Quantifying Sediment and Nutrient Loads to Saginaw Bay

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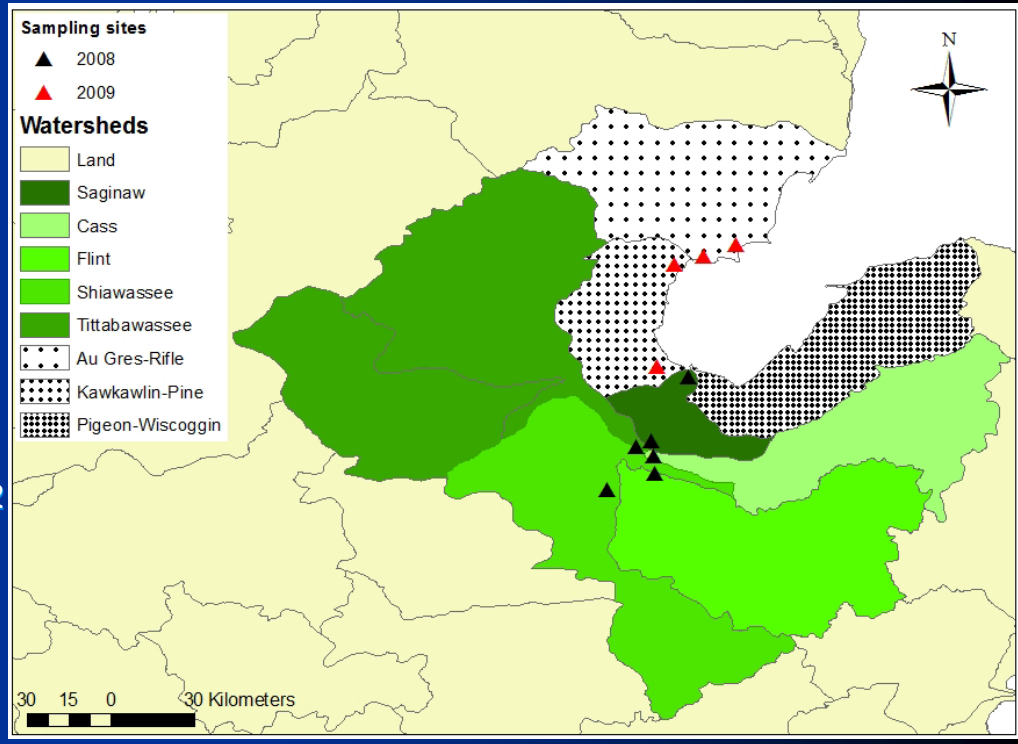
Overview

- Saginaw Bay Watershed
- Available Data
  - Michigan DEQ, USGS
  - 2008 and 2009 Monitoring Programs
- Quantifying TP and TSS loads to the Bay
  - Models and Model Uncertainty
- Localizing TP sources in the watershed
- Nutrient transport model development

Saginaw Bay Watershed



- Area:
  - Total: 23,300 km²
  - Saginaw River: 16,680 km²
  - AuGres-Rifle: 2,777 km²
  - Kawkawlin-Pine: 1,409 km²
  - Pigeon-Wiscoggin: 2,425 km²
- Population: 1.4 Millions in 22 Counties
- Land uses:
  - Agriculture (46% -corn, soybeans, dry beans, and sugar beets)
  - Forest (29%)
  - Open lands (11%)
  - Urban (8%)
  - Wetlands (4%)

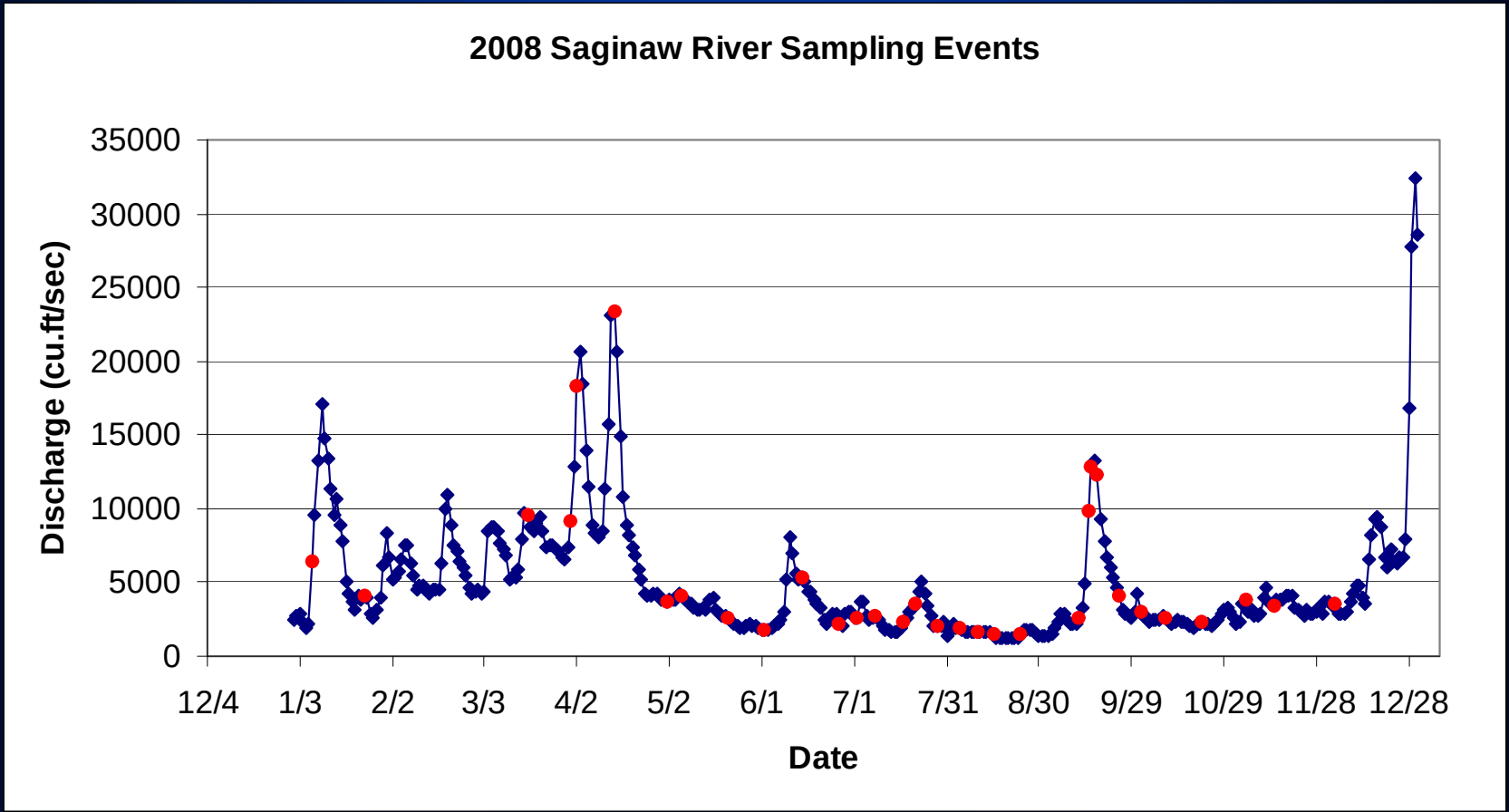
Available In-Stream Water Quality Data

	97	98	99	00	01	02	03	04	05	06	07	08
Flint				3	4	4	11	4	4	4	4	8
Tittabawassee		13		3	4	12	4	4	4	4	12	8
Shiawassee		13		6	4	4	4	4	12	4	4	8
Cass				3	12	4	4	4	4	12	4	8
Saginaw Up	4	4	3	4	4	4	4	4	2	2		32
Essexville		8			12	12	12	12	12	12	12	31

