Yellow Medicine River Watershed Total Maximum Daily Load

A Total Maximum Daily Load Report compiled by the Minnesota Pollution Control Agency

Minnesota Pollution Control Agency

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Seasonal Variation	*E. coli:* Load duration curve methodology accounts for seasonal variation and the standard is developed for critical conditions; *See Section 4.6.1* Turbidity (TSS): Load duration curve methodology accounts for seasonal variation and the standard is developed for critical conditions; *See Section 4.6.2* Nutrient eutrophication: Standard is developed for critical conditions; *See Section 4.6.3*	51
Reasonable Assurance	Changes in the landscape and hydrology will need to occur if pollutant levels are going to decrease. The source reduction strategies detailed in the implementation section have been shown to be effective in improving water quality. Many of the goals outlined in this TMDL report run parallel to objectives outlined in the local water plans. Various programs and funding sources are currently being utilized in the watershed and will also be used in the future. Additionally, Minnesota voters have approved an amendment to increase the state sales tax to fund water quality improvements. *See Section 6*	60
Monitoring	Intensive watershed monitoring will occur on a 10-year schedule. Long term load monitoring at the watershed outlet is currently occurring. *See Section 7*	61

Implementation	A summary of potential management measures is included with a rough approximation of the overall implementation cost to achieve the TMDL**.** *See Section 8*	62
Public Participation	Public participation in the Yellow Medicine has been ongoing for the past two years. With respect to this specific TMDL: A public comment period was open from May 16, 2016 to June 15, 2016. There was one comment letter received and responded to as a result of the public comment period. *See Section 9*	65

Acronyms

ARM	Agricultural Runoff Model
µg/L	Micrograms per Liter
ac-ft/yr	acre feet per year
AF	Anoxic Factor
AUID	Assessment Unit ID
AWQCP	Agricultural Water Quality Certification Program
BMP	Best Management Practice
BWSR	Board of Water and Soil Resources
CAC	Citizens Advisory Committee
CAFO	Concentrated Animal Feeding Operation
cfs	Cubic Feet per Second
cfu	colony-forming unit
Chl-*a*	Chlorophyll-*a*
CWA	Clean Water Act
CWLA	Clean Water Legacy Act
DNR	Minnesota Department of Natural Resources
EPA	U. S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
FWMC	Flow Weighted Mean Concentration
GW	Groundwater
HSPF	Hydrologic Simulation Program – FORTRAN
HUC	Hydrologic Unit Code
in/yr	Inches per Year
kg/ha	Kilograms per Hectare
km^2	Square Kilometer
LA	Load Allocation
lb(s)	Pound(s)
lbs/yr	Pounds per Year
lbs/day	Pounds per Day
LC	Loading Capacity
LGU	Local Government Unit
m	Meter
MDA	Minnesota Department of Agriculture
mg	Milligrams
mg/L	Milligrams per Liter
mg/m^2-day	Milligrams per Square Meter per Day
mgd	Million Gallons per Day
mL	Milliliters
MLCCS	Minnesota Land Cover Classification System
MOS	Margin of Safety

MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
MSU-WRC	Minnesota State University, Mankato – Water Resources Center
NGP	Northern Glaciated Plains
NPDES	National Pollutant Discharge Elimination System
NPS	Non-Point Source
NTU	Nephelometric Turbidity (TSS) Unit
org	Organisms
RR	Release Rate
SDS	State Disposal System
SOD	Sediment Oxygen Demand
SONAR	Statement of Need and Reasonableness
SRO	Surface Runoff
SSTS	Subsurface Sewage Treatment System
SWPPP	Stormwater Pollution Prevention Plan
TDLC	Total Daily Loading Capacity
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
UAL	Unit-Area Load
USGS	United States Geological Survey
WCBP	Western Corn Belt Plains
WLA	Wasteload Allocations
WRAPS	Watershed Restoration and Protection Strategies
WWTF	Wastewater Treatment Facilities
µg/L	Microgram per Liter

Executive Summary

Section 303(d) of the Clean Water Act (CWA) provides authority for completing Total Maximum Daily Loads (TMDLs) to achieve state water quality standards and/or designated uses. The TMDL establishes the maximum amount of a pollutant a waterbody can receive on a daily basis and still meet water quality standards. The TMDL is divided into wasteload allocations (WLAs) for point or permitted sources, load allocations (LAs) for non-point sources (NPSs) and natural background plus a margin of safety (MOS).

This TMDL report addresses impairments for 16 stream reaches consisting of 16 Escherichia coli *(E. coli)* and 3 turbidity (TSS) impairments, as well as 7 lakes for nutrient eutrophication impairments in the Yellow Medicine River Watershed. Addressing multiple impairments in one TMDL report is consistent with Minnesota's Water Quality Framework that seeks to develop watershed wide protection and restoration strategies rather than focus on individual reach impairments.

The Yellow Medicine River Watershed covers approximately 707,000 acres in the Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) ecoregions and drains portions of five counties (Lac qui Parle, Lincoln, Lyon, Redwood, and Yellow Medicine) in the Southwest Minnesota River Basin.

This TMDL report used a variety of methods to evaluate current loading contributions by the various pollutant sources as well as the allowable pollutant loading capacity of the impaired water bodies. These methods include the Hydrologic Simulation Program – FORTRAN (HSPF) model, the load duration curve approach, and the BATHTUB lake eutrophication model.

A general strategy and cost estimate for implementation to address the impairments are included. The NPSs will be the focus of implementation efforts. The NPS contributions are currently not regulated and will need to proceed on a voluntary basis. Permitted point sources will be addressed through the Minnesota Pollution Control Agency's (MPCA) National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Permit (Permit) programs.

1. Project Overview

1.1 Purpose

The CWA Section 303(d) requires that states publish a list of surface waters that do not meet water quality standards and therefore, do not support their designated use(s). These waters are then classified as impaired and placed on the impaired waters list, which dictates that a TMDL report must be completed. The TMDL report calculates the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and resources to state and local governments to accelerate efforts to monitor, assess and restore impaired waters and to protect unimpaired waters. The result has been a comprehensive "watershed approach" that integrates water resource management efforts, local governments, and stakeholders to develop watershed-scale TMDLs, restoration and protection strategies, and plans for each of Minnesota's 80 major watersheds. The information gained and strategies developed in the watershed approach are presented in major watershed-scale Watershed Restoration and Protection Strategy (WRAPS) reports, which should help restore and protect streams, lakes, and wetlands across the watershed, including those for which TMDL calculations are not made.

The watershed approach started in the Yellow Medicine River Watershed in 2010 with intensive watershed monitoring and subsequent assessment, which resulted in 16 stream reaches and 7 lakes being listed as impaired due to one or more water quality parameters (Figure 1.1).

This document addresses Yellow Medicine River Watershed impairments identified in the 2010 monitoring and assessment cycles that have not been addressed in prior TMDLs, have an approved water quality standard, and have sufficient data for assessment. Refer to these TMDL report webpages for more details: *Lake Shaokatan Phosphorus Total Maximum Daily Load Report* (MPCA 2012b), South Branch Yellow Medicine Fecal Coliform TMDL (MPCA 2004a) and the *State-wide Mercury TMDL* (MPCA 2007). Biological impairments and the stressors identified with those impairments were identified within the watershed, however, due to lack of supporting data these impairments were deferred until sufficient data can be collected.

1.2 Identification of Waterbodies

This TMDL report applies to 26 separate impairment listings for 16 stream reaches and 7 lakes in the Yellow Medicine River Watershed (Table 1.1). Supporting documentation for the proposed listing of the impairments can be found in:

Minnesota River - Granite Falls Watershed Monitoring and Assessment Report (MPCA 2012d)

Yellow Medicine River Watershed Stressor ID Report (MPCA 2012c)

Table 1.1: Yellow Medicine River Watershed 303(d) impairments addressed in this TMDL report grouped by Aggregated HUC12 watersheds

Aggregated HUC12 Subwatershed	Stream Reach Description or Lake Name	Stream Use Class or Lake Ecoregion & Type	Assessment Unit ID or MN DNR Lake #	Affected Designated Use	Year Listed	Impairment
Hazel Creek-County Ditch No. 9	T115N, R43W, S33 to Minnesota River	2C	07020004-536	Aquatic Recreation	2014	*Escherichia coli*
Judicial Ditch 10 - Wood Lake Creek	Wood Lake outlet to Minnesota R	2C	07020004-547	Aquatic Recreation	2014	*Escherichia coli*
	Lady Slipper Lake	WCBP Shallow Lakes	42-0020-00	Aquatic Recreation	2014	Nutrient Eutrophication
	Wood Lake	WCBP Shallow Lakes	87-0030-00	Aquatic Recreation	2010	Nutrient Eutrophication
Judicial Ditch 17	CD 3 to Yellow Medicine R	2B, 3C	07020004-622	Aquatic Recreation	2014	*Escherichia coli*
	Cottonwood Lake	WCBP Shallow Lakes	42-0014-00	Aquatic Recreation	2010	Nutrient Eutrophication
Lower Yellow Medicine River	S Br Yellow Medicine R to Spring Cr	2B, 3C	07020004-513	Aquatic Recreation	2014	*Escherichia coli*
				Aquatic Life/ Recreation	2008	Turbidity (TSS)
Mud Creek	Headwaters to T114, R43W, S35, south line	2C	07020004-543	Aquatic Recreation	2014	*Escherichia coli*

Aggregated HUC12 Subwatershed	Stream Reach Description or Lake Name	Stream Use Class or Lake Ecoregion & Type	Assessment Unit ID or MN DNR Lake #	Affected Designated Use	Year Listed	Impairment
North Branch Yellow Medicine River	Steep Bank Lake	NGP Shallow Lakes	41-0082-00	Aquatic Recreation	2014	Nutrient Eutrophication
South Branch Yellow Medicine River	CD 35 Headwaters to Yellow Medicine R	2B, 3C	07020004-503	Aquatic Life	2002	Turbidity (TSS)
				Aquatic Recreation	1994	Fecal coliform bacteria
	JD 29 T111N, R44W, S16 South Line to S Br Yellow Medicine R	2B, 3C	07020004-550	Aquatic Recreation	2006	Fecal coliform bacteria
	T112N, R44W, S20 to T112N, R44W, S26	2B, 3C	07020004-595	Aquatic Recreation	2014	*Escherichia coli*
	T112N, R44W, S26 to T112N, R43W, S18	2B, 3C	07020004-597	Aquatic Recreation	2006	Fecal coliform bacteria
	T112N, R43W, S8 to T113N, R43W, S35	2B, 3C	07020004-599	Aquatic Recreation	2006	Fecal coliform bacteria
	CD 24 to CD 35	2B, 3C	07020004-600	Aquatic Recreation	2006	Fecal coliform bacteria

Aggregated HUC12 Subwatershed	Stream Reach Description or Lake Name	Stream Use Class or Lake Ecoregion & Type	Assessment Unit ID or MN DNR Lake #	Affected Designated Use	Year Listed	Impairment
	Lake Stay	NGP Shallow Lakes	41-0034-00	Aquatic Recreation	2014	Nutrient Eutrophication
Spring Creek	Headwaters to Yellow Medicine R	2B, 3C	07020004-538	Aquatic Recreation	2014	*Escherichia coli*
Stony Run Creek	T116N, R40W, S30, West Line to Minnesota R	2C	07020004-535	Aquatic Recreation	2014	*Escherichia coli*
Upper Yellow Medicine River	T113N, R43W, S20 to T113N, R43W, S9	2B, 3C	07020004-545	Aquatic Recreation	2014	*Escherichia coli*
	Headwaters to Mud Cr	2B, 3C	07020004-584	Aquatic Recreation	2014	*Escherichia coli*
				Aquatic Life	2010	Turbidity (TSS)
	Perch Lake	NGP Shallow Lakes	41-0067-00	Aquatic Recreation	2014	Nutrient Eutrophication
Wood Lake Creek-MN River	T114N, R37W, S20, west line to Minnesota R	2C	07020004-555	Aquatic Recreation	2014	*Escherichia coli*
	Curtis Lake	NGP Shallow Lakes	87-0016-00	Aquatic Recreation	2010	Nutrient Eutrophication

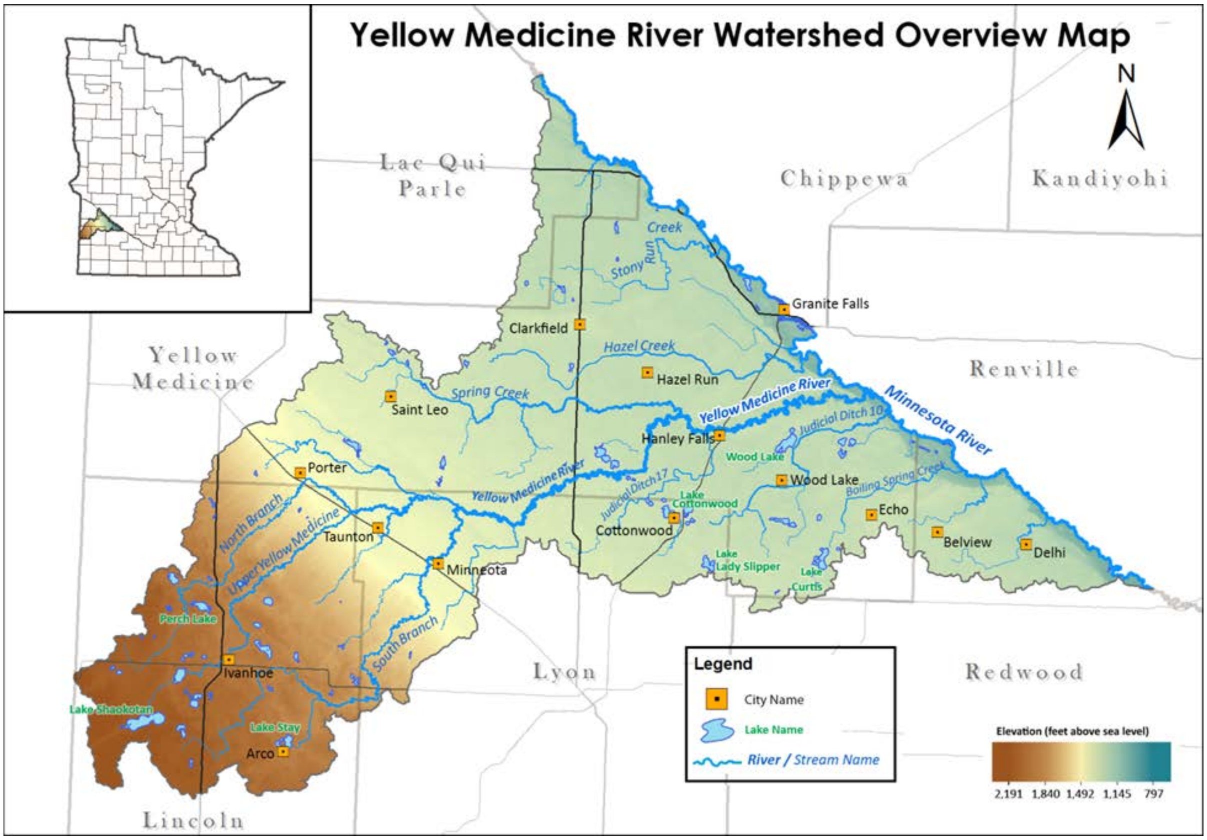

Figure 1.1: Yellow Medicine River Watershed - HUC 07020004 and its location within Minnesota

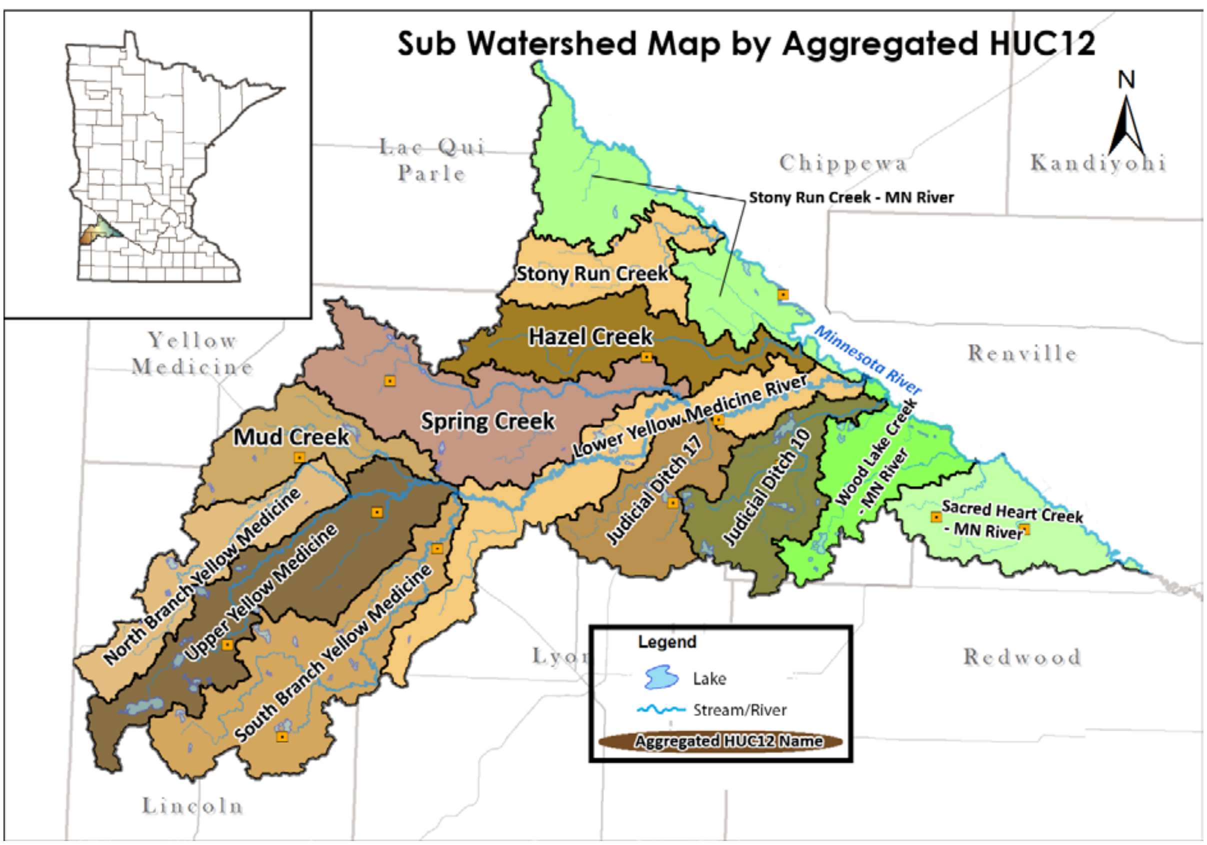

Figure 1.2: Yellow Medicine River Aggregated HUC12 Subwatershed boundaries

1.3 Priority Ranking

The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. Every 10 years Minnesota's 80 major watersheds are on a schedule to be monitored and assessed. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

The criteria used to determine stream and lake impairments are outlined in the MPCA's document *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List* (MPCA 2014). Minn. R. ch. 7050.0470 lists waterbody classifications and Minn. R. ch. 7050.2222 lists applicable water quality standards. The impaired waters covered in this TMDL are classified as Class 2B or 2C, 3B, 3C, 4A, 5, 6 and 7. Relative to aquatic life and recreation, the designated beneficial uses for the most stringent classifications, 2B and 2C waters, are:

Class 2B waters – The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable.

Class 2C waters – The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life, and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable.

The water quality standards shown in Table 2.1 and Table 2.2 are the numeric water quality target for each parameter shown. For more detailed information refer to the *MPCA TMDL Protocols* (MPCA 2014b).

Table 2.1: Surface water quality standards for Yellow Medicine River Watershed stream reaches addressed in this TMDL report

Parameter	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
***Escherichia coli*; Class 2 waters**	Not to exceed 126	**org/100 mL**	Monthly geo mean of at least 5 samples within one calendar month	**April 1 – October 31**
	Not to exceed 1,260	**org/100 mL**	Monthly upper 10th percentile	
TSS Class 2 waters	Not to Exceed 65	**mg/L**	> 10% of total samples cannot exceed 65 mg/L	**April - September**

The class 2B turbidity standard (Minn. R. ch. 7050.0222) that was in place at the time of the impairment assessment for reaches in the Yellow Medicine River Watershed was 25 nephelometric turbidity units (NTUs). Impairment listings occur when greater than 10% of data points collected within the previous 10-year period exceed the 25 NTU standards (or equivalent values for TSS or the transparency tube).

The aforementioned 25 NTU turbidity standard had several weaknesses, including its application statewide and, since turbidity is a measure of light scatter and absorption, it is not a mass unit measurement and therefore not amenable to TMDLs and other load-based studies. Although previously recognized, these weaknesses became a significant problem when the EPA and the MPCA's TMDL program became fully realized in the early 2000s.

As a result, a committee of the MPCA staff across several divisions met for over a year to develop TSS criteria to replace the turbidity standards. These TSS criteria are regional in scope and based on a combination of both biotic sensitivity to the TSS concentrations and reference streams/least impacts streams as data allow. The results of the TSS criteria development were published by the MPCA in 2011 and proposed a 65 mg/L TSS standard for Class 2B waters in the southern region of the state of Minnesota, that may not be exceeded more than 10% of the time over a multiyear data window. The assessment season is identified as April through September. The new TSS standards were approved by EPA in January of 2015. For the purpose of this TMDL report, the newly adopted 65 mg/L standard for Class 2B waters will be used to address the turbidity impairment listings in the Yellow Medicine River Watershed.

Table 2.2: Lake water quality standards for lakes within the Yellow Medicine River Watershed

Ecoregion	Total Phosphorus Standard (µg/L)	Chlorophyll –a Standard (µg/L)	Secchi Depth (m)	Period of Time Standard Applies
NGP Shallow Lakes	**< 90**	**< 30**	**> 0.7**	**June 1 – September 30**
WCBP Shallow Lakes	**< 90**	**< 30**	**> 0.7**	**June 1 – September 30**

In addition to meeting phosphorus limits, chlorophyll-a and Secchi transparency standards must also be met. In developing the lake nutrient standards for Minnesota lakes (Minn. R. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (MPCA 2005). Clear relationships were established between the causal factor total phosphorus and the response variables chlorophyll-a and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the chlorophyll-a and Secchi standards will likewise be met.

3. Watershed and Waterbody Characterization

Located in southwestern Minnesota, the Yellow Medicine River Watershed covers approximately 707,000 acres in the WCBP and NGP ecoregions and drains portions of five counties (Lac qui Parle, Lincoln, Lyon, Redwood and Yellow Medicine). Granite Falls, Ivanhoe, Minneota, and Cottonwood are the largest towns in this largely rural watershed. Land use statistics of the Yellow Medicine River Watershed are shown in Section 3.4 in Table 3.3. For more information on the Yellow Medicine River Watershed, refer to the *Minnesota River - Granite Falls Watershed Monitoring and Assessment Report* (MPCA 2012d).

The western portion of the watershed lies within the NGP Ecoregion and consists mostly of the Prairie Coteau (French for slope or hill), which is a plateau that spans approximately 20,000 square miles and three states, running southeast to northwest across northwestern Iowa, southwestern Minnesota and eastern South Dakota. The plateau rises several hundred feet in elevation above the rest of the watershed and consists of rolling hills and thick glacial deposits. Several small lakes have formed in depressions between the hills. One of these lakes, Lake Shaokatan, is found in the headwaters of the Yellow Medicine River. The *Lake Shaokatan Phosphorus Total Maximum Daily Load Report* (MPCA 2012b) was written in 2012; therefore, Lake Shaokatan is not addressed in this TMDL report. Several other shallow lakes in this region form the headwaters for the various branches of the Yellow Medicine River.

Adjacent to the Coteau is the Prairie Escarpment, a relatively narrow band that runs northwest to southeast along the northern edge of the Coteau. The escarpment is a transition zone, which connects the Coteau with the WCBP Ecoregion. It has a relatively steep gradient and many of the streams straighten out and down cut as the elevation drops roughly 550 feet in approximately 10 miles.

Several branches of the Yellow Medicine River flow down off of the Prairie Escarpment into the WCBP Ecoregion. Just north of the town of Minneota the north and south branches join the Upper Yellow Medicine River, forming the main stem Yellow Medicine River. The river then flows through an area of gently rolling glacial till. Row crop agriculture, growing corn and soybeans, is the dominant land use in this middle section of the watershed. The hydrology of this area has been influenced by the historical tiling of wetlands and the ditching of both wetlands and streams for agricultural drainage. More recently there has been an increase in the number of acres that have been drained using pattern tiling, a practice that lays tile lines across the entire field and drains water from upland areas down into the tile outlet.

The last nine river miles, the Yellow Medicine River cuts rapidly and drops approximately 100 feet in elevation to the confluence with the Minnesota River. This section of the river has high river bluffs and bottomland hardwood forests adjacent to the river channel, with agricultural fields where possible. During high water levels this section of the river is a popular kayaking and paddling route and is one of the only rivers in southwest Minnesota that contains several Class I rapids.

3.1 Lakes

The impaired lakes addressed in the Yellow Medicine River Watershed TMDL are shallow, polymictic lakes in the NGP and WCBP ecoregions (Table 3.1).

Table 3.1: Morphometry and watershed area of lakes addressed in this TMDL report

Aggregated HUC12	Lake Name MN DNR Lake #	Surface Area (acres)	Average Depth (feet)	Max Depth (feet)	Lakeshed Area (acres)	Lakeshed Area : Surface Area Ratio	Littoral Area (%)
Judicial Ditch 10	**Lady Slipper Lake** 42-0020-00	262	4.6	9	1479	5.6 : 1	100
	Wood Lake 87-0030-00	484	6.2	8.5	6101	13 : 1	100
Judicial Ditch 17	**Cottonwood Lake** 42-0014-00	379	3.3	7.9	13002	34 : 1	100
North Branch Yellow Medicine River	**Steep Bank Lake** 41-0082-00	208	3.3	6.6	1794	8.6 : 1	100
South Branch Yellow Medicine River	**Lake Stay** 41-0034-00	220	3.3	6	6039	27.5 : 1	100
Upper Yellow Medicine River	**Perch Lake** 41-0067-00	227	4.9	8.9	838	3.7 : 1	100
Wood Lake Creek – MN River	**Curtis Lake** 87-0016-00	440	3.6	5.9	6061	13.8 : 1	100

3.2 Streams

Watershed areas of impaired stream reaches addressed in this TMDL report are listed in Table 3.2. These areas consist of all of the land that drains into the respective reach.

Table 3.2: Approximate watershed areas of impaired stream reaches

Aggregated HUC12	**Stream Name –** Reach Location Description	Assessment Unit ID #	Area (acres)
Hazel Creek	**County Ditch No. 9 –** Township 115N, Range 43W, Section. 33 to Minnesota River	07020004-536	49,993
Wood Lake Creek -	**Judicial Ditch 10 –** Wood Lake outlet to Minnesota River	07020004-547	45,971
Judicial Ditch 17	**Judicial Ditch 17 –** County Ditch 3 to Yellow Medicine River	07020004-622	39,782
Lower Yellow Medicine River	**Lower Yellow Medicine River –** South Branch Yellow Medicine River to Spring Creek	07020004-513	290,831
Mud Creek	**Mud Creek –** Headwaters to Township 114N, Range 43W, Section 35, South Line	07020004-543	37,461
South Branch Yellow Medicine River	**County Ditch 35 –** Headwaters to Yellow Medicine River	07020004-503	79,504
South Branch Yellow Medicine River	**Judicial Ditch 29 -** Township 111N, Range 44W, Section 16, South Line to South Branch Yellow Medicine River	07020004-550	17,951
South Branch Yellow Medicine River	**Unnamed Creek –** Township 112N, Range 44W, Section 20 to Township 113N, Range 43W, Section 35	07020004-595 07020004-597 07020004-599	8,625
	Unnamed Creek – County Ditch 24 to County Ditch 35	07020004-600	6,422
Spring Creek	**Spring Creek –** Headwaters to Yellow Medicine River	07020004-538	82,771
Stony Run Creek	**Stony Run Creek –** Township 116N, Range 40W, Section 30, West Line to Minnesota River	07020004-535	34,670
Upper Yellow Medicine River	**Unnamed Creek –** Township 113N, Range 43W, Section 20 to Township 113N, Range 43W, Section 9	07020004-545	22,527
	Yellow Medicine River – Headwaters to Mud Creek	07020004-584	163,060
Wood Lake Creek-MN River	**Boiling Spring Creek –** Township 114N, Range 37W, Section 20 west line to Minnesota River	07020004-555	23,326

3.3 Subwatersheds

Areas within the watershed have been grouped together by aggregating HUC12 watersheds into subwatershed areas. This was done in order to group together land area that drains into the individual branches and tributaries that flow into the Yellow Medicine River and direct tributaries of the Minnesota River. The beginning of the watershed consists of the South and North Branches, as well as the Upper branch of the Yellow Medicine River. After these three branches converge they are grouped together as the Lower Yellow Medicine River. Other main tributaries of the river include Mud Creek, Spring Creek, Hazel Creek, and Judicial Ditch 17. Tributary watersheds that flow directly into the Minnesota River are also included in this TMDL report and include Stony Run Creek, Stony Run Creek – Minnesota River, Judicial Ditch 10, Wood Lake Creek – Minnesota River, and Sacred Heart Creek – Minnesota River. See Figure 1.2.

3.4 Land Use

The land use for the entire watershed and aggregated HUC12 subwatersheds is summarized in Table 3.3 with the majority of the land being used for agricultural purposes.

Table 3.3: Approximate land use breakdowns of Yellow Medicine River Watershed HUC12 subwatersheds (MRLC 2011)

Aggregated HUC-12 Subwatershed	Open Water	Developed	Barren/ Mining	Forest/ Shrub	Pasture/ Hay/ Grassland	Cropland	Wetland
Yellow Medicine River Watershed	1.6 %	5.9 %	0.1 %	1.7 %	6.2 %	80.2 %	4.3 %
Hazel Creek- County Ditch No. 9	0.3 %	5.7 %	0.1 %	0.8 %	0.8 %	90.4 %	1.9 %
Judicial Ditch 10 - Wood Lake Creek	3.6 %	4.9 %	0.0 %	0.6 %	1.5 %	87.3 %	2.1 %
Judicial Ditch 17	1.4 %	7.2 %	0.1 %	0.2 %	0.2 %	89.3 %	1.6 %
Lower Yellow Medicine River	0.8 %	5.1 %	0.1 %	1.0 %	3.9 %	84.4 %	4.7 %
Mud Creek	0.5 %	4.8 %	0.2 %	0.4 %	10.2 %	76.3 %	7.6 %
North Branch Yellow Medicine River	1.0 %	4.7 %	0.1 %	1.1 %	22.4 %	67 %	3.7 %
Sacred Heart Creek – MN R	1.4 %	5.1 %	0.1 %	5.7 %	4.2 %	78.3 %	5.2 %
South Branch Yellow Medicine River	1.7 %	5.3 %	0.2 %	1.1 %	20.4 %	68.7 %	2.6 %
Spring Creek	0.5 %	4.7 %	0.2 %	0.2 %	1.0 %	86.8 %	6.6 %
Stony Run Creek	0.4 %	4.7 %	0.1 %	0.6 %	2.2 %	88.7 %	3.3 %
Stony Run Creek – MN R	2.5 %	6.9 %	0.3 %	2.4 %	8.5 %	73.2 %	6.2 %
Upper Yellow Medicine River	2.8 %	5.2 %	0.1 %	0.7 %	21.2 %	66.7 %	3.3 %
Wood Lake Creek – MN R	3.5 %	4.4 %	0.2 %	4.5 %	4.2 %	77.7 %	5.5 %

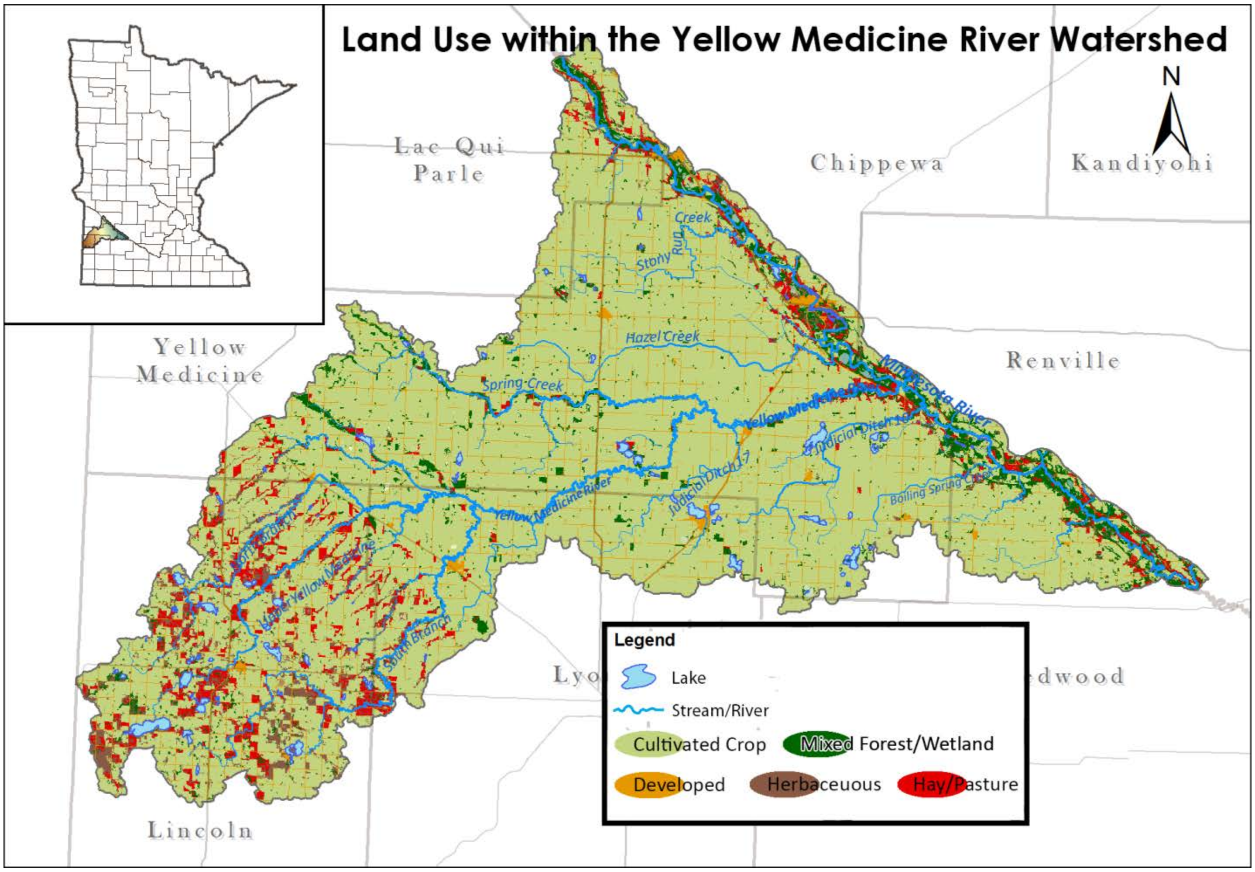

Figure 3.1: Land use of the Yellow Medicine River Watershed

3.5 Current/Historic Water Quality

A summary of current water quality is provided in this section related to the *E. coli* and turbidity (TSS) impairments addressed in this TMDL report. Additional water quality data and analysis for impaired stream reaches can be found in the *Minnesota River – Granite Falls Watershed Monitoring and Assessment Report* (MPCA 2012c) and the *Yellow Medicine River Watershed Biotic Stressor Identification Report* (MPCA 2012d).

3.5.1 Streams

3.5.1.1 *E. coli*

Bacteria data has been collected for multiple years in the Yellow Medicine River Watershed. The summarized data is presented in Table 3.4. Geometric means were calculated using the following equation:

$$Geometric\ mean = \sqrt[n]{x_1 * x_2 * \ldots . x_n}$$

Table 3.4: Summary of *E. coli* data from 2001-2011 for stream reaches impaired for *E. coli*. Red indicates exceedances of the *E. coli* standard as listed in Minn. R. 7050.0222, subp. 4

Aggregated HUC12 Reach AUID # EQuIS Station ID	**Range of data** (org/mL)	**% of samples exceeding 1260 org/100mL** [# of samples]	**Geometric Mean (org/mL)** [# of samples]						
			Apr	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**
Hazel Creek 07020004-536 S006-172	**58 - 921**	**0%**	-	-	**134.1** [5]	**88.5** [5]	**220.1** [5]	**182.1** [2]	-
JD 10 07020004-547 S006-161	**48 - 2420**	**June**: **20%** [5] **Aug**: **20%** [5]	-	-	**170.9** [5]	**147.8** [5]	**284.1** [5]	-	-
Judicial Ditch 17 07020004-622 S002-319	**20 - 1553**	**July**: **20%** [5] **Aug**: **20%** [5]	-	-	**137.8** [5]	**235.1** [5]	**543.2** [5]	**55.3** [2]	-
Lower Yell. Med. River 07020004-513 S002-317	**6.3 - 3784**	**June**: **40%** [5]	**23.3** [6]	**231.8** [3]	**661.9** [5]	-	-	**180.6** [3]	-
Mud Creek 07020004-543 S002-321	**16 - 770**	**0%**	-	-	**169.3** [5]	**216.3** [5]	**123.8** [5]	**205.4** [2]	-
So. Branch Yell. Med. River 07020004-550 S002-331	**1 – 2420**	**May**: **20%** [5] **June**: **20%** [5] **July**: **40%** [5] **Aug**: **17%** [6] **Sep**: 60% [5]	**8.21** [5]	**118.1** [5]	**476.3** [5]	**669.6** [5]	**274.9** [6]	**1158.7** [5]	**163.3** [5]
So. Branch Yell. Med. River	**1 – 2420**	**May**: **20%** [5] **June**: **40%** [5]	**6.0** [5]	**243** [5]	**639.3** [5]	**541.9** [5]	**130.3** [4]	**2420** [3]	**303.4** [5]

Aggregated HUC12 Reach AUID # EQuIS Station ID	Range of data (org/mL)	% of samples exceeding 1260 org/100mL [# of samples]	Geometric Mean (org/mL) [# of samples]						
			Apr	May	June	July	Aug	Sep	Oct
07020004-595 S005-684		**July**: 40% [5] **Sep**: 100% [3] **Oct**: 40% [5]							
So. Branch Yell. Med. River 07020004-597 S002-349	**1 – 2420**	**May**: 20% [5] **Sep**: 75% [4]	**2.5** [5]	**31.4** [5]	**120.1** [5]	**31.5** [5]	**235.1** [6]	**1142** [4]	**125.2** [5]
So. Branch Yell. Med. River 07020004-599 S002-326	**4 - 2420**	**June**: 40% [5] **July**: 40% [5] **Aug**: 50% [6] **Sep**: 80% [5] **Oct**: 40% [5]	**12.5** [5]	**260.2** [5]	**684.1** [5]	**935.6** [5]	**1073** [6]	**1994** [5]	**353.1** [5]
So. Branch Yell. Med. River 07020004-600 S002-334	**2.5 – 622.64**	**0%***	-	**15.9*** [4]	**161.4*** [5]	-	-	-	-
Spring Creek 07020004-538 S002-318	**1 - 2420**	**June**: 20% [5] **Sep**: 33% [3]	**8.2** [6]	**147.6** [3]	**484.8** [5]	-	-	**606.4** [3]	-
Wood Lake Creek – MN River 07020004-555 S004-345	**147 - 1300**	**Aug**: 20% [5]	-	-	**385.8** [5]	**357.2** [5]	**503.6** [5]	-	-

*Geometric mean calculated after converting fecal coliform bacteria using the 200CFU/100ml *E. coli* MPN/100ml

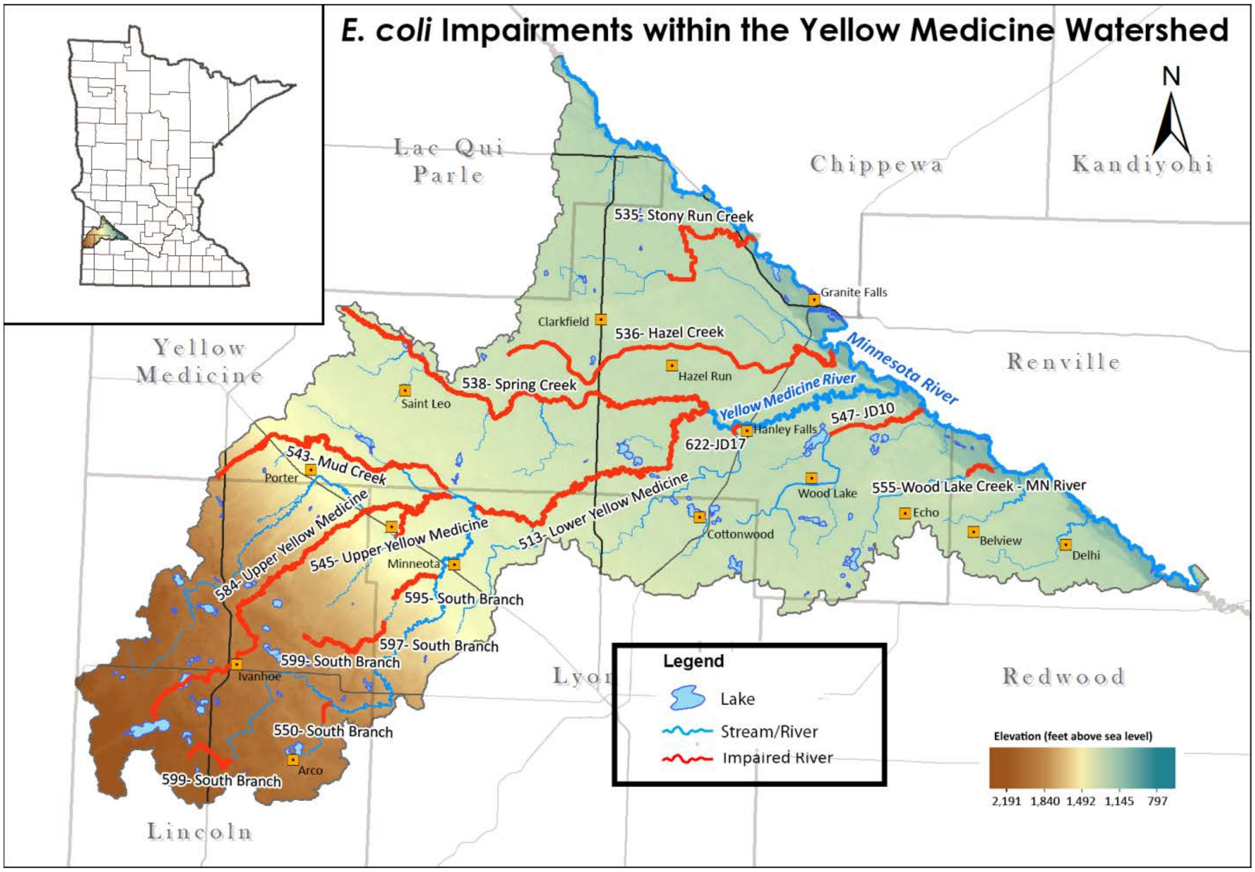

Figure 3.2: ***E. coli*** **stream reach impairments**

3.5.1.2 Turbidity

Transparency tube and turbidity data has been collected for multiple years in the Yellow Medicine River Watershed; the summarized data is presented in Table 3.5.

Table 3.5: Summary of TSS data from 2001-2008 for stream reaches impaired for turbidity/TSS. Red indicates exceedances of the TSS standard

Aggregated HUC12 Reach AUID # EQuIS Station ID	**Range of Data** (mg/L)	**% of Monthly Samples >65mg/L** [# of samples]						**% of Total Samples >65mg/L** [# of samples]
		Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	
Lower Yellow Medicine River 07020004-513 S002-317	**0.5 - 410**	**52%** [19]	**28%** [18]	**52%** [17]	**0%** [10]	**22%** [9]	**0%** [10]	**31%** [83]
South Branch Yellow Med River 07020004-503 S002-320	**0.5 - 354**	**32%** [19]	**22%** [18]	**44%** [18]	**10%** [10]	**20%** [10]	**0%** [10]	**25%** [85]
Upper Yellow Med River 07020004-584 S002-323	**0.29 - 550**	**40%** [20]	**28%** [18]	**44%** [18]	**0%** [10]	**22%** [9]	**20%** [10]	**29%** [85]

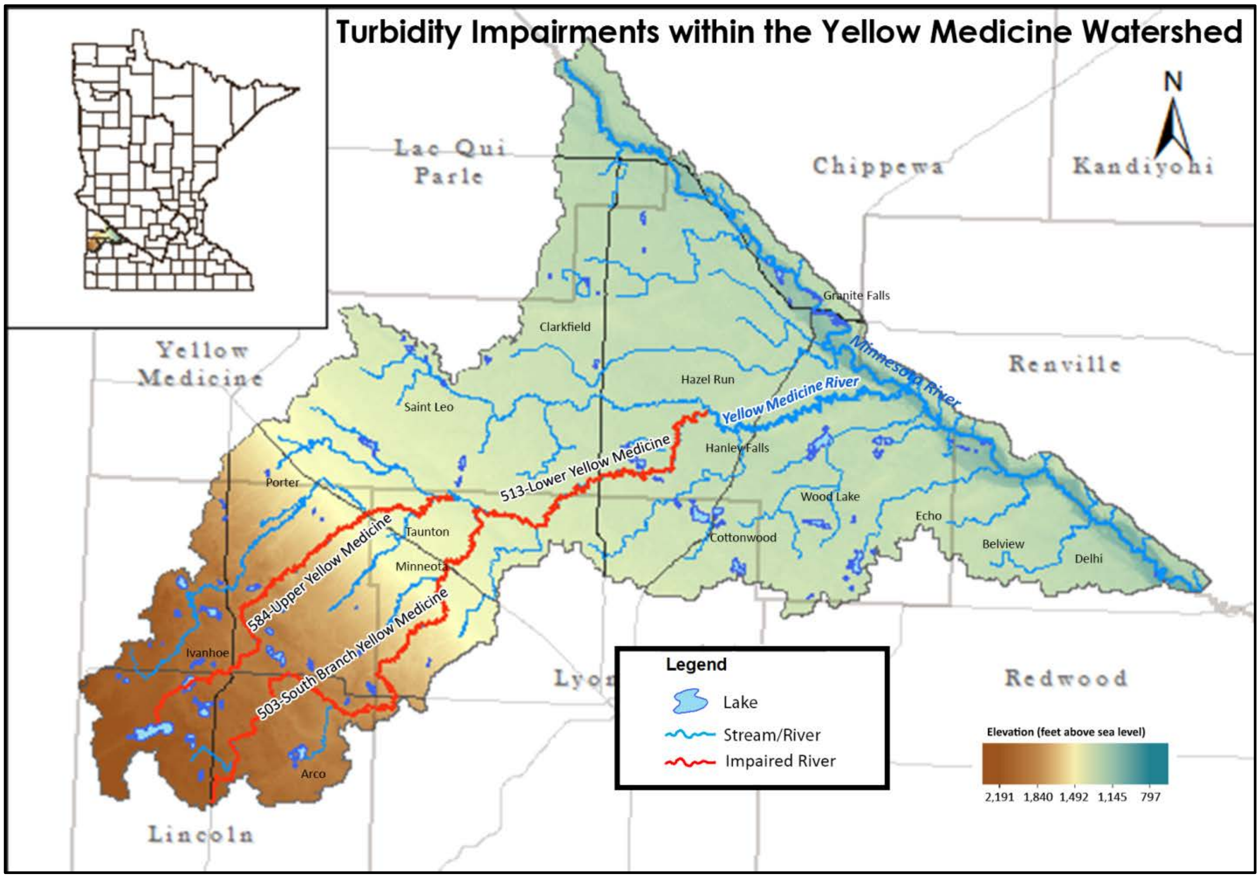

Figure 3.3: Turbidity stream reach impairments

3.5.2 Lakes

Current lake conditions are based on monitoring completed within the last 10 years. The summarized data presented in Table 3.6 indicates that the listed lakes have exceeded the nutrient eutrophication standard as listed in Minn. R. 7050.0222, subp. 4, and Table 2.2.

