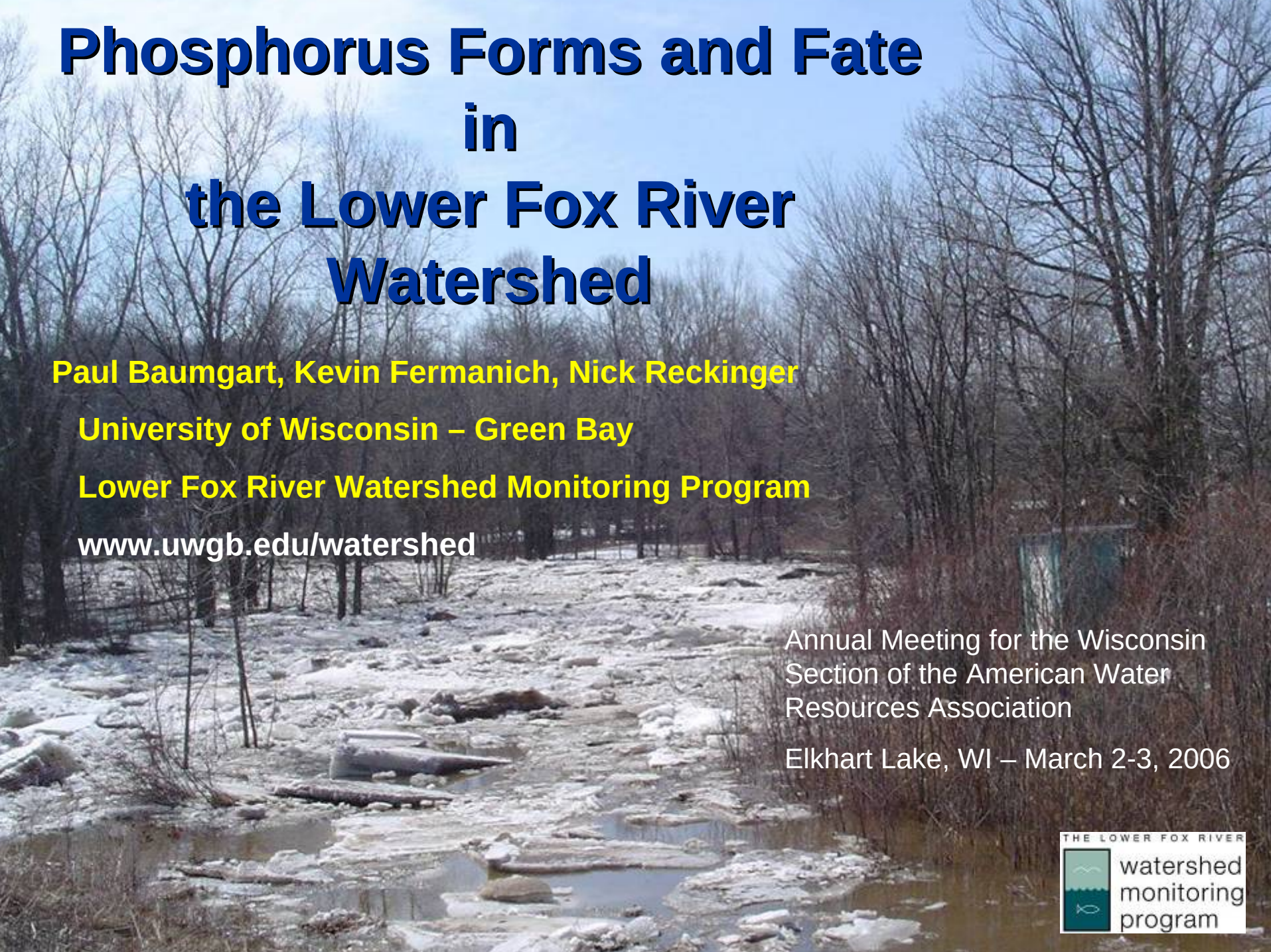
Phosphorus Forms and Fate in the Lower Fox River Watershed

Paul Baumgart, Kevin Fermanich, Nick Reckinger

University of Wisconsin – Green Bay

Lower Fox River Watershed Monitoring Program

www.uwgb.edu/watershed



Annual Meeting for the Wisconsin Section of the American Water Resources Association

Elkhart Lake, WI – March 2-3, 2006

THE LOWER FOX RIVER watershed monitoring program

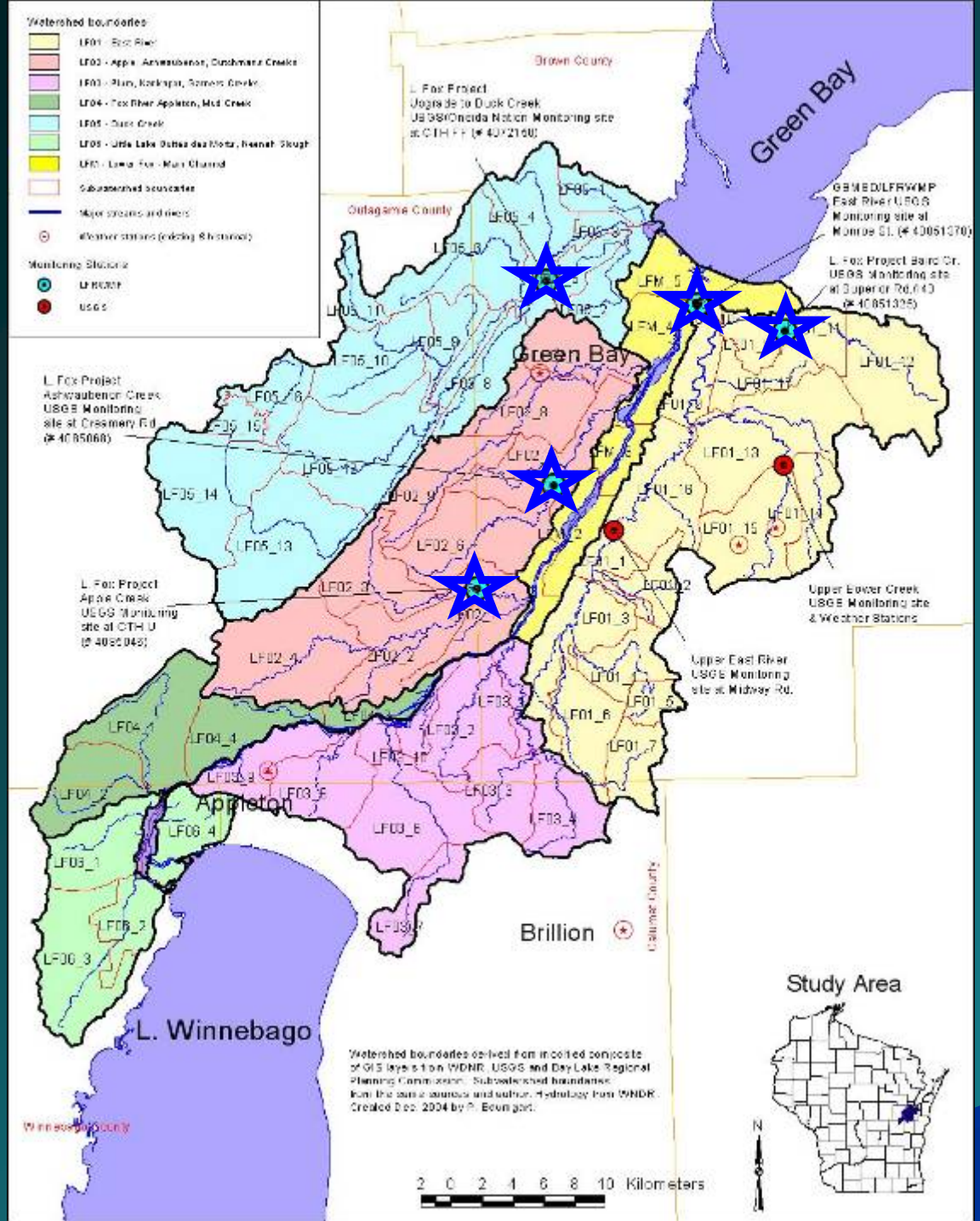
Primary Goal

Better understand the form of phosphorus present so we can predict impact of phosphorus reduction strategies within Lower Fox River Sub-basin (1580 km^2)

Presentation Outline

- Lower Fox River Sub-basin Description and Monitoring Program
- Phosphorus Forms Study Background
- Objectives
- Methods: Apple Creek Study
- Data summary and Statistical Analysis
- Conclusions

