Temporal Assessment of Management Practices and Water Quality in the Duck Creek Watershed, Wisconsin

Daniel Cibulka
Kevin Fermanich
Paul Baumgart
University of Wisconsin – Green Bay
November, 2009

SOVEREIGN ONEIDA NATION OF WISCONSIN

USGS science for a changing world

THE LOWER FOX RIVER watershed monitoring program

UNIVERSITY of WISCONSIN GREEN BAY

Acknowledgement

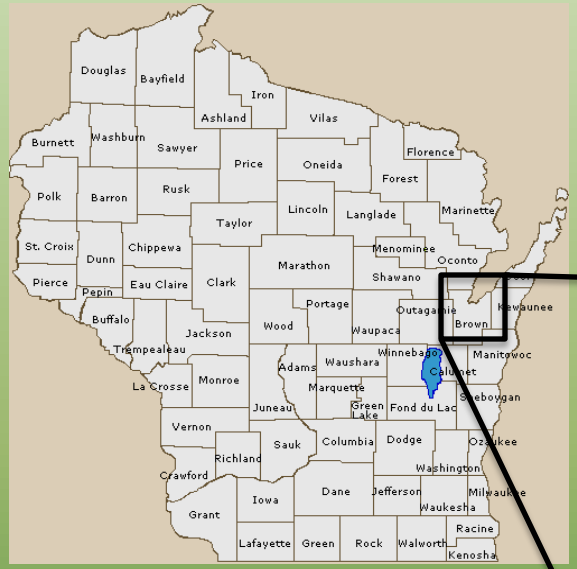
- This presentation is substantially based on thesis work conducted by Daniel Cibulka, Environmental Science and Policy Graduate Program at UW-Green Bay
- Funding for this study was provided by the Oneida Nation of Wisconsin

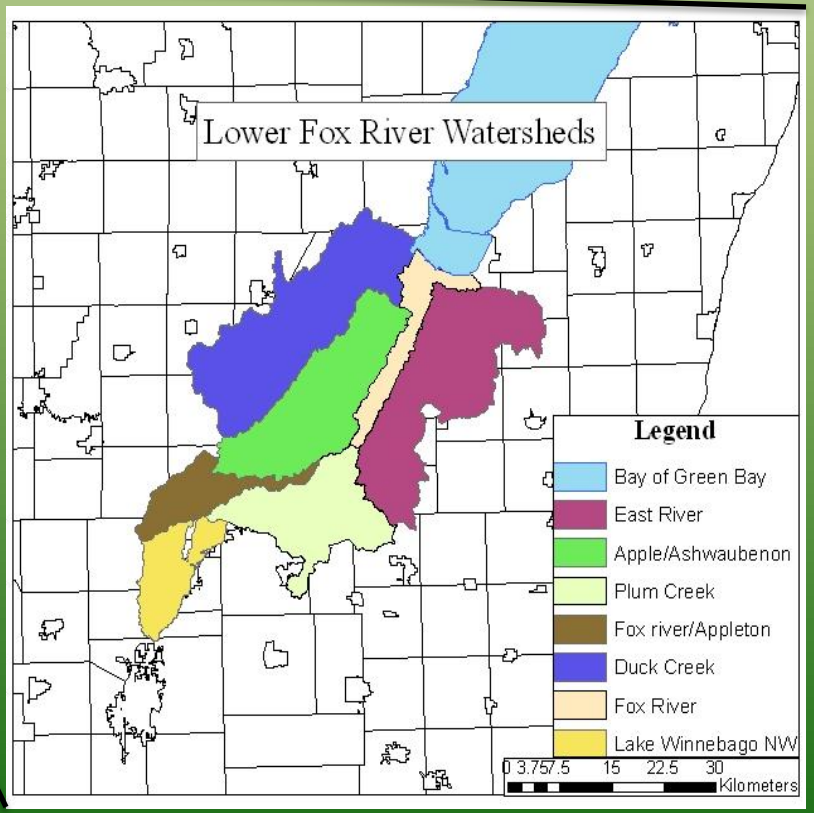
Presentation Outline

- Project Background, Objectives
- Overview of Land Use / Management Changes
- Duck Creek WQ Statistical Analysis
- Trends in Duck Creek Biological Condition
- Trout Creek WQ Characterization
- Project Summary

Project Background

Lower Fox River Watershed

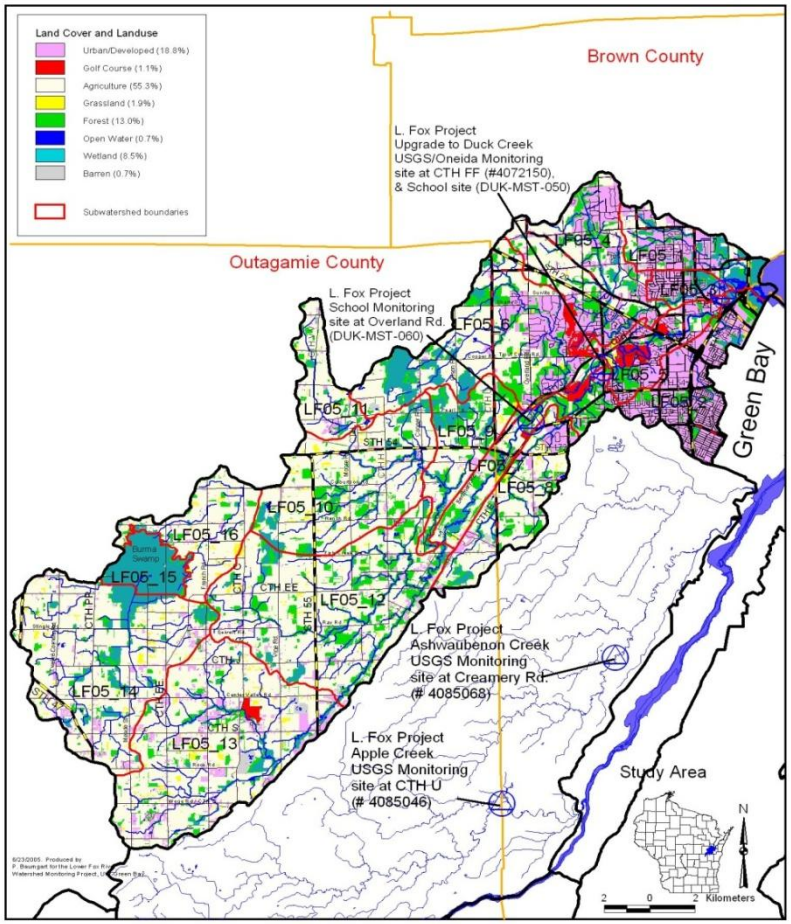




- 1,654 km^2 basin
- Brown, Calumet, Outagamie, Winnebago Counties

Duck Creek Watershed

- 392 km^2
- Predominately agriculture (55%), small urban impact
- Census data: population increase of 24% from 1990 to 2007



Landuse and land cover in the 392 sq. km Duck Creek Watershed. Image based on composite of: 2001 landuse from Brown County Planning Dept.; 2000 landuse from East Central Regional Planning Commission, and 1992 WISCLAND land cover from WDNR.