Table 3.6: Mean in-lake conditions for impaired lakes in the Yellow Medicine River Watershed. The number of samples taken June through September are listed in brackets

Lake Name – MN DNR #	Average Total Phosphorus (µg/L)	Average Chlorophyll-a (µg/L)	Average Secchi Disk Transparency (m)
Lady Slipper Lake – 42-0020-00	**174** [8]	**89.9** [8]	**0.5** [8]
Wood Lake –87-0030-00	**132** [8]	**50.2** [8]	**0.4** [7]
Cottonwood Lake – 42-0014-00	**165** [8]	**136.1** [8]	**0.6** [48]
Steep Bank Lake – 41-0082-00	**140** [8]	**55.5** [8]	**0.4** [8]
Lake Stay – 41-0034-00	**128** [8]	**30.3** [8]	**1.1** [8]
Perch Lake – 41-0067-00	**226** [8]	**52.5** [8]	**0.8** [8]
Curtis Lake – 87-0016-00	**302** [16]	**153.6** [16]	**0.2** [32]

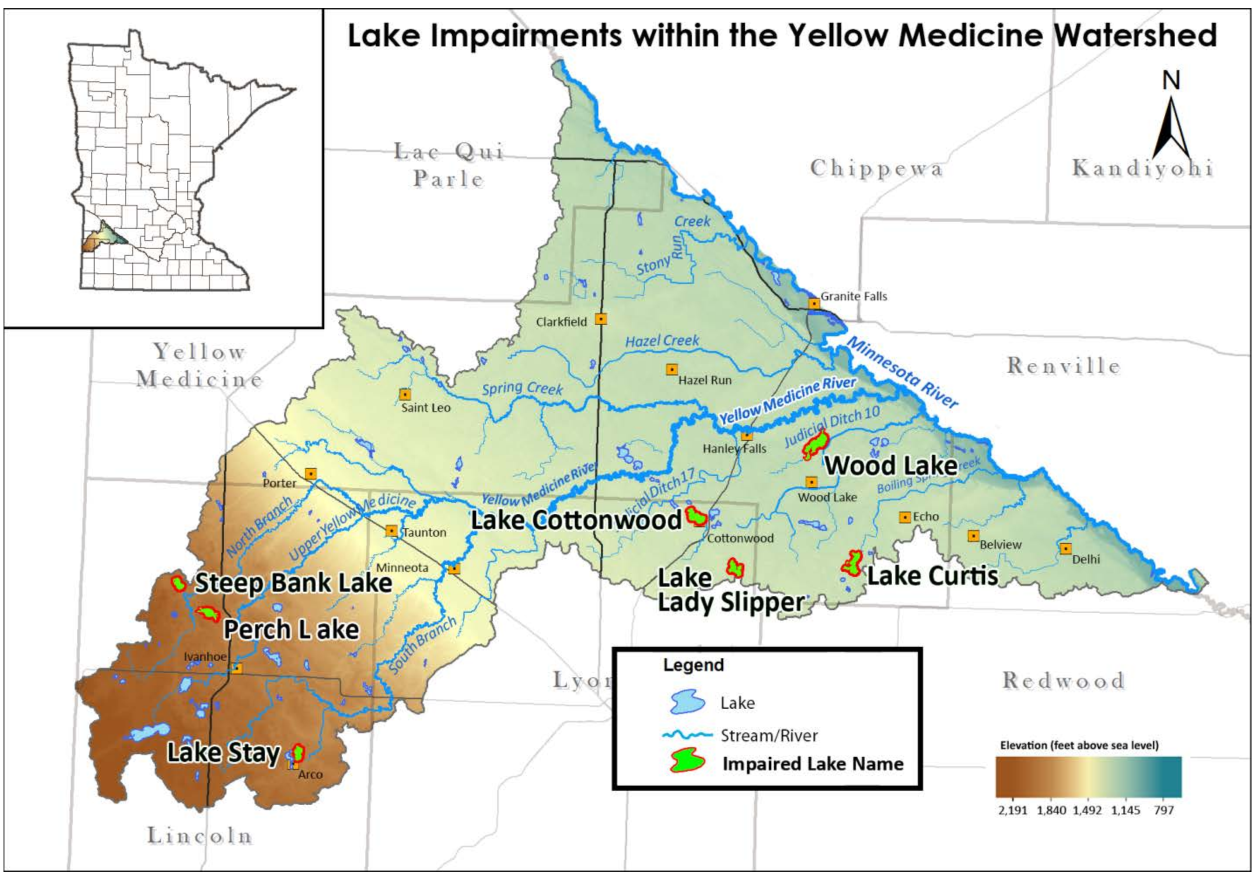

Figure 3.4: Lake nutrient eutrophication impairments as indicated from water monitoring data

3.6 Pollutant Source Summary

3.6.1 *E. coli*

Likely sources of bacteria in the Yellow Medicine River Watershed include feedlot facilities, wastewater treatment facilities (WWTF), subsurface sewage treatment systems (SSTS), livestock manure field application, pasture, natural reproduction, wildlife, and pets. These are described in more detail below. See Section 2.2 of the Yellow Medicine River WRAPS report for additional pollutant source assessments within the Yellow Medicine Watershed.

Feedlot Facilities – Feedlot facilities are present in the Yellow Medicine River Watershed. Livestock can contribute bacteria to the watershed through runoff from these feedlot facilities. In the Yellow Medicine Watershed there are 64 feedlots located within 1000 feet of a lake or 300 feet of a stream or river, an area generally defined as shoreland. Sixty of these feedlots in shoreland have open lots. Open lots present a potential pollution hazard if the runoff from the open lots is not treated prior to reaching surface water. Fourteen of the feedlots in shoreland are operating under an Open Lot Agreement (OLA) with the MPCA. These feedlot sites have been identified as actually having a potential pollution hazard and have or will install short term measures to minimize untreated manure runoff until permanent measures can be installed. Facility and livestock numbers by aggregated HUC12 watersheds, based on the MPCA record of registered feedlot facilities, are listed in Table 3.7. These numbers include both county permitted and NPDES permitted feedlot facilities, both of which are not allowed to discharge animal waste into surface waters. Manure from these feedlots is applied as fertilizer to agricultural fields and is discussed below.

Table 3.7: Number of feedlot facilities and animal units, by aggregated HUC12 subwatershed

Aggregated HUC12 Subwatershed	# of Feedlot Facilities	Livestock Type	Animal Units
Entire Yellow Medicine River Watershed with Direct Tributaries	642	Birds, Bovines, Deer/Elk, Goats/Sheep, Horses, Llamas/Alpacas, Pigs, Other	147,276
County Ditch No. 9 - Hazel Creek	33	Birds, Bovines, Goats/Sheep, Horses, Donkey/Mule, Llamas/Alpacas, Pigs	8,449
Judicial Ditch 10 - Wood Lake Creek	57	Birds, Bovines, Goats/Sheep, Horses, Donkey/Mule, Llamas/Alpacas, Pigs, Other	19,142
Judicial Ditch 17	27	Birds, Bovines, Goats/Sheep, Horses, Pigs	11,295
Lower Yellow Medicine River	63	Bovines, Deer/Elk, Horses, Pigs	22,038
Mud Creek	44	Birds, Bovines, Goats/Sheep, Horses, Pigs	9,479
North Branch Yellow Medicine River	69	Birds, Bovines, Deer/Elk, Goats/Sheep, Pigs	7,062
Sacred Heart Creek – MN River	14	Bovines, Pigs	4,706
South Branch Yellow Medicine River	105	Birds, Bovines, Pigs, Goats/Sheep, Horses	19,830
Spring Creek	85	Birds, Bovines, Donkey/Mule, Goats/Sheep, Horses, Pigs, Rabbit	16,018
Stony Run Creek	12	Birds, Bovines, Goats/Sheep, Horses, Pigs	3,109
Stony Run Creek – MN River	24	Birds, Bovines, Donkey/Mule, Goats/Sheep, Horses, Pigs	5,258
Upper Yellow Medicine River	90	Birds, Bovines, Deer/Elk, Goats/Sheep, Horses, Llamas/Alpacas, Pigs, Other	16,037
Wood Lake Creek – MN River	19	Birds, Bovines, Pigs	4,853

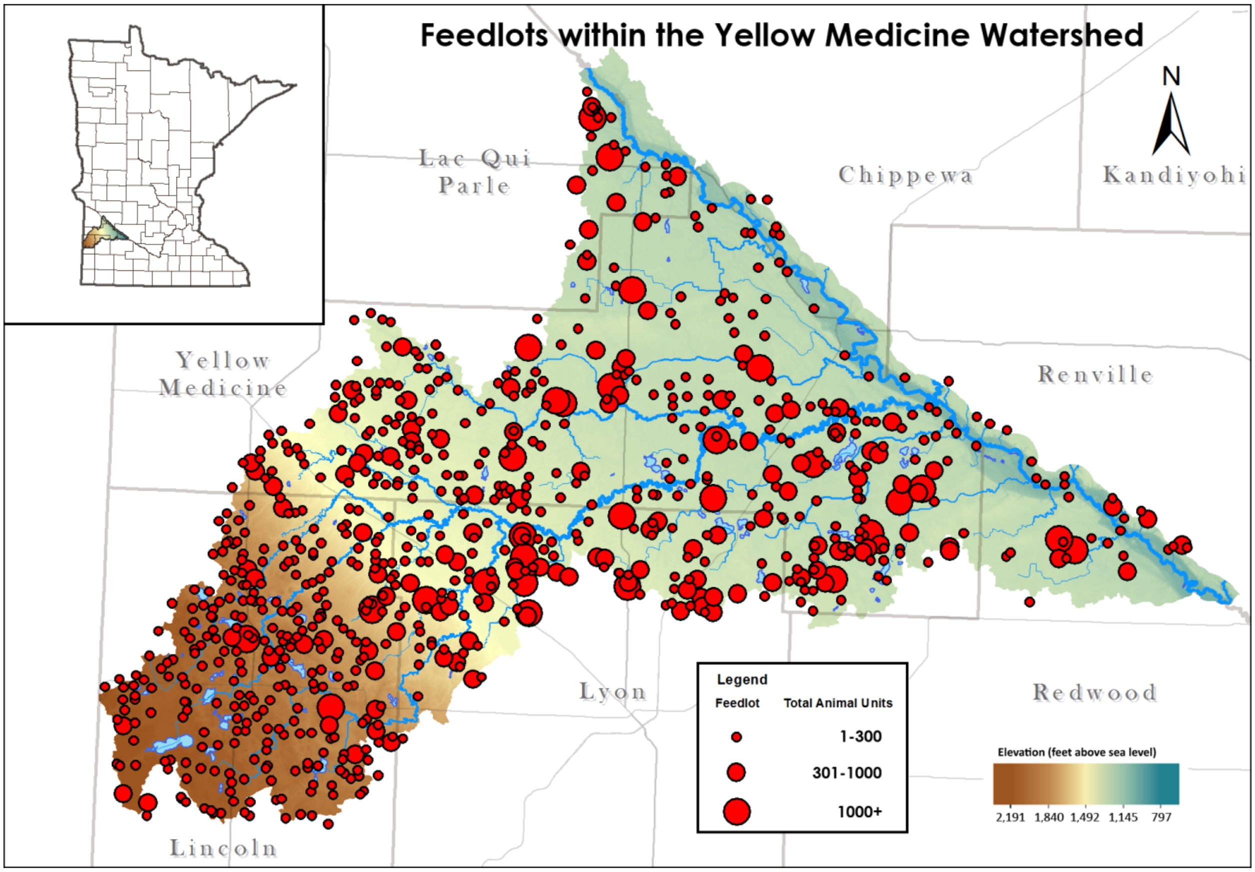

Figure 3.5: Feedlot facility locations of county permitted and state NPDES permitted facilities

Wastewater Treatment Facilities (WWTF) – Human waste can be a significant source of *E. coli* during low flow periods. Nine WWTFs discharge into the impaired stream reaches addressed in this TMDL report. All of these facilities have controlled discharge (pond) systems with discharge windows during higher flows. These controlled discharge facilities are not likely to be a source during low flow periods. Rarely, during extreme high flow conditions, WWTF may also be a source if they become overloaded and have an emergency discharge of partially or untreated sewage, known as a release.

SSTS – Without individual inspections it is difficult to know for certain the rate of compliance for septic systems in the watershed. Individual county estimates from the SSTS County Annual Reports for the Yellow Medicine River Watershed range from 35% to 62% non-compliant. These systems could potentially discharge inadequately treated wastewater into waterways and are a source, especially during low flow conditions.

Manure – Manure is a by-product of animal production and large numbers of animals create large quantities of manure. This manure is usually stockpiled and then spread over agricultural fields to help fertilize the soil. There is a significant amount of late winter solid manure application (before the ground thaws). During this time the manure can be a source of *E. coli* in rivers and streams, especially during precipitation events.

Pasture – Livestock can contribute bacteria to the watershed through runoff from poorly maintained pasture lands as well as direct loading if livestock are allowed access to streams or lakes.

Natural Reproduction – *E. coli* bacteria may have the ability to reproduce naturally in water and sediment. Two Minnesota studies describe the presence and growth of "naturalized" or "indigenous" strains of *E. coli* in watershed soils (Ishii et al. 2006) and ditch sediment and water (Sadowsky et al. 2010). The latter study was conducted in the agriculturally-dominated Seven Mile Creek Watershed located in south-central Minnesota. As much as 36% of *E. coli* strains found in the Seven Mile study was represented by multiple isolates, suggesting persistence of specific *E. coli*. While the primary author of the study suggests 36% might be used as a rough indicator of "background" levels of bacteria during this study, this percentage is not directly transferable to the concentration and count data of *E. coli* used in water quality standards and TMDLs. Additionally, because the study is not definitive as to the ultimate origins of the bacteria, it would not be appropriate to consider it as "natural" background (MPCA 2012a). Caution should be used before extrapolating the results of the Seven Mile Creek study to other watersheds.

Wildlife/Pets – *E. coli* bacteria comes from the digestive tracts of mammals and birds and as such, some *E. coli* may be present in the water from these sources.

3.6.2 Turbidity (TSS)

Likely sources of turbidity (TSS) in the Yellow Medicine River Watershed include overland erosion from land practices and hydrologic changes within the watershed. These are described in more detail below. See Section 2.2 of the Yellow Medicine River WRAPS report for additional pollutant source assessments within the Yellow Medicine Watershed.

Wastewater Treatment Facilities (WWTF) – Human waste can be a source of TSS. Five WWTFs discharge into the impaired stream reaches addressed in this TMDL report. All of these facilities have controlled discharge (pond) systems with discharge windows during higher flows. These controlled discharge facilities are not likely to be a source during low flow periods. Rarely, during extreme high flow conditions, WWTF may also be a source if they become overloaded and have an emergency discharge of partially or untreated sewage, known as a release.

Overland Erosion – High turbidity (TSS) can occur when heavy rains fall on unprotected soils, dislodging the soil particles which are then transported by surface runoff into the rivers and streams (MPCA and MSUM 2009). First order streams, ephemeral streams, and gullies are typically higher up in the watershed and can flow intermittently, which makes them highly susceptible to disturbance. These sensitive areas have a very high erosion potential, which can be exacerbated by farming practices. According to Pierce, "In low-lying areas amenable to extensive row-cropping, forests and perennial grasslands are replaced with annual crops, leaving the land unvegetated (sic) for much of the year. It is well established that removal of vegetation leads to erosion, particularly when followed by recurring conventional tillage" (Pierce 2012). The majority of unprotected soil in the watershed is on agricultural fields, but a percentage every year is unprotected for a variety of reasons, such as construction, mining, or insufficiently vegetated pastures.

Hydrologic Changes – Hydrological changes in the landscape such as subsurface drainage tiling, channelization of waterways, riparian land cover alteration, and increases in impervious surfaces can all lead to increased turbidity (TSS). There are several different ways that changing the hydrology of the watershed can affect water quality. Draining and tiling wetlands decreases water storage on the landscape. Wetlands often form in low areas where the landscape, soils, or a combination of both create an area where water collects. When a wetland is drained, water is moved off of the land at a higher velocity and in a shorter amount of time. The straightening and ditching of natural rivers, both for agricultural drainage or diversions around cities, increases the slope of the original watercourse and also moves water off of the land at a higher velocity and in a shorter amount of time. Changes to the way water moves through a watershed and how it makes its way into the river can lead to increases in water velocity, scouring of the river channel, and increased erosion of the river banks (Schottler et al. 2012) and ravines. Ravine contributions occur in locations where a flow path drops elevation drastically. The natural erosion rates of many ravines are exponentially increased as the amount of water traveling down the ravine is increased due to a drainage outlet discharging at the top a ravine. Figure 3.7 shows the altered hydrology within the Yellow Medicine River Watershed. Velocity changes associated with stormwater systems/drainage ditches are modeled in HSPF by partitioning runoff to surface runoff (rather than shallow or deeper groundwater) based on land use and impervious to pervious area. The surface runoff from an impervious area will arrive at the receiving waterbody sooner than shallow and deeper groundwater from pervious areas. The effects of ditching are captured in HSPF through GIS analysis during model framework development. A spatial analysis calculates the average distance from all the land area in a particular land category to the receiving waterbody. The presence of ditches reduces the average length of the overland flow plane for a land category. Therefore, the presence of ditches reduces the time it takes for watershed runoff to arrive at the receiving waterbody. The effects of agricultural tiling is modeled by shallow groundwater/interflow arriving at the receiving waterbody sooner that deeper groundwater/baseflow.

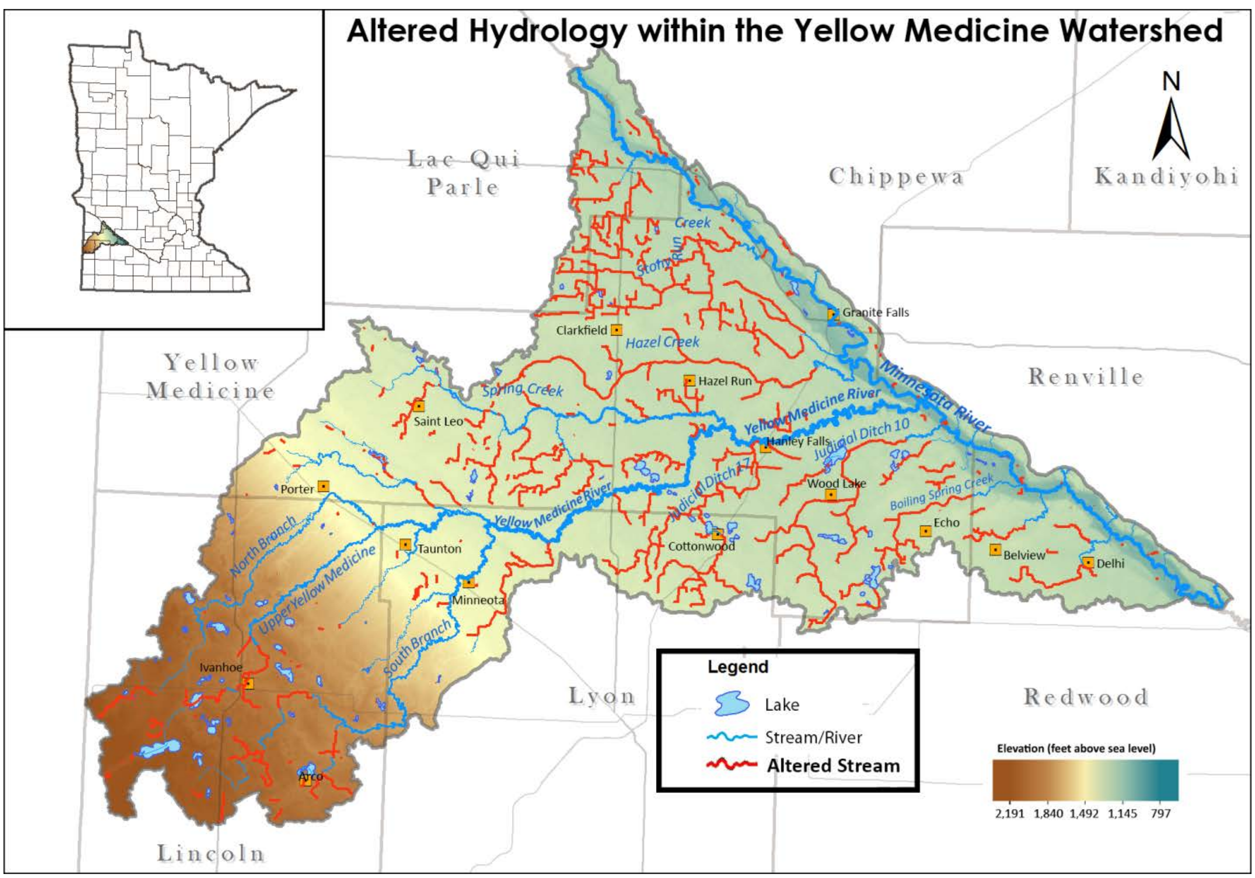

Figure 3.6: Altered hydrology of Yellow Medicine River Watershed

3.6.3 Nutrient Eutrophication

Phosphorus source categories as well as runoff and phosphorus loads were extracted from the Yellow Medicine River Watershed HSPF model. Likely sources of phosphorus in surface water of the Yellow Medicine River Watershed include atmospheric load, SSTS, manure application on agricultural fields, upland erosion, fertilizer application, stream bank erosion, and internal loading. The pathways for pollutants to make their way into surface water include: overland and in-channel erosion, direct precipitation, open tile in-takes, and tile lines. These are described in more detail below. See Section 2.2 of the Yellow Medicine River WRAPS report for additional pollutant source assessments within the Yellow Medicine Watershed.

Atmospheric Load – Direct atmospheric deposition to the surface of the lakes was based on regional values (MPCA 2004b). Sources of particulate phosphorus in the atmosphere may include pollen, soil erosion, oil and coal combustion and fertilizers. The atmospheric export coefficient used in the model was 0.3 kg/ha.

SSTS –The compliance rate of septic systems cannot be determined without individual inspections. Individual County estimates from the SSTS County Annual Reports for the Yellow Medicine River Watershed range from 35% to 62% non-compliant. Phosphorus loads from SSTS were applied to the lake models using estimates from the HSPF model. The estimates of phosphorus load and the percent that SSTS contributes out of the total external load coming in to the lake are shown in Table 3.8.

Table 3.8: Estimate of phosphorus load and the percent contribution from SSTS

Lake Name	Estimate of Phosphorus Delivered via SSTS (lbs/yr)	Total of External Phosphorus Load (%)
Lady Slipper Lake	5.95	1.8
Wood Lake	27.5	2.2
Cottonwood Lake	62.6	1.6
Steep Bank Lake	6.2	1.4
Lake Stay	22.5	1.3
Perch Lake	2.6	1.3
Curtis Lake	25.1	1.6

Manure Application – Runoff from livestock manure application in fields for fertilizer is most likely a significant source of nutrients. There is a significant amount of late winter solid manure application (before the ground thaws). During this time the manure can be a source of phosphorus in lakes, especially during precipitation events. High intensity precipitation often occurs during the spring, which can cause erosion of both the soil and manure.

Upland Erosion – Gullies and ephemeral streams are typically higher upstream in the watershed and can flow intermittently, which makes them highly susceptible to disturbance. These sensitive areas have a very high erosion potential, which can be magnified by some farming practices. The majority of unprotected soil in the watershed is on agricultural fields, and contains phosphorus.

Fertilizer Application – During precipitation events, runoff from fields can contain nutrients from applied fertilizer. Runoff can make its way through a network of drainage tile, into open tile intakes, and eventually into surface waters.

Stream Bank Erosion – The increase in both the velocity and amount of water by drainage, channel widening, and channel straightening can increase flows, which increases stream energy. This energy can cause loading of sediment through streambank erosion. The phosphorus ions can be attached to this sediment and can excessively load waterbodies. The removal of vegetation and buffers along the stream can also increase erosion and streambank instability.

Internal Load – Under anoxic conditions, weak iron-phosphorus bonds break, releasing phosphorus in a highly available form for algal uptake. Carp and other rough fish present in lakes can lead to increased nutrients in the water column as they uproot aquatic macrophytes during feeding and spawning and re-suspend bottom sediments. Over-abundance of aquatic plants can limit recreation activities and invasive aquatic species, such as curly-leaf pondweed, can change the dynamics of internal phosphorus loading. Historical impacts, such as WWTF effluent discharge, can also affect internal phosphorus loading. The nutrient retention models within the BATHTUB framework already account for nutrient recycling. However, additional internal load was added to the lake models ranging from 0.0 (Stay Lake) – 2.91 (Perch Lake) $mg*m^{-2}*day^{-1}$ to bring predicted phosphorus concentrations more in line with the observed. Ideally, independent measurements of internal load would be available to verify the use of additional internal loading. Such data is not available for the impaired Yellow Medicine lakes. However, these internal loading values do fall within the range reported in the literature (Nürnberg 1984; Hoverson 2008). Despite the uncertainty as to the exact contribution internal loading has on phosphorus concentrations in the impaired Yellow Medicine lakes, internal processes are likely a significant source of phosphorus loading and should be addressed in a lake management plan.

Overland Erosion/Open Tile Intakes/Tile Lines – During some precipitation events, erosion can deliver phosphorus into surface waters. Phosphorus attached to soil particles and dissolved in water moves overland, which can directly discharge into surface waters or into open tile inlets and move through tile lines that discharge into surface waters.

The total external loads coming into the lakes from different land use sources were estimated using HSPF for the entire Yellow Medicine River Watershed and the percent that each land use source contributes out of the total external load are listed in Table 3.9.

Table 3.9: Land cover categories, ranges of relative coverage, and P load contribution in the lake catchments

Land Use Source	Description	% Area In Lake Catchments*	External Phosphorus Load (%)
Forest	Runoff from forested land can include decomposing vegetation and organic soils.	**<1 - 1**	**< 1**
Cropland (Conventional and Conservation Tillage)	Runoff from agricultural lands can include applied manure, fertilizers, soil particles and organic material from agronomic crops.	**63 - 89**	**84 - 95**
Grassland/Pasture	Surface runoff can deliver phosphorus from vegetation, livestock and wildlife waste, and soil loss.	**<1 - 26**	**< 1 - 9**
Developed (Pervious and Impervious)	Runoff from residences and impervious surfaces can include fertilizer, leaf and grass litter, pet waste and numerous other sources of phosphorus.	**4 - 10**	**2 - 8**
Wetlands/ Open Water	Wetlands and open water can export phosphorus through suspended solids as well as organic debris that flow through waterways.	**2 - 14**	**< 1 - 1**

*Catchment area does not include area of the lake itself.

Potential point source contributions include construction and industrial stormwater, industrial process wastewater, and WWTF. Construction and industrial stormwater are accounted for in the model through the "Developed" land use phosphorus delivery coefficient as described above. There are no industrial process wastewater discharges or WWTF discharges in the lake watersheds.

4 TMDL Development

A TMDL for a waterbody that is impaired as a result of excessive loading of a particular pollutant can be described by the following equation:

$$\text{TMDL} = \text{LC} = \sum\text{WLA} + \sum\text{LA} + \text{MOS} + \text{RC}$$

Where:

LC = loading capacity, or the greatest pollutant load a waterbody can receive without violating water quality standards;
WLA = wasteload allocation; the portion of the TMDL allocated to existing or future permitted point sources of the relevant pollutant;
LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources of the relevant pollutant;
MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The MOS can be provided implicitly through analytical assumptions or

explicitly by reserving a portion of loading capacity (EPA 1999).
RC = reserve capacity, an allocation of future growth. This is an MPCA-required element, if applicable. Not applicable in this TMDL.

Per Code of Federal Regulations (40CFR 130.2(1)), TMDLs can be expressed in terms of mass per time, toxicity or other appropriate measures. For the Yellow Medicine River Watershed impairments addressed in this TMDL report, the TMDLs, allocations and margins of safety are expressed in mass/day. Each of the TMDL components is discussed in greater detail below.

4.1 Data Sources

4.1.1 Hydrologic Simulation Program – FORTRAN (HSPF)

The HSPF model was used to simulate dissolved oxygen, phosphorus, and flow in the Yellow Medicine River Watershed; this output was used for analysis and TMDL calculations.

The HSPF model is a comprehensive package for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants. The HSPF model incorporates watershed-scale Agricultural Runoff Model (ARM) and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at the outlet of any subwatershed.

The HSPF watershed model contains components to address runoff and constituent loading from pervious and impervious land surfaces, and flow of water and transport/transformation of chemical constituents in stream reaches. Primary external forcing is provided by the specification of meteorological time series. The model operates on a lumped basis within subwatersheds. Upland responses within a subwatershed are simulated on a per-acre basis and converted to net loads on linkage to stream reaches. Within each subwatershed, the upland areas are separated into multiple land use categories.

4.1.2 Environmental Quality Information System (EQuIS)

The MPCA uses a system called EQuIS to store water quality data from more than 17,000 sampling locations across the state. The EQuIS contains information from Minnesota streams and lakes dating back to 1926.

All discreet water quality sampling data utilized for assessments and data analysis for this TMDL report are stored in this accessible database: *Environmental Data Access* (MPCA 2014c).

4.2 Loading Capacity Methodology

The load duration curve method is based on an analysis that encompasses the cumulative frequency of historic flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables of this report (Tables 4.10 – 4.12) mid-points of the five designated flow zones of the entire loading capacity curve are depicted. However, it should be understood that the entire curve represents the TMDL and is what is ultimately approved by the Environmental Protection Agency (EPA).

4.2.1 Streams, *E. coli*

The duration curve approach (EPA 2007) was utilized to address the *E. coli* impairments. A flow duration curve was developed using April through October, 1996 through 2012 daily average flow data provided by the Yellow Medicine River/Hawk Creek Watershed HSPF model. All zero flows estimated from the HSPF model were converted to 0.01 cfs due to the inability of load duration curves to plot zero flows and zero loads. At or below 0.03 billion org/day on the duration curve the stream is considered dry. Flow zones were determined for very high, high, mid, low and very low flow conditions. The mid-point flow value for each flow zone was then multiplied by the standard of 126 org/100ml to calculate the loading capacity. For example, for the "very high flow" zone, the LC is based on the flow value at the 5th percentile. The conversion factors used to compute a flow value and pollutant sample value into a load are shown in Table 4.1. Computed load duration curve graphs are shown in Appendix A.

Table 4.1: Unit conversion factors used for *E. coli* load calculations

Load (billion/day) = Flow (cfs) * Concentration (126 organisms/100 ml) * Conversion Factor						
1	Start with Flow				=	ft^3/sec
2	Multiply by **28,316.8** ml/ft^3 to convert	ft^3	→	ml	ft^3	ml/sec
3	Multiply by **#** organisms (Standard set at 126 MPN/100ml)				=	organisms/sec
4	Divide by **100** ml					
5	Multiply by **60** sec/min to convert	seconds	→	minutes	=	organisms/min
6	Multiply by **60** min/hr to convert	minutes	→	hours	=	organisms/hour
7	Multiply by **24** hours/day to convert	hours	→	days	=	organisms/day
8	Divide by **1 Billion** to convert	organisms	→	billion organisms	=	billion organisms/day

Table 4.10 shows LAs for stream reaches impaired for *E. coli*. Mid-points of the five designated flow zones of the entire loading capacity curve are depicted. However, it should be understood that the components of the TMDL equation could be illustrated for any point on the entire curve. The load duration curve method can be used to display collected *E. coli* monitoring data and allows for estimation of load reductions necessary for attainment of the *E. coli* water quality standard. Load duration curves for the *E. coli* impaired stream reaches are contained in Appendix A.

Estimated reductions for each of the bacteria impaired stream reaches are presented in Table 4.2. Reduction values were computed using a load duration curve and collected *E. coli* sample data for each impaired reach. The above conversion shown in Table 4.1 was used to compute loads for days when samples were taken. The sample concentration (CFU/100mL) was converted into a load (billion organisms per day) using the daily average flow value for that day and inserting the sample concentration values into Step 3 in Table 4.1. These actual observed load values were then summed up for all days samples were collected. This observed load, calculated from actual monitoring data, was then compared to the load if the water sample concentration was equivalent to the water quality standard. The process is described further below.

Observed Load

The sample concentration (CFU/100mL) was converted into a load (billion org per day) using the daily average flow value for that day and inserting the collected sample concentration values into Step 3 in Table 4.1. These actual load values were then summed up for all sample days.

Load at Water Quality Standard

The load value of the concentration of the water met the *E. coli* standard (126 cfu/100ml) was computed using the daily average flow value for the same sample days and multiplying that value through the steps in Table 4.1 using the *E. coli* standard value of 126 cfu/100ml in Step 3. These standard load values were then summed up for all the days a sample was collected and represent the total maximum load that the river is able to take and still meet the water quality standards for the flows on those dates.

Percent Reduction

The sum of the observed loads was compared to the sum of the water quality standard loads. The percent difference is used for the estimated percent reduction values.

Table 4.2: Percent reductions for *E. coli* impaired stream reaches based on 2002-2011 monitoring data

Aggregated HUC12 Subwatershed Stream Reach AUID #	**Observed Load** (billion org) [# of samples]	**Load Set at 126 org /100mL Standard** (billion org)	**Estimated Reduction Needed To Get < 126 org/100 mL**
Hazel Creek- County Ditch No. 9 07020004-536	**4,663** [18]	**2,529**	**46%**
Wood Lake Creek – Judicial Ditch 10 07020004-547	**2,938** [15]	**769**	**74%**
Judicial Ditch 17 07020004-622	**2,940** [17]	**2,322**	**21%**
Lower Yellow Medicine River 07020004-513	**242,884** [17]	**44,803**	**82%**
Mud Creek 07020004-543	**5,903** [17]	**2,830**	**52%**
South Branch Yellow Medicine River 07020004-503	**1,284,040** [189]	**81,784**	**94%**
South Branch Yellow Medicine River 07020004-550	**55,845** [36]	**3,873**	**93%**
South Branch Yellow Medicine River 07020004-595 07020004-597 07020004-599	**59,047** [103]	**10,494**	**82%**
South Branch Yellow Medicine River 07020004-600	**4,629** [10]	**1,394**	**70%**
Spring Creek 07020004-538	**32,256** [17]	**14,617**	**55%**
Stony Run Creek 07020004-535	**4,388** [17]	**1,888**	**57%**
Upper Yellow Medicine River 07020004-545	**19,711** [17]	**2227**	**89%**
Upper Yellow Medicine River 07020004-584	**76,441** [51]	**18,866**	**75%**
Wood Lake Creek – MN River 07020004-555	**1,110** [15]	**294**	**74%**

The resulting reduction percentage is only intended as a rough approximation. Reduction percentages are not a required element of a TMDL (and do not supersede the allocations provided), but are included here to provide a starting point to assess the magnitude of the effort needed in the watershed to achieve the standard.

4.2.2 Streams, Turbidity (TSS)

The duration curve approach (EPA 2007) was utilized to address turbidity impairments. For reasons explained in Section 2, the current southern streams region total suspended solids (TSS) standard of 65mg/L was chosen to develop the TMDL. A flow duration curve was developed using April through September, 1996 through 2012 daily average flow data provided by the Yellow Medicine River/Hawk Creek Watershed HSPF model. All zero flows estimated from the HSPF model were converted to 0.01 cfs due to the inability of load duration curves to plot zero flows and zero loads. At or below 0.0017485 tons TSS/day on the duration curve the stream is considered dry. Flow zones were determined for very high, high, mid, low and very low flow conditions. The mid-point flow value for each flow zone was then multiplied by the TSS southern streams standard of 65 mg/L to calculate the loading capacity. For example, for the "very high flow" zone, the LC is based on the flow value at the 5th percentile. The conversion factors used to compute a flow value and pollutant sample value into a load are shown in Table 4.3. Computed load duration curve graphs are shown in the Appendix A.

Table 4.3: Unit conversion factors used for TSS load calculations

Load (tons/day) = Concentration (mg/1000mL) * Flow (cfs) * Factor						
1	Start with Flow				=	ft^3/sec
2	Multiply by **28,316.8** ml/ft^3 to convert	ft^3	→	ml	=	ml/sec
3	Multiply by **#** mg (Standard set at 65 mg/L)				=	mg/sec
4	Divide by **1000** ml					
5	Divide by **453,592** mg/lb to convert	mg	→	lbs	=	lbs/sec
6	Multiply by **60** sec/min to convert	seconds	→	minutes	=	lbs/min
7	Multiply by **60** min/hr to convert	minutes	→	hours	=	lbs/hour
8	Multiply by **24** hours/day to convert	hours	→	days	=	lbs/day
9	Divide by **2000** lbs/ton to convert	lbs	→	tons	=	tons/day

Table 4.11 shows LAs for TSS for stream reaches impaired for turbidity (TSS). Mid-points of the five designated flow zones of the entire loading capacity curve are depicted. However, it should be understood that the components of the TMDL equation could be illustrated for any point on the entire curve. The load duration curve method can be used to display collected TSS monitoring data and allows for estimation of load reductions necessary for attainment of the TSS water quality standard. Load duration curves for the turbidity (TSS) impaired stream reaches are contained in Appendix A.

Estimated reductions for each of the turbidity (TSS) impaired stream reaches are presented in Table 4.4. Reduction values were computed using a load duration curve and collected TSS sample data for each impaired reach. The above conversion shown in Table 4.3 was used to compute loads for days when samples were collected. The sample concentration (mg/L) was converted into a load (tons per day) using the daily average flow value for that day and inserting the sample concentration values into Step 3 in Table 4.3. These actual observed load values were then summed up for all days samples were collected. This observed load, calculated from actual monitoring data, was then compared to the load if the water sample concentration was equivalent to the water quality standard. The process is described further below.

Observed Load

The sample concentration (mg/L) was converted into a load (tons per day) using the daily average flow value for that day and inserting the collected sample concentration values into Step 3 in Table 4.3. These actual load values were then summed up for all sample days.

Load at Water Quality Standard

The load value of the concentration of the water met the TSS standard (65 mg/L) was computed using the daily average flow value for the same sample days and multiplying that value through the steps in Table 4.3 using the TSS standard value of 65 mg/L in Step 3. These standard load values were then summed up for all the days a sample was collected and represent the total maximum load that the river is able to take and still meet the water quality standards for the flow values on those dates.

Percent Reduction

The sum of the observed loads was compared to the sum of the standard loads. The percent difference is used for the estimated percent reduction values.

Table 4.4: Percent reductions for turbidity (TSS) impaired stream reaches based on 2002-2011 TSS data

Aggregated HUC12 Subwatershed Stream Reach AUID #	**Observed Load (Tons TSS)** [# of samples]	**Load Set at 65 mg/L Standard** (Tons TSS)	**Estimated Reduction Needed To Get < 65 mg/L**
Lower Yellow Medicine River 07020004-513	**9,330.3** [83]	**4,668.3**	**50%**
South Branch Yellow Medicine River 07020004-503	**2,439.4** [85]	**1,338.4**	**45%**
Upper Yellow Medicine River 07020004-584	**3,309.2** [85]	**1,591.7**	**52%**

The resulting reduction percentage is only intended as a rough approximation. Reduction percentages are not a required element of a TMDL (and do not supersede the allocations provided), but are included here to provide a starting point to assess the magnitude of the effort needed in the watershed to achieve the standard.

4.2.3 Lakes, Nutrient Eutrophication

The BATHTUB (version 6.14; Walker 1999) model framework was used to model phosphorus and water balance for lakes within the Yellow Medicine River Watershed. Data used to develop the model framework included: precipitation, evaporation, lake morphometry, lake water quality, animal units, watershed area, land use, flow and water quality, septic systems and NPDES dischargers. For more detail on the Yellow Medicine sources of model data, refer to the *Yellow Medicine River Watershed Monitoring and Assessment Report* (MPCA 2012d).

BATHTUB's first order decay and Canfield Bachmann lakes models were used to estimate loads to the impaired lakes. Six of the seven lakes required using an additional internal loading estimate ranging between 0.39 – 2.91 $mg*m^{-2}*day^{-1}$ to approximate the average in-lake phosphorus concentration (Table 4.5). The nutrient sedimentation models in BATHTUB have been empirically calibrated, so the effects of internal phosphorus loading from sediments are accounted for in the model parameter values (Walker 1999). As such, the model does not explicitly provide an estimate of the internal load. However, in the Yellow Medicine Watershed, several lakes required additional internal loading for the predicted in-lake phosphorus concentrations to match the average phosphorus concentrations based on water quality samples. The additional internal load is shown in column 6 of Table 4.5. It is important to remember this does not represent the entire internal load; rather it is the additional internal P load required for the modeled predictions to match the average conditions. Internal load tends to be a significant source of phosphorus to lakes in the Yellow Medicine Watershed and in-lake efforts will be important to achieve water quality standards. However, any improvements to water quality derived from in-lake efforts will be temporary if external sources are not better controlled so as to reduce the build-up of internal phosphorus.

To calculate the phosphorus load capacity of each lake, phosphorus loads were reduced within the model until the predicted in-lake concentration matched the appropriate standard (columns 4-6 in Table 4.5). This was achieved by reducing total phosphorus concentrations from land use categories that exceeded the river/stream eutrophication standards down to the applicable concentration standard (150 µg/L). The land use categories most often affected by these adjustments were cropland and developed land. In addition, contribution from septic systems was reduced to zero. In cases where reducing the total phosphorus concentrations from the contributing landscape and setting the load from septic systems to zero was not sufficient to meet the lake water quality standard, the internal load was reduced. For Curtis Lake, removing all of the additional internal load was still not sufficient for the lake to achieve the water quality standard so the phosphorus concentration coming off of cropland was reduced further to 132 µg/L. Using the modeled annual loads and the annual load capacities, the load reductions were calculated (column 8 in Table 4.5). Modeled lake loading capacity summaries are shown in Table 4.5.

Table 4.5: Average and modeled mean phosphorus conditions in Yellow Medicine River Watershed lakes; phosphorus load reduction necessary to meet the water quality standard

Lake Name and HSPF Model Segment	Observed Average Total P (µg/L)	Modeled Total P (µg/L)	Total P Standard (µg/L)	Modeled Annual Phosphorus Load (lbs/yr)	Additional Annual Internal Phosphorus Load (lbs/yr)	Modeled Annual Phosphorus Load Capacity (lbs/yr)	Load Reduction to Achieve TP Standard (%)
Lady Slipper - 151	174	174	90	1,656.1	1,280	520.7	69
Wood - 153	132	132	90	3,086.7	1,830	1,650.6	46
Cottonwood - 103	165	165	90	4,437.4	486	2,022	54
Steep Bank - 117	140	140	90	761	310	367	52
Stay - 108	128	128	90	1,662.5	0	1,053	37
Perch - 113	226	226	90	2,354.5	2,155	436.5	81.5
Curtis - 140	302	302	90	2,336	759	695	70

4.3 Wasteload Allocation Methodology

The WLAs are calculated in accordance with EPA guidance (EPA 2002) and presented as categorical WLAs. Categorical WLAs are pollutant loads that are equivalent for multiple permittees (several regulated MS4s) or a group of permittees (e.g. construction stormwater).

4.3.1 Wastewater Treatment Facilities

The WWTF are NPDES/SDS permitted facilities that process primarily wastewater from domestic sanitary sewer sources (sewage). These include city or sanitary district treatment facilities, wayside rest areas, state parks, mobile home parks and resorts. There are no WWTF in the impaired lake watersheds. Relevant WWTF for impaired stream reaches are shown in Table 4.6. Table 4.7

Table 4.6: WWTF permitted facilities applicable to this TMDL report

City WWTF	Permit #	Facility	System Type	Impairment	Stream Reach AUID #
Clarkfield	MNG580093	Municipal WWTF	Controlled Discharge	*E. coli*	07020004-536
Cottonwood	MNG580010	Municipal WWTF	Controlled Discharge	*E. coli*	07020004-547
Wood Lake	MNG580107	Municipal WWTF	Controlled Discharge	*E. coli*	07020004-547
Echo	MNG490046	Municipal WWTF	Controlled Discharge	*E. coli*	07020004-555
Ivanhoe	MNG580103	Municipal WWTF	Controlled Discharge	*E. coli* /Turbidity (TSS)	07020004-513
				E. coli /Turbidity (TSS)	07020004-584
Minneota	MNG580033	Municipal WWTF	Controlled Discharge	Fecal bacteria /Turbidity (TSS)	07020004-503
				E. coli /Turbidity (TSS)	07020004-513
Porter	MNG580128	Municipal WWTF	Controlled Discharge	*E. coli* /Turbidity (TSS)	07020004-513
Taunton	MNG580090	Municipal WWTF	Controlled Discharge	*E. coli* /Turbidity (TSS)	07020004-513
				E. coli	07020004-545
				E. coli /Turbidity (TSS)	07020004-584
Saint Leo	MN0024775	Municipal WWTF	Controlled Discharge	*E. coli*	07020004-538

For the *E. coli* impaired stream reaches controlled discharge WWTF allocations were determined by multiplying the permit limit of 126 org/100ml by the maximum permitted discharge flow (based on a six inch per day discharge from the facility's secondary ponds). Individual *E. coli* WLA calculations and allocations are shown in Table 4.7.

Table 4.7: Individual WWTF *E. coli* WLA calculations

City WWTF	A *E. coli* Permit Limit (billion org/100ml)	B Max Permitted Discharge Flow (mgd)	C Conversion factor	A*B*C Load (billion org/day)
Clarkfield	126	2.933	0.03785	13.986
Cottonwood		1.852		8.835
Echo		0.652		3.108
Ivanhoe		0.554		2.642
Minneota		1.792		8.547
Porter		0.163		0.777
Saint Leo		0.142		0.676
Taunton		0.196		0.932
Wood Lake		0.358		1.709

The flow contribution from each of the WWTF exceeds the designated “very low” flow for all impaired stream reaches with a WWTF discharge. The WWTF load can never exceed the stream load as it is a component of the stream load. To account for this situation, the WLA and LAs are expressed as an equation rather than an absolute number. This equation is:

Allocation = (flow contribution from a given source) x (126 billion org/100ml)

This amounts to assigning a concentration based limit to these sources. While this might be seen as overly stringent, these sources tend not to be significant contributors of bacteria under very low flow conditions.

For the turbidity impaired stream reaches controlled discharge WWTF allocations were determined by multiplying the permit limit of 45 mg/L by the maximum permitted discharge flow (based on a six inch per day discharge from the facility’s secondary ponds). Individual TSS WLA calculations and allocations are shown in Table 4.8.

Table 4.8: Individual WWTF Total Suspended Solids WLA calculations

City WWTF	A TSS Permit Limit (mg/L)	B Max Permitted Discharge Flow (mgd)	C Conversion factor	A*B*C Load (tons/day)
Cottonwood	45	1.85	0.000858	0.07
Ivanhoe		0.54		0.02
Minneota		1.79		0.07
Porter		0.16		0.01
Taunton		0.20		0.01

The flow contribution from each of the WWTF exceeds the designated “very low” flow for some of these streams. The WWTF load can never exceed stream loads as it is a component of stream load. To account for this situation, the WLA and LAs are expressed as an equation rather than an absolute number. This equation is:

Allocation = (flow contribution from a given source) x (TSS Permit Limit)

This amounts to assigning a concentration based limit to these sources. While this might be seen as overly stringent, these sources tend not to be significant contributors of TSS under very low flow conditions.

4.3.2 Industrial Process Wastewater

There are no industrial facilities that discharge water located within the Yellow Medicine River Watershed.

4.3.3 Stormwater

Urban and suburban stormwater runoff both from developing and built-out areas carry pollutant loads that can match or exceed agricultural run-off on a per-acre basis. This runoff can increase flows, which contributes to channel instability and streambank erosion. Pollutants from stormwater runoff can include pesticides, fertilizer, oil, chemicals, metals, pathogens, salt, sediment, litter and other debris. The MPCA has three categories for stormwater permits: municipal, construction and industrial.

Municipal – In 1987, the CWA was amended to include provisions for a two-phase program to address stormwater runoff. In March of 2003, the second phase of the program began. Phase II includes permitting and regulation of smaller construction sites, municipalities MS4 permits, and industrial facilities. There are currently no MS4 communities in the Yellow Medicine River upstream of the confluence with the Minnesota River. There are also no communities likely to become subject to MS4 permit requirements in the near future. As a result, 0% of the TMDL is apportioned to the MS4 allocation.

Construction – The MPCA issues construction permits for any construction activities disturbing:

- One acre or more of soil.
- Less than one acre of soil if that activity is part of a “larger common plan of development or sale” that is greater than one acre.
- Less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources.

Construction stormwater permit application records indicate approximately 0.6% of land use in the study area has been subject to construction over the last 10 years. The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites less than one acre expected to be active in the watershed at any one time, and the best management practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

Industrial – Industrial sites might contribute to stormwater pollution when water comes in contact with pollutants such as toxic metals, oil, grease, de-icing salts and other chemicals from rooftops, roads, parking lots, and from activities such as storage and material handling. Examples of exposed materials that would require a facility to apply for an industrial stormwater permit include: fuels, solvents, stockpiled sand, wood dust, gravel, metal and a variety of other materials. As part of the permit requirements, the facilities are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP uses BMPs designed to eliminate or minimize stormwater contact with significant materials that might result in polluted stormwater discharges from the industrial site. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES Industrial Stormwater Permit coverage is required as well as BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. Industrial Stormwater Permit application records indicate approximately 0.25% of land use in the study area has been subject to permitted industrial activity over the last 10 years. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Nonmetallic Mining and Associated Activities facilities (MNG490000). If a facility owner/operator obtains coverage under the appropriate NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

To account for construction and industrial stormwater, as well as allowing for the potential of higher rates of construction and additional industrial facilities, this TMDL assumes 1% of the land area for the construction and industrial stormwater category. Therefore, 1% of the TMDL is apportioned to these activities through a categorical WLA. The allocation to this category is made after the MOS is subtracted from the total LC.

Livestock Facilities – The NPDES livestock facilities are zero discharge facilities and therefore are given a WLA of zero and should not impact water quality in the watershed as a point source. The number of livestock facilities with NPDES permits located within each subwatershed is shown in Table 4.9. These are General Feedlot Permits and are covered as such under Minnesota’s General Feedlot Permit, MNG440000. Discharge of phosphorus from fields where manure has been land-applied are covered under the LA portion of the TMDLs, provided the manure is applied in accordance with the permit.

