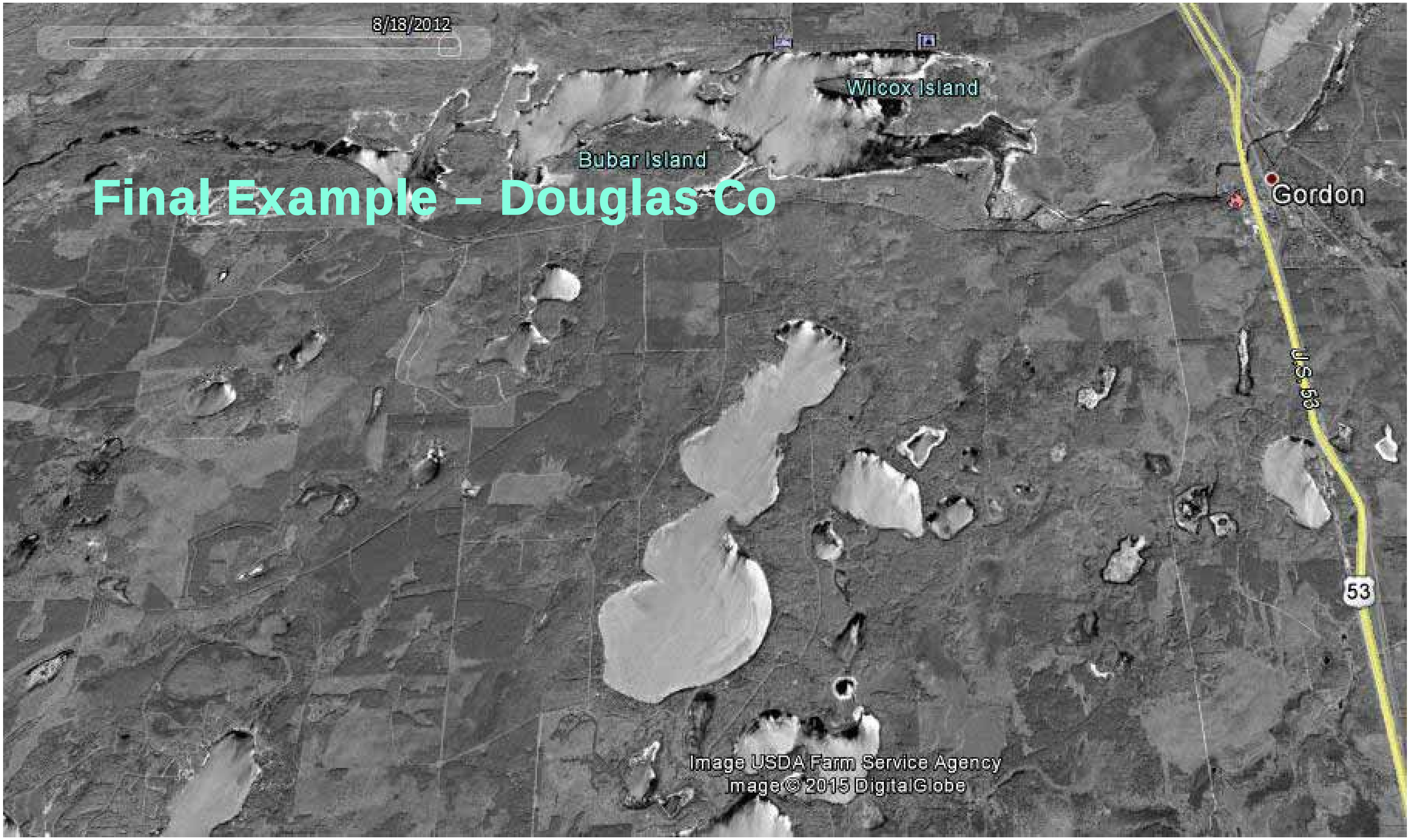


Similar Look



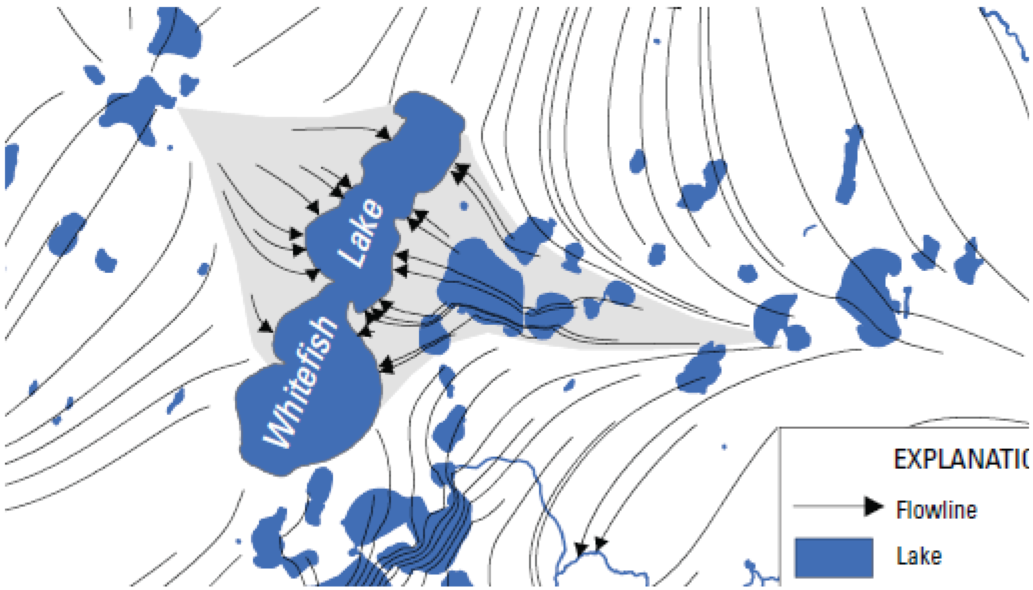

Total Phosphorus Prediction
Setup
Predictions and Uncertainty Analysis
Water and Nutrient Outflow
General
Hydrologic and Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
Enter Data
Metric
acre 0 Tributary Drainage Area 0.000 m^2
in. 0 Total Unit Runoff 0.000 m
acre-ft 0.000 Annual Runoff Volume 0.000 m^3
acre 0 Lake Surface Area <As> 0.000 m^2
acre-ft 0 Lake Volume <V> 0.000 m^3
ft 0.000 Lake Mean Depth <Z> 0.000 m
in. 0 Precipitation - Evaporation 0.000 m
acre-ft/year 0.000 Hydraulic Loading 0.000 m^3/year
ft/year 0.000 Areal Water Load <qs> 0.000 m/year
Lake Flushing Rate <p>: 0.000 1/year
Water Residence Time: 0.000 year
Back
Next
Graphs
% Load (Pie)
% Load (Bar)
Total Load
PS vs. NPS
Export
PDF
Excel
Cancel
Finish
WiLMS: Wisconsin Lakes Modeling Suite

Final Example – Douglas Co

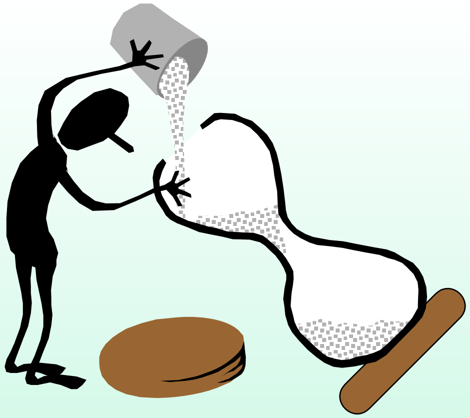


Example IV

- 833 acre lake, Douglas County
- Mean depth of 29 feet
- Measured TP 0.007 mg/l (GSM & SPO)
- 520 acre watershed
  - Assume all forest
- Extra 1200 acres of groundwater contributing area
- Septic Systems



Groundwater & Septic Systems



- General Ideas
  - Groundwater contributing area may not be the same as the surface watershed
    - Treat as a point source, or
    - Treat as another land use (eg forest)
  - Conventional septic systems release phosphorus... even functioning as designed
    - The phosphorus can be retained in the soil profile and the groundwater aquifer
    - The question is... how much “retention” and what’s the best way to describe it?

Groundwater

- For WiLMS need two things for any contributing area / activity
  - Flow rate of water
  - Mass of phosphorus
- For a landuse– that's already included in the
  - Area & the "runoff"
  - Export rate (kg/ha-yr)

Groundwater… if not in surface watershed

- Let’s look at an acre of land, assume 14” of groundwater “produced’’/yr and a groundwater P concentration of 0.015 mg/l.
  –

Groundwater

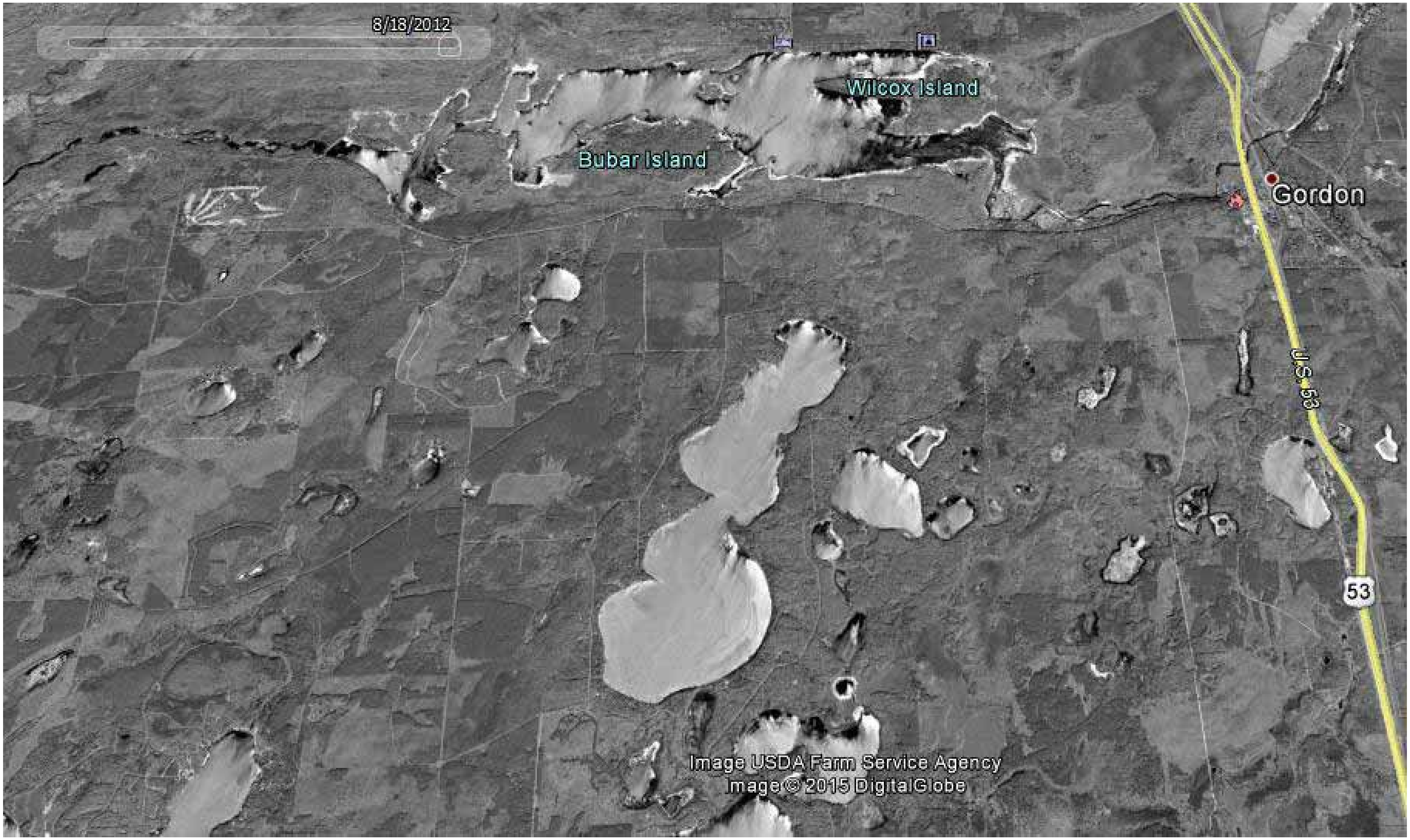
- Let’s look at an acre of land, assume 14” of groundwater “produced’’/yr and a groundwater P concentration of 0.015 mg/l.
  - Point Source Approach **(need a flow and mass/year)**
    - That 14”/year is about 1,440 m3/year for each acre
    - At 0.015 mg/l, that is about 0.02 kg/yr for every acre
  -

Groundwater

- Let’s look at an acre of land, assume 14” of groundwater “produced’’/yr and a groundwater P concentration of 0.015 mg/l.
  - Point Source Approach **(need a flow and mass/year)**
    - That 14”/year is about 1,440 m3/year for each acre
    - At 0.015 mg/l, that is about 0.02 kg/yr for every acre
  - Other Land Use Approach **(enter as area, export rate)**
    - At 14” and 0.015 mg/, that is about 0.05 kg/ha-yr
    - (...why is that about the same as a forested land use?)
  - important... don’t double count!

Septic Systems

- WilMS Approach
  - Assume a number of **people-years**
    - Sum of (# of people)*(fraction of year they use lake)
  - Assume a **kilogram of P/person-year**
    - Usually something like 0.5 kg (range 0.3 to 0.8)
  - Assume a **fraction of the P retained**
    - Will depend on soil– more surface area– more retention
    - Also effect of iron– more iron– more retention
    - Some evidence that more basic soils– less retention
    - But high calcium could tie up some P
    - Probably some complex function of pH / redox /other
    - Assume 70% (range from 50% to 90%)

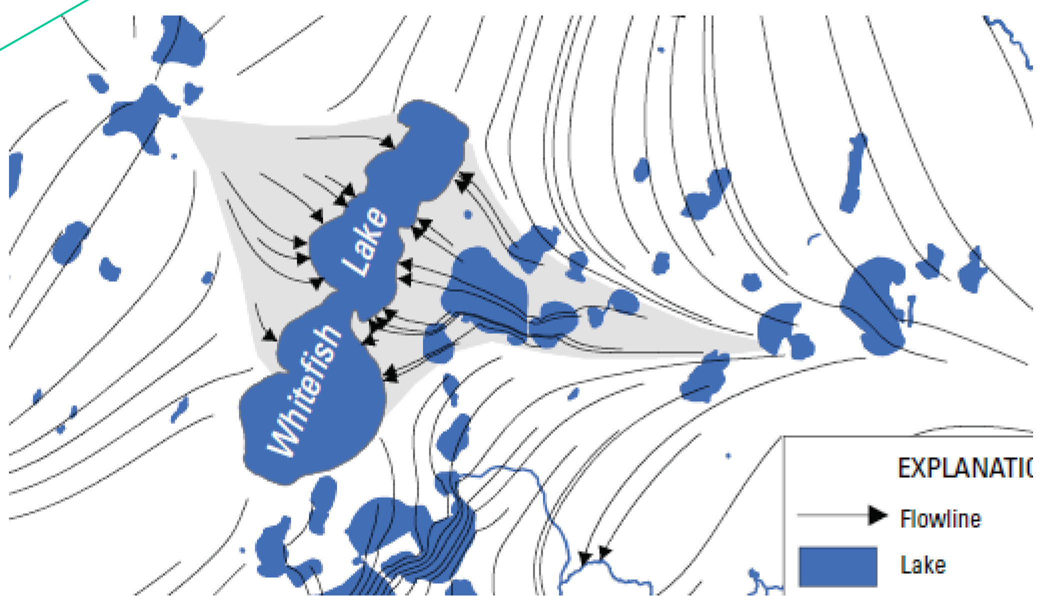

8/18/2012
Wilcox Island
Bubar Island
Gordon
U.S. 53
53
Image USDA Farm Service Agency
Image © 2015 DigitalGlobe

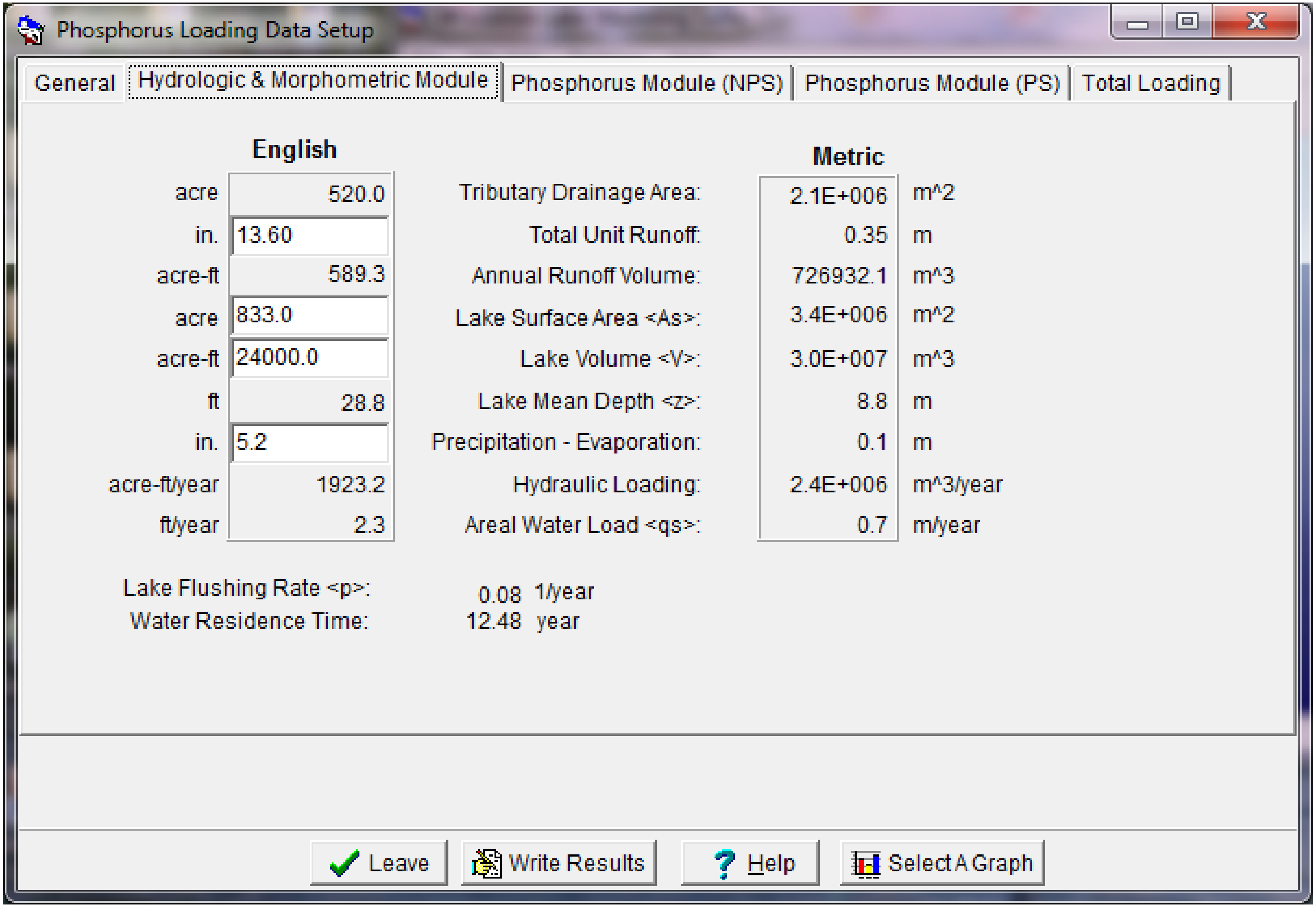
Example IV

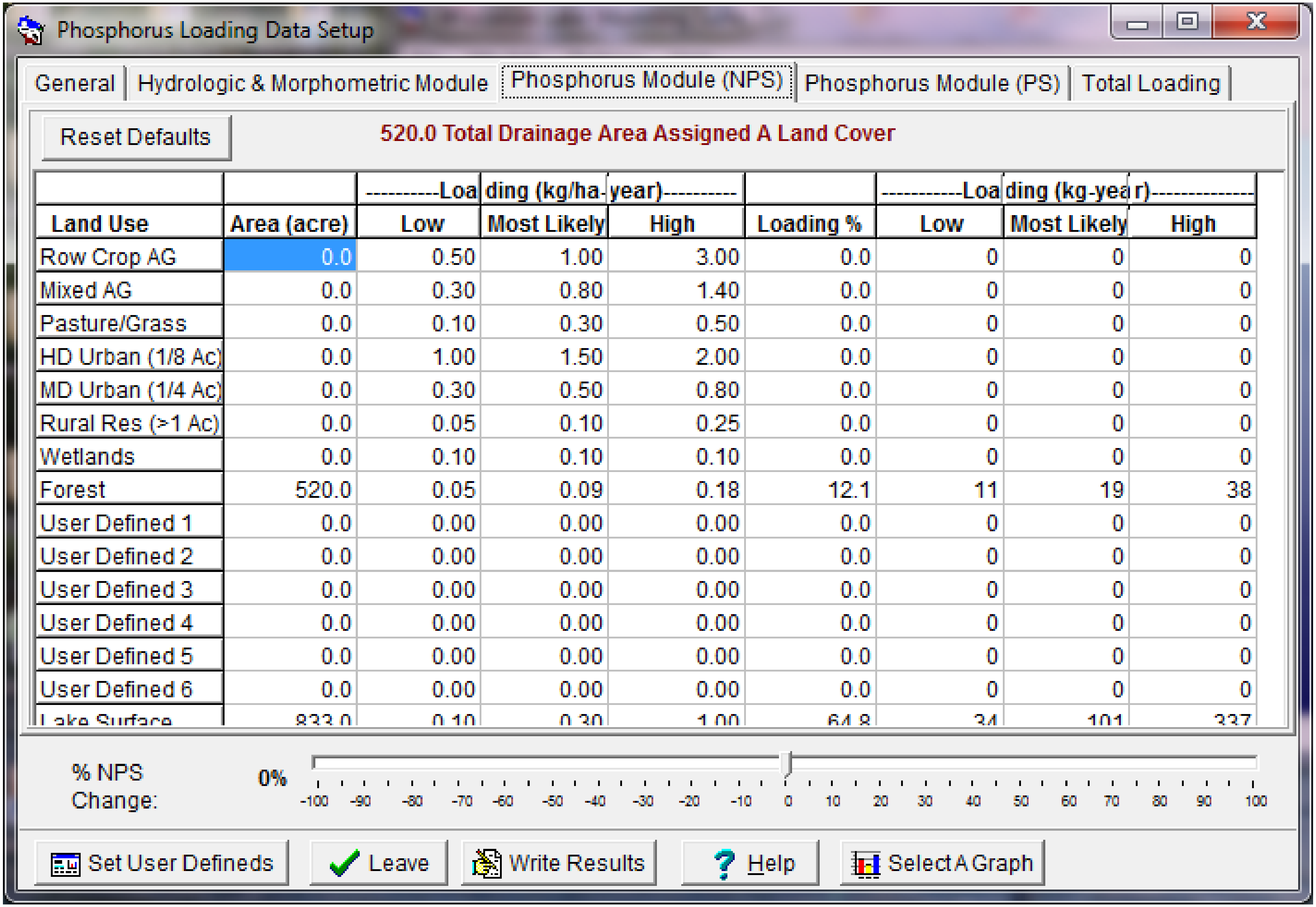
- 833 acre lake, Douglas County
- Mean depth of 29 feet
- Measured TP 0.007 mg/l (GSM & SPO)
- 520 acre watershed
  - Assume all forest
- Extra 1200 acres of groundwater contributing area
  - Use point source
  - 1440 m3/yr-acre (14 inch/yr)
  - 0.02 kg/yr-acre (0.015 mg/l)
- Septic Systems
  - 80 capita-years
  - 70% retention
  - (range 90% to 50%)