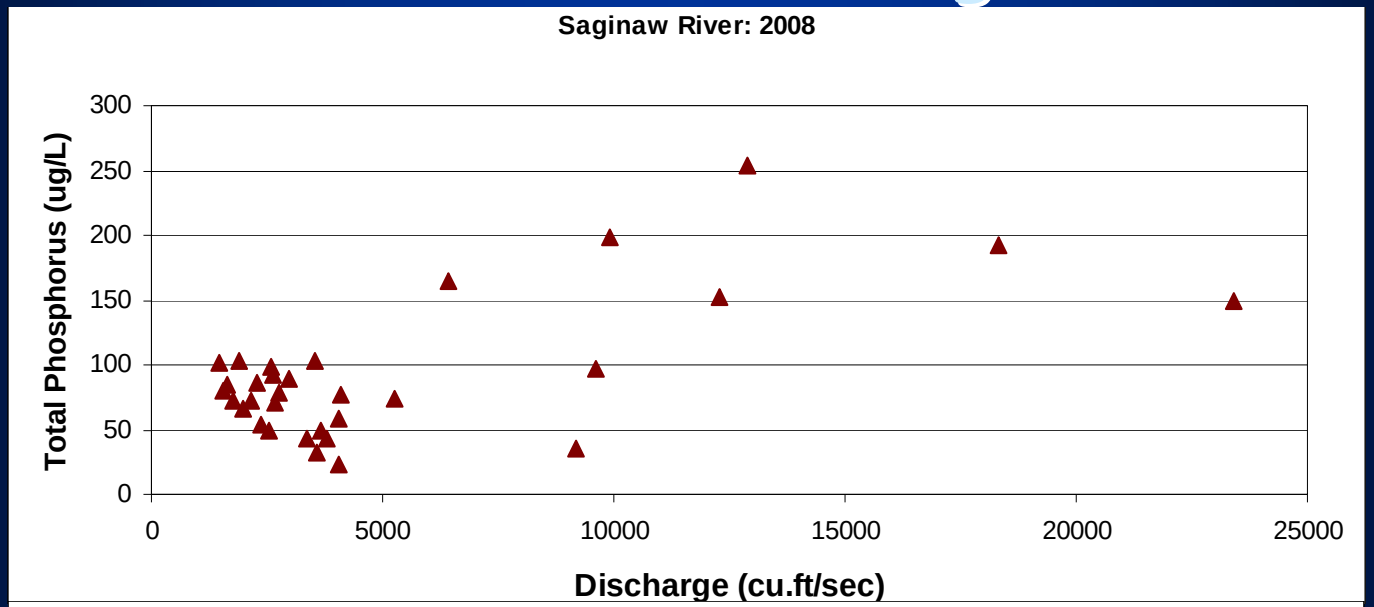
- — MDEQ
- — USGS
- — CILER

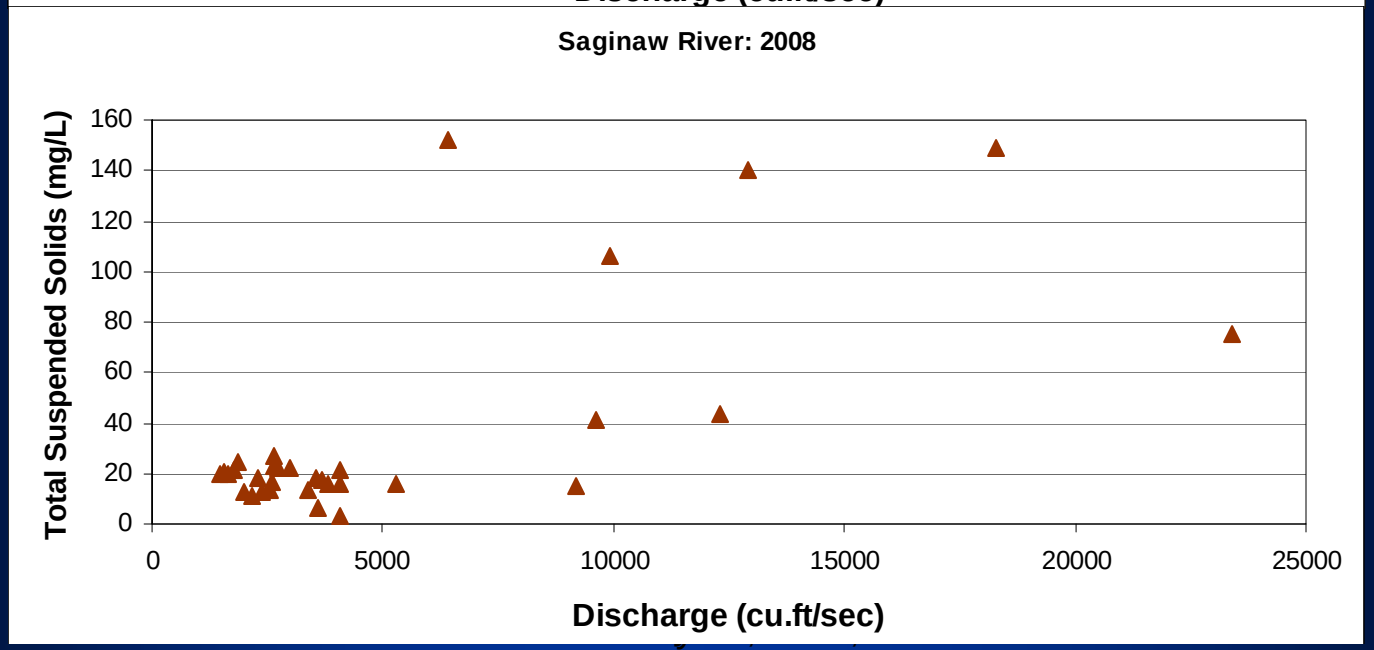
2008 CILER Monitoring Events

T, Spec. Cond., TP, SRP, NH4, NO3, TSM, Inorganic SM, Organic SM

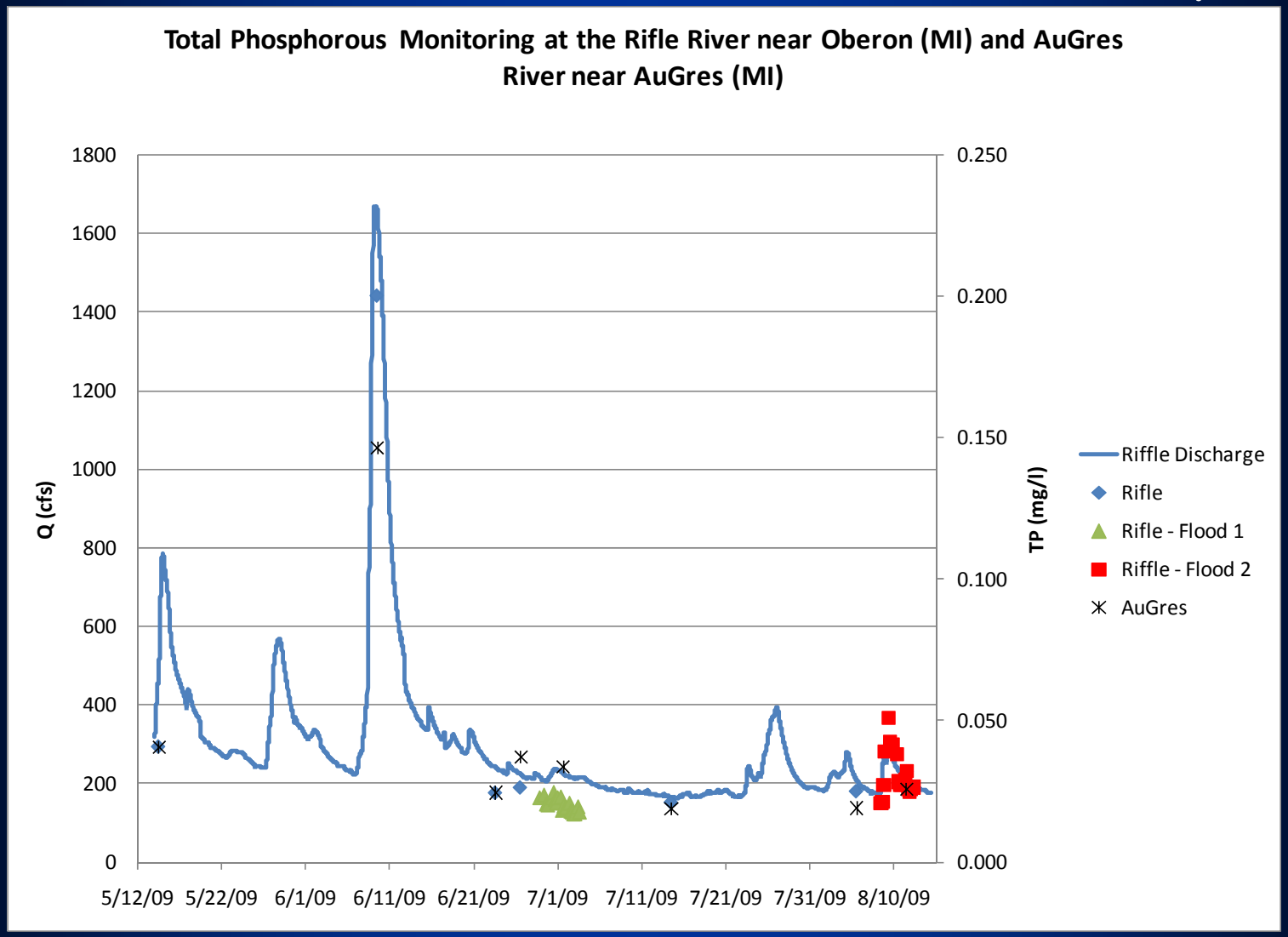


2008 CILER Monitoring Results

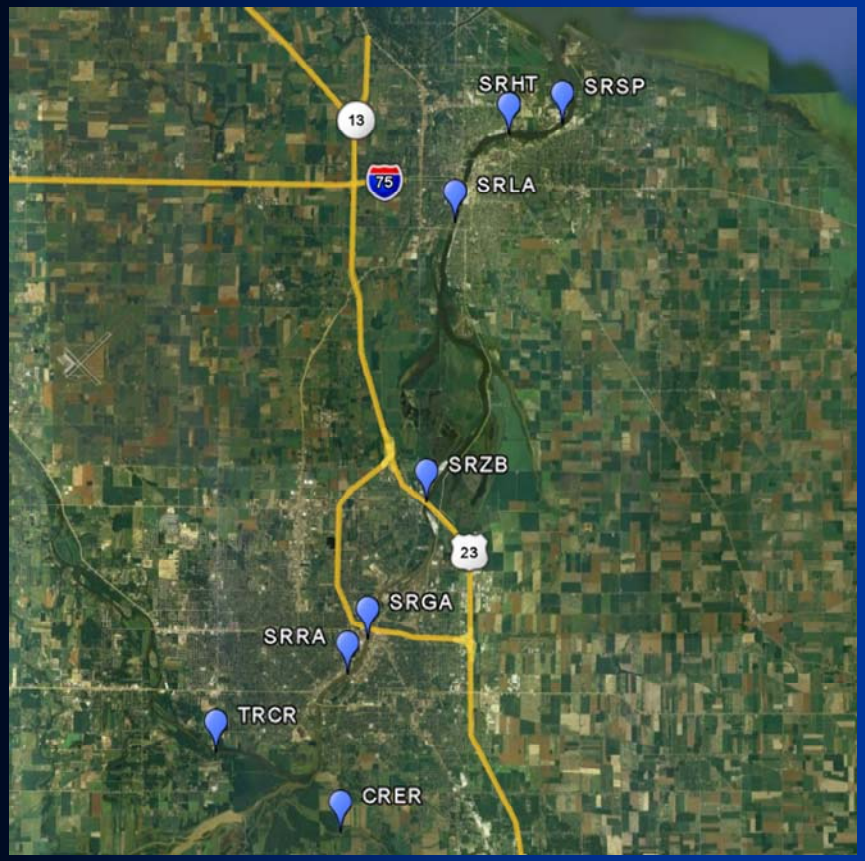


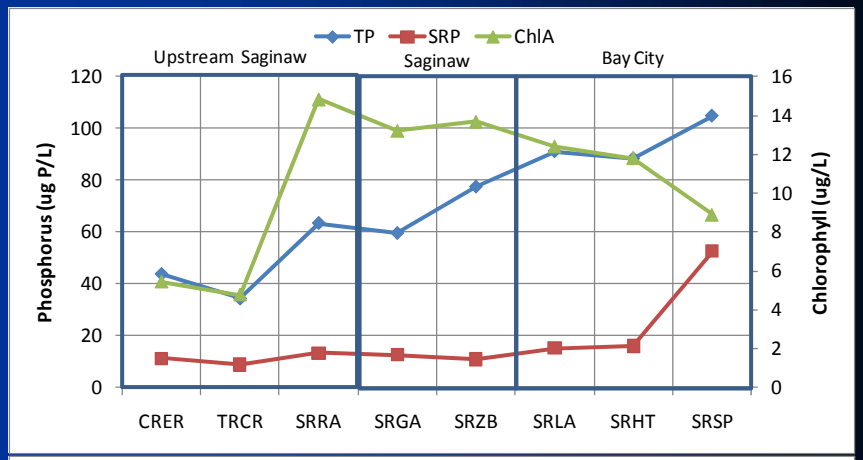


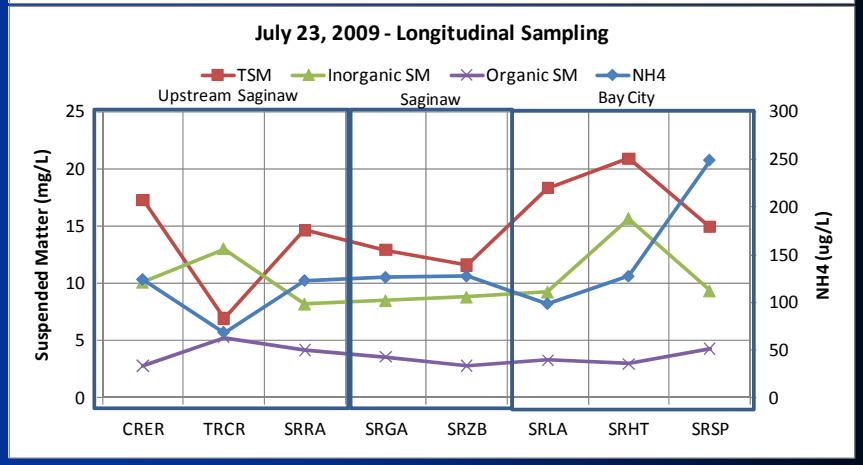
2009 CILER Smaller Tributaries Campaign



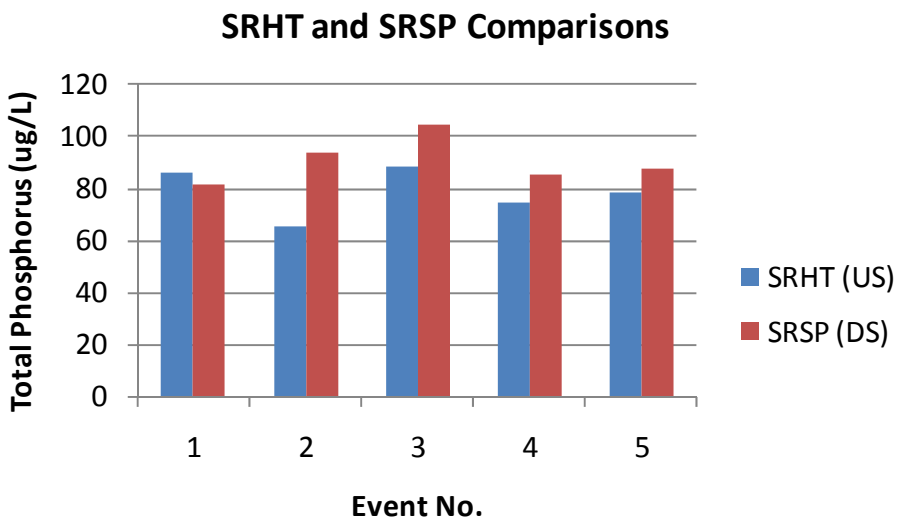
2009 Limno-Tech Saginaw River Transect

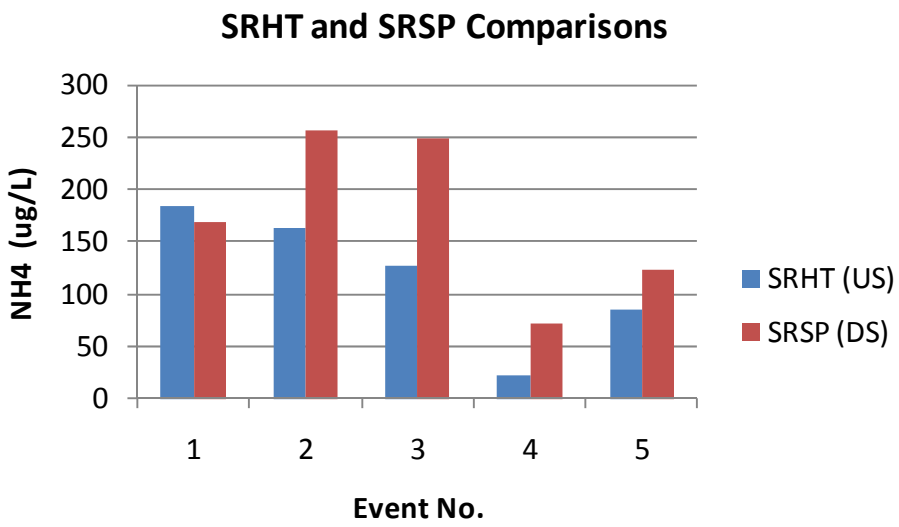


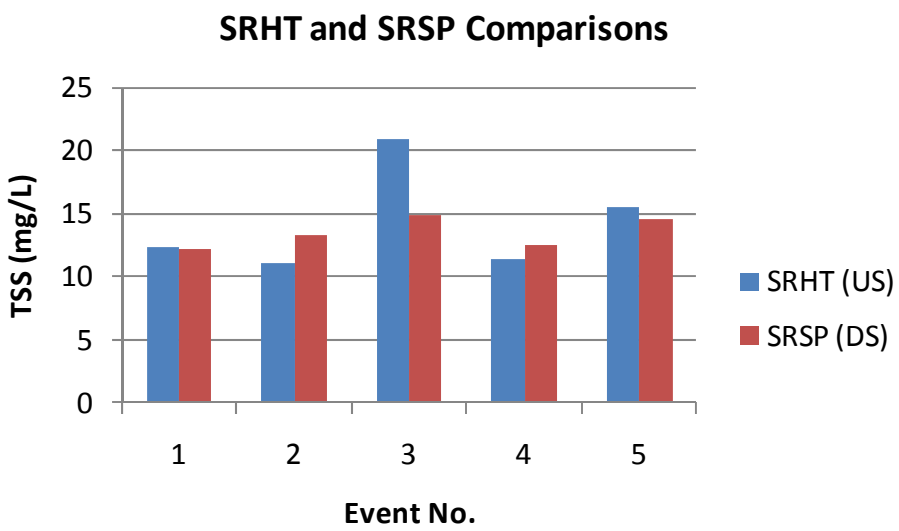


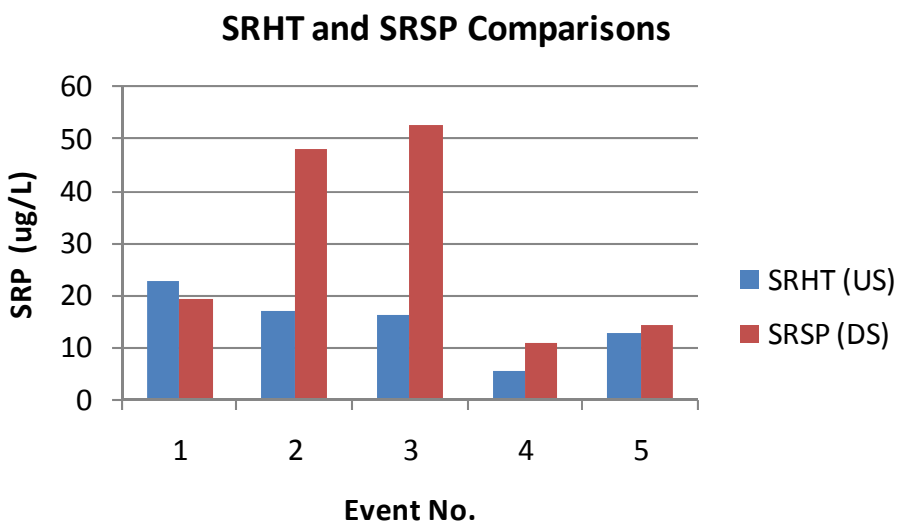


SRHT-SRSP Comparison









Modeling Activities in the Watersheds

- Long-term annual TP load (YoonKyung Cha, Craig Stow, et al.)
