Lower Fox River Suspended Sediment and Phosphorus Load Allocations and Reduction Strategies to Green Bay using the Soil and Water Assessment Tool (SWAT)

Fox-Wolf Watershed Alliance
Research Symposium

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Lawrence University

Appleton, Wisconsin

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Lower Fox River Watershed Monitoring Program – www.uwgb.edu/watershed

THE LOWER FOX RIVER watershed monitoring program

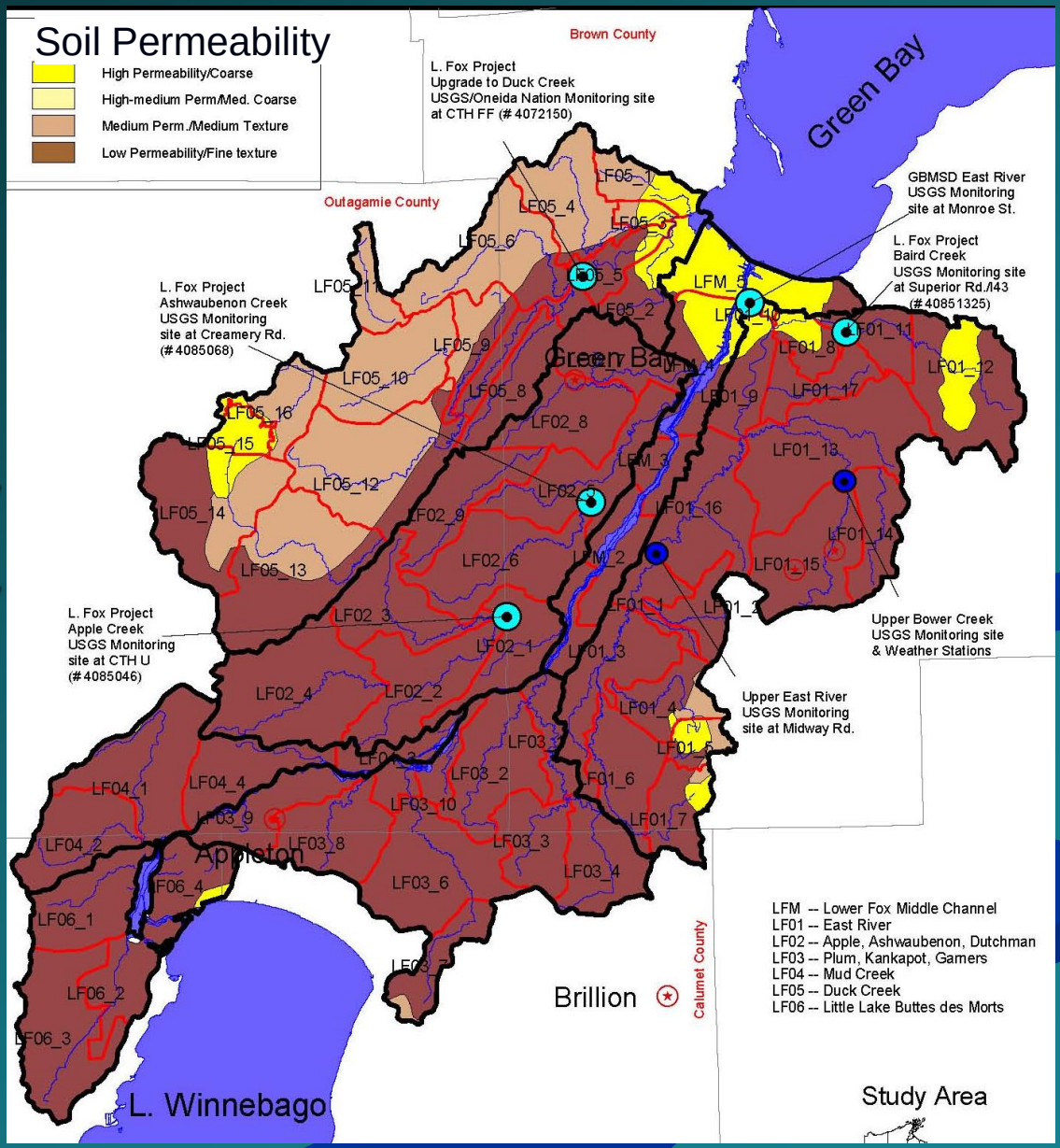
With additional support from EPA funding of the Integrated Watershed Approach Demonstration Project A Pollutant Reduction Optimization Analysis for the Lower FoxRiver Basin and the Green Bay Area of Concern (Laura Blake of The Cadmus Group and Sam Ratick of Clark University)

Primary objective

Utilize watershed simulations to support watershed TMDL load allocations and predict impact of sediment and phosphorus reduction strategies within Lower Fox River Sub-basin (1580 km^2)

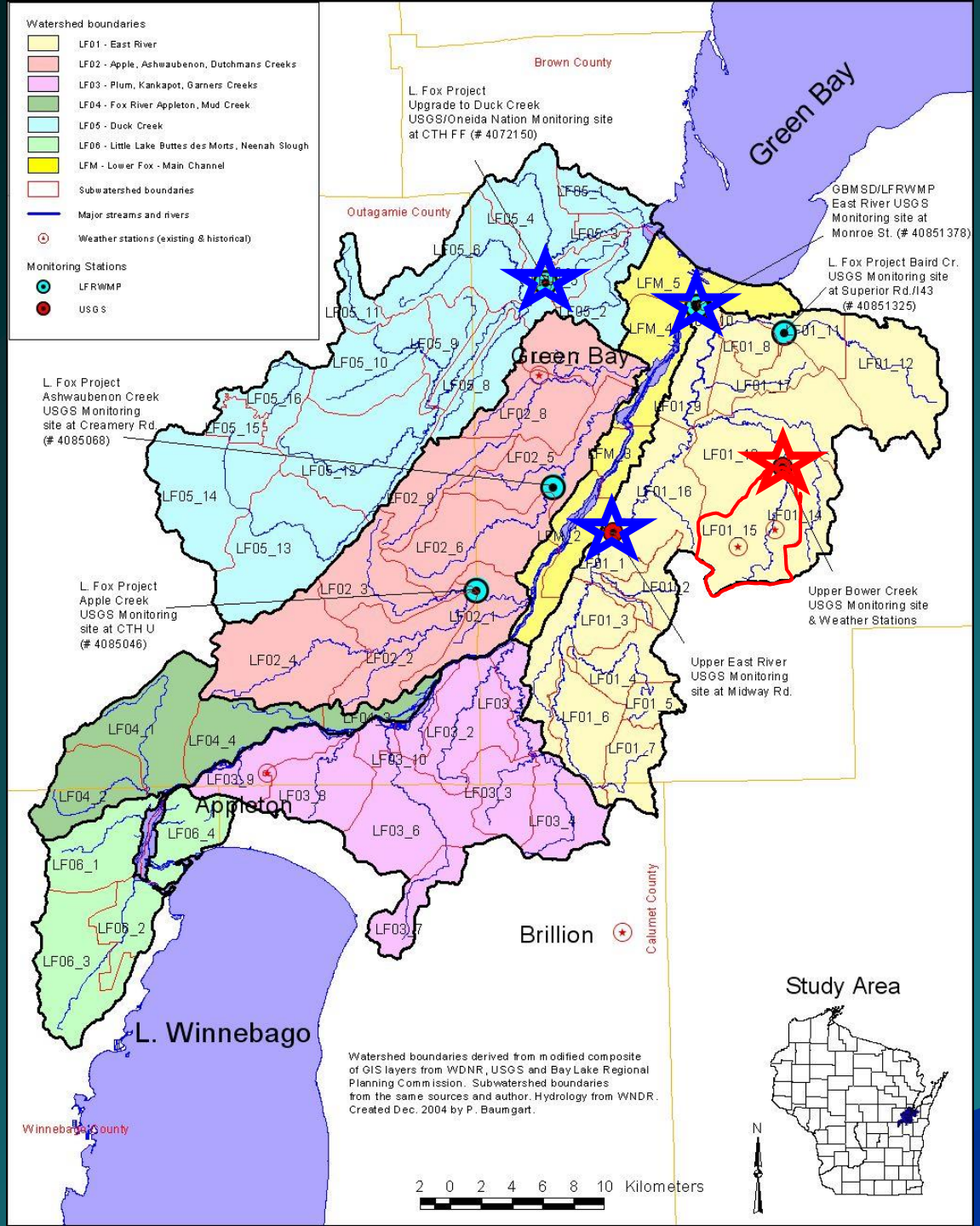
Watershed background:

- Clay soils
- High % runoff
- 730 mm precip avg
- ~ 200-240 mm flow
- ~ 16-27% baseflow



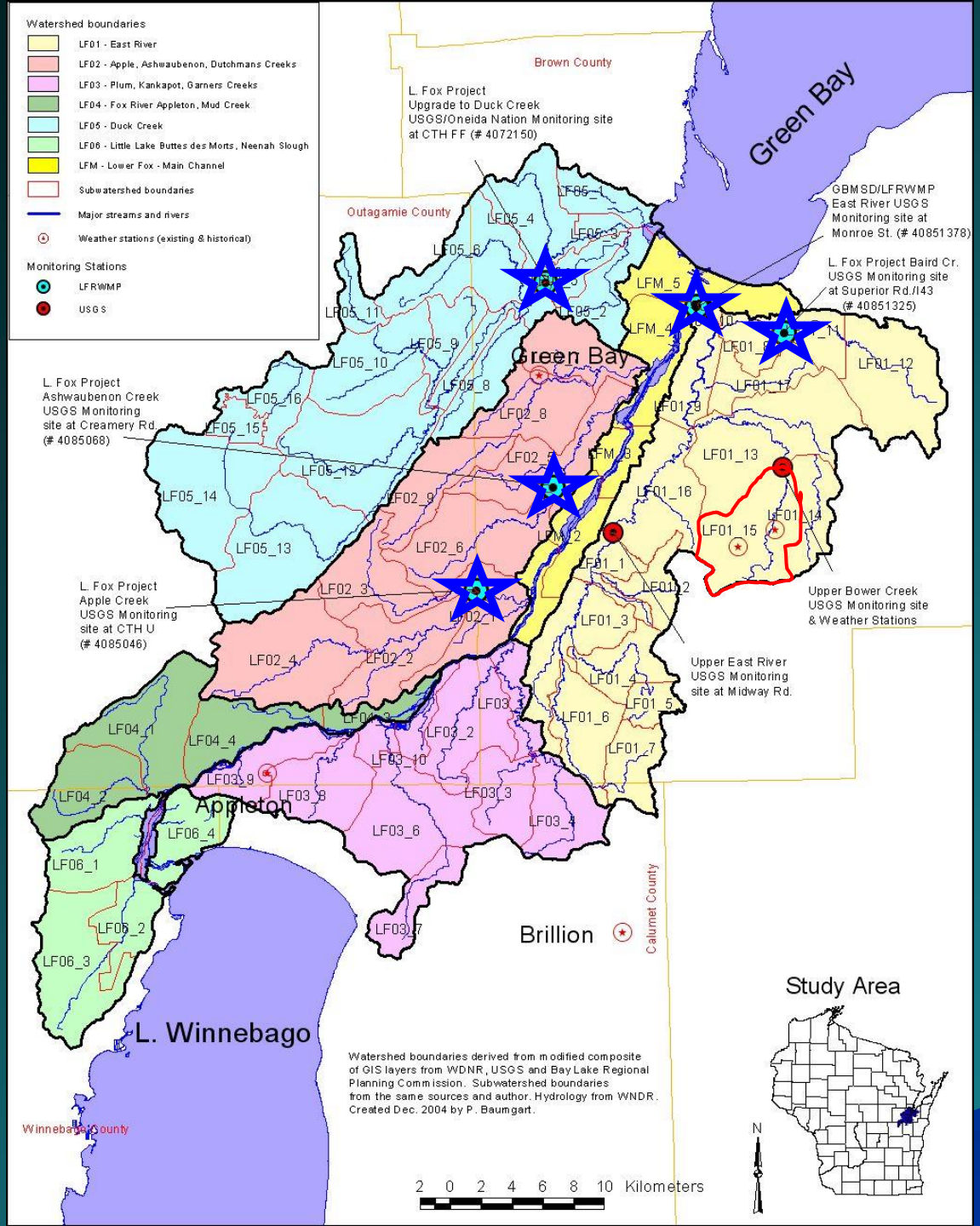
Lower Fox River watersheds & subwatersheds