1,728,000 m3/yr

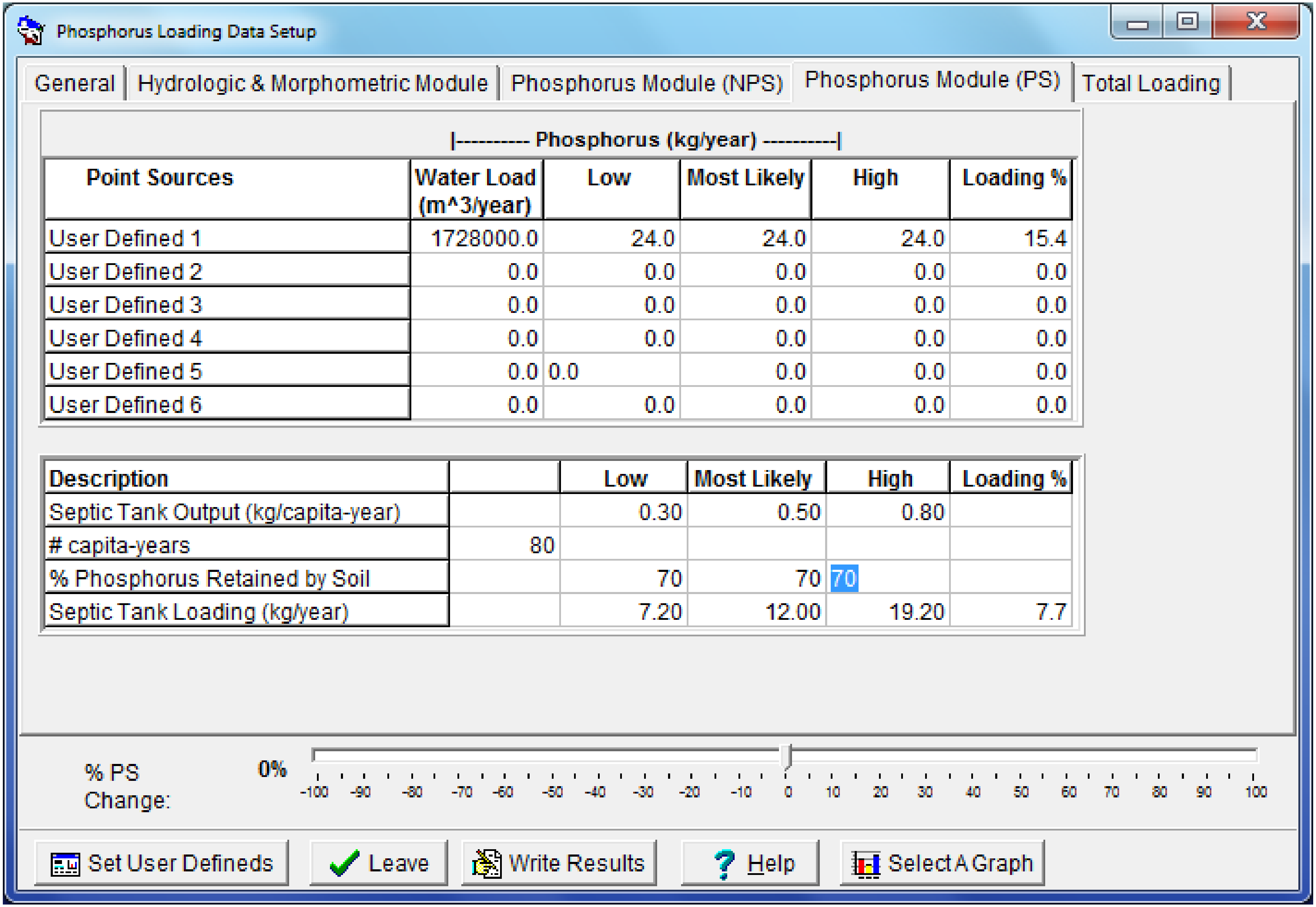
24 kg/yr

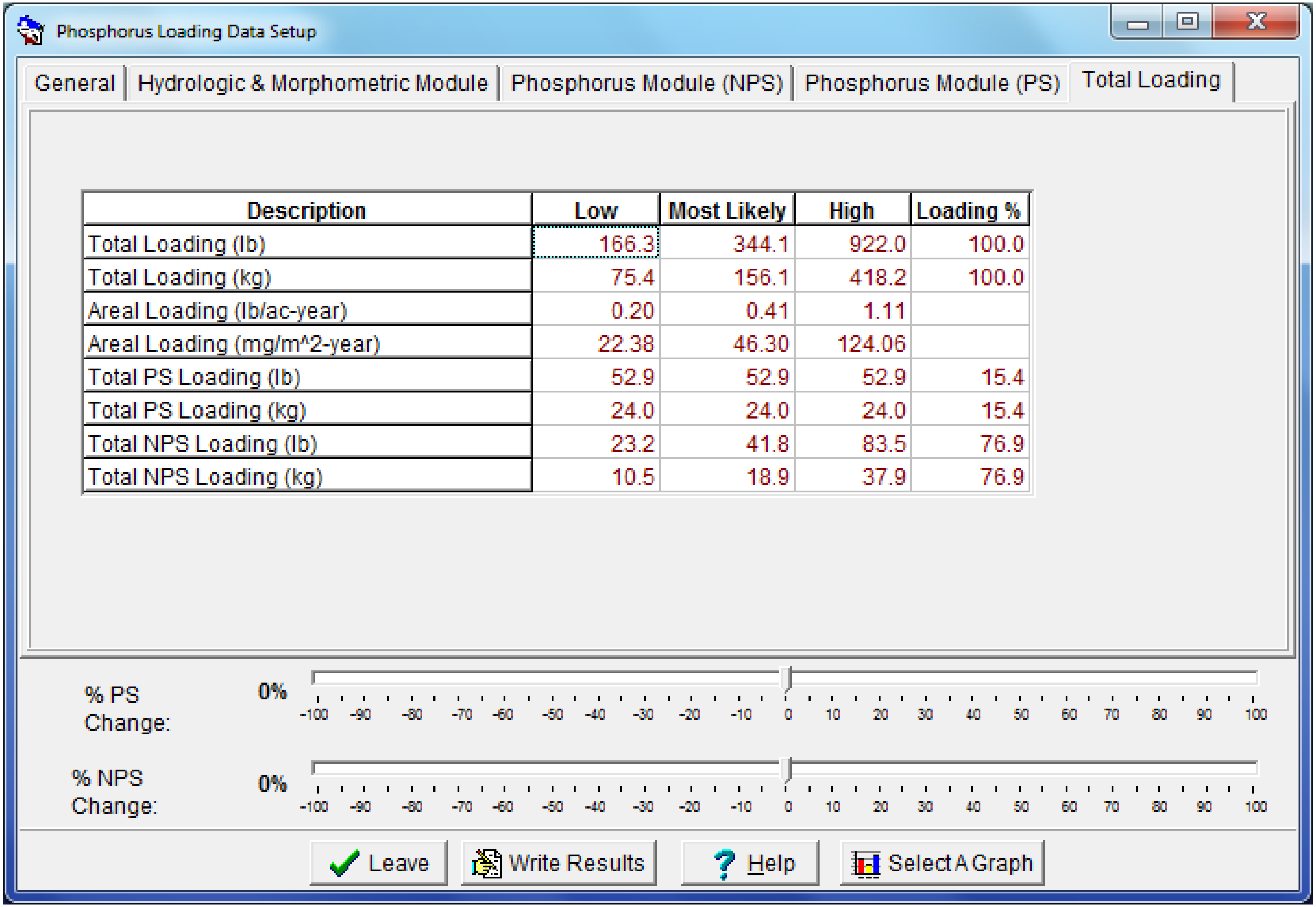



Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
English
Metric
acre 520.0 Tributary Drainage Area: 2.1E+006 m^2
in. 13.60 Total Unit Runoff: 0.35 m
acre-ft 589.3 Annual Runoff Volume: 726932.1 m^3
acre 833.0 Lake Surface Area <As>: 3.4E+006 m^2
acre-ft 24000.0 Lake Volume <V>: 3.0E+007 m^3
ft 28.8 Lake Mean Depth <z>: 8.8 m
in. 5.2 Precipitation - Evaporation: 0.1 m
acre-ft/year 1923.2 Hydraulic Loading: 2.4E+006 m^3/year
ft/year 2.3 Areal Water Load <qs>: 0.7 m/year
Lake Flushing Rate <p>: 0.08 1/year
Water Residence Time: 12.48 year
Leave
Write Results
Help
Select A Graph



		----------Loading (kg/ha-year)----------				----------Loading (kg-year)------------		
Land Use	Area (acre)	Low	Most Likely	High	Loading %	Low	Most Likely	High
Row Crop AG	0.0	0.50	1.00	3.00	0.0	0	0	0
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0
Pasture/Grass	0.0	0.10	0.30	0.50	0.0	0	0	0
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	0.0	0.05	0.10	0.25	0.0	0	0	0
Wetlands	0.0	0.10	0.10	0.10	0.0	0	0	0
Forest	520.0	0.05	0.09	0.18	12.1	11	19	38
User Defined 1	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 2	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 3	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 4	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 5	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 6	0.0	0.00	0.00	0.00	0.0	0	0	0
Lake Surface	833.0	0.10	0.30	1.00	64.8	34	101	337


Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
|---------- Phosphorus (kg/year) ----------|
Point Sources | Water Load (m^3/year) | Low | Most Likely | High | Loading %
User Defined 1 | 1728000.0 | 24.0 | 24.0 | 24.0 | 15.4
User Defined 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
User Defined 6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0
Description | | Low | Most Likely | High | Loading %
Septic Tank Output (kg/capita-year) | | 0.30 | 0.50 | 0.80 |
capita-years | 80 | | | |
% Phosphorus Retained by Soil | | 70 | 70 | 70 |
Septic Tank Loading (kg/year) | | 7.20 | 12.00 | 19.20 | 7.7
% PS Change:
0%
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
Set User Defineds
Leave
Write Results
Help
Select A Graph



Description	Low	Most Likely	High	Loading %
Total Loading (lb)	166.3	344.1	922.0	100.0
Total Loading (kg)	75.4	156.1	418.2	100.0
Areal Loading (lb/ac-year)	0.20	0.41	1.11	
Areal Loading (mg/m^2-year)	22.38	46.30	124.06	
Total PS Loading (lb)	52.9	52.9	52.9	15.4
Total PS Loading (kg)	24.0	24.0	24.0	15.4
Total NPS Loading (lb)	23.2	41.8	83.5	76.9
Total NPS Loading (kg)	10.5	18.9	37.9	76.9

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 7.0 mg/m^3

Observed growing season mean phosphorus (GSM): 7.0 mg/m^3

Back calculation for SPO total phosphorus: 0.0 mg/m^3

Back calculation GSM phosphorus: 0.0 mg/m^3

Nurnberg Model Input - Est. Gross Int. Loading: 0 kg

% Confidence Range: 70

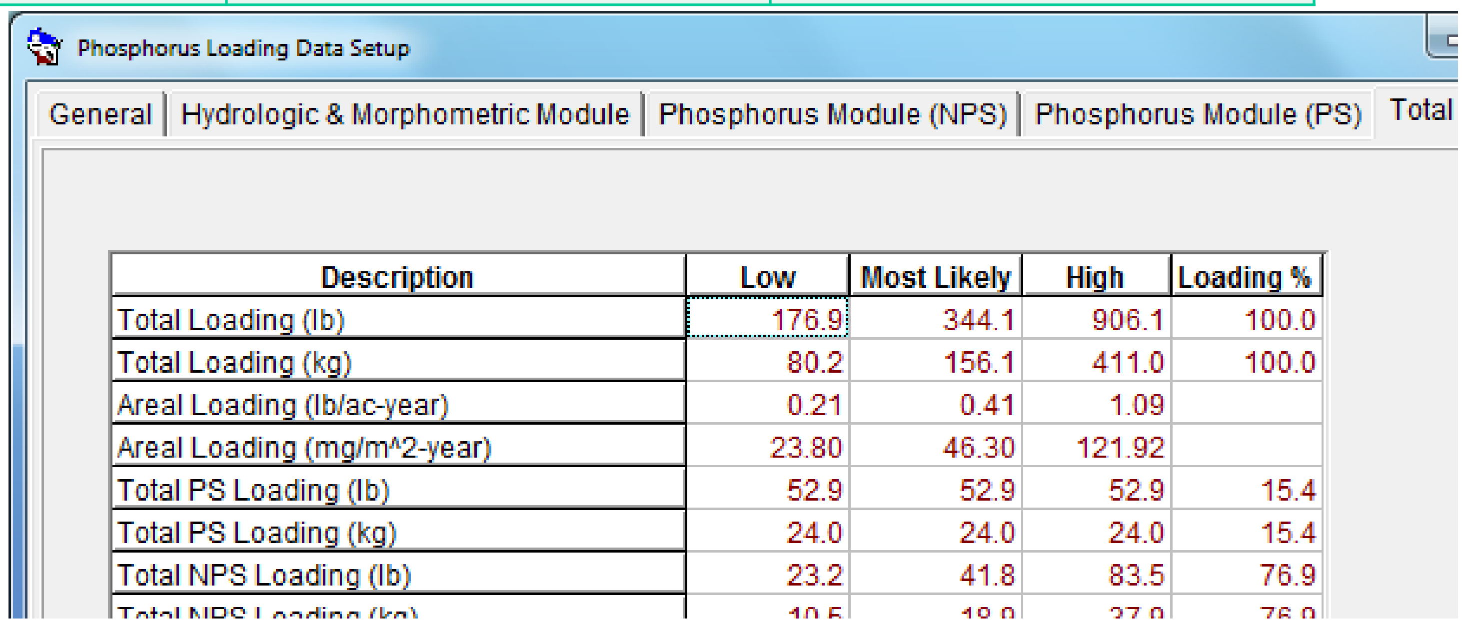
Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound	Confidence Upper Bound	Parameter Fit?	Back Calculation (kg/year)	Model Type
Walker, 1987 Reservoir	9	18	49	11	157	11	38	Tw	0	GSM
Canfield-Bachmann, 1981 Natural Lake	7	12	22	5	71	4	35	FIT	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	9	13	22	6	86	4	37	FIT	1	GSM
Rechow, 1979 General	2	4	10	-3	-43	2	8	L	0	GSM
Rechow, 1977 Anoxic	9	19	50	12	171	11	39	FIT	0	GSM
Rechow, 1977 water load<50m/year	2	5	13	-2	-29	3	10	FIT	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	8	16	43	9	129	8	35	FIT	0	SPO
Vollenweider, 1982 Combined OECD	7	13	28	6	86	6	26	FIT	0	ANN
Dillon-Rigler-Kirchner	6	13	34	6	86	7	27	L qs p	0	SPO
Vollenweider, 1982 Shallow Lake/Res.	5	10	23	3	43	5	20	FIT	0	ANN
Larsen-Mercier, 1976	6	13	34	6	86	8	26	Pin	0	SPO
Nurnberg, 1984 Oxic	5	11	30	4	57	6	24	FIT	0	ANN

Finished | Write Results | Display Parameter Values | Help

Recap

Source	Low kg/year	Most Likely kg/year
Surface watershed	11	19
Atmospheric (lake surface)	34	101
Additional groundwater	24	24
Septic systems	12	12
Total –kilograms/year	81	156
Total—pounds/year	177	344

Note that the septic P doesn't show up in the point source total but it is in the total loading

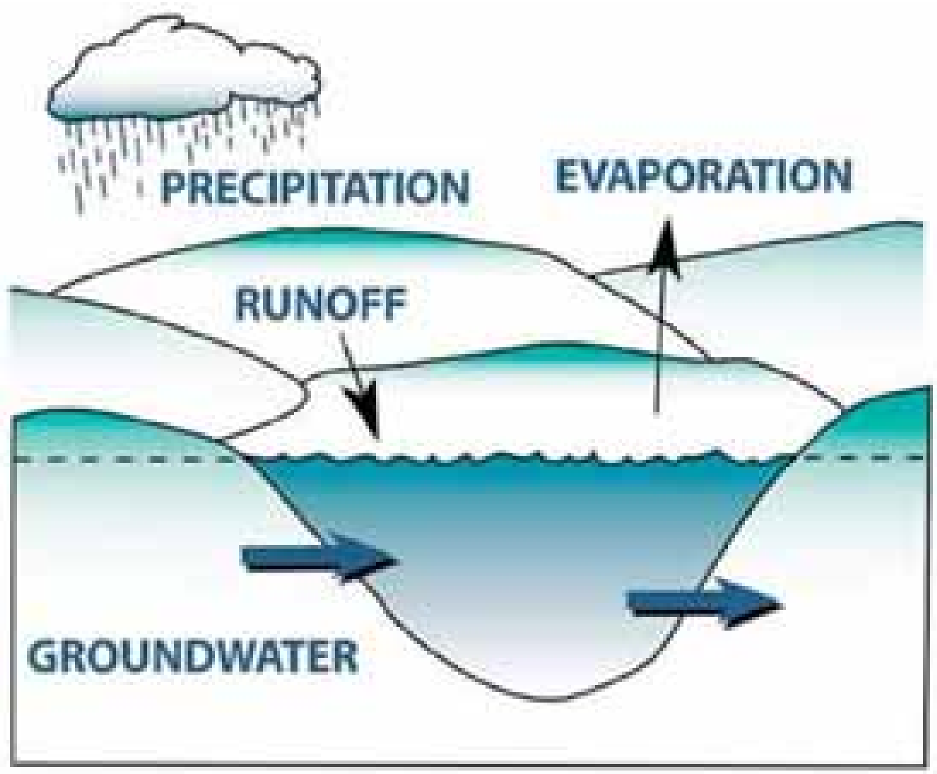


Description	Low	Most Likely	High	Loading %
Total Loading (lb)	176.9	344.1	906.1	100.0
Total Loading (kg)	80.2	156.1	411.0	100.0
Areal Loading (lb/ac-year)	0.21	0.41	1.09	
Areal Loading (mg/m^2-year)	23.80	46.30	121.92	
Total PS Loading (lb)	52.9	52.9	52.9	15.4
Total PS Loading (kg)	24.0	24.0	24.0	15.4
Total NPS Loading (lb)	23.2	41.8	83.5	76.9

We do have some things we can discuss….

- This is a seepage lake
- Let’s take a close look at atmospheric deposition
- Does groundwater actually enter the lake?
- What should the groundwater P concentration be?
- Take another look at steady-state in shallow lakes
- How about riparian runoff?
- Other?