- Short-term daily/annual pollutant loads by regression (Carlo DeMarchi, Weichun Tao, et al.)
- Watershed pollutant generation and transport (Carlo DeMarchi, Chansheng He, et al.)

Long-term Annual TP Load

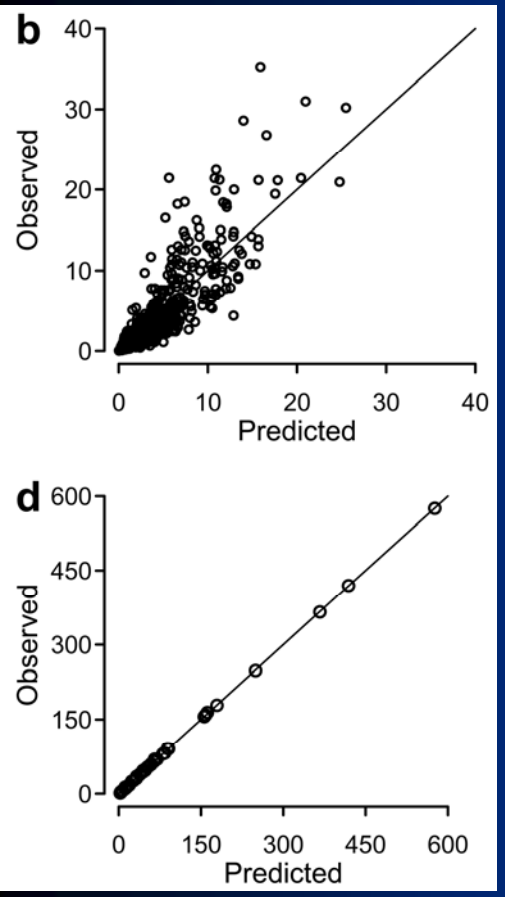
- Annual TP load is determined with a Ratio Estimator:

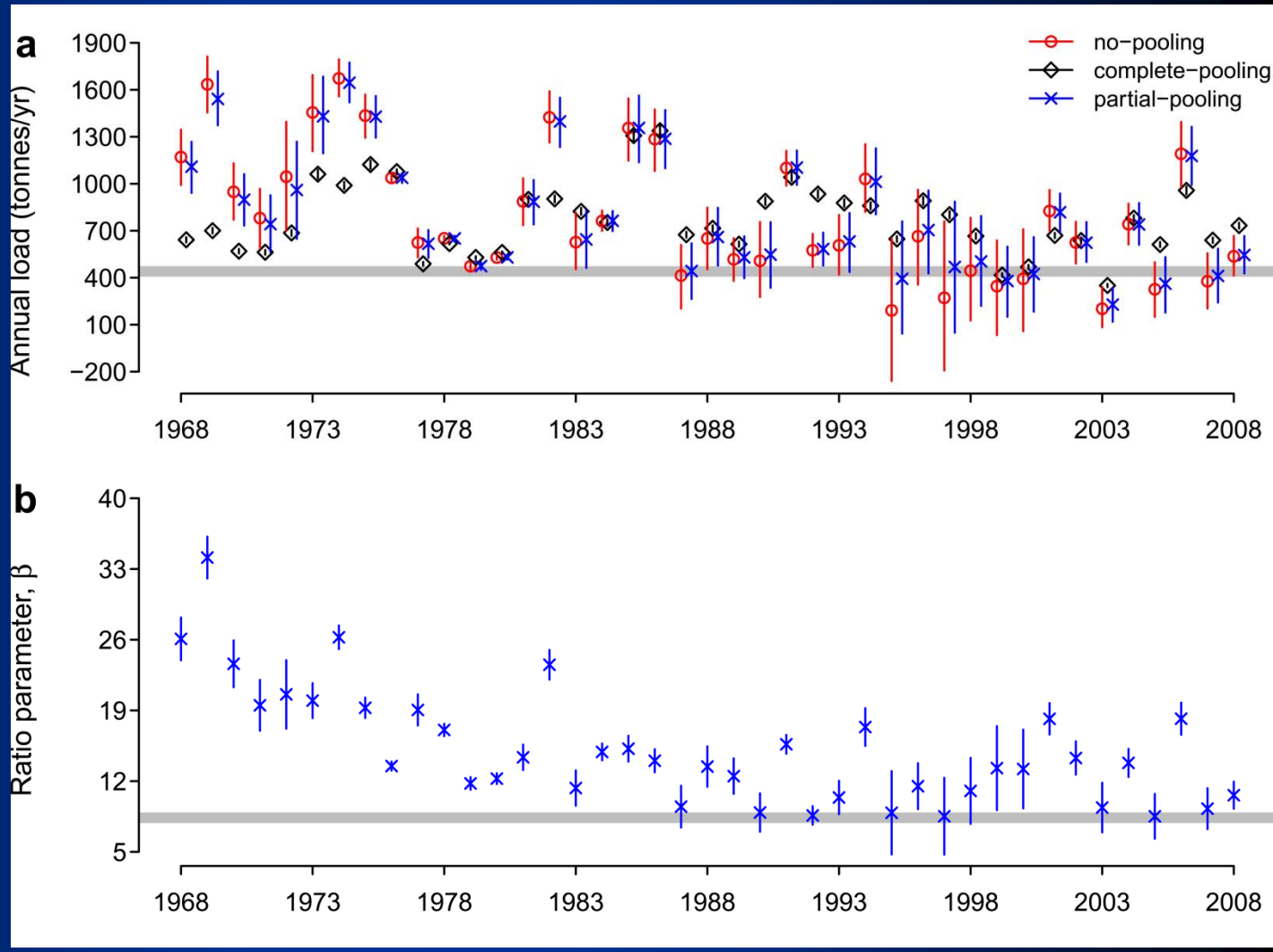
$$\hat{T}_j = \hat{\beta}\left(\sum_{i=1}^{N_j} q_{ij}\right) \qquad \hat{\beta} = \sum_{i=1}^{n_j} l_{s_j} \Big/ \sum_{i=1}^{n_j} q_{s_j}$$

- Bayesian hierarchical ratio estimator

$$\hat{\beta}_j \approx \frac{\left(n_j / \sigma_y^{\,2}\right) \cdot \left(\bar{l}_{s_j} / q_{s_j}\right) + \left(1 / \sigma_\beta^{\,2}\right)\mu}{\left(n_j / \sigma_y^{\,2}\right) + \left(1 / \sigma_\beta^{\,2}\right)}$$