Table 4.9: NPDES permitted livestock CAFOs by subwatershed

Aggregated HUC12 Subwatershed	Feedlot Permit Number	Feedlot Name	Total Animal Units
Hazel Creek - County Ditch No. 9	MNG440401	Christensen Farms Site C071	1280
	MNG440951	Paul Syring Farm	1091
Wood Lake Creek – Judicial Ditch 10	MNG440561	L & N Hog Farms	910
	MNG441226	Ben and Mike Hinz Farm	1410
	MNG441184	Tim Schlenner Farm 17	1080
	MNG441229	Dave Schwerin - Site 3	1440
Judicial Ditch 17	MNG440248	Allied Dairy LLP	1960
Lower Yellow Medicine River	MNG440339	Plainview Farms Inc	2952
	MNG440731	Buysse Inc - Crestview Farm	2952
	MNG440456	Hentges Family Farm	1080
	MNG440796	Stevens Farms LLP	2000
Mud Creek	MNG441144	Mike Verhelst Farm	950
Sacred Heart Creek - MN River	MNG440281	Christensen Farms Site F148	1200
	MNG441285	Hentges Finisher	990
	MNG440316	Jordan Hog Finishing Site	1200
South Branch Yellow Medicine River	MNG440058	Prairieview Pork Inc	1216
	MNG440287	Guy Jeremiason Farm - South	1540
	MNG440462	Kevin R Leibfried Farm	1440
	MNG440144	Pat & Sharon Hennen	1345.3
	MNG441283	John Wambeke Farm	990
Spring Creek	MNG440759	Rob Hill Farms Inc	900
	MNG440125	Christensen Farms Site C072	2264
	MNG440426	Richard Nuytten Farm	1511

Aggregated HUC12 Subwatershed	Feedlot Permit Number	Feedlot Name	Total Animal Units
	MNG440519	Christensen Farms Site C073	1240
Stony Run Creek	MNG440430	Patrick W McCoy Hog Barns	1440
Stony Run Creek - MN River	MNG440843	Montevideo Farms Inc	900
	MNG440970	Sundlee Pork Inc	1778.4
Upper Yellow Medicine River	MNG440665	Christensen Farms Site F068	936
	MNG440461	Steve Citterman Farm	1440
Wood Lake Creek - MN River	MNG441085	Pederson Pork Farm	1350
	MNG441308	Jon Busack Farm	1440
	MNG441052	Kvistad Farms Inc	805

4.3.4 Straight Pipe Septic Systems

Straight pipe septic systems are illegal and therefore receive a WLA of zero. According to Minn. Stat. 115.55, subd. 1, a straight pipe "means a sewage disposal system that includes toilet waste and transports raw or partially settled sewage directly to a lake, a stream, a drainage system, or ground surface".

4.4 Load Allocation Methodology

Once the WLA and MOS were determined for each watershed, the LA was assigned the remaining LC. The LA includes nonpoint pollution sources that are not subject to NPDES Permit requirements, as well as "natural background" sources. Natural background as defined in Minn. R. 7050.0150, subp. 4, refers to the multiplicity of factors that determine the physical, chemical or biological conditions that would exist in a waterbody in the absence of measurable impacts from human activity or influence. Anthropogenic sources of stress are not a component of natural background as it has been defined by Minnesota rule.

4.5 Margin of Safety

The purpose of the MOS is to account for uncertainty that the allocations will result in attainment of water quality standards.

4.5.1 *E. coli*

The Yellow Medicine River Watershed HSPF model was calibrated and validated using 17 years (1996 through 2012) of flow data from USGS gaging station 05313500 and 11 years (1999 through 2009) of water chemistry data. Calibration results indicate that the HSPF model is a valid representation of hydrological conditions in the watershed, therefore, an explicit MOS of 10% was deemed appropriate for the nutrient eutrophication TMDLs. See Appendix C of this report for the HSPF model calibration and validation results. The *E. coli* TMDLs applied a MOS to each flow zone along the duration curves by subtracting 10% of the flow zones loading capacity.

4.5.2 TSS

The Yellow Medicine River Watershed HSPF model was calibrated and validated using 17 years (1996 through 2012) of flow data from USGS gaging station 05313500 and 11 years (1999 through 2009) of water chemistry data. Calibration results indicate that the HSPF model is a valid representation of hydrological and chemical conditions in the watershed. See Appendix C of this report for the HSPF model calibration and validation results. The TSS TMDLs applied a MOS to each flow zone along the duration curves by subtracting 10% of the flow zones loading capacity.

4.5.3 Nutrient Eutrophication

The Yellow Medicine River Watershed HSPF model was calibrated and validated using 17 years (1996 through 2012) of flow data from USGS gaging station 05313500. Calibration results indicate that the HSPF model is a valid representation of hydrological and water quality conditions in the watershed. See Appendix C of this report for the HSPF model calibration and validation results. The external phosphorus load estimates delivered to each lake from the surrounding land were developed using HSPF modeled daily flow and loads. In some instances, the external loading estimates did not result in sufficient phosphorus load for the modeled in-lake phosphorus concentrations to match the average phosphorus concentrations. Internal load adjustments were made within the BATHTUB model until the modeled total phosphorus value matched the mean value of the observed samples. Because of the calibration and validation of the HSPF model as well as the morphometric factors suggesting internal load is a source of phosphorus in these lakes, the MPCA believes the BATHTUB models are an appropriate representation of the natural system. Therefore, an explicit MOS of 10% was deemed appropriate for the nutrient eutrophication TMDLs. The MOS was applied to the lake TMDLs by subtracting 10% of the lake's loading capacity.

4.6 Seasonal Variation

4.6.1 *E. coli*

Concentrations of *E. coli* vary throughout the summer in the Yellow Medicine River Watershed. The standard is based on a monthly geometric mean and must be met for the months April through October. Exceedances of the *E. coli* standard in the impaired stream reaches occur primarily in the months June through September and vary by reach (Table 3.4). The *E. coli* Load Duration Curves were developed using HSPF modeled daily flow data from April thru October. The duration curve approach uses multiple years of flow data and the applicable time period of the standard will provide sufficient water quality protection during the critical summer period.

4.6.2 Turbidity (TSS)

Turbidity (TSS), transparency tube, and TSS data were all collected in the Yellow Medicine River Watershed. Since the majority of the data collected was transparency tube readings, a transparency tube surrogate value of 20 cm was used to determine whether stream reaches met the turbidity (TSS) standard of 25 NTU. Elevated turbidity (TSS) is prevalent throughout much of the year in all of the streams; however, it appears there are differences in critical times between stream reaches. There are likely differing sources contributing to TSS in different parts of the watershed and in different years. The TSS stream Load Duration Curves were developed using HSPF modeled daily flow data from April thru September. The duration curve approach using multiple years of flow data helps to account for some of the yearly variation and will provide adequate protection during the differing times of the year when the standard is exceeded.

4.6.3 Nutrient Eutrophication

Water quality monitoring in Cottonwood, Curtis, Lady Slipper, Perch, Stay, Steep Bank, and Wood Lakes suggests the in-lake TP concentrations vary over the course of the growing season (June through September), generally peaking in mid to late summer. The MPCA eutrophication water quality guideline for assessing TP is defined as the June through September mean concentration. The BATHTUB model was used to calculate the load capacities of each lake, incorporating mean growing season TP values. TP loadings were calculated to meet the water quality standards during the summer growing season, the most critical period of the year. Calibration to this critical period will provide adequate protection during times of the year with reduced loading.

4.7 TMDL Summary

4.7.1 Bacteria Impaired Stream Reach Loading Capacities

Table 4.10: *E. coli* loading capacities and allocations for stream reaches

E. coli					
Hazel Creek - County Ditch No. 9 Township 115N, Range 43W, Section. 33 to Minnesota River AUID# 07020004-536	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity***	364.3	73.7	21.3	4.1	0.03
Margin of Safety	36.4	7.4	2.1	0.4	0.003
Wasteload Allocation					
City of Clarkfield Wastewater Treatment Facility	13.99	13.99	13.99	**	**
Livestock facilities requiring NPDES permits	0	0	0	**	**
"Straight Pipe" Septic Systems	0	0	0	**	**
Load Allocation	313.9	52.3	5.2	**	**
Wood Lake Creek - Judicial Ditch 10 Wood Lake outlet to Minnesota River AUID# 07020004-547	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**

E. coli					
	Billion organisms per day				
Average Daily Loading Capacity* **	240.3	55.4	12.0	1.1	0.03
Margin of Safety	24	5.5	1.2	0.1	0.003
Wasteload Allocation					
Cities of Cottonwood, Wood Lake Wastewater Treatment Facilities	10.54	10.54	10.54	**	**
Livestock facilities requiring NPDES permits	0	0	0	**	**
"Straight Pipe" Septic Systems	0	0	0	**	**
Load Allocation	205.8	39.4	0.26	**	**
Judicial Ditch 17 County Ditch 3 to Yellow Medicine River AUID# 07020004-622	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity* **	264.7	65.7	18.2	4.4	0.03
Margin of Safety	26.5	6.6	1.8	0.4	0.003
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	*	*	*	*	*
Livestock facilities requiring NPDES permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	238.2	59.1	16.4	4.1	0.027
Lower Yellow Medicine River South Branch Yellow Medicine River to Spring Creek AUID# 07020004-513	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity* **	2312.2	500.2	131.7	16.1	0.03
Margin of Safety	231.2	50	13.2	1.6	0.003
Wasteload Allocation					
Cities of Ivanhoe, Minneota, Porter, and Taunton Wastewater Treatment Facilities	12.9	12.9	12.9	12.9	**
Livestock facilities requiring NPDES permits	0	0	0	0	**
"Straight Pipe" Septic Systems	0	0	0	0	**
Load Allocation	2068.1	437.3	105.6	1.6	**
Mud Creek Headwaters to Township 114N, Range 43W, Section 35, South Line AUID# 07020004-543	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity* **	333.3	75.6	18.6	2.3	0.03

E. coli					
Margin of Safety	33.3	7.6	1.9	0.2	0.003
Wasteload Allocation					
City of Porter Wastewater Treatment Facility	0.78	0.78	0.78	0.78	**
Livestock facilities requiring NPDES permits	0	0	0	0	**
"Straight Pipe" Septic Systems	0	0	0	0	**
Load Allocation	299.2	67.2	15.9	1.32	**
South Branch Yellow Medicine River AUID# 07020004-503	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity* **	660.7	130.5	26.1	0.03	0.03
Margin of Safety	66.1	13.1	2.6	0.003	0.003
City of Minneota Wastewater Treatment Facility	8.5	8.5	8.5	**	**
Livestock facilities requiring NPDES permits	0	0	0	**	**
"Straight Pipe" Septic Systems	0	0	0	**	**
Load Allocation	586.1	108.9	15	**	**
South Branch Yellow Medicine River – JD 29 Township 111N, Range 44W, Section 16, South Line to South Branch Yellow Medicine River AUID# 07020004-550	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity* **	168.8	34.1	9.1	2.6	0.2
Margin of Safety	16.9	3.4	0.9	0.3	0.02
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	*	*	*	*	*
Livestock facilities requiring NPDES permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	151.9	30.7	8.2	2.3	0.18
South Branch Yellow Medicine River Township 112N, Range 44W, Section 20 to Township 113N, Range 43W, Section 35 AUID# 07020004-595, -597, -599	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity* **	91.6	14.1	2.9	0.03	0.03
Margin of Safety	9.2	1.4	0.3	0.003	0.003
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	*	*	*	*	*

E. coli					
Livestock facilities requiring NPDES permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	82.4	12.7	2.6	0.027	0.027
South Branch Yellow Medicine River County Ditch 24 to County Ditch 35 AUID# 07020004-600	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity***	162.2	33.1	8.4	1.4	0.005
Margin of Safety	16.2	3.3	0.8	0.1	0.0005
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	*	*	*	*	*
Livestock facilities requiring NPDES permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	146	29.8	7.6	1.3	0.0045
Spring Creek Headwaters to Yellow Medicine River AUID# 07020004-538	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity***	706.4	151	39.2	5.5	0.03
Margin of Safety	70.6	15.1	3.9	0.6	0.003
Wasteload Allocation					
City of St. Leo Wastewater Treatment Facility	0.68	0.68	0.68	0.68	**
Livestock facilities requiring NPDES permits	0	0	0	0	**
"Straight Pipe" Septic Systems	0	0	0	0	**
Load Allocation	635.1	135.2	34.6	4.22	**
Stony Run Creek Township 116N, Range 40W, Section 30, West Line to Minnesota River AUID# 07020004-535	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity***	301.1	52.7	14.2	2.8	0.03
Margin of Safety	30.1	5.3	1.4	0.3	0.003
Wasteload Allocation					
Permitted Wastewater Treatment Facilities	*	*	*	*	*
Livestock facilities requiring NPDES permits	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	271	47.4	12.8	2.5	0.027

E. coli					
Upper Yellow Medicine River Township 113N, Range 43W, Section 20 to Township 113N, Range 43W, Section 9 AUID# 07020004-545	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity***	143.9	23.2	5.9	0.8	0.03
Margin of Safety	14.4	2.3	0.6	0.08	0.003
Wasteload Allocation					
City of Taunton Wastewater Treatment Facility	0.93	0.93	0.93	**	**
Livestock facilities requiring NPDES permits	0	0	0	**	**
"Straight Pipe" Septic Systems	0	0	0	**	**
Load Allocation	128.6	20	4.4	**	**
Upper Yellow Medicine River Headwaters to Mud Creek AUID# 07020004-584	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity***	672.2	118.5	32.7	4.0	0.03
Margin of Safety	67.2	11.9	3.3	0.4	0.003
Wasteload Allocation					
Cities of Taunton and Ivanhoe Wastewater Treatment Facilities	3.57	3.57	3.57	3.57	**
Livestock facilities requiring NPDES permits	0	0	0	0	**
"Straight Pipe" Septic Systems	0	0	0	0	**
Load Allocation	601.4	103	25.8	0.03	**
Wood Lake Creek-MN River T114N, R37W, S20, west line to Minnesota R AUID# 07020004-555	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	Billion organisms per day				
Average Daily Loading Capacity***	122.8	25.6	6.5	0.9	0.03
Margin of Safety	12.3	2.6	0.7	0.1	0.003
Wasteload Allocation					
City of Echo Wastewater Treatment Facility	3.1	3.1	3.1	**	**
Livestock facilities requiring NPDES permits	0	0	0	**	**
"Straight Pipe" Septic Systems	0	0	0	**	**
Load Allocation	107.4	19.9	2.7	**	**

*None located within watershed
**WWTF design/discharge flow exceeded low flow, therefore allocation = (flow contribution from a given source) x (126 org/100ml). See section 4.3 for details.
***Values may be rounded

4.7.2 Turbidity (TSS) Impaired Stream Reach Loading Capacities

Table 4.11: Loading capacities and allocations for stream reaches

TSS					
Lower Yellow Medicine River South Branch Yellow Medicine River to Spring Creek AUID# 07020004-513	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS (tons per day)				
Average Daily Loading Capacity**	147	31	8.5	1.2	0.002
Margin of Safety	14.7	3.1	0.9	0.1	0.0002
Wasteload Allocation					
Cities of Ivanhoe, Minneota, Porter, and Taunton Wastewater Treatment Facilities	0.1	0.1	0.1	0.1	*
Livestock facilities requiring NPDES permits	0	0	0	0	*
"Straight Pipe" Septic Systems	0	0	0	0	*
Construction and Industrial Stormwater 1%	1.3	0.3	0.08	0.01	*
Load Allocation	130.9	27.5	7.42	0.99	*

South Branch Yellow Medicine River – County Ditch 35 Headwaters to Yellow Medicine River AUID# 07020004-503	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS (tons per day)				
Average Daily Loading Capacity**	42	7.9	1.8	0.002	0.002
Margin of Safety	4.2	0.8	0.2	0.0002	0.0002
Wasteload Allocation					
City of Minneota Wastewater Treatment Facility	0.07	0.07	0.07	*	*
Livestock facilities requiring NPDES permits	0	0	0	*	*
"Straight Pipe" Septic Systems	0	0	0	*	*
Construction and Industrial Stormwater 1%	0.4	0.07	0.03	*	*
Load Allocation	37.33	7	1.5	*	*

Upper Yellow Medicine River Headwaters to Mud Creek AUID# 07020004-584	**MID-POINT OF FLOW ZONE**				
	Very High	**High**	**Mid**	**Low**	**Very Low**
	TSS (tons per day)				
Average Daily Loading Capacity**	40.5	7.3	2.1	0.3	0.002
Margin of Safety	4.1	0.7	0.2	0.03	0.0002
Wasteload Allocation					
Cities of Ivanhoe and Taunton Wastewater Treatment Facilities	0.03	0.03	0.03	0.03	*
Livestock facilities requiring NPDES permits	0	0	0	0	*
"Straight Pipe" Septic Systems	0	0	0	0	*

TSS					
Construction and Industrial Stormwater 1%	0.4	0.07	0.02	0.003	*
Load Allocation	36	6.5	1.9	0.24	*

*WWTF design/discharge flow exceeded low flow, therefore allocation = (flow contribution from a given source) x (126 org/100ml). See section 4.3 for details.

**Values may be rounded

4.7.3 Impaired Lake Loading Capacities

Table 4.12: Total phosphorus loading capacities and allocations for impaired lakes within the Yellow Medicine River Watershed

Cottonwood Lake 42-0014-00	**TP lbs/day**
Loading Capacity**	5.54
Margin of Safety	0.55
Wasteload Allocation*	
Construction and industrial stormwater	0.05
Livestock facilities requiring NPDES permits	0
“Straight pipe” septic systems	0
Load Allocation***	4.94

Lady Slipper Lake 42-0020-00	**TP lbs/day**
Loading Capacity**	1.43
Margin of Safety	0.14
Wasteload Allocation*	
Construction and industrial stormwater - 1%	0.01
Livestock facilities requiring NPDES permits	0
“Straight pipe” septic systems	0
Load Allocation***	1.28

Perch Lake 41-0067-00	**TP lbs/day**
Loading Capacity**	1.2
Margin of Safety	0.12
Wasteload Allocation*	
Construction and industrial stormwater	0.01
Livestock facilities requiring NPDES permits	0
“Straight pipe” septic systems	0

Curtis Lake 87-0016-00	**TP lbs/day**
Loading Capacity**	1.9
Margin of Safety	0.19
Wasteload Allocation*	
Construction and industrial stormwater	0.02
Livestock facilities requiring NPDES permits	0
“Straight pipe” septic systems	0
Load Allocation***	1.69

Lake Stay 41-0034-00	**TP lbs/day**
Loading Capacity**	2.89
Margin of Safety	0.29
Wasteload Allocation*	
Construction and industrial stormwater	0.03
Livestock facilities requiring NPDES permits	0
“Straight pipe” septic systems	0
Load Allocation***	2.57

Steep Bank Lake 41-0082-00	**TP lbs/day**
Loading Capacity**	1.01
Margin of Safety	0.1
Wasteload Allocation*	
Construction and industrial stormwater	0.01
Livestock facilities requiring NPDES permits	0
“Straight pipe” septic systems	0

Load Allocation	1.07

Wood Lake 87-0030-00	**TP** **lbs/day**
Loading Capacity**	4.52
Margin of Safety	0.45
Wasteload Allocation*	
Construction and industrial stormwater	0.04
Livestock facilities requiring NPDES permits	0
“Straight pipe” septic systems	0
Load Allocation***	4.03

Load Allocation	0.9

* No Communities Subject to MS4 NPDES requirements or Industrial process wastewater discharges located in the watershed
**Values may be rounded
***Load allocations sub-divided into watershed, atmospheric load (precipitation) and internal load in Appendix B.

5 Future Growth Considerations

Potential changes in population and land use over time in the Yellow Medicine River Watershed could result in changing sources of pollutants. Overall, there is likely very little to no anticipated future growth in the watershed. Possible changes and how they may or may not impact TMDL allocations are discussed below.

5.1 New or Expanding Permitted MS4 WLA Transfer Process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded Urban Area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES Permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

5.2 New or Expanding Wastewater (TSS and *E. coli* TMDLs only)

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding wastewater discharges to waterbodies with an EPA approved TMDL (MPCA 2012e). This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs will be handled by the MPCA, with input and involvement by the EPA, once a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed, and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

There are currently no unsewered communities in the Yellow Medicine River Watershed. All noncompliant SSTS upgrades are being addressed upon property transfer and other local ordinances, though some additional programs will be utilized if deemed necessary. The MPCA has completed a report for small community wastewater needs with the goal of eliminating these sources of pollution (MPCA 2008). It is unlikely that any new communities will develop in the future.

For more information on the overall process visit the MPCA's TMDL Policy and Guidance webpage.

6 Reasonable Assurance

There are no current point source reductions identified within the Yellow Medicine River Watershed. Point source permitting staff works closely with facilities to adjust permits as necessary for limits, adjustments in release times, and/or adjustments to when releases can occur based on current stream flow to ensure the continued compliance of the facilities with minimal disruption to current facility operations. This hands-on approach has proven successful for multiple point source reductions in Minnesota and provides reasonable assurance that the necessary point source reductions will be achieved.

The majority of pollutant reductions in the Yellow Medicine River Watershed will need to come from NPS contributors in order for the impaired waters to meet water quality standards. Of these sources, agricultural drainage and surface runoff are the dominant sources, while other NPS contribute a small portion of the pollutant loads. There is reasonable assurance that adopting the various practices and strategies, in the required amounts, will allow surface waters to meet water quality standards. However, due to the lack of existing state and federal regulations, the current exemptions in creating federal regulations, and the monetary incentives for practices that degrade water quality, there is no guarantee that landowners will do the necessary practices and BMPs to meet these standards. Agencies, organizations, and citizens alike need to recognize that resigning waters to an impaired condition is not acceptable.

See Table 12A of the *Yellow Medicine River WRAPS Report* for strategies that summarize the conditions discussed in Section 2 of the WRAPS report including the pollutants/stressors of concern, the current water quality conditions for each pollutant/stressor, and the watershed-wide water quality goals and targets. This table also presents the allocations of the pollutant/stressor goals and targets to the primary sources. and the estimated years to meet the goal (both developed by the WRAPS Workshop Team). Table 12B presents information most relevant for local planning efforts including the specific strategies and actions, adoption rates, and responsibilities. The strategies and relative adoption rates developed by the WRAPS workshop team were used to calculate the adoption rates needed to meet the pollutant/stressor 10-year targets. While these model summaries indicate that wide-scale adoption of agricultural BMPs will allow waters to meet water quality standards, there is no way to guarantee that citizens and communities will voluntarily adopt the necessary practices at the necessary rate. To best assure that NPS reductions are achieved, a large emphasis has been placed on citizen engagement, where the citizens and communities that hold the power to improve water quality conditions are involved in discussions and decision-making. Refer to Section 9 for citizen engagement that has occurred in the Yellow Medicine River Watershed.

The Board of Water and Soil Resources (BWSR) is a State Agency overseen by 20 board members, including local government representatives and citizens. The board sets a policy agenda designed to enhance service delivery through the use of local government. The BWSR mission is to improve and protect Minnesota's water and soil resources by working in partnership with local organizations and private landowners. Core functions include implementing the state's soil and water conservation policy, comprehensive local water management, and the Wetland Conservation Act as it relates to the 41.7 million acres of private land in Minnesota.

The Yellow Medicine River Watershed was one of five watersheds selected as a pilot area for the One Watershed-One Plan Program administered by BWSR. One Watershed One Plan was started to help local water planners organize and develop focused implementation plans on a watershed scale. BWSR is tasked with prioritizing, targeting, and administering state funds for BMP implementation projects. Areas are identified as possible BMP projects by a strategy of prioritizing and targeting specific geographic areas that focus on critical conditions and pathways to impaired lakes and streams.

In addition to citizen engagement, several government programs have been created to support a political and social infrastructure that aims to increase the adoption of strategies that will improve watershed conditions. Selection of sites for implementation of BMPs will be led by local units of government and SWCDs with guidance and support from BWSR. One example of a program is the Minnesota Agricultural Water Quality Certification Program (AWQCP), which provides regulatory security and incentives to landowners who adopt conservation practices. Additional financial programs include the Clean Water Act Section 319 grant programs, and BWSR and NRCS incentive programs. Programs and activities are also occurring at the local government level, where county staff, commissioners, and residents are beginning to come together to address water quality issues.

7 Monitoring Plan

Data from three water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress towards water quality goals. BMPs implemented by local units of government will be tracked through BWSR’s e-Link system.

Water quality monitoring programs will continue to collect and analyze data in the Yellow Medicine River Watershed as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized below:

Intensive Watershed Monitoring (MPCA 2012a) data provides a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at roughly 100 stream and 50 lake monitoring stations across the watershed in 1 to 2 years, every 10 years. To measure pollutants across the watershed the MPCA will re-visit and re-assess the watershed, as well as have capacity to visit new sites in areas with BMP implementation activity. This work is scheduled to start its second iteration in the Yellow Medicine River Watershed in 2020.

Watershed Pollutant Load Monitoring Network (MPCA 3013a) data provides a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. This will allow the MPCA to re-assess previously listed impairments. In the Yellow Medicine River Watershed, there is a perpetual site near the outlet of the Yellow Medicine River and two seasonal (spring through fall) subwatershed sites.

Citizen Stream and Lake Monitoring Program (MPCA 2013b) data provides a continuous record of waterbody transparency throughout much of the watershed. This program relies on a network of volunteers who make monthly lake and river measurements. This will allow the MPCA to re-assess previously listed impairments. Roughly 15 citizen monitoring locations exist in the Yellow Medicine River Watershed.

8 Implementation Strategy Summary

8.1 Permitted Sources

8.1.1 Construction Stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the number of construction sites greater than one acre expected to be active in the watershed at any one time, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

8.1.2 Industrial Stormwater

The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES Industrial Stormwater Permit coverage is required, and the

BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

8.1.3 MS4

The MPCA oversees all regulated MS4 entities in stormwater management accounting activities. There are no MS4 permitted communities located within the Yellow Medicine Watershed. For any cities that may become a MS4 in the future, the baseline year for implementation will be 2004, the mid-range year of the flow data used for development of the load duration curves. The rationale for this is that projects undertaken recently may take a few years to influence water quality. Any load-reducing BMP implemented since the baseline year will be eligible to “count” toward an MS4’s load reductions. If a BMP was implemented during or just prior to the baseline year, the MPCA is open to presentation of evidence by the MS4 permit holder to demonstrate that it should be considered as a credit.

8.1.4 Wastewater

The MPCA issues permits for WWTF that discharge into waters of the state. The permits have site specific limits that are based on water quality standards. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, SDS Permits set limits and establish controls for land application of sewage.

8.2 Non-Permitted Sources

A group of professional water quality, planning, and conservation staff collaboratively will develop the strategies presented in the Yellow Medicine River WRAPS Report. These strategies, adopted at generally wide-scale and integrated in suites, are expected to bring waters in the Yellow Medicine River Watershed into a supporting status. Below is a summary of the recommended strategies, all of which cannot be credited toward WLA reductions for MS4 communities with permit requirements:

- No-till or strip till conservation tillage
- Cover crops and grassed waterways
- Nutrient, manure, and animal management
- Water retention and increased evapotranspiration from the landscape (basins, wetlands, extended retention)

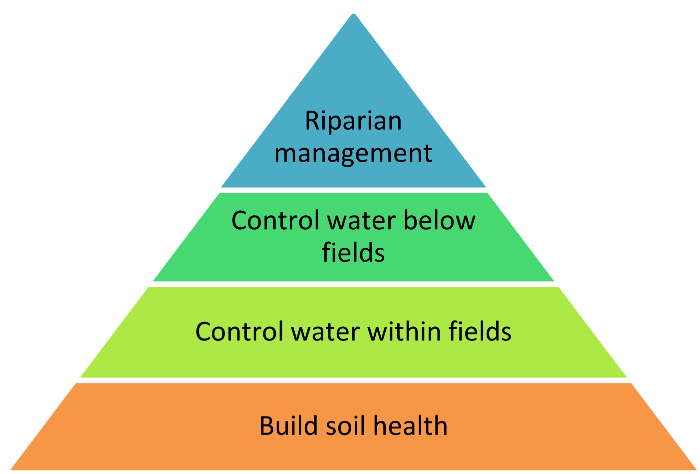

Figure 8.1: A conceptual model to address water quality impairments in agriculturally dominated watersheds

- Field and riparian vegetated buffers
- Drainage volume reductions by system design
- Drainage water pollutant reductions through edge-of-field treatments (bioreactors, saturated buffers, treatment wetlands)
- Citizen education and discussions
- Urban stormwater BMPs (for unregulated areas)
- Changes in policy and increased funding and other support
- Protect currently higher quality areas

Refer to the Tables 12A and 12B of the ***Yellow Medicine River WRAPS Report*** for details of BMPs and adoption rates to meet interim water quality targets. To fully address the widespread water quality impairments in agriculturally-dominated watersheds such as the Yellow Medicine River Watershed, an integrated and multi-faceted approach using suites of BMPs is likely necessary. Initial implementation strategies will focus on reducing external phosphorus loads. Any internal load reduction will be short-lived unless the external inputs can be reduced. Strategies to reduce internal load could include but not be limited to rough fish control, re-establishment of native vegetation and chemical binding of phosphorus. Several models/methods have been developed and are very similar to Figure 8.1 and described in the reports: *Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning* (Tomer et al. 2013), the *Minnesota Nutrient Reduction Strategy* (MPCA 2013c), and the *"Treatment Train" approach as being demonstrated in the Elm Creek Watershed* (ENRTF 2013).

8.3 Cost

Estimating the cost of bringing waters in the Yellow Medicine River Watershed into a supporting status is more an exercise of scale than a practical dollar estimate. Specifically, the costs are highly variable and include many assumptions. Furthermore, the costs will change as progressive practices are voluntarily adopted as the new farming standard. For these reasons, a rough estimate of cost was developed using NRCS cost-share rates, an estimated land value for crops taken out of production, and with assumptions regarding the specific items needed for a practice. This number is a representation of the scale of change that is needed more so than an actual tax-payer or individual burden. The cost also does not include ecosystem benefits, which if considered, could off-set much of the cost. The costs are based on the watershed-wide adoption rates as presented in the Yellow Medicine River WRAPS Report.

The estimated cost of agricultural BMPs to meet the Yellow Medicine River WRAPS 10-year water quality targets is roughly $138 million. The 10-year targets represent pollutant (or stressor) reductions that range from 5%-27%. So very roughly, this number can be extrapolated by (considering the ratio of the total goal to the 10-year target) a factor of five to roughly $690 million to estimate the total agricultural BMP expenditure necessary for waters to meet water quality standards. Additional costs to implement city stormwater, resident, and lake-specific BMPs are roughly estimated to total $100 million based on the scale of reductions needed from these sources.

8.4 Adaptive Management

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. The state of Minnesota has a unique opportunity to adaptively manage water resource plans and implementation activities every 10 years (Figure 8.2). This opportunity resulted from a voter-approved tax increase to improve state waters. The resulting interagency coordination effort is referred to as the Minnesota Water Quality Framework (Figure 8.3), which works to monitor and assess Minnesota's 80 major watersheds every 10 years. This Framework supports ongoing implementation and adaptive management of conservation activities and watershed-based local planning efforts.

Implementation of TMDL related activities can take many years, and water quality benefits associated with these activities can also take many years. As the pollutant source dynamics within the watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired stream reaches. The follow up water monitoring program outlined in Section 7 will be integral to the adaptive management approach, providing assurance that implementation measures are succeeding in attaining water quality standards.

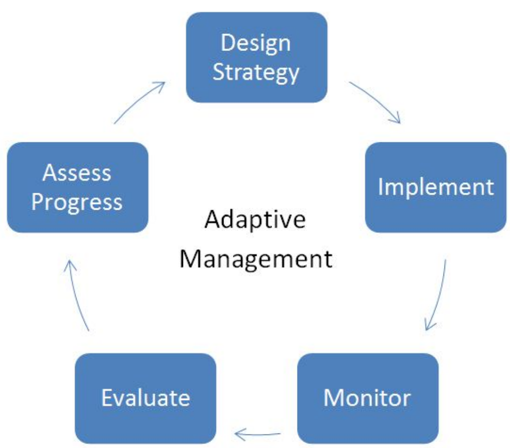

Figure 8.2: Adaptive Management

Figure 8.3: Minnesota water quaility framework

Adaptive management does not include changes to water quality standards or loading capacity. Any changes to water quality standards or loading capacity must be preceded by appropriate administrative processes, including public notice and an opportunity for public review and comment.

9 Public Participation

This section summarizes civic engagement/public participation efforts sponsored by the MPCA in collaboration with local partners: 1) Yellow Medicine River Watershed District, 2) SWCD staff, 3) NRCS staff, 4) State agencies, 5) Citizen and farmer participants, and 6) County and township officials.

9.1 Yellow Medicine River Watershed

The *Yellow Medicine River Watershed District* is composed of watershed residents, concerned citizens and groups, and resource agency staff. Resulting from a series of meetings that started in May of 2012, an Advisory Committee suggested the following recommendations to improve water quality. The summarized recommendations of the committee include:

- Strategically placed buffers, terraces, filter strips and grassed waterways
- Upland erosion control
- Wetland restoration
- Septic system compliance
- Nutrient management/education
- Streambank and ravine stabilization
- River channel maintenance of major snags
- Cover crops
- Controlled/reduced drainage
- Communication and education for watershed residents

9.2 Public Meetings

In addition to a meeting held in August of 2013 to survey the opinions and values in a Zonation Analysis, three public Kick-Off meetings were held in March of 2015 for the pilot program of the One Watershed-One Plan, of citizens who are interested in improving and protecting the waters within the Yellow Medicine River Watershed. The summarization of the meetings was:

Values that progress clean water

- Leaving a legacy for future generations
- Clean surface water for outdoor recreation
- Clean ground water for drinking
- Local pride and stewardship ethos
- Education and continual learning

Values that hinder clean water

- Fear of unknown/resistance to change
- Financial risk avoidance
- High agricultural productivity/yield
- Lack of ownership/responsibility for problem
- Lack of understanding/trust in government

Constraints to higher BMP adoption

- Policies (Farm Bill), rules, and funding that perpetuate status quo
- Inability to guarantee income when making changes
- Unwillingness to break from status quo/differ from those one trusts
- Lack of knowledge of problems and solutions
- Ineffective/conflicting communication/messaging

Opportunities to get higher BMP adoption

- Policies (e.g. Farm Bill) need to facilitate change, flexibility, and less bureaucracy
- Funding for more practices and to prevent income loss when transitioning farms to sustainable practices
- Identify and foster early sustainable farming BMP adopters to be leaders to community
- More/better education on sustainable practices, technologies, benefits, and progress
- Build trust to perpetuate cooperation and stewardship

Recommendations for Education and Networking

- Increased messaging and education including advertisements, social media, billboards, documentaries
- Collaboration with and education/information sharing with ag professionals: co-ops, crop consultants
- Community events/gatherings including clean-ups, banquets, citizen groups, school education
- Peer-leader and peer-to-peer networking events such as fields days and coffee klatches

9.3 Public Notice

This TMDL report was published for public comments from May 16, 2016 through June 15, 2016.

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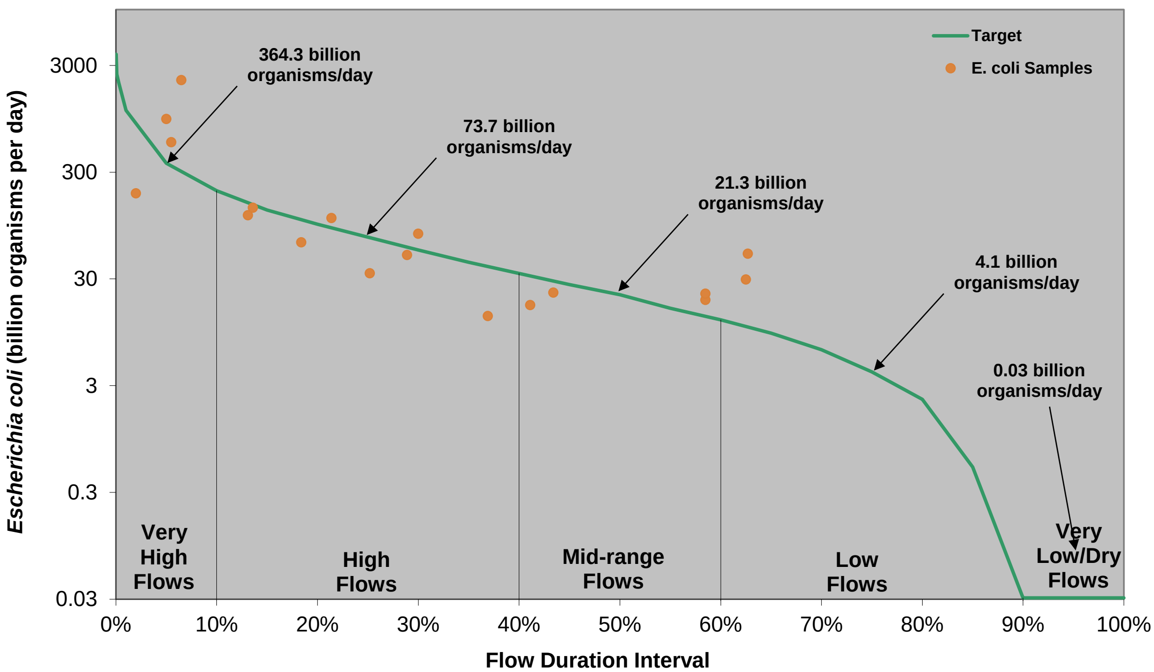
Appendix A

Load duration curves for stream reach impairments

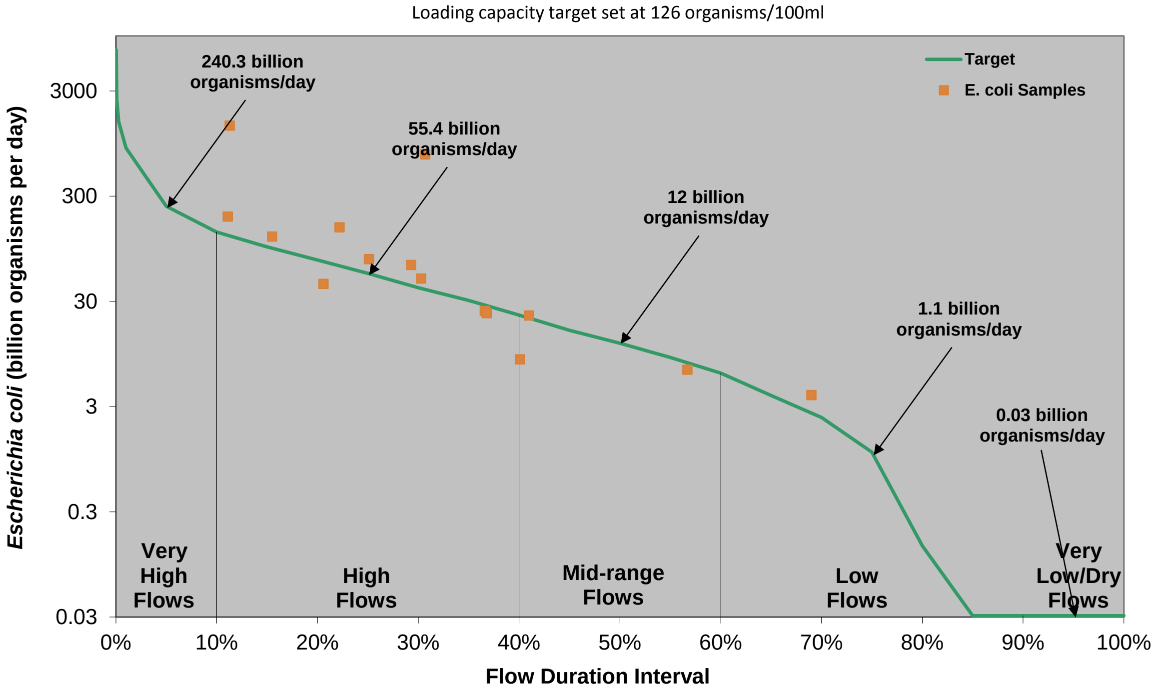
Hazel Creek AUID# 07020004-536

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring station S006-172
Loading capacity target set at 126 organisms/100ml



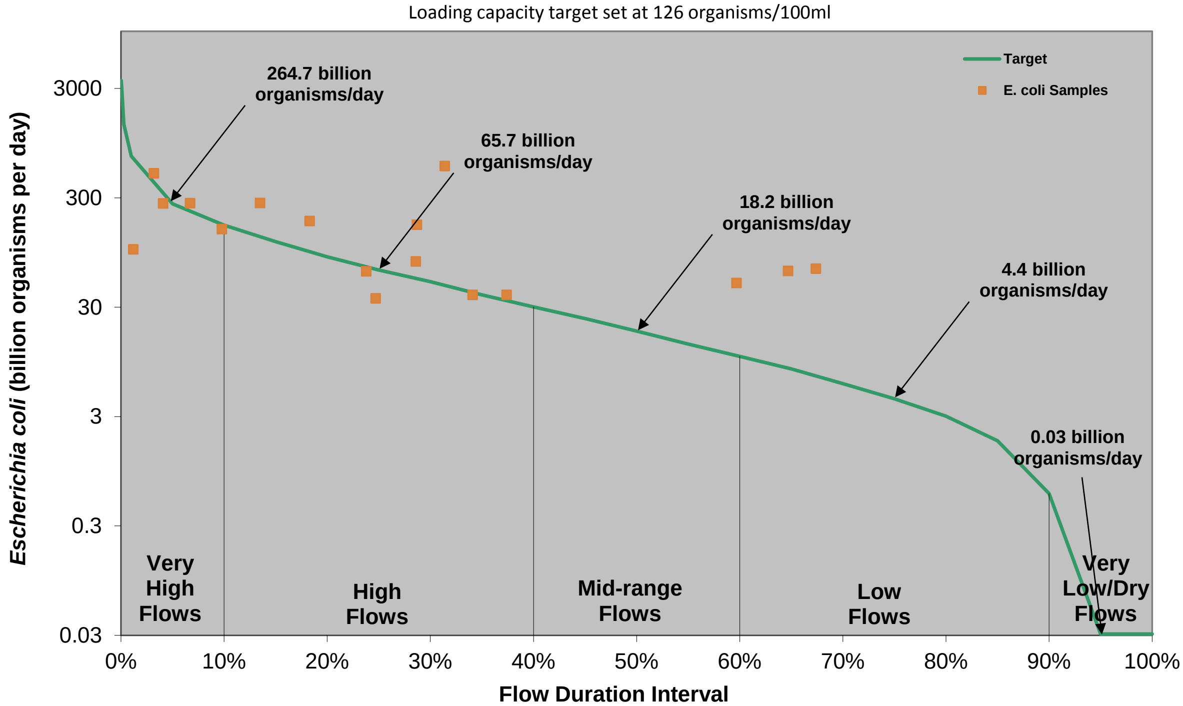
Judicial Ditch 10 AUID# 07020004-547

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring station S006-161
Loading capacity target set at 126 organisms/100ml



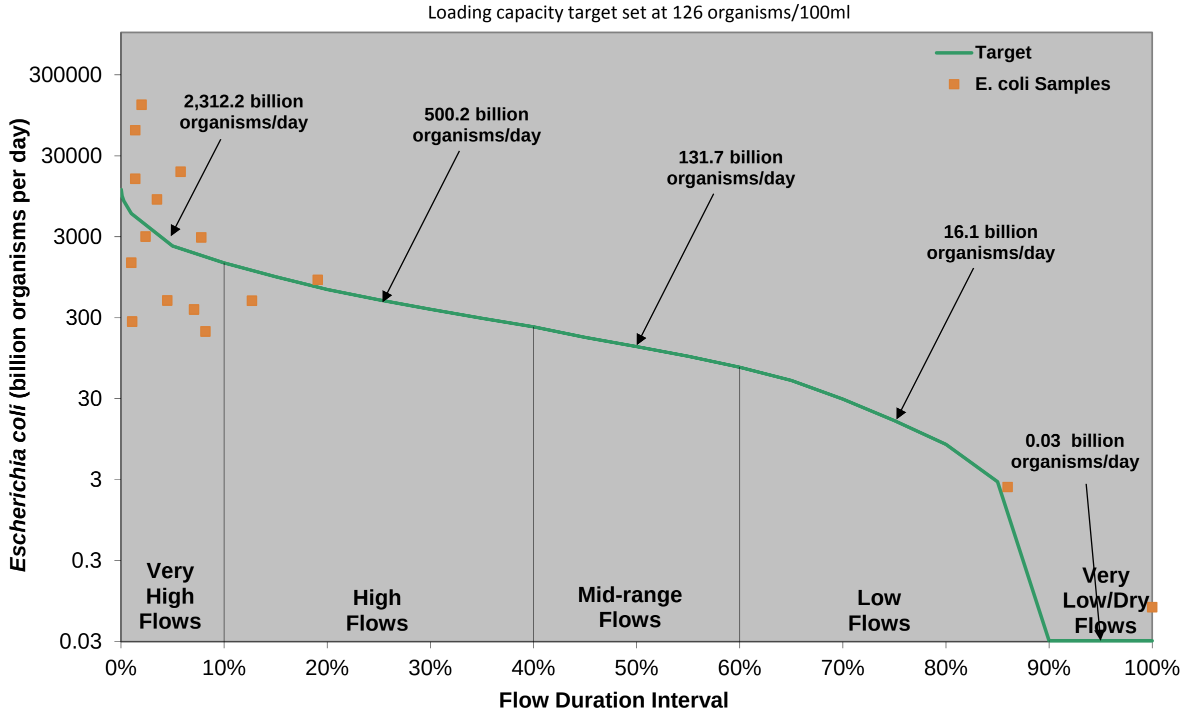
Judicial Ditch 17 AUID# 07020004-622

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring station S002-319
Loading capacity target set at 126 organisms/100ml



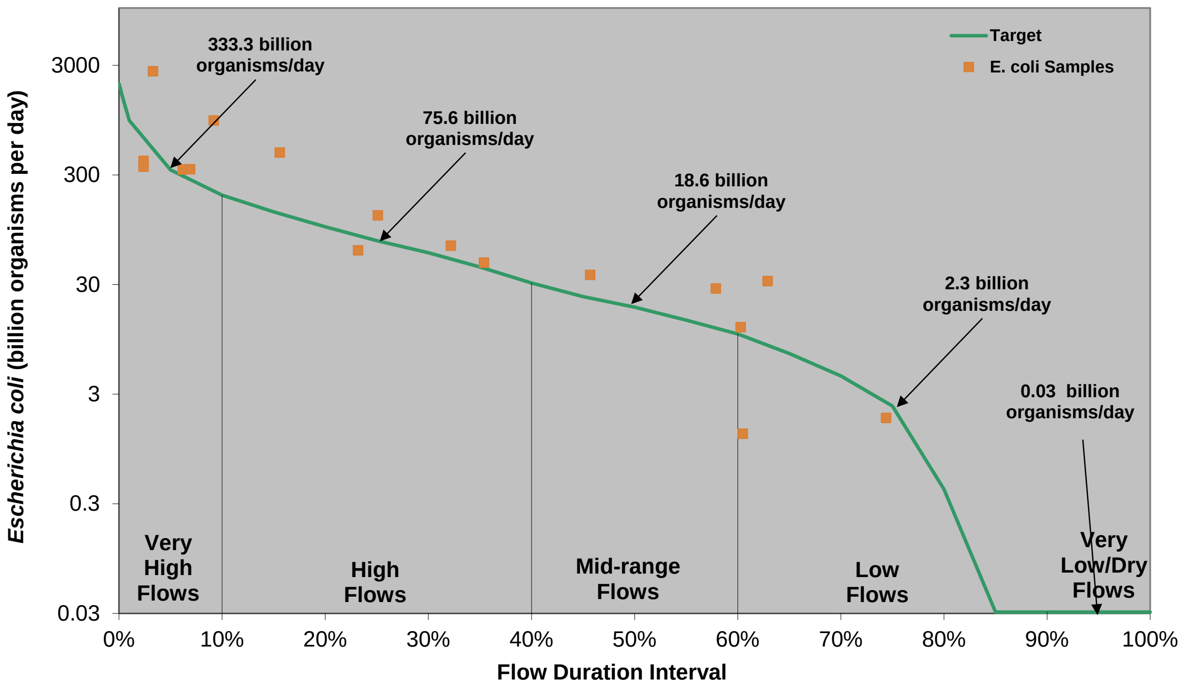
Lower Yellow Medicine River AUID# 07020004-513

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2011 *E. coli* samples from EQuIS monitoring station S002-317
Loading capacity target set at 126 organisms/100ml