Seepage Lake



Atmospheric Deposition

- **“Lake Surface”**

- **WiLMS Default**
  - **“Most likely” estimate 0.3 kg/ha-yr (similar to Reckhow and Simpson p 81 in notes w/ range 0.15 to 0.5 in that paper)**

- **Other Values**
  - **0.06 kg/ha-yr: N WI (Rose, W.J., 1993 Balsam Lake 1987-89: USGS WRI 91-4125)**

  - **0.16 kg/ha-yr: (Field and Duerk, 1988 Delavan Lake USGS WRI 87-4168)**

  - **0.17 kg/ha-yr (Ontario LCM modified in 2006, p 118 in notes)**

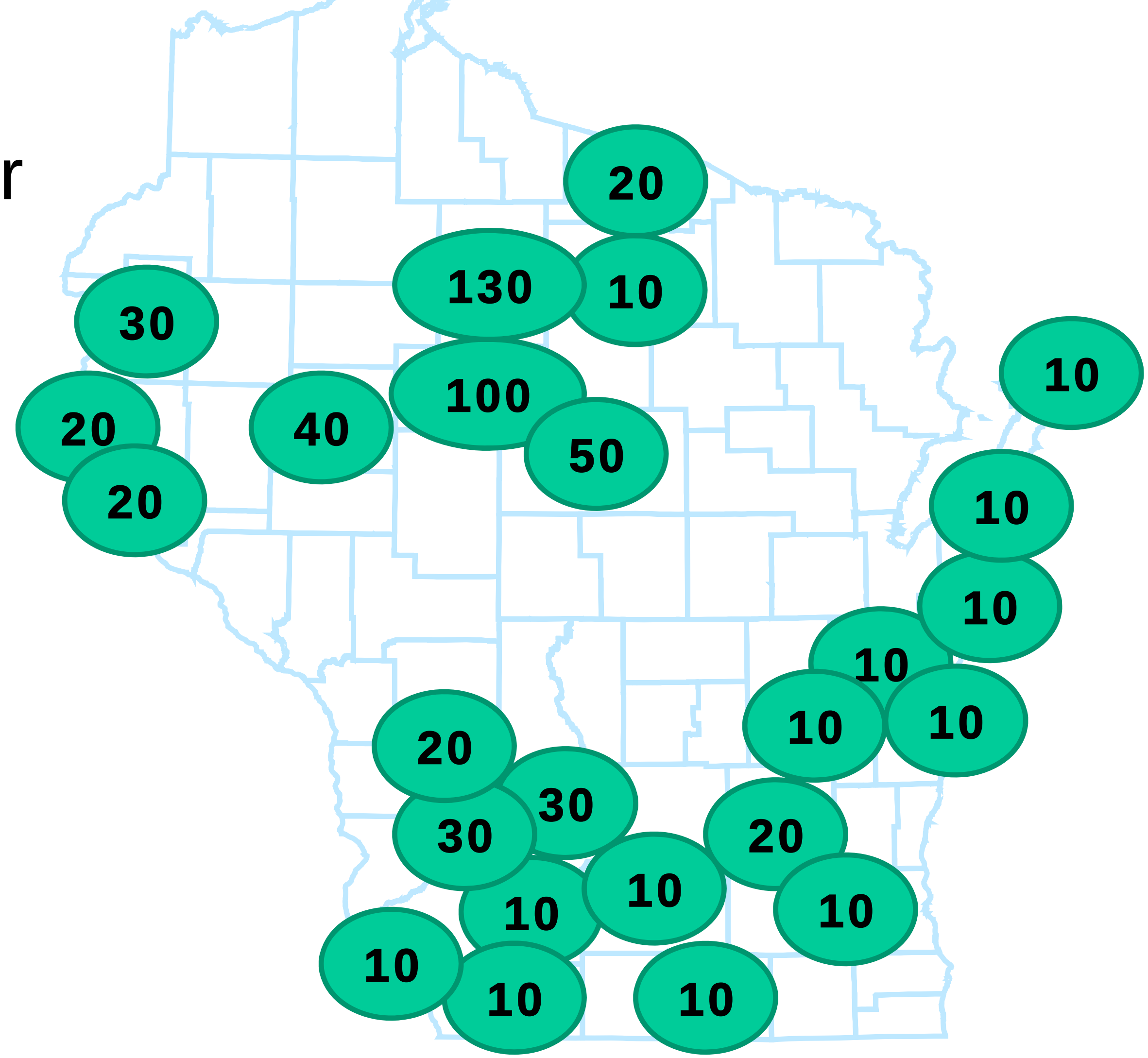
  - **Robertson (Whitefish Lake Study) used**
    - **Dry deposition**
      - **0.12 kg/ha-yr for small lake, conifers**
      - **0.07 for large lake, conifers**
    - **Wet deposition**
      - **0.13 kg/ha-yr (0.016 mg/l assumed)**

Used ~0.19 kg/ha-yr
Or ~ 60 kg total for
833 acre lake

Groundwater P Conc?

Groundwater Median P µg/l

UWSP Drinking Water Program Data




Do we have time to discuss
RIPARIAN RUNOFF MODELS?

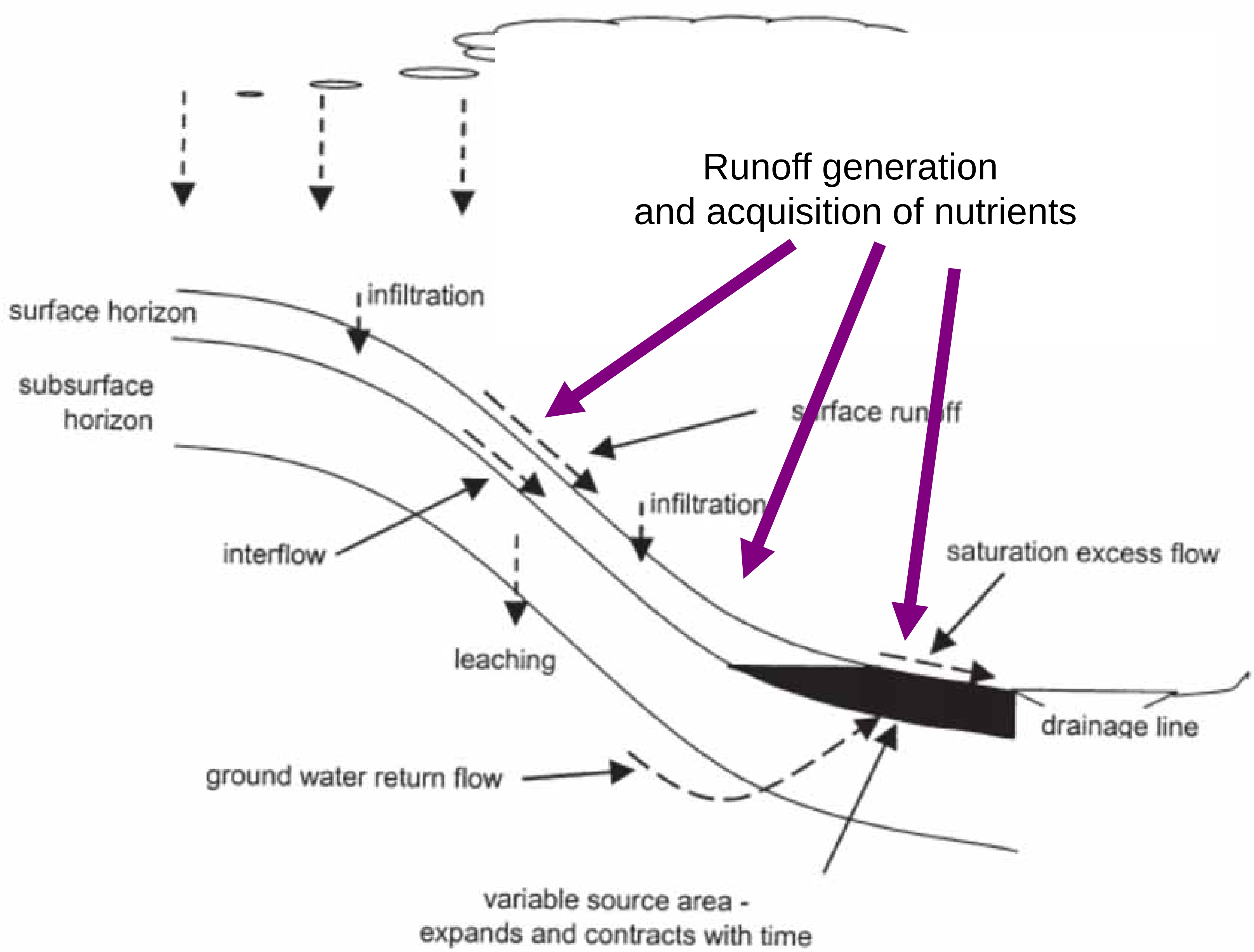


Fig. 4. Basic components of hillslope hydrology.

Changes to phosphorus movement because of development?

- Changes in vegetation
  - Interception
  - Evapo-transpiration
- Changes in infiltration
  - Compaction
- Changes in runoff generation
  - Sources of runoff
  - Pathways it takes
- Changes in nutrient availability
  - Fertilizer
  - Vegetation

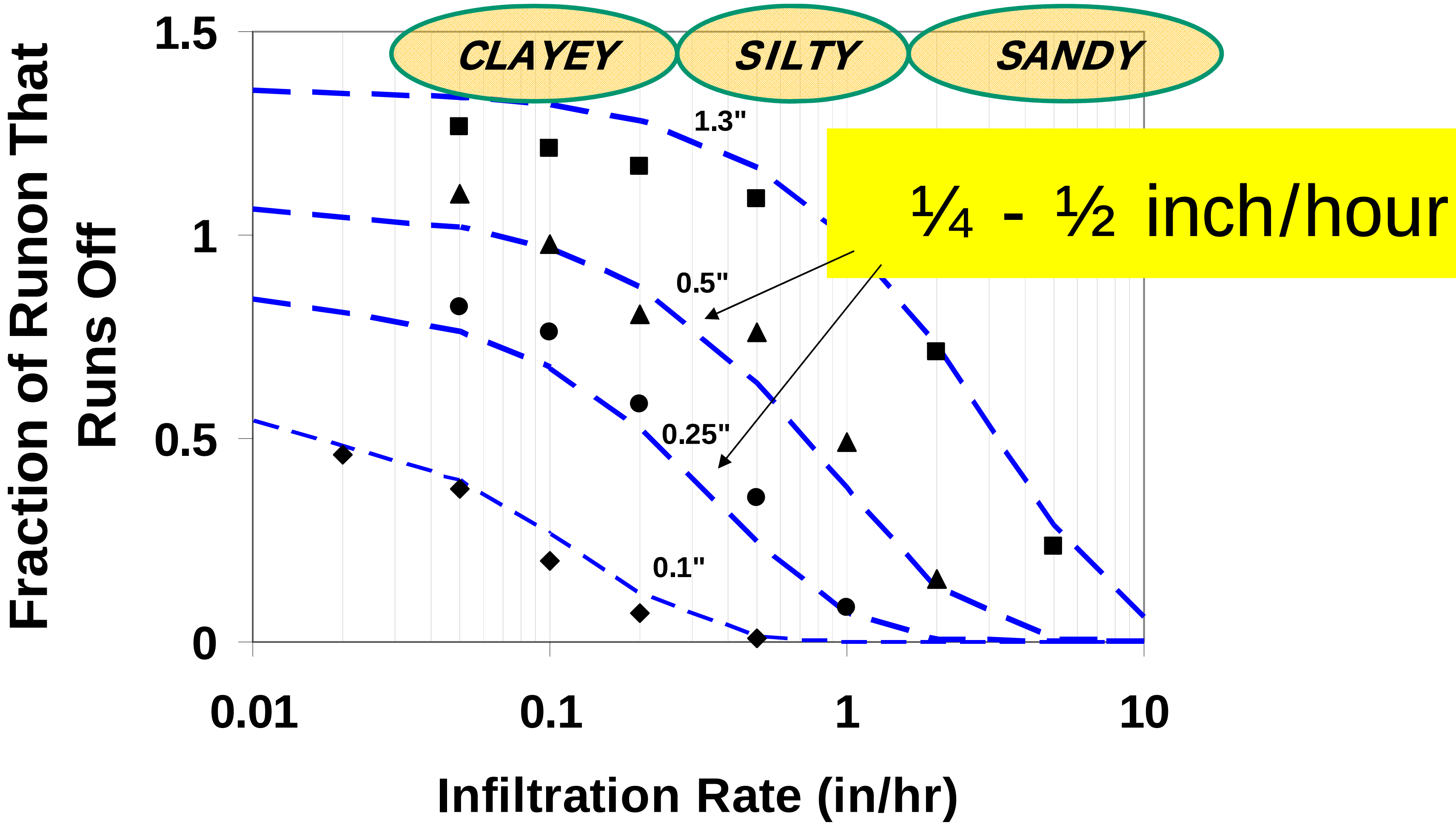
Observations (WDNR N WI Study)

- Concentrations of P in runoff may be similar in woods and lawn
  - Both reflect movement of water across high P surfaces
- Runoff volume differences likely the biggest contributor to differences in export
  - 10x, 50x, 100x differences in runoff volume between developed/undeveloped
- Export = (volume)*(concentration)

Ideas?

- Delivery? Connectivity?
- What is the quality of the runoff?
  - Runoff that originates from a roof and is conveyed across vegetation can have a very different concentration
- Controls – Infiltration?

What controls the infiltration rate?

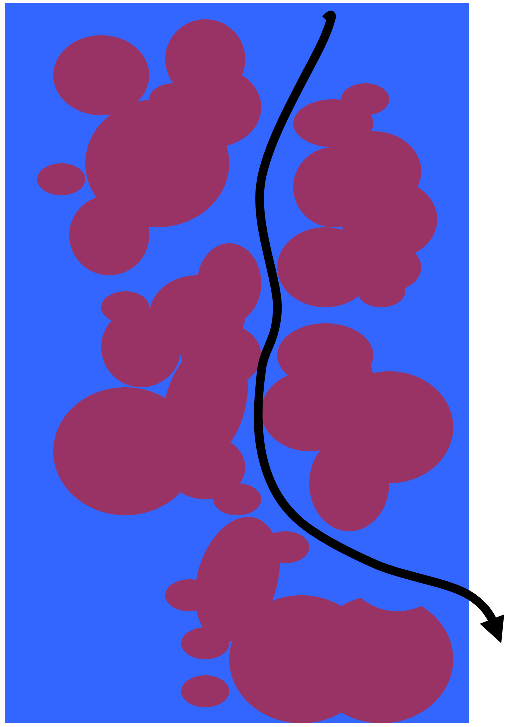


The fraction of runon to the secondary buffer that would infiltrate for different storm sizes and infiltration rates (assumes a 500 ft2 impervious area draining to a five foot wide channel, forty feet long and one hour storm of depth shown). Dashed lines show the fitted equation based on soil infiltration rate and storm depth.

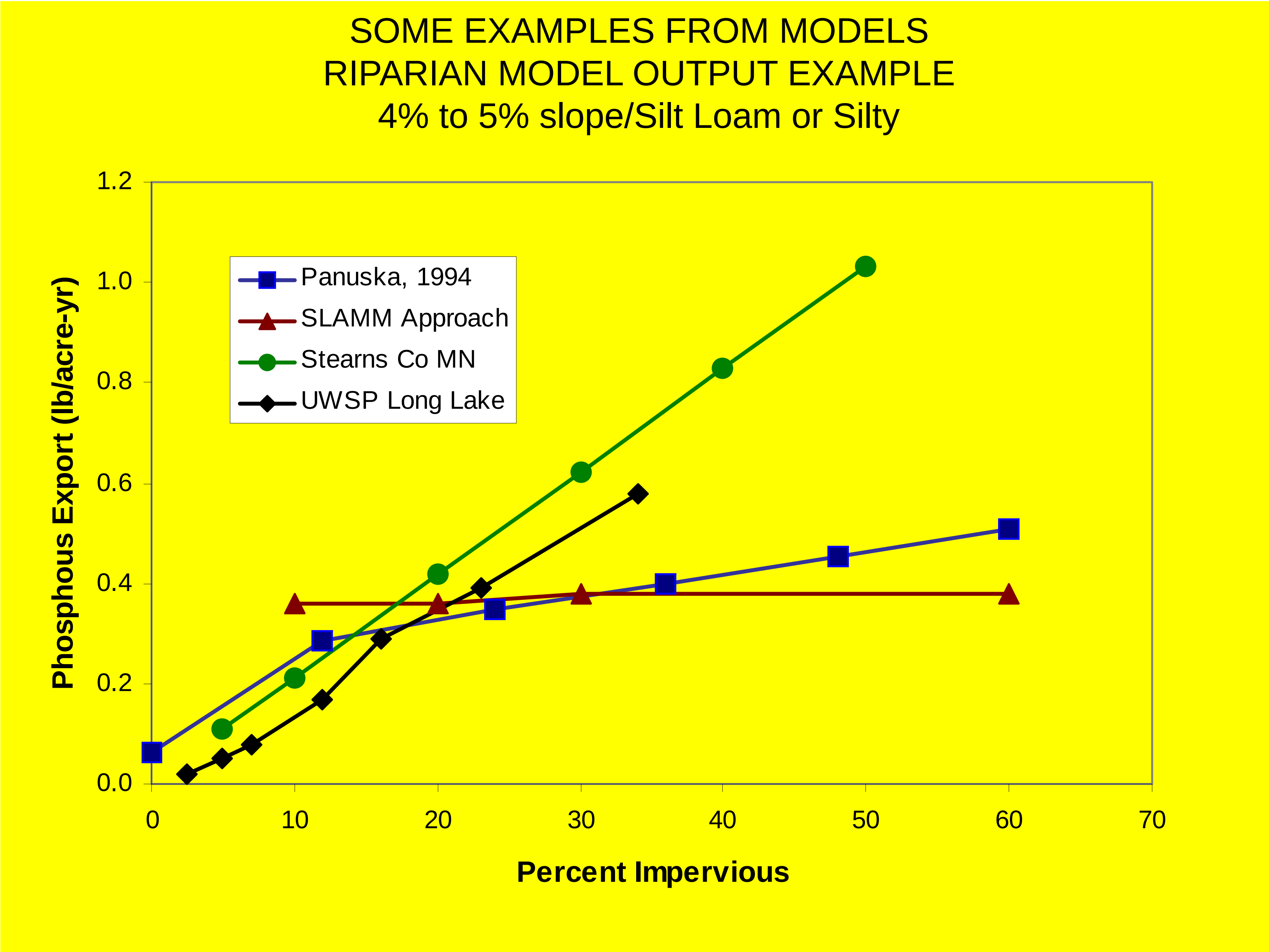
Runon Ratio
500 / 5(w) x 40 (L)

What about compaction?

Condition	Ponded Infiltration Rate (in/hr)
Vegetated	3.4
Open Soil	0.7
Traffic	0.1



Silt loam soil described by Vervoort, R.W., S.M. Dabney and M.J.M. Romkens. 2001. Tillage and Row Position Effects on Water and Solute Infiltration Characteristics, Soil Science Society of America Journal 65:1227-1234.



SOME EXAMPLES FROM MODELS
RIPARIAN MODEL OUTPUT EXAMPLE
4% to 5% slope/Silt Loam or Silty
Phosphous Export (lb/acre-yr)
Percent Impervious
Panuska, 1994
SLAMM Approach
Stearns Co MN
UWSP Long Lake
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0
10
20
30
40
50
60
70

Big Finish…!

