Today's Presentation

- Brief background on modeling
- RWQMPU modeling process and results

Modeling 101

- What is a model?
  - A theoretical construct,
  - together with assignment of numerical values to model parameters,
  - incorporating some prior observations drawn from field and laboratory data,
  - and relating external inputs or forcing functions to system variable responses

* Definition from: Thomann and Mueller, 1987

How Models Work

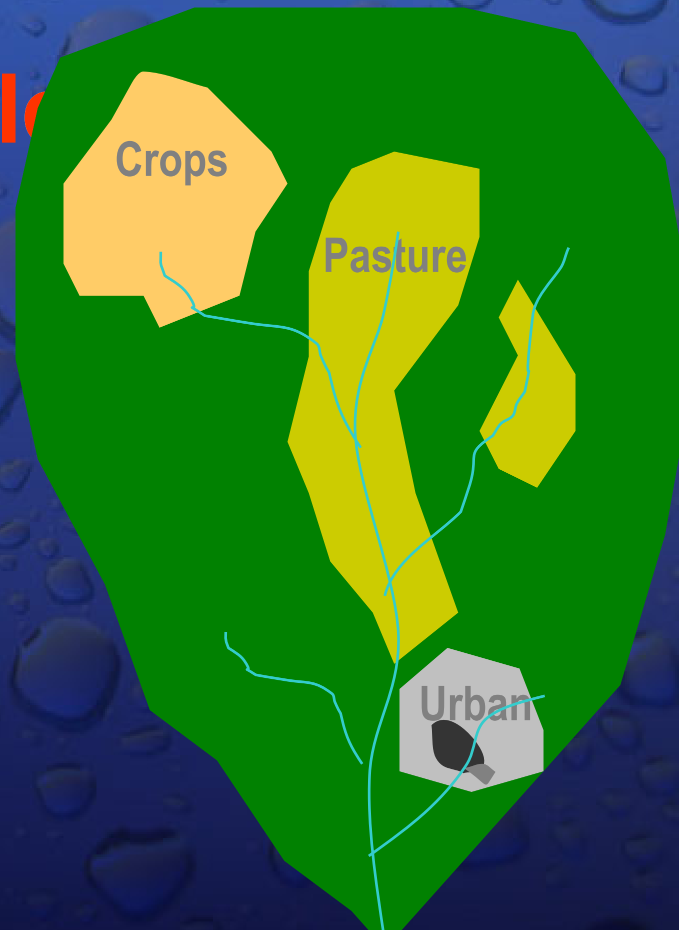
Inputs + Model Equations = Output

Land Use/Land Cover
Weather Data
Soil Characteristics
Point Sources
Agricultural Practices

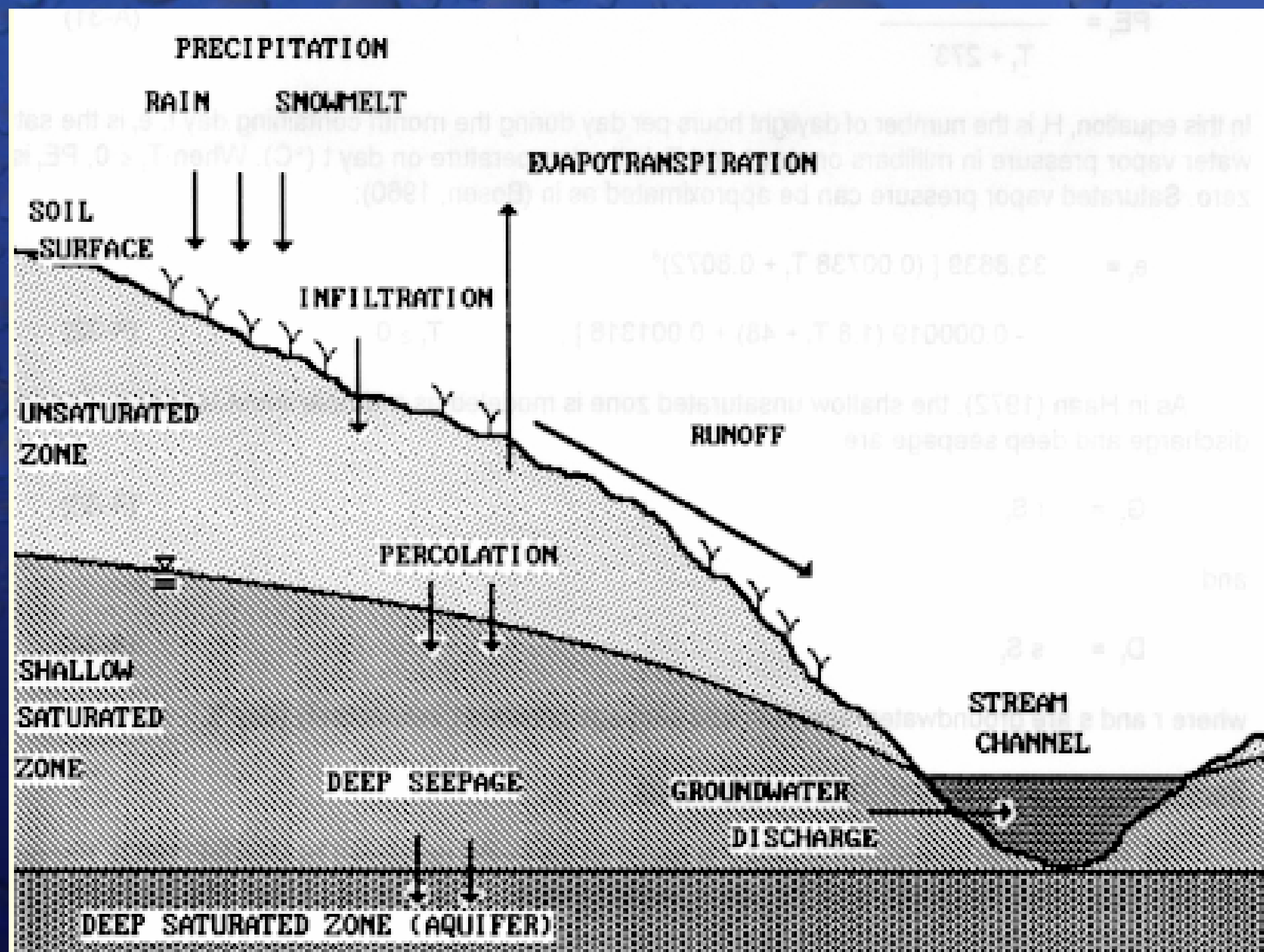
Runoff
Groundwater
Total Flow
Temperature
Sediment (TSS)
Dissolved Oxygen
Total Nitrogen
Total Phosphorous
Fecal Coliform
Cu