Lower Fox River Sub-basin Description and Monitoring Program

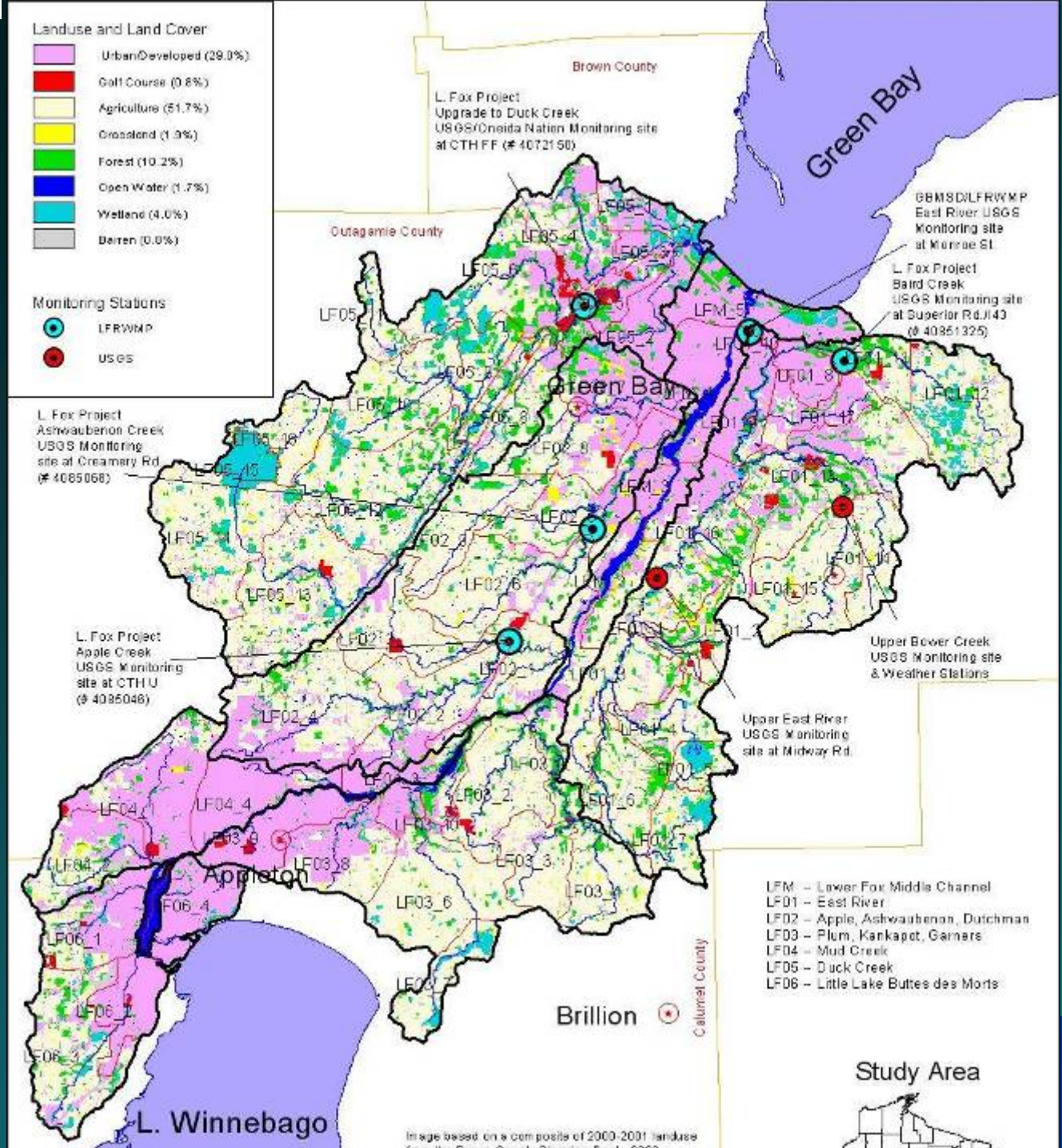


Lower Fox River watersheds, subwatersheds, and primary project monitoring stations

Overall Project Goal

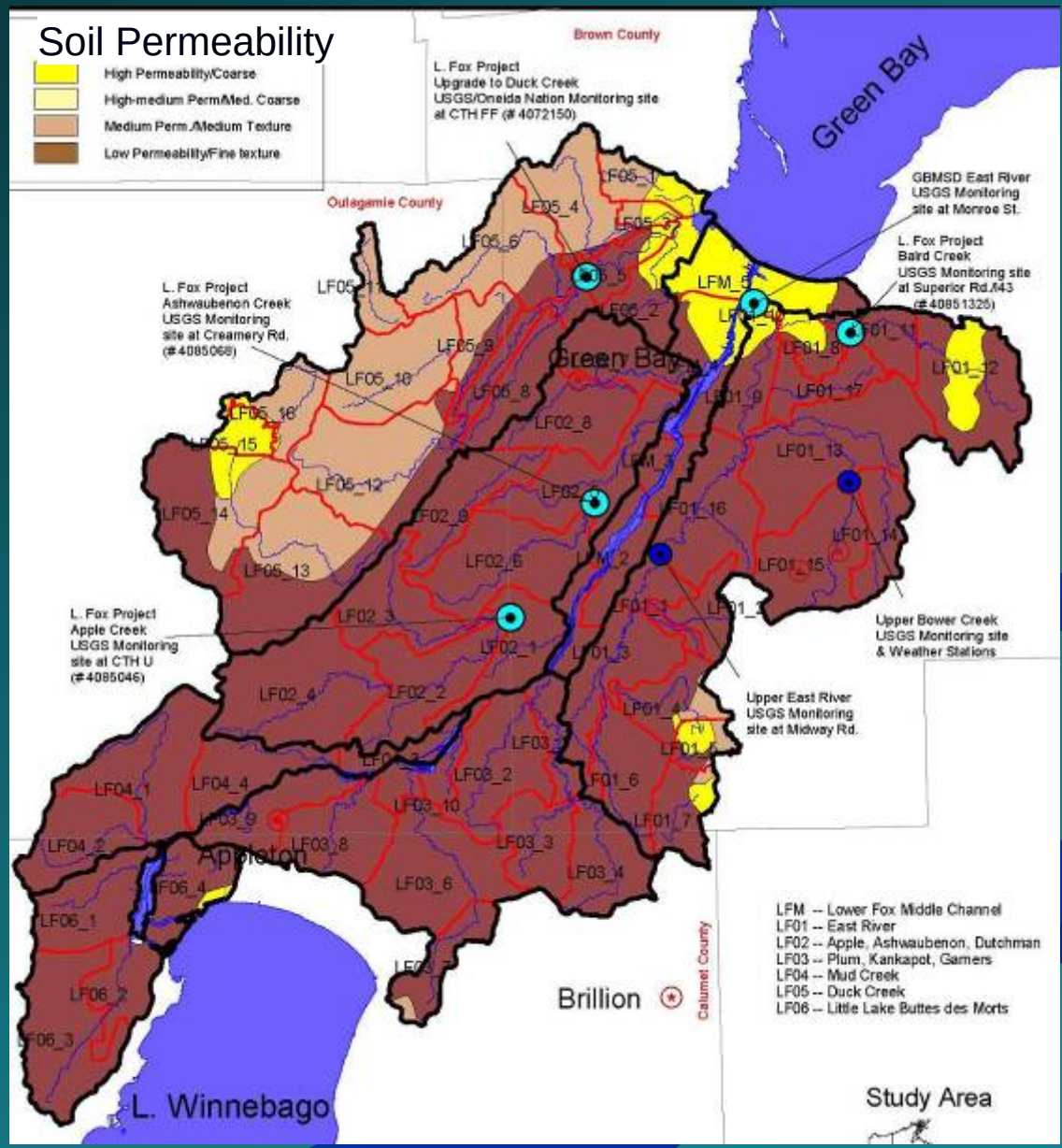
Establish a long-term monitoring program that improves our ability to address watershed quality issues (water quality, stream ecosystem integrity, etc.).

Lower Fox River Year 2000 Landuse and Land cover



Watershed background:

- Clay soils
- High % runoff
- 715 mm precip avg
- ~ 200 mm flow
- ~ 30 mm baseflow