Let’s take a look at one way to organize different Eutrophication Models

Quick Modeling Overview

General Categories of Models --------- Examples	
Single Event Rainfall / Runoff	TR-55, Rational Method
Continuous Hydrologic	HEC-1
Hydraulic	SWMM, HEC-RAS, HydroCAD
Steady-State Nutrient Export	WILMS, BATHTUB
Continuous Hydrologic w/ Nutrient & Sediment Export	Urban – P8, WinSLAMM Mixed Watershed – SWAT, HSPF
Steady-State Water Response Continuous Water Response	WILMS, BATHTUB AQUATOX, WASP, QUAL2E
NOTE– Increasingly these models overlap in capability	

Quick Modeling Overview

General Categories of Models ---------	Examples
Single Event Rainfall / Runoff	TR-55, Rational Method
Continuous Hydrologic	HEC-1
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Steady-State Water Response Continuous Water Response	WILMS, BATHTUB AQUATOX, WASP, QUAL2E
NOTE– Increasingly these models overlap in capability	

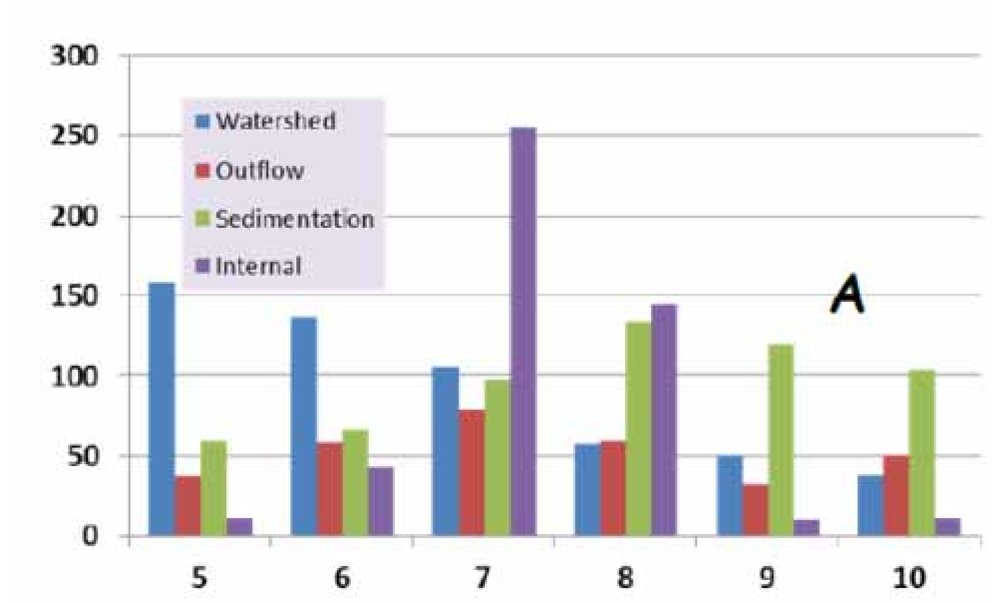
For more information

- Notepack (pdf file)
  - Includes many of the original articles
- Questions
  - Paul McGinley pmcginle@uwsp.edu
    (715) 346-4501
  - Nancy Turyk nturyk@uwsp.edu

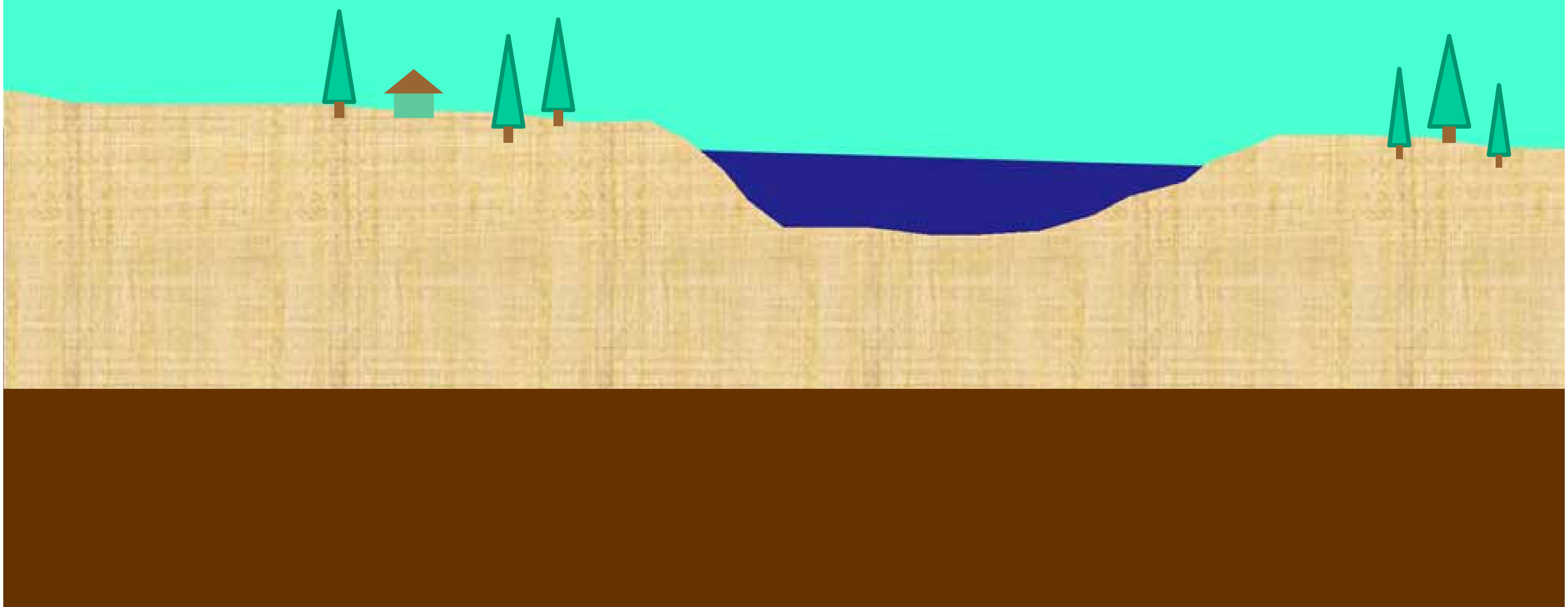

QUESTIONS & TIME FOR YOUR PROJECTS

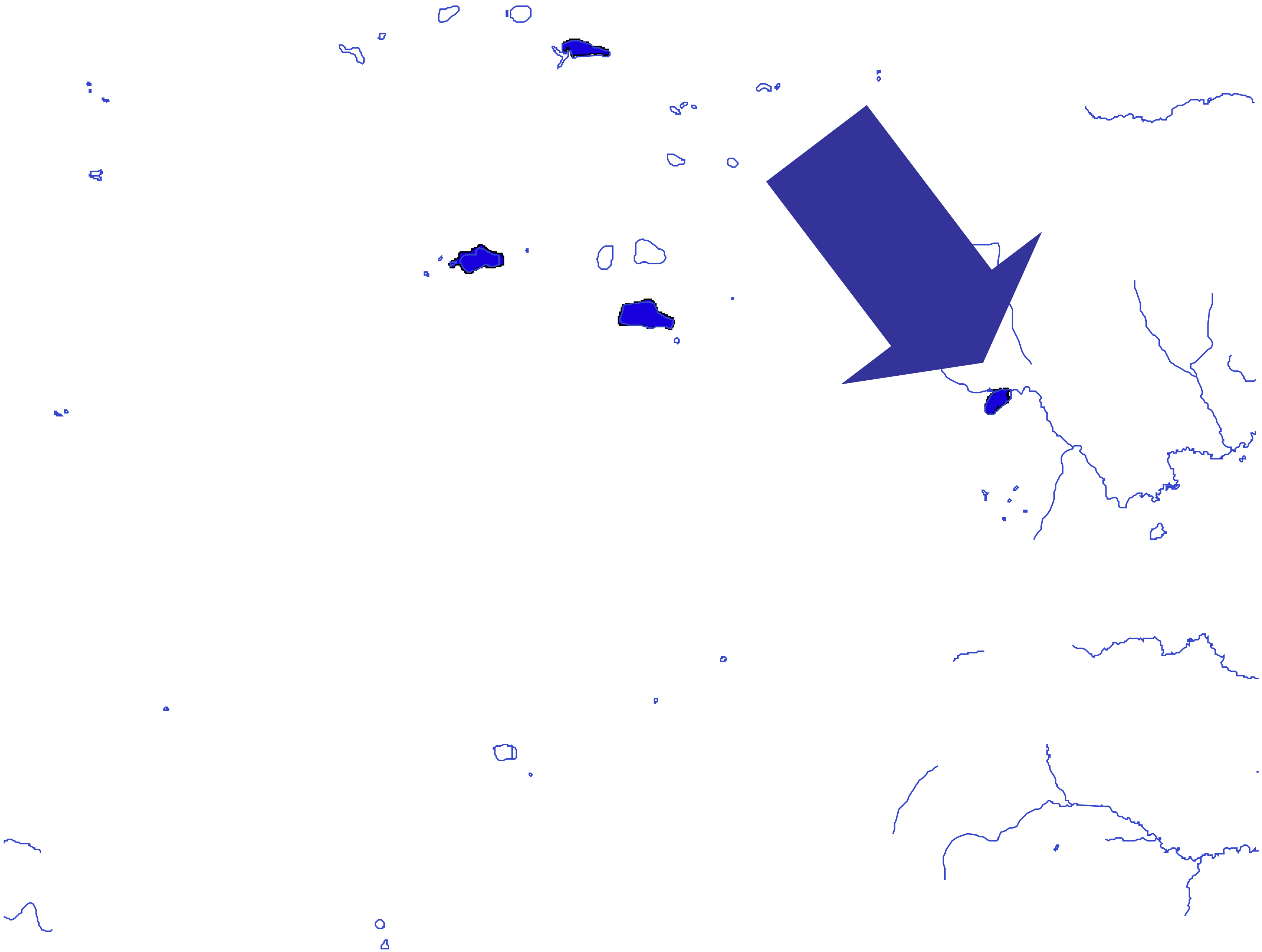
Usefulness of shorter time-step?

- Partition seasonal loads?
  – Here looking at the monthly P (in kilograms) for watershed loading (blue)

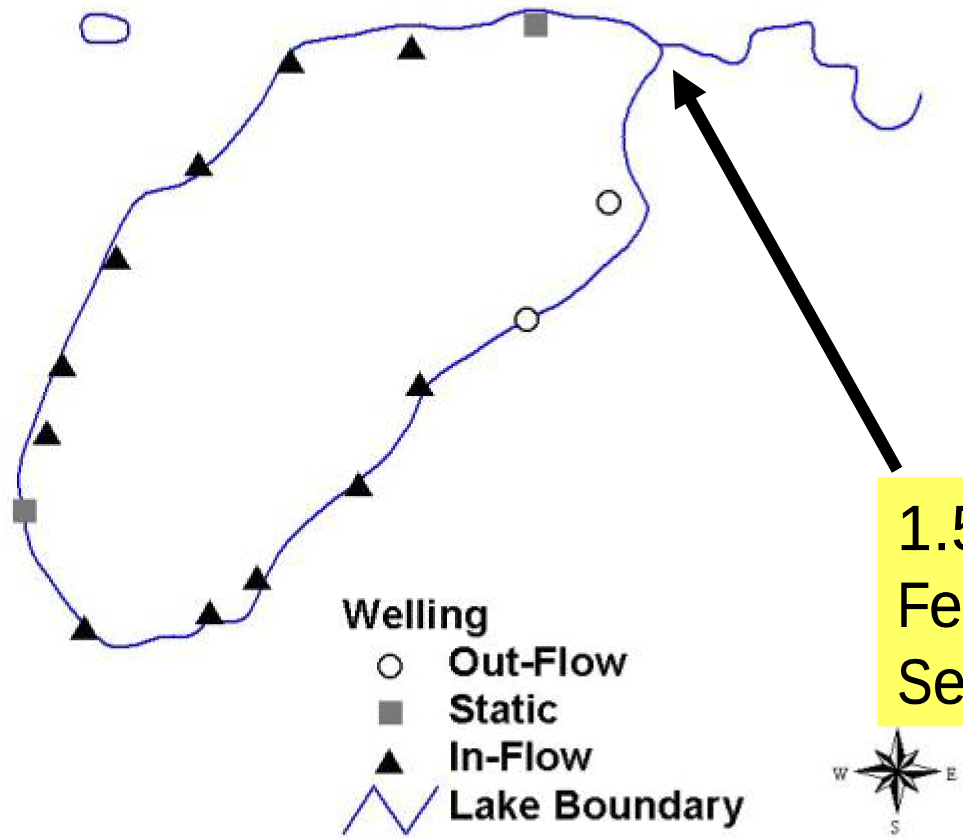


Lakes are connected to groundwater…

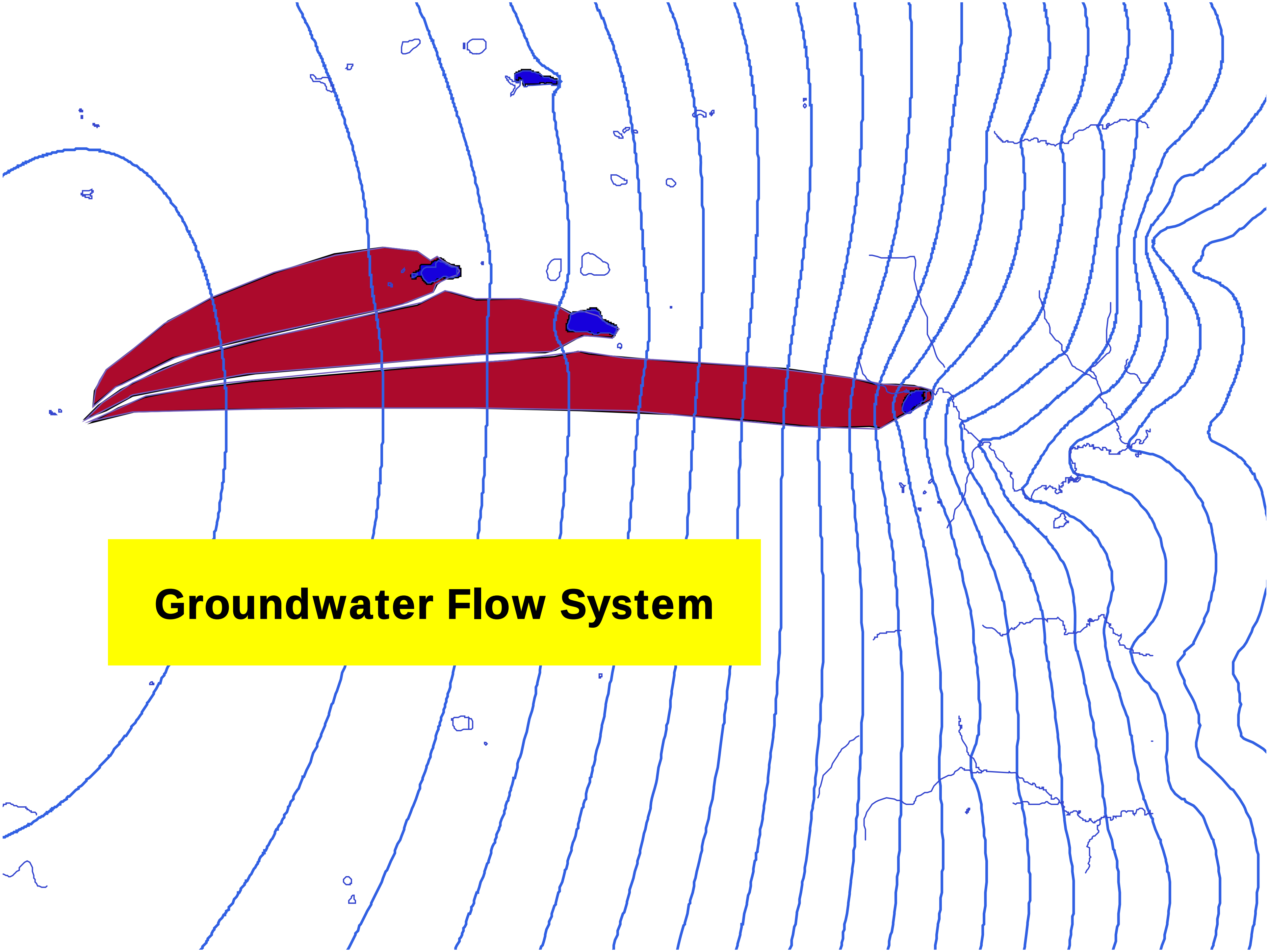




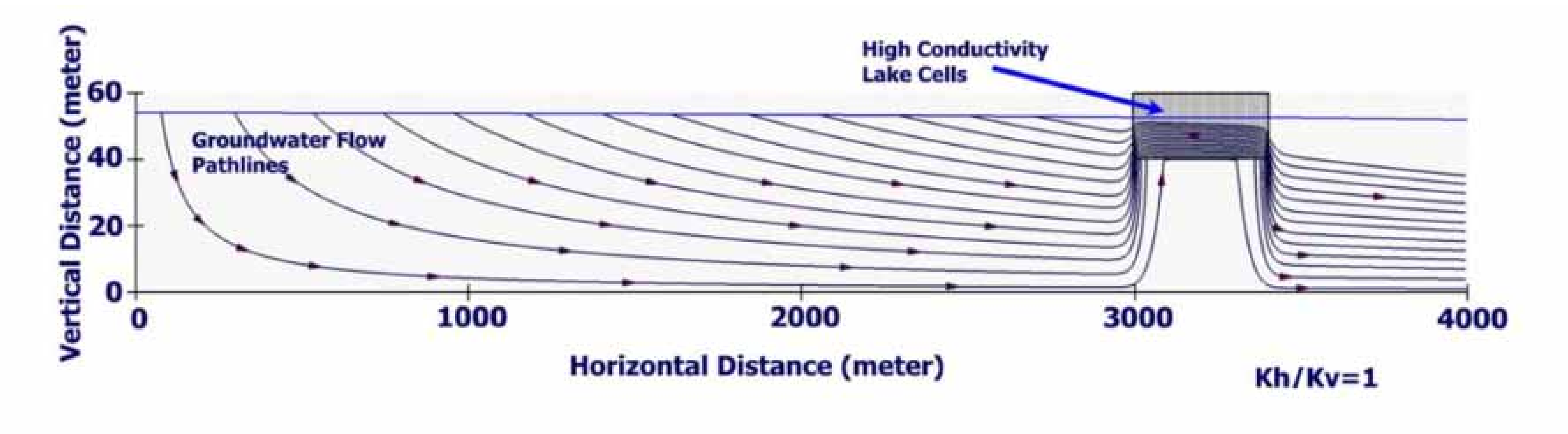
Fountain Lake



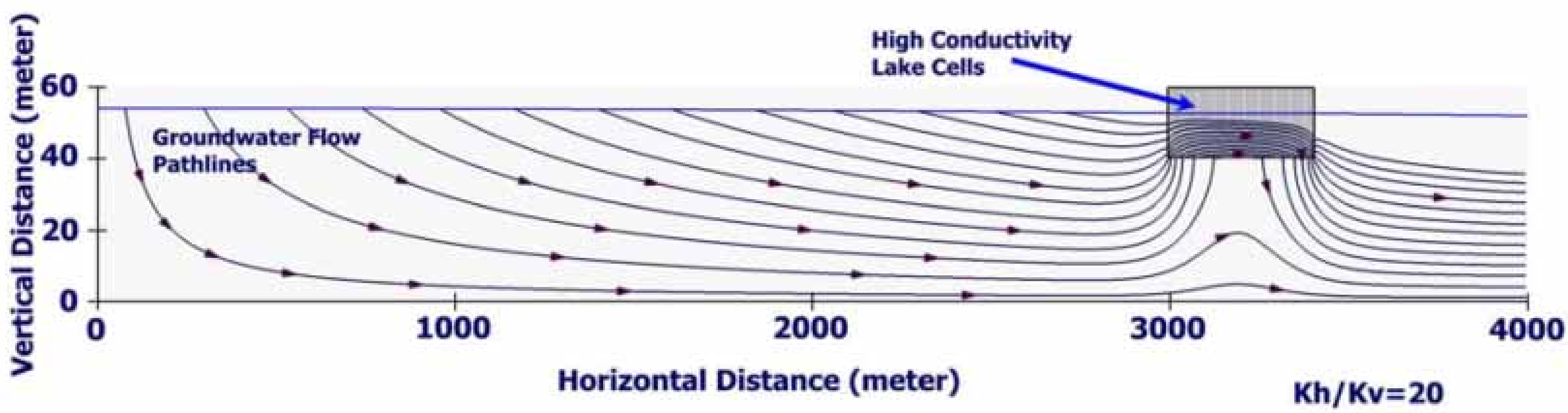
1.5 Cubic Feet Per Second


Groundwater Flow System

Does groundwater flow under lakes?

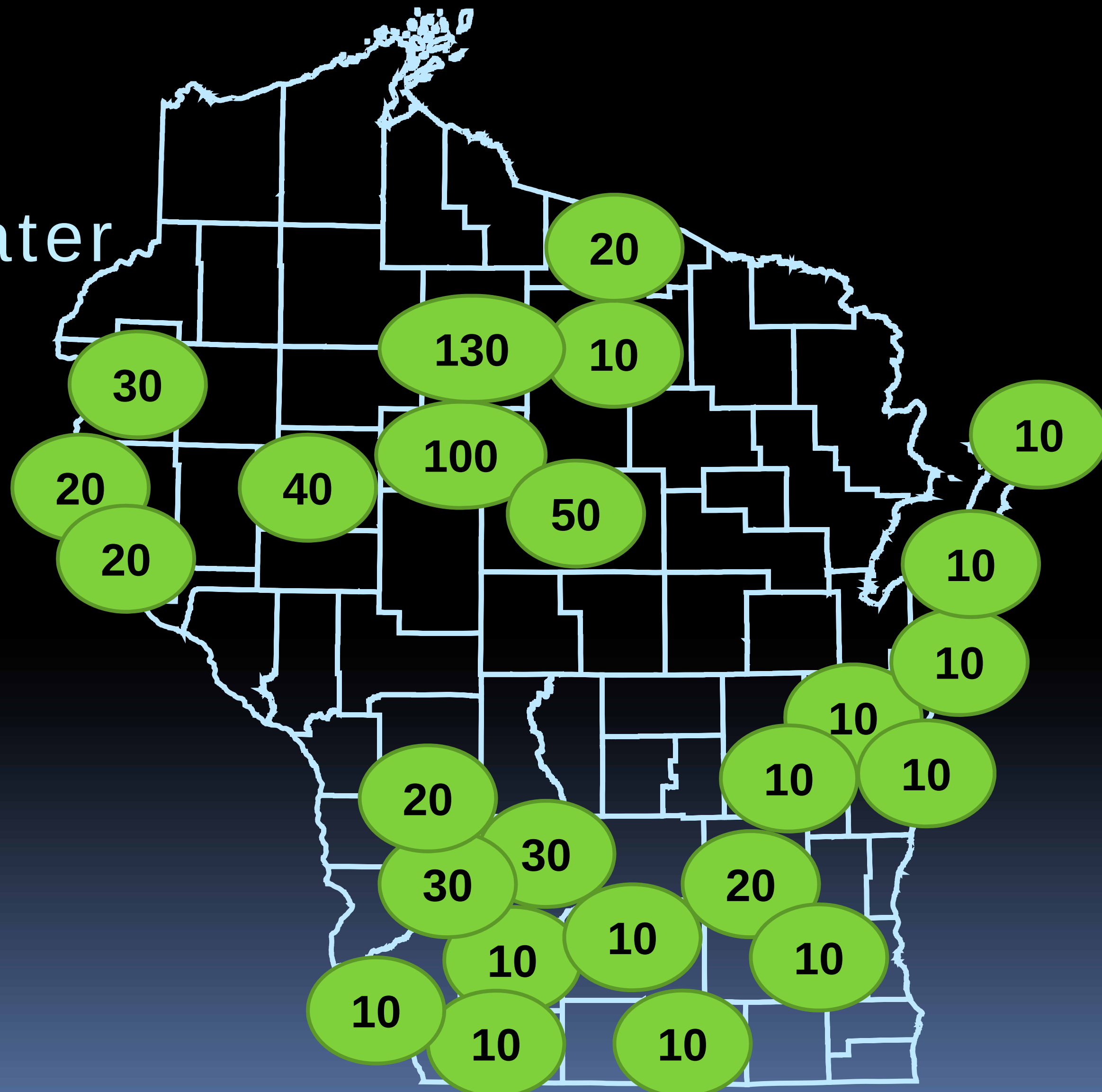


Does groundwater flow under lakes?