Geology, Hydrology and Soils

- Galena formation of Sinnipee limestone group underlies watershed
  - Permeable rock layer
- USGS 1991 study: 15 losing reaches
    - Some reaches lose up to 390,000 gallons per day
- Glacial till from Wisconsin Stage glacier
  - Sand/sand-loam deposits in north
  - Reddish clay-loam mix in south

Mainstem Duck Creek Conditions

- 39.5 of 57.6 stream miles on Wisconsin “Impaired Waters” list
  - Sediment, phosphorous, ammonia primary pollutants
  - Aquatic life rated “poor to fair”
  - Streambank erosion, barnyard animal lots and sediment runoff from croplands major concern
  - Tributary streams have shown higher water quality, biotic integrity

Rationale and Objectives

20+ years of watershed management activities…

- Have efforts to restore watershed been effective?
  - Have nutrient concentrations changed?
  - Have biological communities responded?
- What is the water quality of Trout Creek?
  - Special consideration to Brook Trout survival

Objectives

1. Characterize changes in land use and management
2. Analyze relationships between historical/recent water quality and biotic integrity data
3. Explore relationship between land use changes and water quality/biotic condition in Duck Creek
4. Characterize the water quality in Trout Creek
5. Assess management implications of analysis

Land Use / Management Changes

Changes in the Watershed

- Duck, Apple, Ashwaubenon Priority Watershed Project
  - Approval in 1997
  - Cost-sharing and technical assistance
  - Identification of “critical sites”
  - Preliminary results show estimated reduction of ~51,000 tons (sediment) and ~130,000 lbs. (phosphorous)*

* Reduction estimates based upon modeled results and reflect all three watersheds, not Duck Creek alone

Changes in the Watershed

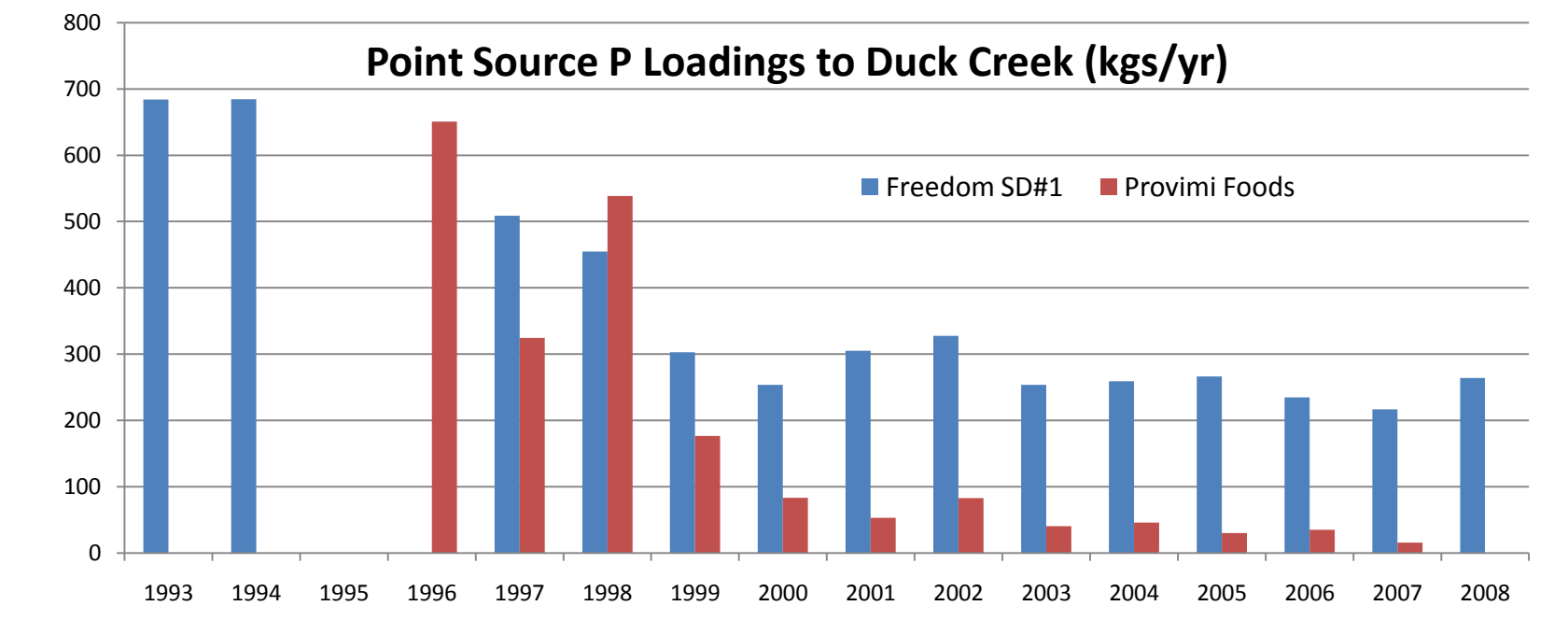
- Agricultural Tillage Survey
  - Survey completed spring 2009
  - Conventional tillage ↓ from 2002 to 2009
  - Conservation tillage ↑ from 2002 to 2009

Year	Survey Time	Conv. Till	Mulch Till	No Till
2009	Before spring tillage	50%	41%	9%
2002	After spring planting	96%	4%	0%
1999/2000	After spring planting	69%	29%	2%
1996	After spring planting	74%	26%	0%

- General trend of increasing corn and decreasing forage proportions between 1992 and 2007

Changes in Watershed

- Permitted Point Source Dischargers



Freedom SD#1: -68% **Provimi Foods: -98%**

Changes in the Watershed

- Dairy Farm and Cow Trends
  - Dairy farms ↓ in watershed by 59%*
  - Dairy cows have ↑ (7.9%) in Brown County, and have ↓ in Outagamie County (19.6%) +