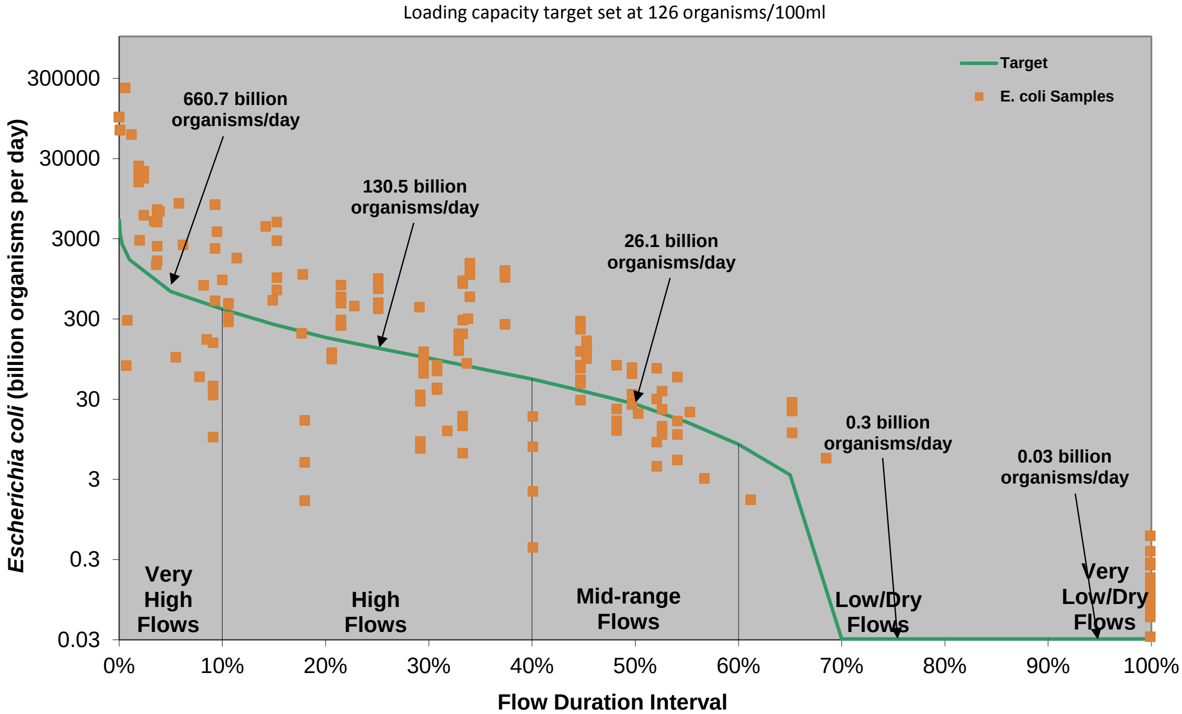
Mud Creek AUID# 07020004-543

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring station S002-321
Loading capacity target set at 126 organisms/100ml



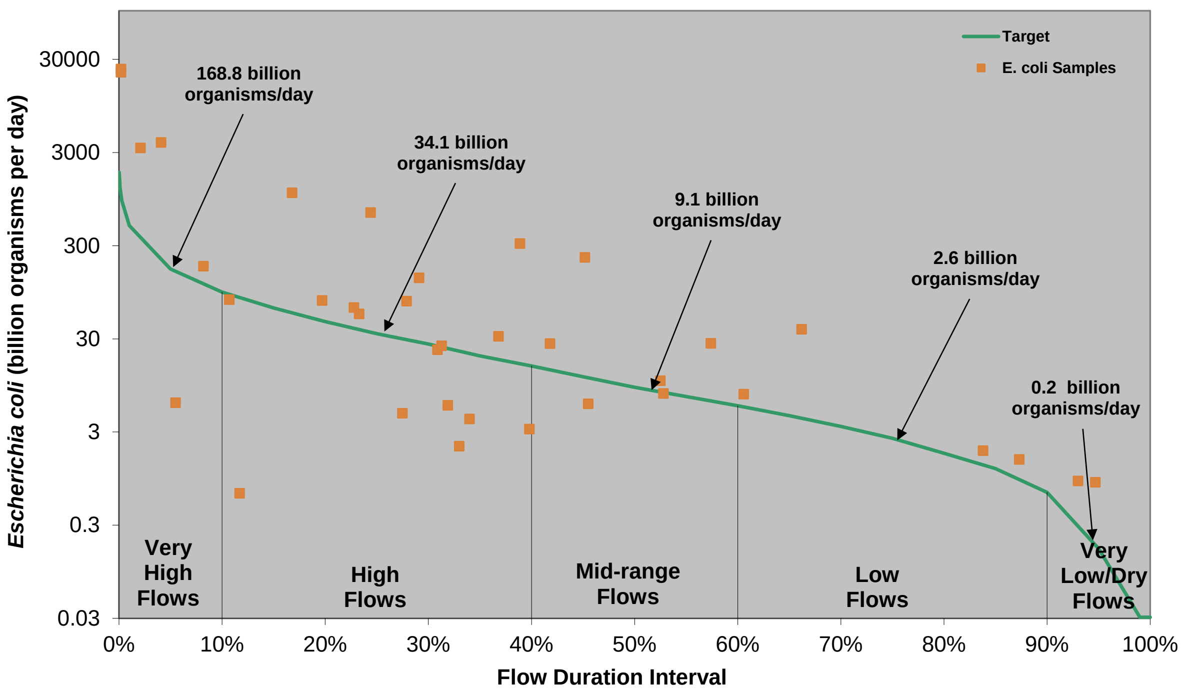
South Branch Yellow Medicine AUID# 07020004-503

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2009-2011 *E. coli* samples from EQuIS monitoring stations S001-156, S002-320, S002-330, S002-338
Loading capacity target set at 126 organisms/100ml



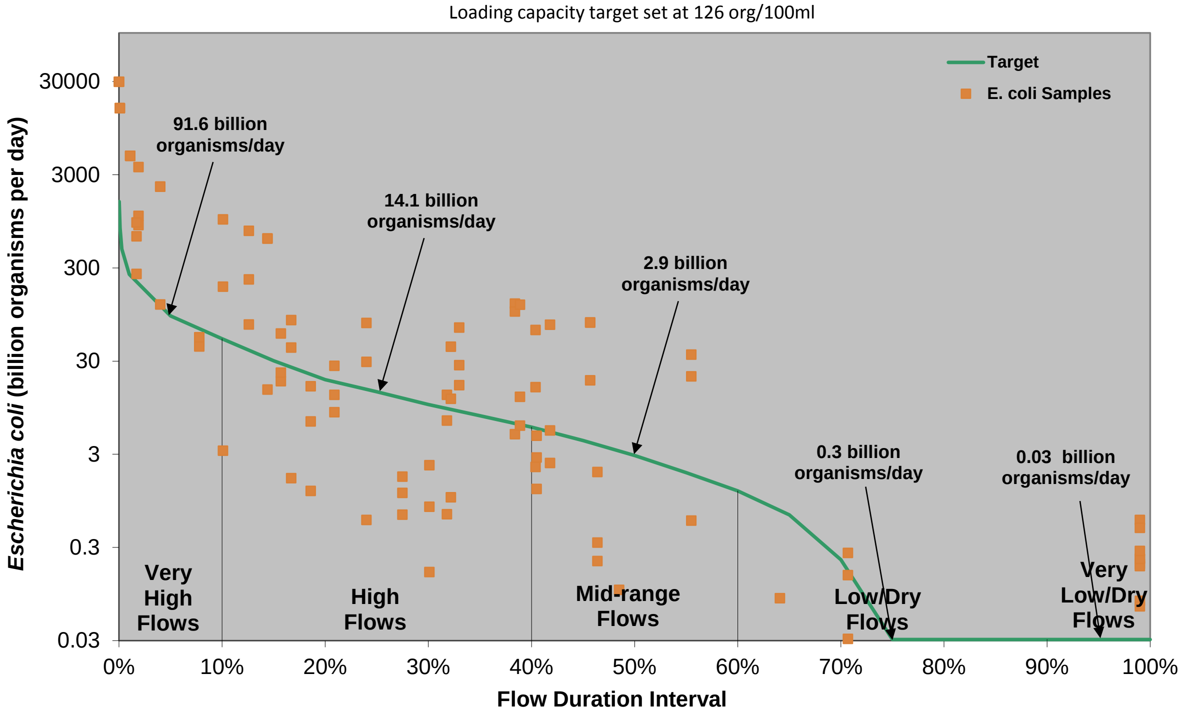
South Branch Yellow Medicine River AUID# 07020004-550

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2009-2010 E. coli samples from EQuIS monitoring station S002-331
Loading capacity target set at 126 organisms/100ml



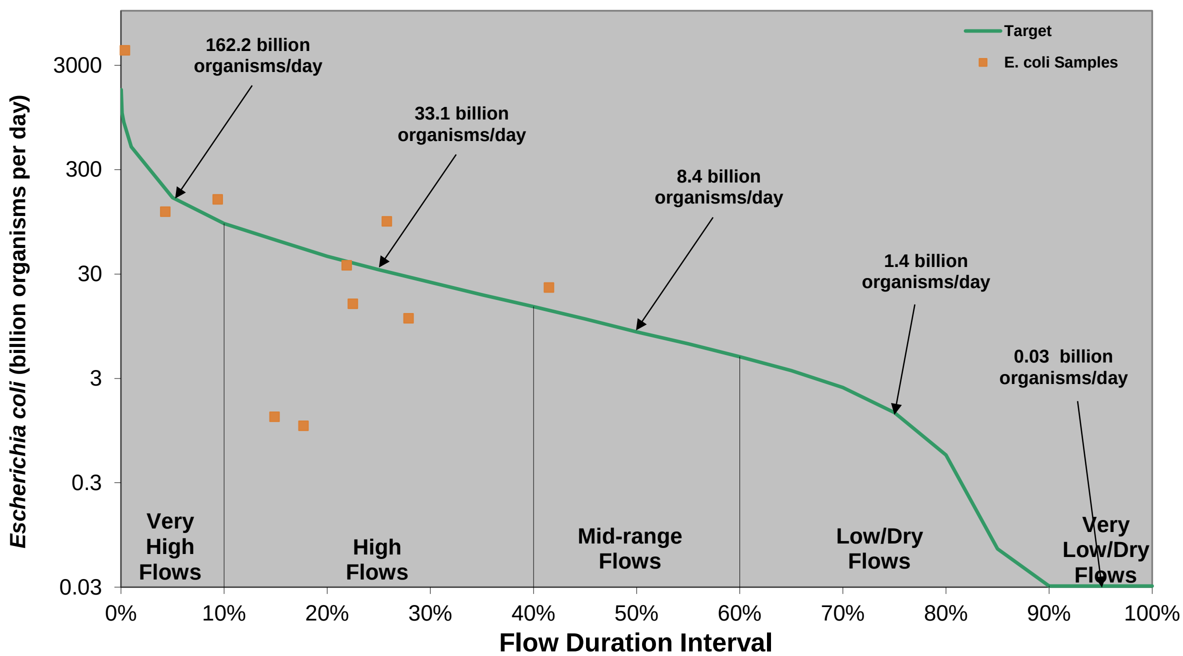
South Branch Yellow Medicine River AUID# 07020004-595, 597, 599

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2009-2010 *E. coli* samples from EQuIS monitoring stations S005-684; S002-349; S002-326
Loading capacity target set at 126 org/100ml



South Branch Yellow Medicine River AUID# 07020004-600

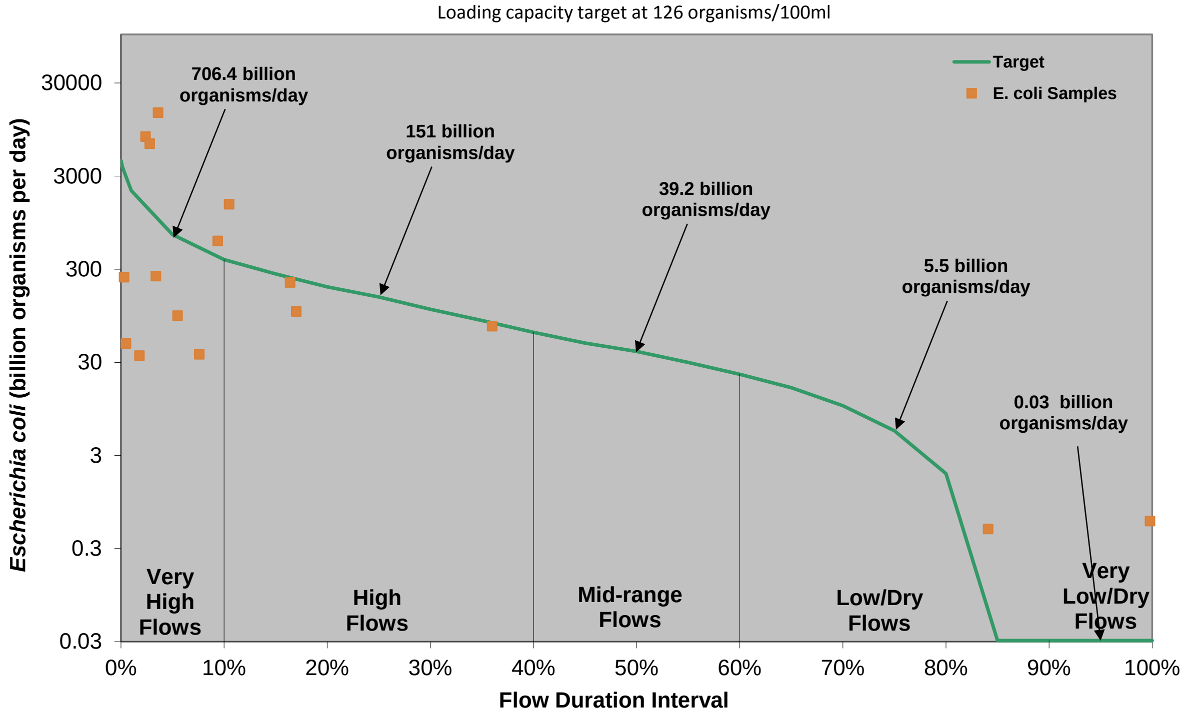
1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
1999 *E. coli** samples from EQuIS monitoring stations S002-334
Loading capacity target set at 126 org/100ml



*fecal colifrom converted into E. coli using the conversion factor of 126 CFU E. coli/200 CFU fecal coliform

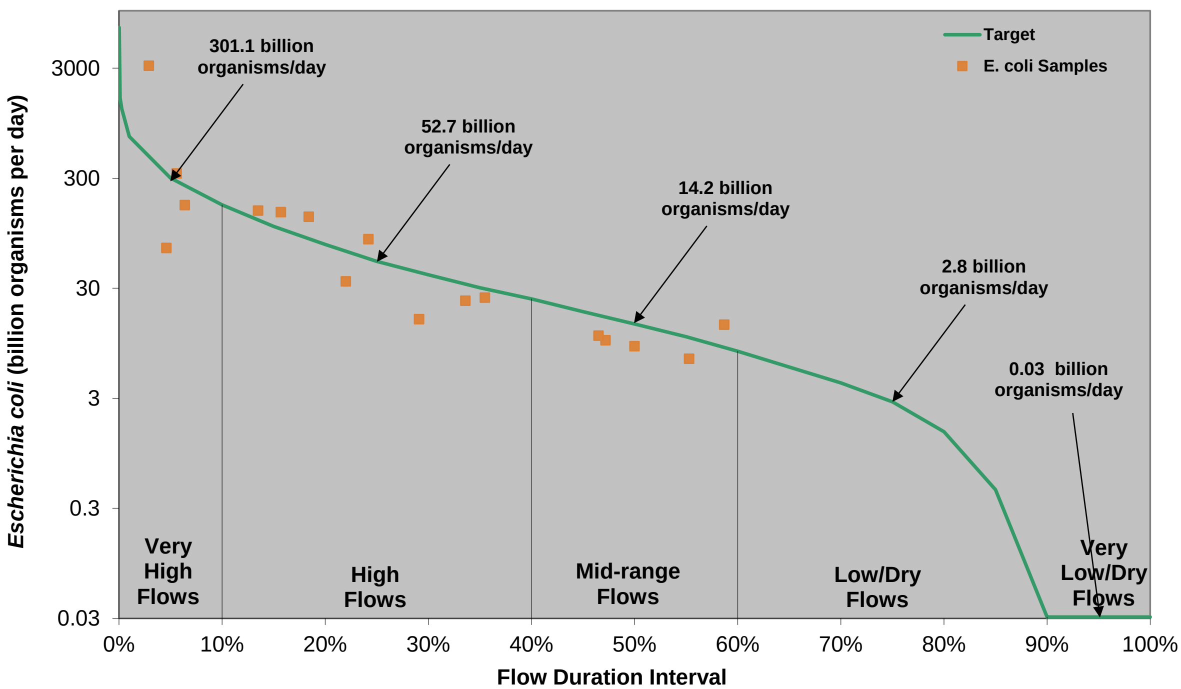
Spring Creek AUID# 07020004-538

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2011 *E. coli* samples from EQuIS monitoring station S002-318
Loading capacity target at 126 organisms/100ml



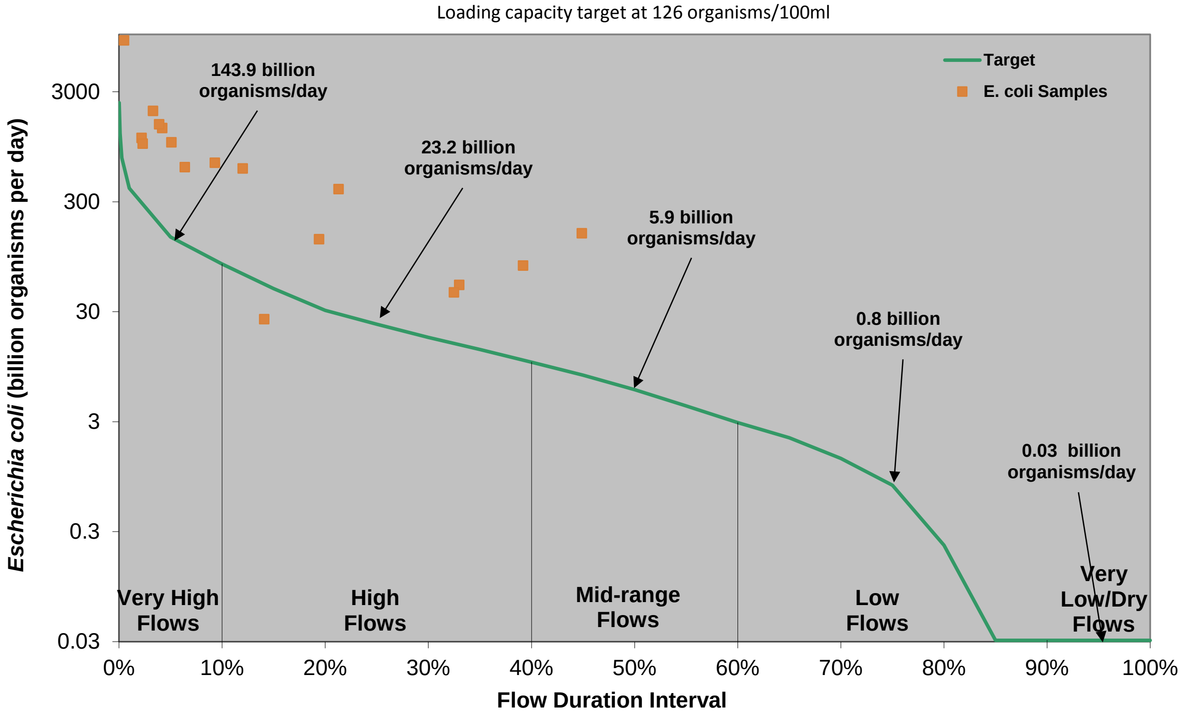
Stony Run Creek AUID# 07020004-535

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring station S006-171
Loading capacity target at 126 organisms/100ml



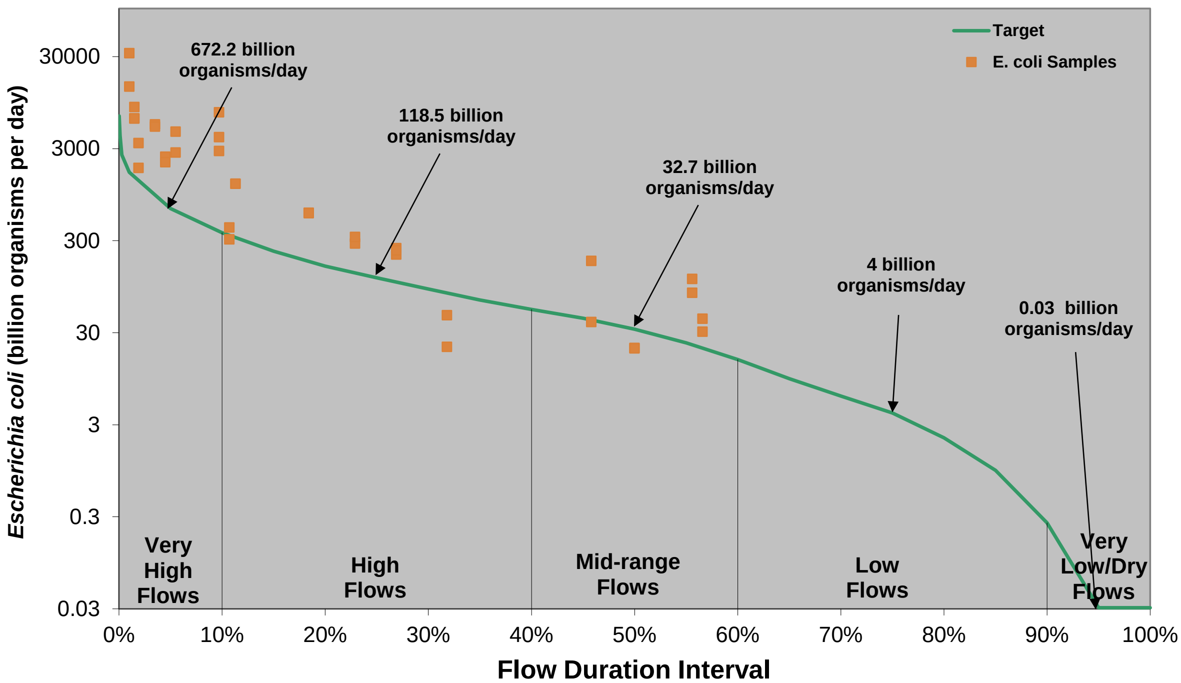
Upper Yellow Medicine River AUID# 07020004-545

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring station S006-170
Loading capacity target at 126 organisms/100ml



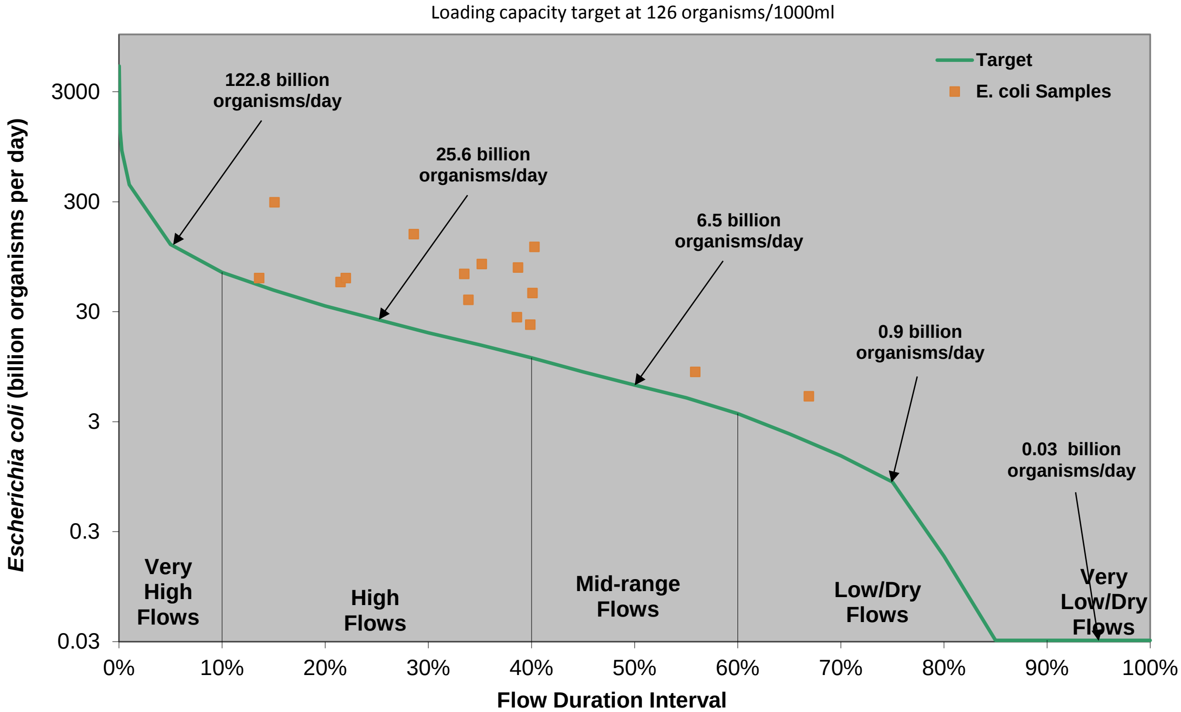
Upper Yellow Medicine River AUID# 07020004-584

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring stations S006-173; S002-323
Loading capacity target at 126 organisms/100ml



Wood Lake Creek - MN River AUID# 07020004-555

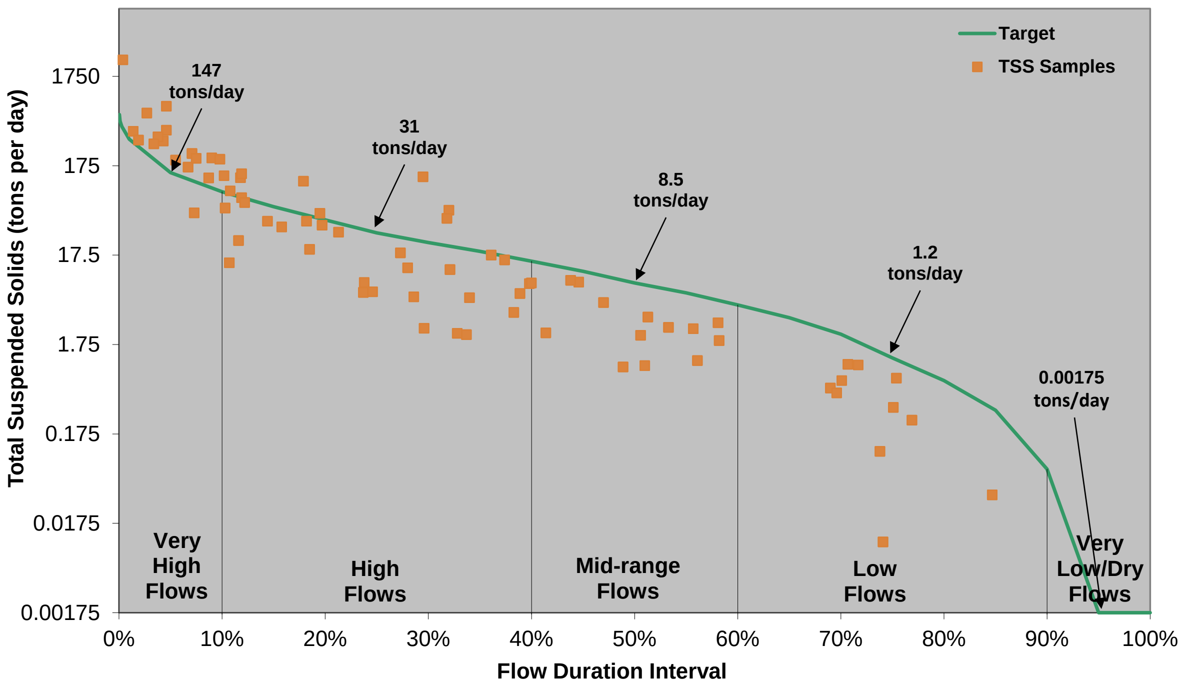
1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2010-2011 *E. coli* samples from EQuIS monitoring station S004-345
Loading capacity target at 126 organisms/1000ml



Load duration curves for turbidity (TSS) stream reach impairments

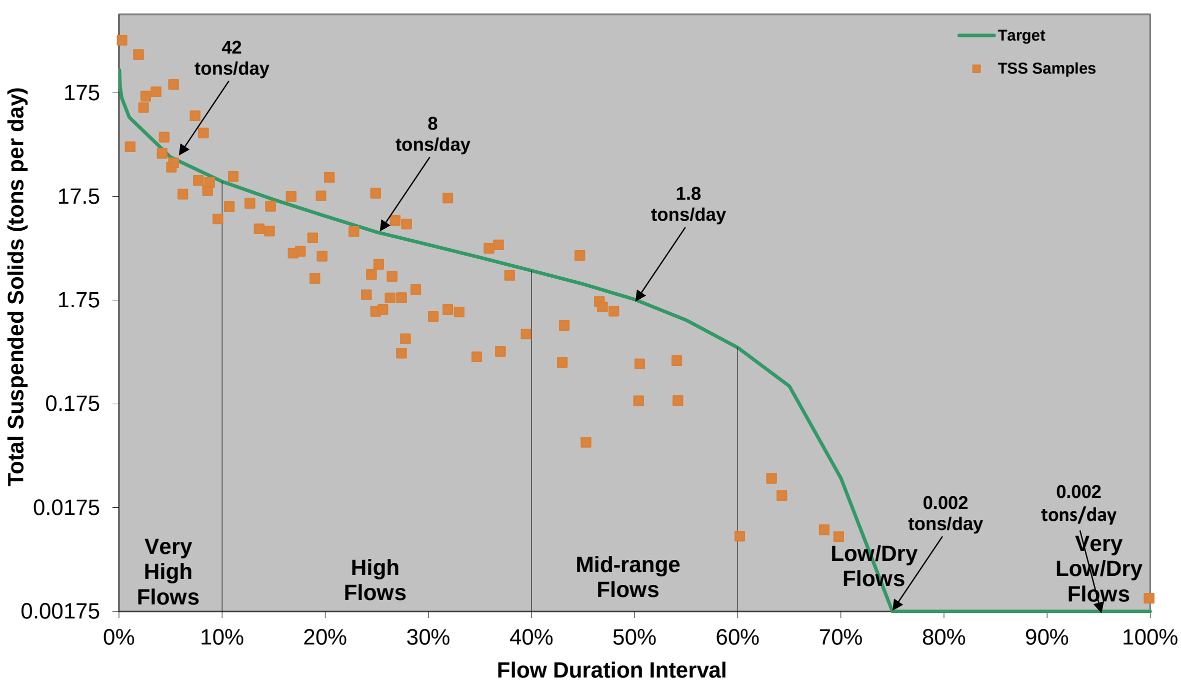
Lower Yellow Medicine River AUID# 07020004-513

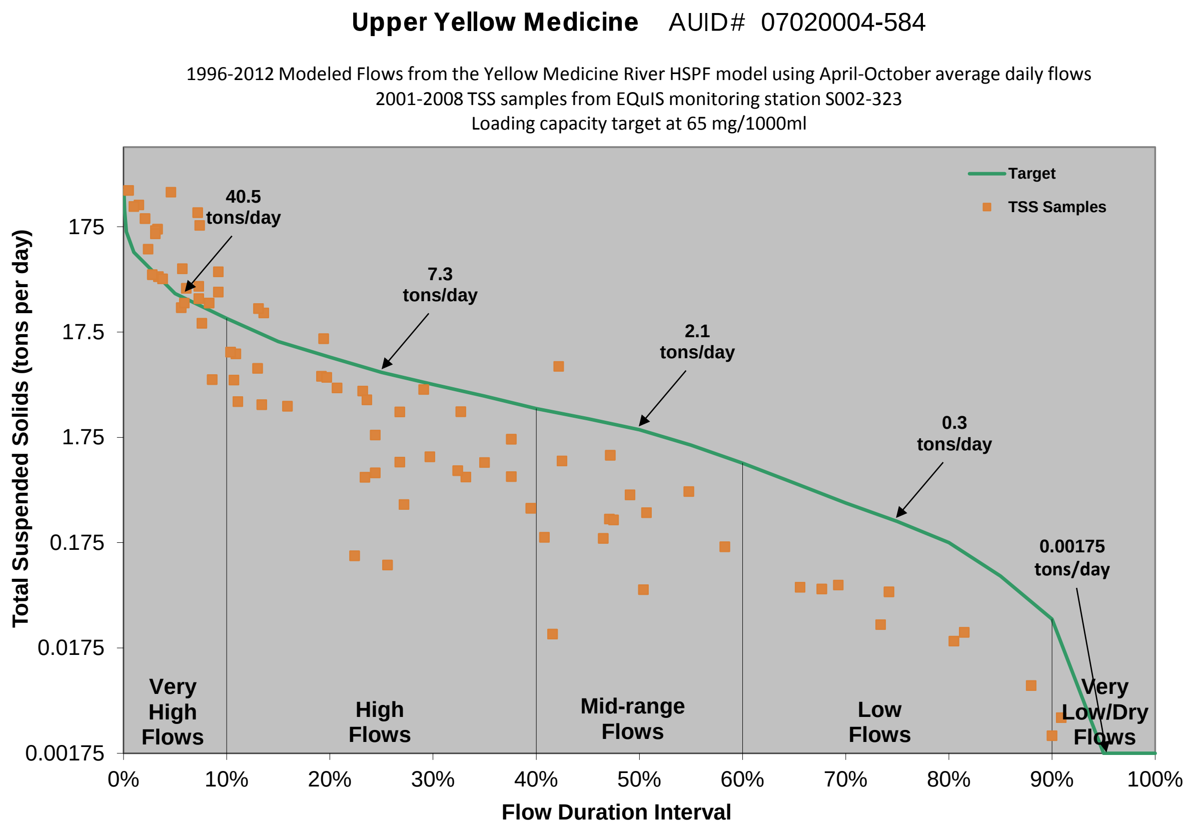
1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-September average daily flows
2001-2008 TSS samples from EQuIS monitoring station S002-317
Loading Capacity target set at 65 mg/1000ml



South Branch Yellow Medicine AUID# 07020004-503

1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2001-2008 TSS samples from EQuIS monitoring station S002-320
Loading capacity target set at 65 mg/1000ml




Upper Yellow Medicine AUID# 07020004-584
1996-2012 Modeled Flows from the Yellow Medicine River HSPF model using April-October average daily flows
2001-2008 TSS samples from EQuIS monitoring station S002-323
Loading capacity target at 65 mg/1000ml
Target
TSS Samples
40.5 tons/day
7.3 tons/day
2.1 tons/day
0.3 tons/day
0.00175 tons/day
Very High Flows
High Flows
Mid-range Flows
Low Flows
Very Low/Dry Flows
Total Suspended Solids (tons per day)
175
17.5
1.75
0.175
0.0175
0.00175
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Flow Duration Interval

Lake model output data

Lady Slipper Lake BATHTUB Model Run – Modeled to Observed In-lake Phosphorus

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Lady Slipper Lake Shed		0.4	0.00E+00	0.00	
PRECIPITATION				1.1	0.7	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					0.4	0.00E+00	0.00	
***TOTAL INFLOW				1.1	1.2	0.00E+00	0.00	1.09
ADVECTIVE OUTFLOW				1.1	0.2	0.00E+00	0.00	0.15
***TOTAL OUTFLOW				1.1	0.2	0.00E+00	0.00	0.15
***EVAPORATION					1.0	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	Load Variance %Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	SSTS	2.6	0.4%	0.00E+00		0.00	264.0	
2	2	1	Lady Slipper Lake Shed	136.0	18.1%	0.00E+00		0.00	312.3	
PRECIPITATION				31.8	4.2%	2.53E+02	100.0%	0.50	44.8	30.0
INTERNAL LOAD				580.7	77.3%	0.00E+00		0.00		
TRIBUTARY INFLOW				2.6	0.4%	0.00E+00		0.00	264.0	
NONPOINT INFLOW				136.0	18.1%	0.00E+00		0.00	312.3	
***TOTAL INFLOW				751.2	100.0%	2.53E+02	100.0%	0.02	650.0	708.6
ADVECTIVE OUTFLOW				27.7	3.7%	1.36E+02		0.42	173.7	26.1
***TOTAL OUTFLOW				27.7	3.7%	1.36E+02		0.42	173.7	26.1
***RETENTION				723.5	96.3%	3.78E+02		0.03		

Overflow Rate (m/yr)	0.2	Nutrient Resid. Time (yrs)	0.3433
Hydraulic Resid. Time (yrs)	9.3214	Turnover Ratio	2.9
Reservoir Conc (mg/m3)	174	Retention Coef.	0.963

Lady Slipper Lake BATHTUB Model Run – Modeled to Phosphorus Standard

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Lady Slipper Lake Shed		0.4	0.00E+00	0.00	
PRECIPITATION				1.1	0.7	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					0.4	0.00E+00	0.00	
***TOTAL INFLOW				1.1	1.2	0.00E+00	0.00	1.09
ADVECTIVE OUTFLOW				1.1	0.2	0.00E+00	0.00	0.15
***TOTAL OUTFLOW				1.1	0.2	0.00E+00	0.00	0.15
***EVAPORATION					1.0	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	SSTS	2.6	1.1%	0.00E+00		0.00	264.0	
2	2	1	Lady Slipper Lake Shed	136.0	57.6%	0.00E+00		0.00	312.3	
PRECIPITATION				31.8	13.5%	2.53E+02	100.0%	0.50	44.8	30.0
INTERNAL LOAD				65.8	27.9%	0.00E+00		0.00		
TRIBUTARY INFLOW				2.6	1.1%	0.00E+00		0.00	264.0	
NONPOINT INFLOW				136.0	57.6%	0.00E+00		0.00	312.3	
***TOTAL INFLOW				236.2	100.0%	2.53E+02	100.0%	0.07	204.4	222.9
ADVECTIVE OUTFLOW				14.4	6.1%	3.54E+01		0.41	90.5	13.6
***TOTAL OUTFLOW				14.4	6.1%	3.54E+01		0.41	90.5	13.6
***RETENTION				221.8	93.9%	2.71E+02		0.07		

Overflow Rate (m/yr)	0.2	Nutrient Resid. Time (yrs)	0.5685
Hydraulic Resid. Time (yrs)	9.3214	Turnover Ratio	1.8
Reservoir Conc (mg/m3)	90	Retention Coef.	0.939

Wood Lake BATHTUB Model Run – Modeled to Observed In-lake Phosphorus

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Wood Lake Shed		2.0	0.00E+00	0.00	
PRECIPITATION				2.0	1.3	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					2.0	0.00E+00	0.00	
***TOTAL INFLOW				2.0	3.3	0.00E+00	0.00	1.71
ADVECTIVE OUTFLOW				2.0	1.5	0.00E+00	0.00	0.77
***TOTAL OUTFLOW				2.0	1.5	0.00E+00	0.00	0.77
***EVAPORATION					1.8	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	Load %Total	Load Variance (kg/yr)^2	Load Variance %Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	SSTS	12.5	0.9%	0.00E+00		0.00	1251.4	
2	2	1	Wood Lake Shed	498.4	35.6%	0.00E+00		0.00	246.1	
PRECIPITATION				58.8	4.2%	8.64E+02	100.0%	0.50	44.8	30.0
INTERNAL LOAD				830.4	59.3%	0.00E+00		0.00		
TRIBUTARY INFLOW				12.5	0.9%	0.00E+00		0.00	1251.4	
NONPOINT INFLOW				498.4	35.6%	0.00E+00		0.00	246.1	
***TOTAL INFLOW				1400.1	100.0%	8.64E+02	100.0%	0.02	418.1	714.3
ADVECTIVE OUTFLOW				198.5	14.2%	5.59E+03		0.38	131.8	101.3
***TOTAL OUTFLOW				198.5	14.2%	5.59E+03		0.38	131.8	101.3
***RETENTION				1201.6	85.8%	6.31E+03		0.07		

Overflow Rate (m/yr)	0.8	Nutrient Resid. Time (yrs)	0.3505
Hydraulic Resid. Time (yrs)	2.4724	Turnover Ratio	2.9
Reservoir Conc (mg/m3)	132	Retention Coef.	0.858

Wood Lake BATHTUB Model Run – Modeled to Phosphorus Standard

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Wood Lake Shed		2.0	0.00E+00	0.00	
PRECIPITATION				2.0	1.3	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					2.0	0.00E+00	0.00	
***TOTAL INFLOW				2.0	3.3	0.00E+00	0.00	1.71
ADVECTIVE OUTFLOW				2.0	1.5	0.00E+00	0.00	0.77
***TOTAL OUTFLOW				2.0	1.5	0.00E+00	0.00	0.77
***EVAPORATION					1.8	0.00E+00	0.00	

Overall Mass Balance Based Upon — **Predicted** — **Outflow & Reservoir Concentrations**

Component: — **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	SSTS	12.5	1.7%	0.00E+00		0.00	1251.4	
2	2	1	Wood Lake Shed	498.4	66.6%	0.00E+00		0.00	246.1	
PRECIPITATION				58.8	7.9%	8.64E+02	100.0%	0.50	44.8	30.0
INTERNAL LOAD				179.0	23.9%	0.00E+00		0.00		
TRIBUTARY INFLOW				12.5	1.7%	0.00E+00		0.00	1251.4	
NONPOINT INFLOW				498.4	66.6%	0.00E+00		0.00	246.1	
***TOTAL INFLOW				748.7	100.0%	8.64E+02	100.0%	0.04	223.6	382.0
ADVECTIVE OUTFLOW				135.0	18.0%	2.37E+03		0.36	89.6	68.9
***TOTAL OUTFLOW				135.0	18.0%	2.37E+03		0.36	89.6	68.9
***RETENTION				613.6	82.0%	3.04E+03		0.09		

Overflow Rate (m/yr)	0.8	Nutrient Resid. Time (yrs)	0.4459
Hydraulic Resid. Time (yrs)	2.4724	Turnover Ratio	2.2
Reservoir Conc (mg/m3)	90	Retention Coef.	0.820

Cottonwood Lake BATHTUB Model Run – Modeled to Observed In-lake Phosphorus

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	ISTS		0.0	0.00E+00	0.00	
2	2	1	Cottonwood Lake Shed		5.9	0.00E+00	0.00	
PRECIPITATION				1.5	1.0	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					5.9	0.00E+00	0.00	
***TOTAL INFLOW				1.5	6.9	0.00E+00	0.00	4.47
ADVECTIVE OUTFLOW				1.5	5.5	0.00E+00	0.00	3.53
***TOTAL OUTFLOW				1.5	5.5	0.00E+00	0.00	3.53
***EVAPORATION					1.5	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	Load Variance %Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	ISTS	28.4	1.4%	0.00E+00		0.00	2843.9	
2	2	1	Cottonwood Lake Shed	1717.0	85.3%	0.00E+00		0.00	292.2	
PRECIPITATION				46.5	2.3%	5.41E+02	100.0%	0.50	44.8	30.0
INTERNAL LOAD				220.8	11.0%	0.00E+00		0.00		
TRIBUTARY INFLOW				28.4	1.4%	0.00E+00		0.00	2843.9	
NONPOINT INFLOW				1717.0	85.3%	0.00E+00		0.00	292.2	
***TOTAL INFLOW				2012.8	100.0%	5.41E+02	100.0%	0.01	290.6	1298.6
ADVECTIVE OUTFLOW				903.2	44.9%	4.86E+04		0.24	165.2	582.7
***TOTAL OUTFLOW				903.2	44.9%	4.86E+04		0.24	165.2	582.7
***RETENTION				1109.6	55.1%	4.88E+04		0.20		

Overflow Rate (m/yr)	3.5	Nutrient Resid. Time (yrs)	0.1280
Hydraulic Resid. Time (yrs)	0.2852	Turnover Ratio	7.8
Reservoir Conc (mg/m3)	165	Retention Coef.	0.551

Cottonwood Lake BATHTUB Model Run – Modeled to Phosphorus Standard

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	ISTS		0.0	0.00E+00	0.00	
2	2	1	Cottonwood Lake Shed		5.9	0.00E+00	0.00	
PRECIPITATION				1.5	1.0	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					5.9	0.00E+00	0.00	
***TOTAL INFLOW				1.5	6.9	0.00E+00	0.00	4.47
ADVECTIVE OUTFLOW				1.5	5.5	0.00E+00	0.00	3.53
***TOTAL OUTFLOW				1.5	5.5	0.00E+00	0.00	3.53
***EVAPORATION					1.5	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	ISTS	28.4	3.1%	0.00E+00		0.00	2843.9	
2	2	1	Cottonwood Lake Shed	842.4	91.8%	0.00E+00		0.00	143.3	
PRECIPITATION				46.5	5.1%	5.41E+02	100.0%	0.50	44.8	30.0
TRIBUTARY INFLOW				28.4	3.1%	0.00E+00		0.00	2843.9	
NONPOINT INFLOW				842.4	91.8%	0.00E+00		0.00	143.3	
***TOTAL INFLOW				917.4	100.0%	5.41E+02	100.0%	0.03	132.5	591.9
ADVECTIVE OUTFLOW				494.0	53.8%	1.03E+04		0.21	90.3	318.7
***TOTAL OUTFLOW				494.0	53.8%	1.03E+04		0.21	90.3	318.7
***RETENTION				423.4	46.2%	1.04E+04		0.24		

Overflow Rate (m/yr)	3.5	Nutrient Resid. Time (yrs)	0.1535
Hydraulic Resid. Time (yrs)	0.2852	Turnover Ratio	6.5
Reservoir Conc (mg/m3)	90	Retention Coef.	0.462

Steep Bank Lake BATHTUB Model Run – Modeled to Observed In-lake Phosphorus

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Steep Bank Lake Shed		0.5	0.00E+00	0.00	
PRECIPITATION				0.8	0.6	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					0.5	0.00E+00	0.00	
***TOTAL INFLOW				0.8	1.1	0.00E+00	0.00	1.33
ADVECTIVE OUTFLOW				0.8	0.3	0.00E+00	0.00	0.39
***TOTAL OUTFLOW				0.8	0.3	0.00E+00	0.00	0.39
***EVAPORATION					0.8	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	Load Variance %Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	SSTS	2.8	0.8%	0.00E+00		0.00	278.5	
2	2	1	Steep Bank Lake Shed	176.0	51.0%	0.00E+00		0.00	324.7	
PRECIPITATION				25.2	7.3%	1.59E+02	100.0%	0.50	44.8	30.0
INTERNAL LOAD				141.1	40.9%	0.00E+00		0.00		
TRIBUTARY INFLOW				2.8	0.8%	0.00E+00		0.00	278.5	
NONPOINT INFLOW				176.0	51.0%	0.00E+00		0.00	324.7	
***TOTAL INFLOW				345.2	100.0%	1.59E+02	100.0%	0.04	309.6	410.9
ADVECTIVE OUTFLOW				45.5	13.2%	3.01E+02		0.38	139.9	54.2
***TOTAL OUTFLOW				45.5	13.2%	3.01E+02		0.38	139.9	54.2
***RETENTION				299.7	86.8%	4.35E+02		0.07		

Overflow Rate (m/yr)	0.4	Nutrient Resid. Time (yrs)	0.3404
Hydraulic Resid. Time (yrs)	2.5823	Turnover Ratio	2.9
Reservoir Conc (mg/m3)	140	Retention Coef.	0.868

Steep Bank Lake BATHTUB Model Run – Modeled to Phosphorus Standard

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Steep Bank Lake Shed		0.5	0.00E+00	0.00	
PRECIPITATION				0.8	0.6	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					0.5	0.00E+00	0.00	
***TOTAL INFLOW				0.8	1.1	0.00E+00	0.00	1.33
ADVECTIVE OUTFLOW				0.8	0.3	0.00E+00	0.00	0.39
***TOTAL OUTFLOW				0.8	0.3	0.00E+00	0.00	0.39
***EVAPORATION					0.8	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Component: TOTAL P — Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	Load Variance %Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	SSTS	2.8	1.7%	0.00E+00		0.00	278.5	
2	2	1	Steep Bank Lake Shed	138.4	83.2%	0.00E+00		0.00	255.4	
PRECIPITATION				25.2	15.1%	1.59E+02	100.0%	0.50	44.8	30.0
TRIBUTARY INFLOW				2.8	1.7%	0.00E+00		0.00	278.5	
NONPOINT INFLOW				138.4	83.2%	0.00E+00		0.00	255.4	
***TOTAL INFLOW				166.4	100.0%	1.59E+02	100.0%	0.08	149.3	198.1
ADVECTIVE OUTFLOW				29.1	17.5%	1.13E+02		0.37	89.5	34.7
***TOTAL OUTFLOW				29.1	17.5%	1.13E+02		0.37	89.5	34.7
***RETENTION				137.3	82.5%	2.37E+02		0.11		

Overflow Rate (m/yr)	0.4	Nutrient Resid. Time (yrs)	0.4518
Hydraulic Resid. Time (yrs)	2.5822	Turnover Ratio	2.2
Reservoir Conc (mg/m3)	90	Retention Coef.	0.825