Groundwater P Conc?

Groundwater Median P µg/l

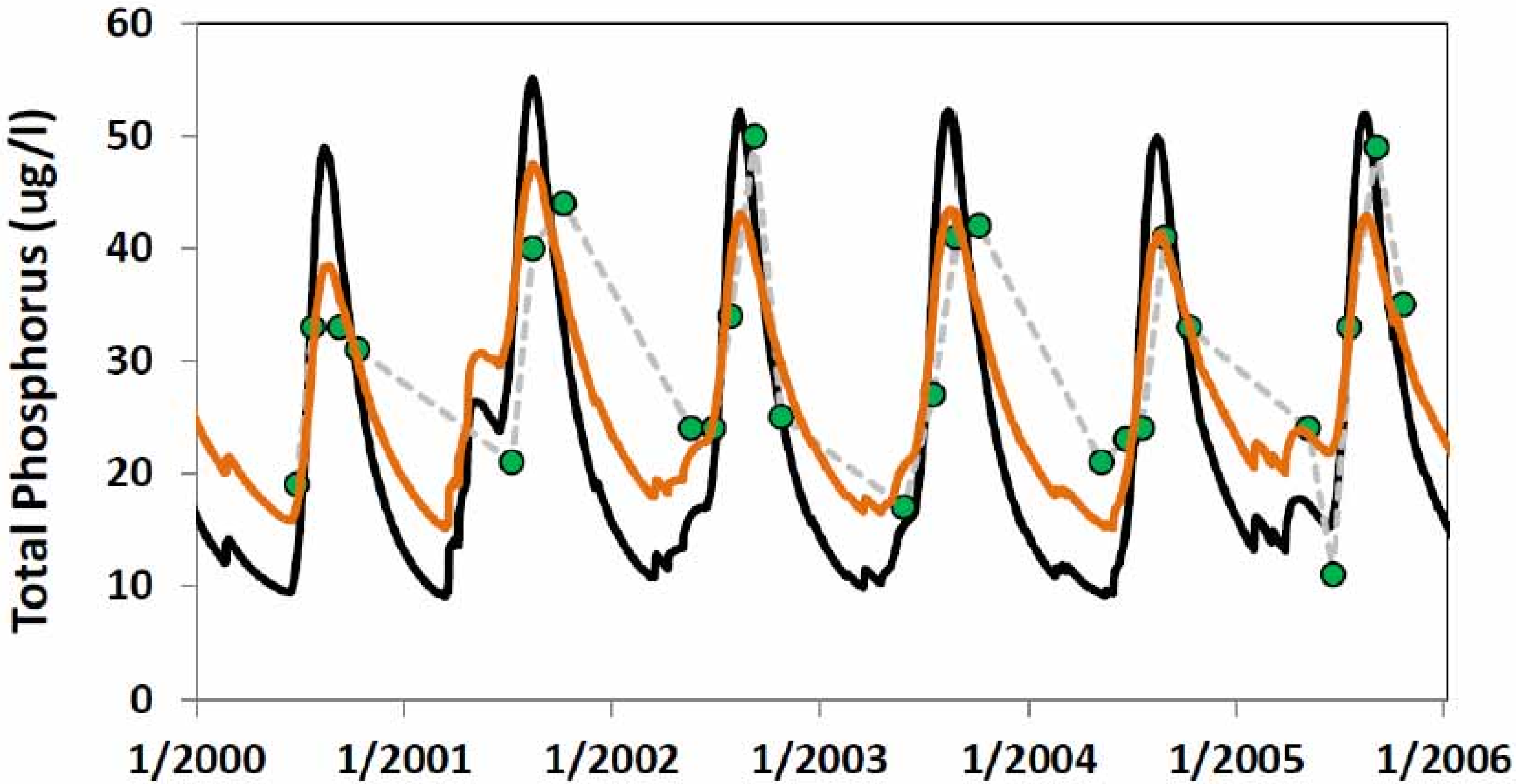


UWSP Drinking Water Program Data

What about Steady-State?

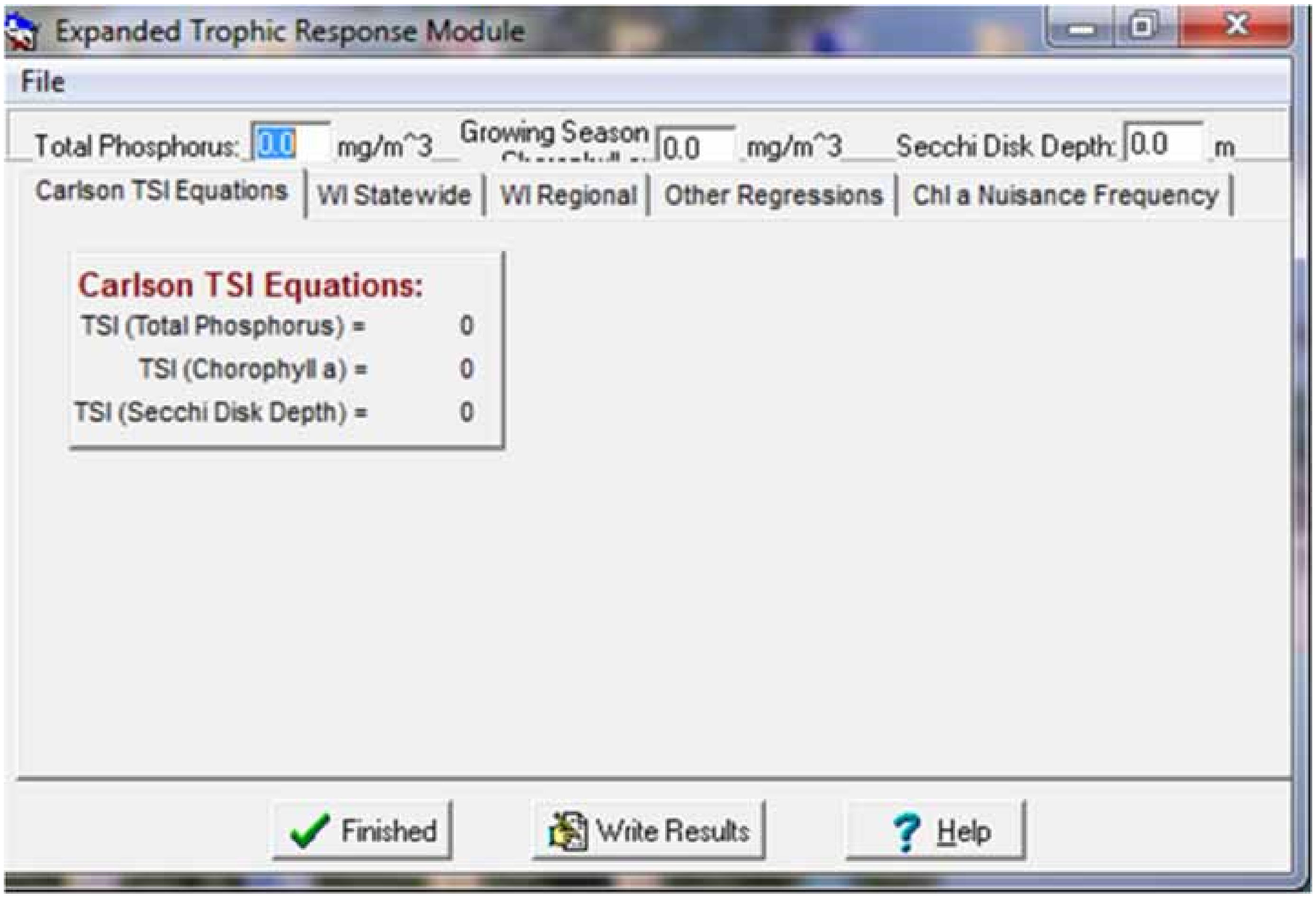
- Is that an important assumption?
- What about concentrations that vary during the growing season

Is this steady-state?



Extra Stuff

- Trophic Response Model Discussion?



- **The expanded trophic response menu in WiLMS** evaluates water body trophic response using total phosphorus, chlorophyll a and Secchi depth transparency. The purpose of this feature is to allow **stand-alone or model generated** trophic response conditions to be evaluated. This part of WiLMS consists of four evaluation components driven by total phosphorus, chlorophyll a and Secchi depth transparency inputs. The four evaluation components are:

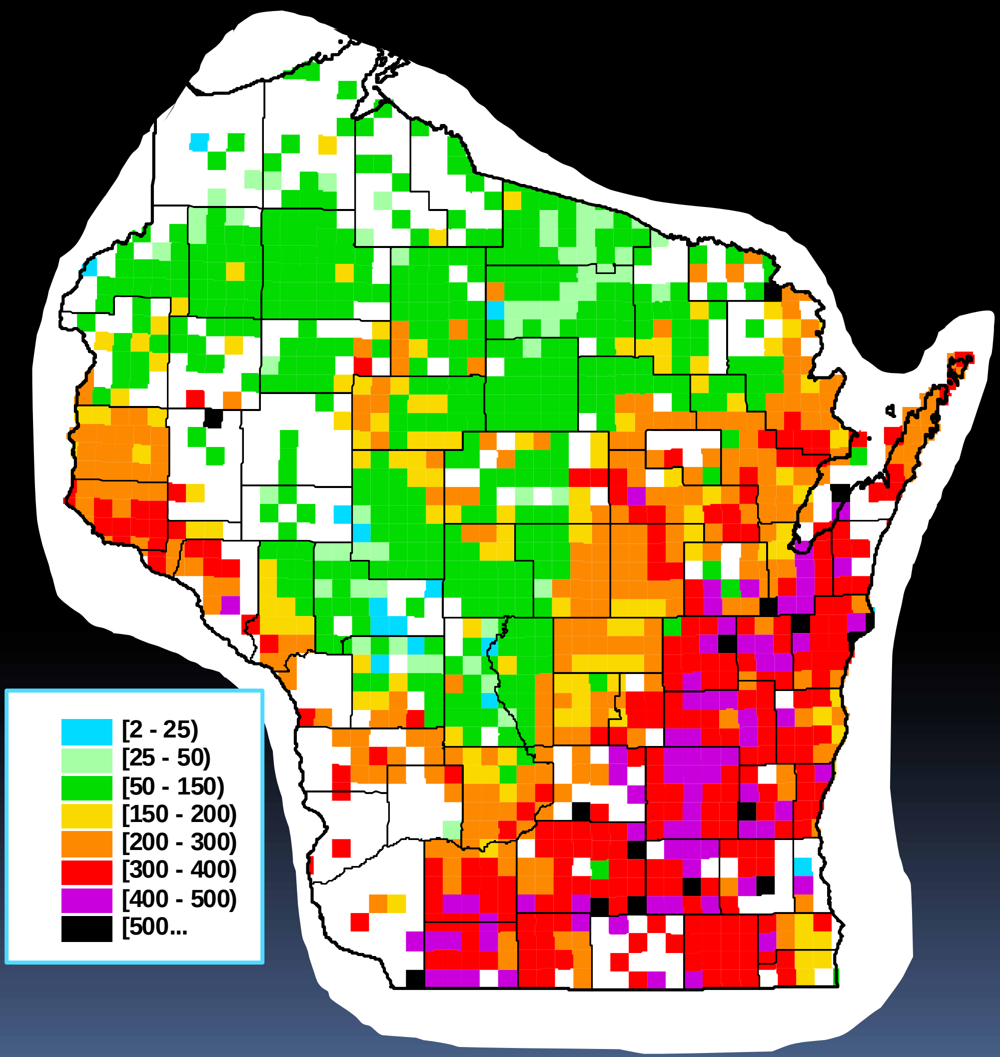
- *1. Carlson trophic state evaluation equations*

- *2. Wisconsin statewide predictive equations*

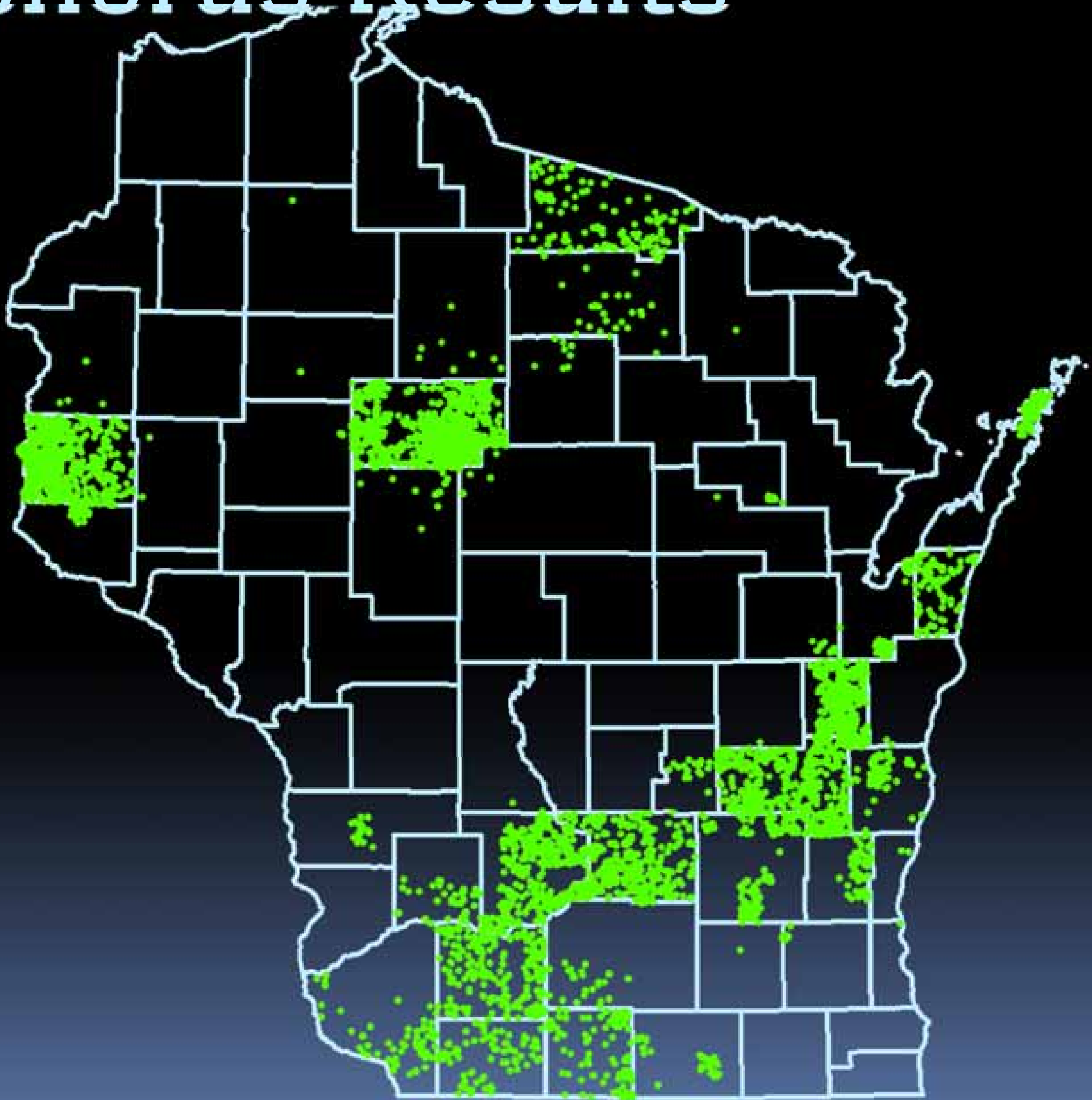
- *3. Wisconsin regions predictive equations*

- *4. Commonly used regressions including user defined.*

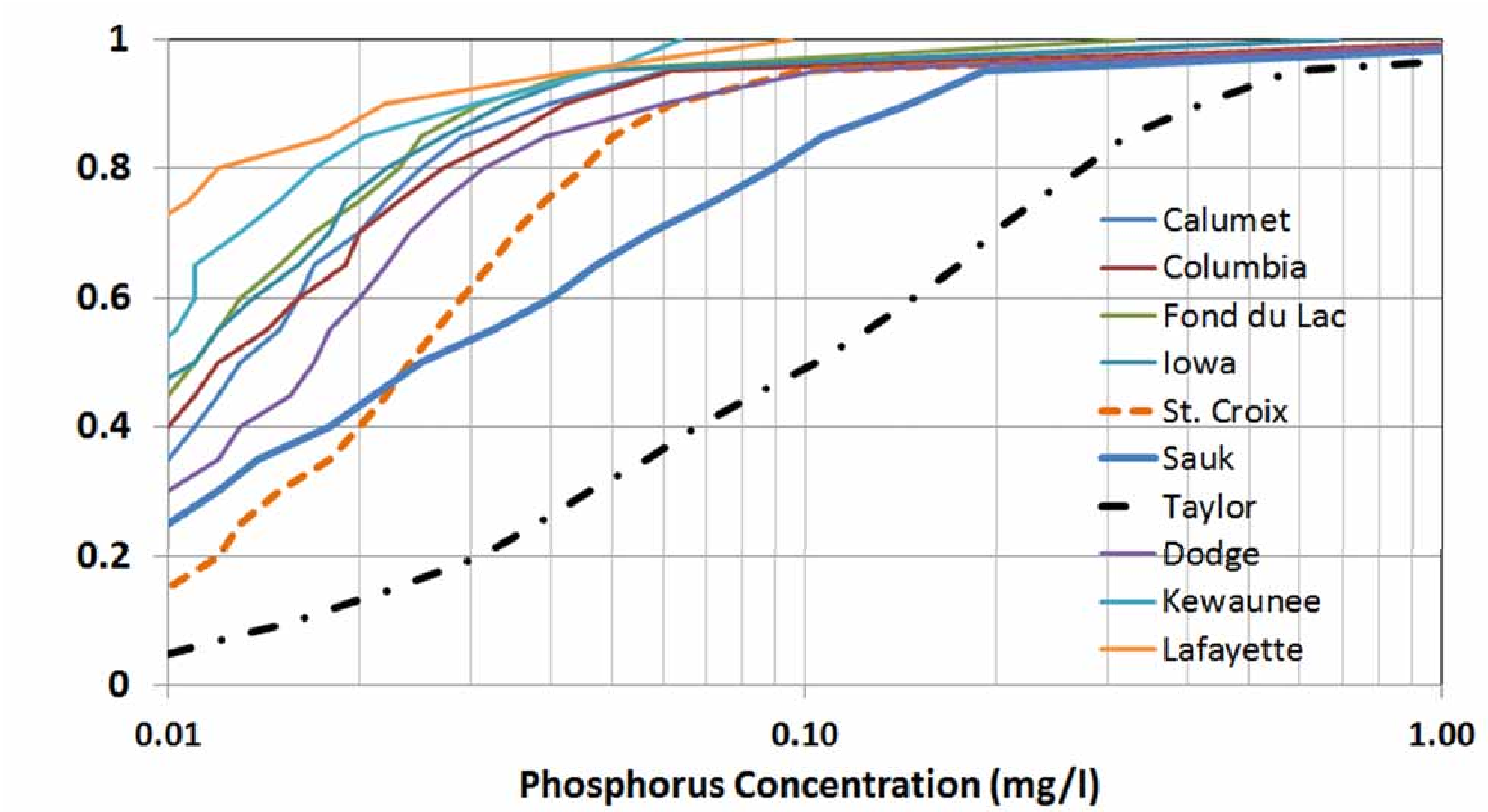
Wisconsin Private Well Data
Calcium & Magnesium (Hardness)