*1989-2008

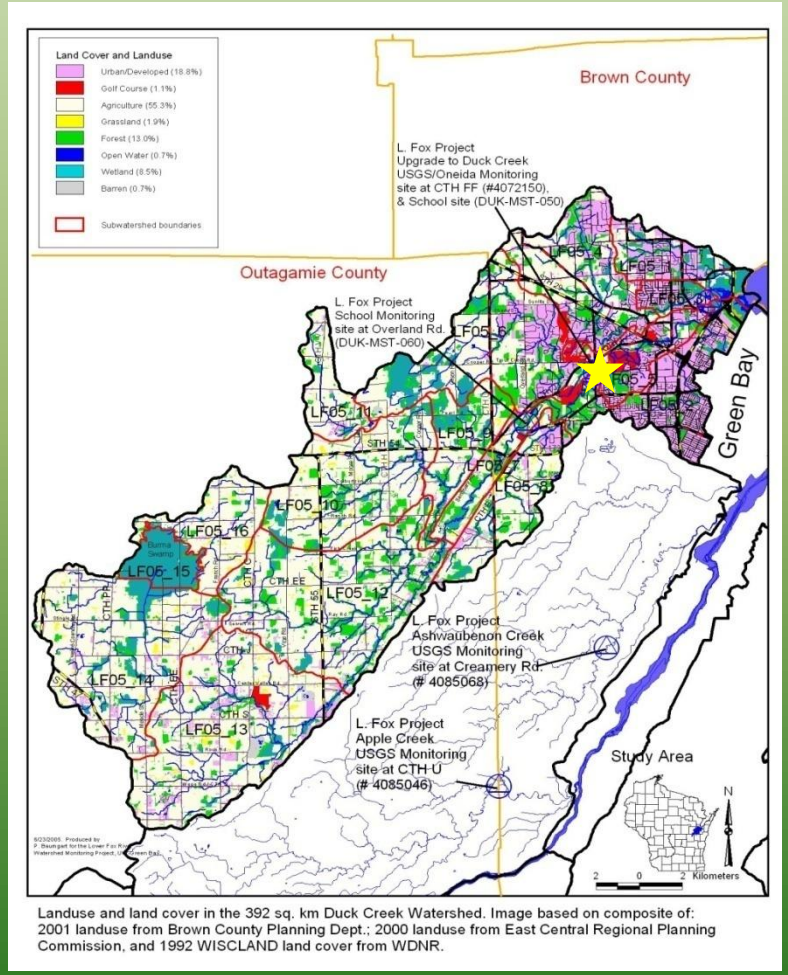
+1988-2007

Oneida Initiatives

- Extensive buffering program
- Intensive rotational grazing plan for beef cattle on Oneida Farms (>600 acres)
- >1,000 acres of restored wetlands
- Nutrient management plans have been implemented on all Oneida Farms
- Focus on “critical sites” and habitat restoration in Trout sub-watershed

Duck Creek Water Quality Trend Analysis

Water Quality Monitoring

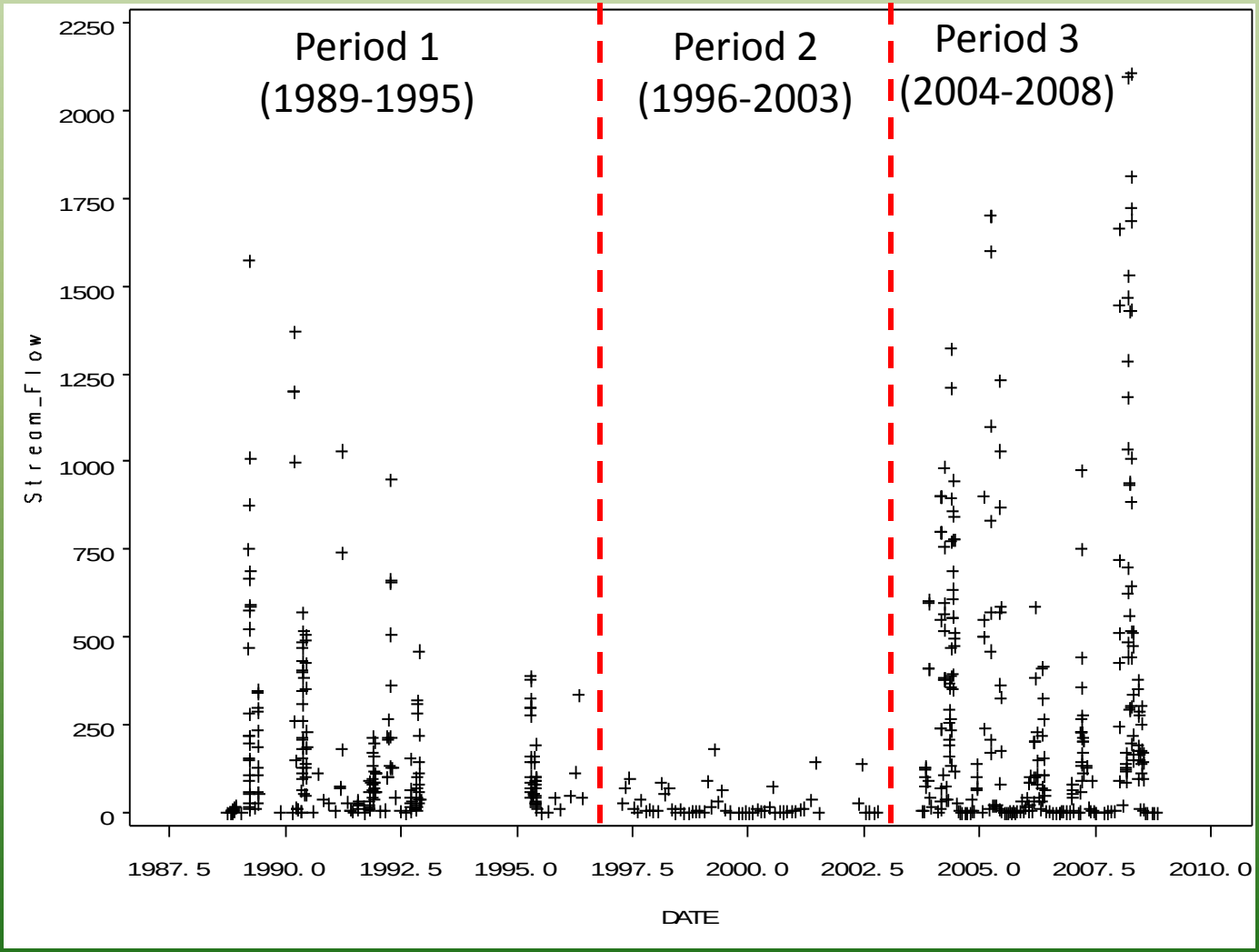


Landuse and land cover in the 392 sq. km Duck Creek Watershed. Image based on composite of: 2001 landuse from Brown County Planning Dept.; 2000 landuse from East Central Regional Planning Commission, and 1992 WISCLAND land cover from WDNR.

- USGS monitoring station # 4072150
  - Flow (20 yr)
  - TP (20 yr)
  - DP (20 yr)

Water Quality Monitoring

sampling protocol changes



Dataset Modifications

- Duplicate samples flagged and removed
- TP “outliers” (>1.3 mg/L) were removed
- 4-month period in 1999 sub-sampled
- TP and DP concentrations log-transformed

Statistical Analysis

- 5 Statistical Tests Run on Dataset
  - 20-year multiple linear regression
  - Period specific regressions
  - Period comparisons using Wilcoxon Rank sum test with data censoring
  - Period comparisons using Wilcoxon Rank sum test, with additional data censoring (data set sub-sampled monthly)
  - Period specific regressions of monthly and weekly sub-sampled data sets