Stay Lake BATHTUB Model Run – Modeled to Observed In-lake Phosphorus

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Stay Lake Shed		3.0	0.00E+00	0.00	
PRECIPITATION				0.9	0.6	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					3.0	0.00E+00	0.00	
***TOTAL INFLOW				0.9	3.6	0.00E+00	0.00	4.00
ADVECTIVE OUTFLOW				0.9	2.7	0.00E+00	0.00	3.06
***TOTAL OUTFLOW				0.9	2.7	0.00E+00	0.00	3.06
***EVAPORATION					0.8	0.00E+00	0.00	

Overall Mass Balance Based Upon — **Predicted** — **Outflow & Reservoir Concentrations**

Component: **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	Load Variance %Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	SSTS	10.2	1.4%	0.00E+00		0.00	1019.7	
2	2	1	Stay Lake Shed	717.2	95.1%	0.00E+00		0.00	242.9	
PRECIPITATION				26.7	3.5%	1.78E+02	100.0%	0.50	44.8	30.0
TRIBUTARY INFLOW				10.2	1.4%	0.00E+00		0.00	1019.7	
NONPOINT INFLOW				717.2	95.1%	0.00E+00		0.00	242.9	
***TOTAL INFLOW				754.1	100.0%	1.78E+02	100.0%	0.02	211.9	847.3
ADVECTIVE OUTFLOW				348.3	46.2%	6.91E+03		0.24	127.9	391.3
***TOTAL OUTFLOW				348.3	46.2%	6.91E+03		0.24	127.9	391.3
***RETENTION				405.8	53.8%	6.96E+03		0.21		

Overflow Rate (m/yr)	3.1	Nutrient Resid. Time (yrs)	0.1519
Hydraulic Resid. Time (yrs)	0.3289	Turnover Ratio	6.6
Reservoir Conc (mg/m3)	128	Retention Coef.	0.538

Stay Lake BATHTUB Model Run – Modeled to Phosphorus Standard

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Stay Lake Shed		3.0	0.00E+00	0.00	
PRECIPITATION				0.9	0.6	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					3.0	0.00E+00	0.00	
***TOTAL INFLOW				0.9	3.6	0.00E+00	0.00	4.00
ADVECTIVE OUTFLOW				0.9	2.7	0.00E+00	0.00	3.06
***TOTAL OUTFLOW				0.9	2.7	0.00E+00	0.00	3.06
***EVAPORATION					0.8	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	Load Variance %Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	SSTS	10.2	2.1%	0.00E+00		0.00	1019.7	
2	2	1	Stay Lake Shed	440.9	92.3%	0.00E+00		0.00	149.3	
PRECIPITATION				26.7	5.6%	1.78E+02	100.0%	0.50	44.8	30.0
TRIBUTARY INFLOW				10.2	2.1%	0.00E+00		0.00	1019.7	
NONPOINT INFLOW				440.9	92.3%	0.00E+00		0.00	149.3	
***TOTAL INFLOW				477.8	100.0%	1.78E+02	100.0%	0.03	134.2	536.8
ADVECTIVE OUTFLOW				245.6	51.4%	2.83E+03		0.22	90.2	275.9
***TOTAL OUTFLOW				245.6	51.4%	2.83E+03		0.22	90.2	275.9
***RETENTION				232.2	48.6%	2.87E+03		0.23		

Overflow Rate (m/yr)	3.1	Nutrient Resid. Time (yrs)	0.1690
Hydraulic Resid. Time (yrs)	0.3289	Turnover Ratio	5.9
Reservoir Conc (mg/m3)	90	Retention Coef.	0.486

Perch Lake BATHTUB Model Run – Modeled to Observed In-lake Phosphorus

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Perch Lake Shed		0.3	0.00E+00	0.00	
PRECIPITATION				0.9	0.6	0.00E+00	0.00	0.68
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					0.3	0.00E+00	0.00	
***TOTAL INFLOW				0.9	0.9	0.00E+00	0.00	0.97
ADVECTIVE OUTFLOW				0.9	0.0	0.00E+00	0.00	0.03
***TOTAL OUTFLOW				0.9	0.0	0.00E+00	0.00	0.03
***EVAPORATION					0.9	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	Load %Total	Load Variance (kg/yr)²	Load Variance %Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	SSTS	1.2	0.1%	0.00E+00		0.00	121.6	
2	2	1	Perch Lake Shed	61.6	5.8%	0.00E+00		0.00	242.0	
PRECIPITATION				27.6	2.6%	1.90E+02	100.0%	0.50	44.1	30.0
INTERNAL LOAD				977.8	91.5%	0.00E+00		0.00		
TRIBUTARY INFLOW				1.2	0.1%	0.00E+00		0.00	121.6	
NONPOINT INFLOW				61.6	5.8%	0.00E+00		0.00	242.0	
***TOTAL INFLOW				1068.3	100.0%	1.90E+02	100.0%	0.01	1199.9	1161.2
ADVECTIVE OUTFLOW				5.8	0.5%	6.28E+00		0.43	225.9	6.3
***TOTAL OUTFLOW				5.8	0.5%	6.28E+00		0.43	225.9	6.3
***RETENTION				1062.5	99.5%	1.96E+02		0.01		

Overflow Rate (m/yr)	0.0	Nutrient Resid. Time (yrs)	0.2918
Hydraulic Resid. Time (yrs)	54.0604	Turnover Ratio	3.4
Reservoir Conc (mg/m3)	226	Retention Coef.	0.995

Perch Lake BATHTUB Model Run – Modeled to Phosphorus Standard

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Perch Lake Shed		0.3	0.00E+00	0.00	
PRECIPITATION				0.9	0.6	0.00E+00	0.00	0.68
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					0.3	0.00E+00	0.00	
***TOTAL INFLOW				0.9	0.9	0.00E+00	0.00	0.97
ADVECTIVE OUTFLOW				0.9	0.0	0.00E+00	0.00	0.03
***TOTAL OUTFLOW				0.9	0.0	0.00E+00	0.00	0.03
***EVAPORATION					0.9	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted **Outflow & Reservoir Concentrations**
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	SSTS	1.2	0.6%	0.00E+00		0.00	121.6	
2	2	1	Perch Lake Shed	61.6	31.1%	0.00E+00		0.00	242.0	
PRECIPITATION				27.6	13.9%	1.90E+02	100.0%	0.50	44.1	30.0
INTERNAL LOAD				107.5	54.3%	0.00E+00		0.00		
TRIBUTARY INFLOW				1.2	0.6%	0.00E+00		0.00	121.6	
NONPOINT INFLOW				61.6	31.1%	0.00E+00		0.00	242.0	
***TOTAL INFLOW				198.0	100.0%	1.90E+02	100.0%	0.07	222.4	215.2
ADVECTIVE OUTFLOW				2.3	1.2%	9.93E-01		0.43	90.0	2.5
***TOTAL OUTFLOW				2.3	1.2%	9.93E-01		0.43	90.0	2.5
***RETENTION				195.7	98.8%	1.89E+02		0.07		

Overflow Rate (m/yr)	0.0	Nutrient Resid. Time (yrs)	0.6275
Hydraulic Resid. Time (yrs)	54.0604	Turnover Ratio	1.6
Reservoir Conc (mg/m3)	90	Retention Coef.	0.988

Curtis Lake BATHTUB Model Run – Modeled to Observed In-lake Phosphorus

Overall Water & Nutrient Balances

Overall Water Balance					Averaging Period =		1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	Type	Seg	Name	km^2	hm^3/yr	$(hm3/yr)^2$	-	m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Curtis Lake Shed		2.0	0.00E+00	0.00	
PRECIPITATION				1.8	1.2	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					2.0	0.00E+00	0.00	
***TOTAL INFLOW				1.8	3.2	0.00E+00	0.00	1.81
ADVECTIVE OUTFLOW				1.8	1.6	0.00E+00	0.00	0.87
***TOTAL OUTFLOW				1.8	1.6	0.00E+00	0.00	0.87
***EVAPORATION					1.7	0.00E+00	0.00	

Overall Mass Balance Based Upon				Predicted		Outflow & Reservoir Concentrations				
Component:				TOTAL P						
				Load		Load Variance			Conc	Export
Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
1	1	1	SSTS	11.4	1.1%	0.00E+00		0.00	1138.5	
2	2	1	Curtis Lake Shed	650.5	61.4%	0.00E+00		0.00	321.0	
PRECIPITATION				53.4	5.0%	7.13E+02	100.0%	0.50	44.8	30.0
INTERNAL LOAD				344.6	32.5%	0.00E+00		0.00		
TRIBUTARY INFLOW				11.4	1.1%	0.00E+00		0.00	1138.5	
NONPOINT INFLOW				650.5	61.4%	0.00E+00		0.00	321.0	
***TOTAL INFLOW				1059.8	100.0%	7.13E+02	100.0%	0.03	328.2	595.4
ADVECTIVE OUTFLOW				469.3	44.3%	1.35E+04		0.25	301.6	263.6
***TOTAL OUTFLOW				469.3	44.3%	1.35E+04		0.25	301.6	263.6
***RETENTION				590.6	55.7%	1.36E+04		0.20		

Overflow Rate (m/yr)	0.9	Nutrient Resid. Time (yrs)	0.5572
Hydraulic Resid. Time (yrs)	1.2585	Turnover Ratio	1.8
Reservoir Conc (mg/m3)	302	Retention Coef.	0.557

Curtis Lake BATHTUB Model Run – Modeled to Phosphorus Standard

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	SSTS		0.0	0.00E+00	0.00	
2	2	1	Curtis Lake Shed		2.0	0.00E+00	0.00	
PRECIPITATION				1.8	1.2	0.00E+00	0.00	0.67
TRIBUTARY INFLOW					0.0	0.00E+00	0.00	
NONPOINT INFLOW					2.0	0.00E+00	0.00	
***TOTAL INFLOW				1.8	3.2	0.00E+00	0.00	1.81
ADVECTIVE OUTFLOW				1.8	1.6	0.00E+00	0.00	0.87
***TOTAL OUTFLOW				1.8	1.6	0.00E+00	0.00	0.87
***EVAPORATION					1.7	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	Load Variance %Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	SSTS	11.4	3.6%	0.00E+00		0.00	1138.5	
2	2	1	Curtis Lake Shed	250.5	79.5%	0.00E+00		0.00	123.6	
PRECIPITATION				53.4	16.9%	7.13E+02	100.0%	0.50	44.8	30.0
TRIBUTARY INFLOW				11.4	3.6%	0.00E+00		0.00	1138.5	
NONPOINT INFLOW				250.5	79.5%	0.00E+00		0.00	123.6	
***TOTAL INFLOW				315.3	100.0%	7.13E+02	100.0%	0.08	97.6	177.1
ADVECTIVE OUTFLOW				139.6	44.3%	1.32E+03		0.26	89.7	78.4
***TOTAL OUTFLOW				139.6	44.3%	1.32E+03		0.26	89.7	78.4
***RETENTION				175.7	55.7%	1.41E+03		0.21		

Overflow Rate (m/yr)	0.9	Nutrient Resid. Time (yrs)	0.5572
Hydraulic Resid. Time (yrs)	1.2585	Turnover Ratio	1.8
Reservoir Conc (mg/m3)	90	Retention Coef.	0.557

Appendix C

HSPF Flow and Water Quality Calibration Results

Hydrologic Calibration and Validation for the Hawk Creek/Yellow Medicine HSPF Model

1 Yellow Medicine River near Granite Falls, 2001-2009

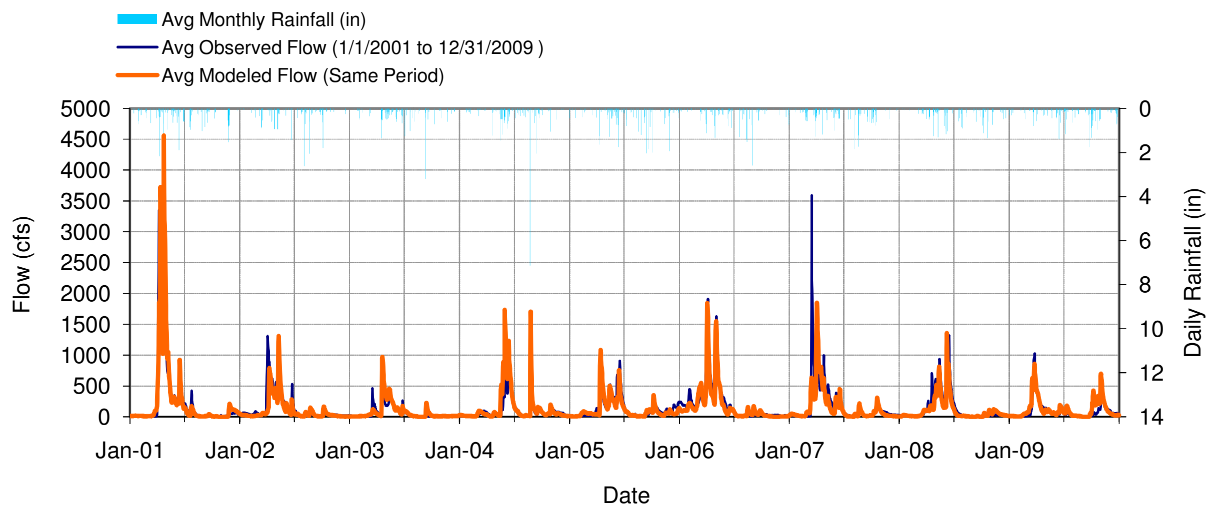


Figure 1. Mean daily flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN

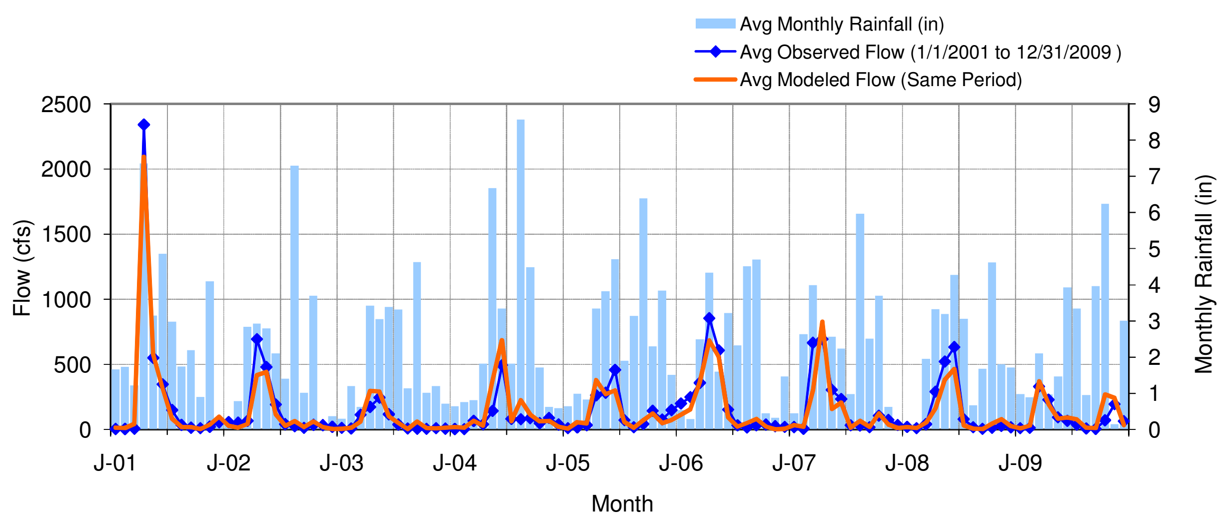


Figure 2. Mean monthly flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN

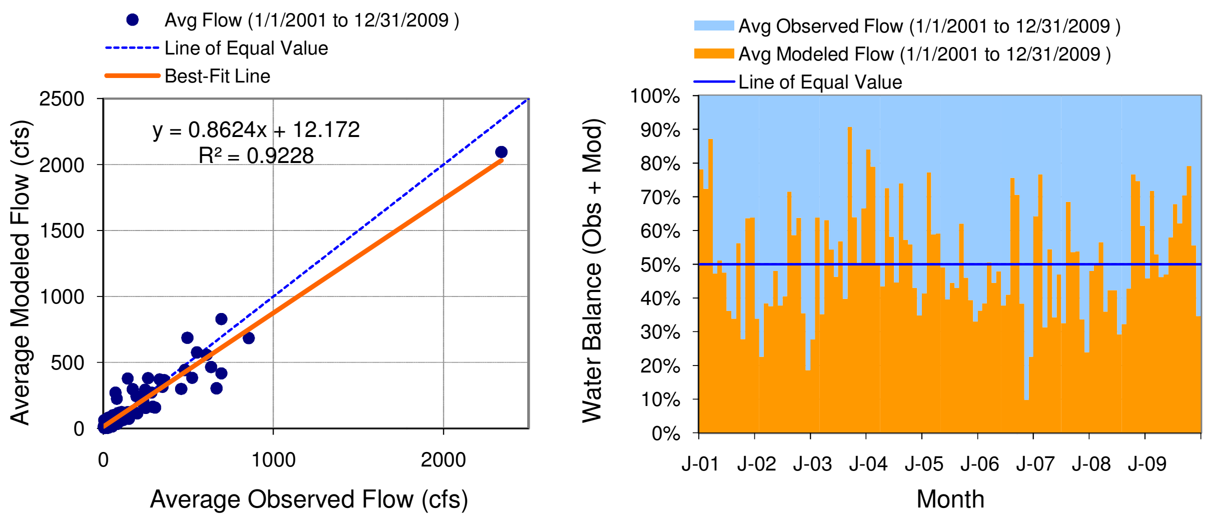


Figure 3. **Monthly flow regression and temporal variation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

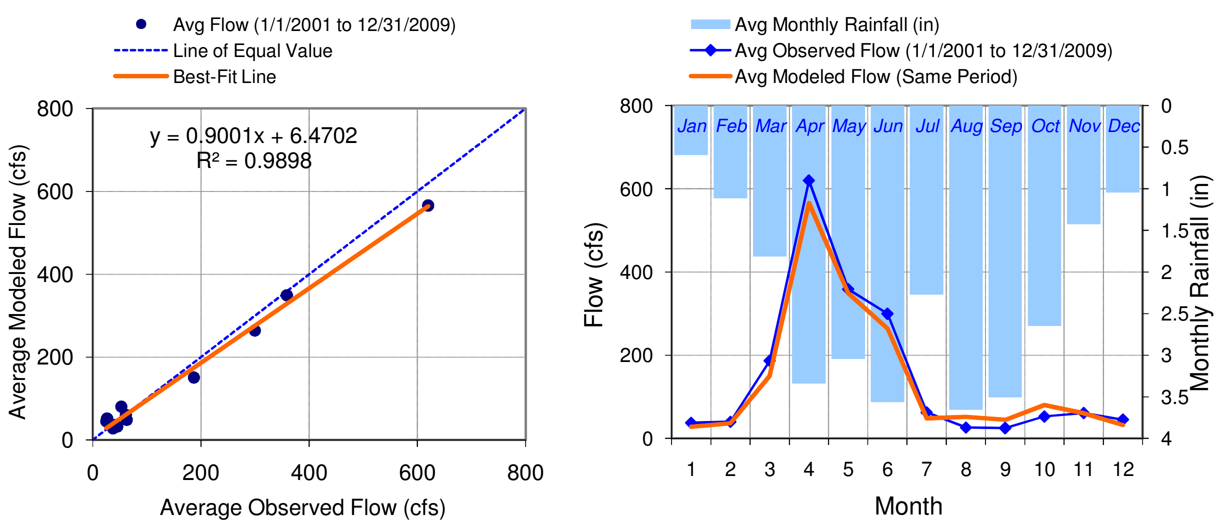


Figure 4. **Seasonal regression and temporal aggregate: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

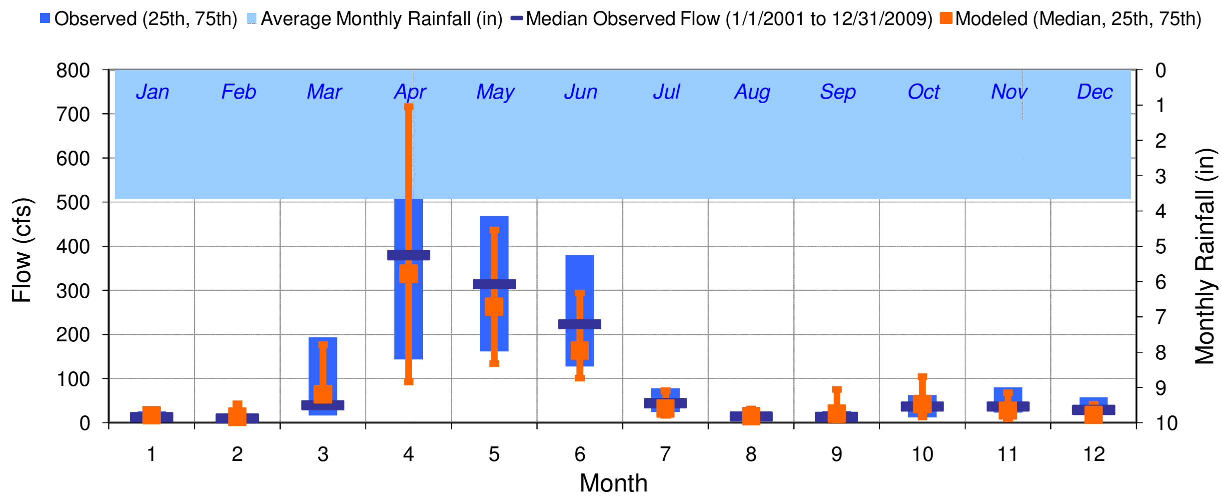


Figure 5. Seasonal medians and ranges: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN

Table 1. Seasonal summary: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	37.55	13.00	7.00	26.00	27.95	17.15	7.95	29.37
Feb	40.05	9.90	5.43	20.75	36.19	14.08	10.23	43.05
Mar	186.93	40.00	16.50	193.50	150.64	64.68	39.54	177.83
Apr	619.86	380.00	143.25	681.25	565.99	337.70	93.09	716.46
May	358.79	314.00	161.50	468.50	349.39	263.51	134.21	437.17
Jun	299.69	223.50	128.00	379.75	264.07	163.64	101.26	294.75
Jul	62.77	44.00	24.50	78.50	48.51	32.38	16.94	72.69
Aug	26.48	14.00	9.95	23.00	51.81	14.86	8.34	31.32
Sep	25.19	13.50	6.53	26.75	44.80	20.86	6.00	76.06
Oct	52.79	37.00	12.00	63.00	80.60	42.80	13.53	104.88
Nov	61.25	37.00	23.00	80.75	60.76	27.70	9.71	68.95
Dec	45.34	29.00	19.00	58.00	32.17	18.17	8.58	42.50

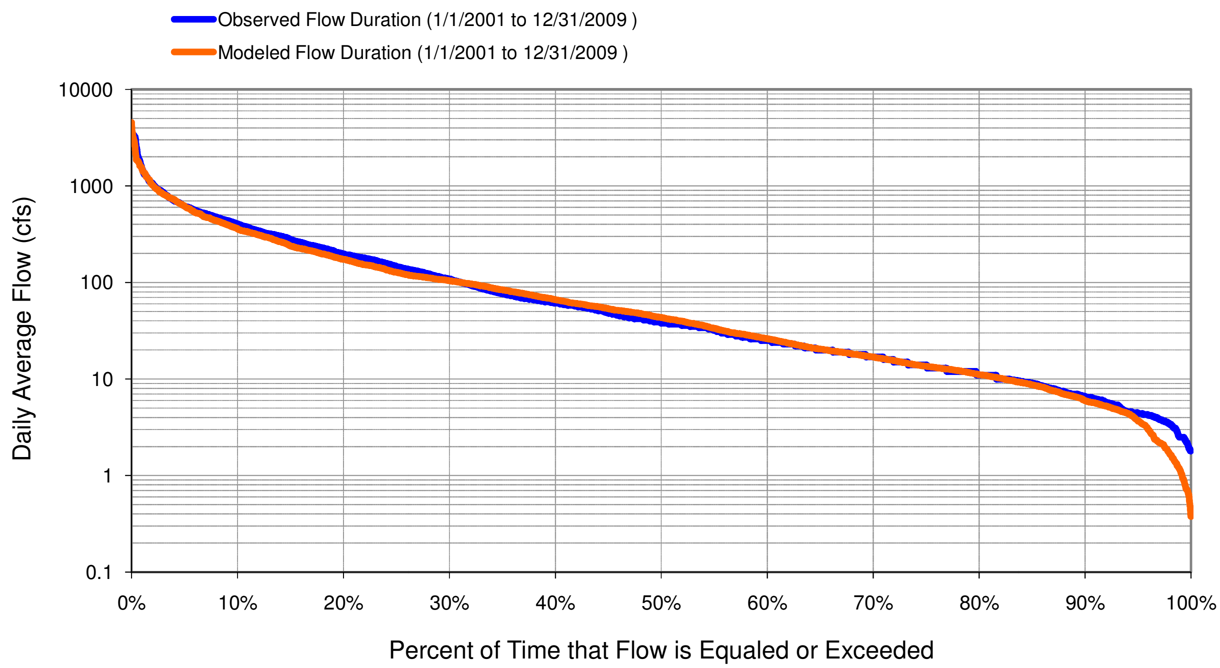


Figure 6. Flow exceedence: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN

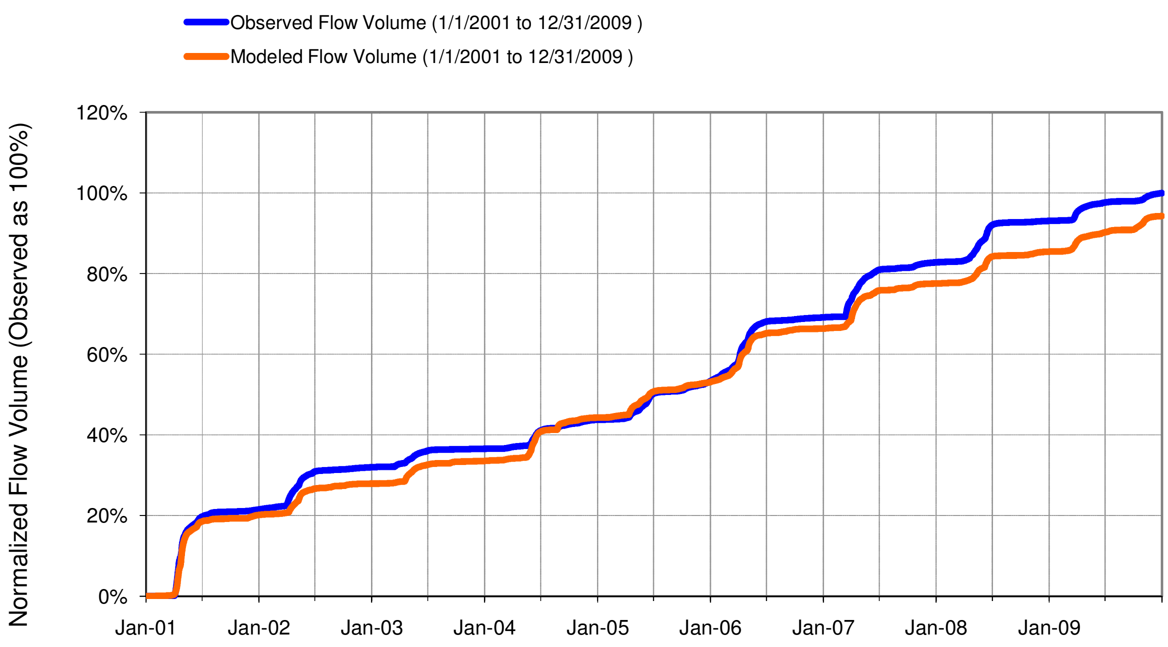


Figure 7. Flow accumulation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN

Table 2. Summary statistics: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 100 9-Year Analysis Period: 1/1/2001 - 12/31/2009 Flow volumes are (inches/year) for upstream drainage area		USGS 05313500 YELLOW MEDICINE RIVER NEAR GRANITE FALLS, MN Hydrologic Unit Code: 7020004 Latitude: 44.72166667 Longitude: -95.5188889 Drainage Area (sq-mi): 664	
Total Simulated In-stream Flow:	**2.92**	Total Observed In-stream Flow:	**3.09**
Total of simulated highest 10% flows:	**1.68**	Total of Observed highest 10% flows:	**1.78**
Total of Simulated lowest 50% flows:	**0.17**	Total of Observed Lowest 50% flows:	**0.16**
Simulated Summer Flow Volume (months 7-9):	**0.25**	Observed Summer Flow Volume (7-9):	**0.20**
Simulated Fall Flow Volume (months 10-12):	**0.30**	Observed Fall Flow Volume (10-12):	**0.27**
Simulated Winter Flow Volume (months 1-3):	**0.37**	Observed Winter Flow Volume (1-3):	**0.45**
Simulated Spring Flow Volume (months 4-6):	**2.00**	Observed Spring Flow Volume (4-6):	**2.17**
Total Simulated Storm Volume:	**0.87**	Total Observed Storm Volume:	**0.81**
Simulated Summer Storm Volume (7-9):	**0.09**	Observed Summer Storm Volume (7-9):	**0.05**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	-5.68	10	
Error in 50% lowest flows:	1.72	10	
Error in 10% highest flows:	-5.26	15	
Seasonal volume error - Summer:	26.45	30	
Seasonal volume error - Fall:	8.99	30	
Seasonal volume error - Winter:	-18.93	30	
Seasonal volume error - Spring:	-7.69	30	
Error in storm volumes:	7.13	20	
Error in summer storm volumes:	**75.48**	**50**	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.744	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.625	as E or E' approaches 1.0	
Monthly NSE	0.911		

2 Hawk Creek at Priam

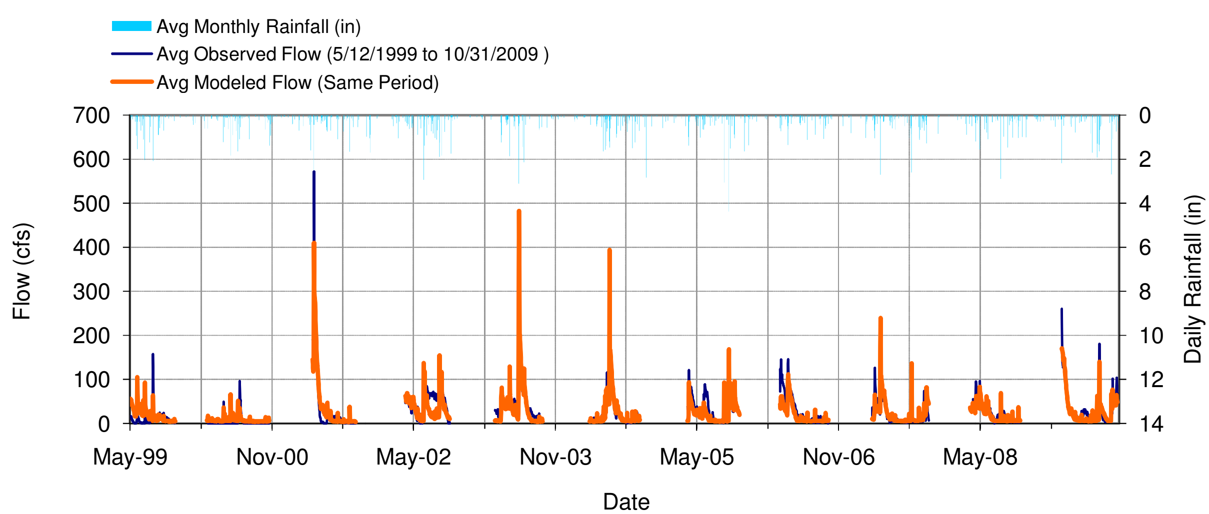


Figure 8. Mean daily flow: Model DSN 700 vs. Hawk Creek - Priam (S002-140)

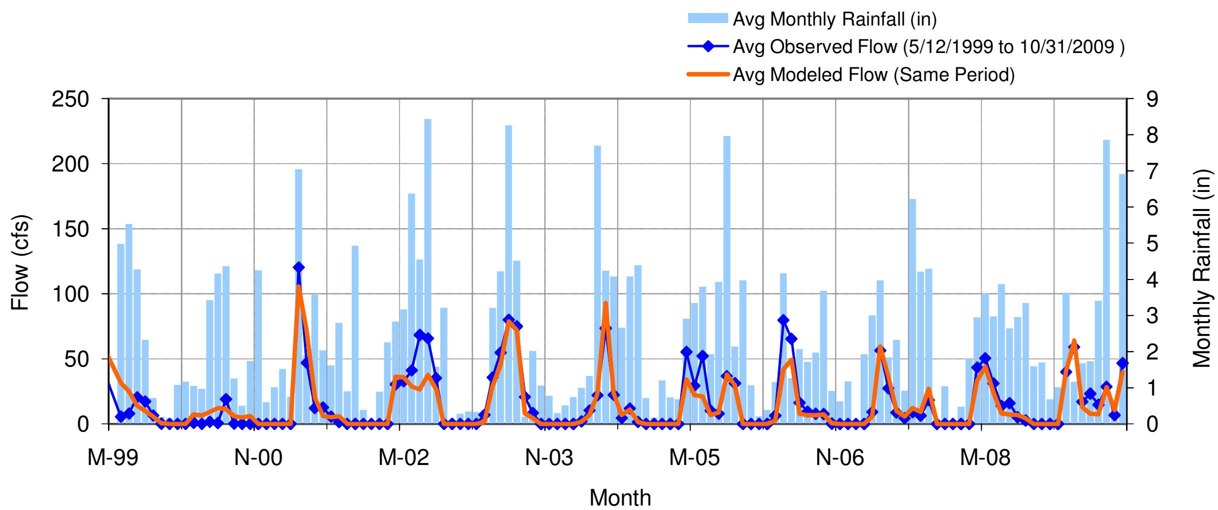


Figure 9. Mean monthly flow: Model DSN 700 vs. Hawk Creek - Priam (S002-140)

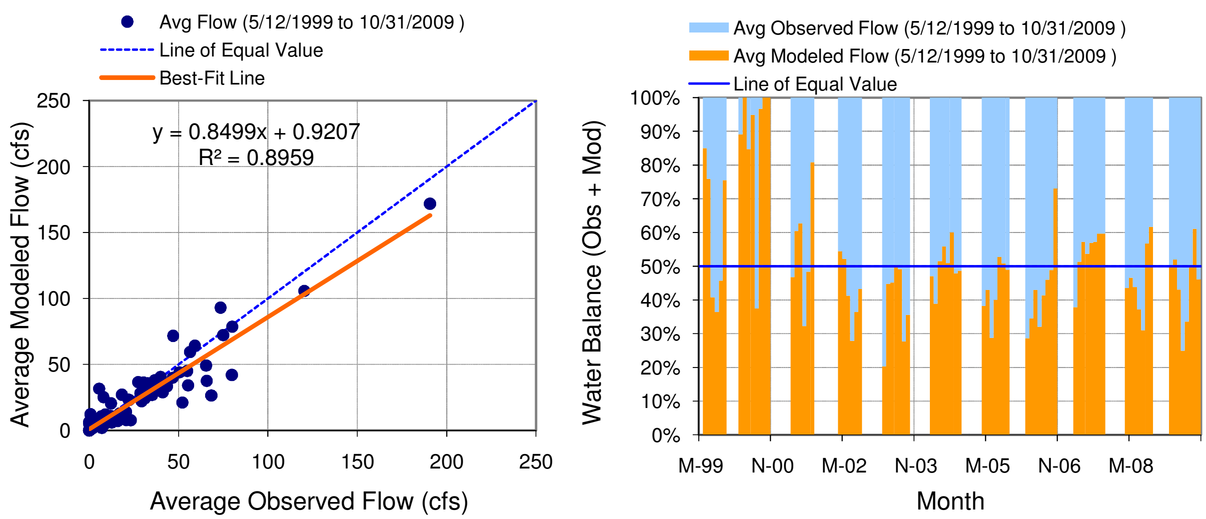
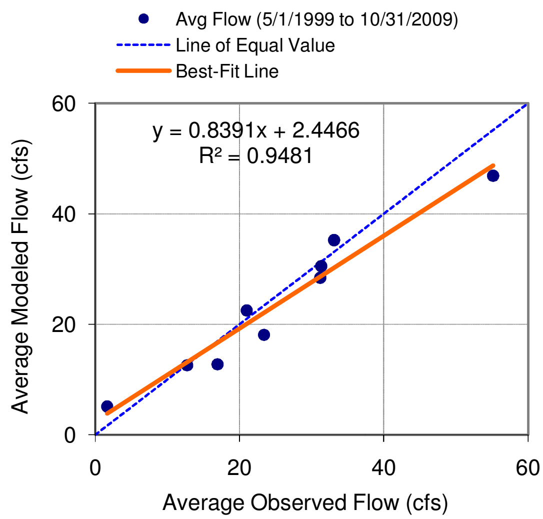


Figure 10. Monthly flow regression and temporal variation: Model DSN 700 vs. Hawk Creek - Priam (S002-140)



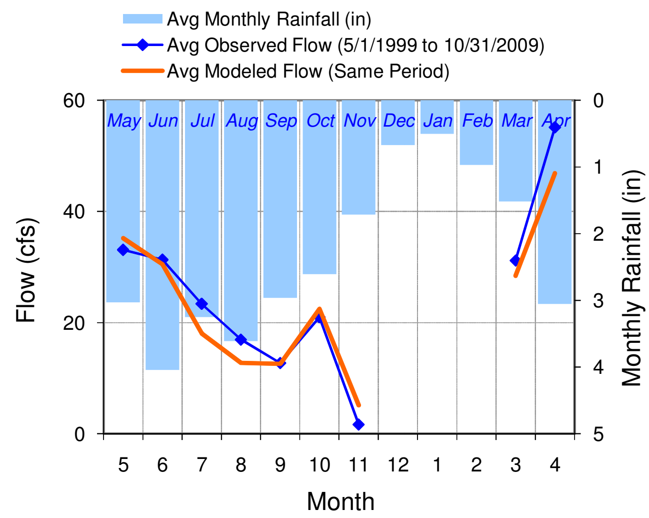


Figure 11. Seasonal regression and temporal aggregate: Model DSN 700 vs. Hawk Creek - Priam (S002-140)

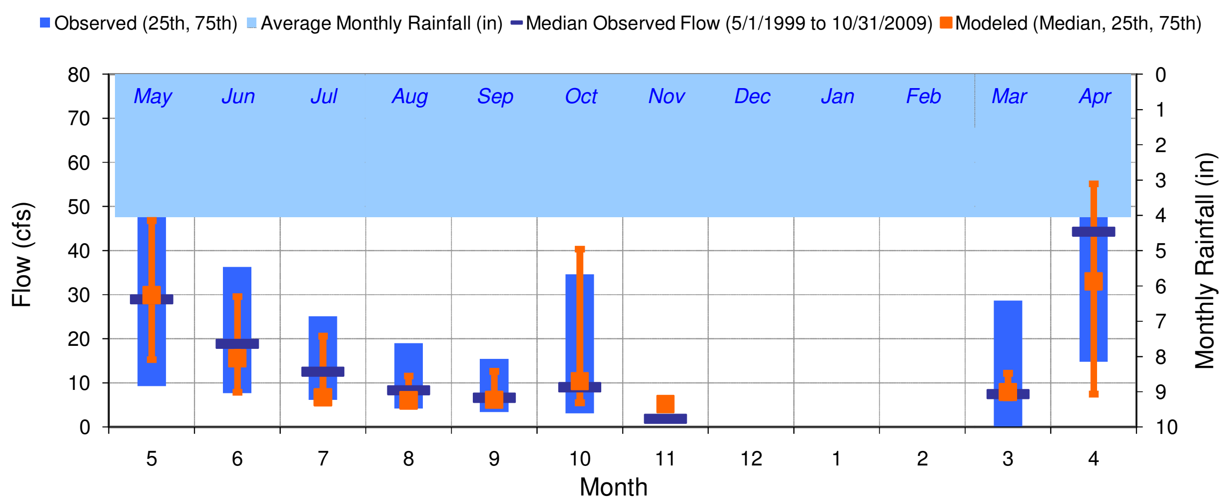


Figure 12. Seasonal medians and ranges: Model DSN 700 vs. Hawk Creek - Priam (S002-140)

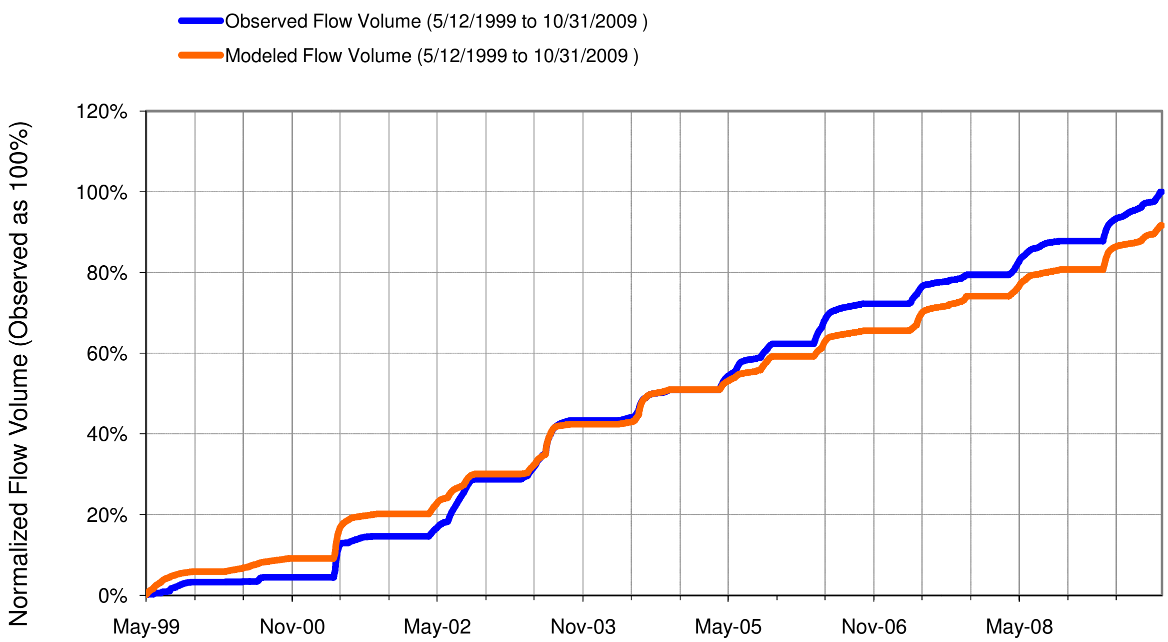


Figure 13. Flow accumulation: Model DSN 700 vs. Hawk Creek - Priam (S002-140)

Table 3. Summary statistics: Model DSN 700 vs. Hawk Creek - Priam (S002-140)

HSPF Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM DSN 700 10.48-Year Analysis Period: 5/1/1999 - 10/31/2009 Flow volumes are (inches/year) for upstream drainage area		**Hawk Priam (S002-140)** Manually Entered Data Drainage Area (sq-mi): 50.08	
Total Simulated In-stream Flow:	**3.84**	Total Observed In-stream Flow:	**4.20**
Total of simulated highest 10% flows:	**1.60**	Total of Observed highest 10% flows:	**1.69**
Total of Simulated lowest 50% flows:	**0.49**	Total of Observed Lowest 50% flows:	**0.40**
Simulated Summer Flow Volume (months 7-9):	**1.03**	Observed Summer Flow Volume (7-9):	**1.27**
Simulated Fall Flow Volume (months 10-12):	**0.25**	Observed Fall Flow Volume (10-12):	**0.24**
Simulated Winter Flow Volume (months 1-3):	**0.13**	Observed Winter Flow Volume (1-3):	**0.14**
Simulated Spring Flow Volume (months 4-6):	**2.43**	Observed Spring Flow Volume (4-6):	**2.55**
Total Simulated Storm Volume:	**0.78**	Total Observed Storm Volume:	**0.89**
Simulated Summer Storm Volume (7-9):	**0.24**	Observed Summer Storm Volume (7-9):	**0.33**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-8.45	10		
Error in 50% lowest flows:	**20.39**	**10**		
Error in 10% highest flows:	-5.14	15		
Seasonal volume error - Summer:	-18.42	30		
Seasonal volume error - Fall:	7.45	30		
Seasonal volume error - Winter:	-8.89	30		
Seasonal volume error - Spring:	-4.95	30		
Error in storm volumes:	-12.03	20		
Error in summer storm volumes:	-28.76	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.744	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.536	as E or E' approaches 1.0		
Monthly NSE	0.934			

3 Hawk Creek at Maynard

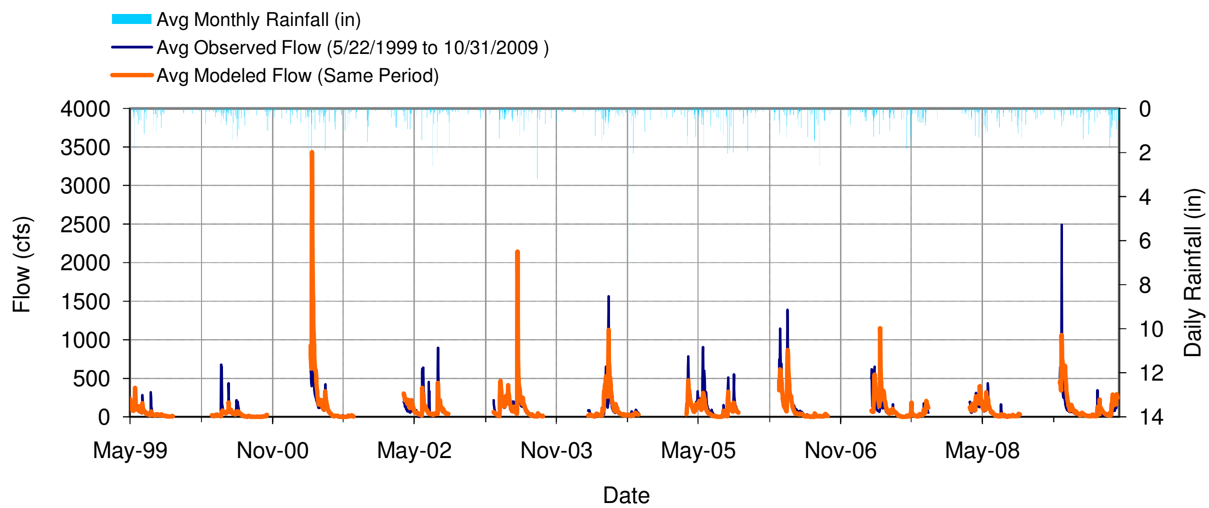


Figure 14. Mean daily flow: Model DSN 800 vs. Hawk - Maynard (S002-148)

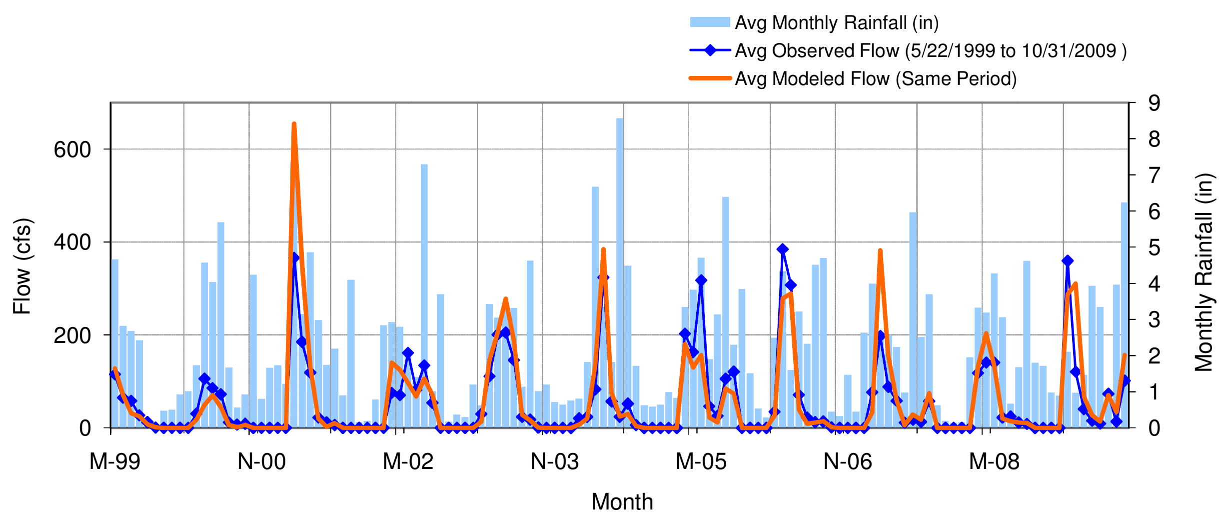


Figure 15. Mean monthly flow: Model DSN 800 vs. Hawk - Maynard (S002-148)