Phosphorus Results

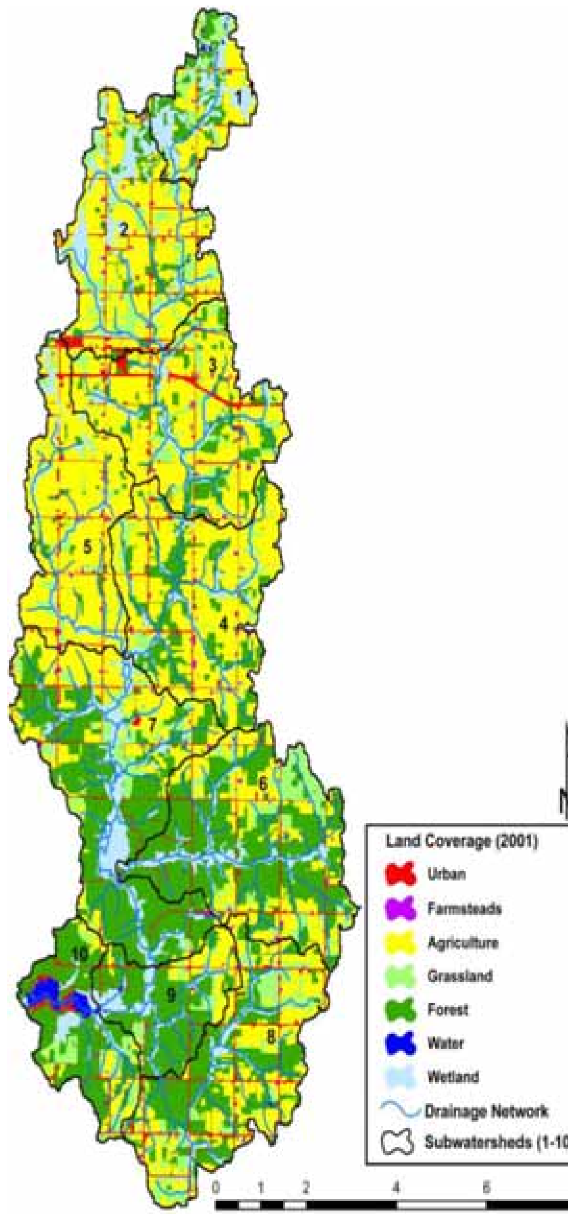


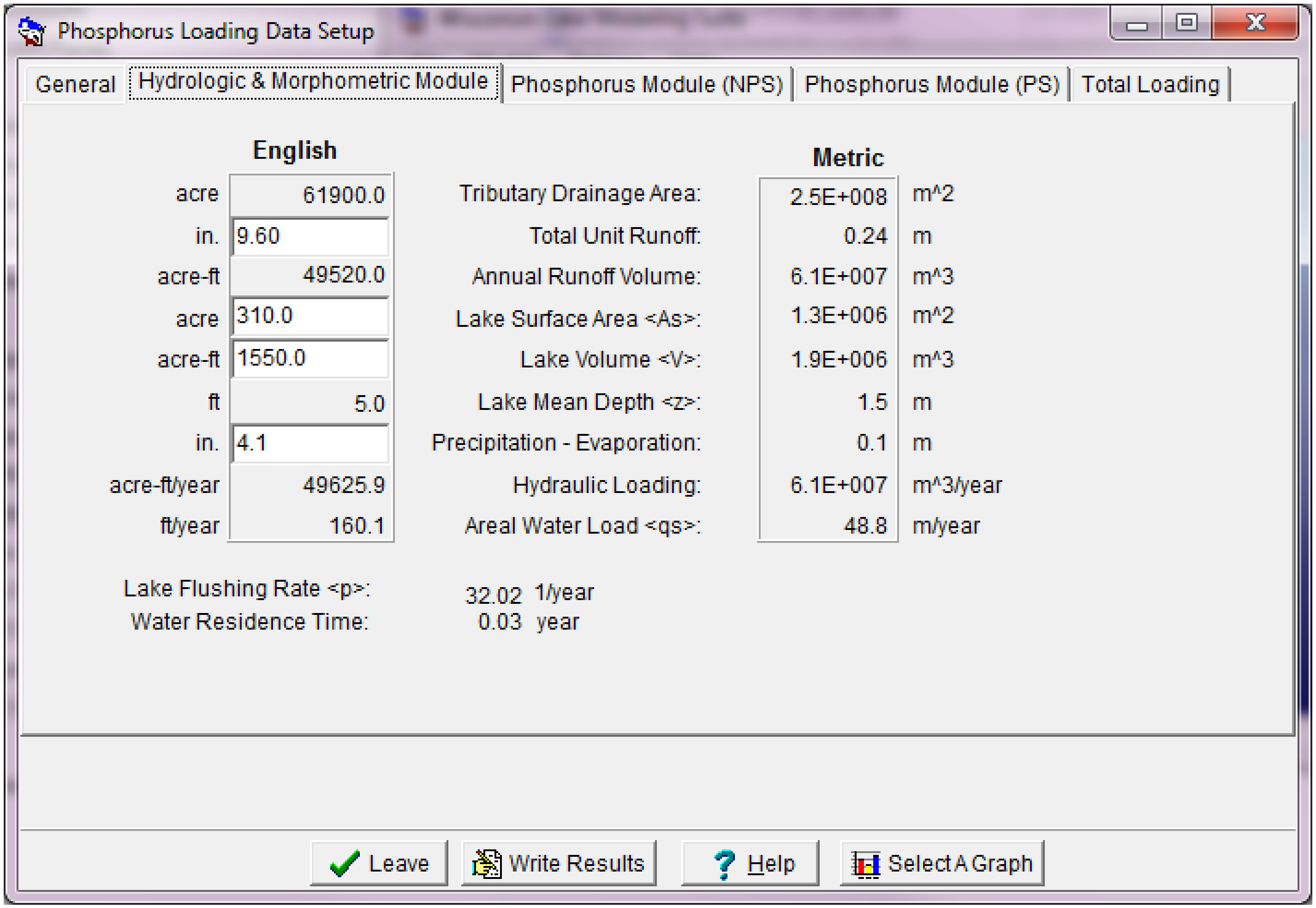
Phosphorus Distributions by County

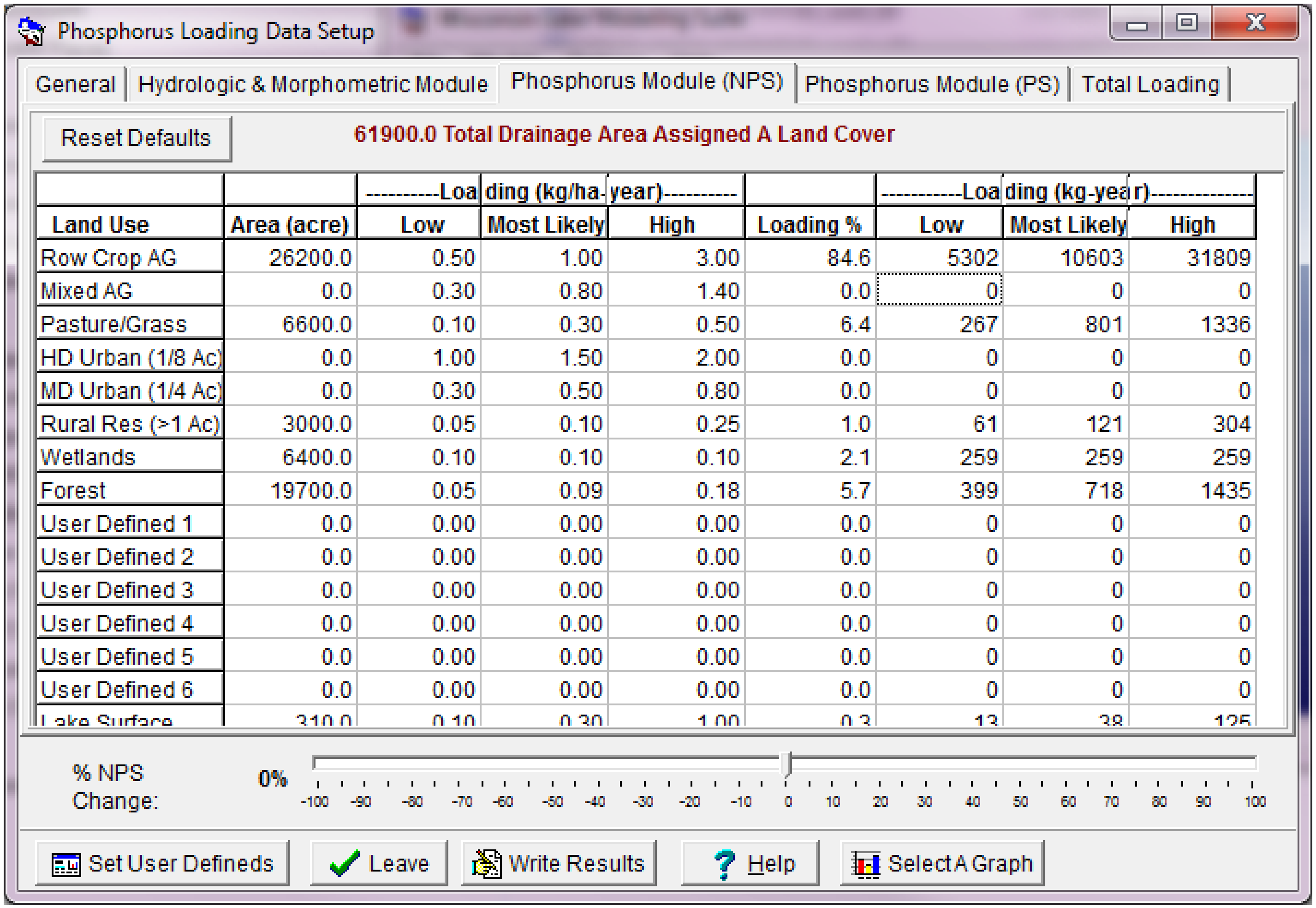


Extra Example

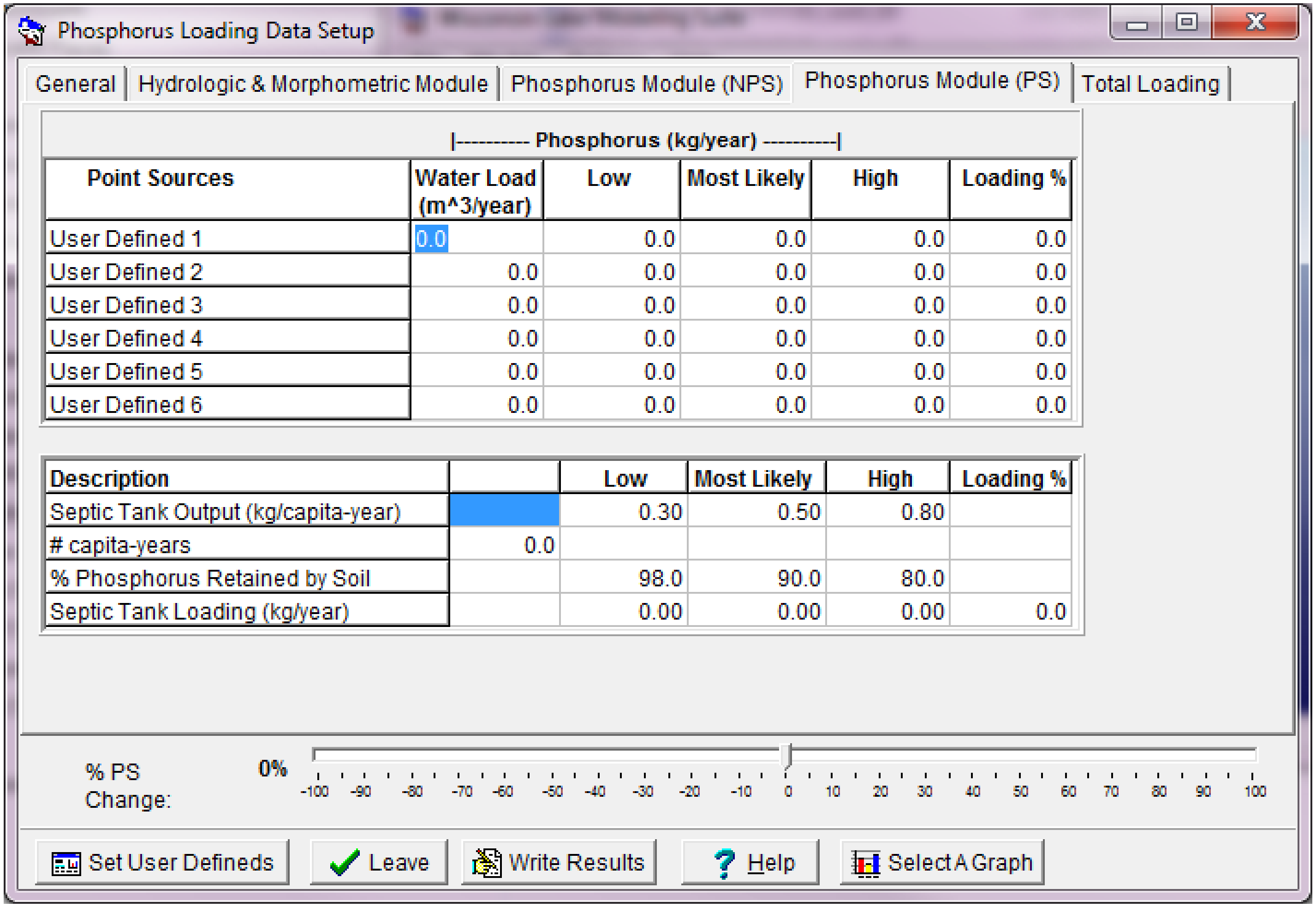
- 310 acre lake, Clark Co
- Mean depth 5 feet
- Average TP 110 ug/l (GSM/SPO)
- 61,900 acre watershed
  - Agriculture: 26,200
  - Grassland: 6,600
  - Forest: 19,700
  - Residential: 3,000
  - Water/Wetland: 6,400
- What is the areal water load?
- What is the water residence time?
- What is the predicted lake TP?

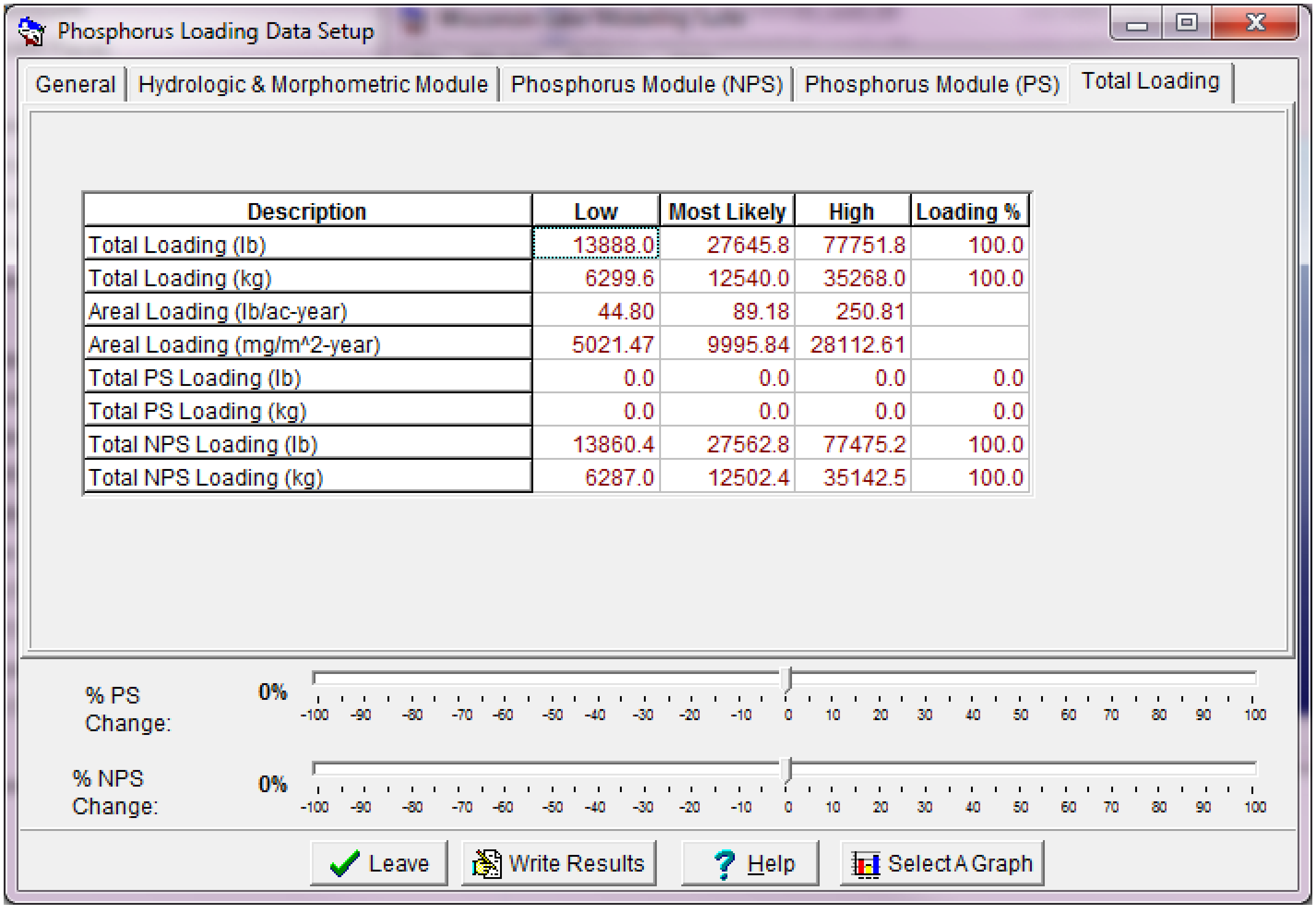



Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
English
Metric
acre 61900.0 Tributary Drainage Area: 2.5E+008 m^2
in. 9.60 Total Unit Runoff: 0.24 m
acre-ft 49520.0 Annual Runoff Volume: 6.1E+007 m^3
acre 310.0 Lake Surface Area <As>: 1.3E+006 m^2
acre-ft 1550.0 Lake Volume <V>: 1.9E+006 m^3
ft 5.0 Lake Mean Depth <z>: 1.5 m
in. 4.1 Precipitation - Evaporation: 0.1 m
acre-ft/year 49625.9 Hydraulic Loading: 6.1E+007 m^3/year
ft/year 160.1 Areal Water Load <qs>: 48.8 m/year
Lake Flushing Rate <p>: 32.02 1/year
Water Residence Time: 0.03 year
Leave
Write Results
Help
Select A Graph



		----------Loading (kg/ha-year)----------				----------Loading (kg-year)----------		
Land Use	Area (acre)	Low	Most Likely	High	Loading %	Low	Most Likely	High
Row Crop AG	26200.0	0.50	1.00	3.00	84.6	5302	10603	31809
Mixed AG	0.0	0.30	0.80	1.40	0.0	0	0	0
Pasture/Grass	6600.0	0.10	0.30	0.50	6.4	267	801	1336
HD Urban (1/8 Ac)	0.0	1.00	1.50	2.00	0.0	0	0	0
MD Urban (1/4 Ac)	0.0	0.30	0.50	0.80	0.0	0	0	0
Rural Res (>1 Ac)	3000.0	0.05	0.10	0.25	1.0	61	121	304
Wetlands	6400.0	0.10	0.10	0.10	2.1	259	259	259
Forest	19700.0	0.05	0.09	0.18	5.7	399	718	1435
User Defined 1	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 2	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 3	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 4	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 5	0.0	0.00	0.00	0.00	0.0	0	0	0
User Defined 6	0.0	0.00	0.00	0.00	0.0	0	0	0
Lake Surface	310.0	0.10	0.30	1.00	0.3	13	38	125


Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
|---------- Phosphorus (kg/year) ----------|
Point Sources
Water Load (m^3/year)
Low
Most Likely
High
Loading %
User Defined 1 0.0 0.0 0.0 0.0 0.0
User Defined 2 0.0 0.0 0.0 0.0 0.0
User Defined 3 0.0 0.0 0.0 0.0 0.0
User Defined 4 0.0 0.0 0.0 0.0 0.0
User Defined 5 0.0 0.0 0.0 0.0 0.0
User Defined 6 0.0 0.0 0.0 0.0 0.0
Description
Low
Most Likely
High
Loading %
Septic Tank Output (kg/capita-year) 0.30 0.50 0.80
capita-years 0.0
% Phosphorus Retained by Soil 98.0 90.0 80.0
Septic Tank Loading (kg/year) 0.00 0.00 0.00 0.0
% PS Change:
0%
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
Set User Defineds
Leave
Write Results
Help
Select A Graph


Phosphorus Loading Data Setup
General
Hydrologic & Morphometric Module
Phosphorus Module (NPS)
Phosphorus Module (PS)
Total Loading
Description | Low | Most Likely | High | Loading %
Total Loading (lb) | 13888.0 | 27645.8 | 77751.8 | 100.0
Total Loading (kg) | 6299.6 | 12540.0 | 35268.0 | 100.0
Areal Loading (lb/ac-year) | 44.80 | 89.18 | 250.81 |
Areal Loading (mg/m^2-year) | 5021.47 | 9995.84 | 28112.61 |
Total PS Loading (lb) | 0.0 | 0.0 | 0.0 | 0.0
Total PS Loading (kg) | 0.0 | 0.0 | 0.0 | 0.0
Total NPS Loading (lb) | 13860.4 | 27562.8 | 77475.2 | 100.0
Total NPS Loading (kg) | 6287.0 | 12502.4 | 35142.5 | 100.0
% PS Change:
0%
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
% NPS Change:
0%
-100 -90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100
Leave
Write Results
Help
Select A Graph

Phosphorus Predictions & Uncertainty Analysis

Observed spring overturn total phosphorus (SPO): 110.0 mg/m^3

Observed growing season mean phosphorus (GSM): 110.0 mg/m^3

Back calculation for SPO total phosphorus: 0.0 mg/m^3

Back calculation GSM phosphorus: 0.0 mg/m^3

Nurnberg Model Input - Est. Gross Int. Loading: 0 kg

% Confidence Range: 70

Lake Phosphorus Model	Low Total P (mg/m^3)	Most Likely Total P (mg/m^3)	High Total P (mg/m^3)	Predicted -Observed (mg/m^3)	% Dif.	Confidence Lower Bound	Confidence Upper Bound	Parameter Fit?	Back Calculation (kg/year)	Model Type
Walker, 1987 Reservoir	66	132	371	22	20	78	285	Tw	0	GSM
Canfield-Bachmann, 1981 Natural Lake	85	160	396	50	45	50	461	L	1	GSM
Canfield-Bachmann, 1981 Artificial Lake	72	126	267	16	15	39	363	FIT	1	GSM
Rechow, 1979 General	72	142	401	32	29	81	310	P	0	GSM
Rechow, 1977 Anoxic	91	180	507	70	64	108	388	FIT	0	GSM
Rechow, 1977 water load<50m/year	53	106	298	-4	-4	61	230	P	0	GSM
Rechow, 1977 water load>50m/year	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Walker, 1977 General	88	175	492	65	59	88	394	FIT	0	SPO
Vollenweider, 1982 Combined OECD	61	107	249	-3	-3	53	220	FIT	0	ANN
Dillon-Rigler-Kirchner	66	131	368	21	19	78	282	P L	0	SPO
Vollenweider, 1982 Shallow Lake/Res.	52	96	238	-14	-13	47	202	FIT	0	ANN
Larsen-Mercier, 1976	87	174	490	64	58	107	373	P Pin p	0	SPO
Nurnberg, 1984 Oxic	80	159	447	49	45	84	353	P L	0	ANN