Regression Model

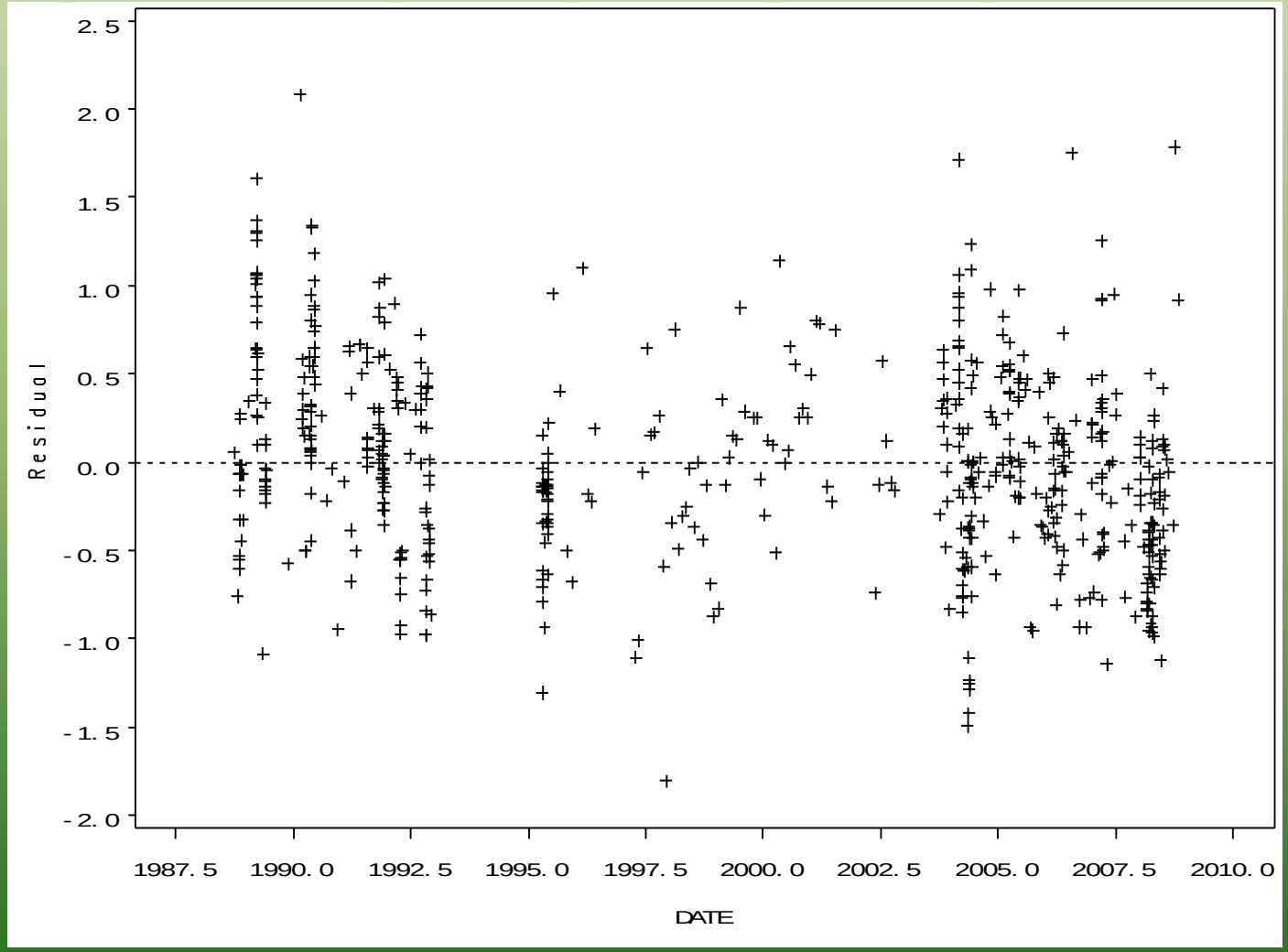
- Based off of USGS LOADEST Program, run through SAS with CP option
- Includes “centered” option to reduce collinearity
- Sine & Cosine terms to account for seasonality
- Flow terms to account for flow variation
- Time term entered as decimal time (for trend analysis)

20-Year Regression Results (test 1)

- TP, DP concentrations decreased significantly ($p<0.0001$)
- However, decreasing trend not linear since it occurred primarily during Period 1
- So, linear regression results not valid when applied over 20 year record, so applied separately to Periods 1 and 3

20-Year Residual Plot

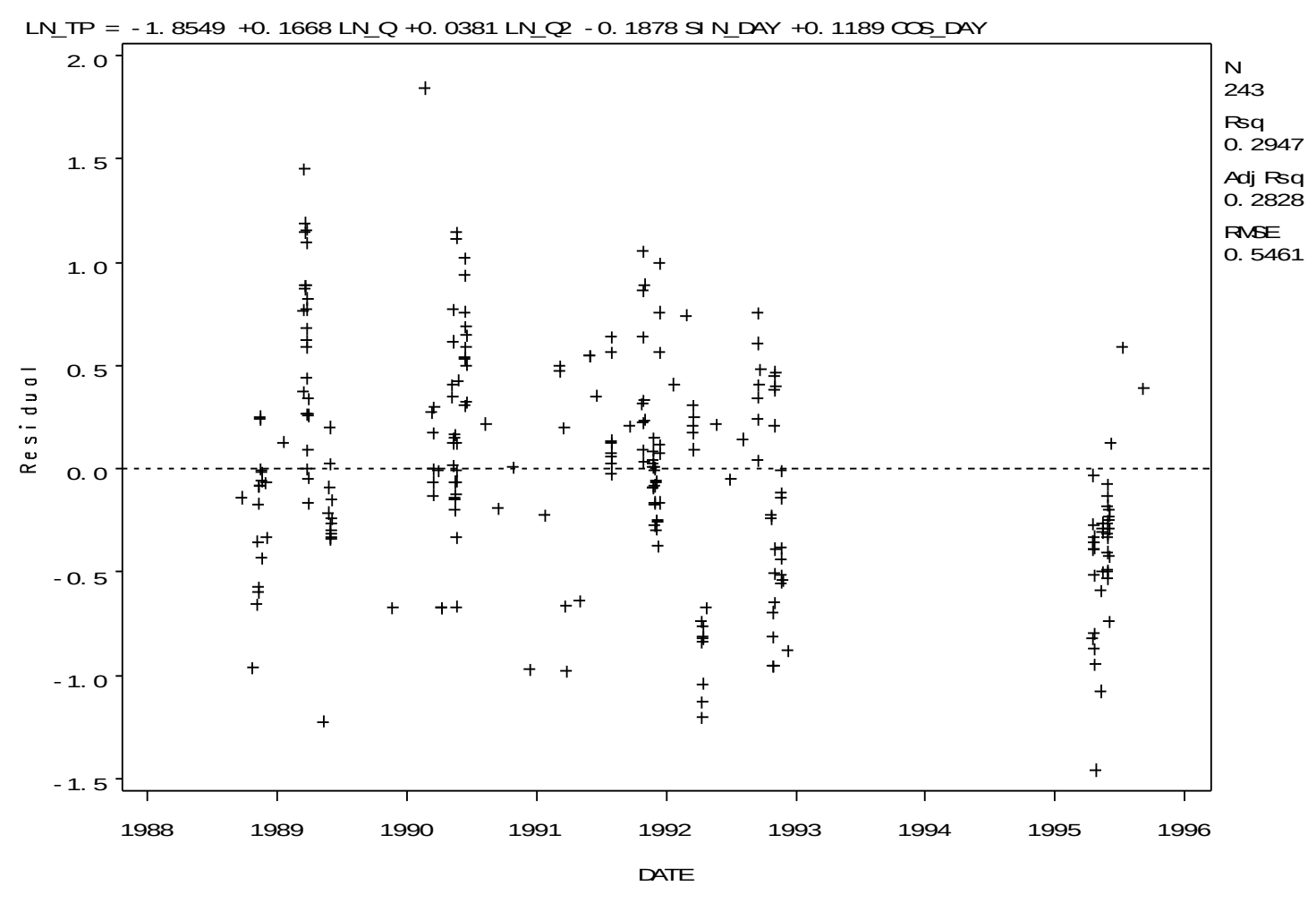
Decrease of TP occurred primarily in Period 1