Types of Models

- Landscape/Site-scale models
- Receiving water models
- Watershed models



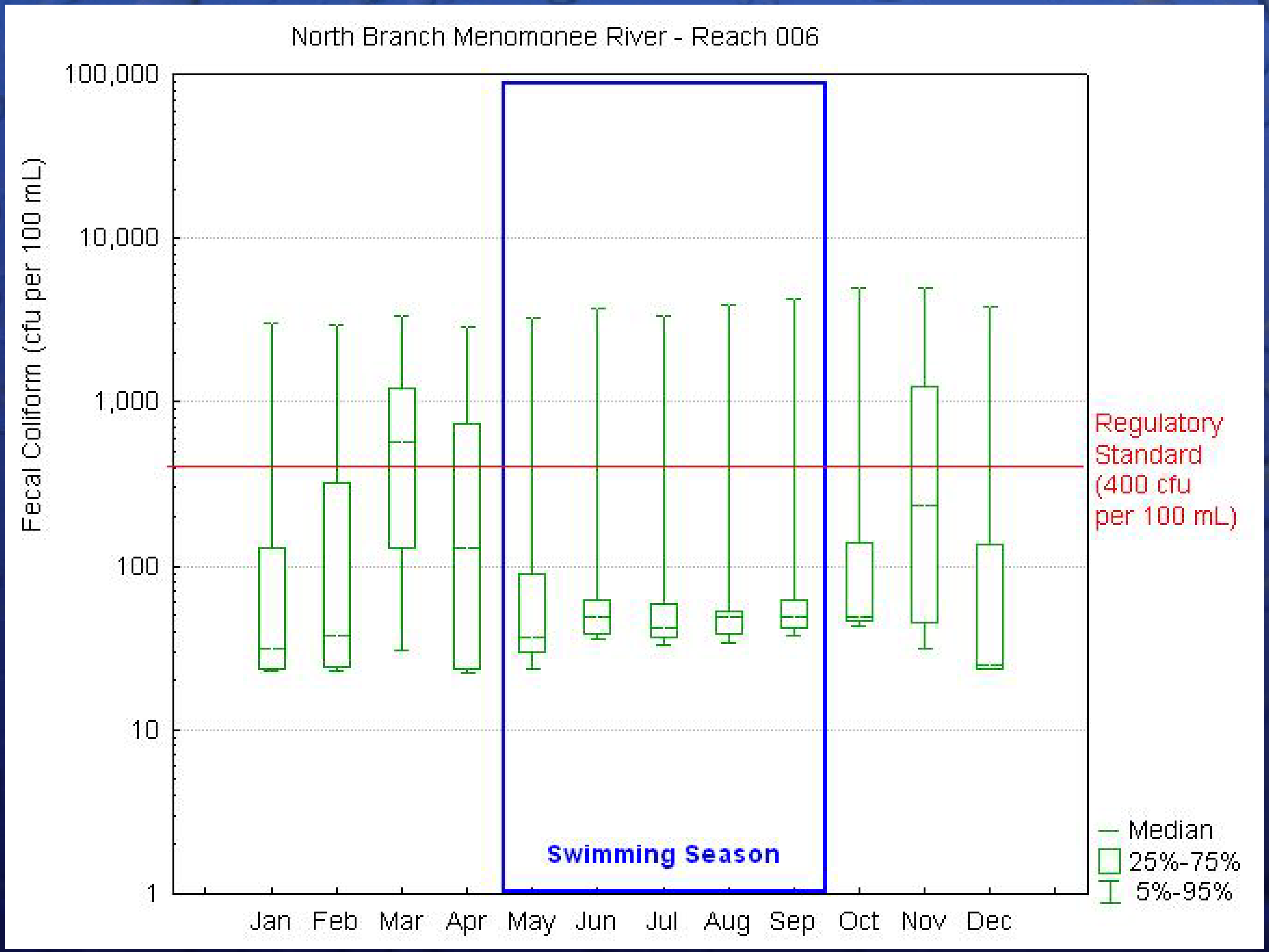
Key Processes Modeled



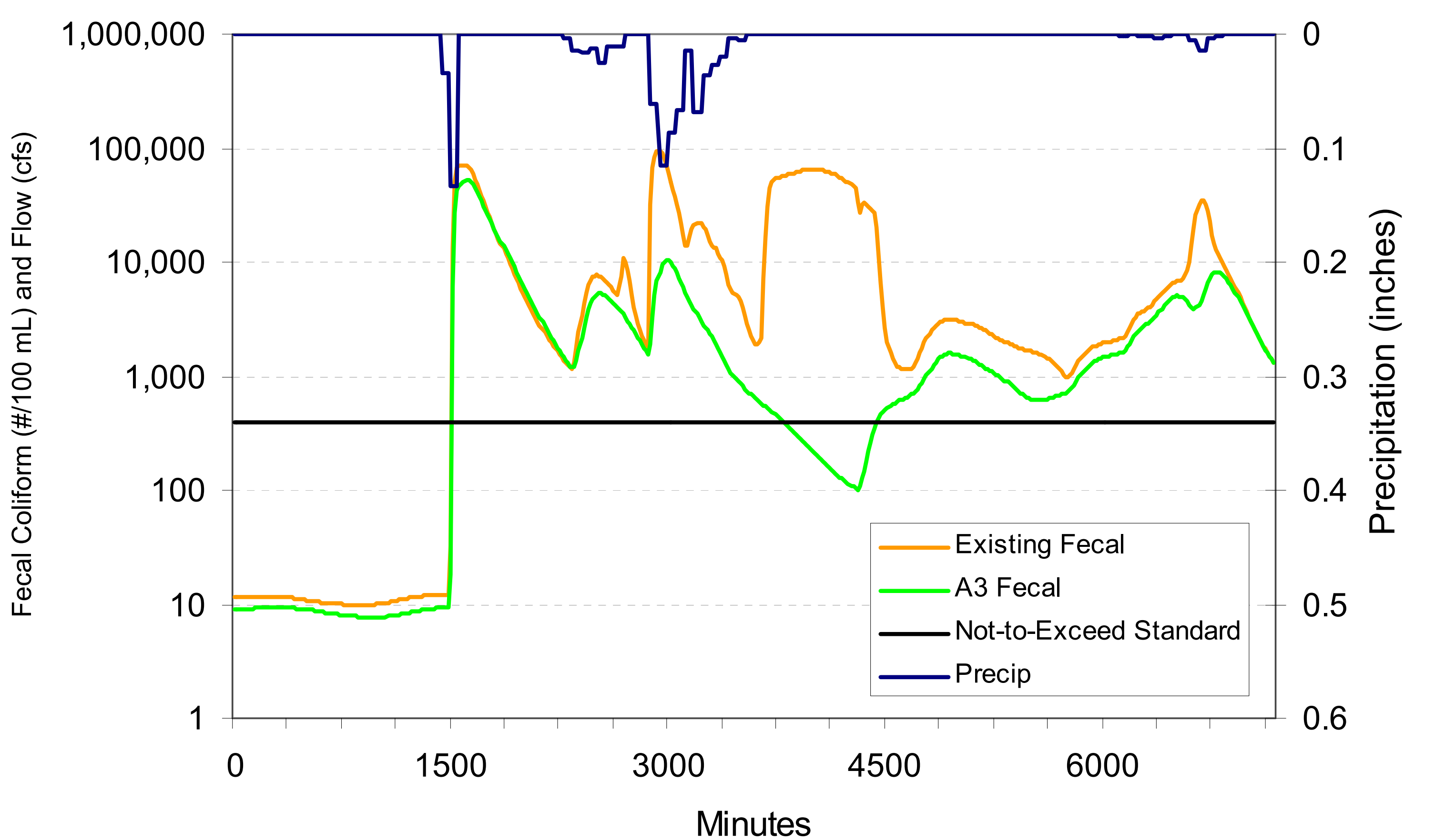
Why Model?

- We'll never have sufficient monitoring data to answer all of the questions we have about water quality
- Link sources of pollution to water quality impacts
- Evaluate magnitude of source loadings
- Evaluate/simulate future management actions

Addressing Data Gaps



Linking Sources to Water Quality



MENOMONEE RIVER @ 70TH ST - WET WEATHER EVENT

Evaluating Magnitude of Source Loadings

AVERAGE ANNUAL LOADS OF TOTAL PHOSPHORUS IN THE GREATER MILWAUKEE WATERSHEDS[a]

	Point Sources					Nonpoint Sources			
Watershed	Industrial Point Sources (pounds)	SSOs (pounds)	CSOs (pounds)	Sewage Treatment Plants (pounds)	Subtotal (pounds)	Urban (pounds)	Rural (pounds)	Subtotal (pounds)	Total (pounds)
Kinnickinnic River	1,440	890	490	- -	2,820	9,860	70	9,930	12,750
Menomonee River	17,550	580	1,880	- -	20,010	29,040	4,070	33,110	53,120
Milwaukee River	93,840	780	1,790	51,740	148,150	45,290	81,060	126,350	274,500
Subtotal from Rivers to Harbor	112,830	2,250	4,160	51,740	170,980	84,190	85,200	169,390	340,370
Percent of Load from Rivers to Harbor	33.1	0.7	1.2	15.2	50.2	24.8	25.0	49.8	100.0
Oak Creek	10	10	- -	- -	20	8,500	2,110	10,610	10,630
Root River	130	10	- -	3,150	3,290	26,510	54,260	80,770	84,060
Riverine Subtotal	112,970	2,270	4,160	54,890	174,290	119,200	141,570	260,770	435,060
Percent of Riverine Load	26.0	0.5	1.0	12.6	40.1	27.4	32.5	59.9	100.0
Lake Michigan Direct Drainage Area................	- -	40	160	316,550	316,750	13,180	2,240	15,420	332,170
Total	112,970	2,310	4,320	371,440	491,040	132,380	143,810	276,190	767,230
Percent of Total Load	14.7	0.3	0.6	48.4	64.0	17.3	18.7	36.0	100.0

[a]Loads from groundwater are included. The results are annual averages based on simulation of year 2000 land use conditions and approximated current point source loads and wastewater conveyance, storage, and treatment system operating conditions. The simulations were made using meteorological data from 1988 through 1997, which is a representative rainfall period for the study area.

Source: Brown and Caldwell; HydroQual, Inc.; Tetra Tech, Inc.; and SEWRPC.

Simulating Future Management Scenarios

Statistic	Existing	Original 2020 Baseline	Alternative[a]			
			B1	B2	C1	C2
Mean (cells per 100 ml)	5,373	4,533	4,522	4,522	3,960	3,960
Percent compliance with single sample standard (<2,000 cells per 100 ml)[b]	79	80	80	80	80	80
Geometric mean (cells per 100 ml)	371	318	318	318	282	282
Days of compliance with geometric mean standard (<1,000 cells per 100 ml)[b]	305	317	317	317	322	322

2020/RWQMPU Modeling

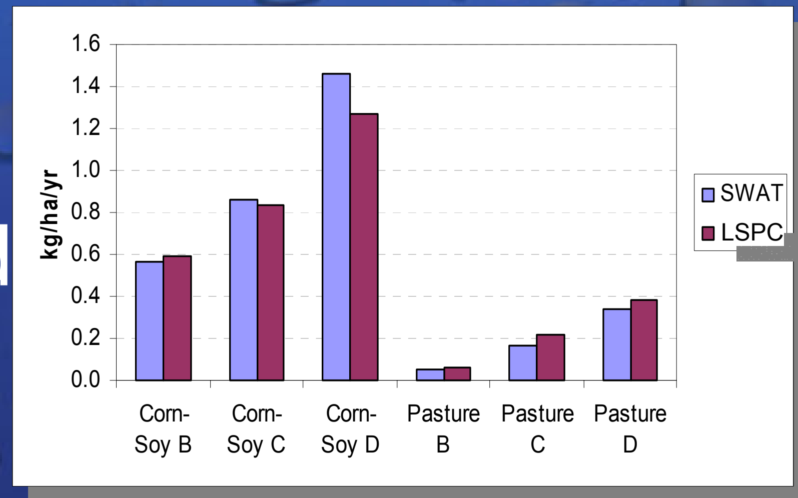
- Scope
  - System Modeling – treatment/conveyance (resulting CSO and SSO)
  - Watershed Models
    - Kinnickinnic River, Oak Creek, Menomonee River, Milwaukee River, and Root Rivers (1100 square miles)
  - Lake Michigan Harbor/Estuary Model
- Objectives
  - Allow planners to evaluate the potential water quality benefits of a range of alternatives