Finished | Write Results | Display Parameter Values | Help

Internal Loading

- What is it?
- Importance

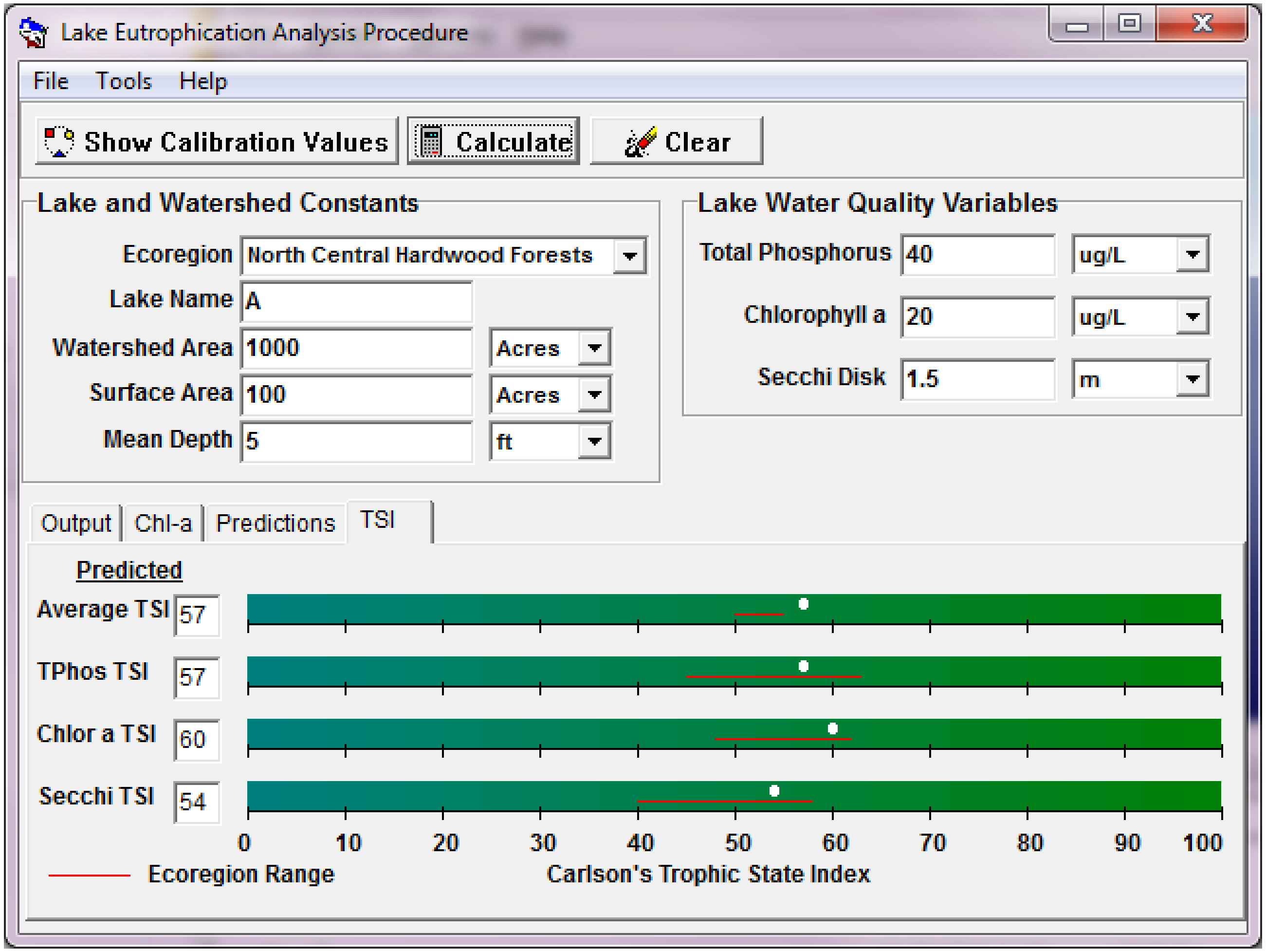
Internal Loading

- Estimating
  - Internal Load Estimator
  - Iterate using Nurnberg loading
- Prediction Options
  - Using lake response model that includes internal load (net reduced retention)
  - Using Nurnberg Oxic + Internal Model

Discussion on LEAP

(Lake Eutrophication Analysis Procedure)

- Tools ... Ecoregion Setup
- Pick state
- Pick ecoregion
- Enter lake & watershed information
- Enter water quality information



Lake Eutrophication Analysis Procedure
File Tools Help
Show Calibration Values
Calculate
Clear
Lake and Watershed Constants
Ecoregion North Central Hardwood Forests
Lake Name A
Watershed Area 1000 Acres
Surface Area 100 Acres
Mean Depth 5 ft
Lake Water Quality Variables
Total Phosphorus 40 ug/L
Chlorophyll a 20 ug/L
Secchi Disk 1.5 m
Output
Chl-a
Predictions
TSI
Predicted
Average TSI 57
TPhos TSI 57
Chlor a TSI 60
Secchi TSI 54
0 10 20 30 40 50 60 70 80 90 100
Ecoregion Range
Carlson's Trophic State Index

LEAP

- Lake Eutrophication Analysis Procedure
- Reference- Wilson and Walker, 1989
  - MNLEAP
  - page 154

LEAP

- Inflow TP / Mean Depth / Residence Time
  - TP
    - Chl a
      - Secchi

Applications (S. Heiskary)

- How is a lake doing for its ecoregion and morphometry
- Quick estimates of water and nutrient budgets
- Flag lakes for additional study
- Compare TP / Chl-a / Secchi observed versus the reference lakes
- Estimate background P, Chl-a, Secchi
- Set goals? Along with other info

LEAP

- Average precip, evap, runoff
- Water Outflow = (runoff*wshed area) – (lake area*(precip-evap))
- P Loading = (lake area*atm dep) + (wshed area*runoff*regional stream P)
- Canfield & Bachmann (1981) P Model
- Some type of TP/Chl a/Secchi Model
  - State-wide set (MN)
  - WI?

According to SH

- Maybe best for dimictic lakes in less impacted regions
- Probably most difficult to use for polymictic lakes with significant internal load, turbid lakes, seepage lakes

Example Problem

- 112 ha lake (275 acre)
- 750 ha watershed (1800 acre)
  - 50% Forested
  - 50% Row Crop Agriculture
- Overturn P of 30 ug/l
- Growing Season Mean 27 ug/l


A little discussion on other watershed models...SWAT

Briefly… Soil and Water Assessment Tool (brc.tamus.edu/swat)

Daily Time Step

HRU – Subbasin - Reach

Hydrology – NRCS CN

Sediment – Modified USLE

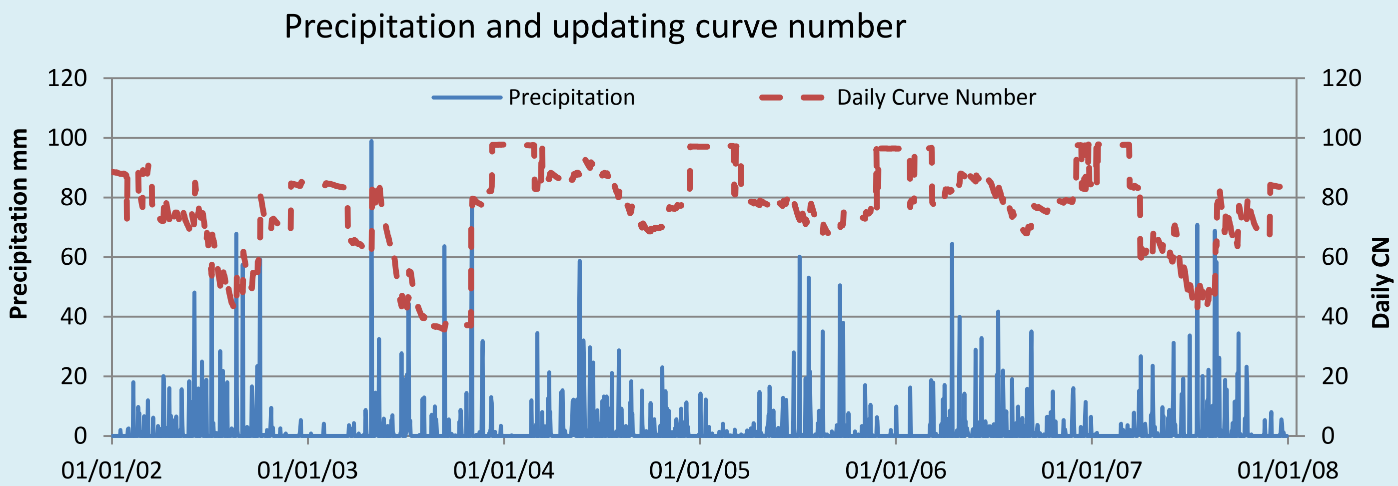
Phosphorus – Link Runoff and Sediment to P "pools"

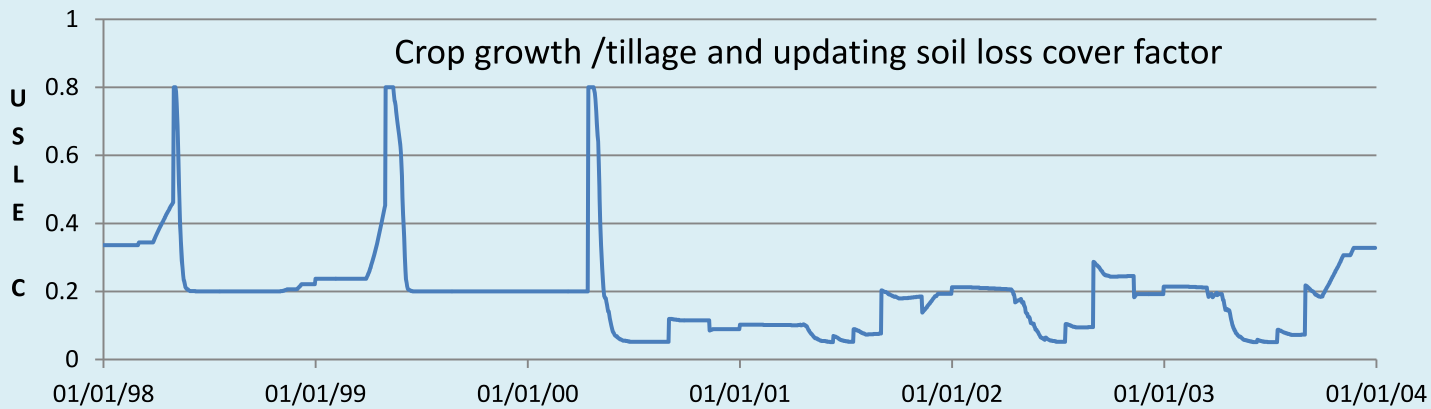
SWAT2000 (w/ revisions)

SWAT2005

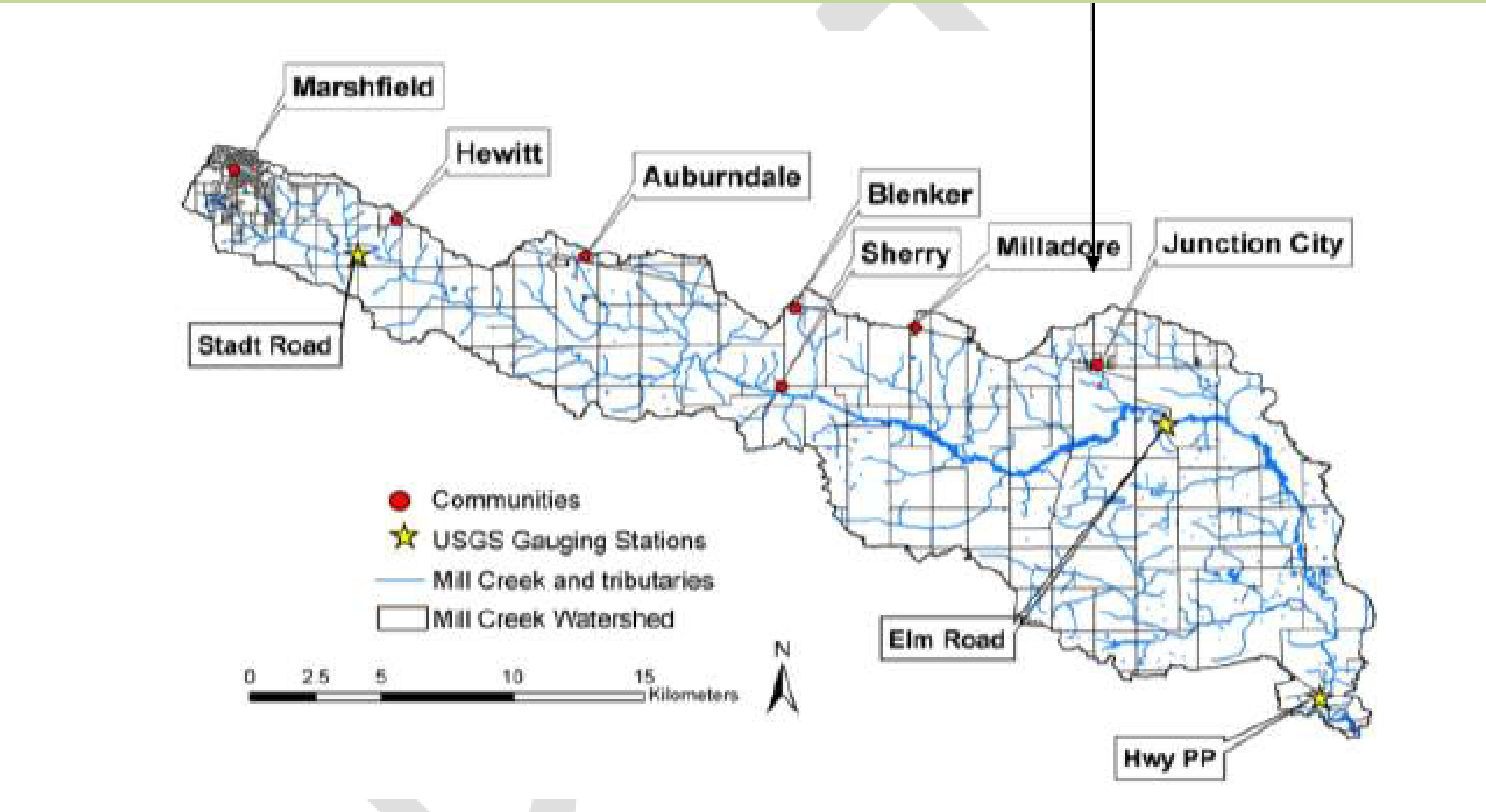
Primarily use in DOS

Excel VB for pre & post-processing

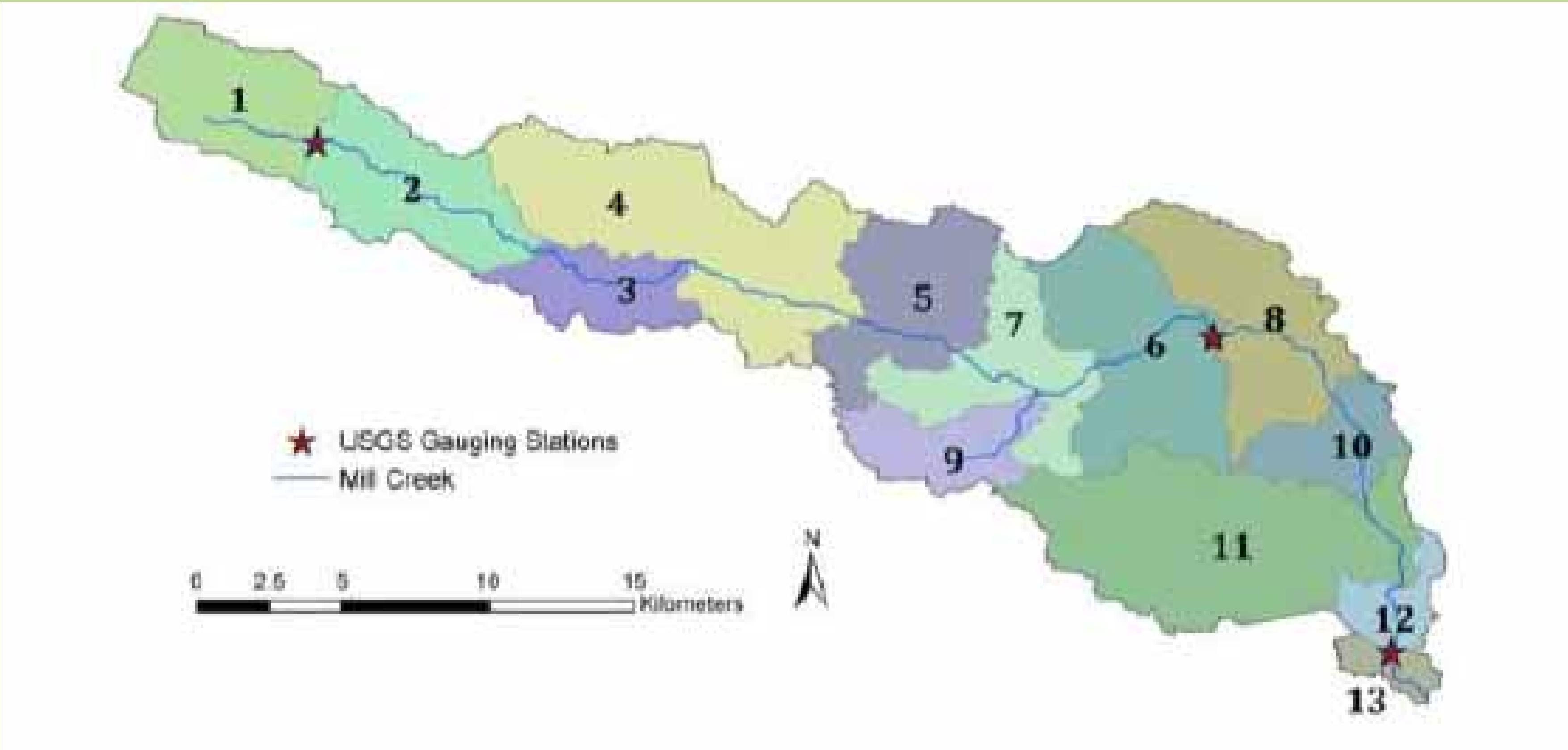




Mill Creek


Marshfield
Hewitt
Auburndale
Blenker
Sherry
Milladore
Junction City
Stadt Road
Elm Road
Hwy PP
Communities
USGS Gauging Stations
Mill Creek and tributaries
Mill Creek Watershed
0 2.5 5 10 15 Kilometers
N

Divide into "subbasins"



Divide into "hydrologic response units" (land mgt & soils)