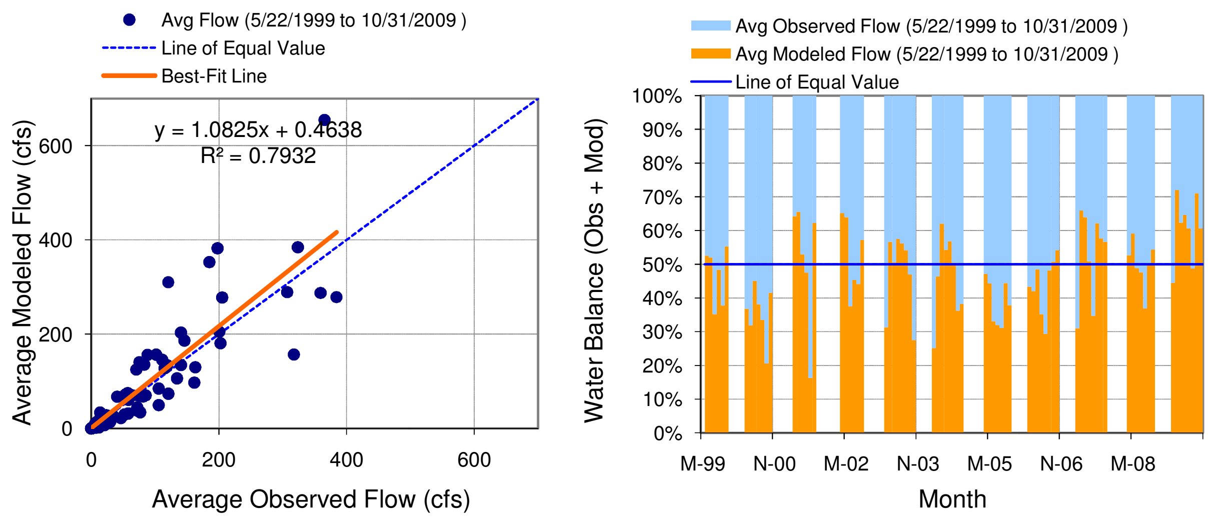


Figure 16. Monthly flow regression and temporal variation: Model DSN 800 vs. Hawk - Maynard (S002-148)

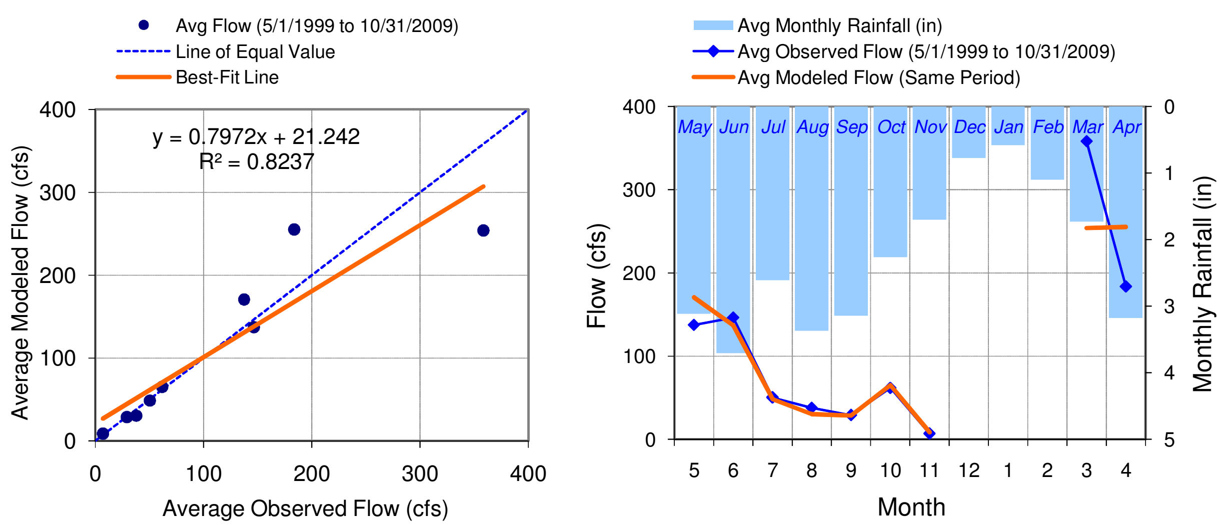


Figure 17. Seasonal regression and temporal aggregate: Model DSN 800 vs. Hawk - Maynard (S002-148)

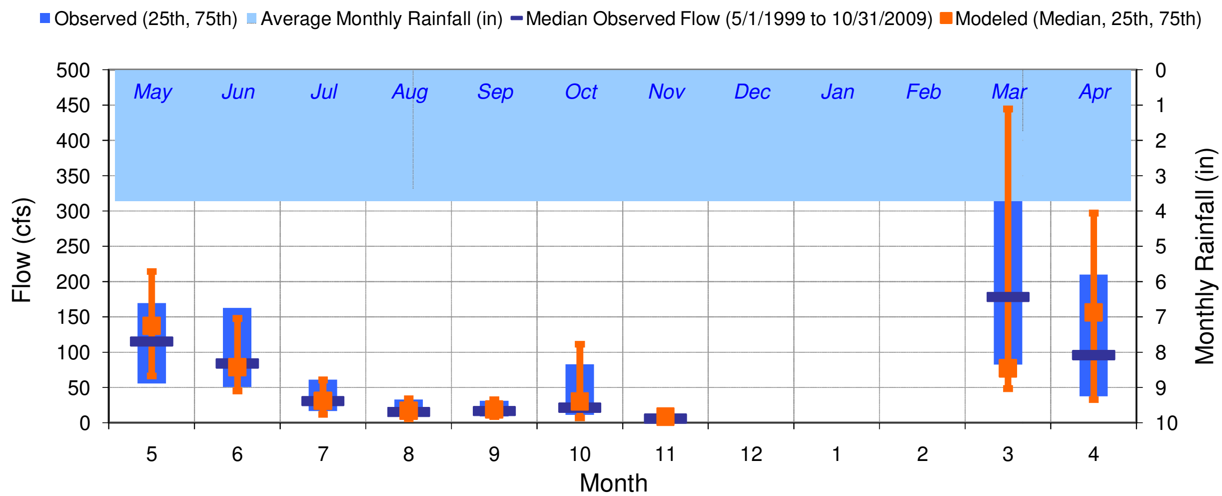


Figure 18. Seasonal medians and ranges: Model DSN 800 vs. Hawk - Maynard (S002-148)

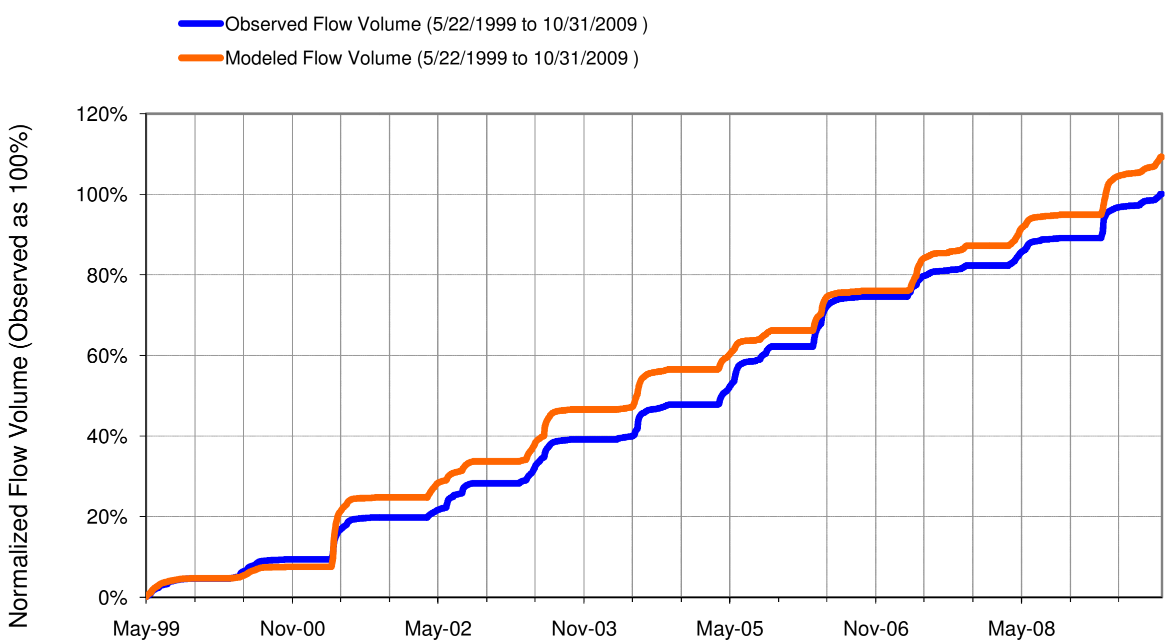


Figure 19. Flow accumulation: Model DSN 800 vs. Hawk - Maynard (S002-148)

Table 4. Summary statistics: Model DSN 800 vs. Hawk - Maynard (S002-148)

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 800 10.45-Year Analysis Period: 5/1/1999 - 10/31/2009 Flow volumes are (inches/year) for upstream drainage area		Hawk Maynard (S002-148) Manually Entered Data Drainage Area (sq-mi): 321.97	
Total Simulated In-stream Flow:	**2.50**	Total Observed In-stream Flow:	**2.29**
Total of simulated highest 10% flows:	**1.21**	Total of Observed highest 10% flows:	**1.09**
Total of Simulated lowest 50% flows:	**0.21**	Total of Observed Lowest 50% flows:	**0.22**
Simulated Summer Flow Volume (months 7-9):	**0.40**	Observed Summer Flow Volume (7-9):	**0.44**
Simulated Fall Flow Volume (months 10-12):	**0.11**	Observed Fall Flow Volume (10-12):	**0.11**
Simulated Winter Flow Volume (months 1-3):	**0.13**	Observed Winter Flow Volume (1-3):	**0.18**
Simulated Spring Flow Volume (months 4-6):	**1.85**	Observed Spring Flow Volume (4-6):	**1.56**
Total Simulated Storm Volume:	**0.72**	Total Observed Storm Volume:	**0.83**
Simulated Summer Storm Volume (7-9):	**0.11**	Observed Summer Storm Volume (7-9):	**0.16**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	9.17	10	
Error in 50% lowest flows:	-5.68	10	
Error in 10% highest flows:	10.19	15	
Seasonal volume error - Summer:	-8.39	30	
Seasonal volume error - Fall:	5.33	30	
Seasonal volume error - Winter:	-29.15	30	
Seasonal volume error - Spring:	18.76	30	
Error in storm volumes:	-13.29	20	
Error in summer storm volumes:	-29.56	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.510	Model accuracy increases as E or E' approaches 1.0	
Baseline adjusted coefficient (Garrick), E':	0.484		
Monthly NSE	0.921		

4 Chetomba Creek

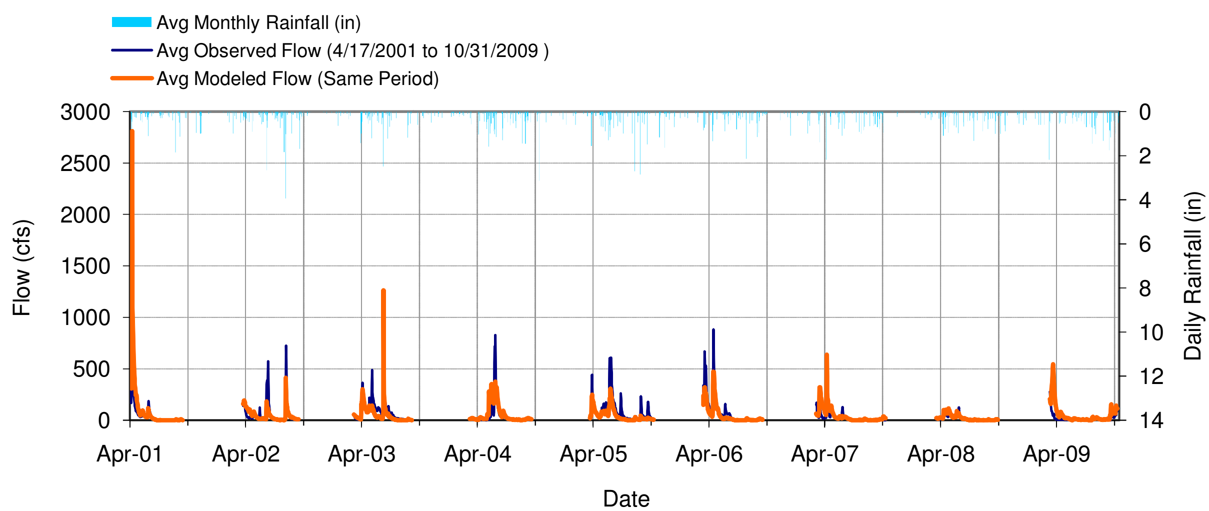


Figure 20. Mean daily flow: Model DSN 900 vs. Chetomba Creek (S002-152)

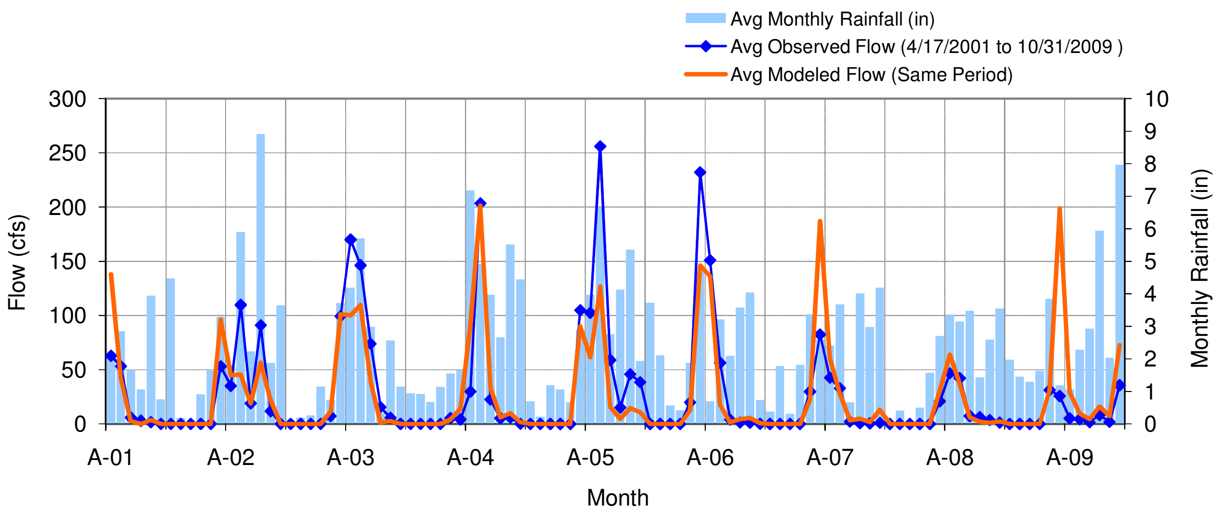


Figure 21. Mean monthly flow: Model DSN 900 vs. Chetomba Creek (S002-152)

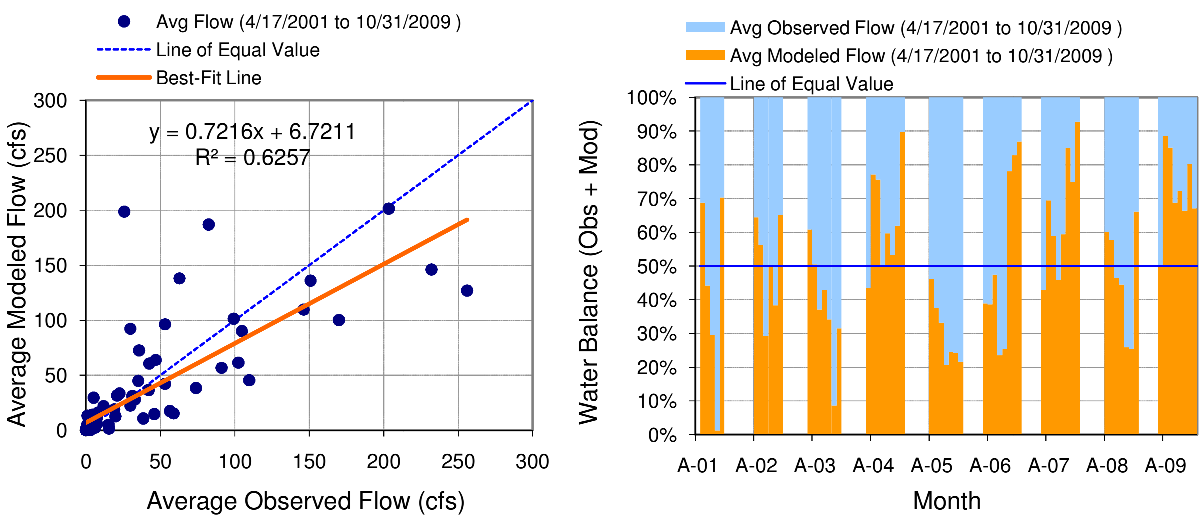


Figure 22. Monthly flow regression and temporal variation: Model DSN 900 vs. Chetomba Creek (S002-152)

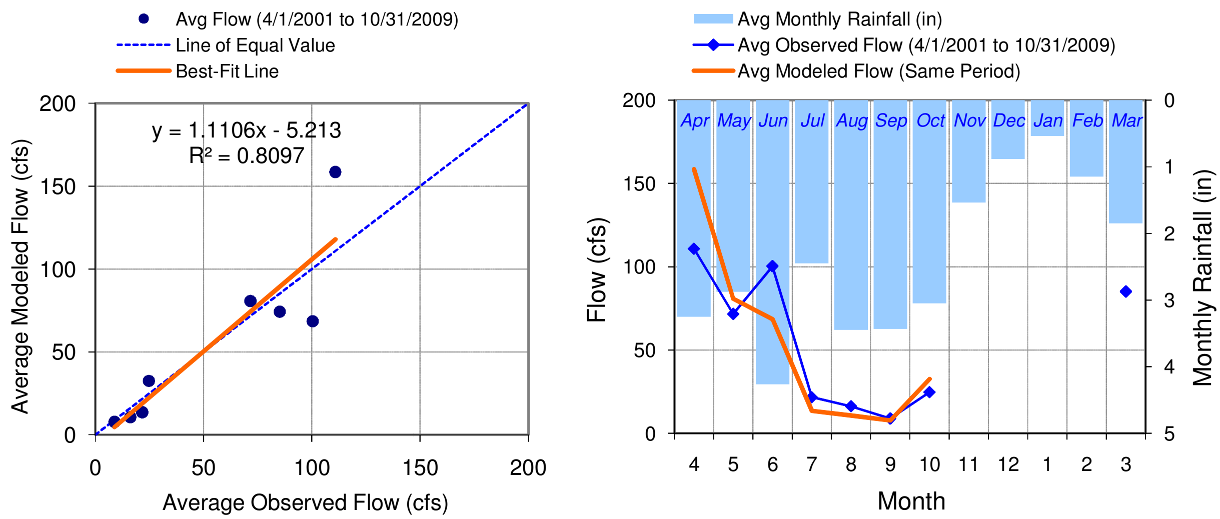


Figure 23. Seasonal regression and temporal aggregate: Model DSN 900 vs. Chetomba Creek (S002-152)

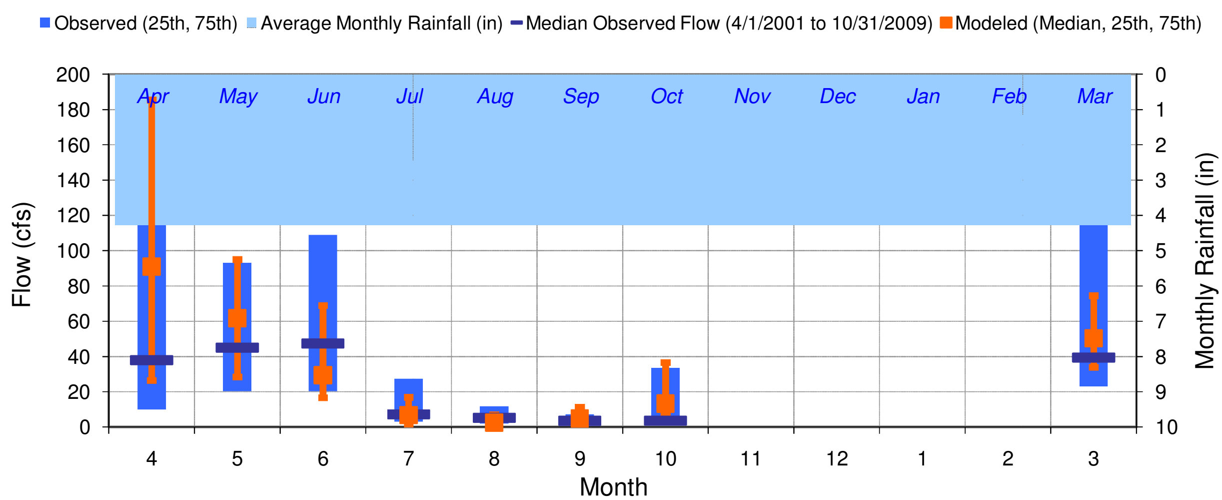


Figure 24. Seasonal medians and ranges: Model DSN 900 vs. Chetomba Creek (S002-152)

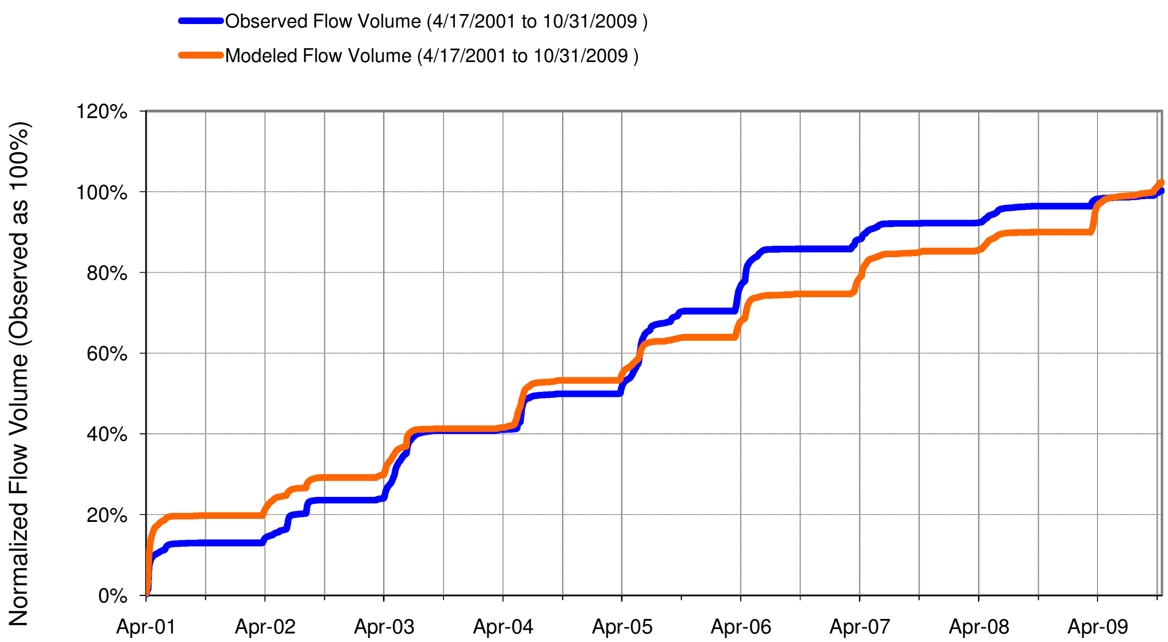


Figure 25. Flow accumulation: Model DSN 900 vs. Chetomba Creek (S002-152)

Table 5. Summary statistics: Model DSN 900 vs. Chetomba Creek (S002-152)

HSPF Simulated Flow		**Observed Flow Gage**		
REACH OUTFLOW FROM DSN 900 8.54-Year Analysis Period: 4/1/2001 - 10/31/2009 Flow volumes are (inches/year) for upstream drainage area		**Chetomba (S002-152)** Manually Entered Data Drainage Area (sq-mi): 142.84		
Total Simulated In-stream Flow:	**2.85**	Total Observed In-stream Flow:		**2.80**
Total of simulated highest 10% flows:	**1.58**	Total of Observed highest 10% flows:		**1.60**
Total of Simulated lowest 50% flows:	**0.16**	Total of Observed Lowest 50% flows:		**0.12**
Simulated Summer Flow Volume (months 7-9):	**0.27**	Observed Summer Flow Volume (7-9):		**0.39**
Simulated Fall Flow Volume (months 10-12):	**0.10**	Observed Fall Flow Volume (10-12):		**0.07**
Simulated Winter Flow Volume (months 1-3):	**0.08**	Observed Winter Flow Volume (1-3):		**0.09**
Simulated Spring Flow Volume (months 4-6):	**2.41**	Observed Spring Flow Volume (4-6):		**2.24**
Total Simulated Storm Volume:	**0.72**	Total Observed Storm Volume:		**0.88**
Simulated Summer Storm Volume (7-9):	**0.08**	Observed Summer Storm Volume (7-9):		**0.13**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	1.71	10		
Error in 50% lowest flows:	**26.91**	**10**		
Error in 10% highest flows:	-1.05	15		
Seasonal volume error - Summer:	**-31.59**	**30**		
Seasonal volume error - Fall:	**31.47**	**30**		
Seasonal volume error - Winter:	-12.79	30		
Seasonal volume error - Spring:	7.17	30		
Error in storm volumes:	-17.84	20		
Error in summer storm volumes:	-38.56	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.483	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.445	as E or E' approaches 1.0		
Monthly NSE	0.929			

5 Hawk Creek at Outlet

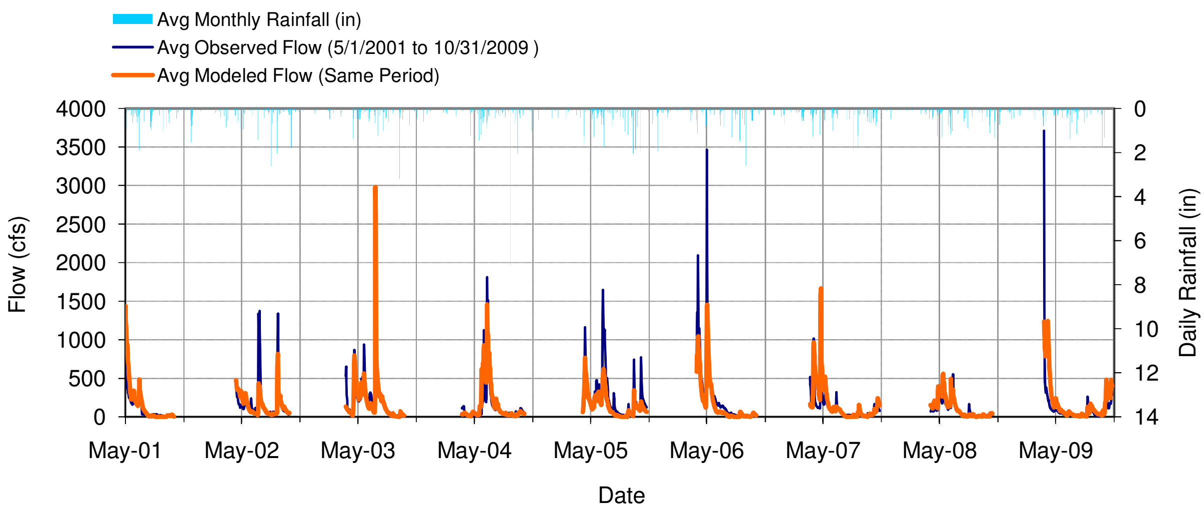


Figure 26. Mean daily flow: Model DSN 600 vs. Hawk - Outlet (S002-12)

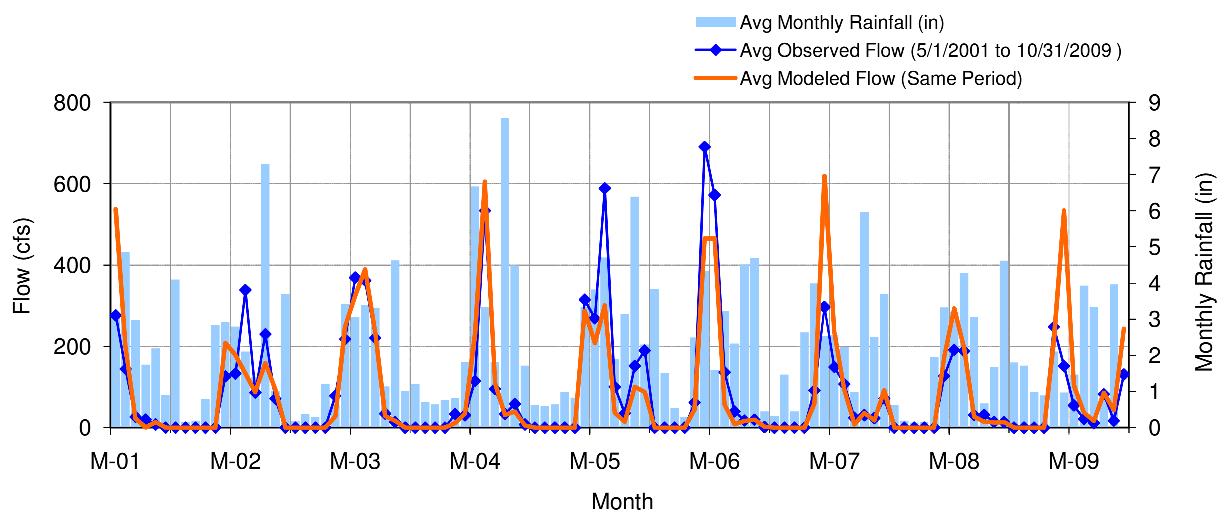


Figure 27. Mean monthly flow: Model DSN 600 vs. Hawk - Outlet (S002-12)

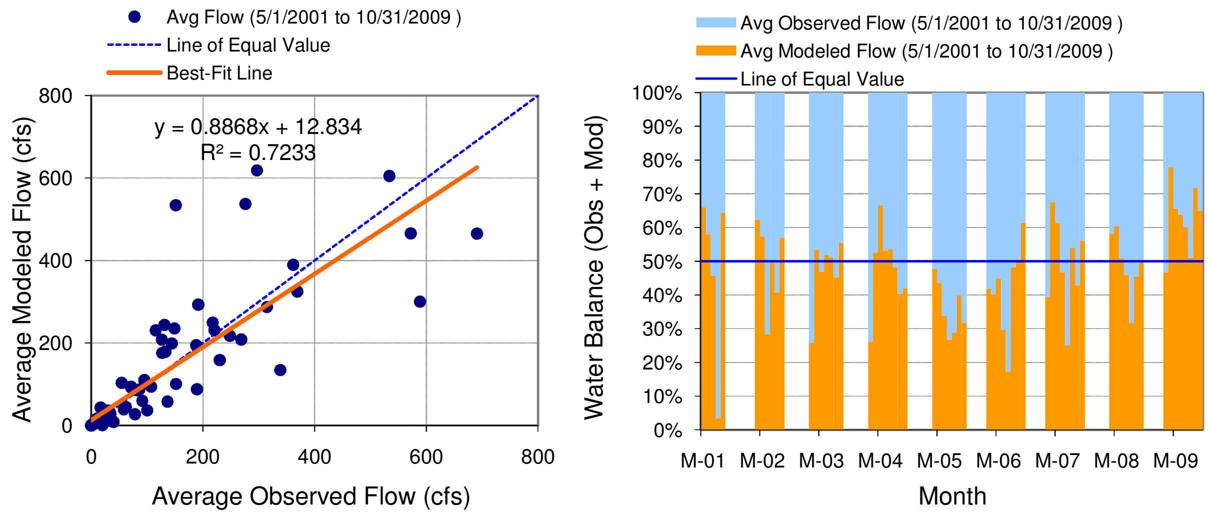


Figure 28. Monthly flow regression and temporal variation: Model DSN 600 vs. Hawk - Outlet (S002-12)

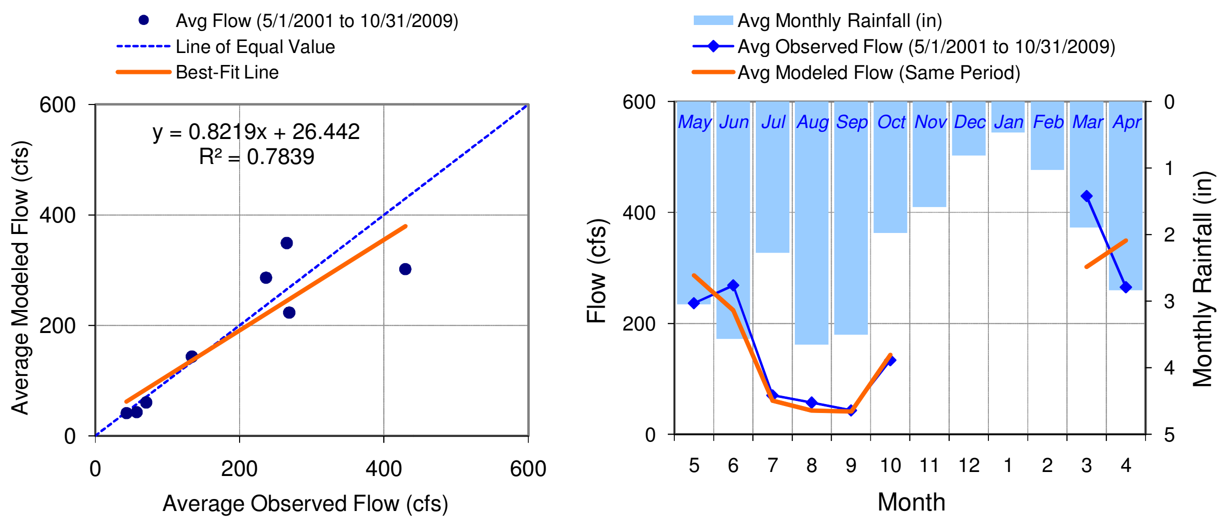


Figure 29. Seasonal regression and temporal aggregate: Model DSN 600 vs. Hawk - Outlet (S002-12)

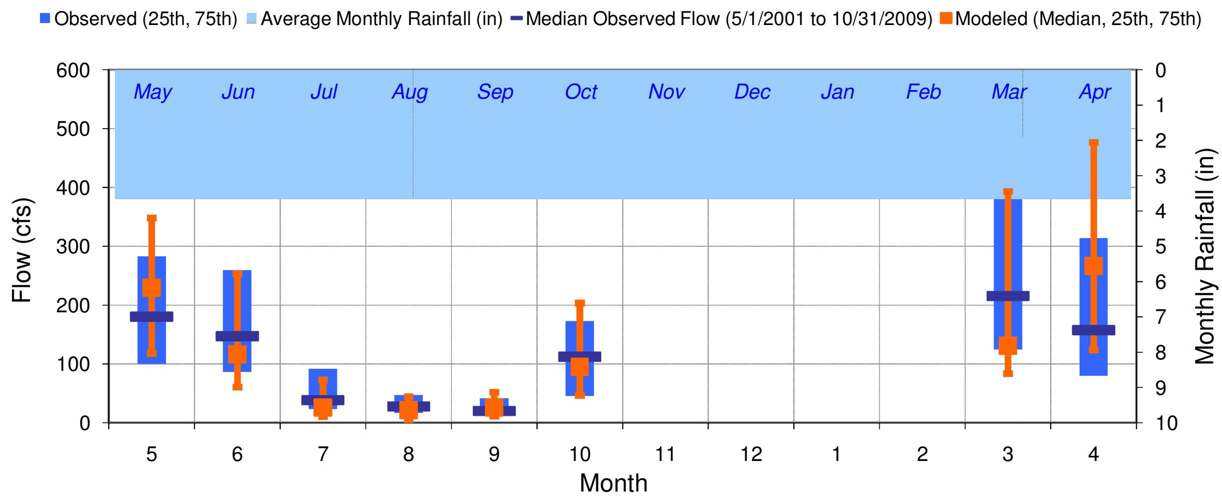


Figure 30. Seasonal medians and ranges: Model DSN 600 vs. Hawk - Outlet (S002-12)

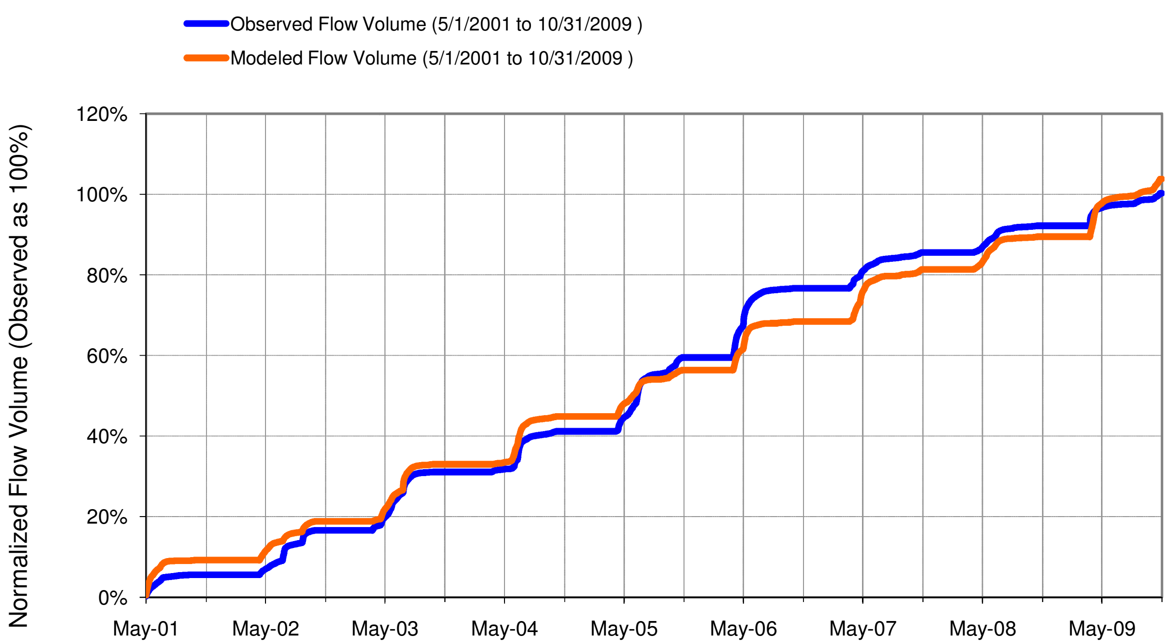


Figure 31. Flow accumulation: Model DSN 600 vs. Hawk - Outlet (S002-12)

Table 6. Summary statistics: Model DSN 600 vs. Hawk - Outlet (S002-12)

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 600 8.5-Year Analysis Period: 5/1/2001 - 10/31/2009 Flow volumes are (inches/year) for upstream drainage area		Hawk Outlet (S002-12) Manually Entered Data Drainage Area (sq-mi): 507.96	
Total Simulated In-stream Flow:	**2.43**	Total Observed In-stream Flow:	**2.35**
Total of simulated highest 10% flows:	**1.10**	Total of Observed highest 10% flows:	**1.12**
Total of Simulated lowest 50% flows:	**0.20**	Total of Observed Lowest 50% flows:	**0.22**
Simulated Summer Flow Volume (months 7-9):	**0.34**	Observed Summer Flow Volume (7-9):	**0.40**
Simulated Fall Flow Volume (months 10-12):	**0.12**	Observed Fall Flow Volume (10-12):	**0.11**
Simulated Winter Flow Volume (months 1-3):	**0.10**	Observed Winter Flow Volume (1-3):	**0.14**
Simulated Spring Flow Volume (months 4-6):	**1.87**	Observed Spring Flow Volume (4-6):	**1.70**
Total Simulated Storm Volume:	**0.69**	Total Observed Storm Volume:	**0.81**
Simulated Summer Storm Volume (7-9):	**0.10**	Observed Summer Storm Volume (7-9):	**0.13**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	3.29	10		
Error in 50% lowest flows:	**-11.73**	**10**		
Error in 10% highest flows:	-1.44	15		
Seasonal volume error - Summer:	-15.69	30		
Seasonal volume error - Fall:	7.15	30		
Seasonal volume error - Winter:	-29.74	30		
Seasonal volume error - Spring:	10.22	30		
Error in storm volumes:	-15.36	20		
Error in summer storm volumes:	-23.24	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.508	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.458	as E or E' approaches 1.0		
Monthly NSE	0.898			

6 West Fork Beaver Creek

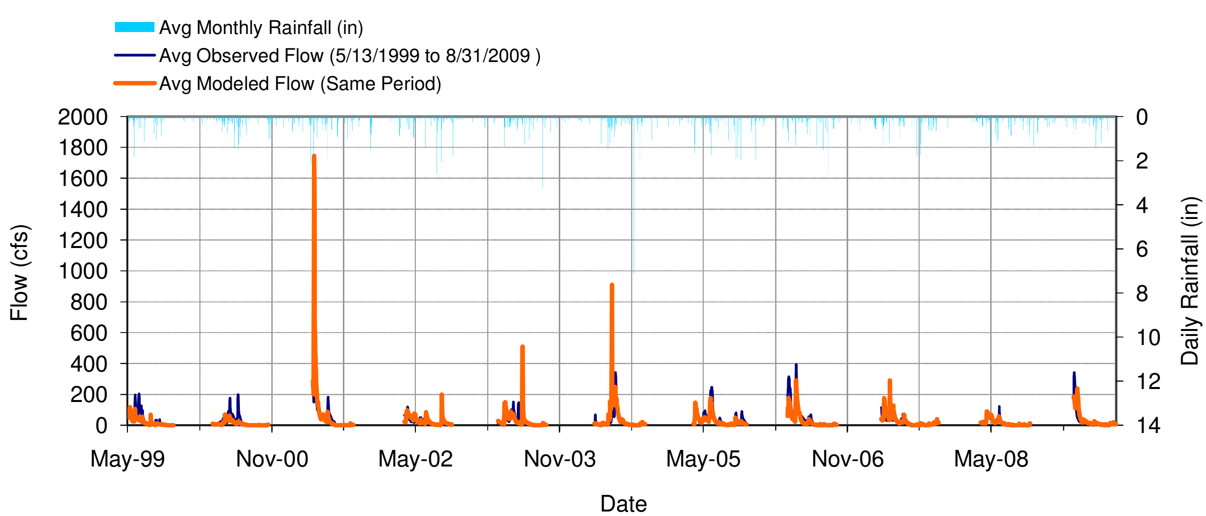


Figure 32. Mean daily flow: Model DSN 300 vs. West Fork Beaver Creek (S000-405)

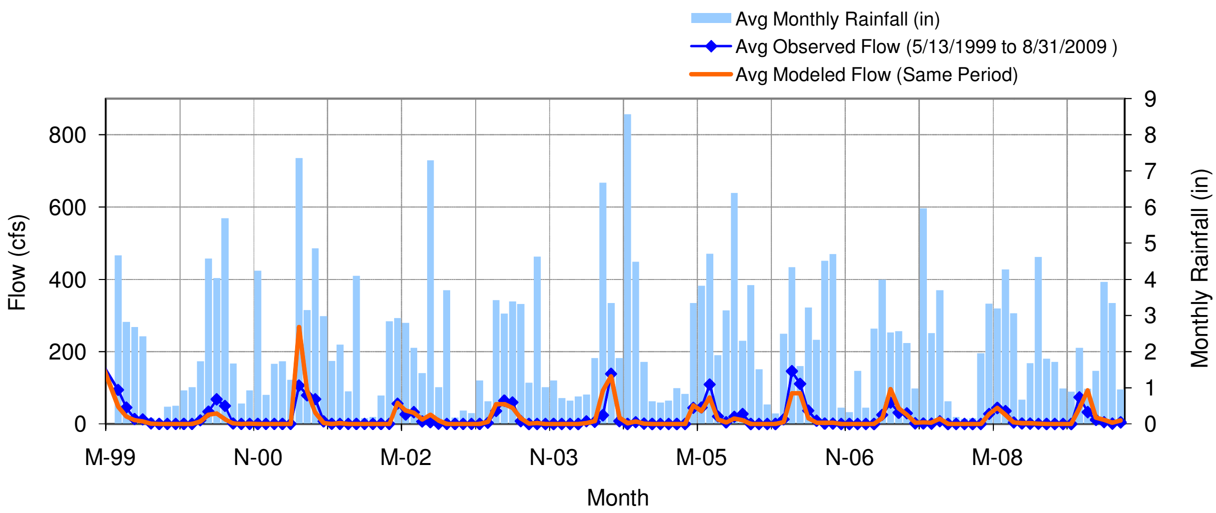


Figure 33. Mean monthly flow: Model DSN 300 vs. West Fork Beaver Creek (S000-405)

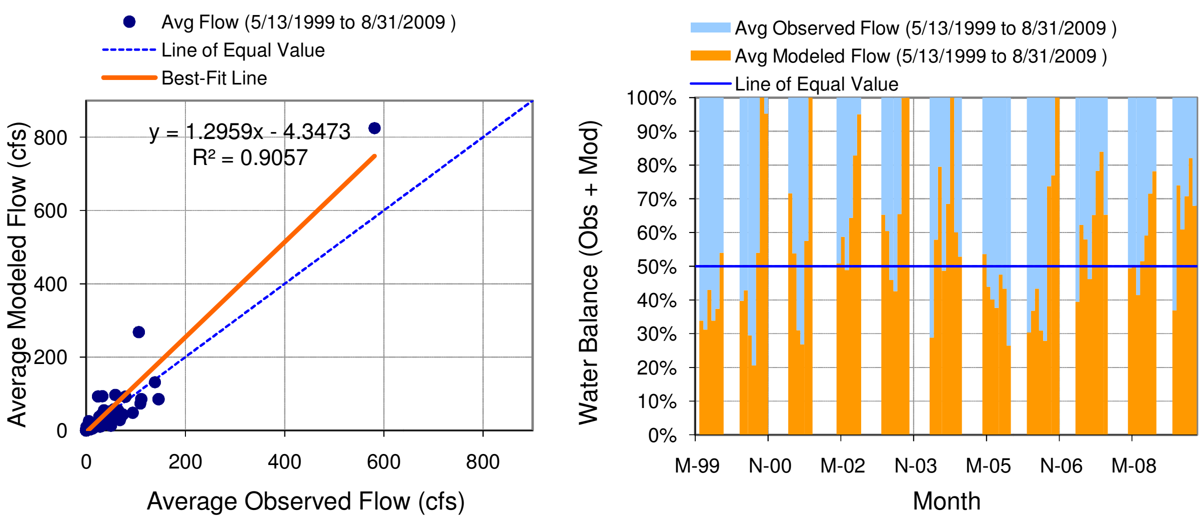


Figure 34. Monthly flow regression and temporal variation: Model DSN 300 vs. West Fork Beaver Creek (S000-405)

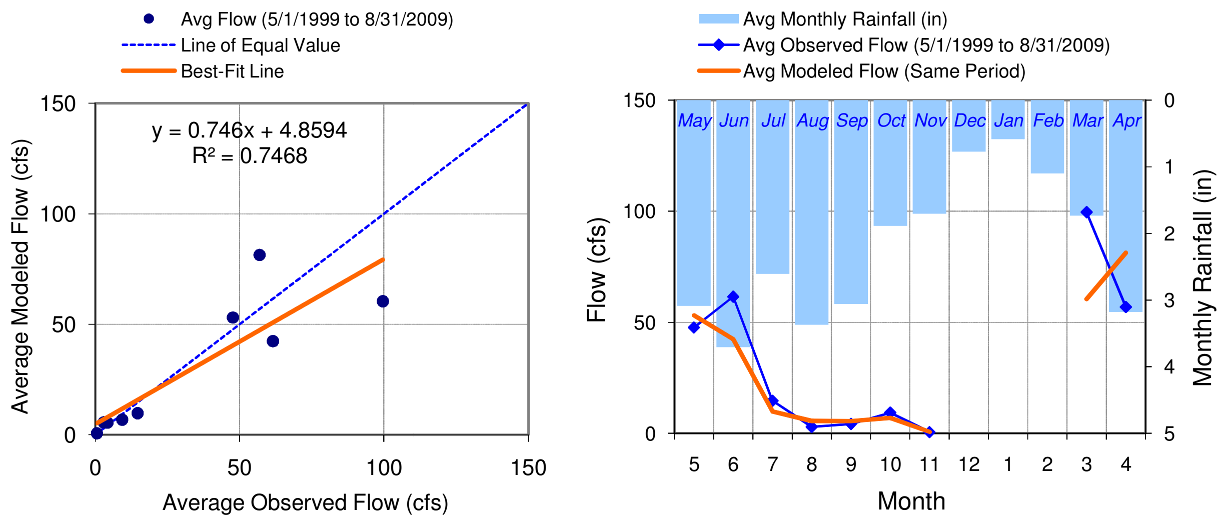


Figure 35. Seasonal regression and temporal aggregate: Model DSN 300 vs. West Fork Beaver Creek (S000-405)