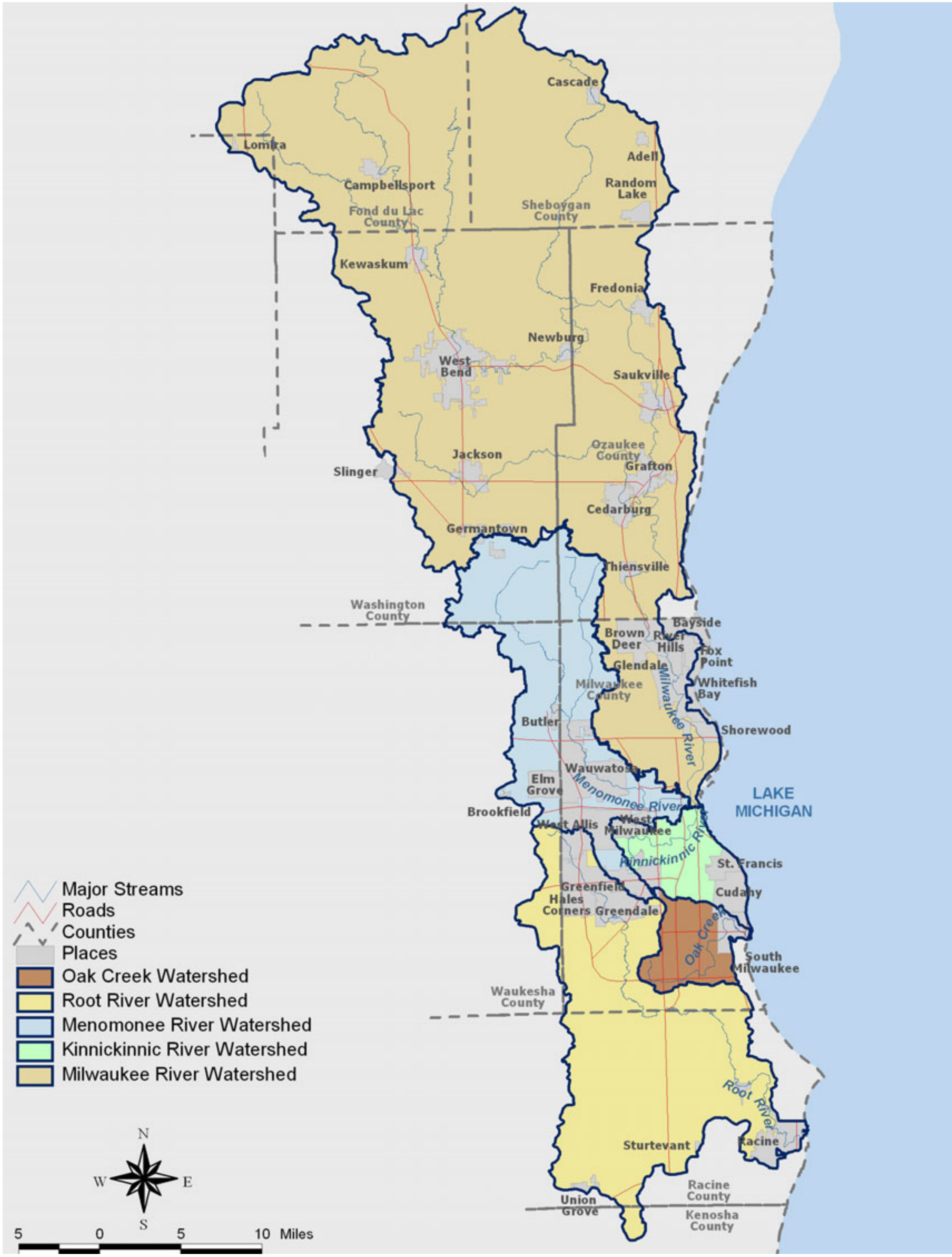
Watershed Modeling

- Loading Simulation Program in C++ (LSPC)
  - Updated version of Hydrologic Simulation Program Fortran (HSPF)
- Comprehensive watershed and receiving water quality modeling framework
- Maintained by the EPA Office of Research and Development

SWAT and SLAMM Modeling

- "Nested" modeling approach
- Match edge of field loadings
- Consider management/cropping / practices
- Consistent with Wisconsin DNR methods




Cascade
Lomira
Adell
Campbellsport
Random Lake
Sheboygan County
Fond du Lac County
Kewaskum
Fredonia
Newburg
West Bend
Saukville
Ozaukee County
Jackson
Grafton
Slinger
Cedarburg
Germantown
Thiensville
Washington County
Bayside
Brown Deer
River Hills
Fox Point
Glendale
Whitefish Bay
Milwaukee County
Milwaukee River
Butler
Shorewood
Wauwatosa
Elm Grove
Menomonee River
LAKE MICHIGAN
Brookfield
West Allis
West Milwaukee
Kinnickinnic River
St. Francis
Greenfield
Hales Corners
Greendale
Cudahy
Oak Creek
South Milwaukee
Waukesha County
Root River
Racine
Sturtevant
Racine County
Union Grove
Kenosha County
Major Streams
Roads
Counties
Places
Oak Creek Watershed
Root River Watershed
Menomonee River Watershed
Kinnickinnic River Watershed
Milwaukee River Watershed
N
W
E
S
5
0
5
10
Miles

Seven Step Process

1) Establish the model structure
2) Develop the model data sets
3) Perform hydrologic and hydraulic calibration and validation
4) Perform water quality calibration and validation
5) Perform harbor/estuary and lake water quality calibration
6) Perform production runs as required for project planning
7) Document results

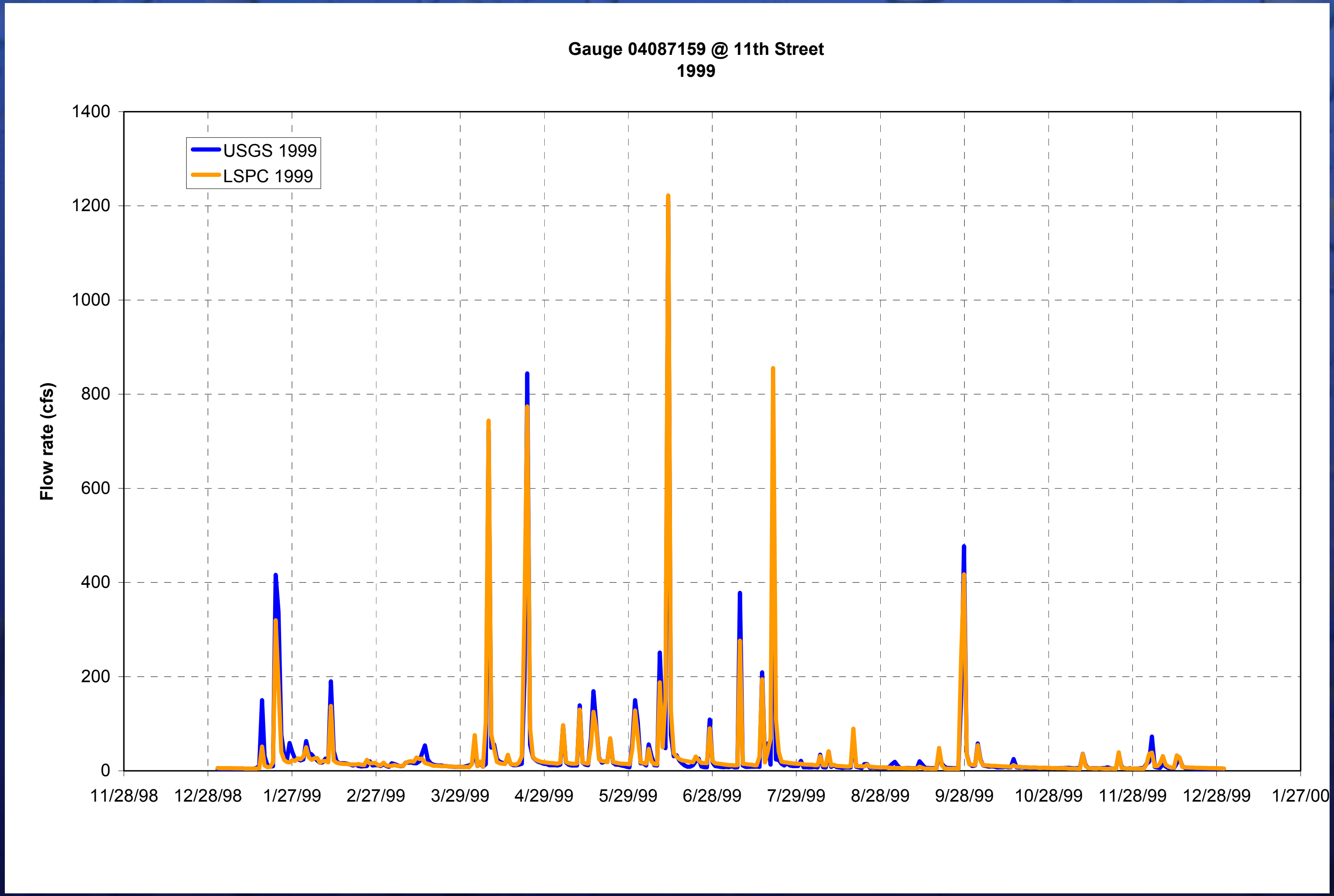
Calibration:

1) Flow
2) Sediment (TSS)
3) Temperature
4) Initial - gross nutrient (N,P) transport
5) Initial - BOD and DO
6) Algae
7) Final of nutrient species and DO
8) Fecal coliform bacteria
9) Includes simulation of metals at a simplified level