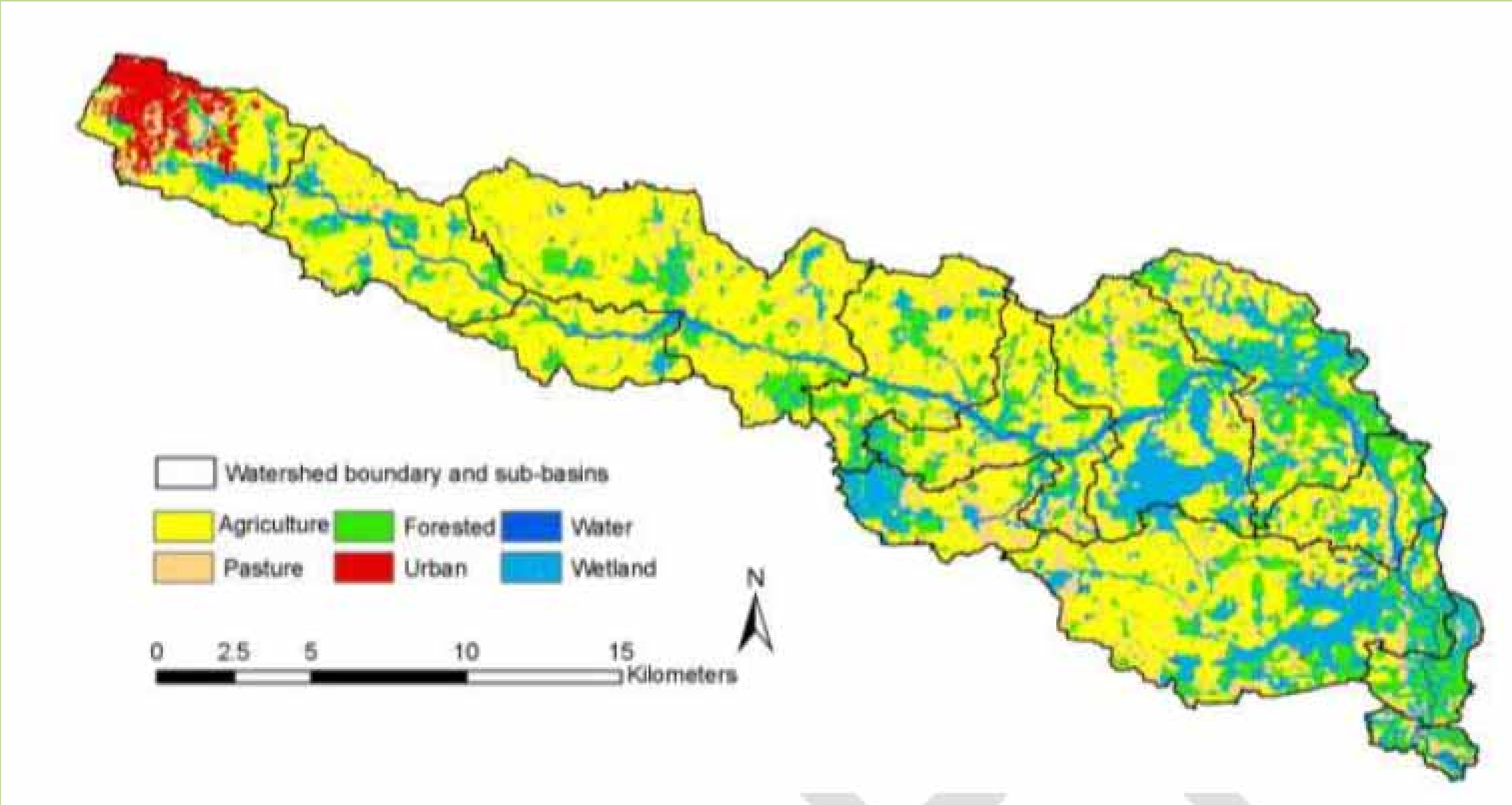


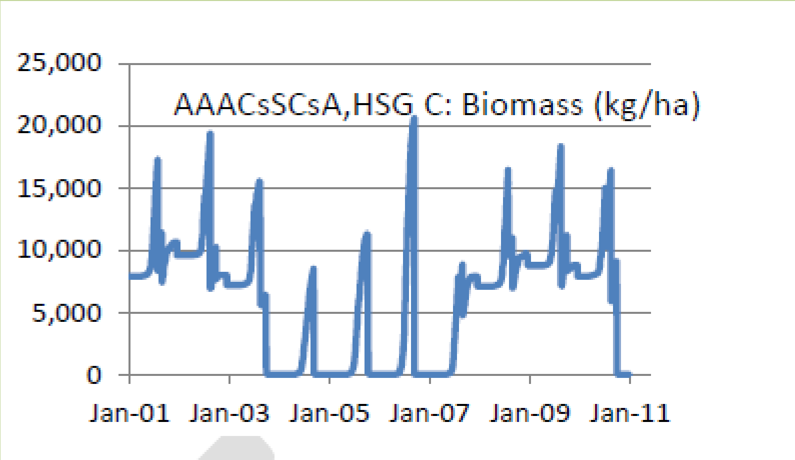
Figure out what's going on in the watershed… create model inputs

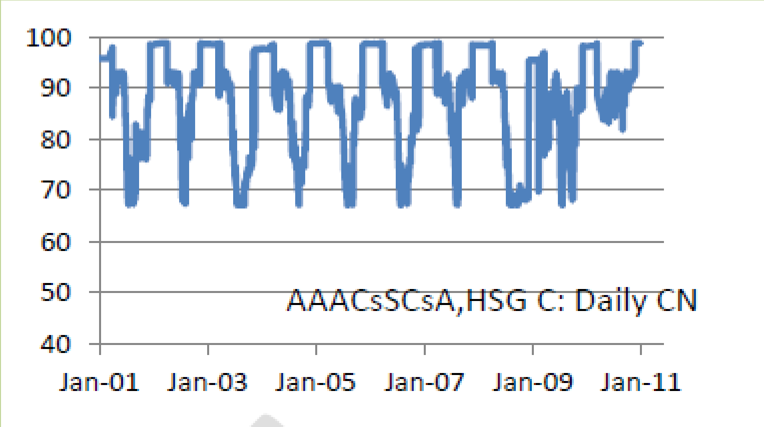
Table 3 Four rotation schedules used in the Mill Creek simulation

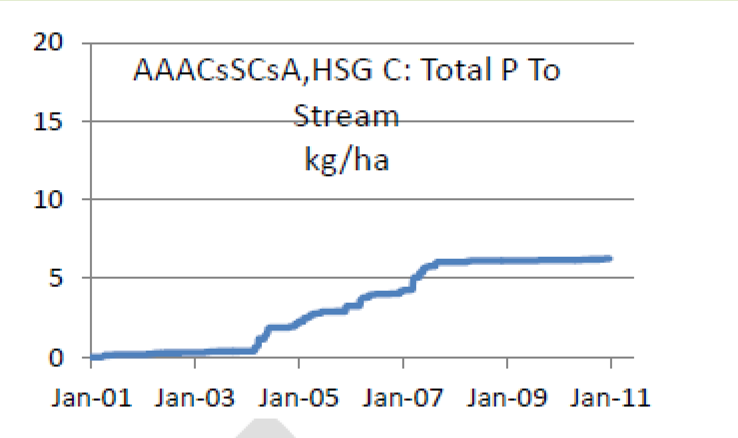
	Rotation A			Rotation B			Rotation C			Rotation D		
Year	**Crop**	**Operation**[1]	**Date**	**Crop**	**Operation**[1]	**Date**	**Crop**	**Operation**[1]	**Date**	**Crop**	**Operation**[1]	**Date**
1	Cs	MS	Jan-May	A	Harvest	6/8	C	Spread	5/1	A	Till-Chisel	4/20
		Till-MB	5/3		Harvest	7/1		Till-Chisel	5/3		Spread	5/1
		Plant	5/7		Harvest	8/1		Plant	5/7		Plant	5/15
		Harvest/kill	9/15		Harvest	9/1		Cultivate	6/10		Harvest	7/1
		MS	Oct - Dec					Harvest/kill	10/15		Harvest	8/1
								Spread	10/18		Harvest	9/1
2	C	Spread	5/1	A	Harvest	6/8	C	MS	Jan-May	A	Harvest	6/8
		Till-Chisel	5/3		Harvest	7/10		Till-MB	5/3		Harvest	7/10
		Plant	5/7		Harvest	8/20		Plant	5/7		Harvest	8/20
		Cultivate	6/10		Harvest	10/1		Cultivate	6/10			
		Harvest/kill	9/15					Harvest/kill	10/15			
		Spread	10/1					MS	Oct - Dec			
3	Cs	Spread	5/1	A	Harvest	6/8	S	Spread	5/1	A	MS	Jan- May
		Till-Chisel	5/3		Harvest	7/10		Till -Disk	5/2		Harvest	6/8
		Plant	5/7		Harvest	8/20		Plant	5/20		Harvest	7/10
		Cultivate	6/10		Harvest/kill	10/1		Harvest/kill	10/15		Spread	7/11
		Harvest/kill	10/15					Spread	10/18		Harvest	8/20
		Spread	10/18					Till-Chisel	10/20		Till-Chisel	10/3
											MS	Oct-Dec

Then add water– combine daily rainfall and land management

- simulate – crop growth, runoff etc…

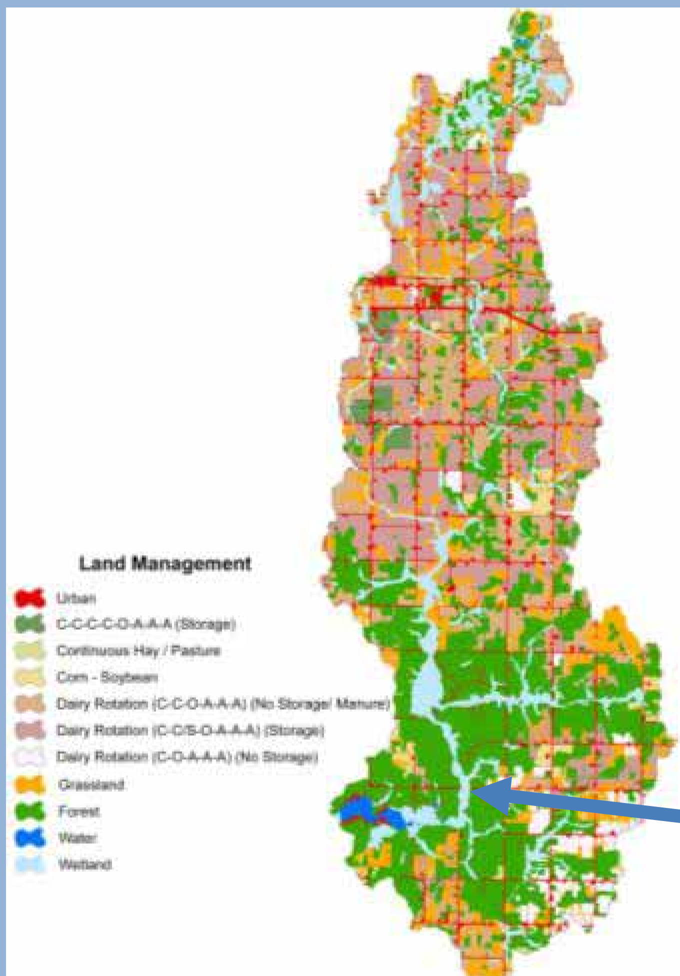


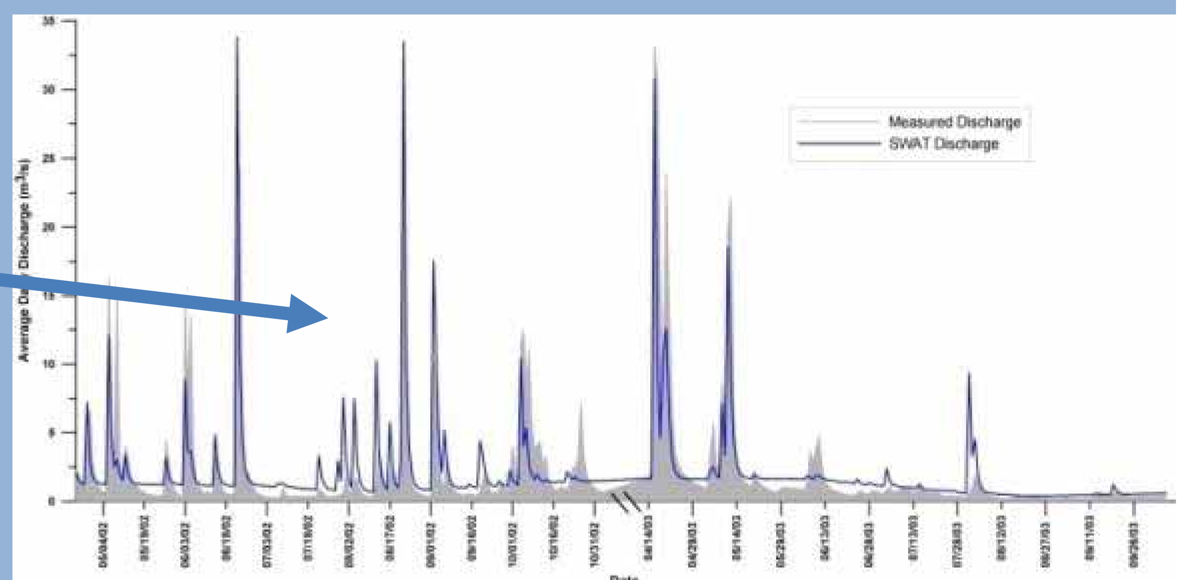




Example- Mead Lake

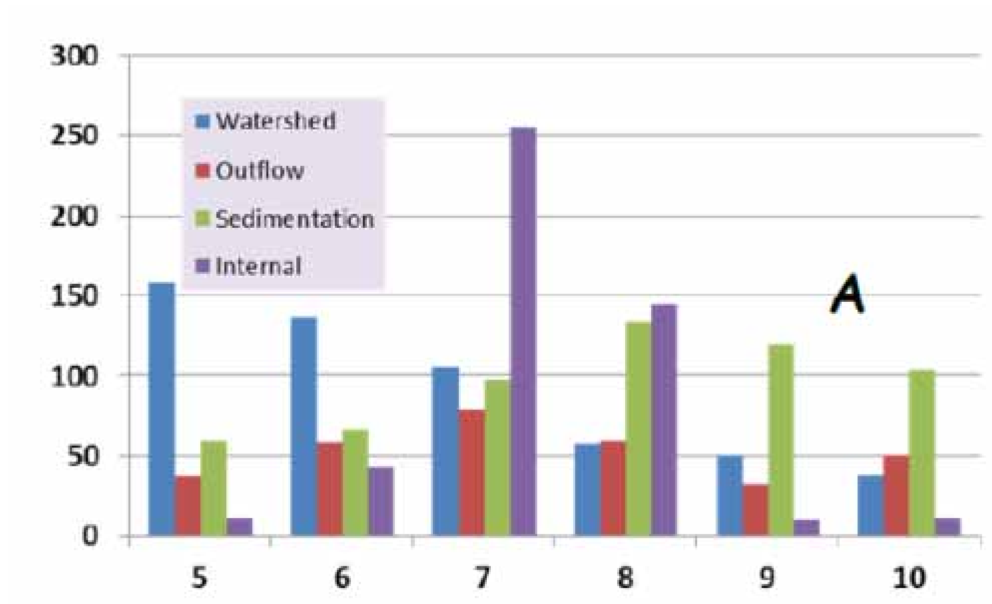
- Watershed
  - **250 km^2**
- SWAT Model
  - **10 subbasins**
  - **119 HRUs**
- Calibration
  - **2 years flow/ TSS / TP**
  - **Matched total w/ CN**
  - **Adjusting USLEP, Filterw**
  - **Tried to fit P fractions and P Content**



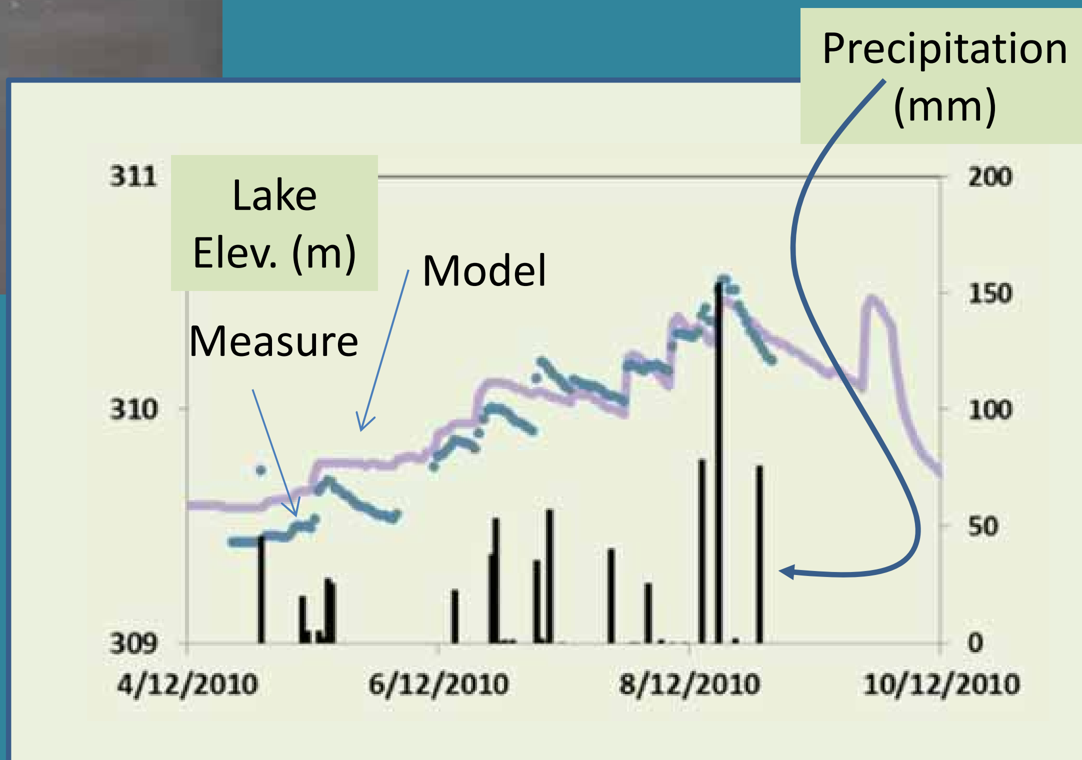


Usefulness of shorter time-step?

- Partition seasonal loads?
  - Here looking at the monthly P (in kilograms) for watershed loading (blue)



Daily Tracking– Lake Volume/Depth

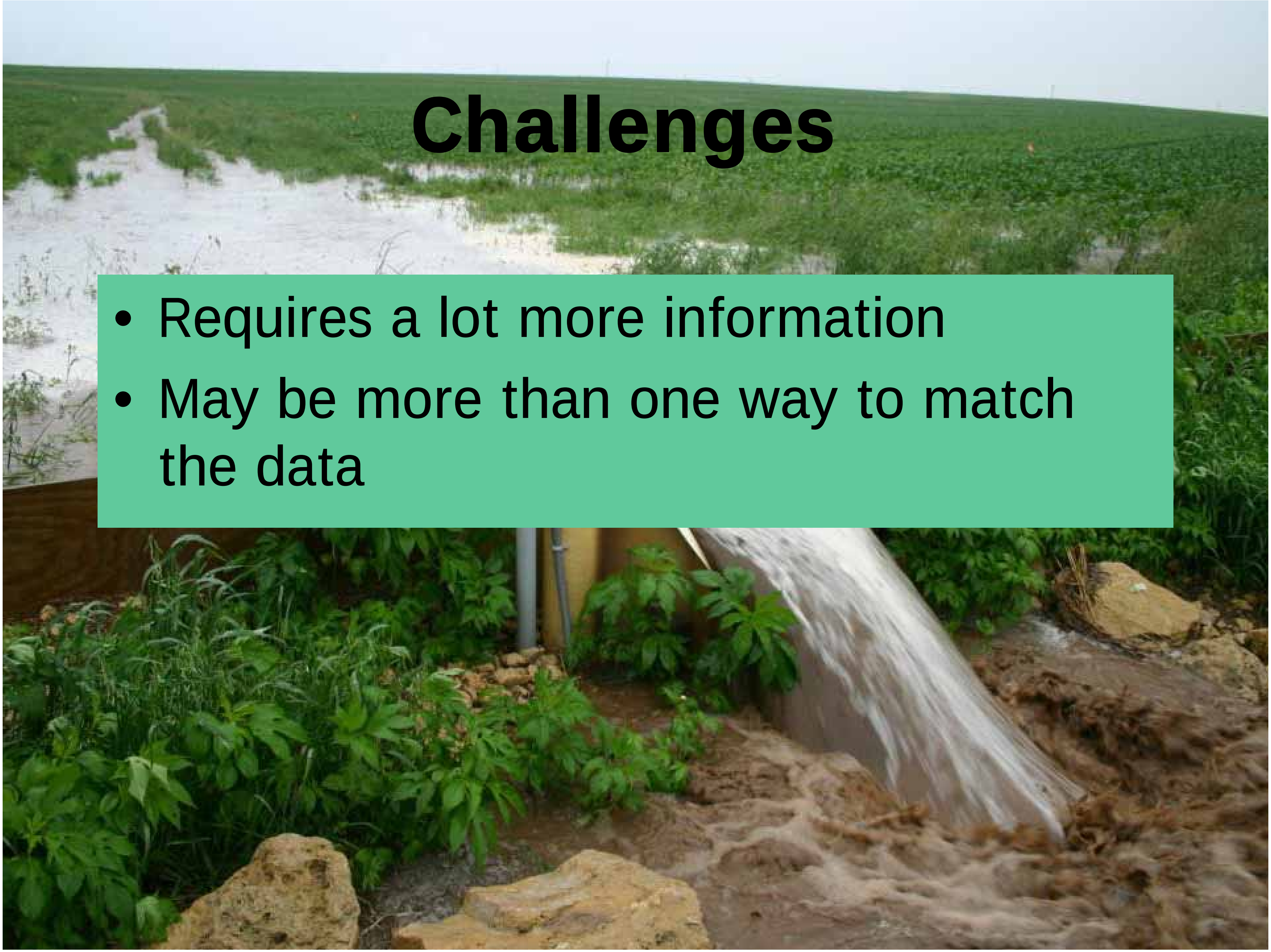


Why more detail on the model?

- Comparing effect of land management on P export.

Table 3. Simulated Phosphorus Export Under Different Management Scenarios[1]

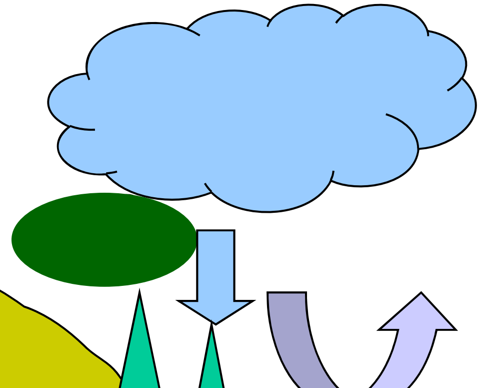
Scenario	Total Phosphorus kg/May-Sept / (lb/May-Sept) / Reduction %
Baseline	1703 / (3743)
Reducing Soil P (25 ppm)	1470 / (3231) / 14%
Reducing Soil Erosion (50% reduction in USLE P)	1465 / (3220) / 14%



Challenges

- Requires a lot more information
- May be more than one way to match the data

SURFACE RUNOFF



Study	Surface Runoff Total P (mg/l)
Graczyk et al., 2003	0.3-1.1
Garn, 2002	1.8-4.0
Stuntebeck, 2002	1.1-1.3
Bannerman, 1996	0.3
Waschbusch et al,	1.0-1.5

Combine some runoff measurements

- Graczyk, Greb– Woods / Lawn
- Pioneer Farm – Corn/Alfalfa