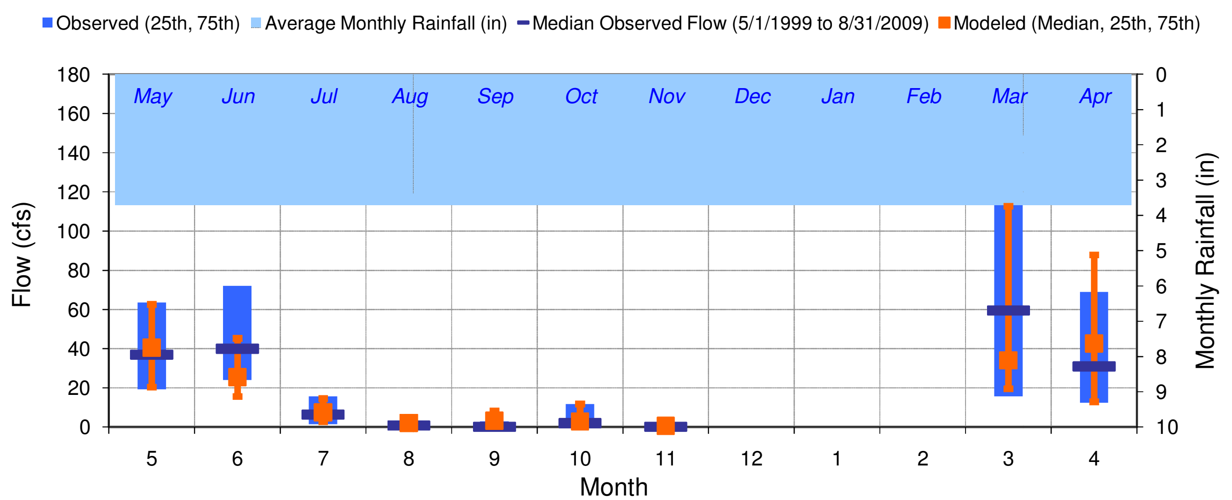


Figure 36. Seasonal medians and ranges: Model DSN 300 vs. West Fork Beaver Creek (S000-405)

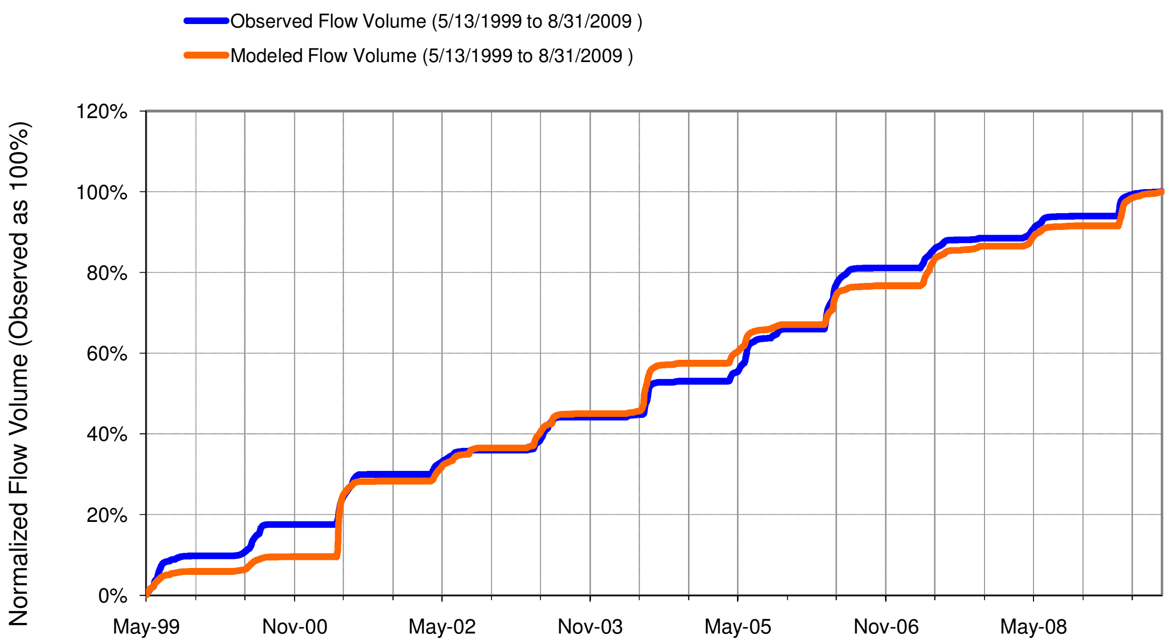


Figure 37. Flow accumulation: Model DSN 300 vs. West Fork Beaver Creek (S000-405)

Table 7. Summary statistics: Model DSN 300 vs. West Fork Beaver Creek (S000-405)

HSPF Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM DSN 300 10.31-Year Analysis Period: 5/1/1999 - 8/31/2009 Flow volumes are (inches/year) for upstream drainage area		**WF Beaver (S000-405)** Manually Entered Data Drainage Area (sq-mi): 99.29	
Total Simulated In-stream Flow:	**2.32**	Total Observed In-stream Flow:	**2.32**
Total of simulated highest 10% flows:	**1.25**	Total of Observed highest 10% flows:	**1.17**
Total of Simulated lowest 50% flows:	**0.15**	Total of Observed Lowest 50% flows:	**0.09**
Simulated Summer Flow Volume (months 7-9):	**0.25**	Observed Summer Flow Volume (7-9):	**0.26**
Simulated Fall Flow Volume (months 10-12):	**0.03**	Observed Fall Flow Volume (10-12):	**0.04**
Simulated Winter Flow Volume (months 1-3):	**0.08**	Observed Winter Flow Volume (1-3):	**0.14**
Simulated Spring Flow Volume (months 4-6):	**1.96**	Observed Spring Flow Volume (4-6):	**1.88**
Total Simulated Storm Volume:	**0.60**	Total Observed Storm Volume:	**0.55**
Simulated Summer Storm Volume (7-9):	**0.07**	Observed Summer Storm Volume (7-9):	**0.08**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	0.00	10		
Error in 50% lowest flows:	**69.09**	**10**		
Error in 10% highest flows:	7.17	15		
Seasonal volume error - Summer:	-5.61	30		
Seasonal volume error - Fall:	-25.93	30		
Seasonal volume error - Winter:	**-39.36**	**30**		
Seasonal volume error - Spring:	4.25	30		
Error in storm volumes:	8.95	20		
Error in summer storm volumes:	-17.86	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	-0.396	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.454	as E or E' approaches 1.0		
Monthly NSE	0.930			

7 Beaver Creek at Beaver Falls

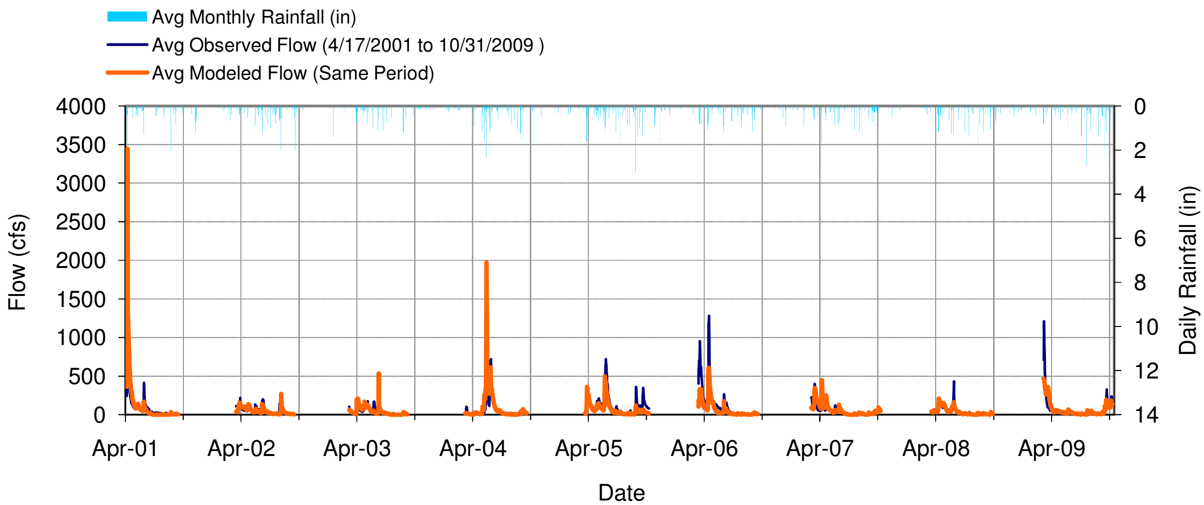


Figure 38. Mean daily flow: Model DSN 400 vs. Beaver Falls (S000-666)

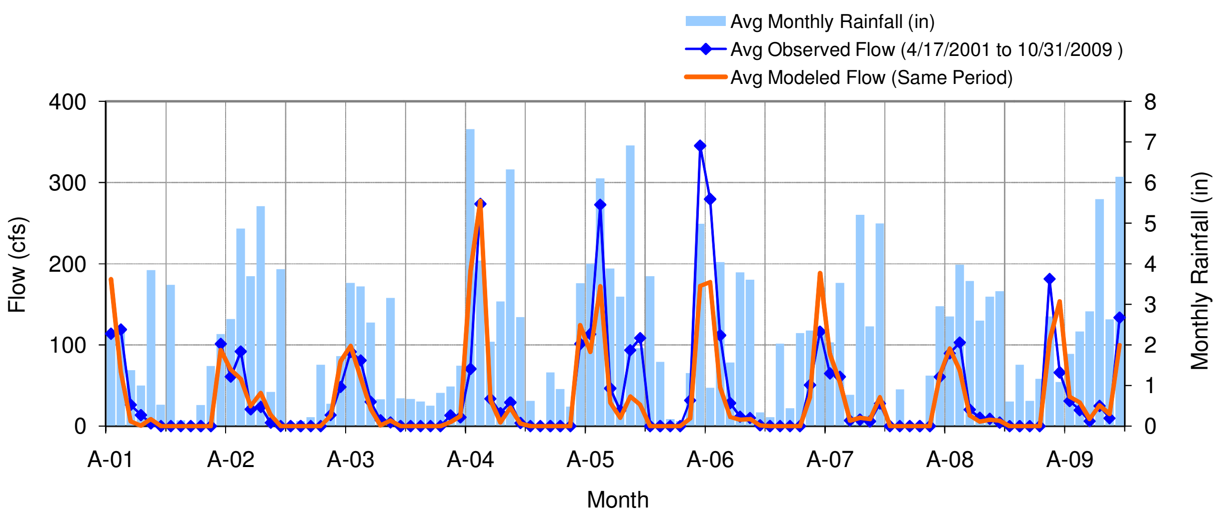


Figure 39. Mean monthly flow: Model DSN 400 vs. Beaver Falls (S000-666)

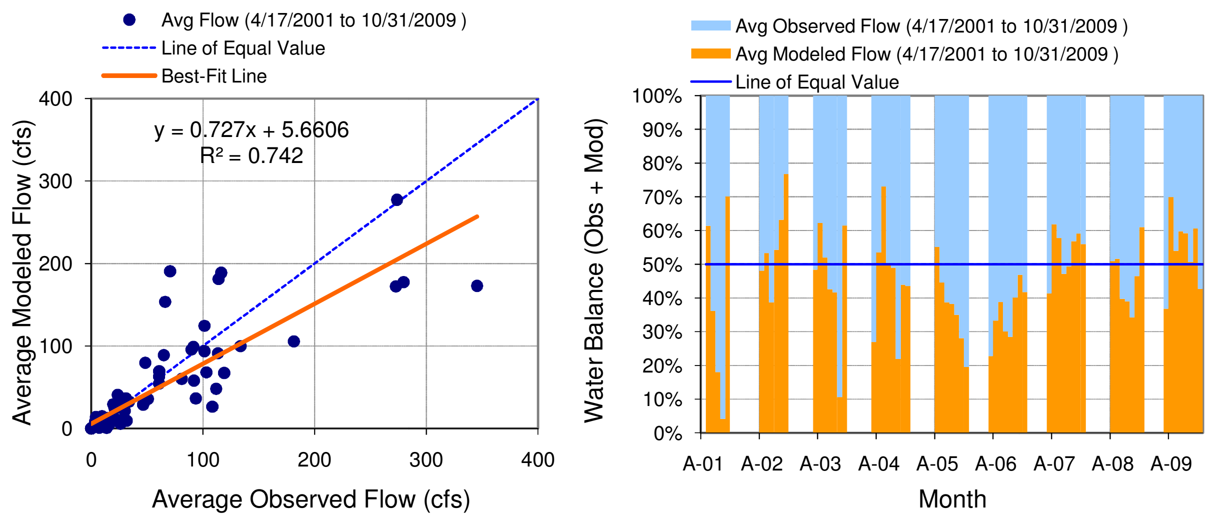


Figure 40. Monthly flow regression and temporal variation: Model DSN 400 vs. Beaver Falls (S000-666)

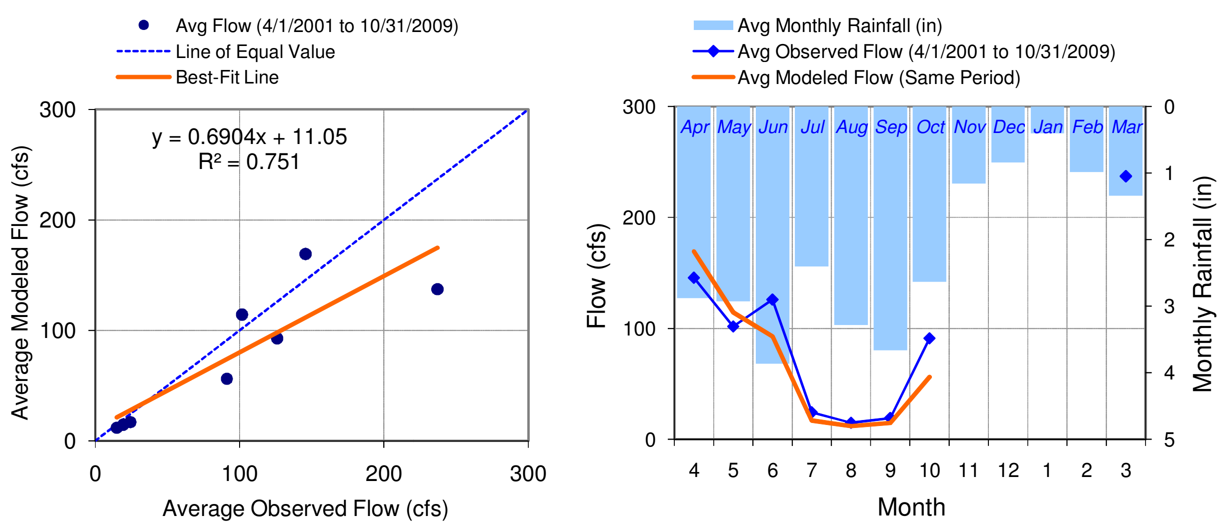


Figure 41. Seasonal regression and temporal aggregate: Model DSN 400 vs. Beaver Falls (S000-666)

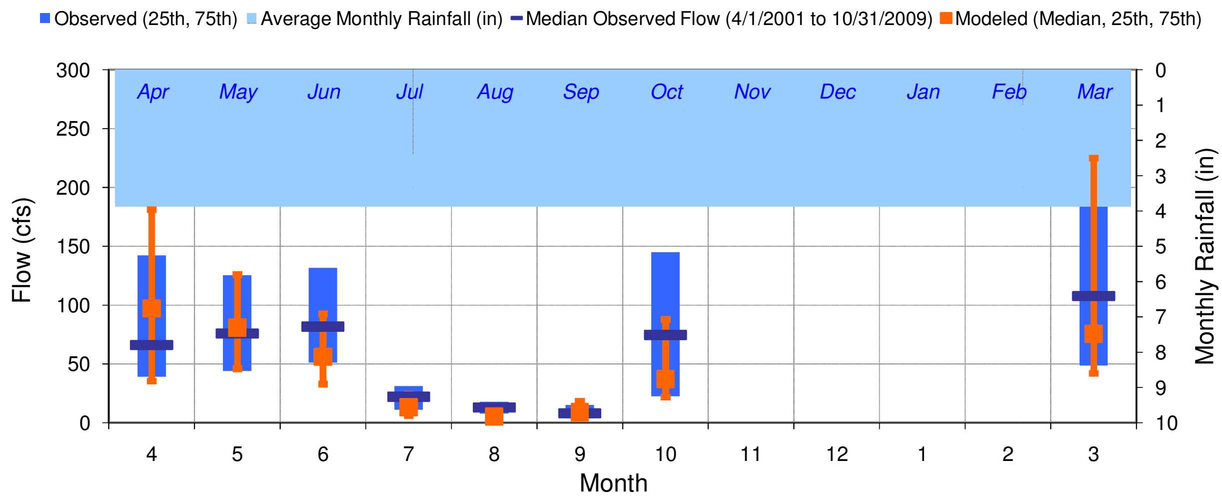


Figure 42. Seasonal medians and ranges: Model DSN 400 vs. Beaver Falls (S000-666)

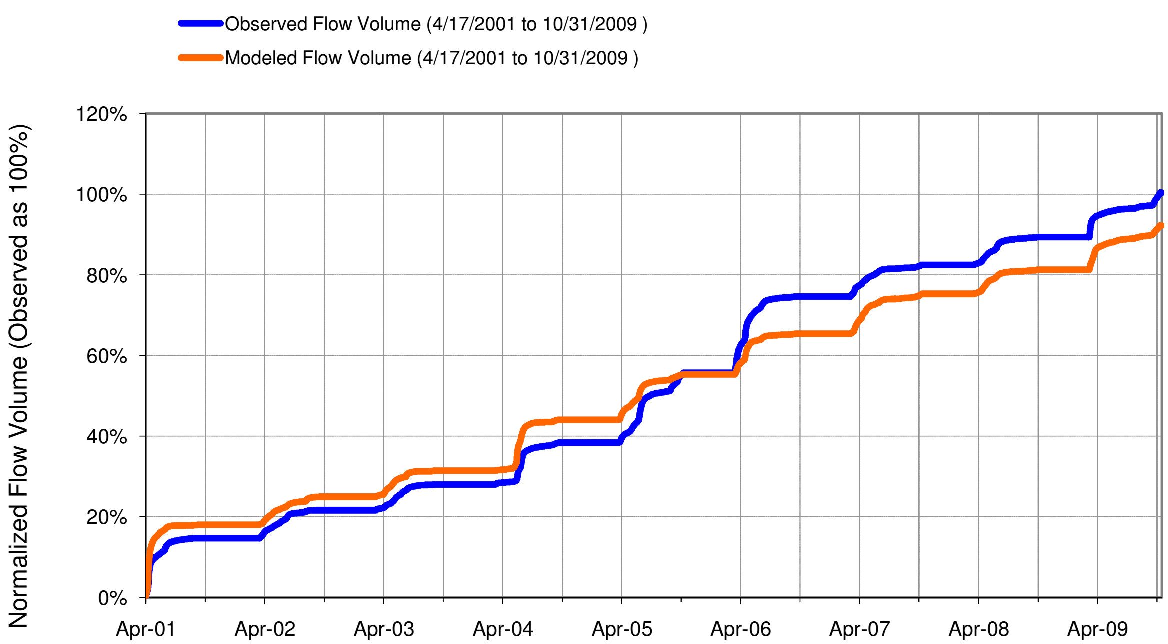


Figure 43. Flow accumulation: Model DSN 400 vs. Beaver Falls (S000-666)

Table 8. Summary statistics: Model DSN 400 vs. Beaver Falls (S000-666)

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 400 8.54-Year Analysis Period: 4/1/2001 - 10/31/2009 Flow volumes are (inches/year) for upstream drainage area		Beaver Falls (S000-666) Manually Entered Data Drainage Area (sq-mi): 198.13	
Total Simulated In-stream Flow:	**2.66**	Total Observed In-stream Flow:	**2.90**
Total of simulated highest 10% flows:	**1.38**	Total of Observed highest 10% flows:	**1.44**
Total of Simulated lowest 50% flows:	**0.21**	Total of Observed Lowest 50% flows:	**0.26**
Simulated Summer Flow Volume (months 7-9):	**0.26**	Observed Summer Flow Volume (7-9):	**0.35**
Simulated Fall Flow Volume (months 10-12):	**0.12**	Observed Fall Flow Volume (10-12):	**0.19**
Simulated Winter Flow Volume (months 1-3):	**0.11**	Observed Winter Flow Volume (1-3):	**0.20**
Simulated Spring Flow Volume (months 4-6):	**2.17**	Observed Spring Flow Volume (4-6):	**2.16**
Total Simulated Storm Volume:	**0.67**	Total Observed Storm Volume:	**0.72**
Simulated Summer Storm Volume (7-9):	**0.07**	Observed Summer Storm Volume (7-9):	**0.08**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-8.25	10		
Error in 50% lowest flows:	**-20.30**	**10**		
Error in 10% highest flows:	-4.48	15		
Seasonal volume error - Summer:	-25.95	30		
Seasonal volume error - Fall:	**-38.37**	**30**		
Seasonal volume error - Winter:	**-42.08**	**30**		
Seasonal volume error - Spring:	0.39	30		
Error in storm volumes:	-7.84	20		
Error in summer storm volumes:	-7.98	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.442	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.506	as E or E' approaches 1.0		
Monthly NSE	0.926			

8 Yellow Medicine River near Granite Falls, 1994-2000

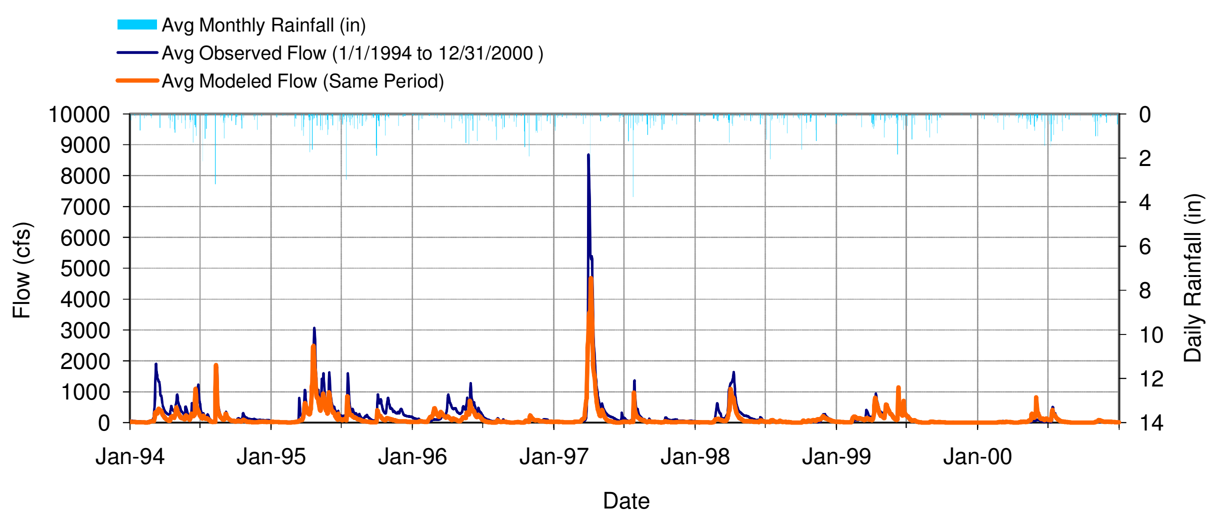


Figure 44. Mean daily flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

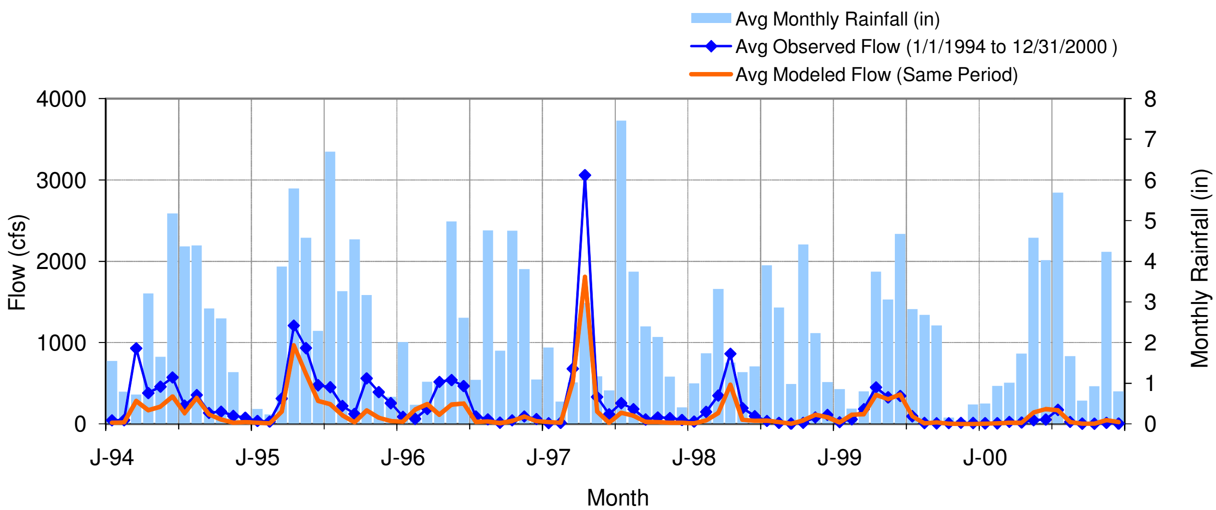


Figure 45. Mean monthly flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

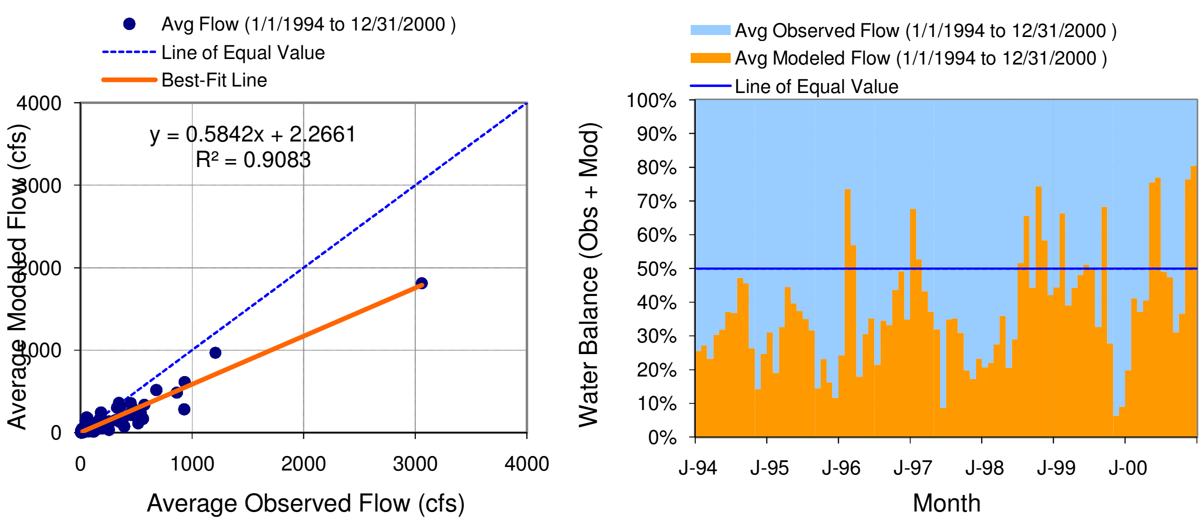


Figure 46. Monthly flow regression and temporal variation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

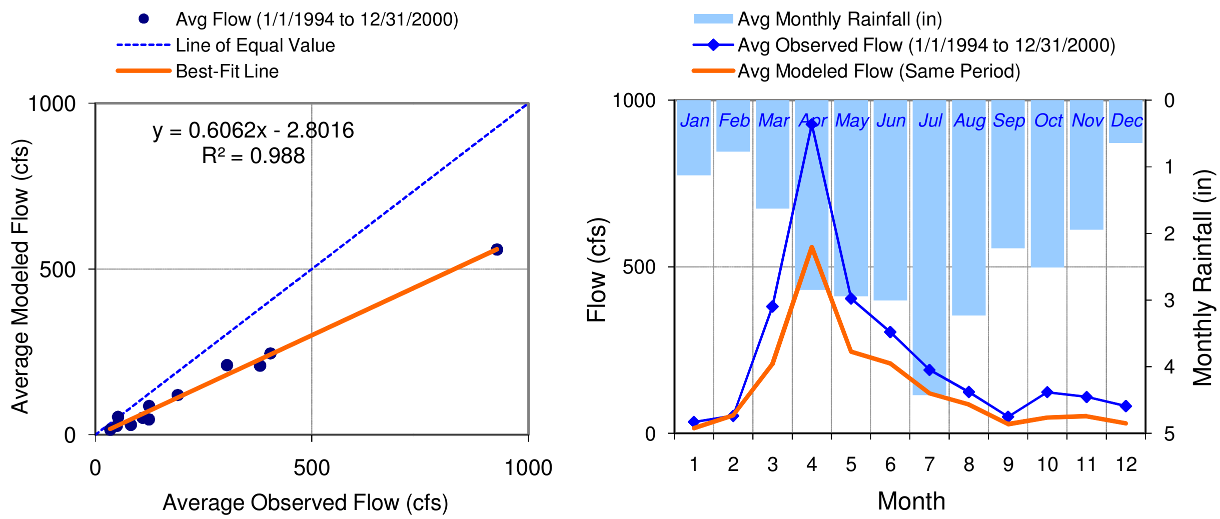


Figure 47. Seasonal regression and temporal aggregate: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

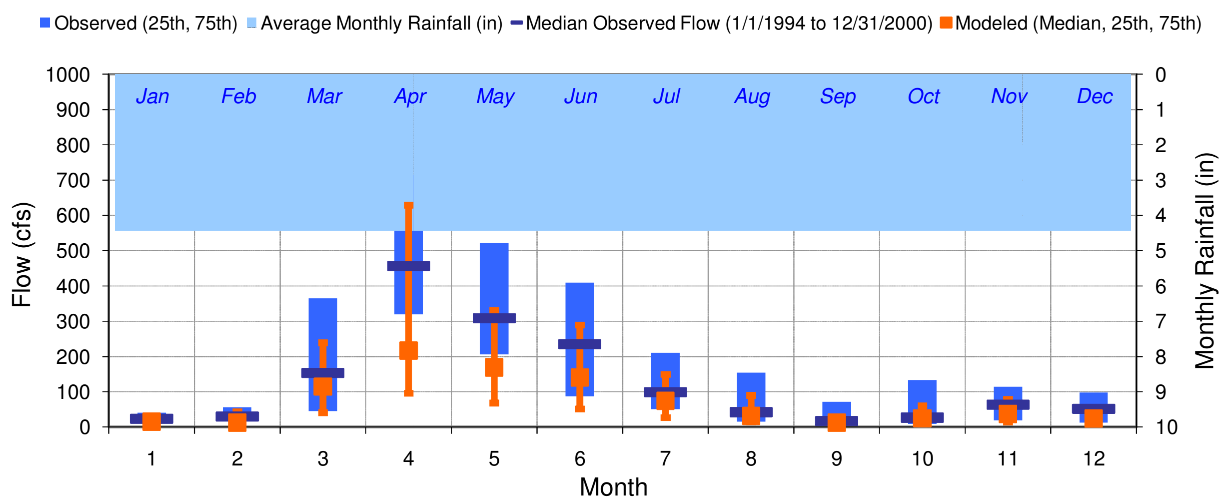


Figure 48. Seasonal medians and ranges: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

Table 9. Seasonal summary: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	34.58	24.00	11.00	41.00	15.61	14.91	8.16	20.59
Feb	52.62	29.50	17.00	56.00	54.15	12.49	6.44	44.18
Mar	380.82	153.00	45.00	365.00	208.50	114.82	40.69	239.06
Apr	927.93	456.50	320.00	938.75	558.87	216.48	95.97	629.75
May	404.75	309.00	206.00	522.00	245.42	169.38	68.59	331.26
Jun	304.28	235.00	87.25	409.25	209.97	140.47	51.21	289.52
Jul	190.51	99.00	51.00	211.00	120.04	74.52	26.72	150.06
Aug	124.41	42.00	15.00	154.00	86.70	31.60	15.76	90.20
Sep	49.95	17.00	5.60	71.25	27.36	12.50	3.55	26.92
Oct	123.88	27.00	9.00	134.00	46.74	24.87	3.62	60.68
Nov	109.32	63.00	19.25	113.75	51.30	36.99	14.09	78.23
Dec	82.10	52.00	13.00	98.00	30.20	24.04	14.15	35.29

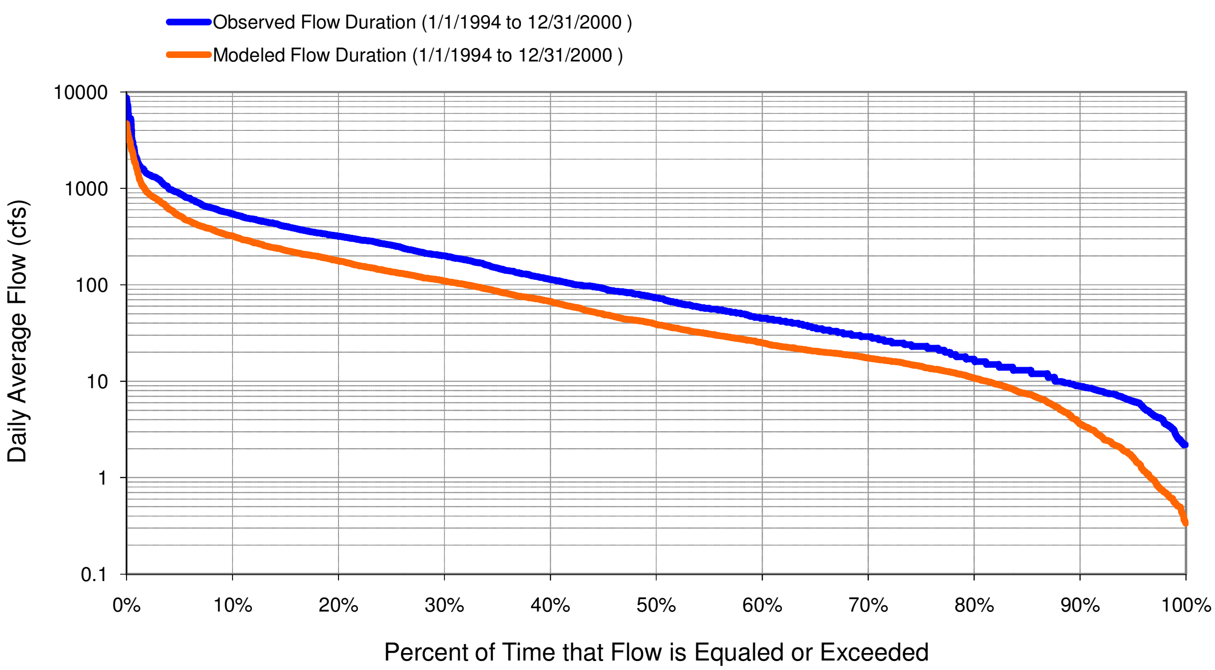


Figure 49. Flow exceedence: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

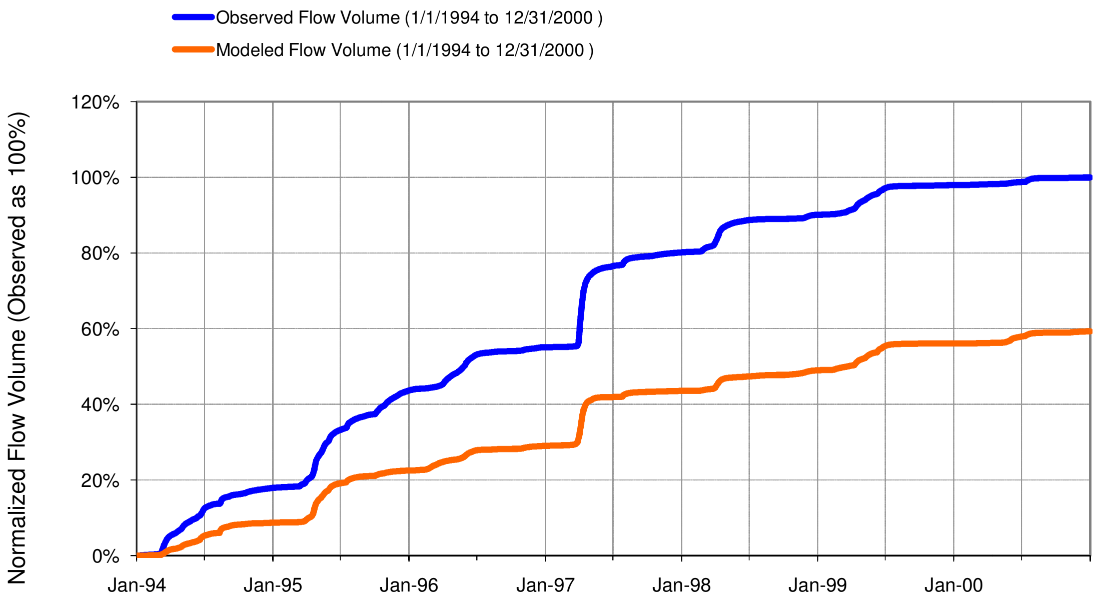


Figure 50. Flow accumulation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

Table 10. Summary statistics: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 100 7-Year Analysis Period: 1/1/1994 - 12/31/2000 Flow volumes are (inches/year) for upstream drainage area		USGS 05313500 YELLOW MEDICINE RIVER NEAR GRANITE FALLS, MN Hydrologic Unit Code: 7020004 Latitude: 44.72166667 Longitude: -95.5188889 Drainage Area (sq-mi): 664	
Total Simulated In-stream Flow:	**2.82**	Total Observed In-stream Flow:	**4.75**
Total of simulated highest 10% flows:	**1.62**	Total of Observed highest 10% flows:	**2.61**
Total of Simulated lowest 50% flows:	**0.15**	Total of Observed Lowest 50% flows:	**0.28**
Simulated Summer Flow Volume (months 7-9):	**0.40**	Observed Summer Flow Volume (7-9):	**0.63**
Simulated Fall Flow Volume (months 10-12):	**0.22**	Observed Fall Flow Volume (10-12):	**0.54**
Simulated Winter Flow Volume (months 1-3):	**0.47**	Observed Winter Flow Volume (1-3):	**0.80**
Simulated Spring Flow Volume (months 4-6):	**1.72**	Observed Spring Flow Volume (4-6):	**2.77**
Total Simulated Storm Volume:	**0.79**	Total Observed Storm Volume:	**1.21**
Simulated Summer Storm Volume (7-9):	**0.14**	Observed Summer Storm Volume (7-9):	**0.21**

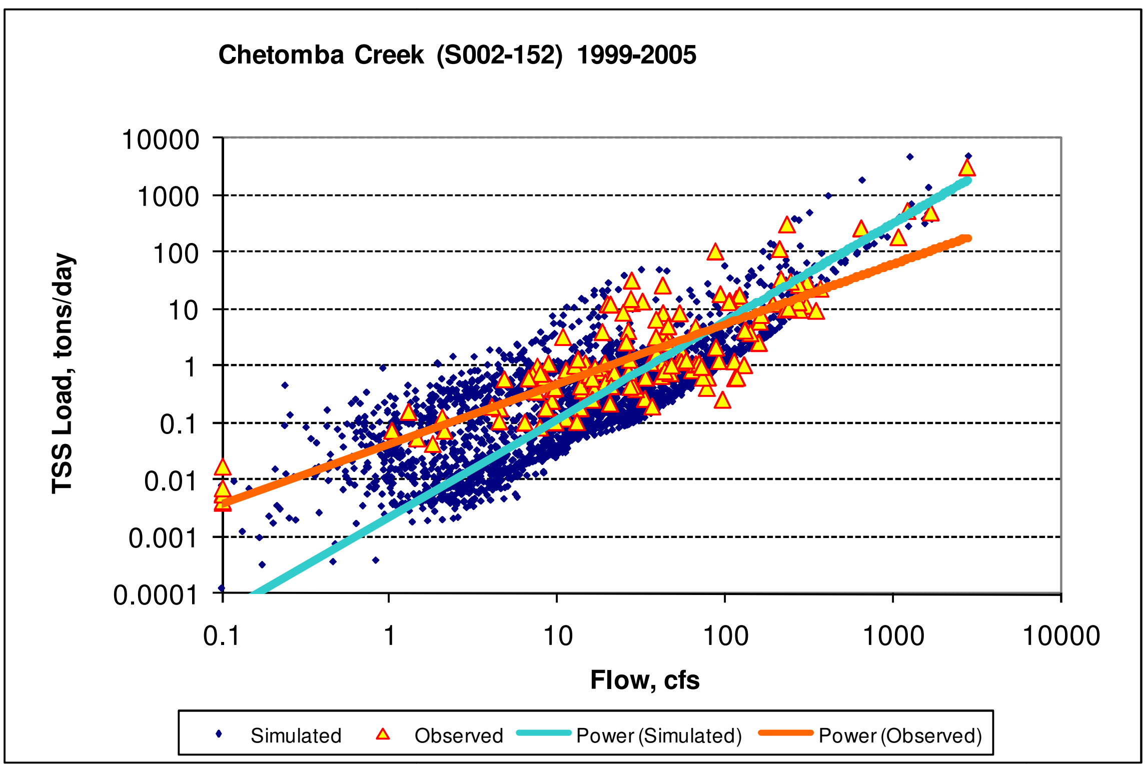
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	**-40.68**	**10**		
Error in 50% lowest flows:	**-44.24**	**10**		
Error in 10% highest flows:	**-37.91**	**15**		
Seasonal volume error - Summer:	**-35.80**	**30**		
Seasonal volume error - Fall:	**-59.40**	**30**		
Seasonal volume error - Winter:	**-40.98**	**30**		
Seasonal volume error - Spring:	**-38.05**	**30**		
Error in storm volumes:	**-34.68**	**20**		
Error in summer storm volumes:	-31.78	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.703	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.519	as E or E' approaches 1.0		
Monthly NSE	0.847			

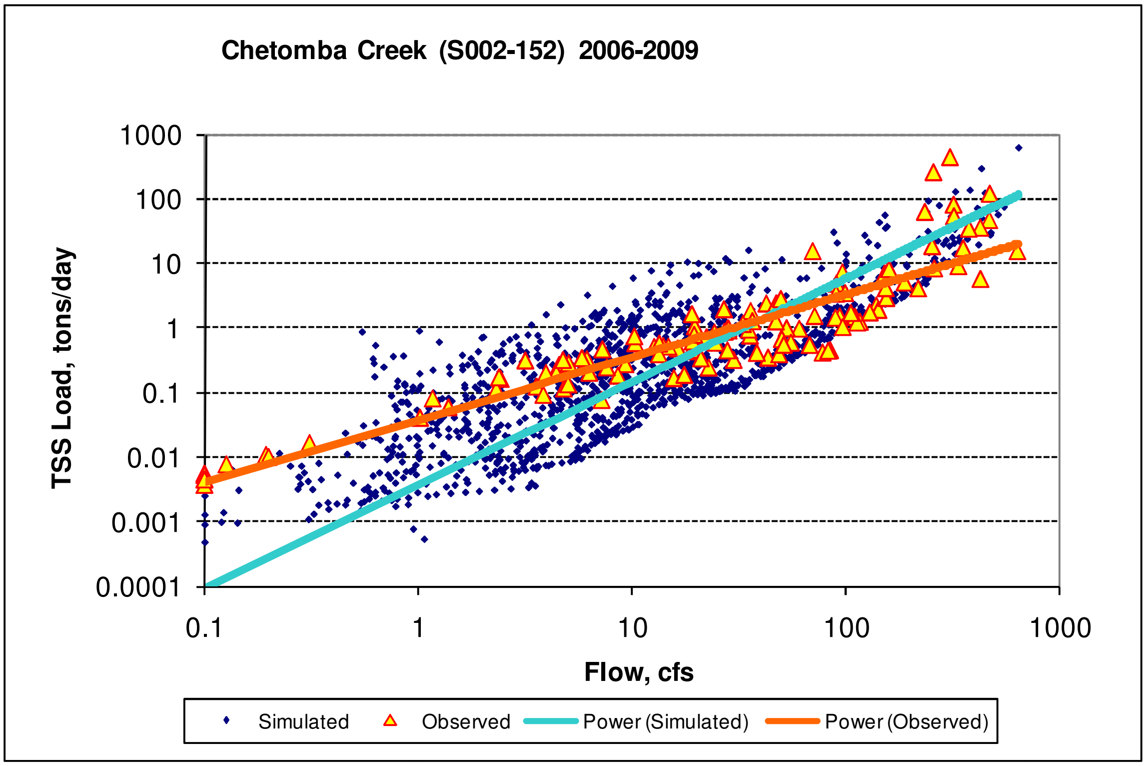
Water Quality Calibration and Validation for the Hawk Creek/Yellow Medicine HSPF Model

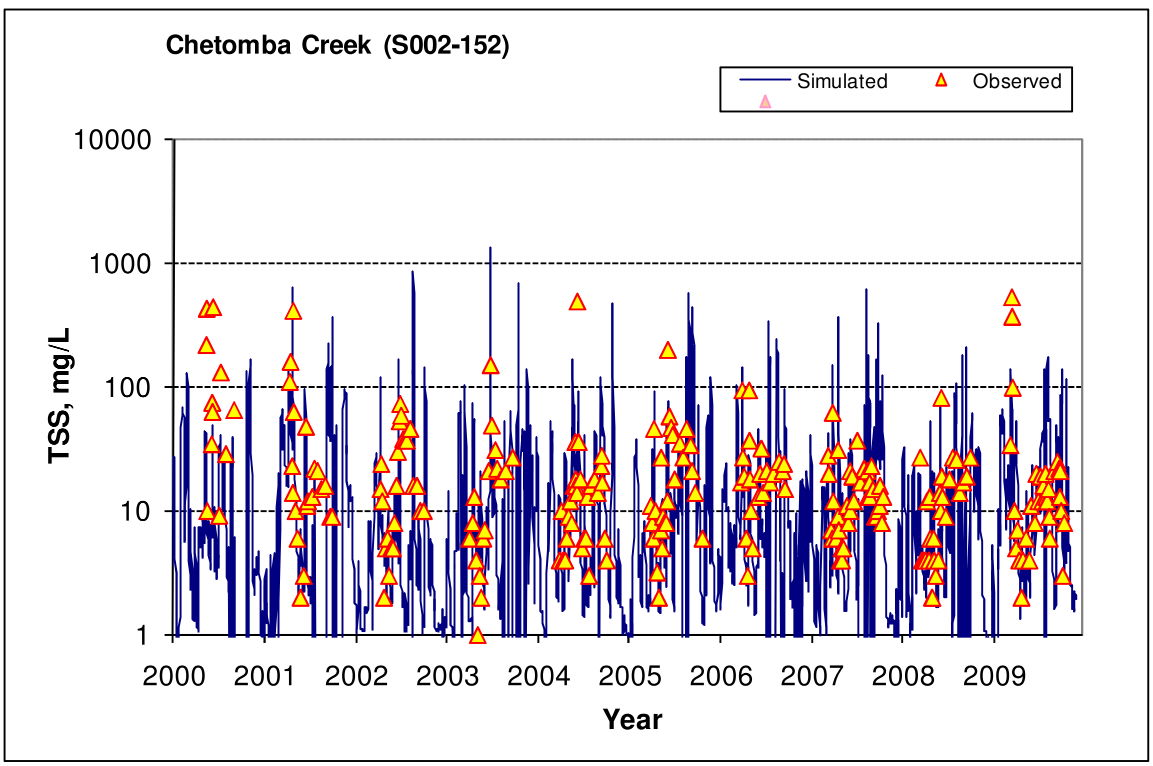
1 Chetomba Creek (S002-152)

1.1 Total Suspended Sediment

Parameter	1999 - 2005	2006 - 2009
Count	138	120
Conc Ave Error	-10.43%	35.93%
Conc Median Error	-9.49%	4.43%
Load Ave Error	42.73%	24.96%
Load Median Error	-0.34%	0.32%
Paired t conc	0.70	0.23
Paired t load	0.38	0.46