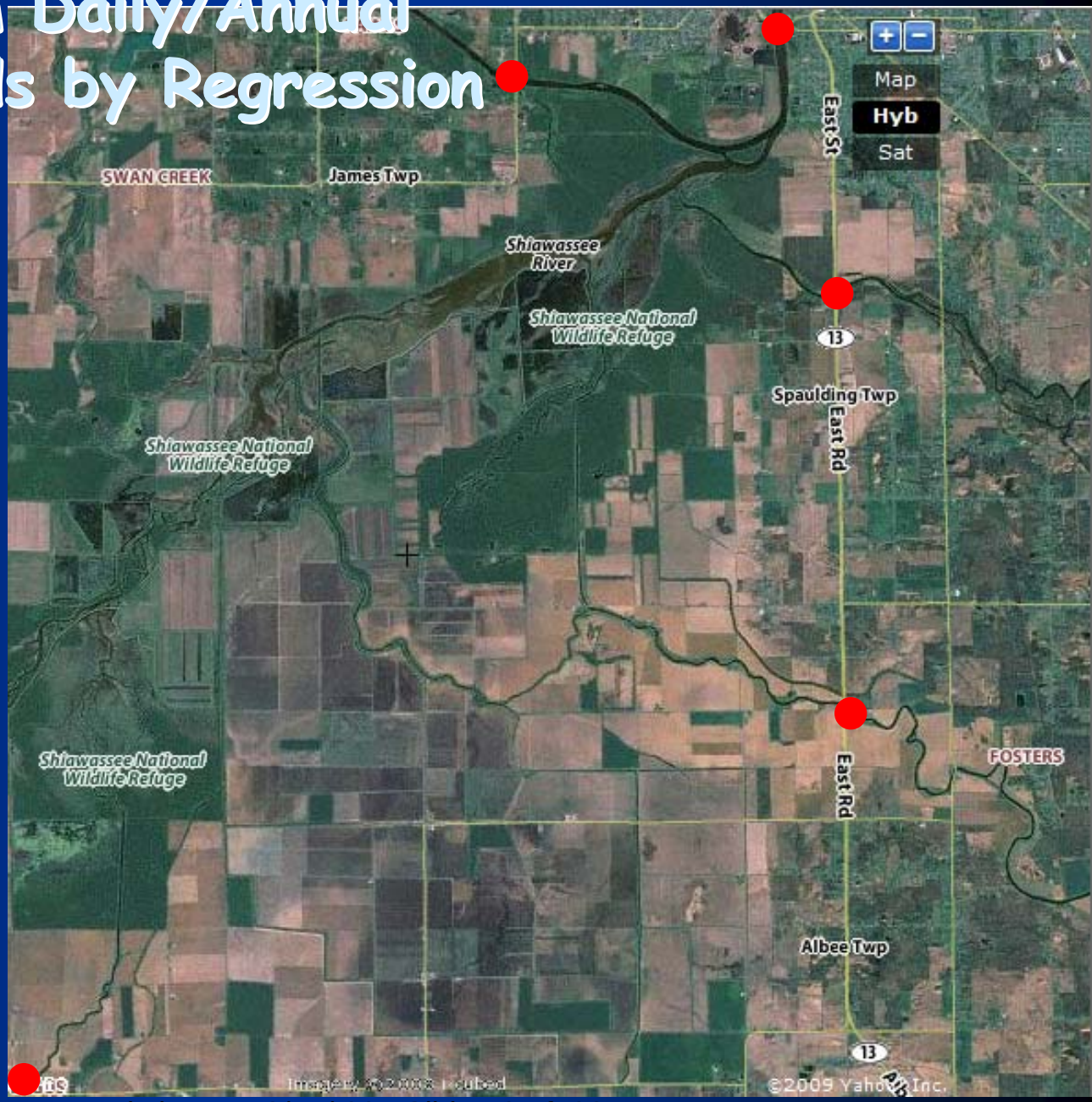
Long-term TP Annual Load Variation





Short-term Daily/Annual Pollutant Loads by Regression

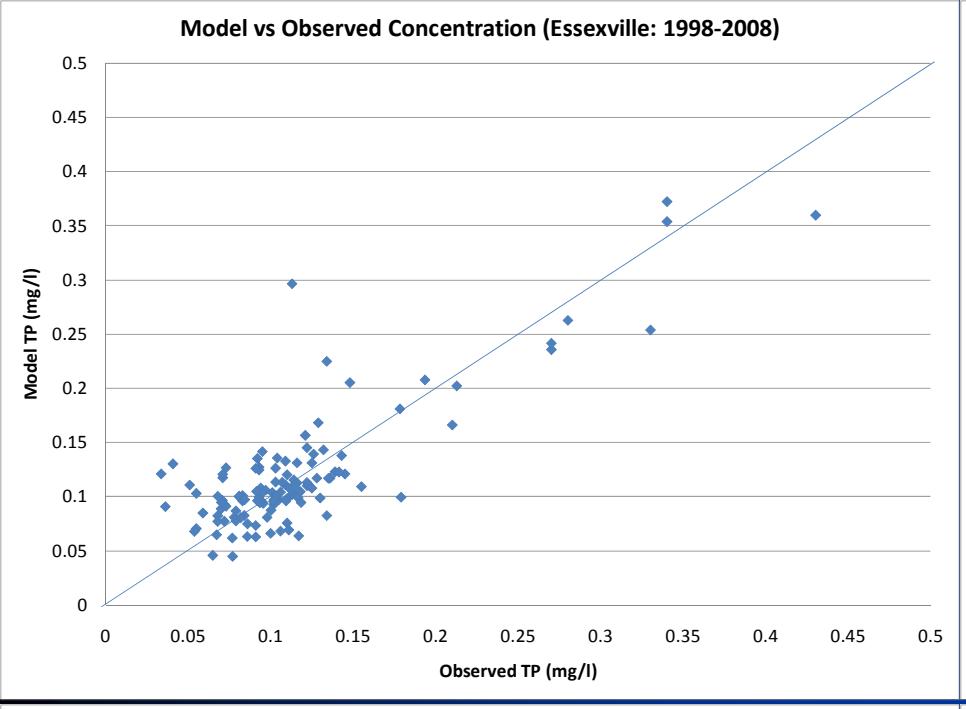
- Period considered 1997-2008

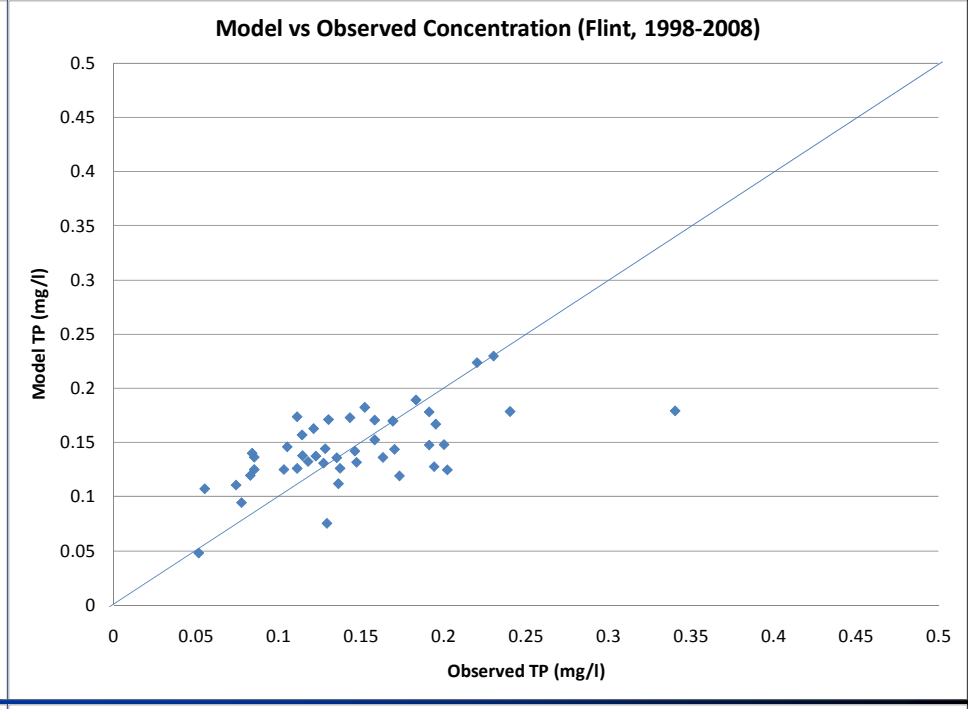


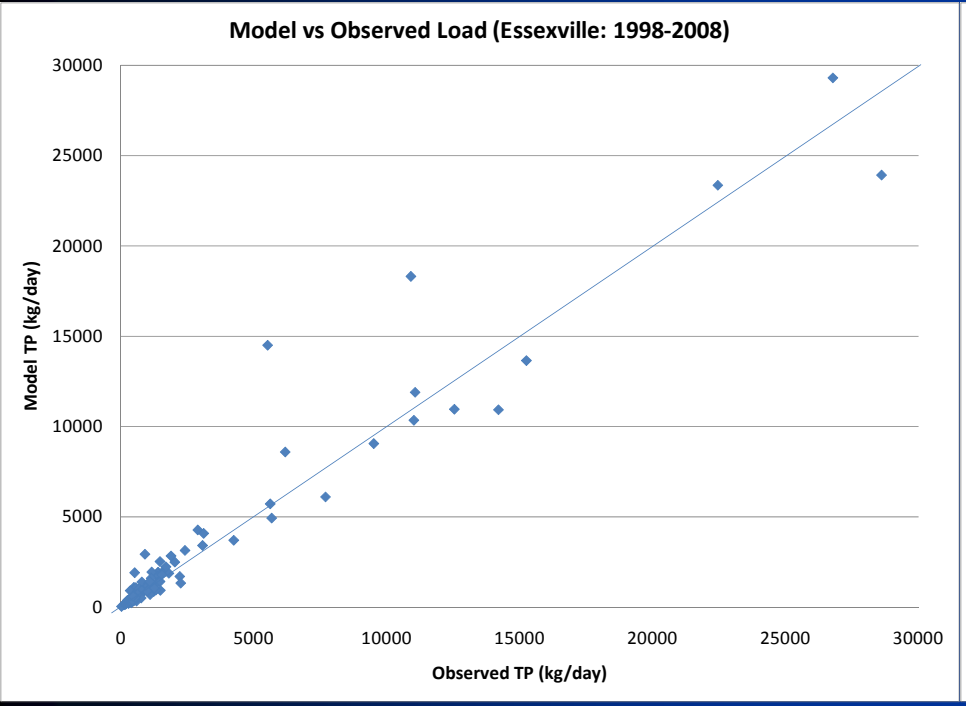
TP Regression Model

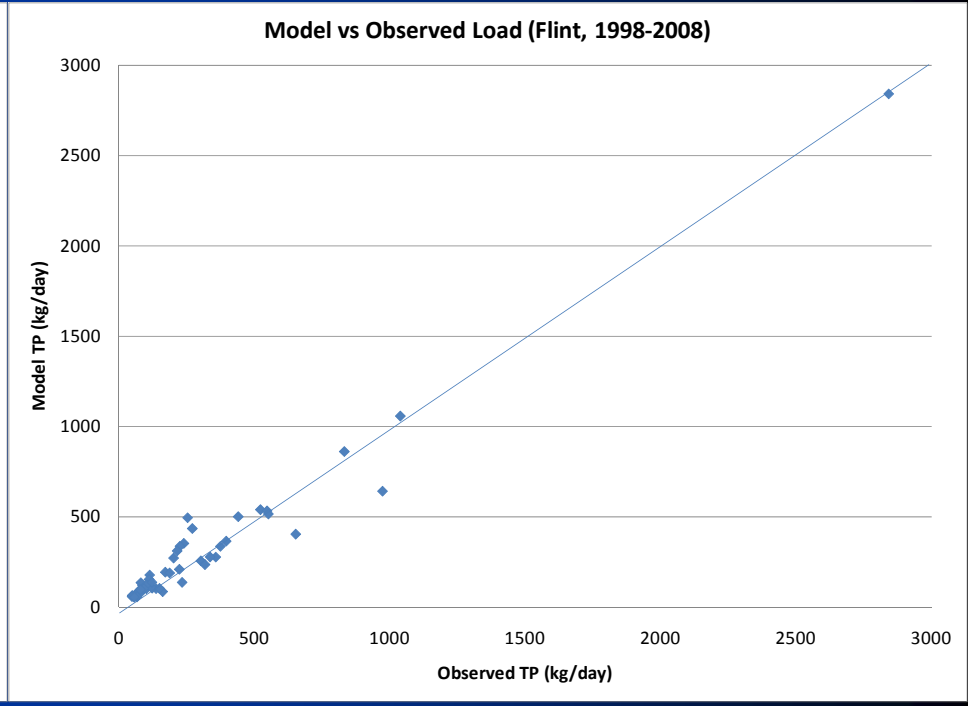
$$C(t) = a + b \cdot Q(t) + c \cdot Q_5(\mathrm{t}) + d \cdot Q_{10}(t) + e \cdot t$$

	Saginaw River at Essexville	Saginaw River Upstream Saginaw	Flint River	Shiawassee Tittabaw. Cass
Bias (C)	0.035	0.0	0.0	0.0
R (C)	0.84	0.76	0.62	0.63
RMSE/Avg C	0.29	0.34	0.29	0.41
Bias (L)	0.069	0.0	0.0	0.047
R (L)	0.96	0.96	0.98	0.97
RMSE/Avg L	0.53	0.55	0.28	0.61

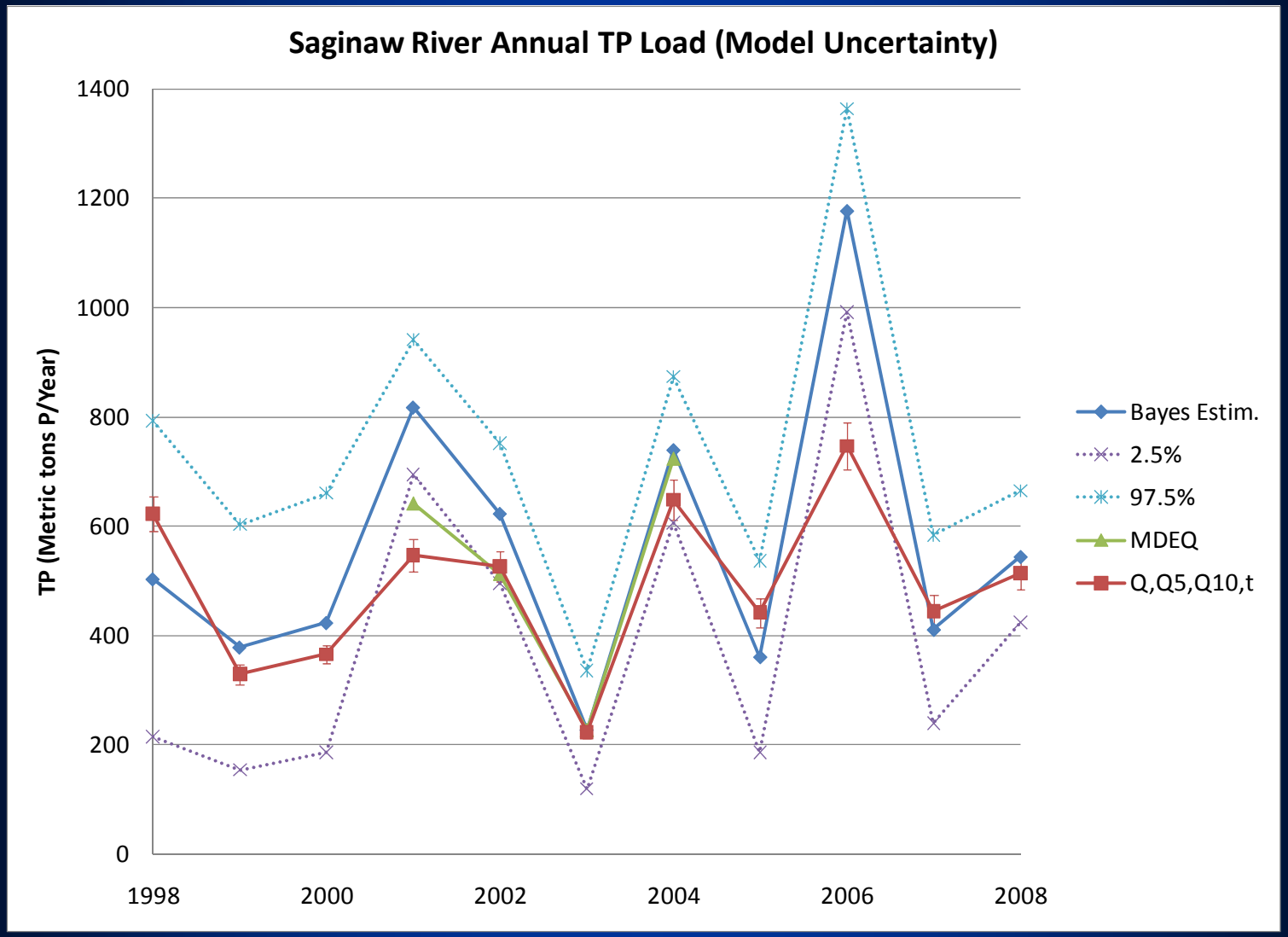

Model vs Observed Concentration (Essexville: 1998-2008)
Model TP (mg/l)
Observed TP (mg/l)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5