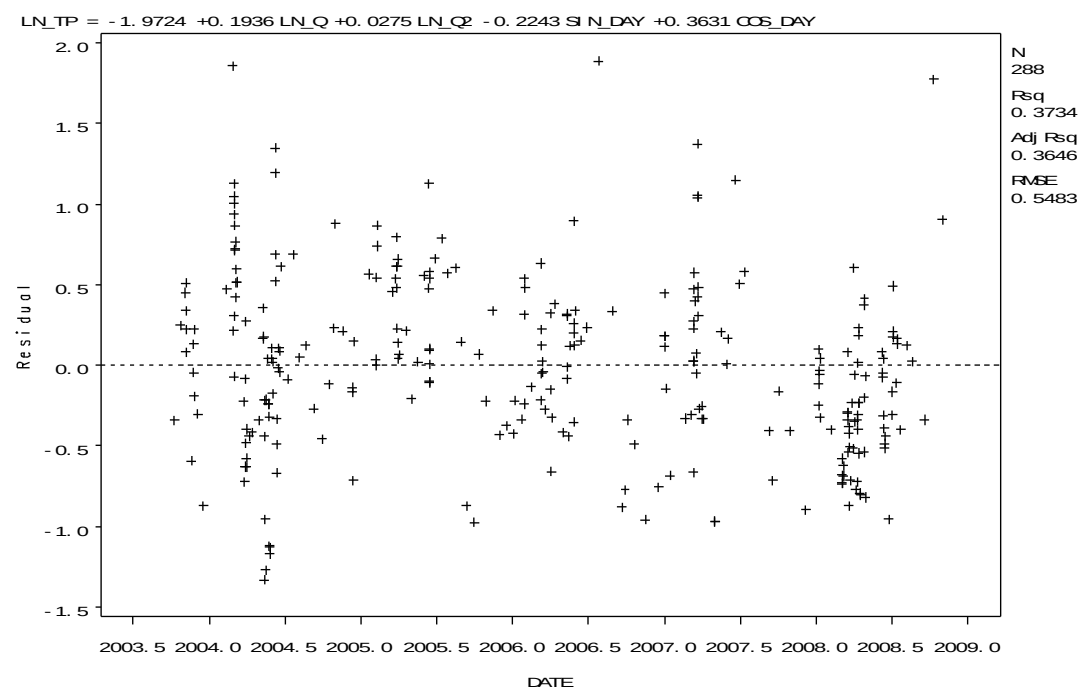


Period Specific Regressions (test 2)

- Same Regression Model Applied to Period 1 and Period 3
  - Period 1 (1989-1995):
    - TP and DP significant decrease ↓ ($p<0.0001$) of roughly 10% and 11% per year
  - Period 3 (2004-2008):
    - TP and DP no significant change when 2008 excluded ($p = 0.79$ for TP)
    - Significant decrease in TP and DP detected ONLY when year 2008 included, BUT 2008 likely ANOMALY or outlier
      - Issues with ISCO sampling line and high flow samples
      - Record snowfall, high snowmelt
      - Analysis of TSS data confirmed 2008 was probable anomaly

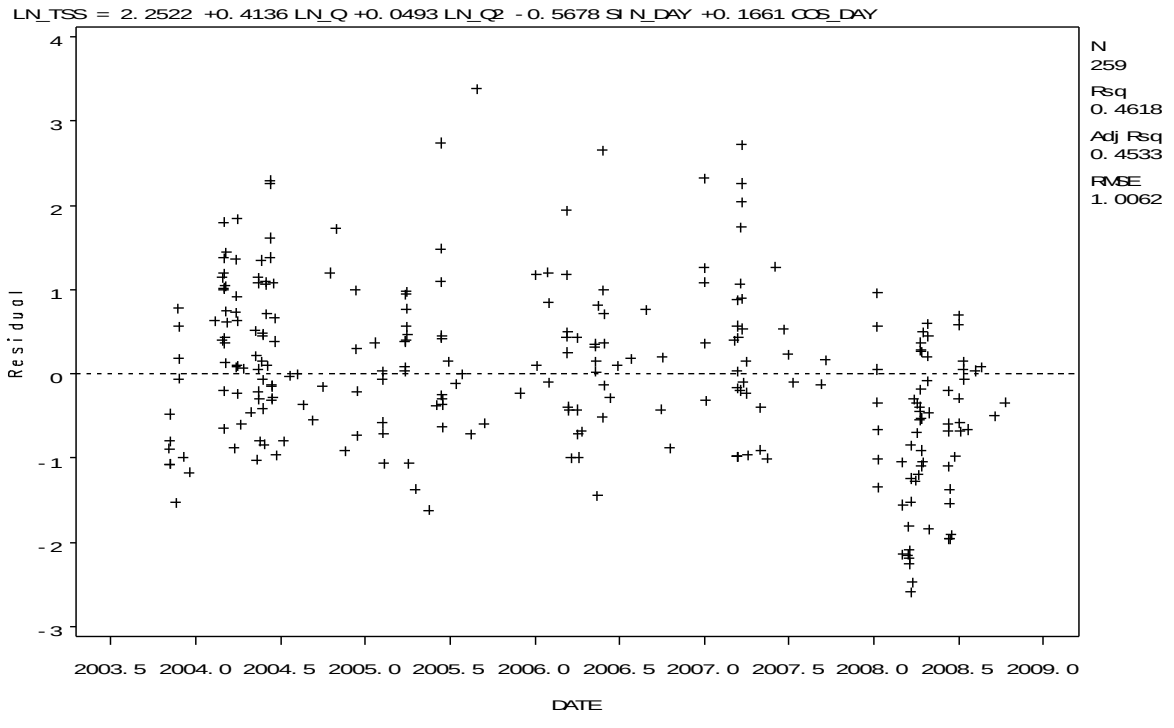
Period 1 declining trend of TP





Period 3 TP, no obvious trend, but lower TP in 2008 (likely anomaly)

Period 3 TSS, no obvious trend, but much lower TSS in 2008 (likely anomaly)



Period Specific Comparisons (test 3)

- Wilcoxon Rank Sum-Test between Period 1 & 3
- TP, DP lower in Period 3 ($p<0.05$, $p<0.002$)
  - For all flow (cfs) and data censoring scenarios*

Variable	All Flow	w/o 1995	Flow < 1000	Flow < 750	Flow < 500	Flow < 250	Flow < 75	Flow > 75 and < 750	Flow > 75 and < 750 w/o 2008
TP	For all flow scenarios Period 3 Concentrations < Period 1								
DP									
DP/TP	P1=P3	**P1>P3***	P1=P3	P1=P3	P1=P3	P1=P3	P1=P3	P1=P3	P1=P3
	Ratios not significantly different between Period 3 & Period 1								
N for TP	243 – P1	205	199	196	182	157	98	97	97
	288 – P3	288	264	237	210	167	89	148	102

* All flow scenarios omit water-year 1995, except “All Flow”

Sub-Sampling Comparisons (tests 4 & 5)
Period 1 (1989-1995) vs Period 3 (2004-08)