Calibration Sites

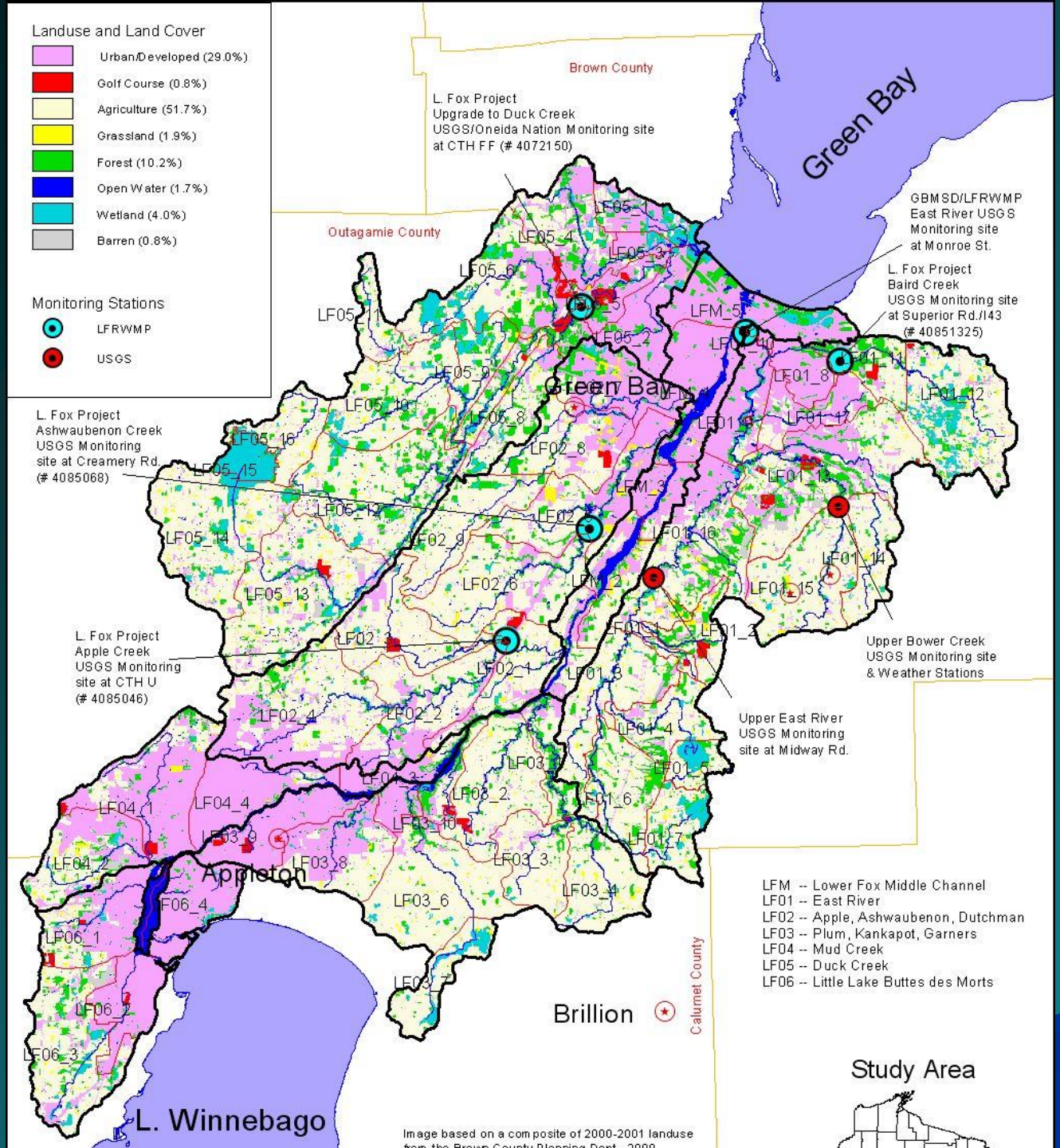


Lower Fox River watersheds & subwatersheds

LFRWMP Validation Sites



Lower Fox River Year 2000 Landuse and Land cover



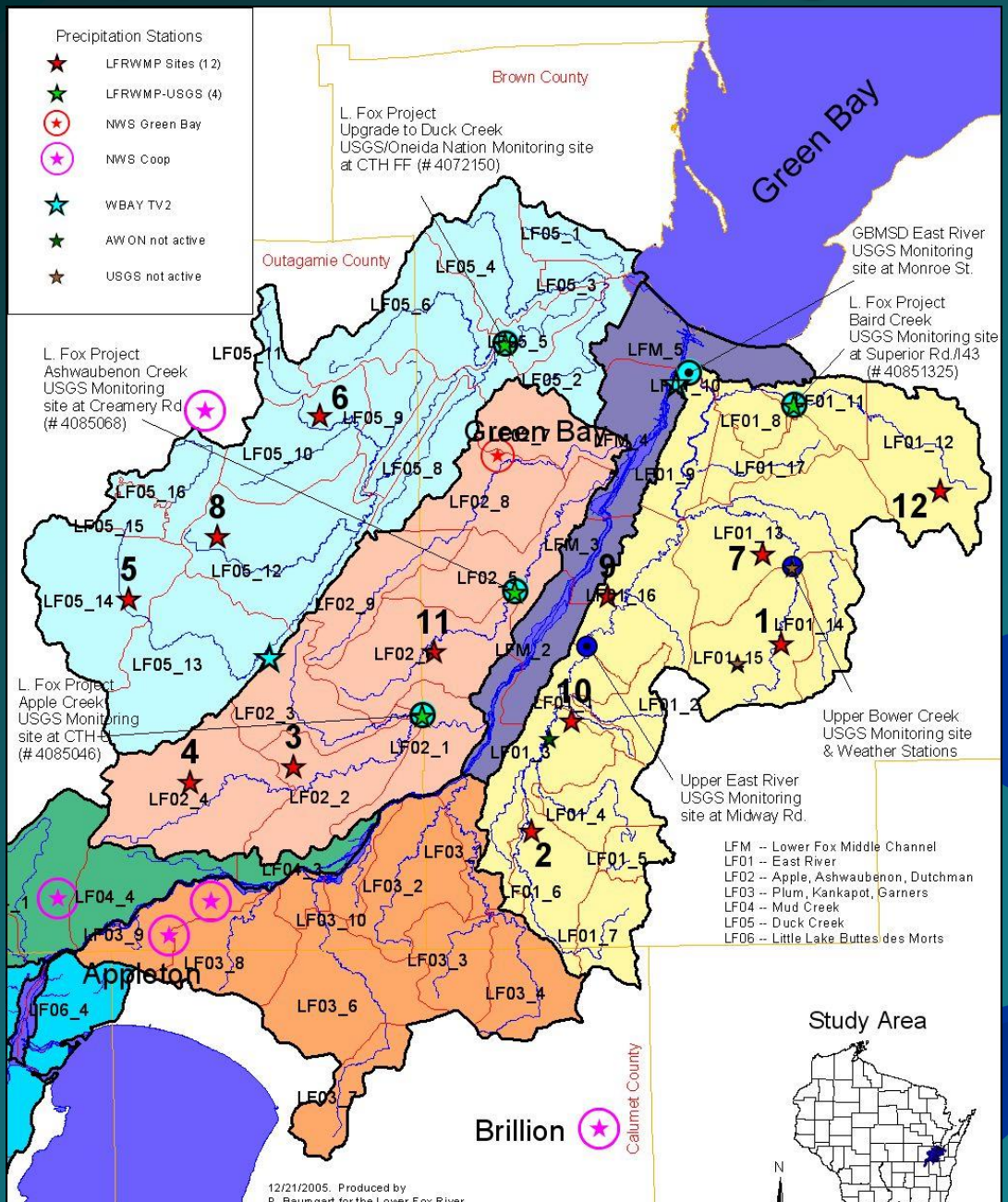
Soil and Water Assessment Tool - SWAT

- USDA – ARS model: J.G. Arnold, J.R. Williams, Temple Texas
- Continuous daily time step, river basin/watershed scale model ------- physically based
- Routes water, sediment, nutrients and pesticides to watershed and basin outlets
- Predict impacts of management on water, sediment and chemical yields
- Long-term simulations of many decades
- Tracks crop growth, tillage, fertilizer/manure application, nutrient cycling on a daily basis
- Conservation Effects Assessment Project Tool (CEAP)
- Applied modified version of SWAT 2000 code
- GIS > spreadsheet > SWAT 2000: to allow more flexible/complex management files