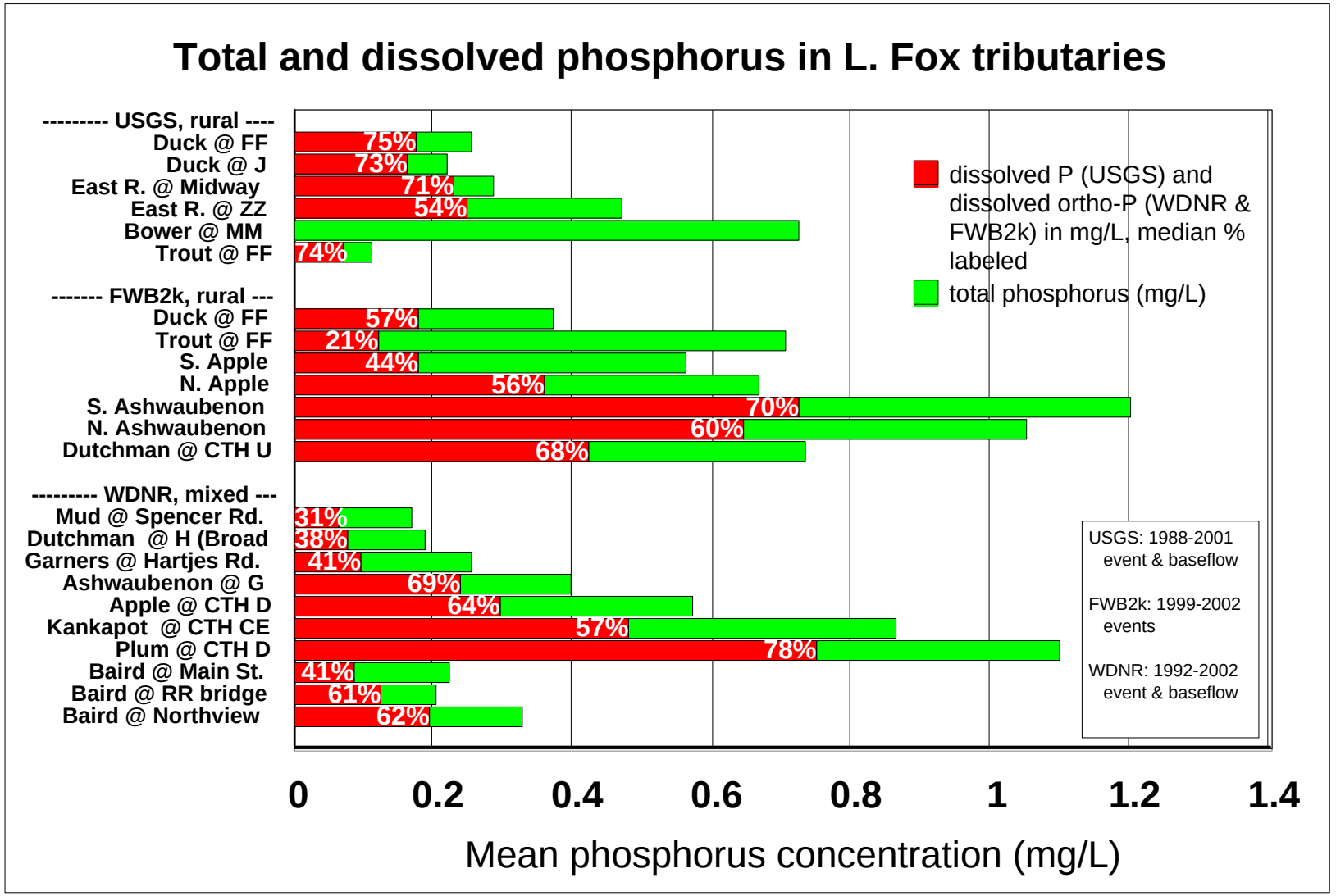


Phosphorus Forms Study Background

- Early modeling efforts in the Fox-Wolf Basin assumed 10 to 30% of TP in dissolved form from Ag source areas and only 11% in Lower Fox Basin (NEWWT modeling with SWRRB,1993)

- Fox-Wolf Basin 2000 (1999-2002) monitored tributaries to assess/validate SWAT model predictions. Found that proportion of dissolved P assumed in models not supported by data.

Phase 1: Concentration Analysis
Dissolved P fraction (most: 40-70%)



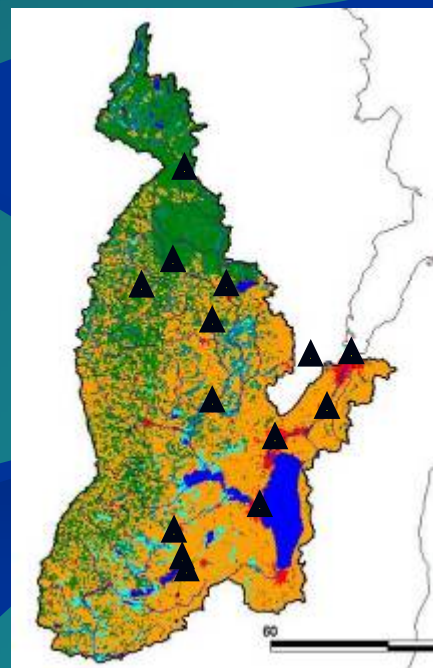
Phase 2:
USGS LOAD Analysis

P Loading: TP vs DP

Site	Fraction DOP	Fraction DP
Duck Howard	50.0%	58.9%
Duck Seminary	62.3%	74.7%
East	56.8%	62.0%
Langlade	27.8%	
NewLondon	37.1%	
Berlin	12.5%	
Oshkosh	6.0%	
Neenah/Menasha	17.4%	
Appleton	26.5%	
Wrightstown	18.2%	
DePere	21.2%	
Mouth	32.0%	

- Smaller tribs in Lower Fox:
  - 50-70% as Dissolved P
- BMPs effectiveness on DP?

- Main stems of Fox-Wolf:
  - 10-30% DP (DP transformed to organic PP)