Potential for Serial Correlation in Dataset

- Sub-sampled once per month, nearest to mid-month
  - TP, DP concentrations still Lower in Period 3 ($p=0.023$ for both constituents), than Period 1
    - Wilcoxon Rank sum test
  - Sub-sampled dataset once per week with similar results

- Regression performed on Period 1 and Period 3 for sub-sampled data
    - All tests not significant ($p>0.05$)
    - BUT, weight-of-evidence from other tests and visual inspection of trends supports conclusion that TP and DP concentrations have decreased

Trends in Duck Creek Biological Condition

Monitoring of Fish & Macroinvertebrates

- Sources Contributing Data
  - Kirby Kohler (UWSP)
  - Lower Fox River Watershed Monitoring Program
    - UW-Green Bay and UW-Milwaukee
  - Oneida Tribe of Indians
  - USGS (NAWQA Program)
  - UWSP Aquatic Entomology Lab
  - US Fish and Wildlife Service
  - Wisconsin DNR

Biological Indices

Fisheries Biotic Index

- Karr et al. 1986 - Standardized method of assessing fish community "health"
- Reflects vital components of community
- Regionally specific

Macroinvertebrate Biotic Index

- Hilsenhoff 1987, 1988 – means of determining degree of organic pollution
- Popular means of assessing bug community
- Bugs assigned a value based upon tolerance to organic pollution & oxygen demand

Lyon's IBI

1992 Permanent Warmwater Stream Method

2006 Intermittent Warmwater Stream Method

Species Richness and Composition

Trophic and Reproductive Function

Fish Abundance & Condition

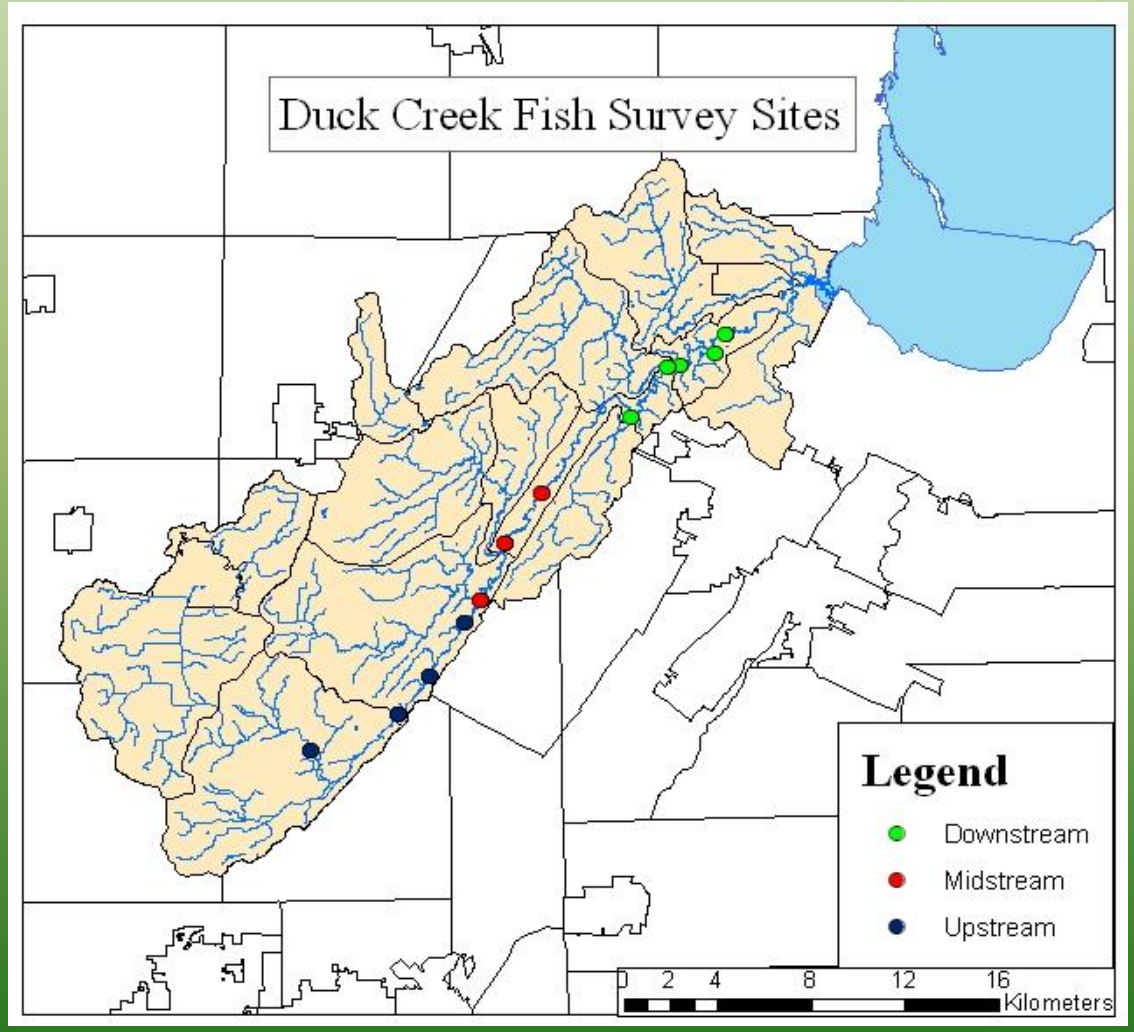
12 Metrics

7 Metrics

Fish Analysis Methods

- Lyon's 1992 and 2006 IBI and IBI metrics calculated for all surveys (12 locations, 148 surveys)
- Dataset reduced to summer surveys (12 locations, 91 surveys remaining)
- Surveys lumped spatially and by Period
- Exact Wilcoxon test used to compare Period 1 metrics with Period 3

Biotic Sampling Locations - Fish



Fish Results

Metric	P-Value	Location	Change	Implication
Abundance	0.0057	DS	Increase	Positive
	0.0424	US	Increase	Positive
No. of Native Species	<0.0001	DS	Increase	Positive
	0.0201	MS	Increase	Positive
No. of Darters	0.0022	DS	Increase	Positive
No. of Suckers	0.0019	DS	Decrease	Negative
No. of Sunfish	0.0394	US	Increase	Positive
No. of Intolerant Species	0.0356	MS	Decrease	Negative
% Tolerant Species	0.0263	DS	Increase	Negative
% Insectivores	0.0071	DS	Increase	Positive
% Top Carnivores	0.0148	DS	Decrease	Negative
	0.0154	MS	Decrease	Negative
1992 IBI	0.0452	DS	Increase	Positive
No. of Minnow Species	<0.0001	DS	Increase	Positive
	0.0028	MS	Increase	Positive
Catch of Non-Tolerant Species	0.0037	DS	Increase	Positive
	0.0439	MS	Increase	Positive
	0.0394	US	Increase	Positive
Catch of Brook Stickleback	0.0122	MS	Increase	Positive
2006 IBI	0.0045	DS	Increase	Positive