Modeled Simulations

- 1977-2000 climatic period
- “2004” landuse Baseline conditions
- Alternative management scenarios
  - 2004 landuse conditions with modifications

Model Inputs – Rain Gauge Network



Model Calibration & Assessment

- Calibrate: 1) flow 2) crop yields and nutrient levels 3) suspended sediment 4) phosphorus 5) diss. P
- Validate/assess: flow, SS, P at different time and/or site
- Daily, event, monthly, annual, total basis
- Primary Calibration site:

  USGS/WDNR - Upper Bower Cr. (36 km^2)
- Primary Validation sites (Lower Fox River Watershed Monitoring Program Watersheds --- plus USGS, GBMSD, Oneida Nation funding):

  Apple Creek at Campground - 117 km^2

  Ashwaubenon Creek at Creamery Rd. - 48 km^2

  Baird Creek at Superior - 54 km^2

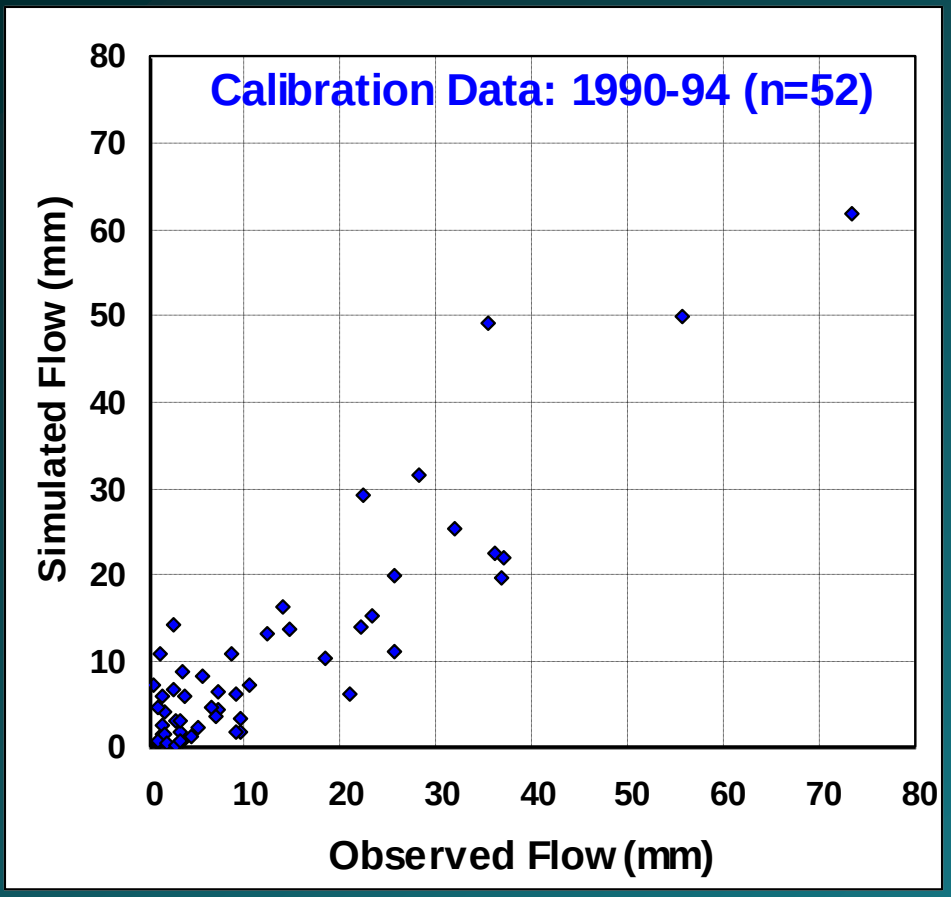
  Duck Creek at FF - 276 km^2

  East River at Monroe St. – 374 km^2

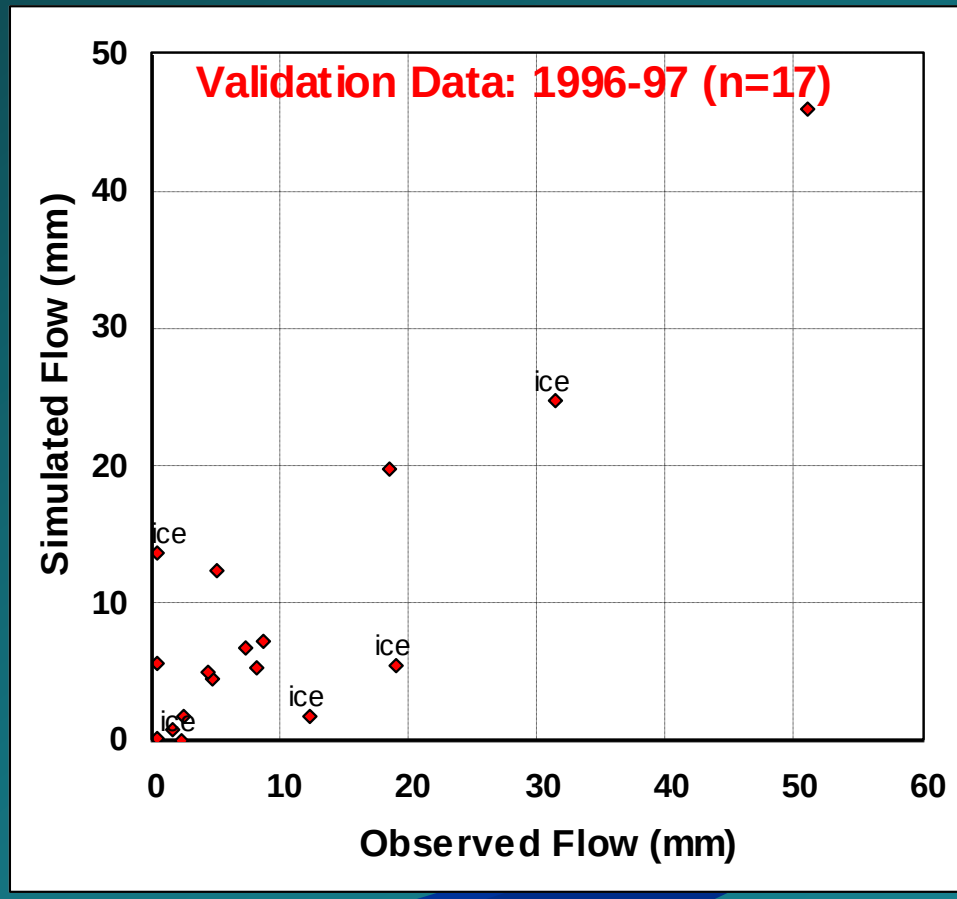
Calibration & Validation

Examples

Calibrate – Validate: Stream Flow
Upper Bower Creek events

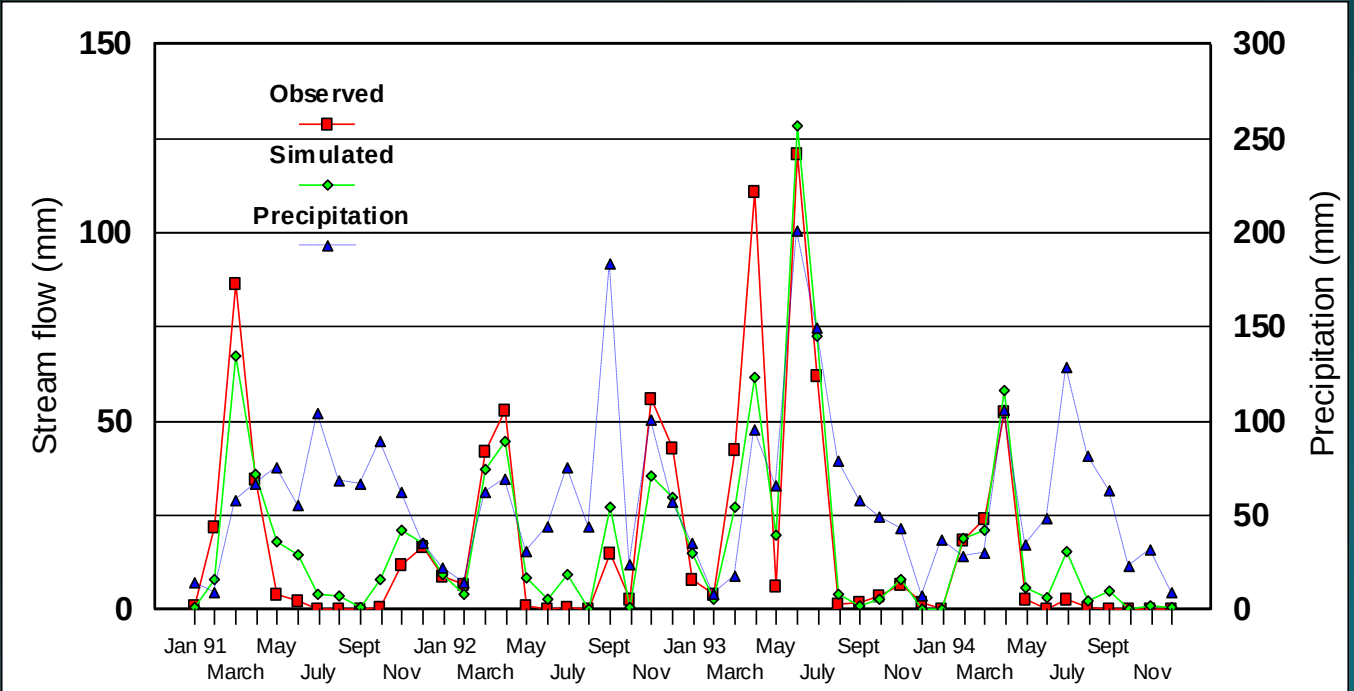


Untransformed: R^2 = 0.80, NSE = 0.80



Untransformed: R^2 = 0.95, NSE = 0.94

for n = 12, not ice-affected events



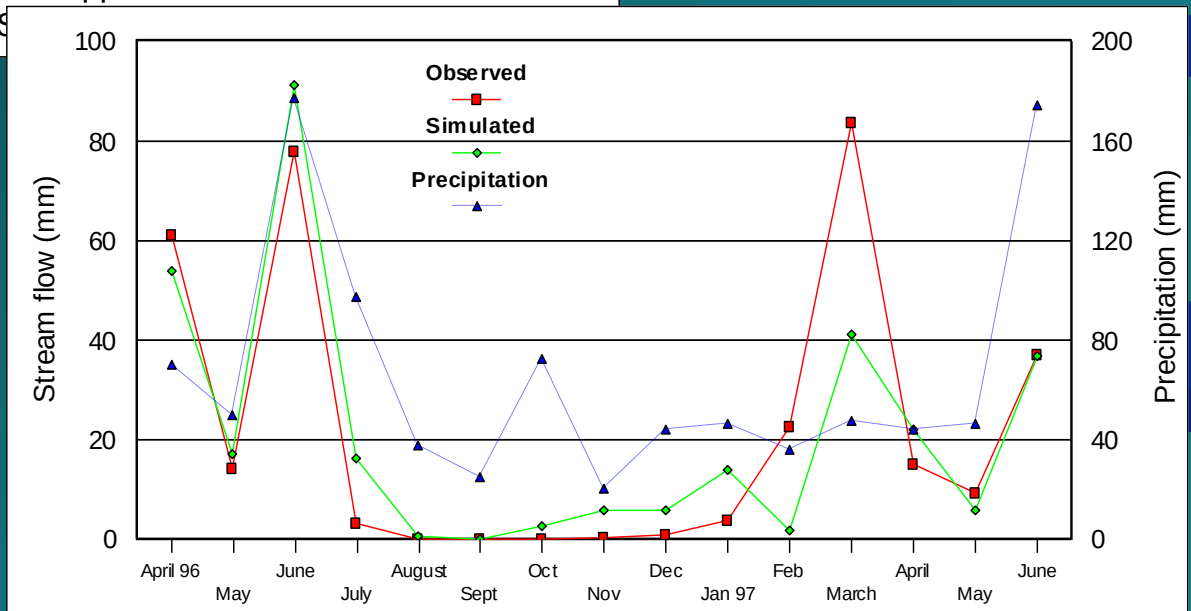
Observed and simulated monthly stream flow - Upper Bower Creek.
1990-94 calibration period. Precipitation from US