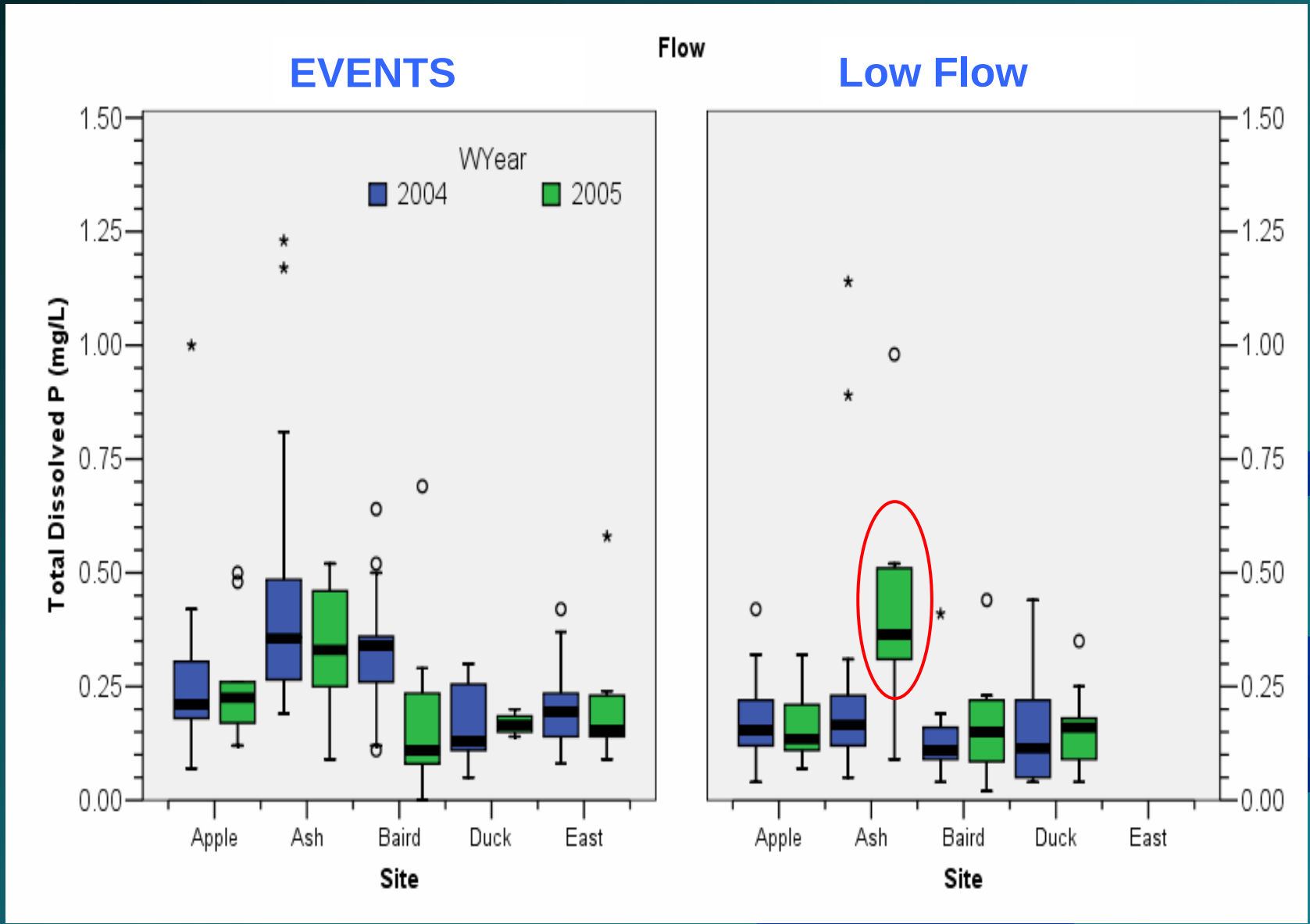
Phase 3: Phosphorus Forms Study

Objectives

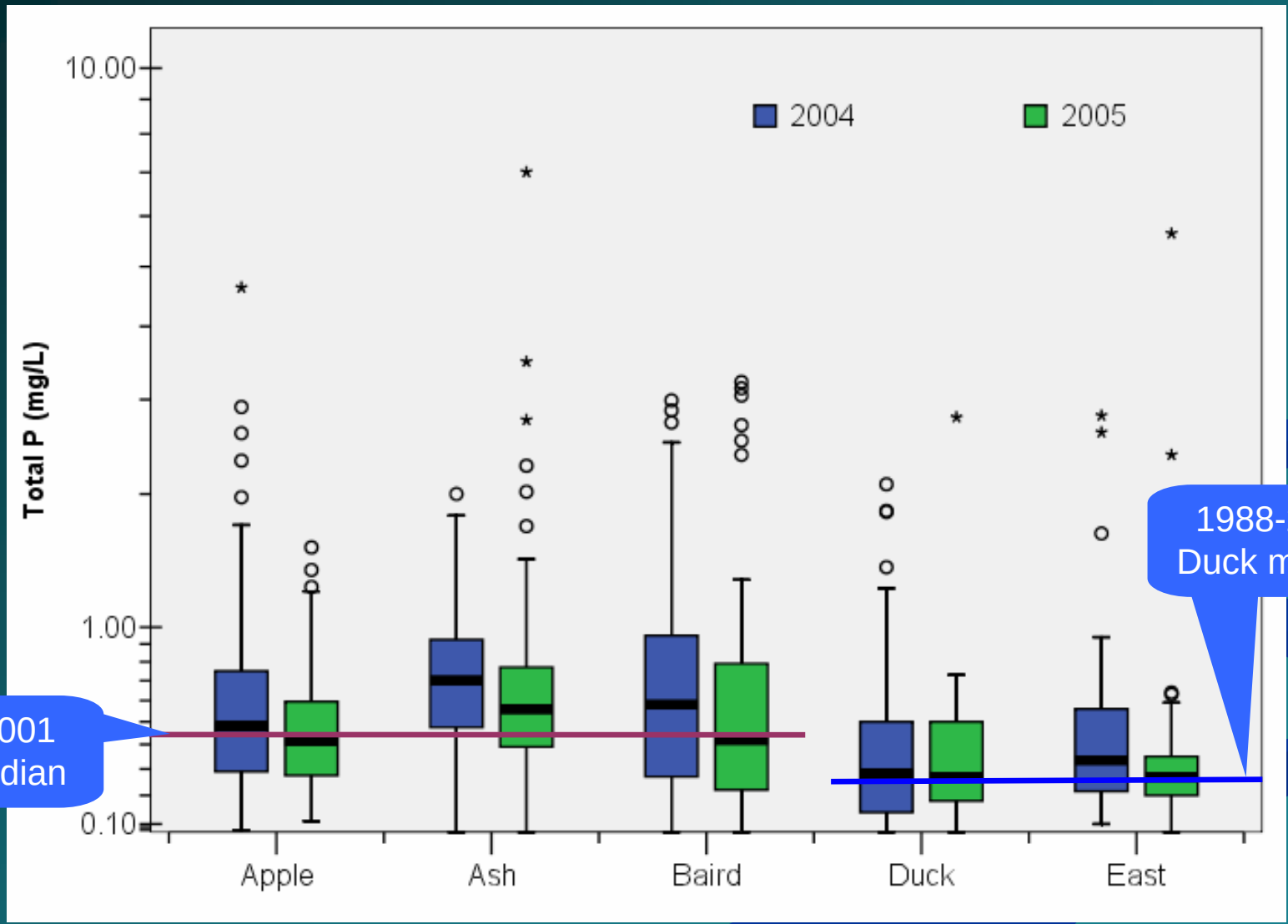
- Determine proportion of Dissolved P to Total P in streams at different scales
- Track DP, TP, TSS along flow path (source vs integrators; upstream vs downstream)
- Relate results to watershed characteristics (soils, management, topography) and previous studies
- Apply SNAP-Plus, derive P-Index & compare to WQ
- Evaluate models (P-Index, SWAT)

Lower Fox River Watersheds: Major Tributary Monitoring

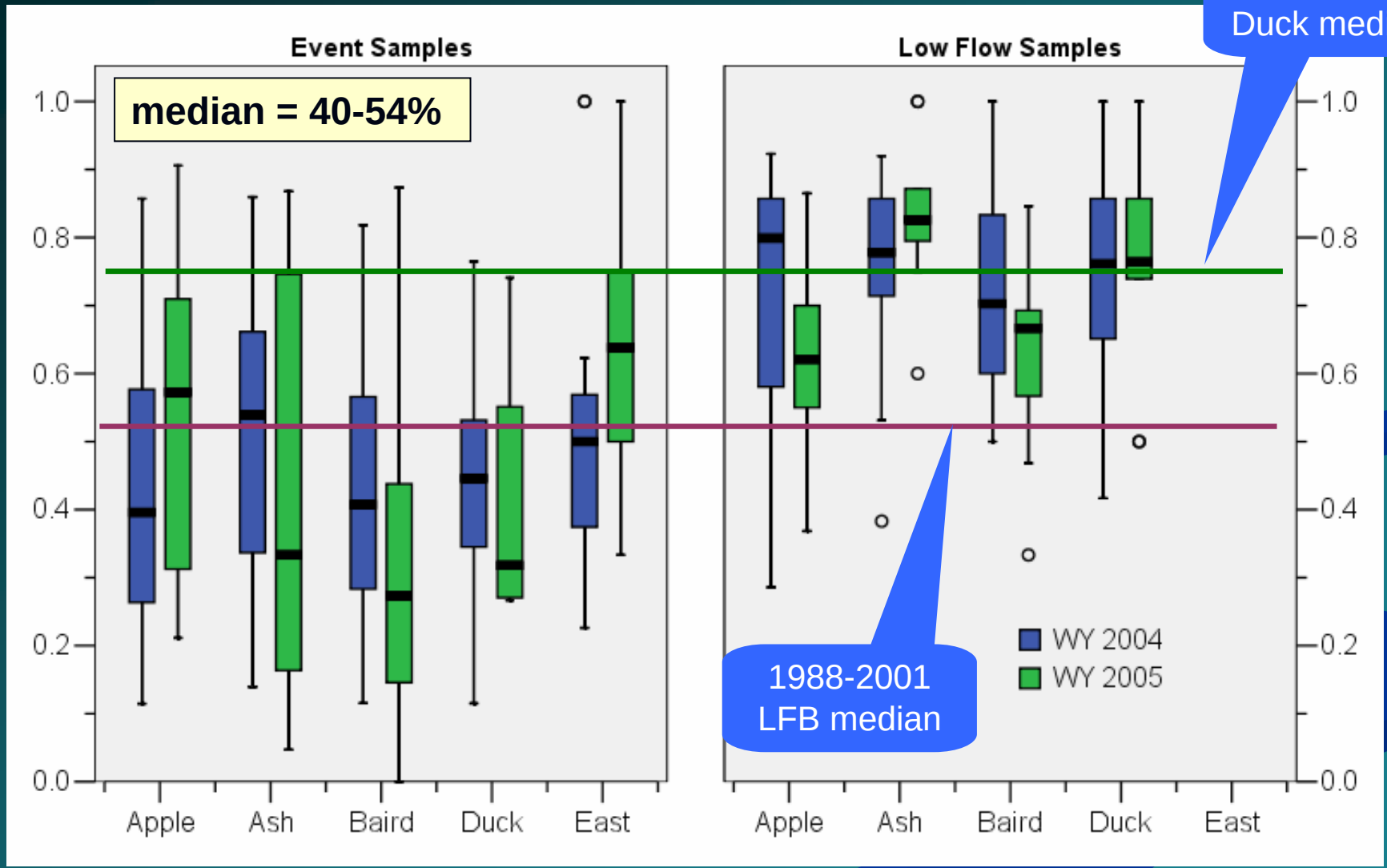
Dissolved P (mg/L): 2004-05



TP (mg/L): 2004-05



Dissolved P:TP Ratio (2004-05)



Conclusions: 2004-05 Monitoring Results Five Major Tributaries in Lower Fox

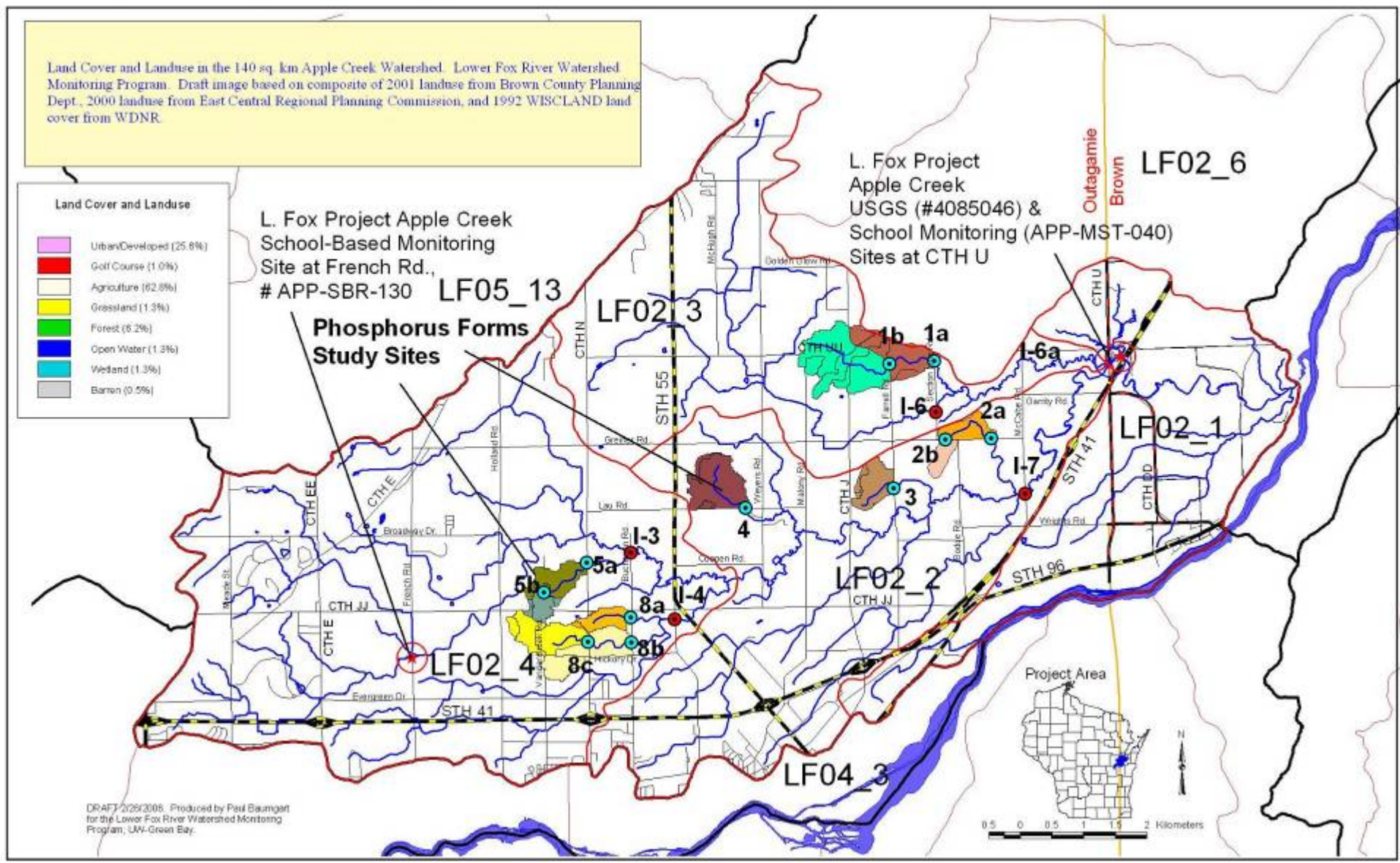
- DP 40 to 54% of TP concentration during events
  - DP significant form of runoff P
  - Implications for BMPs?