Summary by Watershed Location

Location	Significant Changes	Positive	Negative
DS	11	8	3
MS	6	4	2
US	3	3	0

Macroinvertebrate Analysis

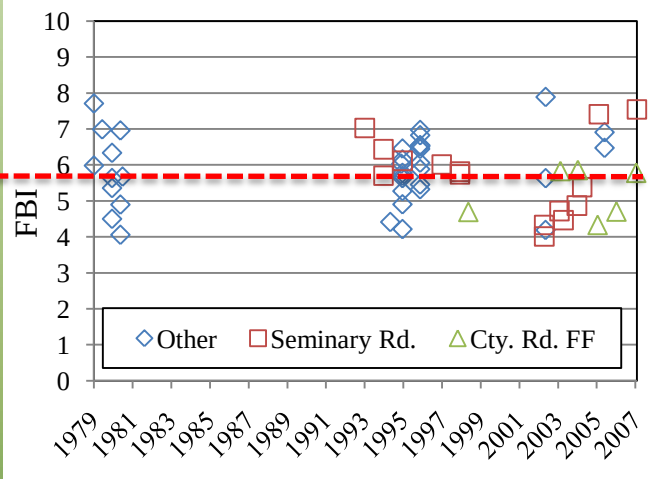
HBI Value	FBI Value	Water Quality
0.00-3.50	0.00-3.75	Excellent
3.51-4.50	3.76-4.25	Very Good
4.51-5.50	4.26-5.00	Good
5.51-6.50	5.01-5.75	Fair
6.51-7.50	5.76-6.50	Fairly poor
7.51-8.50	6.51-7.25	Poor
8.51-10.0	7.26-10.0	Very poor

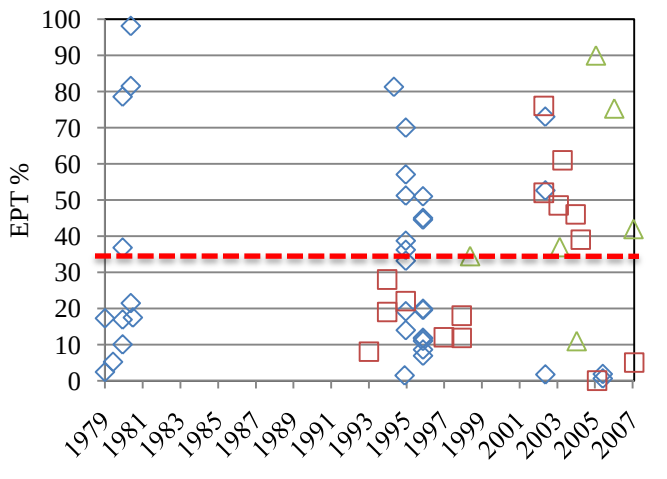
- Metrics Analyzed:
  - HBI (1987) & FBI (1988)
  - EPT %
    - Measures percent of "sensitive" species
  - Number of Species
- UWSP BUG Biomonitoring Program

Macroinvertebrate Results

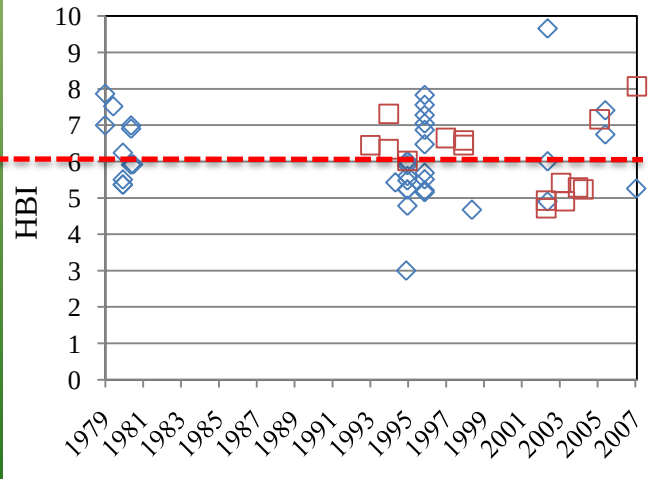
= *Average for all sites*

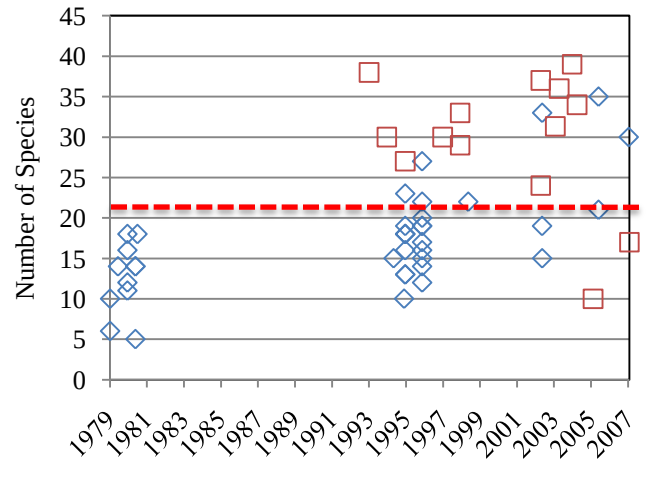
"Fair"





"Fair"

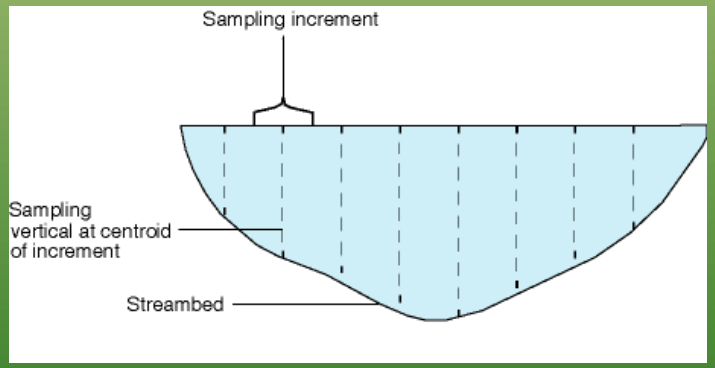




Characterization of Trout Creek Water Quality

Trout Creek Methodology

- Two monitoring locations
- TSS, TP, DP samples collected
  - Equal Width Interval sampler and Siphon Samplers used
  - Analysis through GBMSD
- Low-flow & event samples
- Low-flow statistical comparison between sites