Calibrate Monthly Stream flow Upper Bower Creek

R^2=.87, NS=0.86

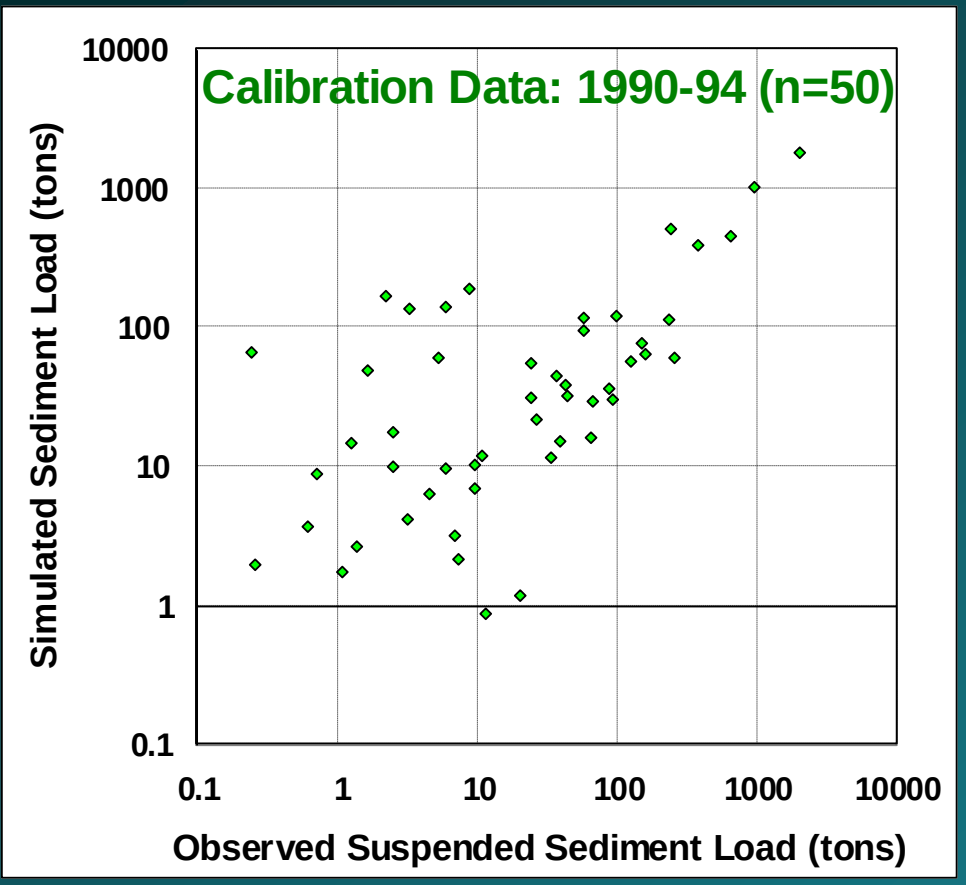
Validate Monthly Stream flow Upper Bower Creek

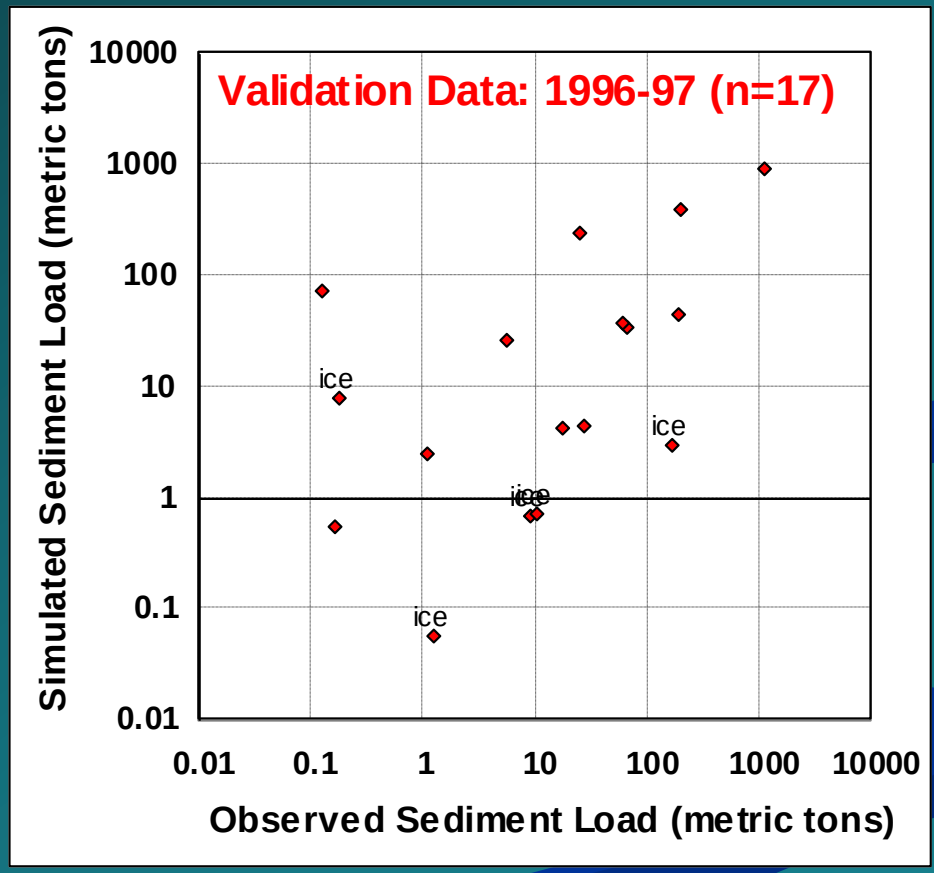
R^2=0.76, NS=0.76



Observed and simulated monthly stream flow - Upper Bower Creek.
1996-97 validation period. Precipitation from USGS weather stations is also shown.

Calibrate – Validate: Suspended Sediment Upper Bower Creek events





Untransformed: $R^2 = 0.96$, NSE = 0.95

Untransformed: $R^2 = 0.85$, NSE = 0.85

Assessment/Validation Summary: unadjusted model applied to LFRWMP watersheds (2004-05 data)

Initially 2006 data not utilized because not finalized at time (Nov 06 to April 07)

Validation criteria objective: R^2 or NSCE of 0.6 or greater (with some qualifications)

Table 3-1. Simulated and observed monthly flow, SS and TP statistics: WY2004-05. Simulated results based on un-adjusted LFR calibration parameters. Relative differences are for the entire period.

	Flow			SS			Phosphorus		
Stream	**R^2**	**NSCE**	**% diff**	**R^2**	**NSCE**	**% diff**	**R^2**	**NSCE**	**% diff**
Apple	0.86	0.86	6.3%	0.87	0.77	-21.7%	0.81	0.81	-3.6%
Ashwaubenon	0.90	0.85	26.1%	0.69	0.69	1.9%	0.82	0.82	-3.1%
Baird	0.84	0.83	16.6%	0.66	0.65	-3.7%	0.70	0.66	-0.9%
Duck	0.86	0.84	-12.5%	0.77	0.75	3.0%	0.67	0.64	25.5%
East River	0.94	0.93	-8.0%	0.72	0.59	45.6%	0.86	0.86	7.6%

Assessment/Validation Summary: adjusted* Duck Cr. & East River (2004-05)

* Duck Creek: P sorption coefficient and P partitioning coef.

* East River: sediment transport factor (800 mg/L to 500 mg/L)

Table 3-3. Simulated and observed monthly flow, SS and TP statistics: WY2004-05. Simulated results based on adjusted LFR calibration parameters*. Relative differences are for the entire period.

	Flow			SS			Phosphorus		
Stream	**R^2**	**NSCE**	**% diff**	**R^2**	**NSCE**	**% diff**	**R^2**	**NSCE**	**% diff**
Apple	0.86	0.86	6.3%	0.87	0.77	-21.7%	0.81	0.81	-3.6%
Ashwaubenon	0.90	0.85	26.1%	0.69	0.69	1.9%	0.82	0.82	-3.1%
Baird	0.84	0.83	16.6%	0.66	0.65	-3.7%	0.70	0.66	-0.9%
Duck*	0.86	0.83	-12.8%	0.75	0.73	3.9%	0.66	0.66	5.6%
East River*	0.94	0.93	-8.0%	0.74	0.72	20.7%	0.86	0.86	7.6%

Assessment/Validation Summary: adjusted* Duck Cr. & East River (2004-06)

* Duck Creek: P absorption coefficient and P partitioning coef.