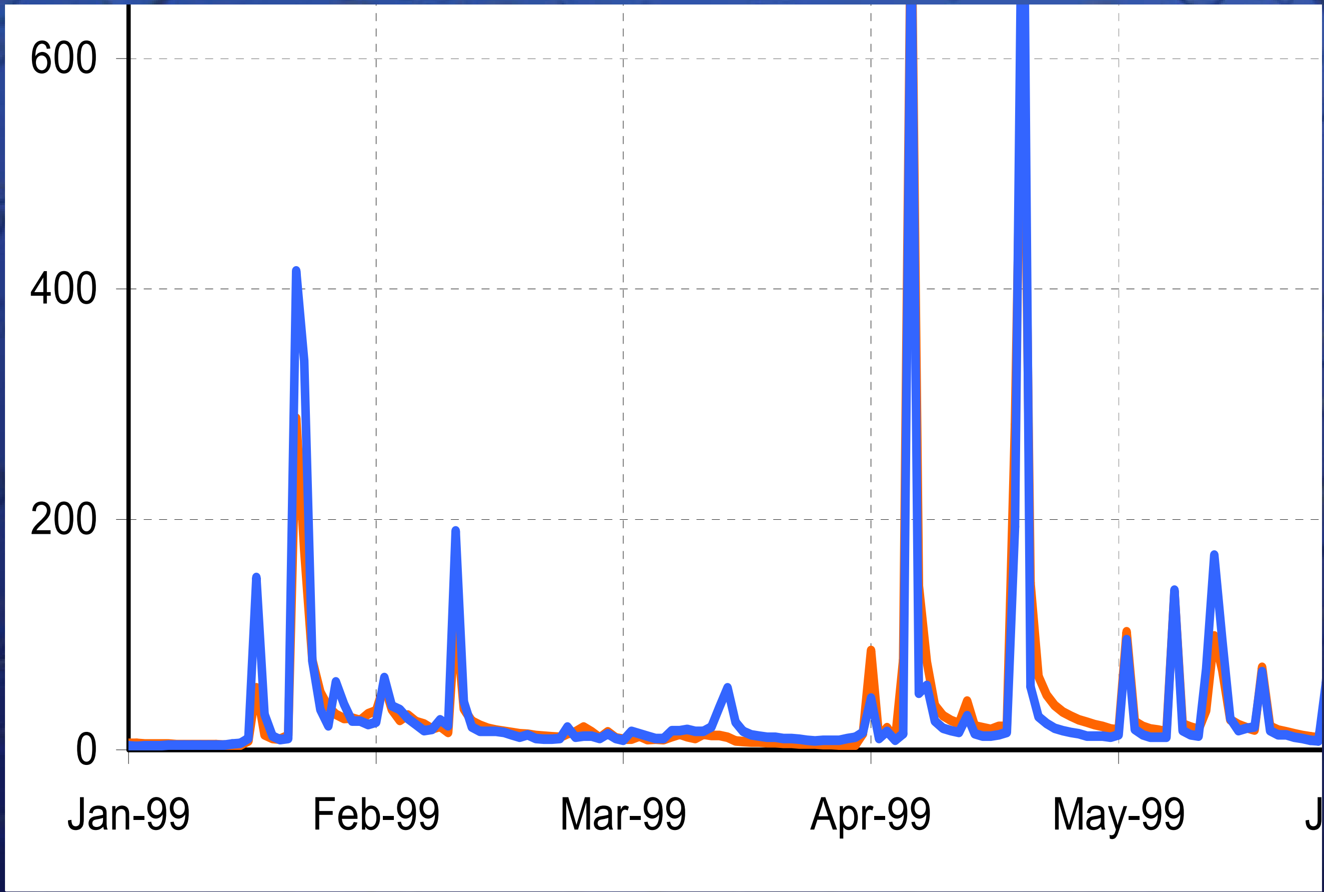
Testing Model Performance

- Extensive review by Modeling Subcommittee
  - SEWRPC, WDNR, MMSD, USEPA, Marquette University, UWM and others
- Calibrated to 1994 to 1998 data
- Validated to 1999 to 2001 data
- Various tests for both hydrology and water quality calibration

Hydrologic Calibration



Hydrologic Calibration (cont)

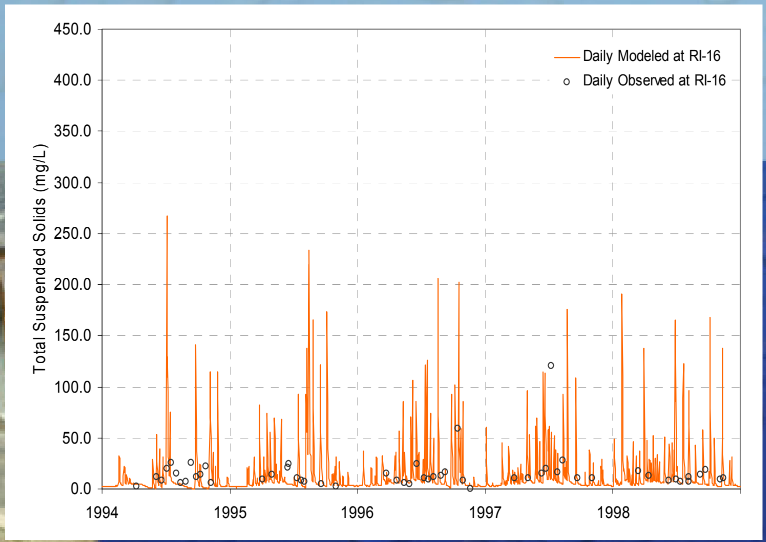


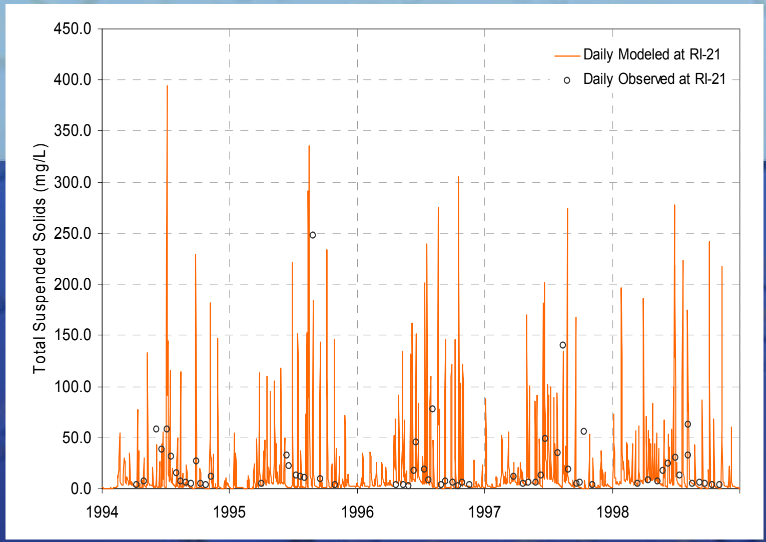
Visual Evaluations – Shaping, Timing, Recession, Seasons, Snowmelt

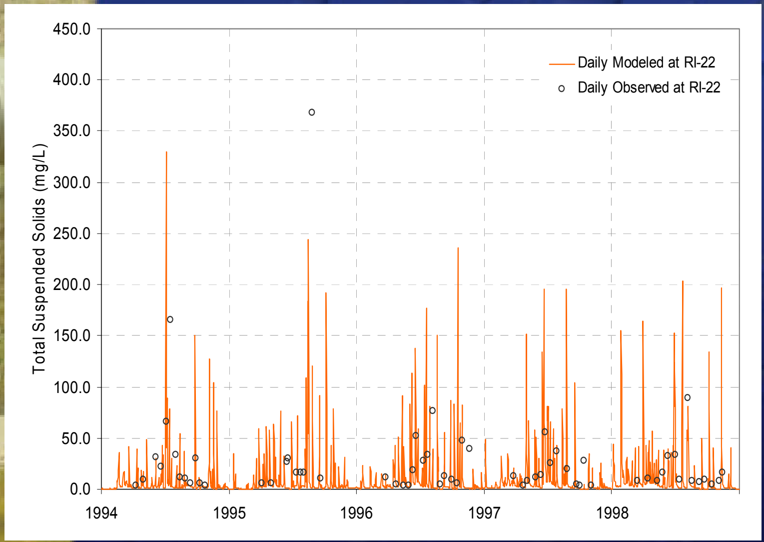
Hydrologic Calibration (cont)

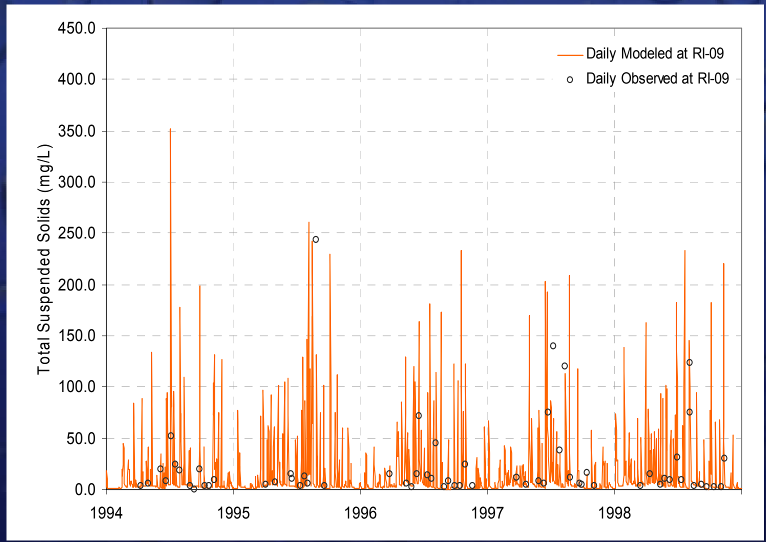
Category	LSPC volume (ac-ft)	USGS volume (ac-ft)	Percent Difference	Tolerance
Total Highest 10% volume	49,000	53,806	-8.9%	15%
Total Highest 20% volume	58,143	63,518	-8.5%	15%
Total Highest 50% volume	71,767	74,965	-4.3%	15%
Total Lowest 10% volume	1,255	1,319	-4.8%	10%
Total Lowest 30% volume	5,064	4,872	4.0%	10%
Total Lowest 50% volume	10,849	9,508	14.1%	10%