Model vs Observed Concentration (Flint, 1998-2008)
Model TP (mg/l)
Observed TP (mg/l)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

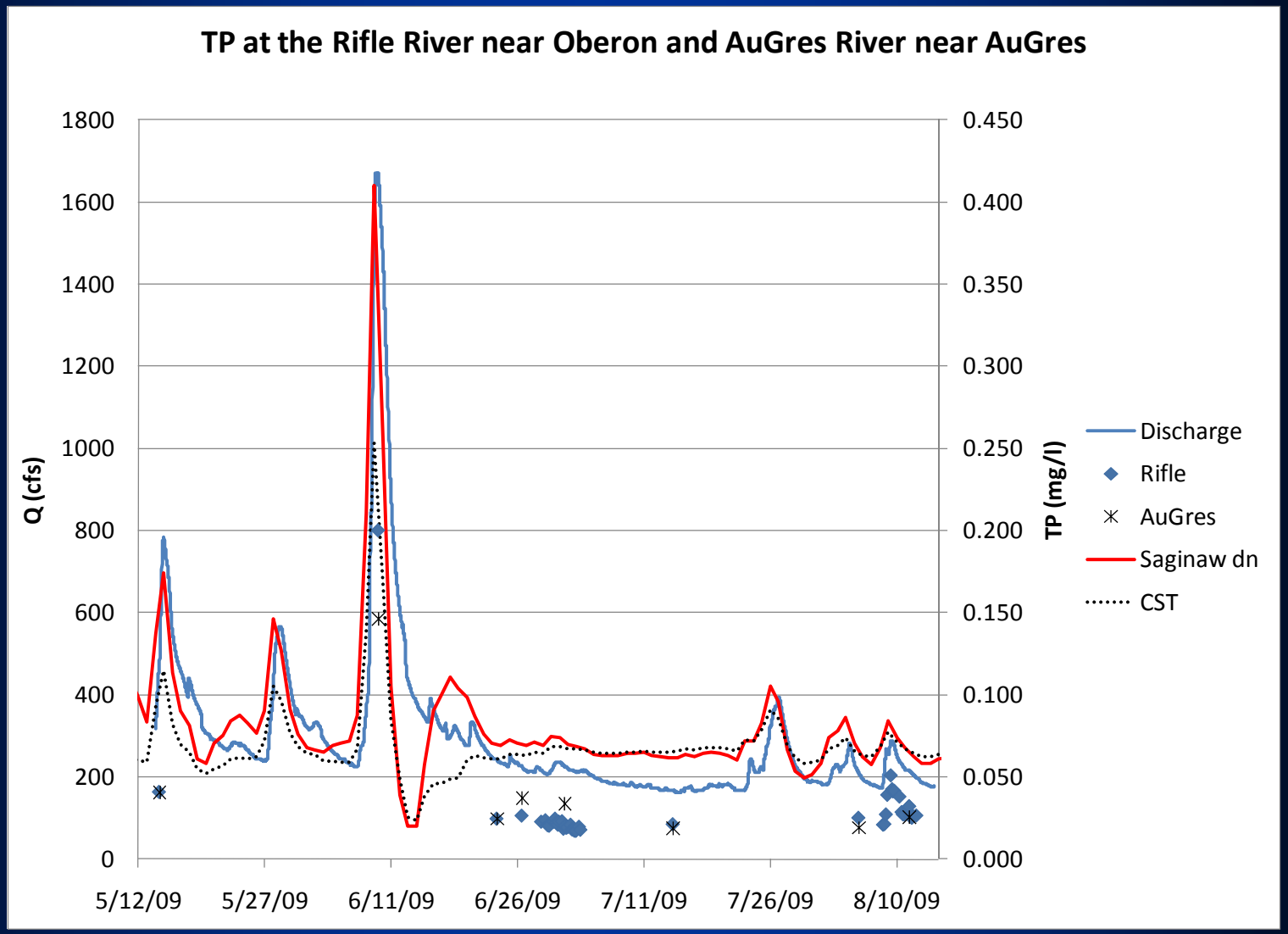

Model vs Observed Load (Essexville: 1998-2008)
Model TP (kg/day)
Observed TP (kg/day)
0
5000
10000
15000
20000
25000
30000


Model vs Observed Load (Flint, 1998-2008)
Model TP (kg/day)
Observed TP (kg/day)
0
500
1000
1500
2000
2500
3000

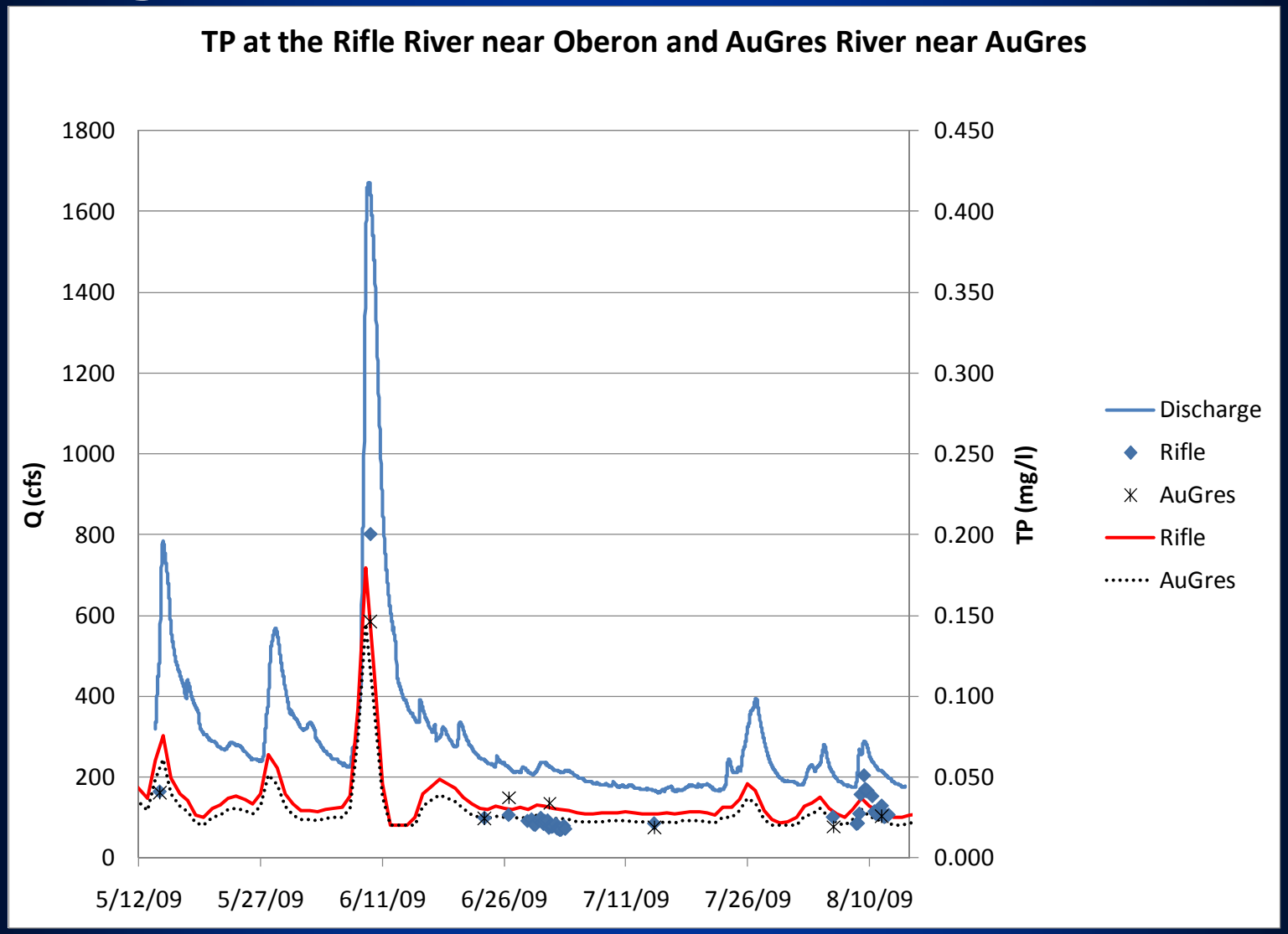
TP Annual Load Comparison



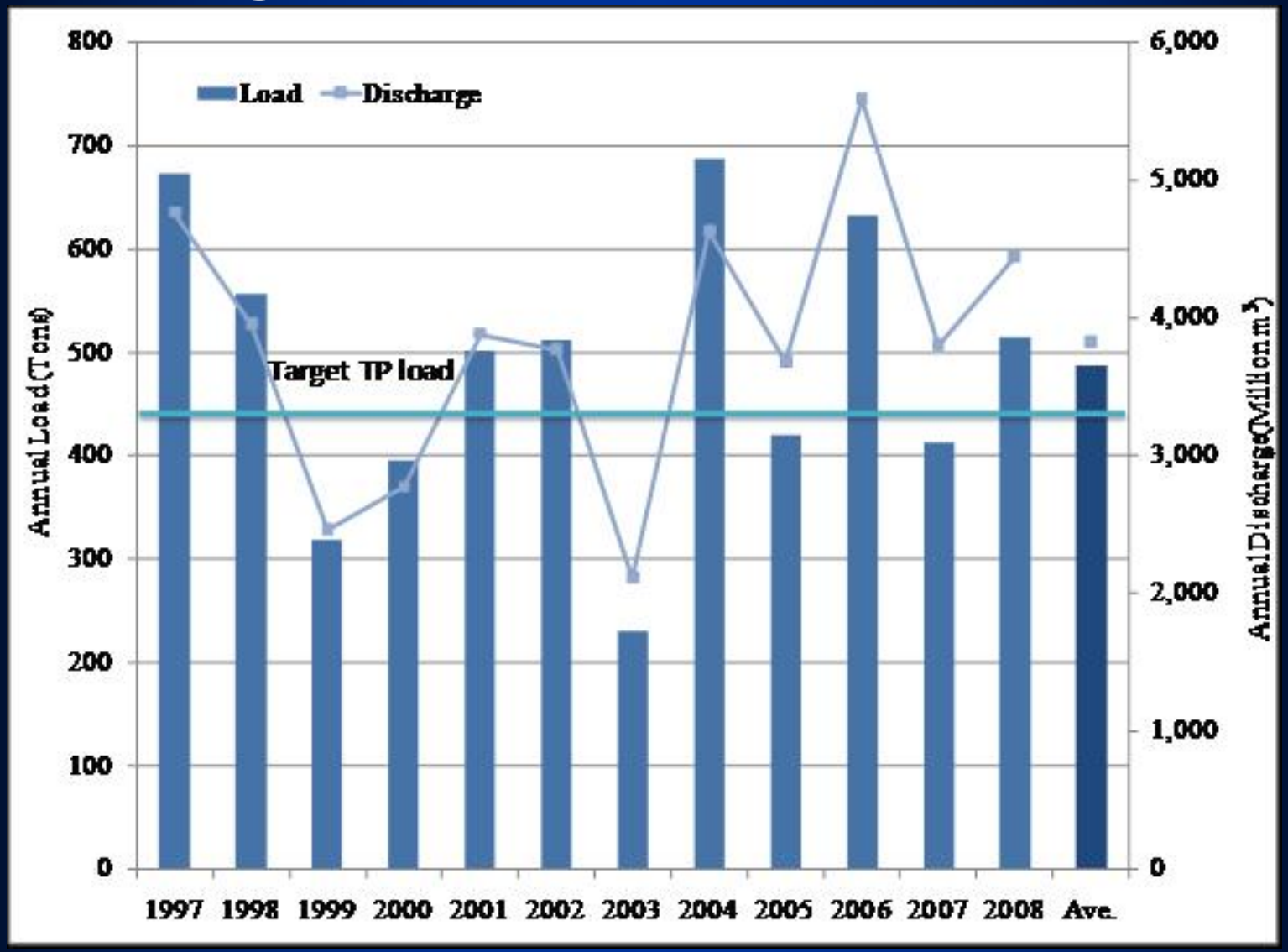
TP Regression Model for AuGres and Rifle