- Loads highly event driven
  - 8 days (5 events): 55% of annual P & 71% of TSS load in Apple Creek in WY04

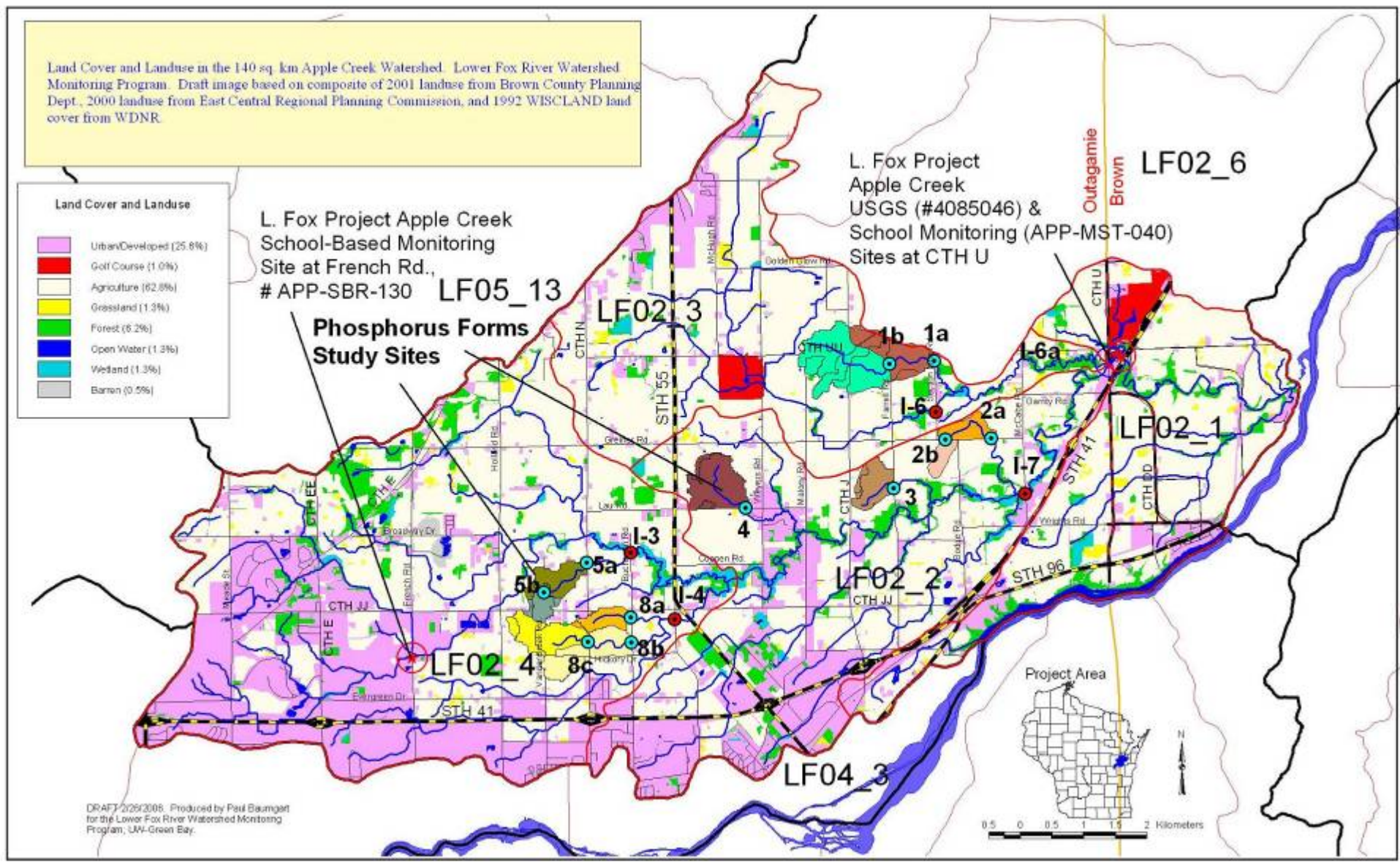
Phosphorus Forms Study: Apple Creek

Apple Creek trib: May 23 2004 site #3 upstream

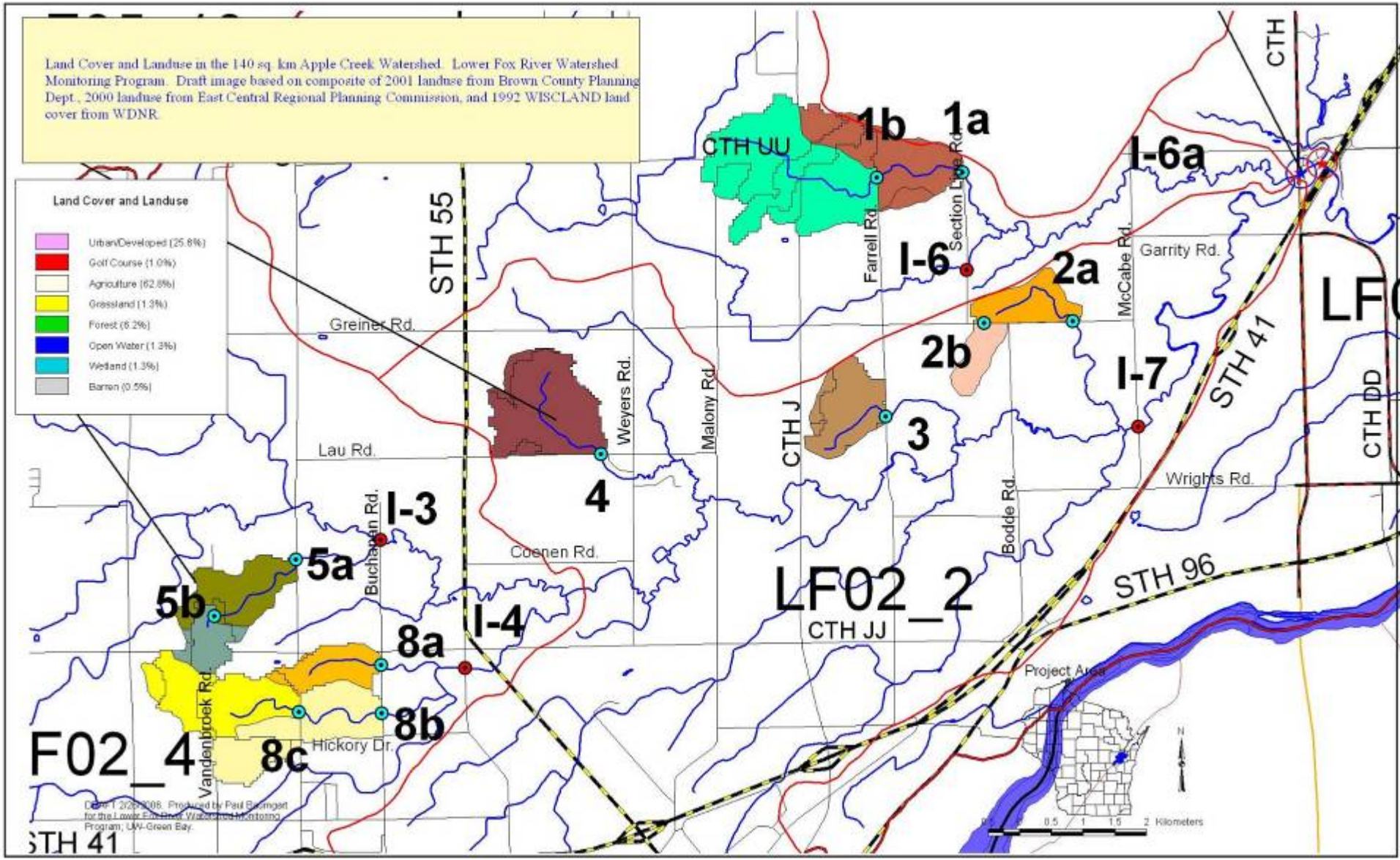
Apple Creek P-Forms Study Monitoring Sites



Apple Creek P-Forms Study: Monitoring Sites and Landuse



Apple Creek P-Forms Study Monitoring Sites – close up



Monitoring Methods: Apple Creek

- RUNOFF EVENTS: Grab samples at 11 Source Area (0.2 to 2.1 km^2) and 4 integrator sites (12 to 85 km^2), at or near peak flow
  - Targeted uniform precip events tape-down measurements for relative discharge on event basis
- Source area sites selected in quasi-random basis (agricultural landuse; suitable discharge, area not too large)
- Downstream Main Stem USGS Site: Continuous discharge & automated samples at campground (117 km^2)
- TSS, total P, dissolved P analysis at Green Bay MSD lab
- Samples collected during 5 runoff events (March to June, 2004), plus 1 in 2005, 1 complete event in Jan 2006