Total Suspended Solids

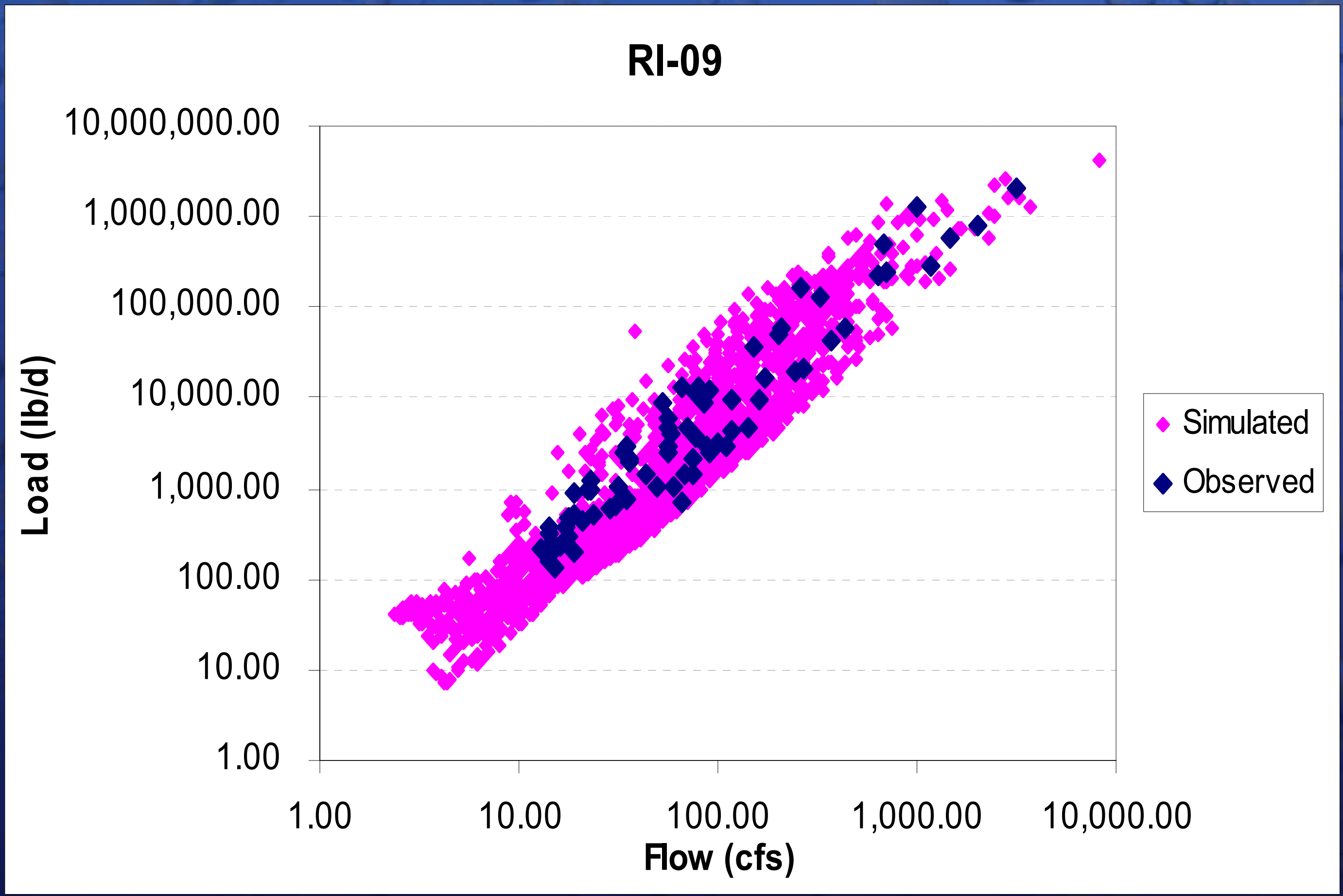




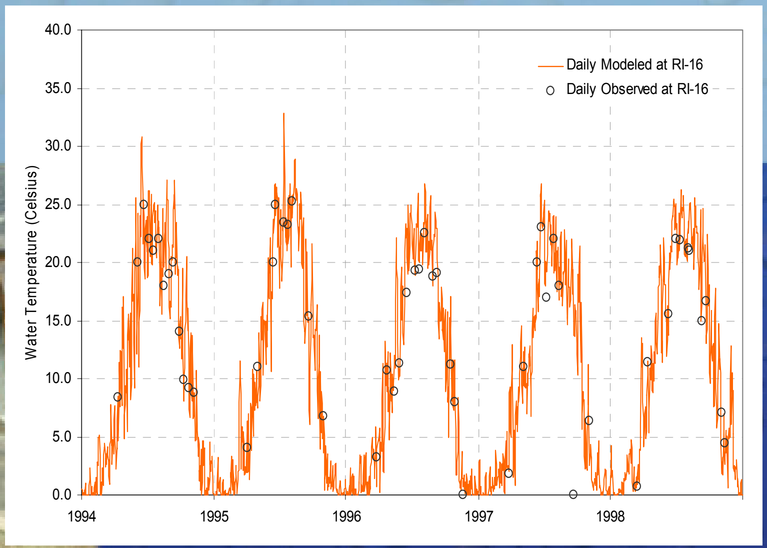


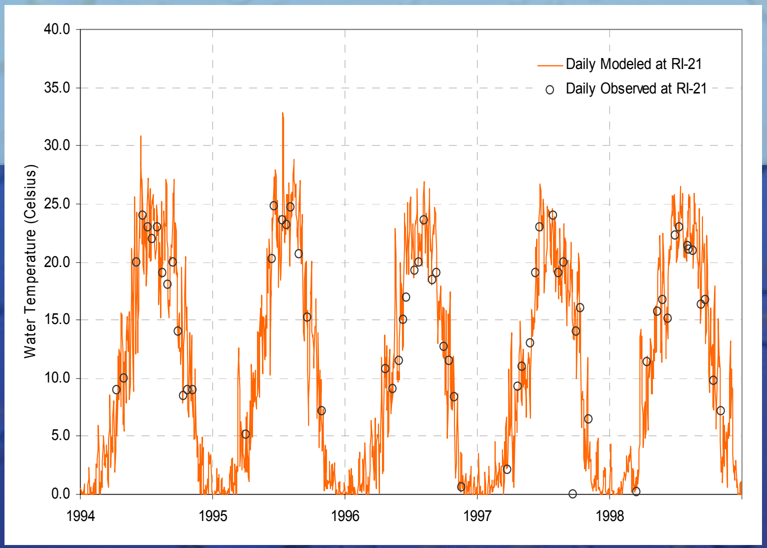


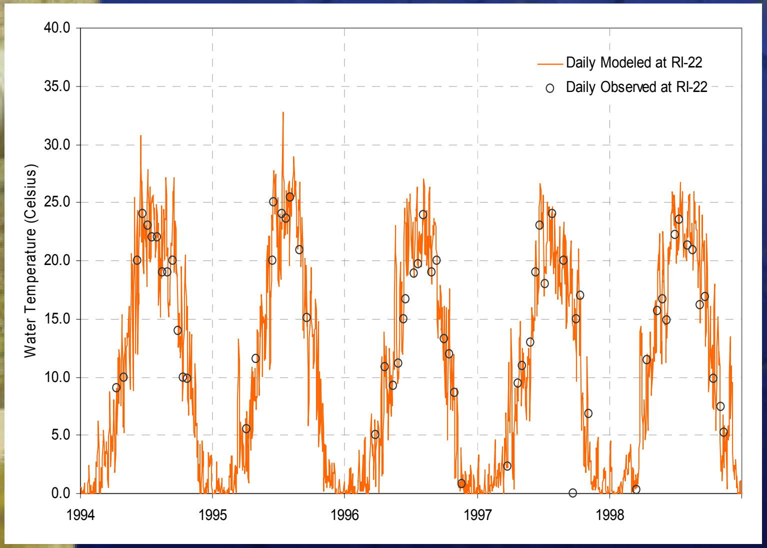
Sediment Load

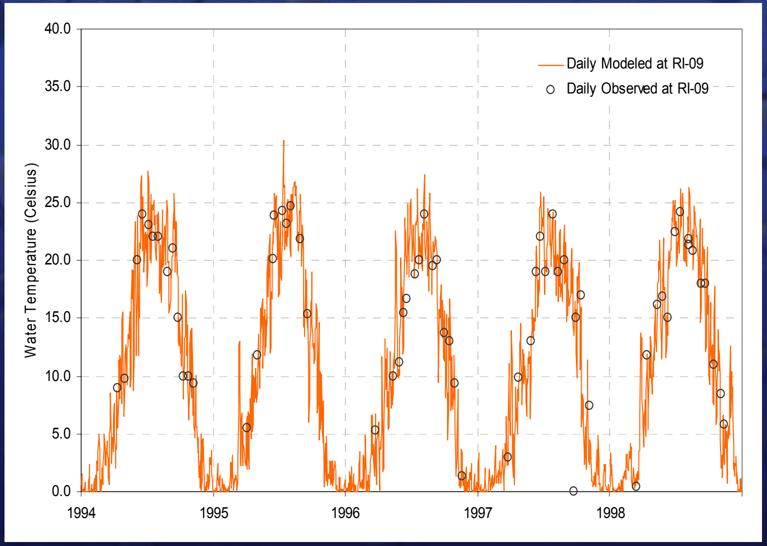


Temperature

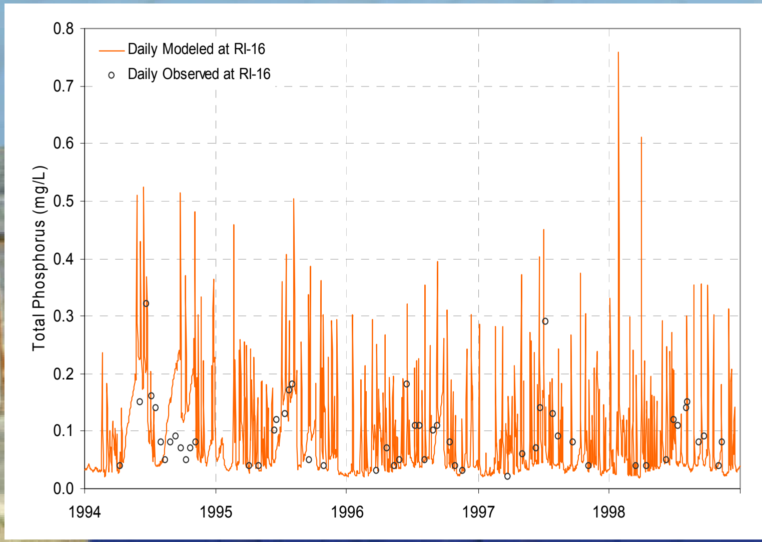


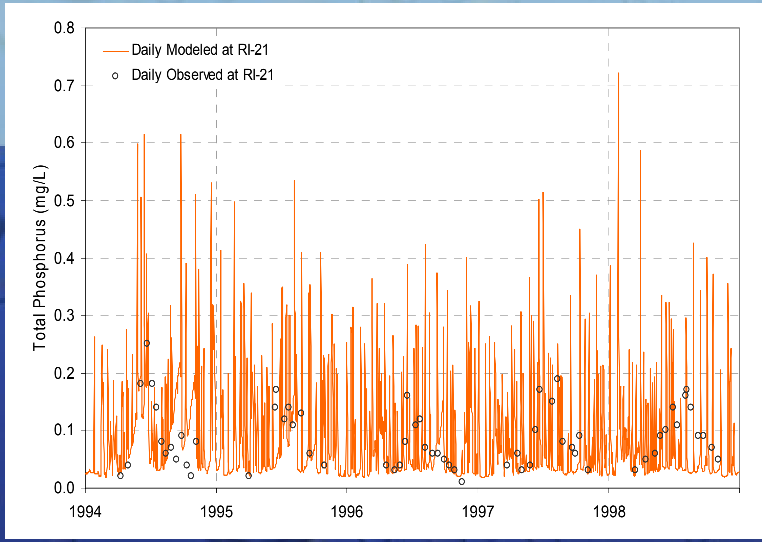


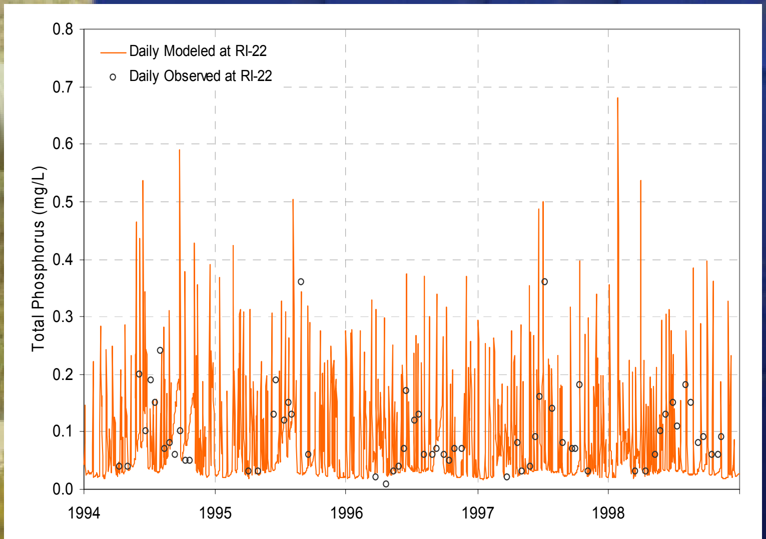


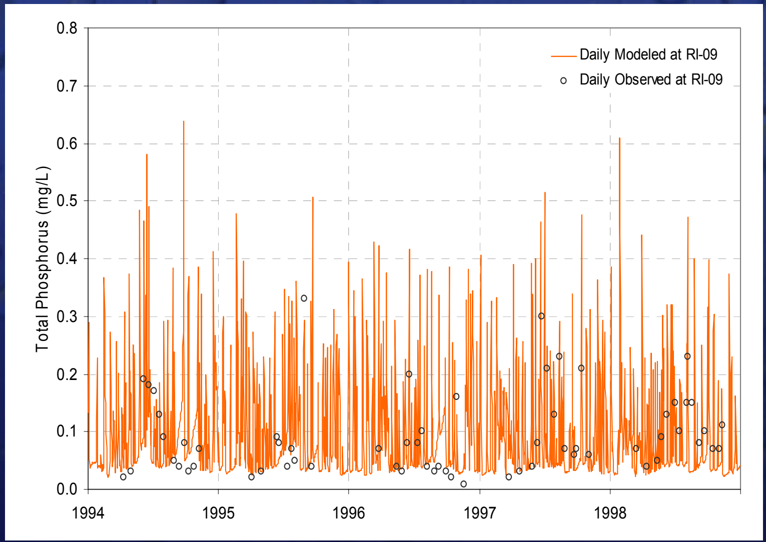


Total Phosphorus

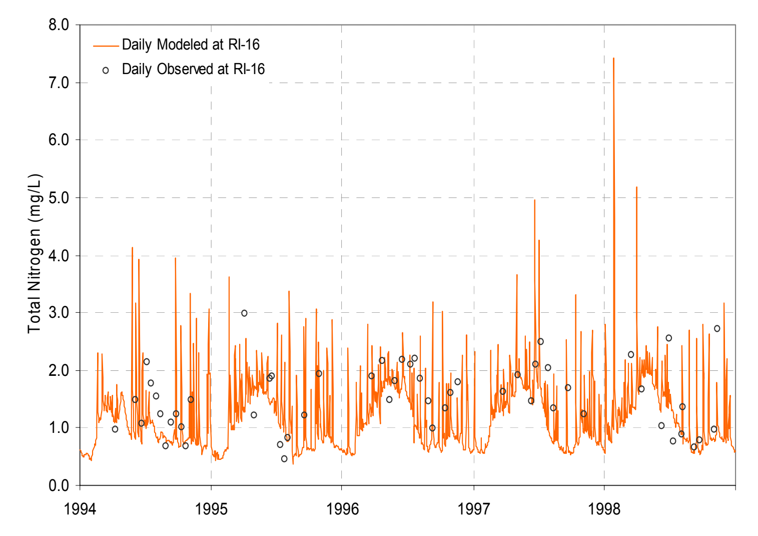


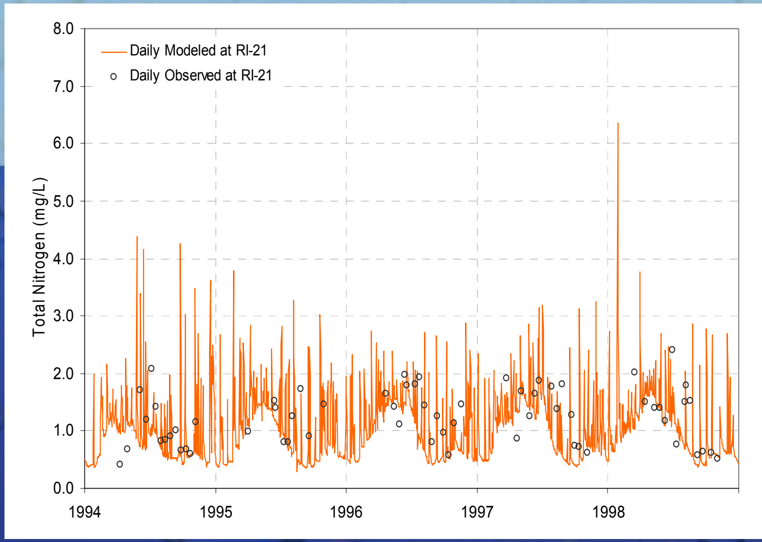


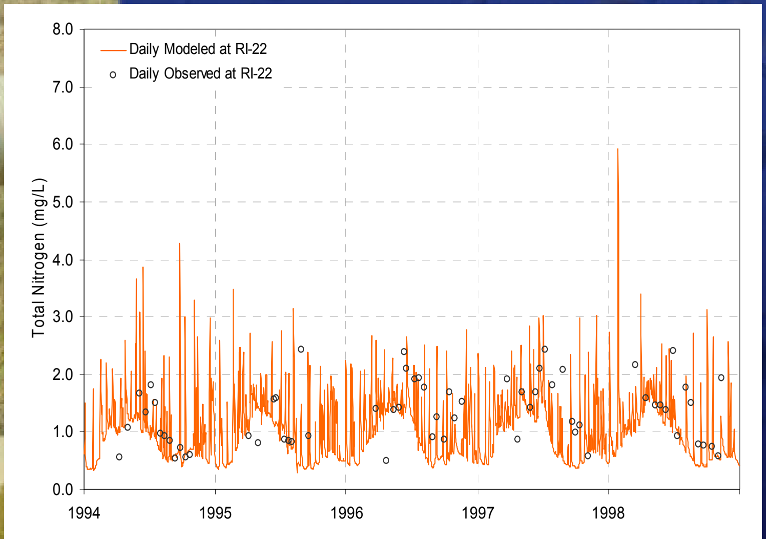


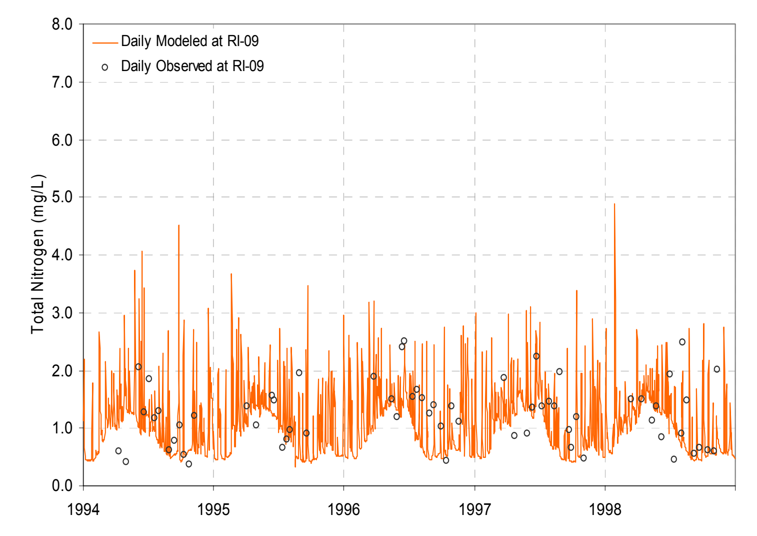


Total Nitrogen

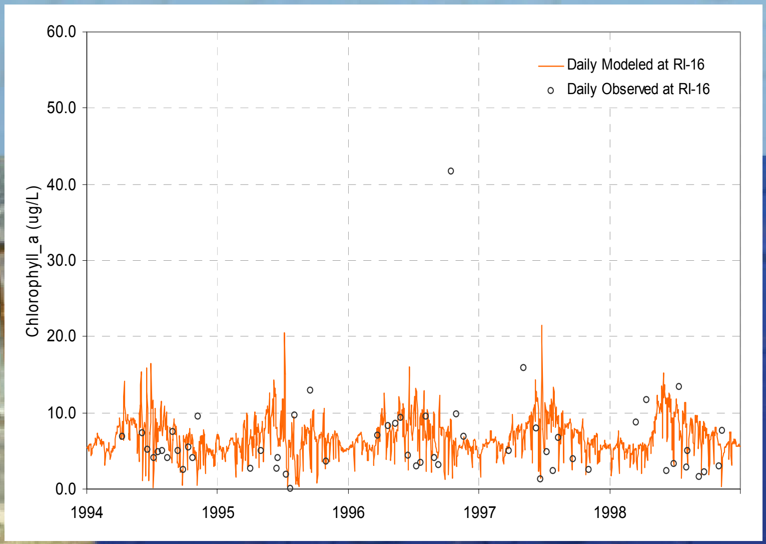


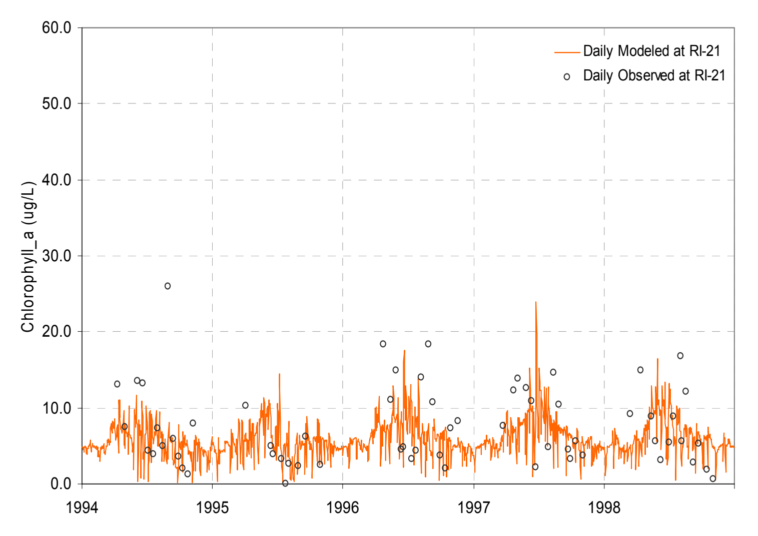


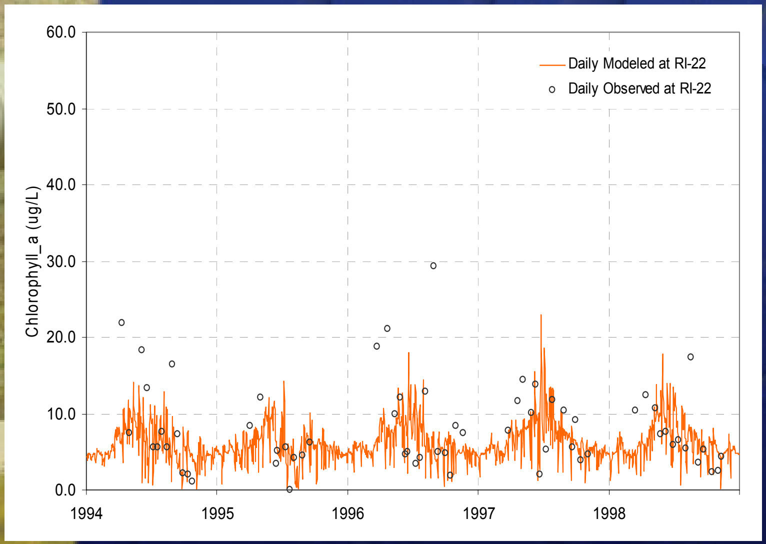