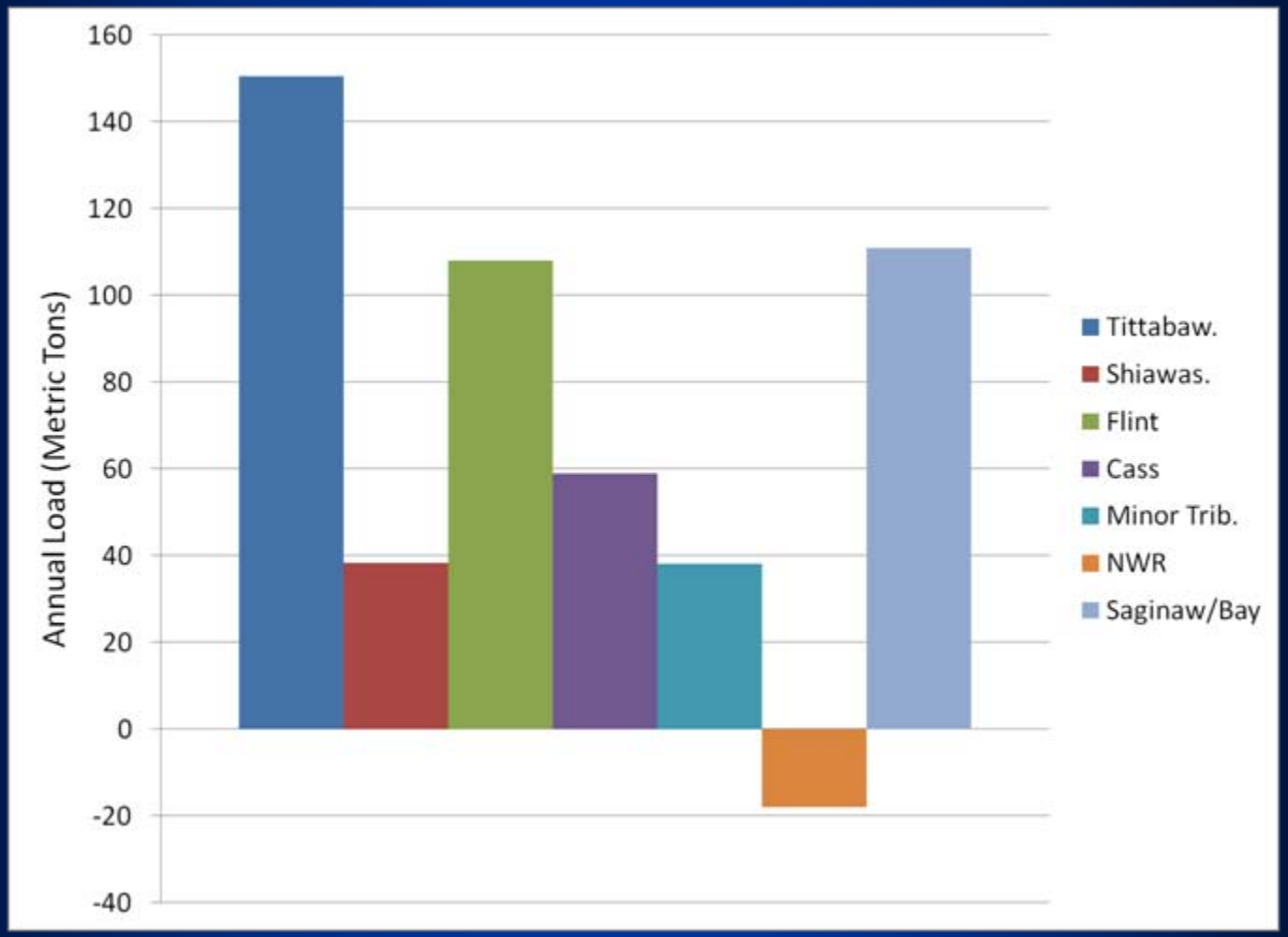
TP Regression Model for AuGres and Rifle