* East River: sediment transport factor (800 mg/L to 500 mg/L)

Table 3-3a. Simulated and observed monthly flow, TSS and phosphorus statistics: WY2004-06. Simulated results based on adjusted LFR calibration parameters*. Relative differences are for the entire period.

Stream	Flow R^2	Flow NSCE	Flow % diff	TSS R^2	TSS NSCE	TSS % diff	Phosphorus R^2	Phosphorus NSCE	Phosphorus % diff
Apple	0.84	0.83	14.7%	0.79	0.73	-8.3%	0.76	0.75	7.8%
Ashwaubenon	0.89	0.82	30.4%	0.65	0.64	23.1%	0.82	0.82	4.4%
Baird	0.84	0.82	21.6%	0.60	0.60	12.2%	0.67	0.66	11.9%
Duck*	0.85	0.83	-8.4%	0.73	0.71	21.3%	0.64	0.64	13.2%
East River*	0.92	0.91	-6.6%	0.66	0.59	37.6%	0.80	0.79	16.1%

When 2006 data added, model did not perform as well, which reduced statistical measures

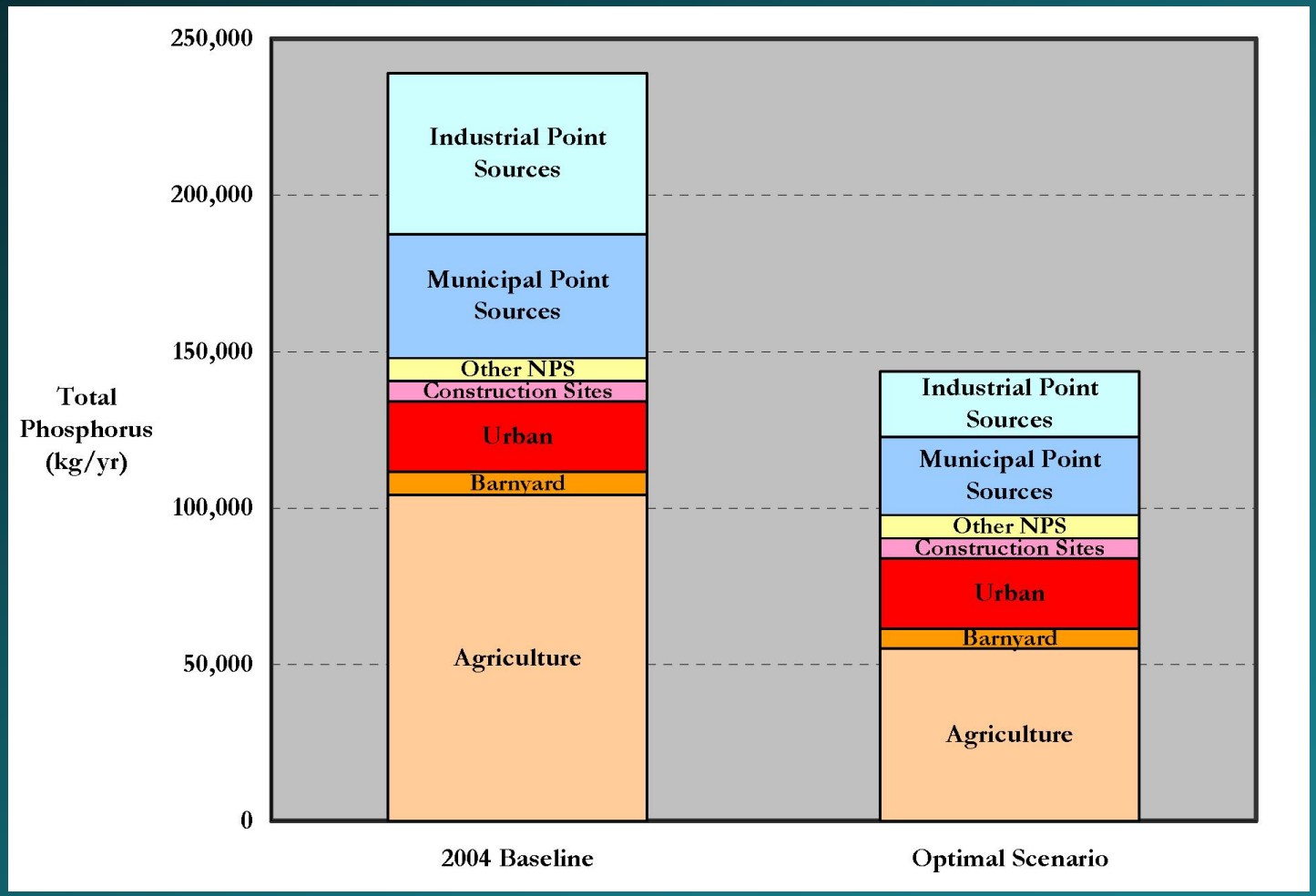
Model Assessment Summary

- In general, a fairly good correspondence between simulated and observed stream flow and loads of phosphorus and suspended sediment (monthly, annual, totals)
- Model response acceptable for predictive simulations in sub-basin
- Model least able to predict flow and loads:
  - from small events, affected phosphorus loads most
  - after prolonged dry periods
  - during snow melt periods
  - from East River at this time (sediment loads)

Model Results – Baseline Conditions

- Stream flow and loads at sub-basin, watershed and sub-watershed scales
- Total, and by HRU/landuse category

Simulated P Load to Lower Green Bay from LFR Basin: 2004 Baseline vs. Opt. Scenario of Ag BMPs and Point Source Reductions (note: Winn load ~ 288,000 kg/yr)



From: Integrated Watershed Approach Demonstration Project A Pollutant Reduction Optimization Analysis for the Lower Fox River Basin and the Green Bay Area of Concern (Table 6). Prepared by Laura Blake of The Cadmus Group for U.S. EPA (with contributions by P. Baumgart of UW-Green Bay and Sam Ratick of Clark University)

Simulated impacts and cost of Optimal Scenario on phosphorus non-pt source loads to Green Bay from LFR subbasin. Optimized for P reduction.

BMP Scenarios	Phosphorus (kg)	% Reduced	Total Cost	Avg Cost per kg of Phosphorus Reduced
Baseline 2004 Conditions	147,900			
1. Nutrient Management: Dairy P Feed Ration: Reduce by 25%; Implement 90%	140,600	4.9%	$0	$0.00
2. plus: Increase manure incorporation from 50% to 85%	133,800	9.5%	$394,000	$27.94
3. plus: Stabilize Soil P (90% implement)	125,300	15.3%	$1,646,000	$72.82
4. plus: Conservation Tillage - CT40%, MT45%, ZT15%	115,100	22.1%	$2,731,000	$83.25
5. plus: Cover Crops on corn silage and some soybean fields	111,600	24.5%	$3,200,000	$88.16
6. plus: Buffer Strips installed on 100% of 1:24k hydrology strear	107,600	27.2%	$3,372,000	$83.68
7. plus: Reduce Soil P to 25 ppm; Implemention = 35%	100,600	32.0%	$5,901,000	$124.75
8. plus: Biofuel Switch grass crop; 7% of all total crop acres	97,700	33.9%	$6,929,000	$138.03

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Simulated impacts and cost of Optimal Scenario on sediment and phosphorus non-point source loads to Green Bay from LFR subbasin. Optimized for P reduction.