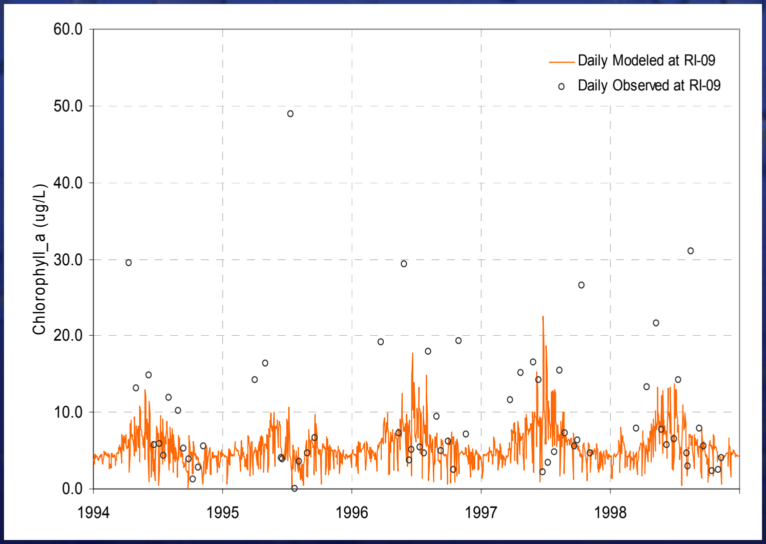


Chlorophyll *a*

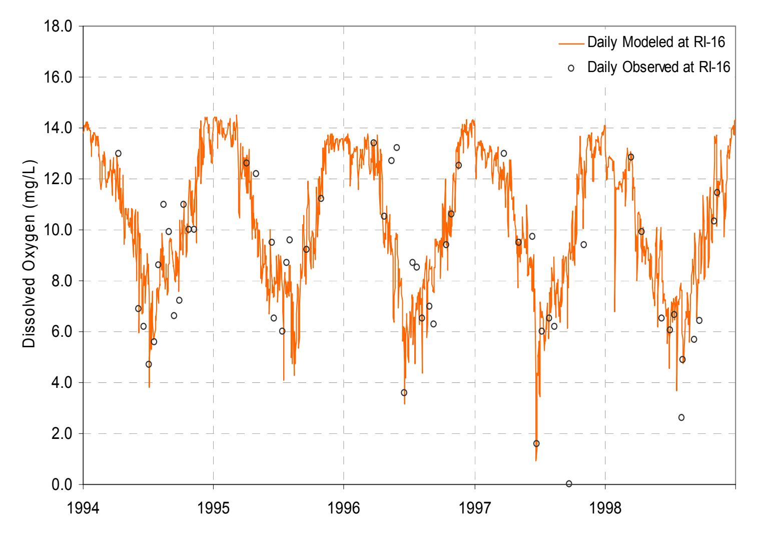


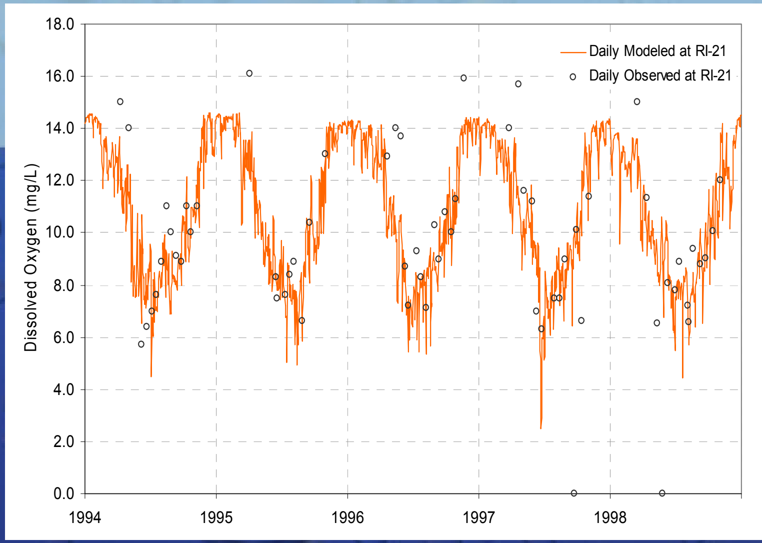


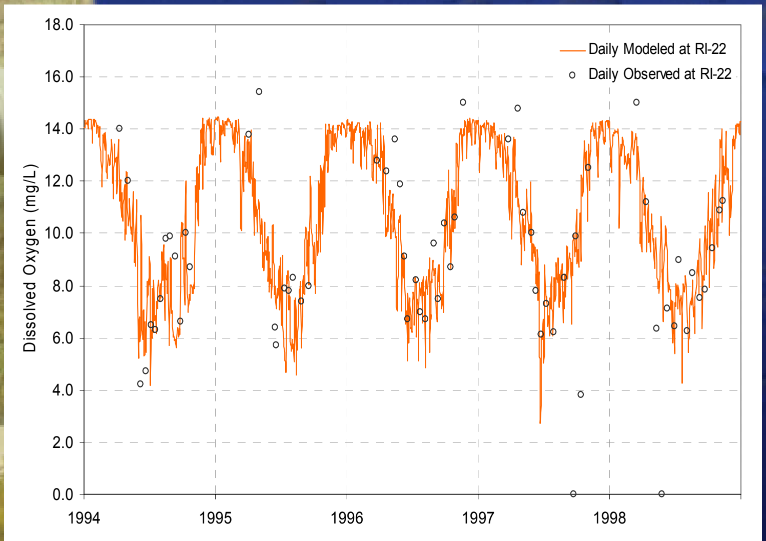


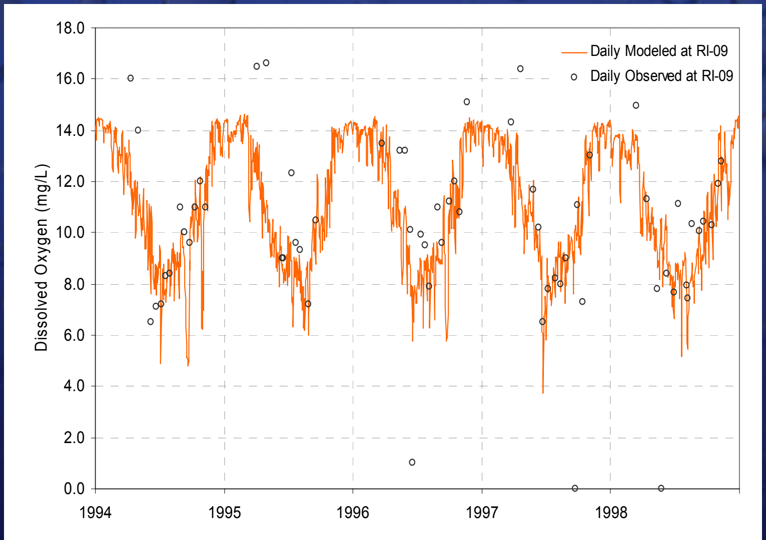


Dissolved Oxygen

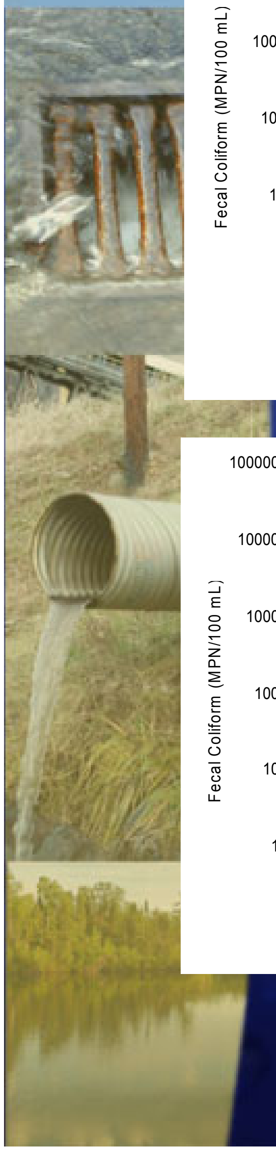


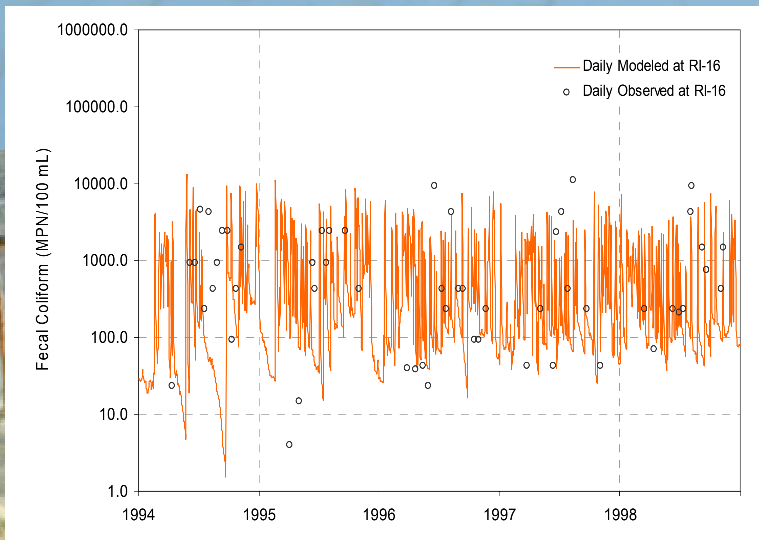


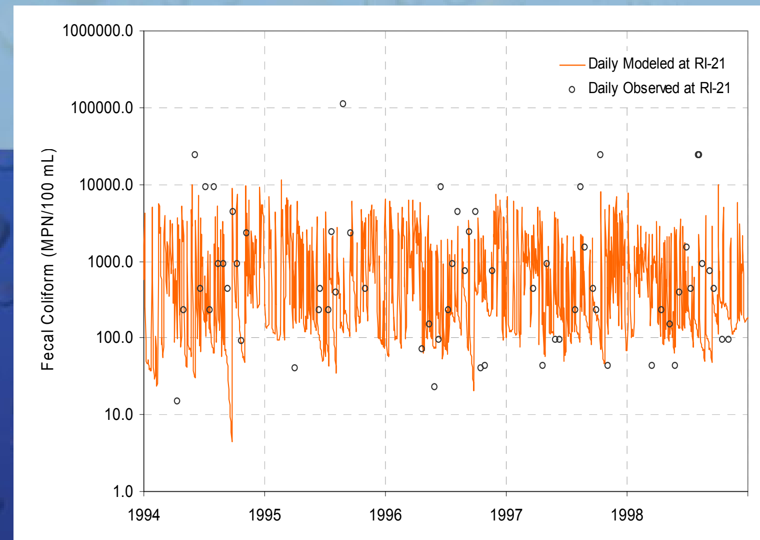


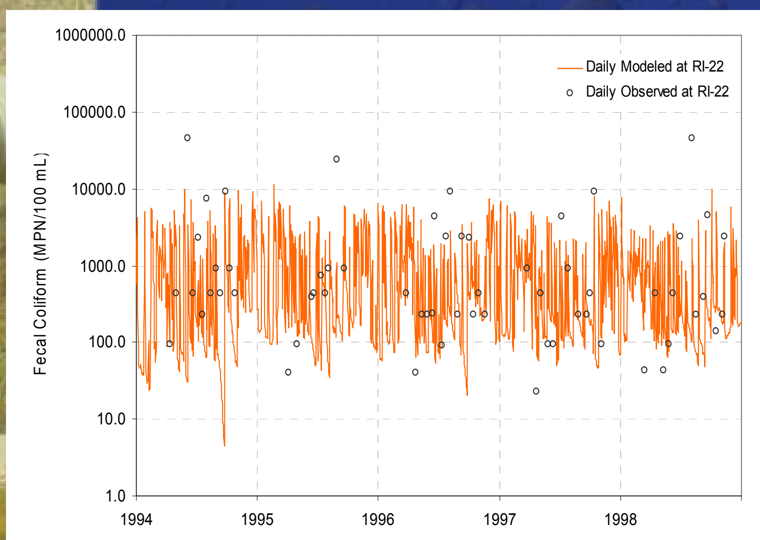


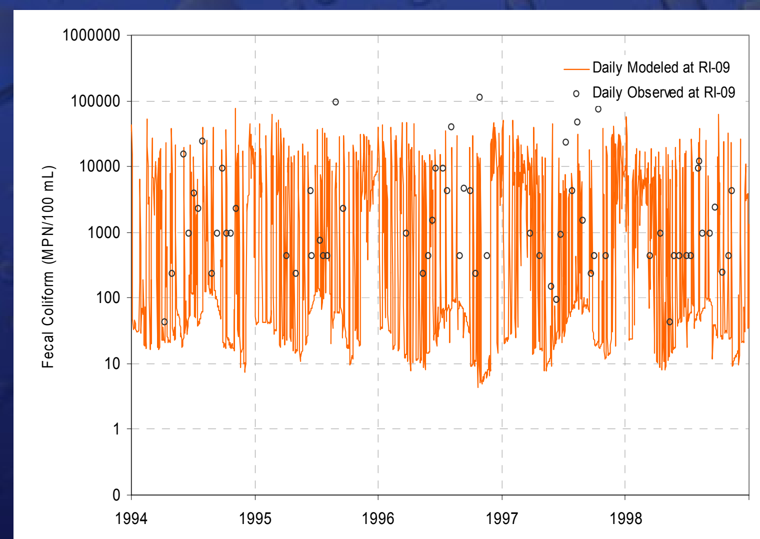
Fecal Coliform











Water Quality Calibration (cont)

Table 2. Menomonee River Concentration Validation Statistics (1999-2001)

	RI-16	RI-21	RI-22	RI-09
Chlorophyll a (mg/L)				
Sample Size	41	41	42	42
Observed Mean	6.194	8.449	7.939	10.038
Observed St. Dev.	2.854	8.508	6.111	6.959