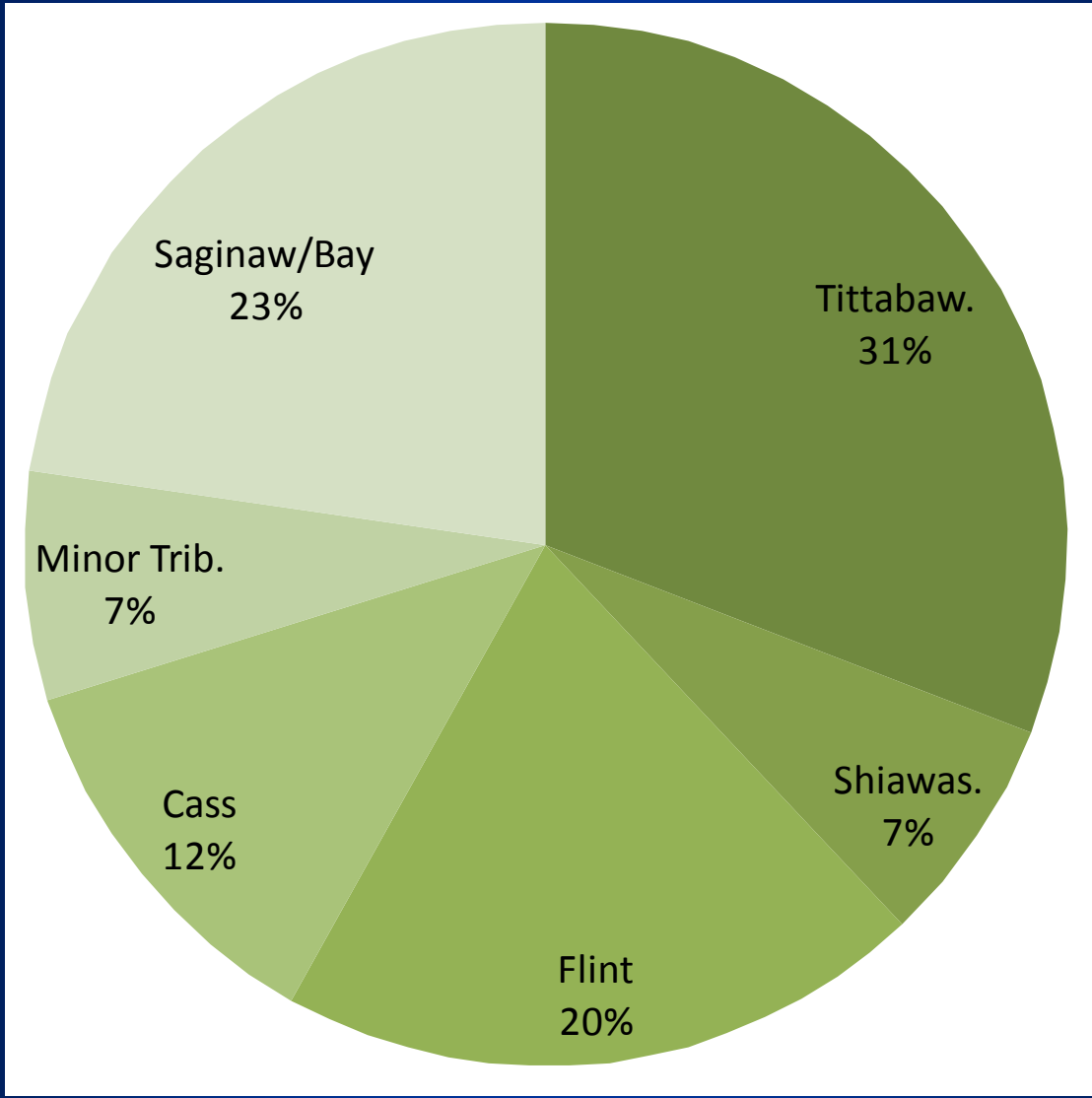
Saginaw River Annual TP Load

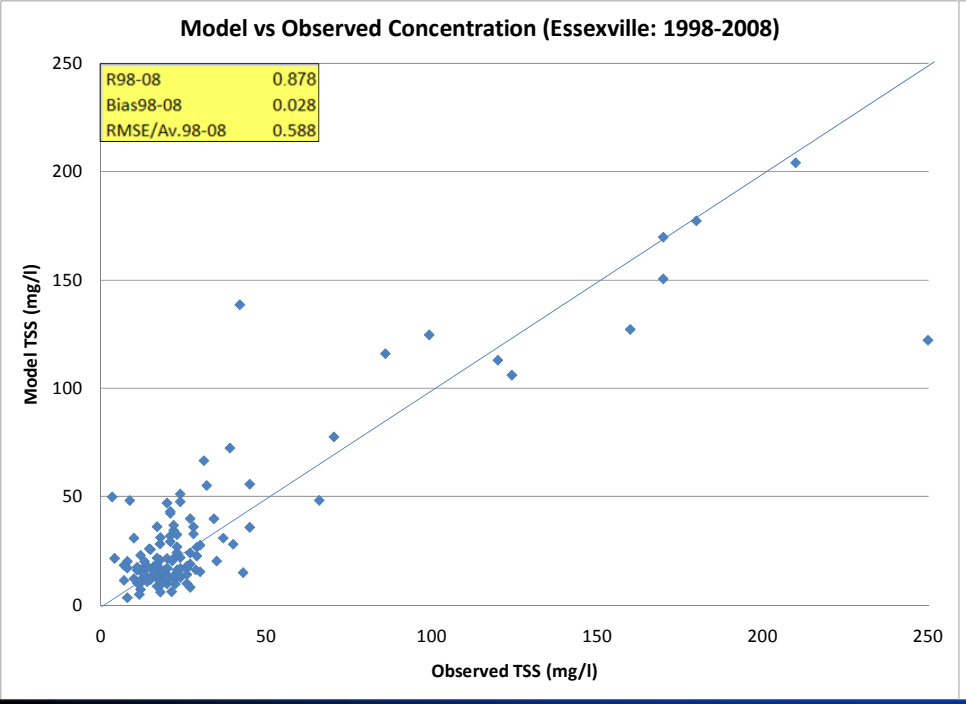


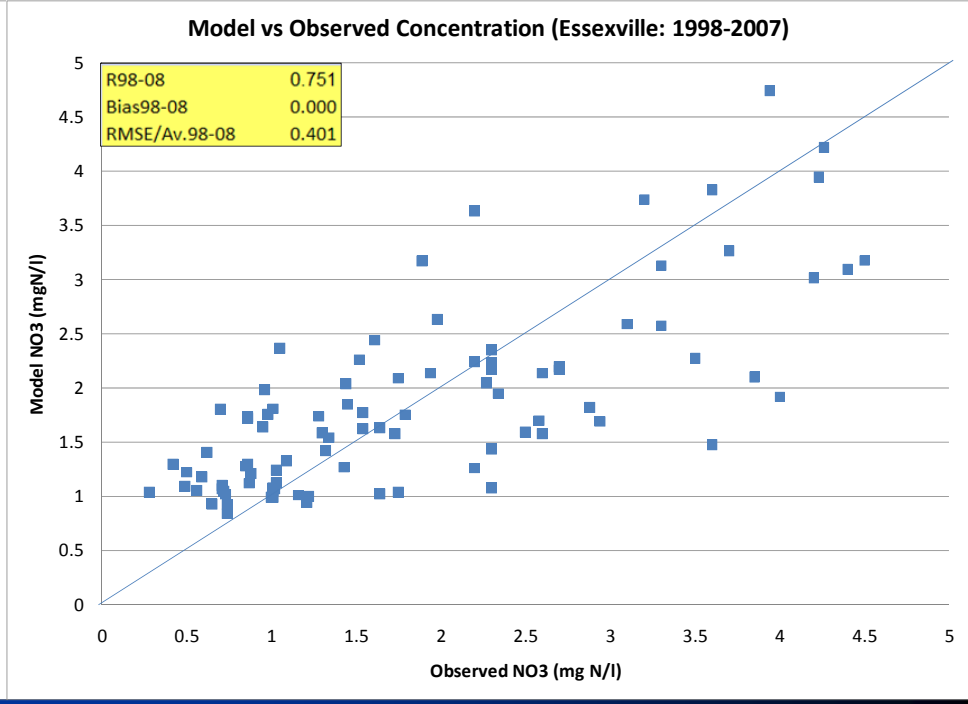
Average TP Loads at the Tributaries

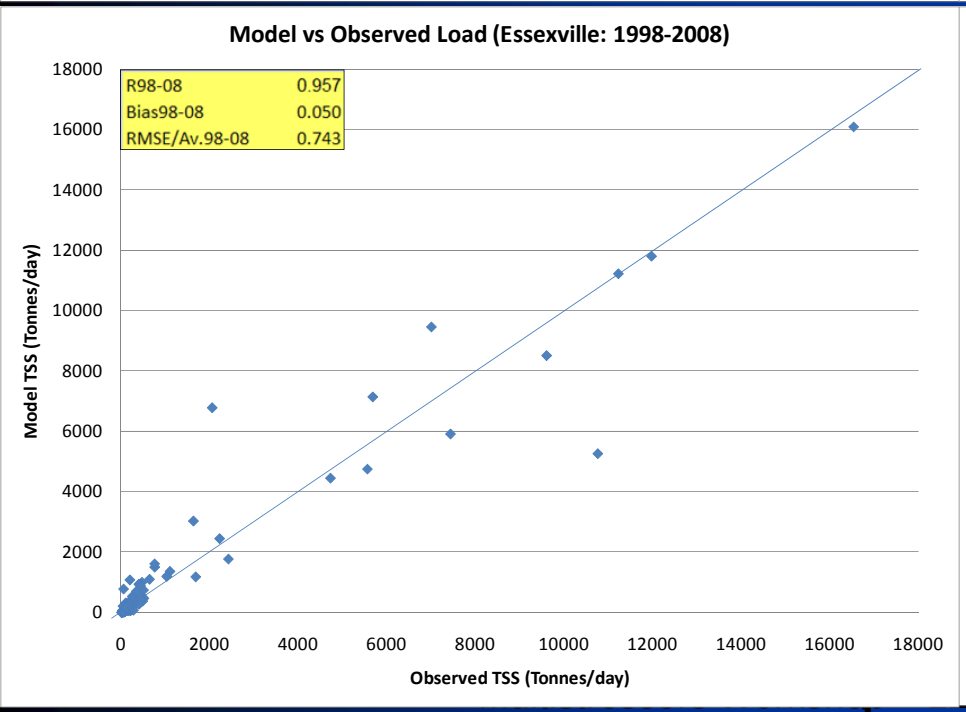


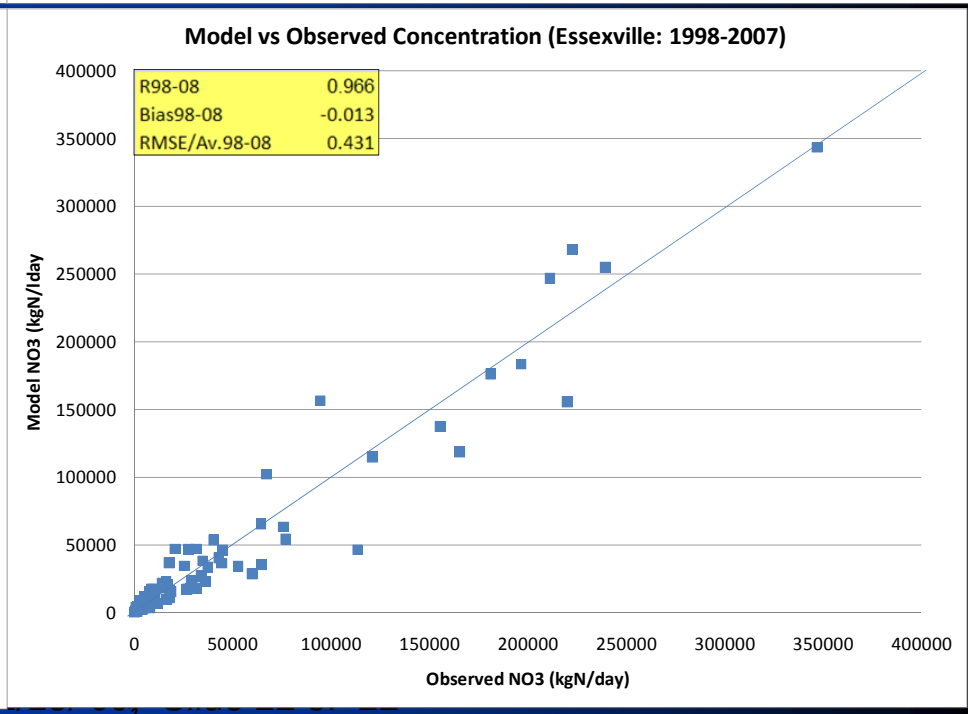
Sources of the Saginaw River TP Load




Model vs Observed Concentration (Essexville: 1998-2008)
R98-08 0.878
Bias98-08 0.028
RMSE/Av.98-08 0.588
Model TSS (mg/l)
Observed TSS (mg/l)
0
50
100
150
200
250


Model vs Observed Concentration (Essexville: 1998-2007)
R98-08 0.751
Bias98-08 0.000
RMSE/Av.98-08 0.401
Model NO3 (mgN/l)
Observed NO3 (mg N/l)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5


Model vs Observed Load (Essexville: 1998-2008)
R98-08 0.957
Bias98-08 0.050
RMSE/Av.98-08 0.743
Model TSS (Tonnes/day)
Observed TSS (Tonnes/day)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000

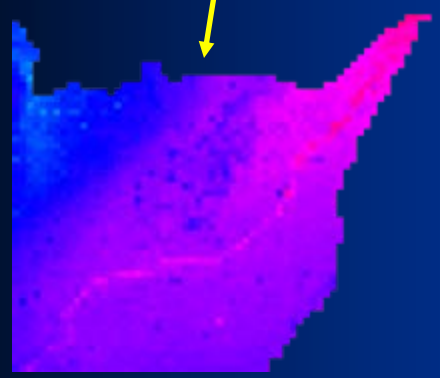

Model vs Observed Concentration (Essexville: 1998-2007)
R98-08 0.966
Bias98-08 -0.013
RMSE/Av.98-08 0.431
Model NO3 (kgN/lday
Observed NO3 (kgN/day)
0
50000
100000
150000
200000
250000
300000
350000
400000

Modeling Approach to Saginaw Bay Watershed (DLBRM)

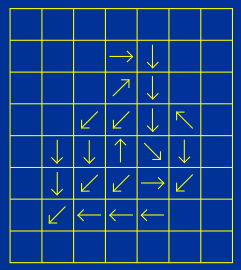
Subdivided the basin in four subbasins

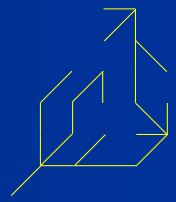
- Saginaw River
- AuGres/Rifle
- Kawkawlin/Pine
- Pigeon/Wiscoggin

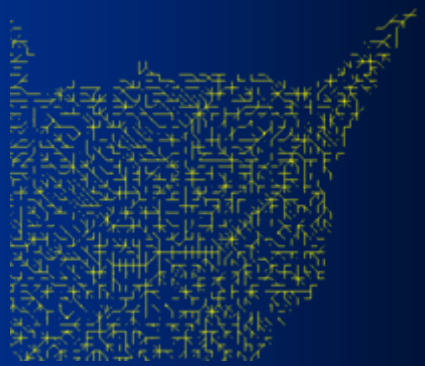
- Subwatersheds are subdivided into a grid of square pixels (1 km x 1 km or 0.5 km x 0.5 km)
- Water and pollutants move horizontally according to the difference in elevation between neighboring pixels



Elevation







Flow network

Calibration 1950-64

	Saginaw River	AuGres-Rifle	Kawkawlin-Pine	Pigeon-Wiscoggin (1986-93)
1 x 1 km				
Relative Bias	-5.0%	-1.7%	7.5%	6.9%
Correlation	0.90	0.86	0.79	0.79
RMSE/Q_{Ave}	61%	55%	148%	128%
0.5 x 0.5 km				
Relative Bias	--	-3.7%	7.1%	7.7%
Correlation	--	0.86	0.79	0.80
RMSE/Q_{Ave}	--	55%	146%	126%

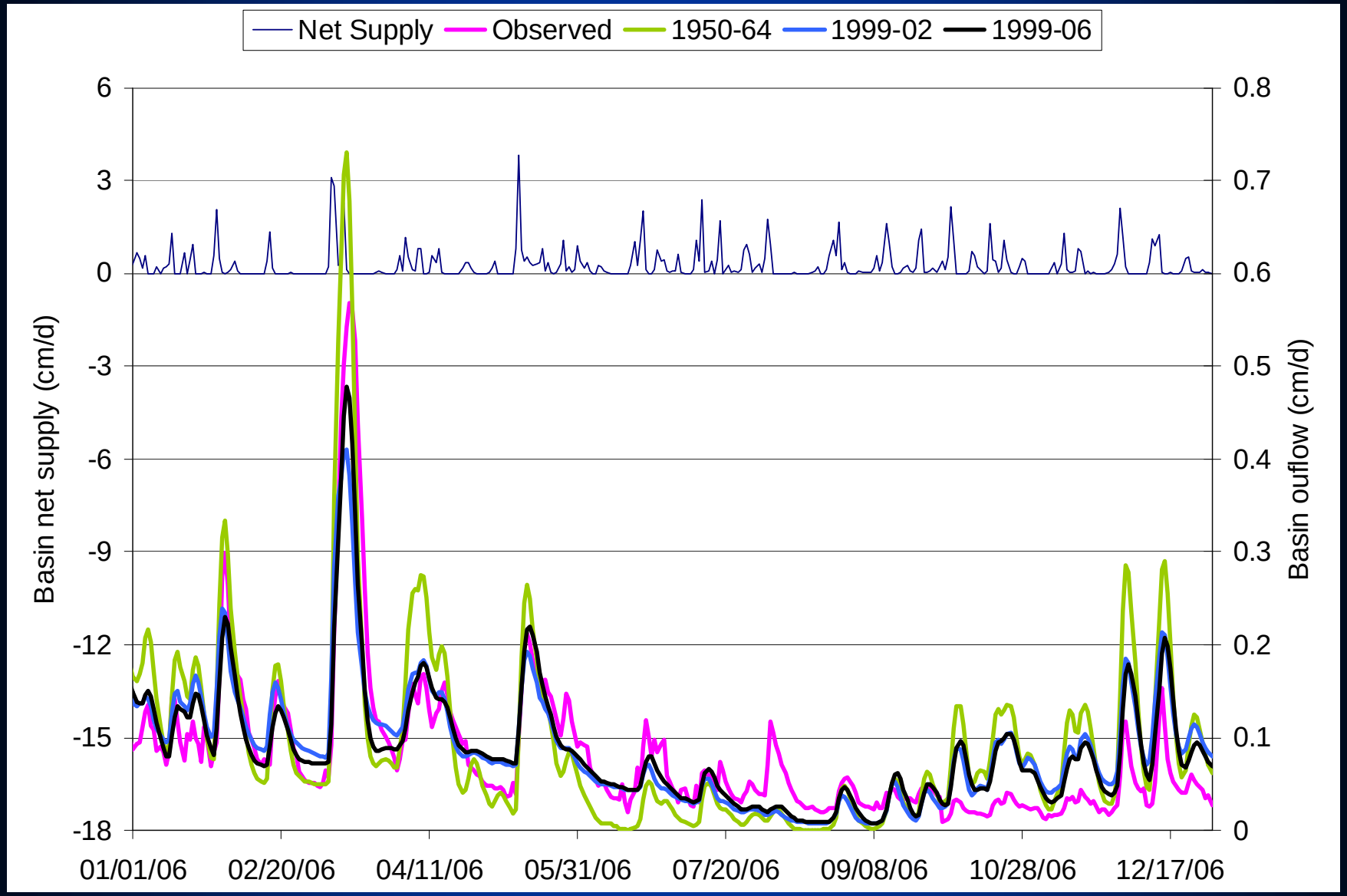
Robustness Test (1999-07)

	Saginaw River	AuGres-Rifle	Kawkawlin-Pine (1974-82)	Pigeon-Wiscoggin
1 x 1 km				
Relative Bias	-0.2%	0.2%	-7.1%	--
Correlation	0.79	0.85	0.79	--
RMSE/Q_{Ave}	73%	50%	131%	--
0.5 x 0.5 km				
Relative Bias	--	-1.3%	-11%	--
Correlation	--	0.87	0.80	--
RMSE/Q_{Ave}	--	41%	132%	--

Recalibration 1999-07

	Saginaw River	AuGres-Rifle	Kawkawlin-Pine (1974-82)	Pigeon-Wiscoggin
1 x 1 km				
Relative Bias	2.0%	-1.7%	14%	--
Correlation	0.84	0.89	0.80	--
RMSE/Q_{Ave}	60%	36%	127%	--
0.5 x 0.5 km				
Relative Bias	1.9%	-1.8%	13%	--
Correlation	0.83	0.89	0.81	--
RMSE/Q_{Ave}	61%	36%	126%	--