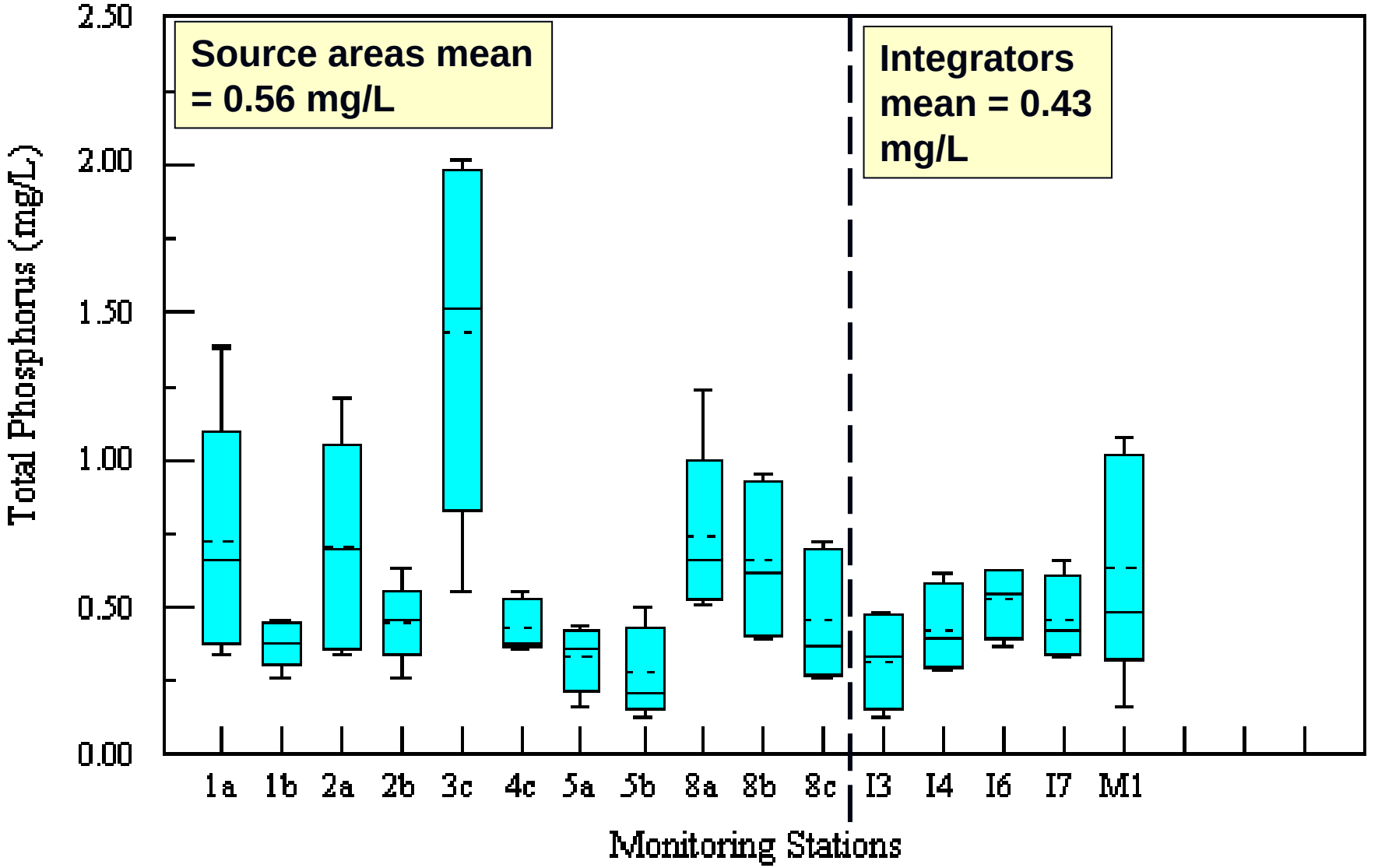
Apple Creek trib: May 23 2004 site #3 downstream

Statistical Analysis

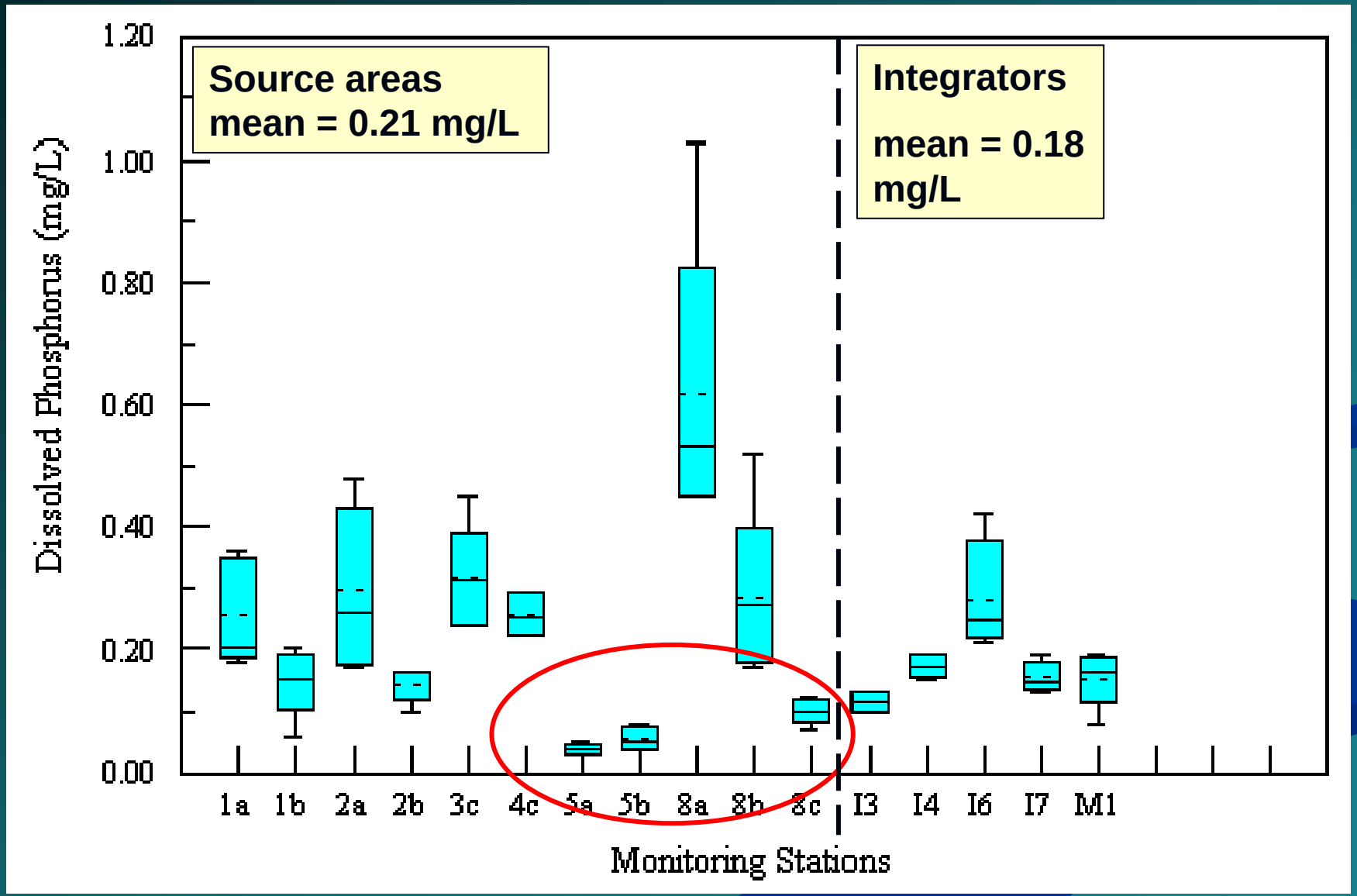
- SAS, SPSS, PRO-STAT for analysis
- 2004 data with 5 events analyzed
  - 2005: 1 event
  - 2006: 1 complete event
  - these events not included in analysis yet