Simulated Mean	7.075	6.427	6.687	6.125
Simulated St. Dev.	2.026	2.183	2.467	2.504
RMSE	3.854	8.917	6.827	8.163
Paired t-test (pval)	0.145	0.149	0.239	0.001
pass t-test?	Yes	Yes	Yes	No

Evaluating Response to Changes

1. Existing Condition – 2000 land use & facilities
2. Future Condition
   - Projected 2020 land use (increase)
   - Committed MMSD projects
   - Full adoption of all urban NR151 measures
   - Same weather data as Existing Condition
3. Scenarios/Alternatives - various combinations of controls on point and nonpoint
4. Innovative approaches to simulating various controls
   - Detention facilities
   - Infiltration
   - Disinfection units

Presentation of Results

- Multiple Locations
  - 5 rivers, numerous modeling reaches
- Multiple Indicators
  - Fecal coliform, TSS, nutrients, DO, etc
- Time
  - Annual, seasonal, daily, statistics
- Vast amount of output
  - 682 modeling subwatersheds X 10 year model runs X 14 parameters X 365 days in a year X hourly output X 20 modeling runs= 10 billion+ data points!

Presentation of Results (cont)

- Selected 94 assessment points
- Summarized output in a variety of ways to facilitate decision making
  - Geometric Mean
  - Mean
  - Median
  - Days Meeting Standards
  - Percent of Time Standards are Met

Conclusions

1. Models are a good fit to the large data base of actual water quality sampling data
2. Models produced massive amounts of output which can be used in the WRP to target potential actions
3. Comprehensive modeling system is a good framework for beginning the WRP's