BMP Scenarios	Suspended Sediment (ton)	Phosphorus (kg)	% Reduced SS	% Reduced Phos	Total Cost	Avg Cost per kg of Phosphorus Reduced
Baseline 2004 Conditions	54,500	147,900				
1. Nutrient Management: Dairy P Feed Ration: Reduce by 25%; Implement 90%	54,500	140,600	0.0%	4.9%	$0	$0.00
2. & Increase manure incorporation from 50% to 85%	54,500	133,800	0.1%	9.5%	$394,000	$27.94
3. & Stabilize Soil P (90% implement)	54,500	125,300	0.1%	15.3%	$1,646,000	$72.82
4. & Conservation Tillage - CT40%, MT45%, ZT15%	48,200	115,100	11.6%	22.1%	$2,731,000	$83.25
5. & Cover Crops on corn silage and some soybean fields	46,400	111,600	14.9%	24.5%	$3,200,000	$88.16
6. & Buffer Strips installed on 100% of 1:24k hydrology stream	44,900	107,600	17.6%	27.2%	$3,372,000	$83.68
7. & Reduce Soil P to 25 ppm; Implemention = 35%	44,900	100,600	17.6%	32.0%	$5,901,000	$124.75
8. & Biofuel Switch grass crop; 7% of all total crop acres	43,300	97,700	20.6%	33.9%	$6,929,000	$138.03

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Next Steps

- Refine SWAT stream bank erosion estimates - Sediment source tracing with radionuclides

Sediment Tracer Preliminary Investigation

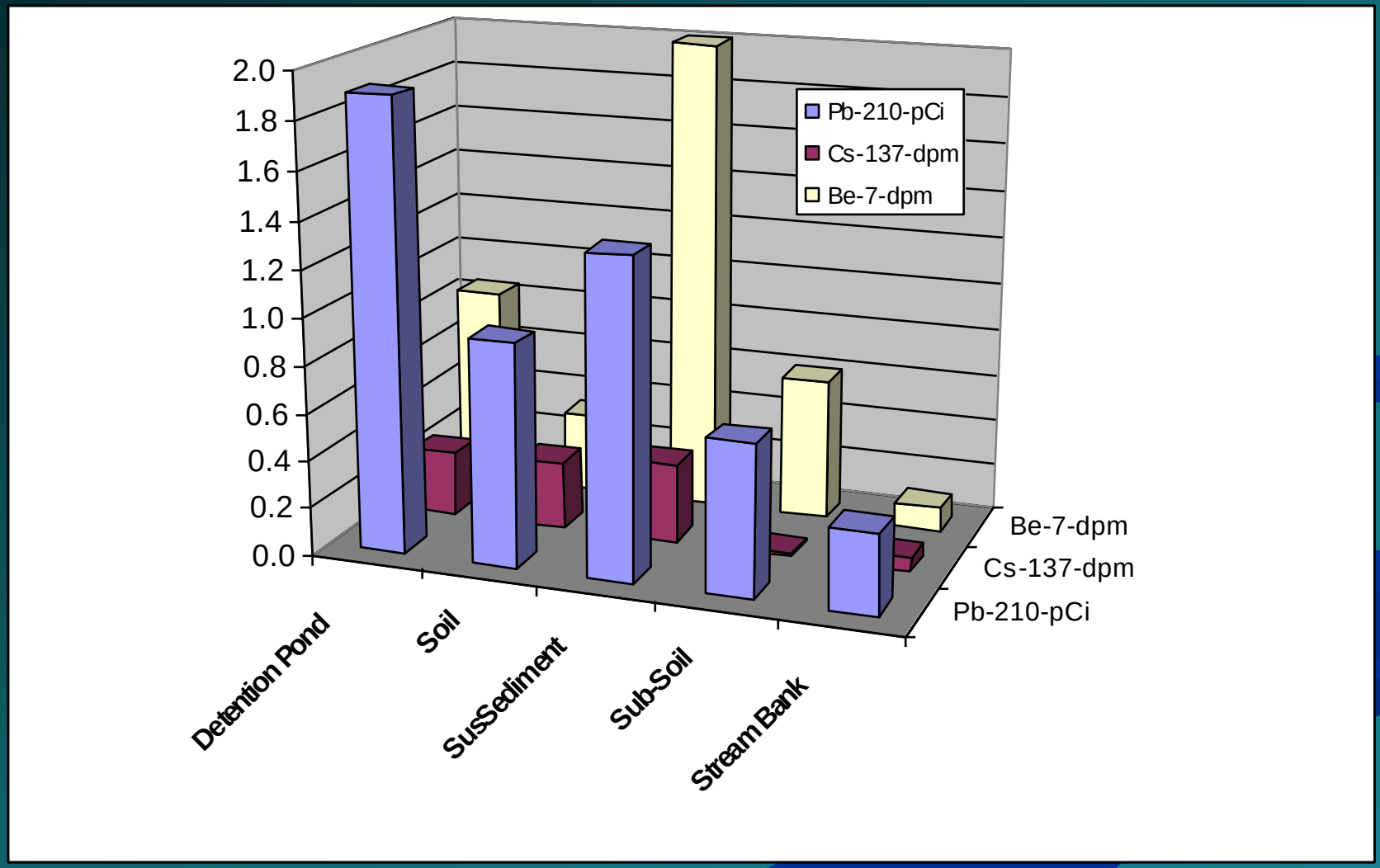
- Objective: determine relative contributions of suspended sediment sources to streams in Lower Fox watersheds
- Sources: rural runoff, stream bank, construction site, urban
- UW-Milwaukee (Val Klump) radionuclide analysis (Cs-137, Pb-210, Be-7)
- UW-Green Bay sampling & processing & other chemical analysis (GBMSD and/or UWGB)
- 66 samples collected/analyzed from 2006 to Oct. 2007
  1. Suspended sediment (streams – 9 samples) including Spring snowmelt samples from Baird North & South branches
  2. Soils (surface, top, bottom for total of 36)
  3. Sub-soil (3 samples)
  4. Stream bank (6 samples - Baird Creek)
  5. Huron-Sitka Detention pond (2 cores, 12 samples)

- Lab results from UW-Milw. done, but not fully analyzed yet

Sediment Tracer Preliminary Investigation

Time-integrated suspended sediment sampler

Sediment Tracer Preliminary Investigation: CAUTION: Very preliminary results: comparison as example only



Acknowledgements

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- Bud Harris, Dave Dolan -- UWGB
- Jesse Baumann, Jessie Fink, Jon Habeck, Nick Reckinger, Erika Sisal, Zach Zachariah -- UWGB
- Arjo Wiggins Appleton, Inc.

Questions?

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Full reports: www.uwgb.edu/watershed