Preliminary Results

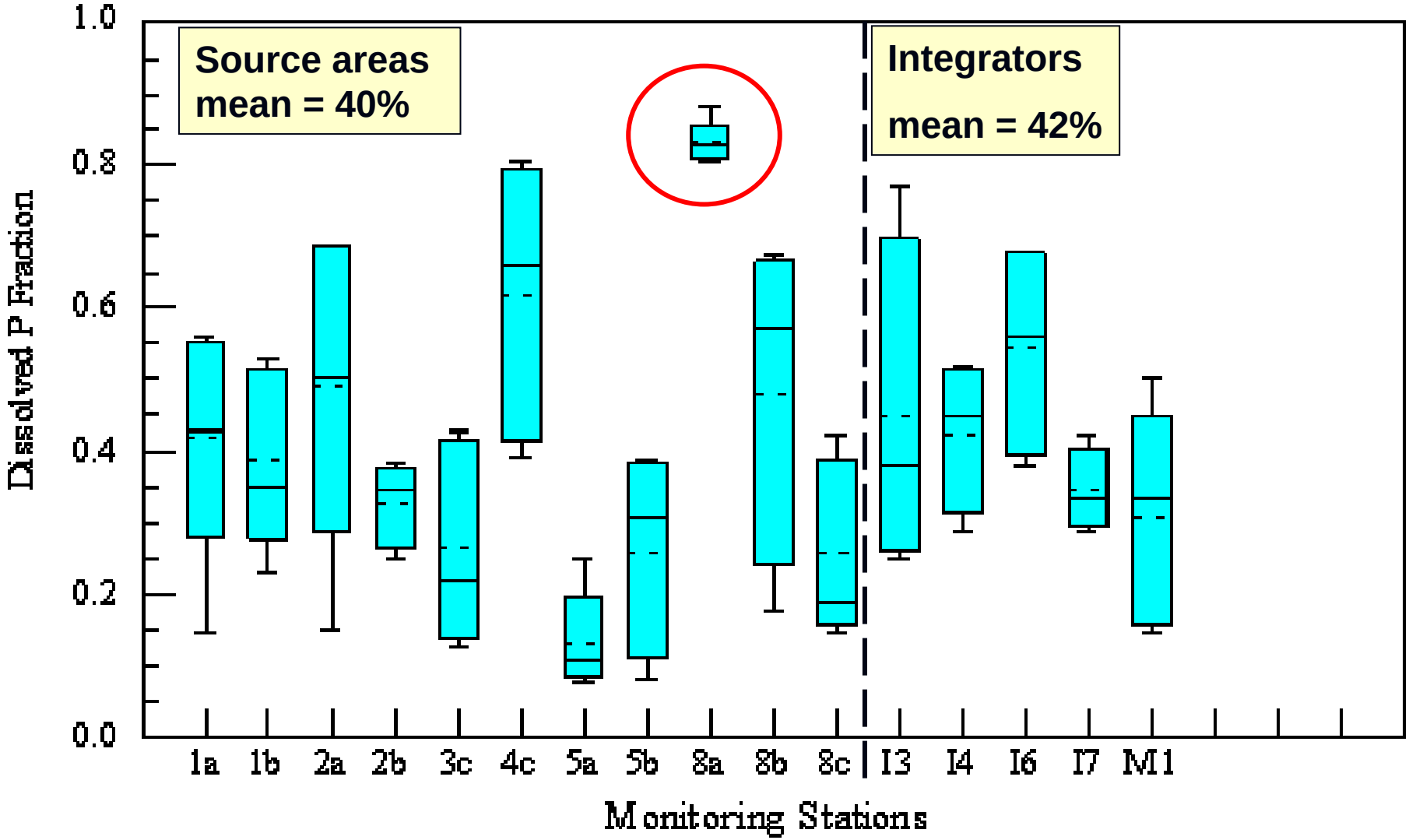
Total Phosphorus (mg/L) - 2004



Dissolved Phosphorus (mg/L) - 2004



Dissolved/Total Phosphorus ratio - 2004



Statistical Analysis: Source Areas

- Source Areas (11 sites, 5 events)
- Non-parametric Wilcoxon Rank Sum Test
  - EVENT MEANS: NO significant difference between events for DP and DP/TP ratio (alpha=0.05)
- One-way ANOVA, Event as Repeated measures factor
  - SITE MEANS: All parameters significant difference

EVENT MEANS		SITE MEANS Wilcoxon		SITE MEANS ANOVA-Repeated
Variable	**P value**	**P value**	**Variable**	**P value**
Total P	<0.0072**	<0.004**	Ln TP	<0.0001**
Dissolved P	0.91	<0.0001**	Ln DP	<0.0001** w/o repeated
DP/TP	0.11	0.0003**	DP/TP	<0.0003** w/o repeated
TSS	<0.0001**	0.13	Ln TSS	<0.0001**

Next step: ANOVA – Multiple Comparison tests

- Natural log transform for TSS, total P, dissolved P
- Alpha = 0.05

Ln Dissolved P - TUKEY MCP

one-way ANOVA, not repeated

- Site 8a significantly *higher* than all except site 4
- Sites 5a and 5b are significantly *lower* than all sites except 8c
- Sites 5a, 5b, and 8c form a cluster of low dissolved P in runoff
- Hypothesis: soil-P levels above sites 5a, 5b and 8c are low

Tukey Grouping			Mean	N	SITE
	A		-0.5361	5	8a
	A				
B	A		-1.1865	5	3
B					
B			-1.3071	5	2a
B					
B	C		-1.3411	5	8b
B	C				
B	C		-1.3781	5	4
B	C				
B	C		-1.4171	5	1a
B	C				
B	C	D	-1.7796	4	1b
	C	D			
	C	D	-1.9681	5	2b
		D			
	E	D	-2.3184	5	8c
	E				
F	E		-2.9237	5	5b
F					
F			-3.2893	5	5a

DP/TP ratio - TUKEY MCP

one-way ANOVA, not repeated

- Site 8a significantly higher DP/TP ratio than all except site 4
- Sites 8a & 4 are significantly higher than site 3, 5b, 8c, and 5a
- Large range of mean ratios, but most sites not signif. different. Variability within sites higher than DP.
- Hypothesis: site 8a has high soil-P, and/or high applied manure/fertilizer

Tukey Grouping			Mean	N	SITE
	A		0.83303	5	8a
	A				
B	A		0.61602	5	4
B					
B	C		0.48913	5	2a
B	C				
B	C		0.47770	5	8b
B	C				
B	C	D	0.42531	4	1b
B	C	D			
B	C	D	0.41848	5	1a
B	C	D			
B	C	D	0.32623	5	2b
	C	D			
	C	D	0.26607	5	3
	C	D			
	C	D	0.25928	5	5b
	C	D			
	C	D	0.25663	5	8c
		D			
		D	0.13239	5	5a

Ln Total P - TUKEY MCP

one-way ANOVA, repeated measures on Event

- Site 3 significantly higher than all except site 8a
- Sites 5a & 5b significantly lower than 3, 8a, 1a, 2a
- Large range of means, but most sites not significantly different. Greater variability than dissolved P
- Hypothesis: site 8a has high soil-P, and/or high applied manure/fertilizer (TSS was low)

Tukey Grouping			Mean	N	SITE
	A		0.2595	5	3
	A				
B	A		-0.3529	5	8a
B					
B			-0.4476	5	1a
B					
B			-0.4658	5	2a
B					
B	C		-0.4842	5	8b
B	C				
B	C	D	-0.8338	5	2b
B	C	D			
B	C	D	-0.8513	5	4
B	C	D			
B	C	D	-0.8657	5	8c
B	C	D			
B	C	D	-0.9024	4	1b
	C	D			
	C	D	-1.1729	5	5a
		D			
		D	-1.4061	5	5b

Spatial Location: Up vs Down Stream

- POOLED – 4 sets of Up vs Downstream sites (1ab, 2ab, 5ab, 8bc)
  - PAIRED WILCOXON SIGN RANK: DP (p=0.0015**), TP (p=0.009**), DP/TP (p=0.018**), TSS (p=0.29)

- Same Multiple Comparison Tukey Test on source area sites
- Only detected following differences ($p<0.05$):
  - 2a vs 2b (Ln diss P)
  - 8b vs 8c (Ln diss P)
    - 1a vs 1b (Ln Total P nearly significant)

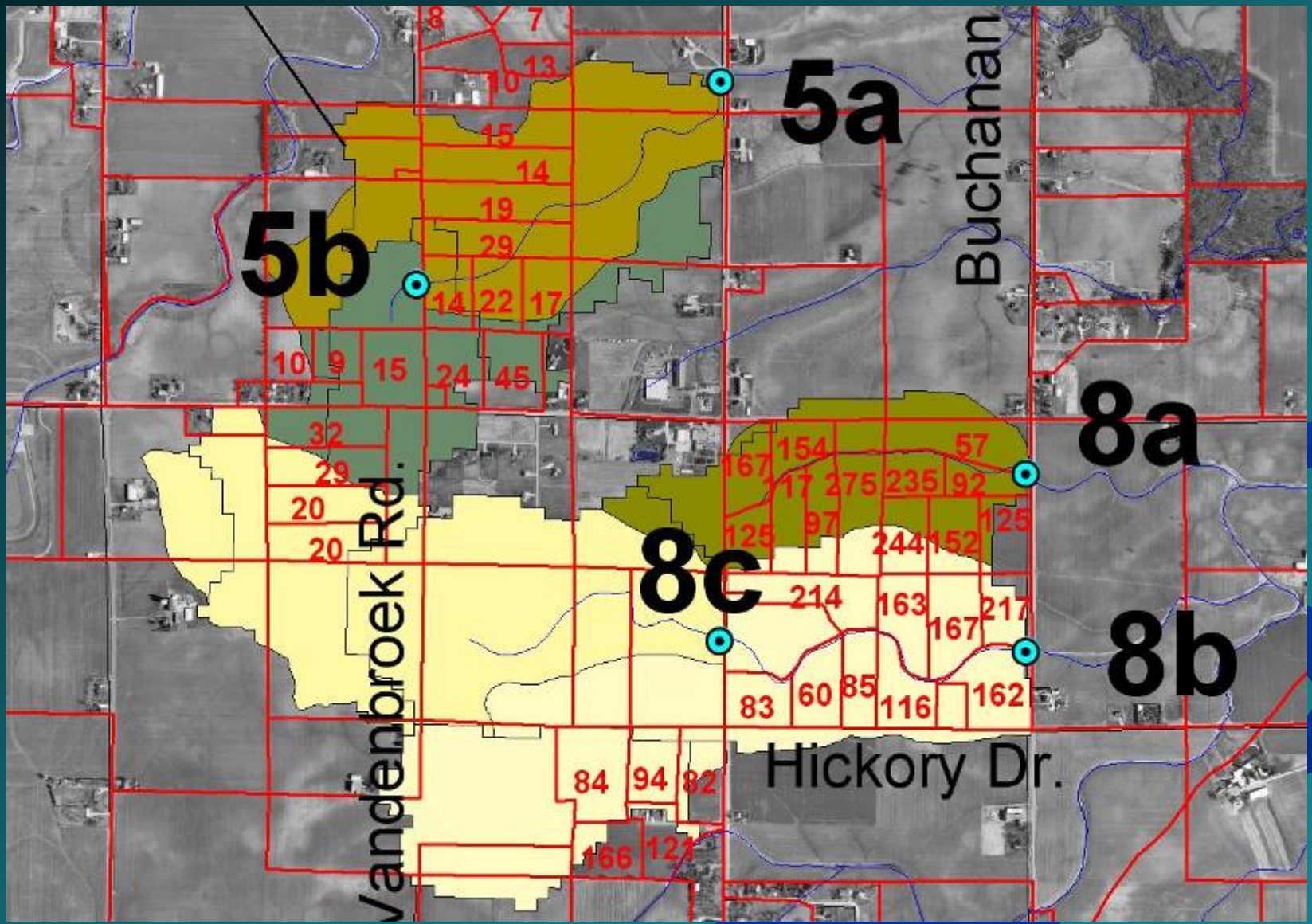
- Hypothesis: Soil-test P *Higher* at downsteam sites 2a,8b than upstream sites 2b,8c; respectively