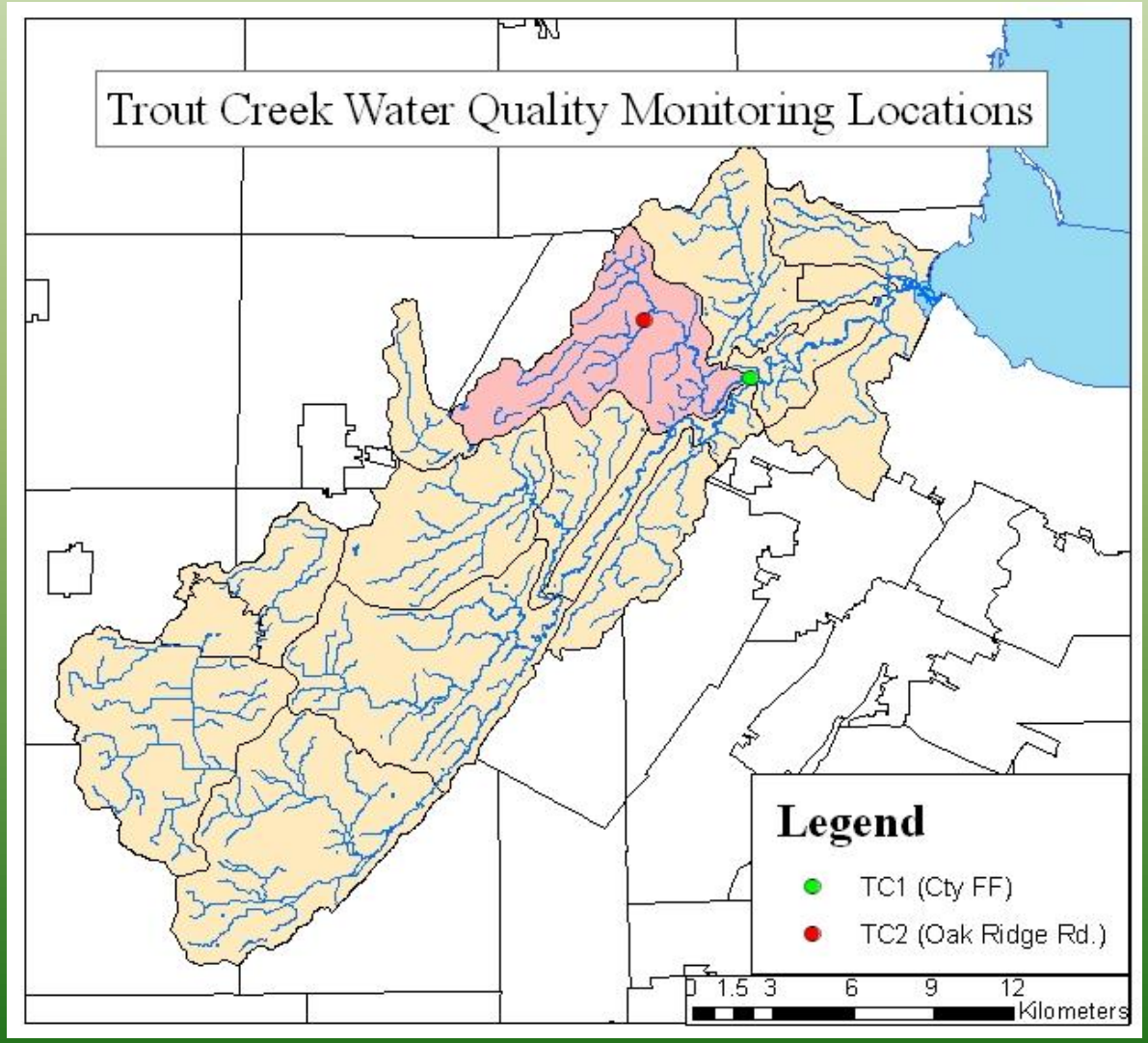


Picture courtesy of USGS Website

Methodology cont.

- YSI 6600 EDS Sondes
  - Temperature
  - Dissolved Oxygen
  - Turbidity
  - pH
  - Conductivity
  - Depth

Monitoring Locations



Specific BMP Efforts

Picture courtesy of Jim Snitgen, Oneida Tribe

Sonde Results: 2009

Temperature, D.O., pH, Turbidity values mostly within tolerable/optimal range for Brook Trout

TC1 – County Road FF

	Temp °C	D.O. mg/L
Summer Average	17	8.8
Fall Average	6	9.9
Range	0-23	4.7-14.5*

TC2 – Oak Ridge Road

	Temp °C	D.O. mg/L
Summer Average	17	7.8
Fall Average	9	7.6
Range	2-23	3.1-11.8+

Published Tolerance to Temperature and D.O. for Brook Trout (*S. fontinalis*)

Parameter	Optimal Conditions	Tolerable Range
D.O. (mg/L)	7.0 to 9.0	5.0 to Saturation
Temperature	11.0 to 16.0	0 to 24.0

*D.O. dropped below 5.0 mg/L for a 5 hour period at TC1

+D.O. dropped below 5.0 mg/L for two periods (9 and 64 hours) at TC2

Nutrient and TSS Monitoring Results

- Statistical comparison between sites (baseflow conditions, n=8)
- Paired T-test for paired samples (log-transformed)
- TP and DP significantly lower ($p<0.05$) at downstream TC1 site (CTH FF) during baseflow conditions (i.e., low flow non-event)
- All in mg/L

	TSS		TP		DP	
	TC1	**TC2**	**TC1**	**TC2**	**TC1**	**TC2**
Mean	6.0	4.7	**0.060**	**0.085**	**0.037**	**0.049**
Min	2.1	2.0	0.015	0.015	0.015	0.015
Max	16.0	14.0	0.113	0.151	0.060	0.092
Std	5.1	4.1	0.034	0.044	0.019	0.025
p-value	0.5421		**0.0163**		**0.0031**	

TSS, TP, DP Concentrations (mg/L) at Trout Stations: All Flow Conditions

- Few event samples collected (total sample n=18 at TC1 & n=10 at TC2 but these include 8 low flow samples at each station)
- TSS and TP high during events (max = 1490 mg/L TSS at CTH FF)
- Observed relatively deep sediment deposits in stream bed at CTH FF, also sandy deposits above bank from large event(s)

	TC1 - County FF			TC2 - Oak Ridge Rd.		
	TSS	**TP**	**DP**	**TSS**	**TP**	**DP**
N	18	18	17	10	10	10
Mean	198	0.296	0.057	64	0.224	0.073
Median	49	0.161	0.044	4	0.095	0.055
Max	1490	1.160	0.156	442	0.830	0.210
Min	2	0.015	0.015	2	0.015	0.015

Project Summary

Project Summary

- Land Management changes have occurred
  - Not well documented
  - DAAPWP a success
  - Barnyard reductions substantial
  - Point source reductions also substantial

- 4 statistical tests indicate significant ↓ Decrease of TP and DP concentrations in Duck Creek at CTH FF
  - Most reductions seen between 1989-1995
  - Role of point sources, improved barnyards, less winter spreading of manure or greater manure incorporation?

Project Summary continued

- Fish and Macroinvertebrate Analysis
  - Fish
    - Positive changes have occurred
    - “Sensitive” species making a comeback
    - More diversity seen in communities
  - Macroinvertebrates
    - Insufficient dataset
    - Long-term sites established?

Project Summary continued

- Trout Creek WQ Characterization
  - Baseflow conditions met Oneida Tribe WQ standard for phosphorous (0.1 mg/L) 81% of the time
  - Temperature, D.O., pH, Turbidity values mostly within tolerable/optimal range for Brook Trout
  - CTH FF site: High TSS concentrations during events, relatively deep deposits of fine-grained sediment in stream bed and deposits above bank from large events
    - May pose problems for Brook Trout survival or reproduction (Scudder et al. 2000; Alexander and Hansen 1986; Curry & MacNeill 2003)

Management Recommendations

- Emphasize streambank vegetation and stability
  - Events still produce harsh conditions
- Man-made barriers discouraged
  - Restricts access to pools during low-flow
- Long-term trend monitoring plan
  - Quantifiable land management changes
  - USGS monitoring station
  - Utilize established biotic monitoring sites

Questions