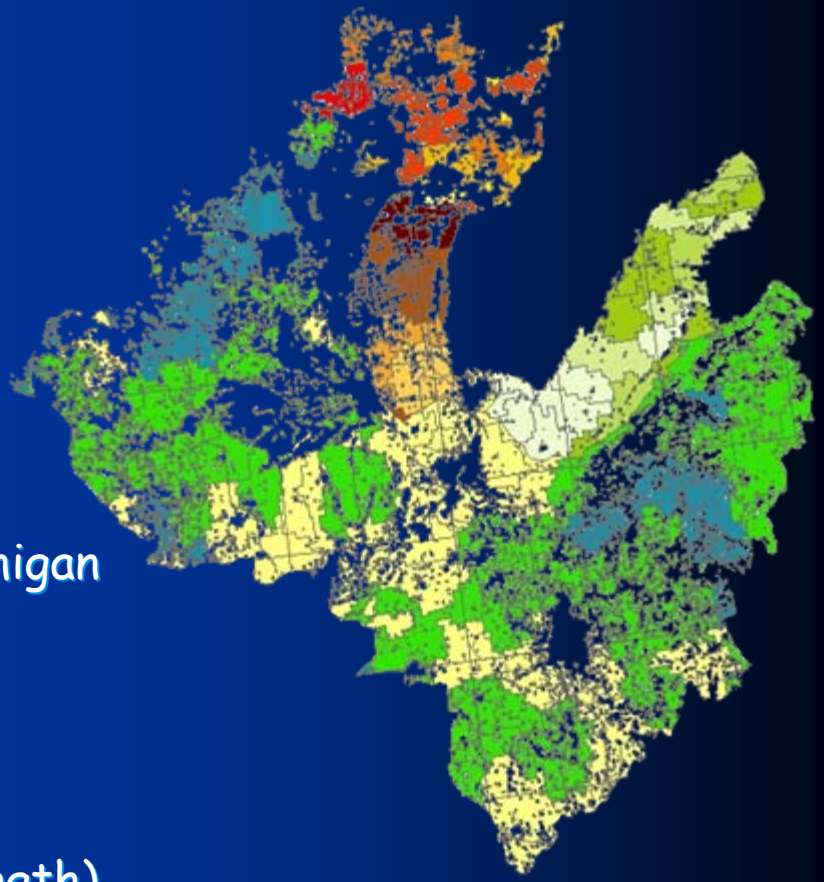
Saginaw River (1999-2006)



Surface Pollutant Surveys Databases

Annual
- Manure
  - 1987, 1992, 1997, 2002
  - N, P205, K20
- Fertilizer
  - 1987, 1992, 1997, 2002
  - N, P205, K20
- Atrazine
  - 80% of all pesticide used in Michigan
  - 2000, 2001, 2002, 2003, 2004

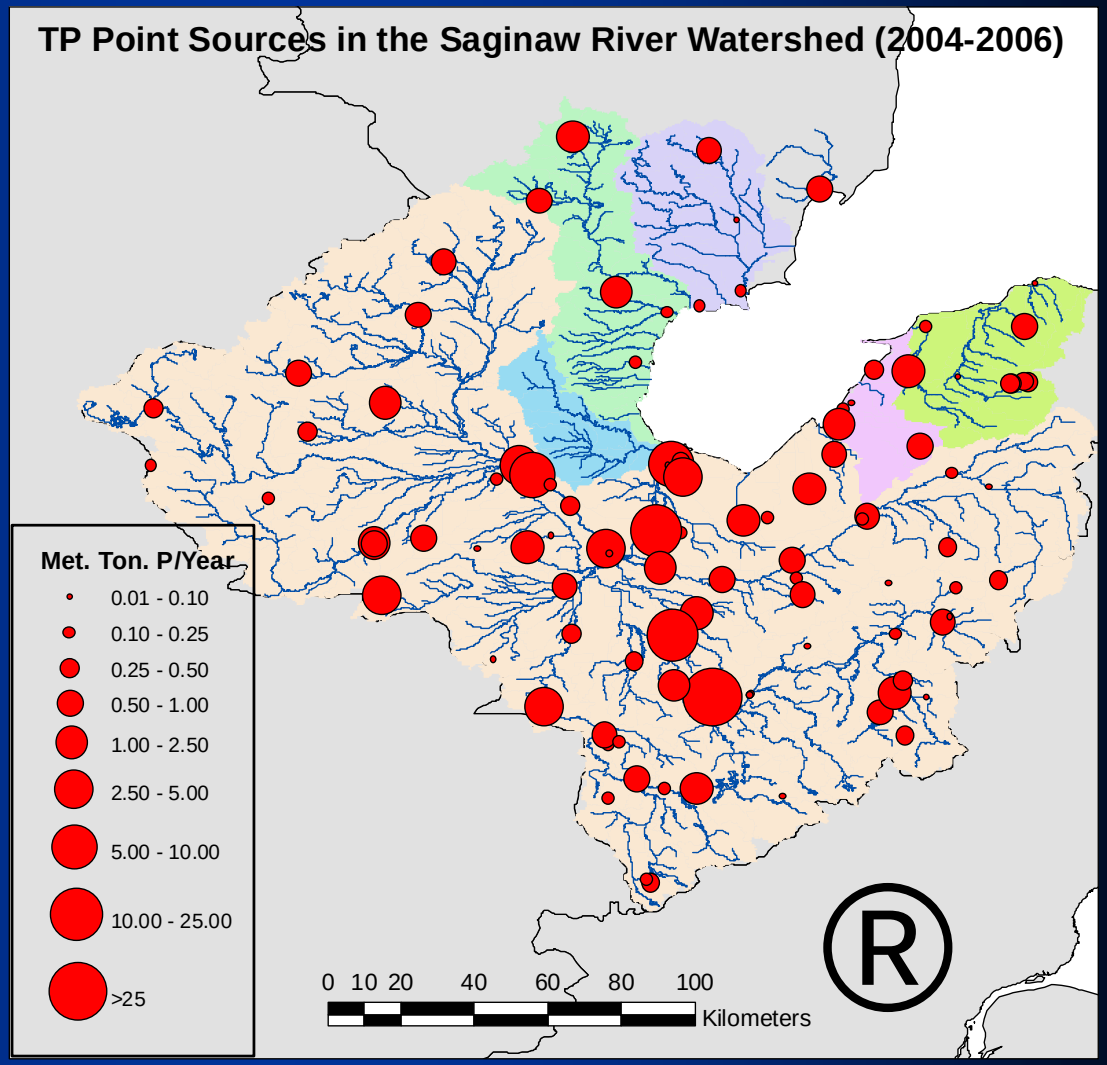
Monthly
- RUSLE2 parameters
- topographical factor (slope * slope length)
- cover factor
- support practice factor
- soil erodibility factor



2002 Nitrogen (Manure) Loading

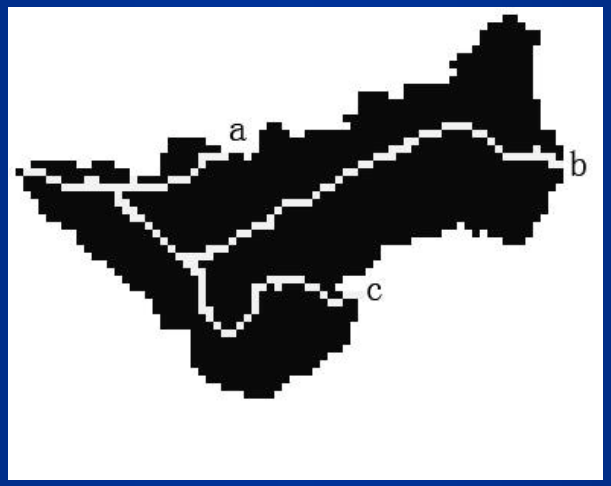
Point Pollution Sources Survey Database

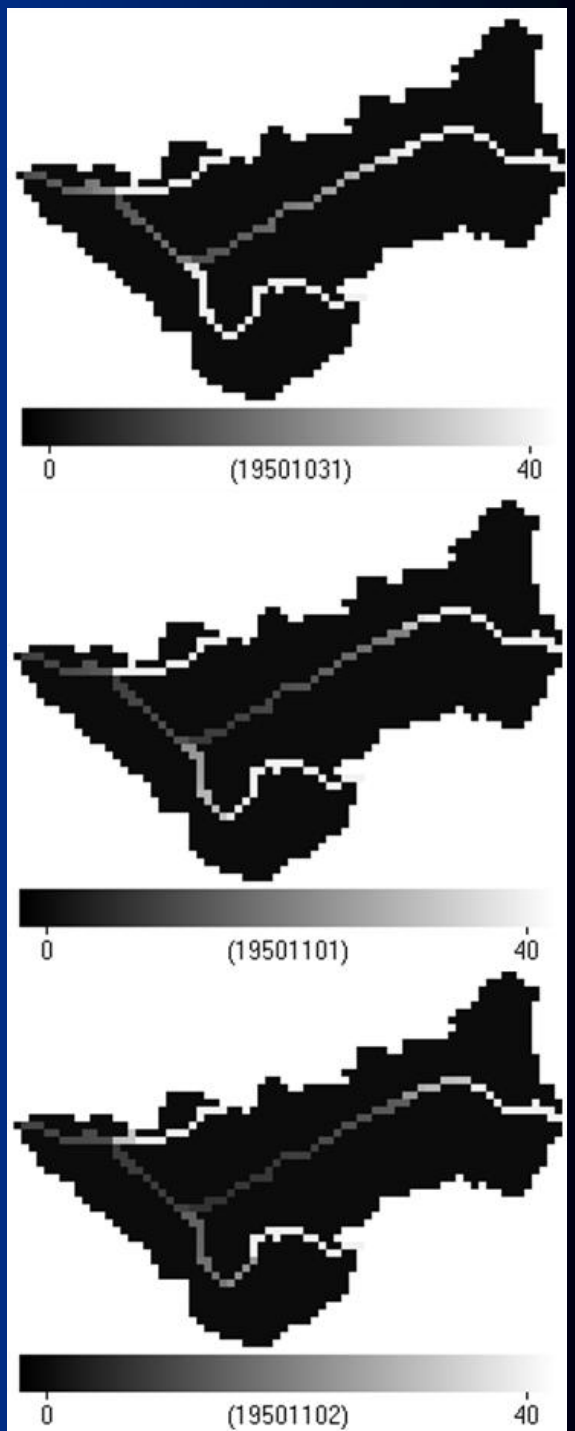
- NPDES Permits
- Monthly loads 2004-2007



Point Sources

- Monthly discharge schedule for:
  - Q, T, TSS, BOD, DO, OP, SRP, ON, NO3, NH4, and FC
- BOD dynamics (1st order)





Erosion/Transport Models

- Sediment Transport:
- Daily version of RUSLE/RUSLE2 approach. For each pixel i and each (average) day j:

$a'_{ij}=(r'(Pr_{ij}))/(r'_{im(j)})\ r_{im(j)}\ k_i\ l_i\ S_i\ c_{ij}\ p_{ij}$

$r'(Pr_{ij})=a_i Pr_{ij}^{bi}$ (Richardson et al., 1983;Hollinger et al., 2002)

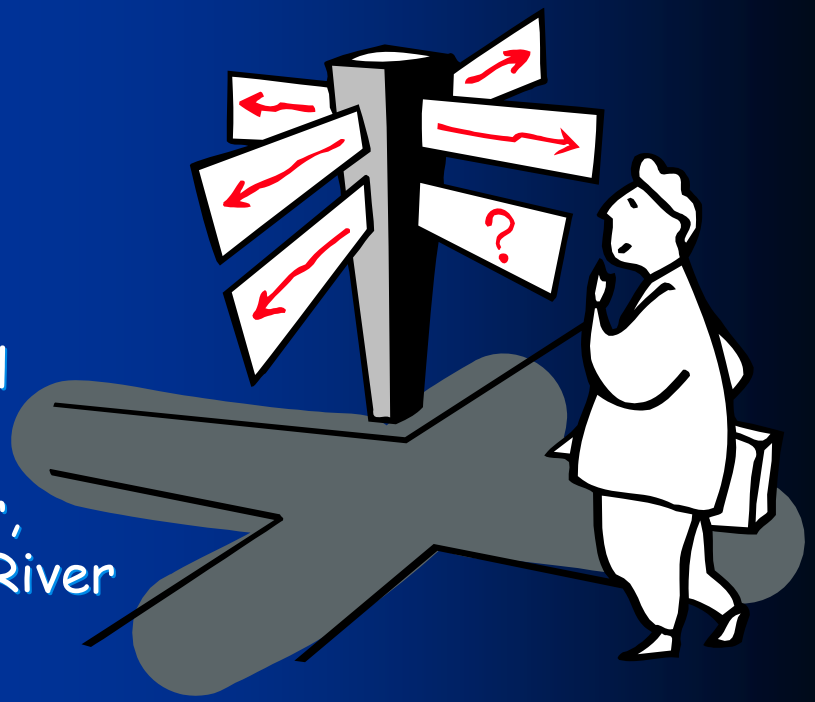
$r'_{i,m(j)}$ = long term average of r' during month m(j)

- Erosion/deposition along river system simulated with carrying capacity concept

$$\frac{dX_i}{dt} = e_i + q_i - r_i = e_i + q_i - \min(X_i, \alpha_s Sc_{\max})$$

Thanks for the Attention!

- Questions? Comments? Suggestions?



This research was supported by the NOAA Center for Sponsored Coastal Ocean Research (CSCOR)

Particular thanks go to Steve Blumer, USGS, for providing 2008 Saginaw River flow data

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