- SCALE: Source drainage areas NOT correlated with mean TSS, TP, DP, DP/TP levels --- (5 events) at 11 source area sites ($R^2 < 0.009$)

P-Index and Farm Field Analysis

- Farm field input data: Nutrient Management Plans and WPDES Permits → SNAP-Plus P-Index model
- Soils, crops, tillage, fertilizer/manure, etc.
- Just started collecting farm field data, input to SNAP
- So far: Nutrient M. Plan with soil-P test data available for monitoring sites 5a,b & 8a,b,c

Soil-test P levels in Apple Creek sub-watersheds (ppm Bray-P1)

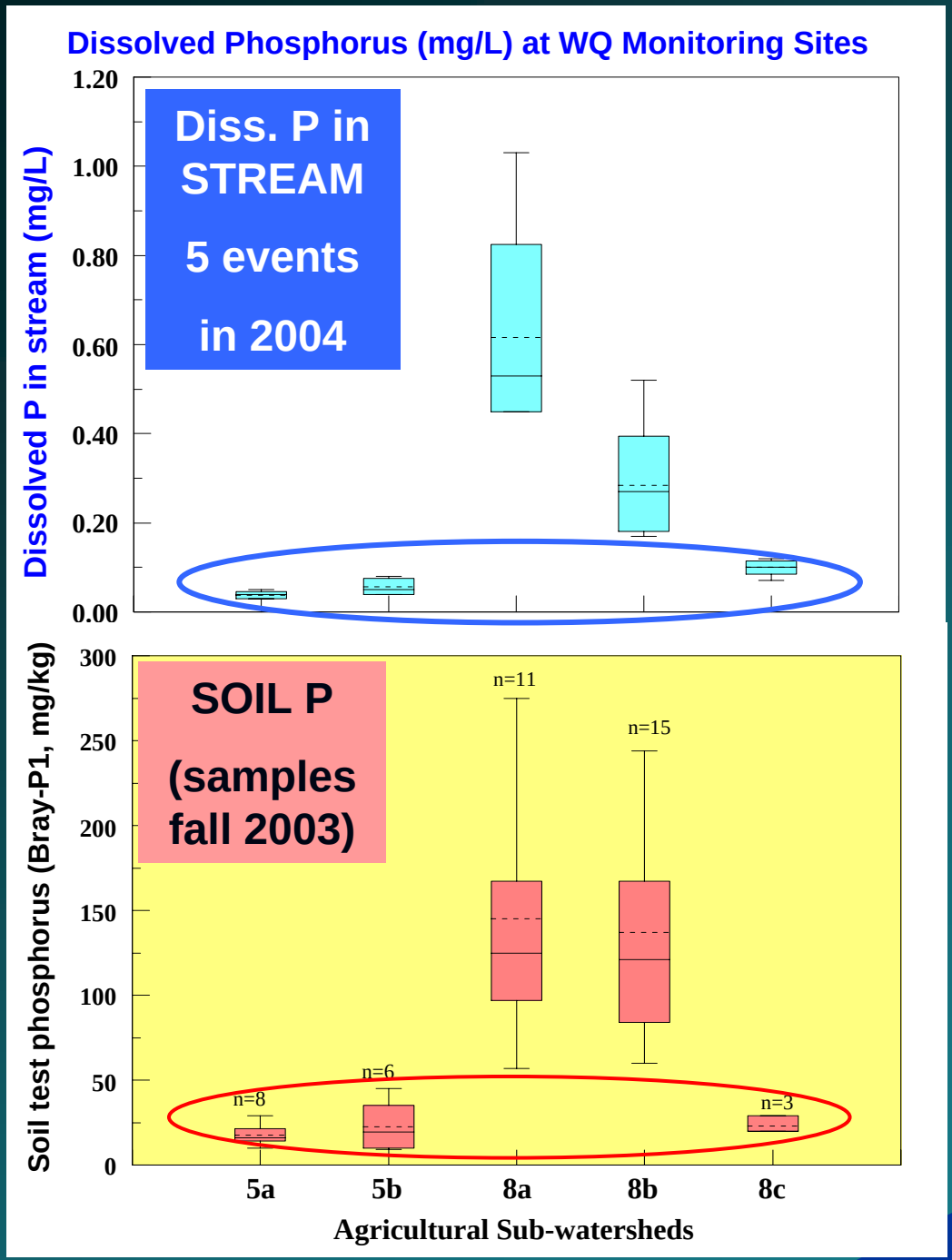


Preliminary Results of P-Index and Farm Field Analysis

- Soil-test P results: soils within sub-watersheds 5a, 5b, 8c each significantly lower than 8a or 8b

ANOVA and TUKEY HSD Probability Matrix --- Soil Test P within each drainage area (Bray-P1):

	5a	5b	8c	8b
5b	1.000			
8c	1.000	1.000		
8b	0.000	0.000	0.005	
8a	0.000	0.000	0.003	0.994



Apple Creek Agricultural sub-watersheds

< Dissolved P in Stream (mg/L)

closely matches

< Soil test P in drainage area (mg/L Bray-P1)

Preliminary P-Index Results

- Nutrient Management Plan data input to SNAP-PLUS
- Applied SNAP-PLUS → Preliminary P-Index values
- SNAP database output linked to GIS to derive area-weighted sub-watershed P-Index values

Site	location	PI-total	PI-Part	PI-Soluble	Sol-P (%)	Stream Mean Diss-P (%)
5a	**down**	7.0	6.3	0.4	5%	13%
5b	**up**	4.9	4.0	0.5	10%	26%
8a		10.6	5.0	3.0	28%	83%
8b	**down**	8.5	4.0	2.7	32%	48%
8c	**up**	1.8	0.2	0.6	33%	26%

- Except for DP at 8a, relative P-Index values resemble stream samples
  - NOTE: Acute Loss PI not shown. Up-stream and downstream areas treated separately for now (total area of 5a actually includes 5b, etc.)

P-Index Assessment

TO BE COMPLETED

Apple Creek Monitoring Data Rediscovered

- Apple Creek Watershed: ~ 48% load as DP in 1971-72 study (P. Sager, J. Wiersma; 1975)
- Mean Soil-test P levels have risen from ~ 25 ppm in early 1970's to > 40 ppm in 2000

- Why hasn't DP fraction increased at Apple Creek?
  - Perhaps major DP source(s) decreased relative to PP (barnyards, cattle in stream, direct manure runoff)
  - Alternatively, PP may have increased relative to DP

Conclusions

- Dissolved P fraction fairly high at main stem sites (40-60%)
  Coincides with earlier findings in Lower Fox
- EVENT Dissolved P fraction at source area sites (0.2 to 2.1 km^2) similar to integrator sites (12 to 85 km^2) and main stem site (117 km^2) → no obvious net concentration change observed
- Significant differences in Dissolved P from source areas
- In-stream DP closely parallels Soil-test P (Bray-P1), where data available
  - available soil-P implicated as major source of stream DP
- Source area sites with low dissolved P had low DP/TP ratio, still relatively high TP (although may be reduced some)
  - Implications for effectiveness of BMP's
- Preliminary P-Index application/assessment:
  - areas evaluated so far: WQ measurements generally reflect relative P-Index values for TP, DP, and PP

Next Steps

- Complete P-Index modeling in Apple Creek
- Complete SWAT modeling at different spatial scales in Apple Creek and for 5 LFRWMP watersheds
- Compare P-Index and SWAT model results to observed data at different scales
- Evaluate ability of models to mimic relative or absolute monitoring results for total P, dissolved P, and TSS
- Gather additional WQ data and management data as needed

Acknowledgements

Special thanks to the following people for their assistance with this project:

- Dave Graczyk, Paul Reneau, Dale Robertson and Troy Rutter -- U.S. Geological Survey
- John Kennedy and Tracy Valenta, GBMSD
- Oneida Nation
- Outagamie LCD (Sue McBurney, Jim Poweleit, Ann Francart
- Bud Harris, Dave Dolan -- UWGB
- Jesse Baumann, Jessie Fink, Jon Habeck Erika Sisal -- UWGB
- Arjo Wiggins Appleton, Inc.

Questions?

For more information: www.uwgb.edu/watershed

Email: baumgarp@uwgb.edu