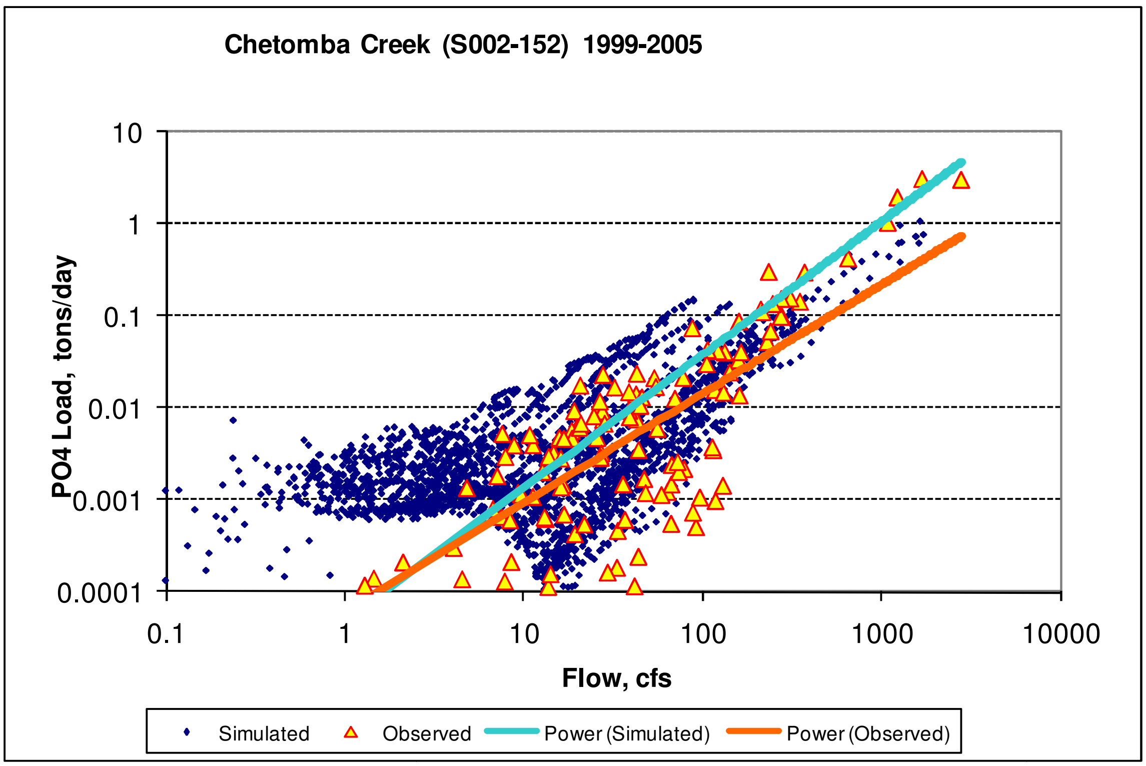


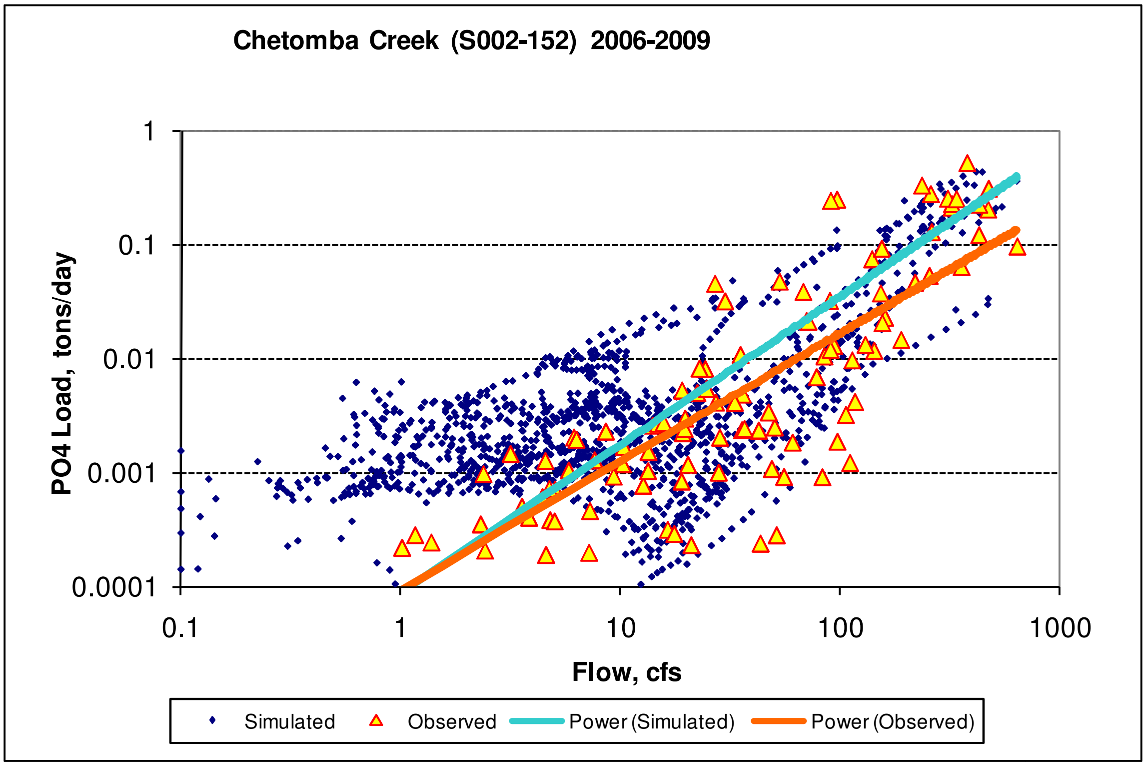

Chetomba Creek (S002-152) 2006-2009
TSS Load, tons/day
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

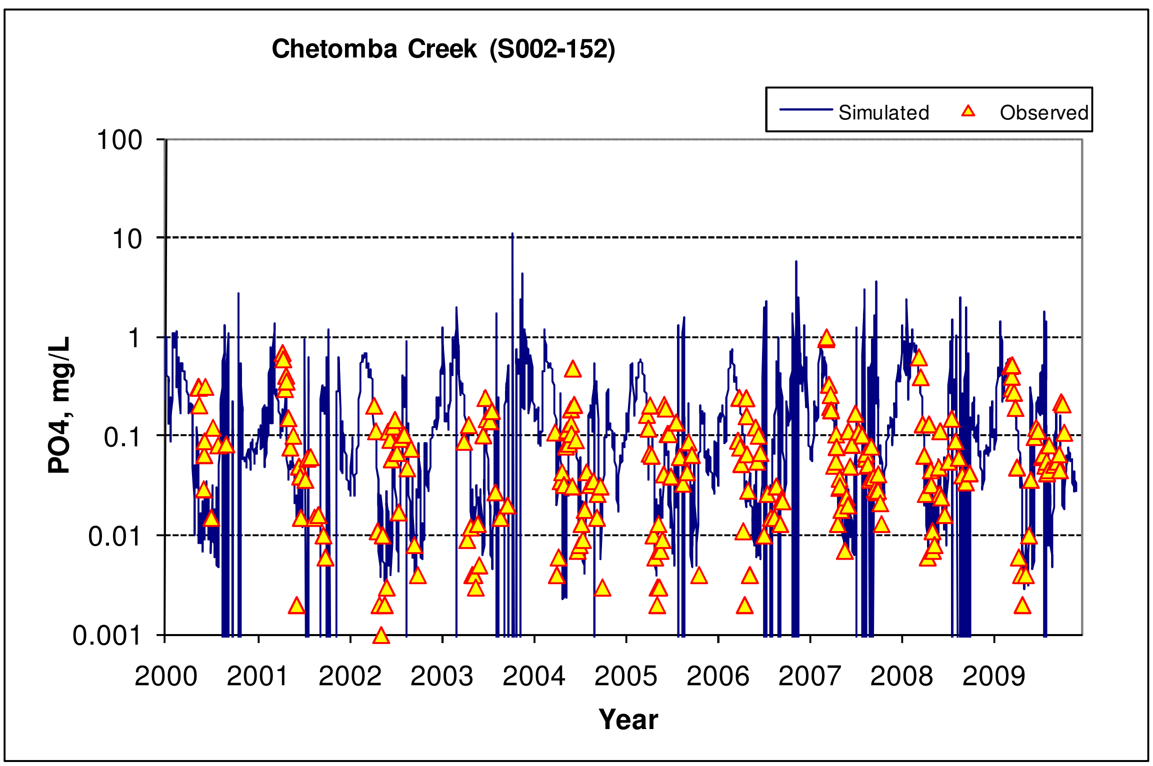

Chetomba Creek (S002-152)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

1.2 ORTHOPHOSPHATE (AS P)

Parameter	1999 - 2005	2006 - 2009
Count	134	114
Conc Ave Error	-11.82%	12.84%
Conc Median Error	-12.98%	4.58%
Load Ave Error	-45.46%	-21.28%
Load Median Error	-0.26%	0.51%
Paired t conc	0.77	0.70
Paired t load	0.22	0.47

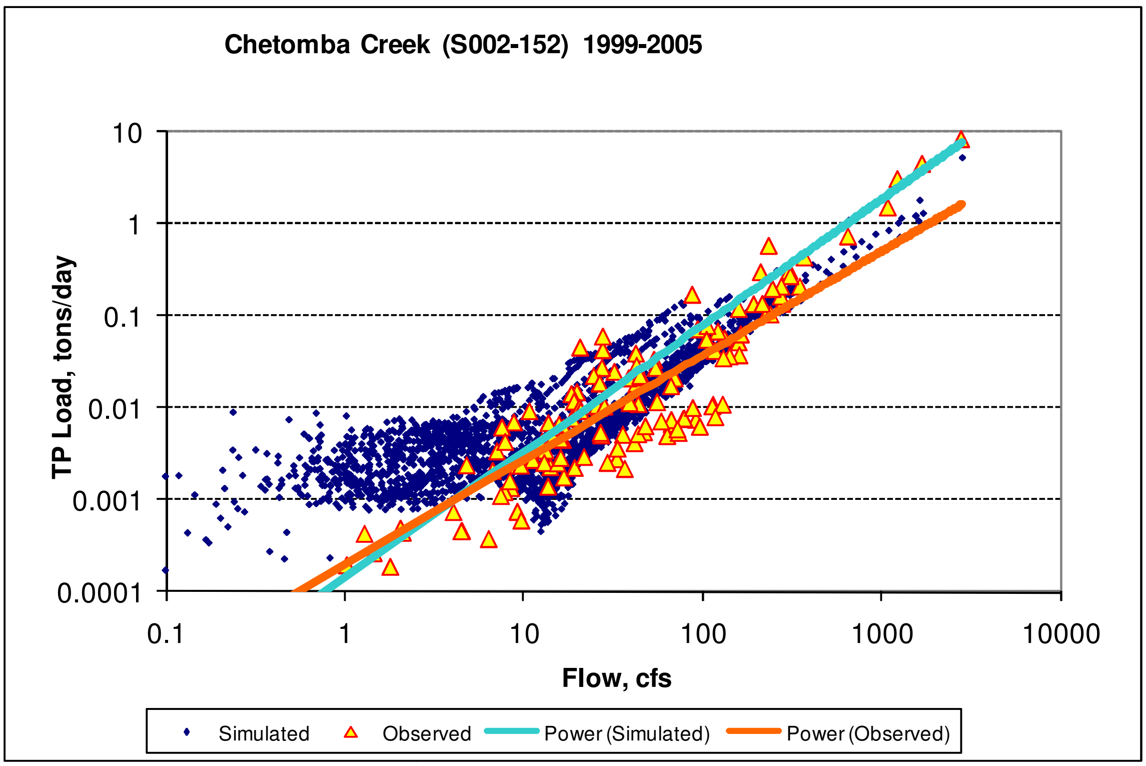


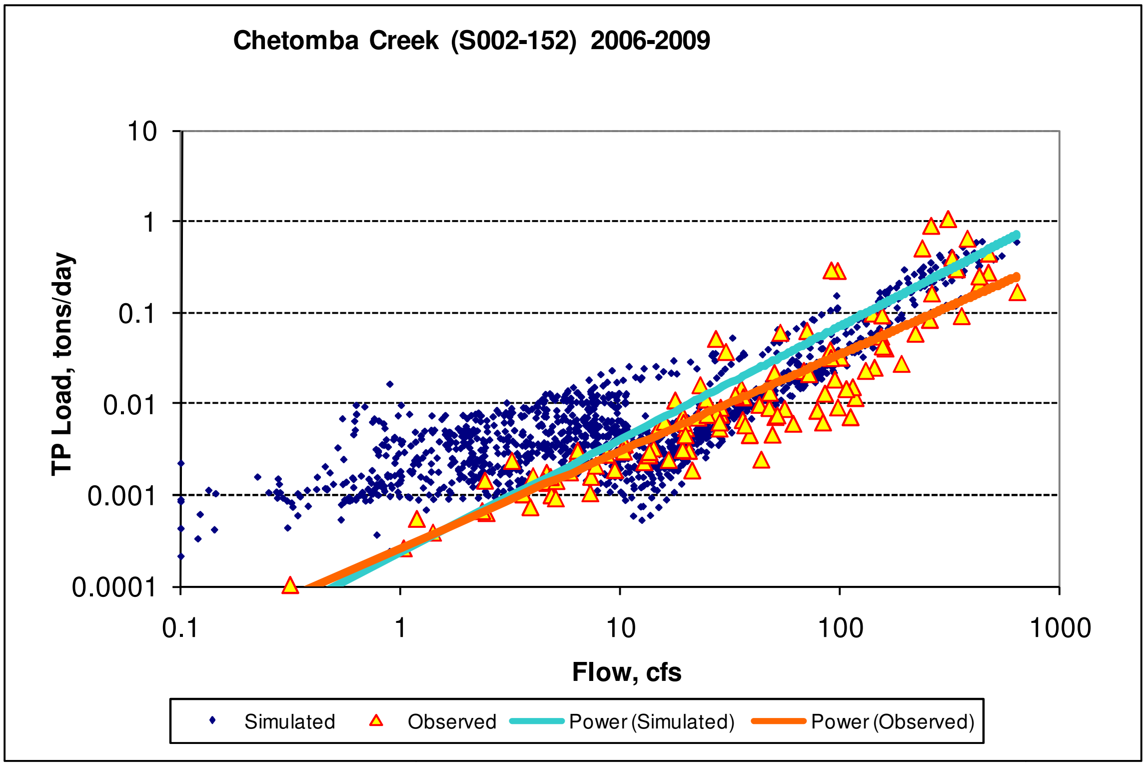

Chetomba Creek (S002-152) 2006-2009
PO4 Load, tons/day
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

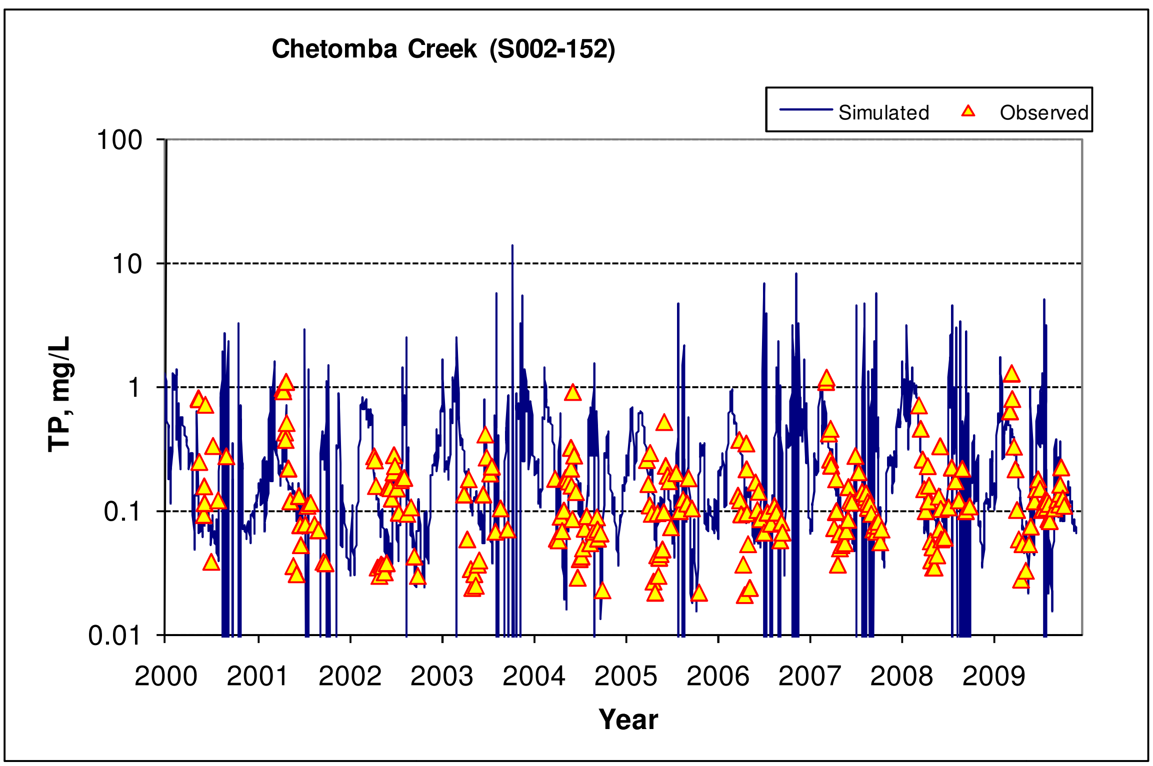

Chetomba Creek (S002-152)
Simulated
Observed
PO4, mg/L
100
10
1
0.1
0.01
0.001
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

1.3 TOTAL PHOSPHORUS

Parameter	1999 - 2005	2006 - 2009
Count	138	121
Conc Ave Error	0.16%	28.65%
Conc Median Error	0.62%	15.42%
Load Ave Error	-40.99%	-18.55%
Load Median Error	0.10%	2.30%
Paired t conc	0.98	0.25
Paired t load	0.27	0.53

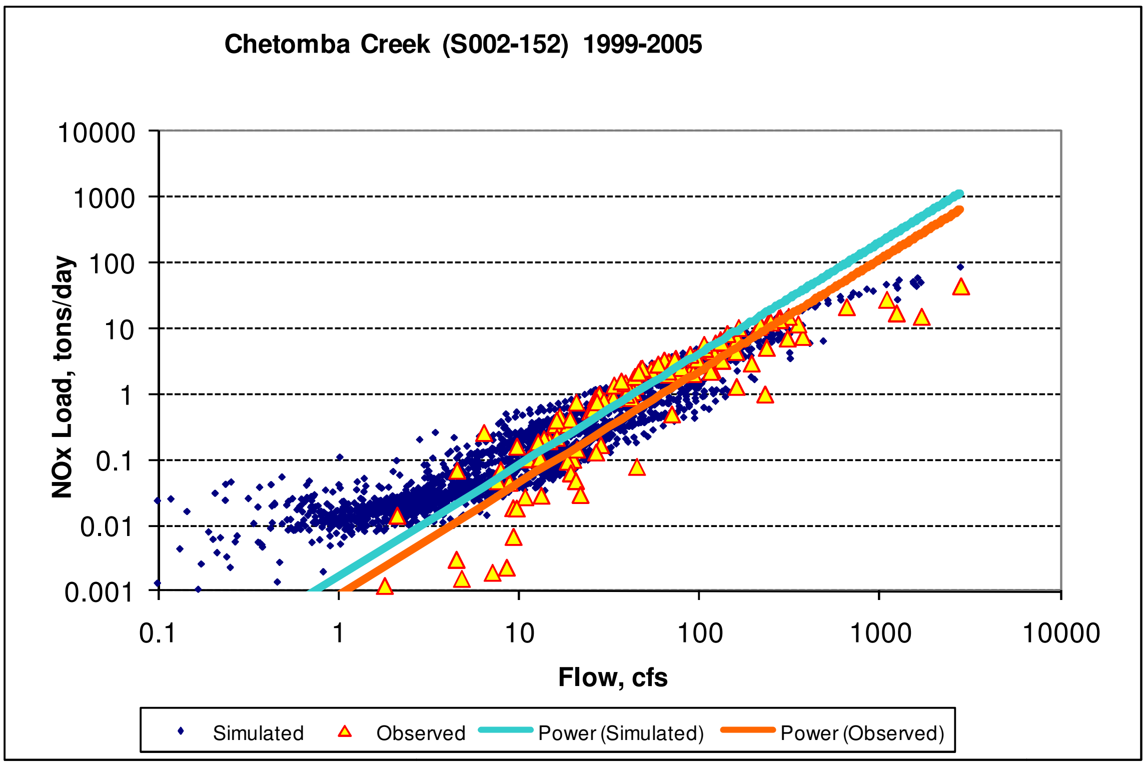


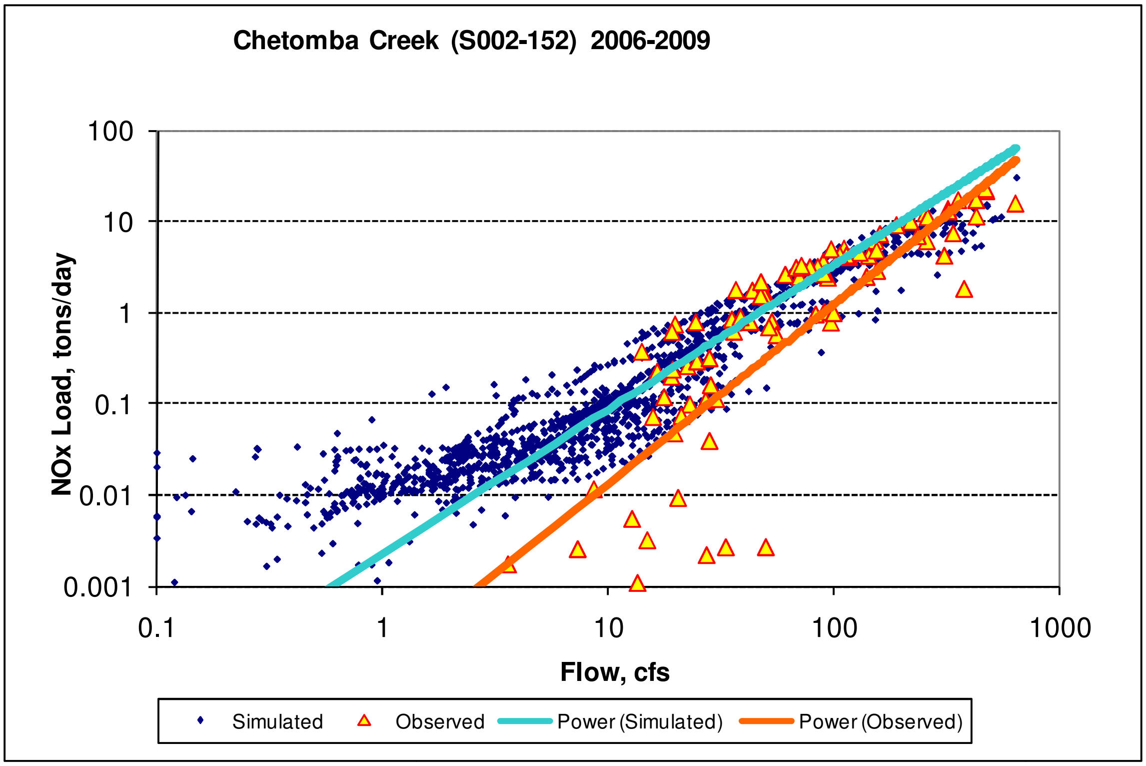

Chetomba Creek (S002-152) 2006-2009
10
1
0.1
0.01
0.001
0.0001
TP Load, tons/day
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

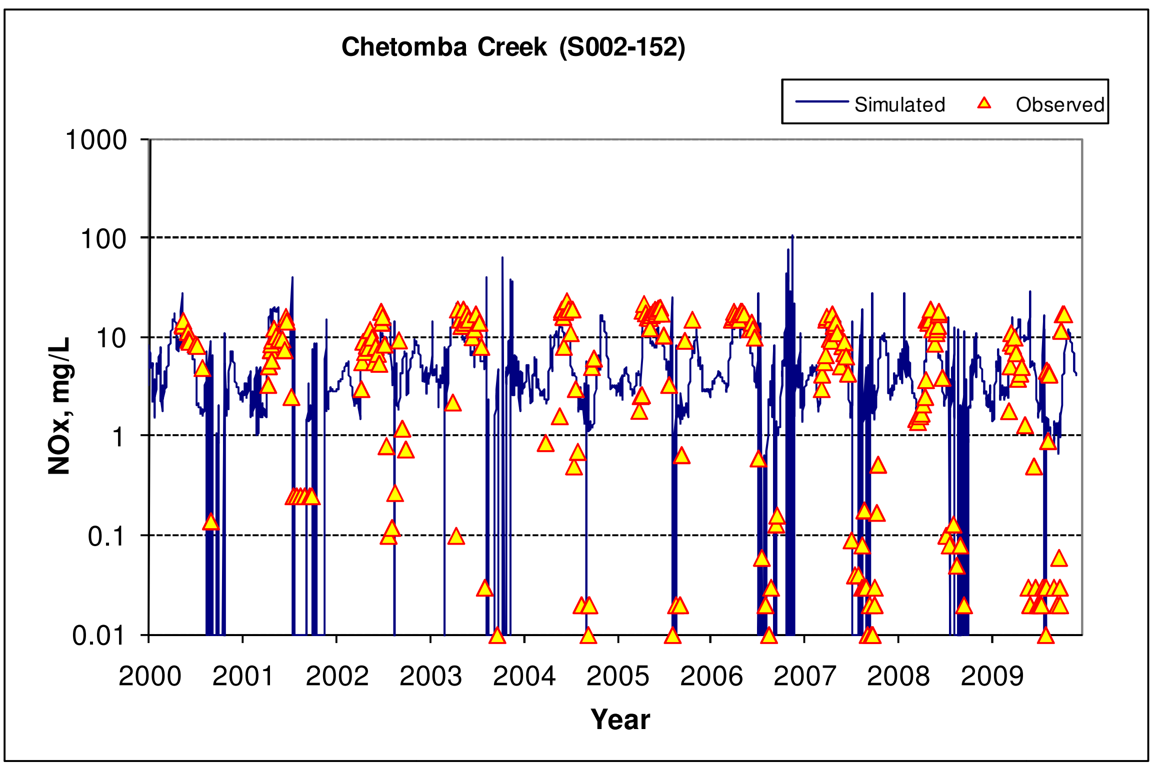

Chetomba Creek (S002-152)
Simulated
Observed
100
10
1
0.1
0.01
TP, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

1.4 NITRATE PLUS NITRITE NITROGEN (AS N)

Parameter	1999 - 2005	2006 - 2009
Count	129	119
Conc Ave Error	-14.05%	-2.02%
Conc Median Error	-4.32%	5.90%
Load Ave Error	19.29%	-7.98%
Load Median Error	-1.13%	0.56%
Paired t conc	0.84	0.98
Paired t load	0.51	0.77

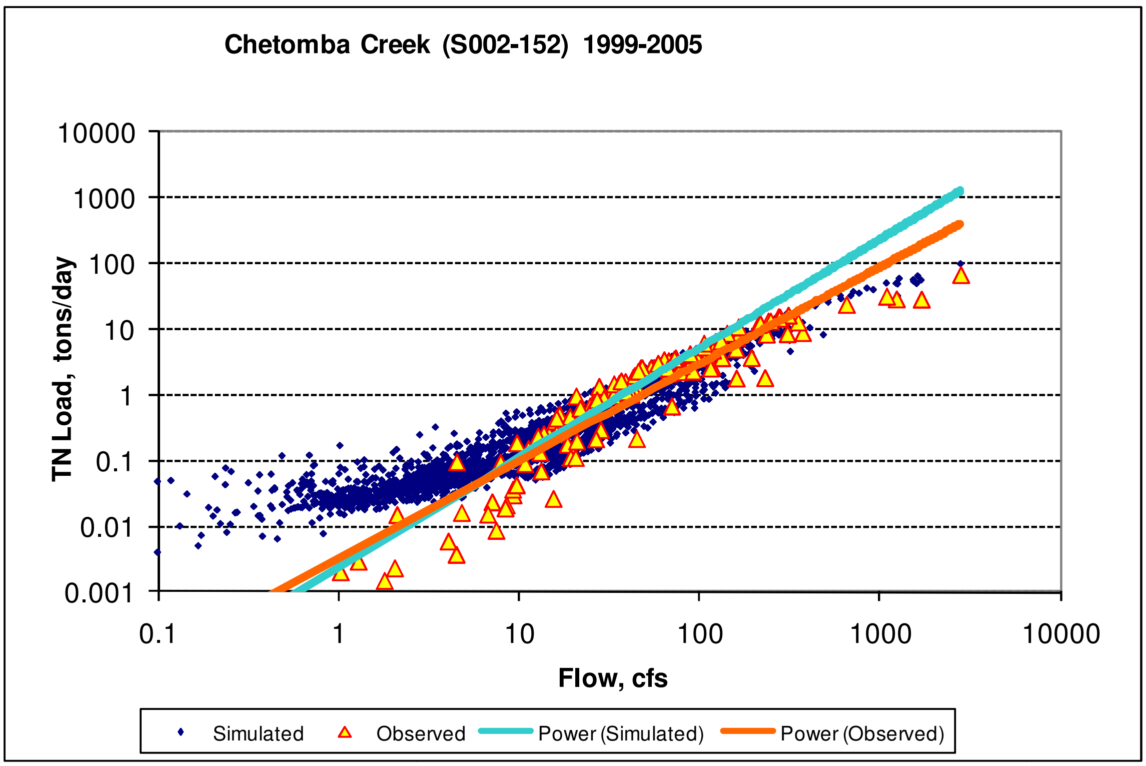


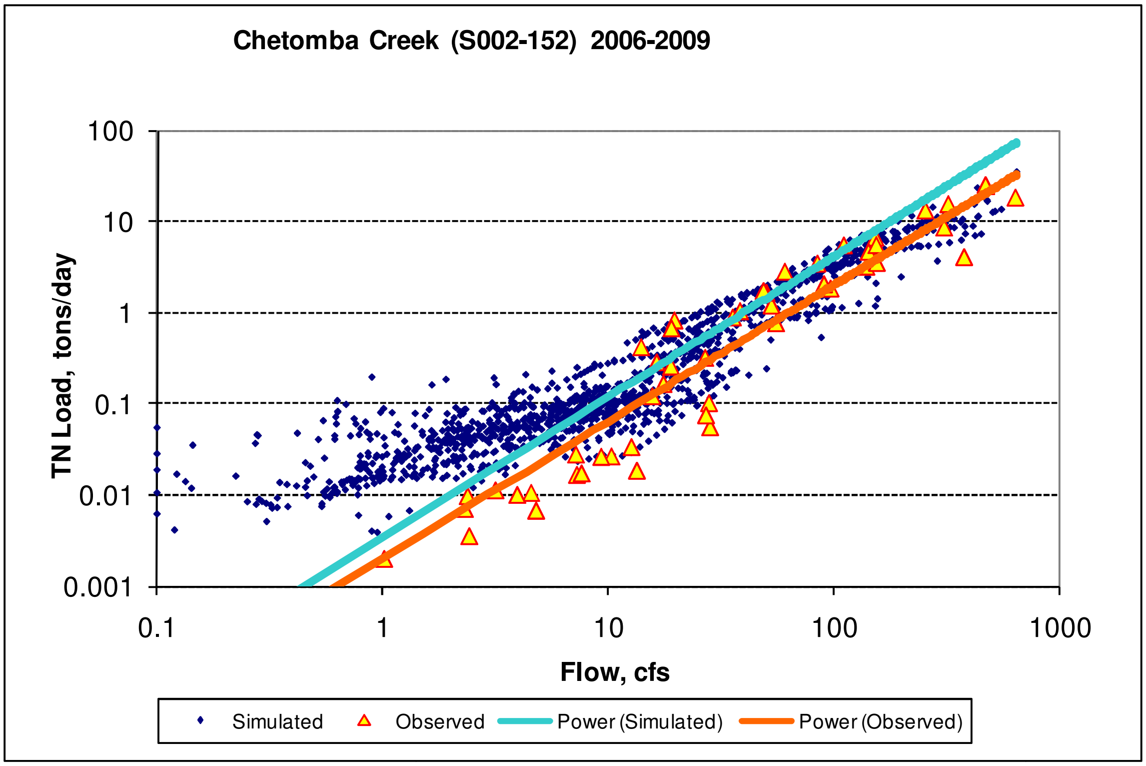

Chetomba Creek (S002-152) 2006-2009
100
10
1
0.1
0.01
0.001
NOx Load, tons/day
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

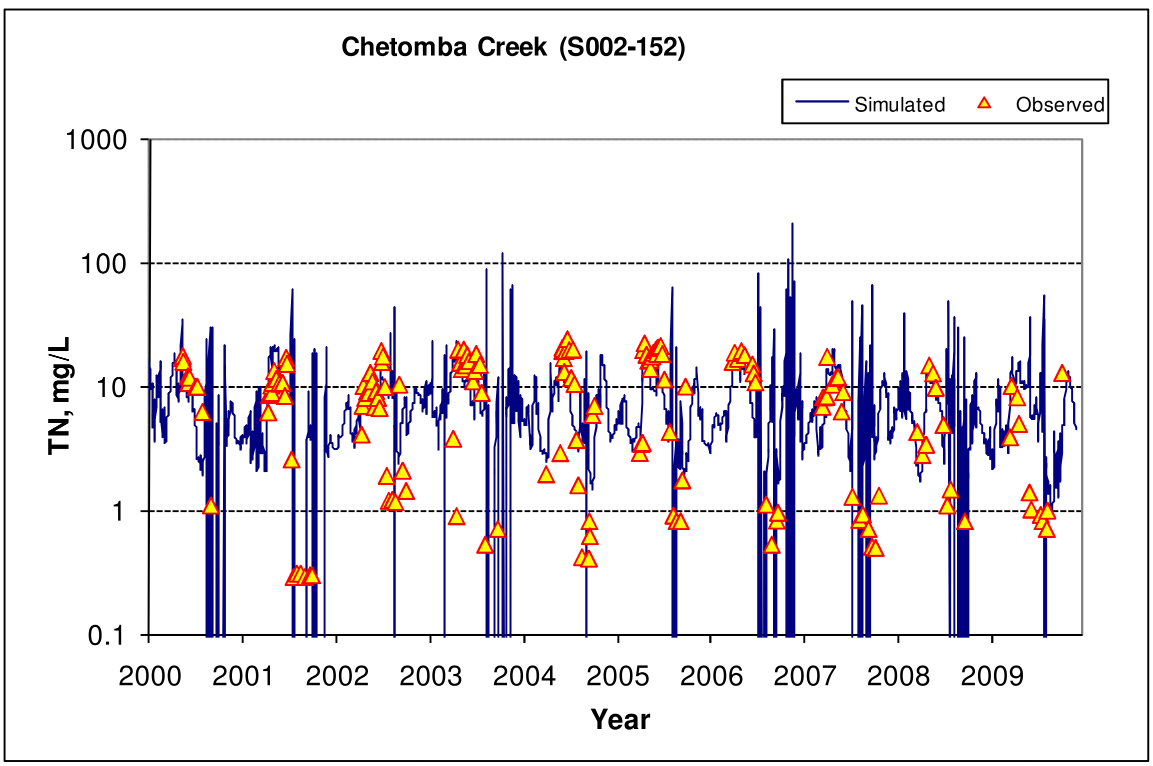

Chetomba Creek (S002-152)
Simulated
Observed
1000
100
10
1
0.1
0.01
NOx, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

1.5 TOTAL NITROGEN

Parameter	1999 - 2005	2006 - 2009
Count	125	51
Conc Ave Error	-11.51%	13.50%
Conc Median Error	-16.39%	17.66%
Load Ave Error	11.99%	-5.27%
Load Median Error	-3.05%	1.08%
Paired t conc	0.94	0.72
Paired t load	0.63	0.71



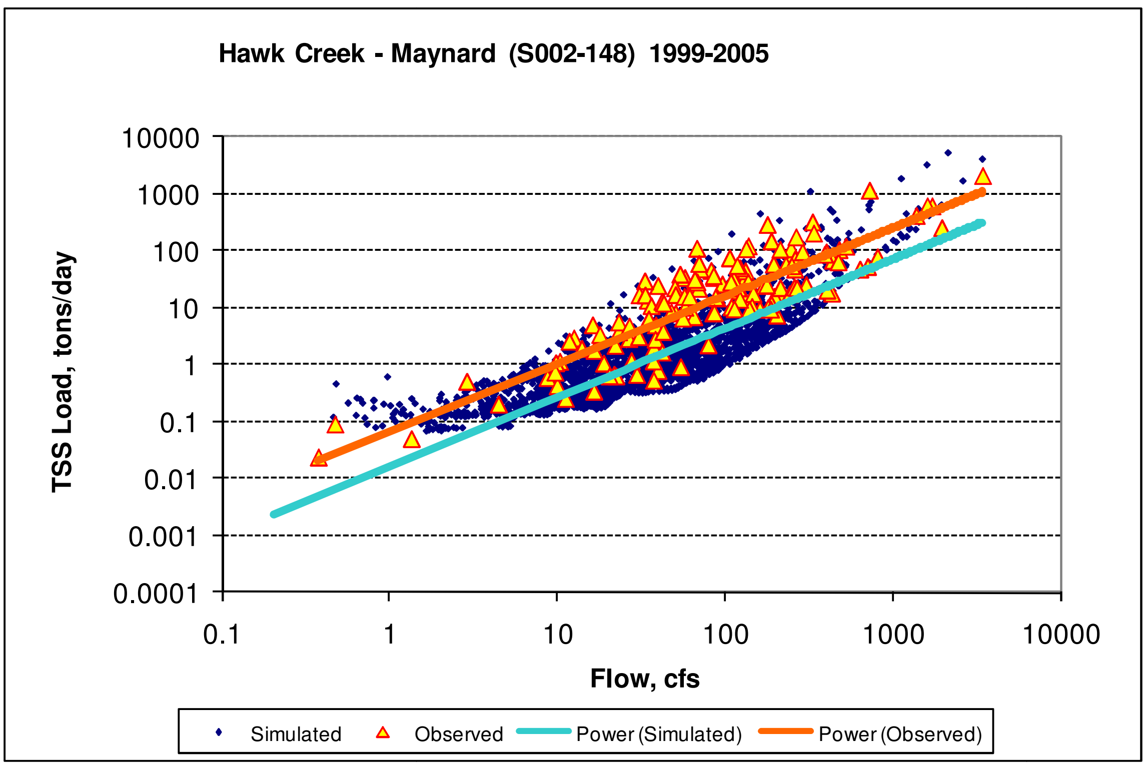

Chetomba Creek (S002-152) 2006-2009
100
10
1
0.1
0.01
0.001
TN Load, tons/day
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

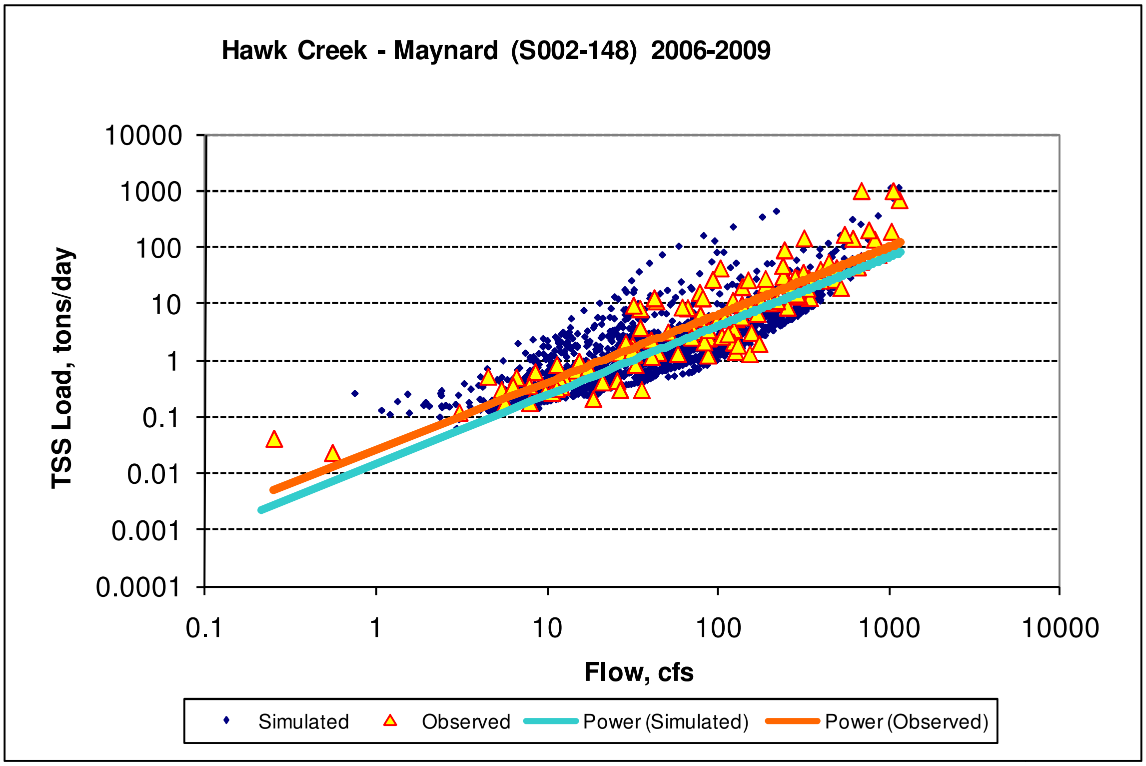

Chetomba Creek (S002-152)
Simulated
Observed
1000
100
10
1
0.1
TN, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

2 Hawk Creek at Maynard (S002-148)

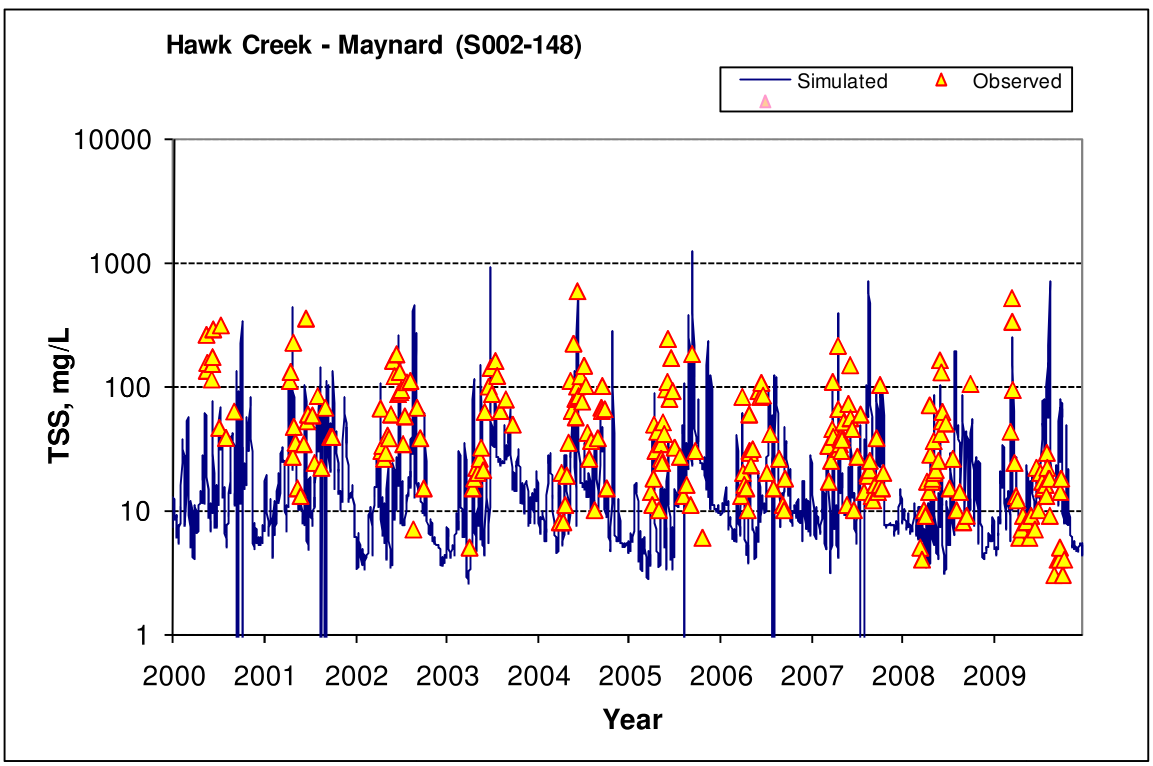
2.1 Total Suspended Sediment

Parameter	1999 - 2005	2006 - 2009
Count	141	119
Conc Ave Error	-55.27%	32.12%
Conc Median Error	-35.04%	-5.42%
Load Ave Error	18.55%	14.21%
Load Median Error	-10.56%	-0.14%
Paired t conc	0.00	0.26
Paired t load	0.51	0.57





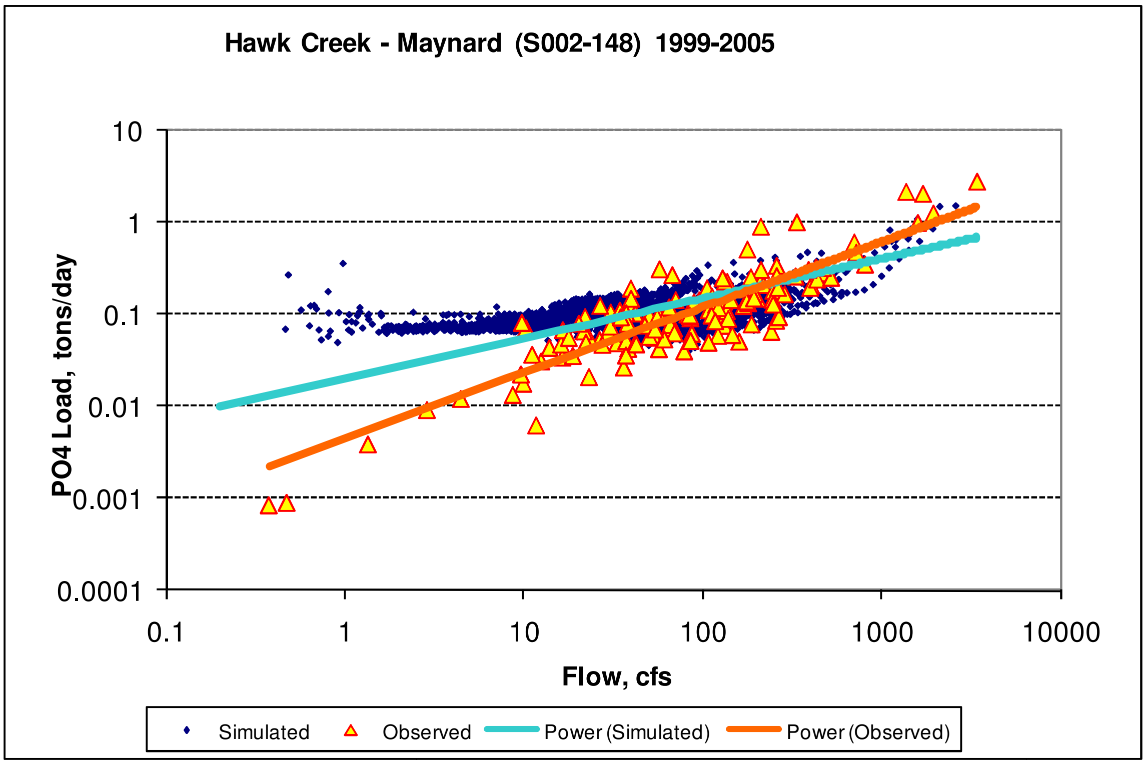
Hawk Creek - Maynard (S002-148) 2006-2009
TSS Load, tons/day
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

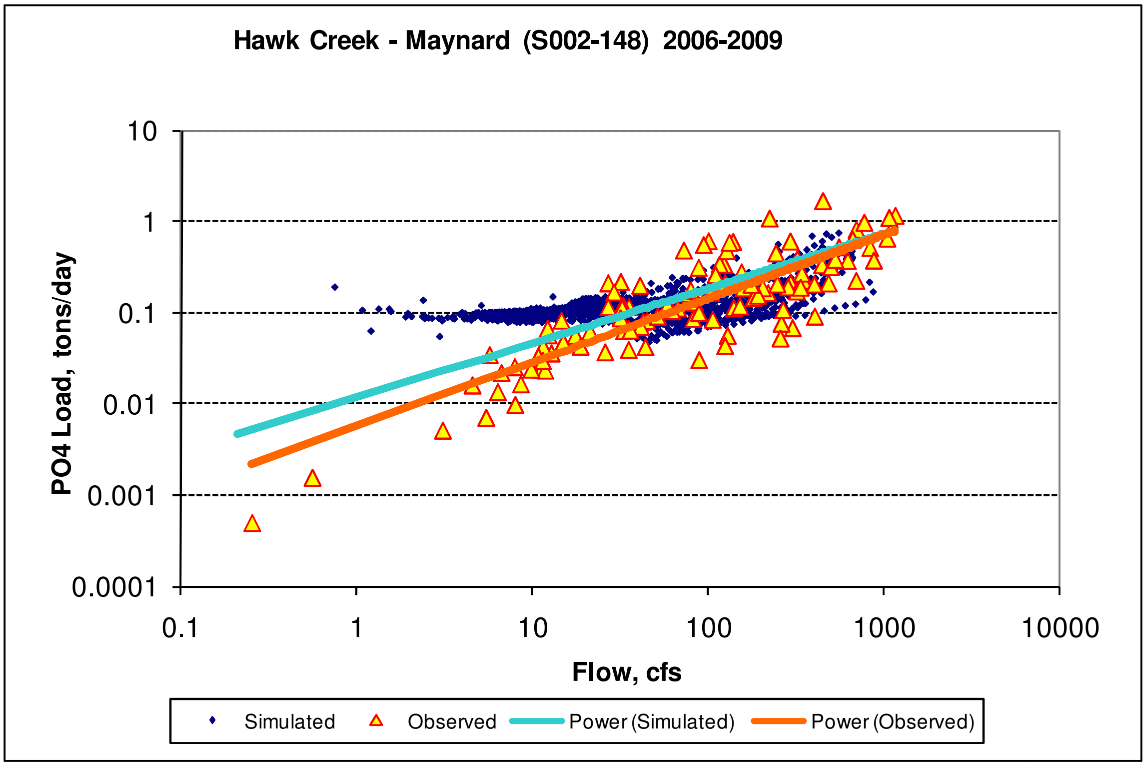


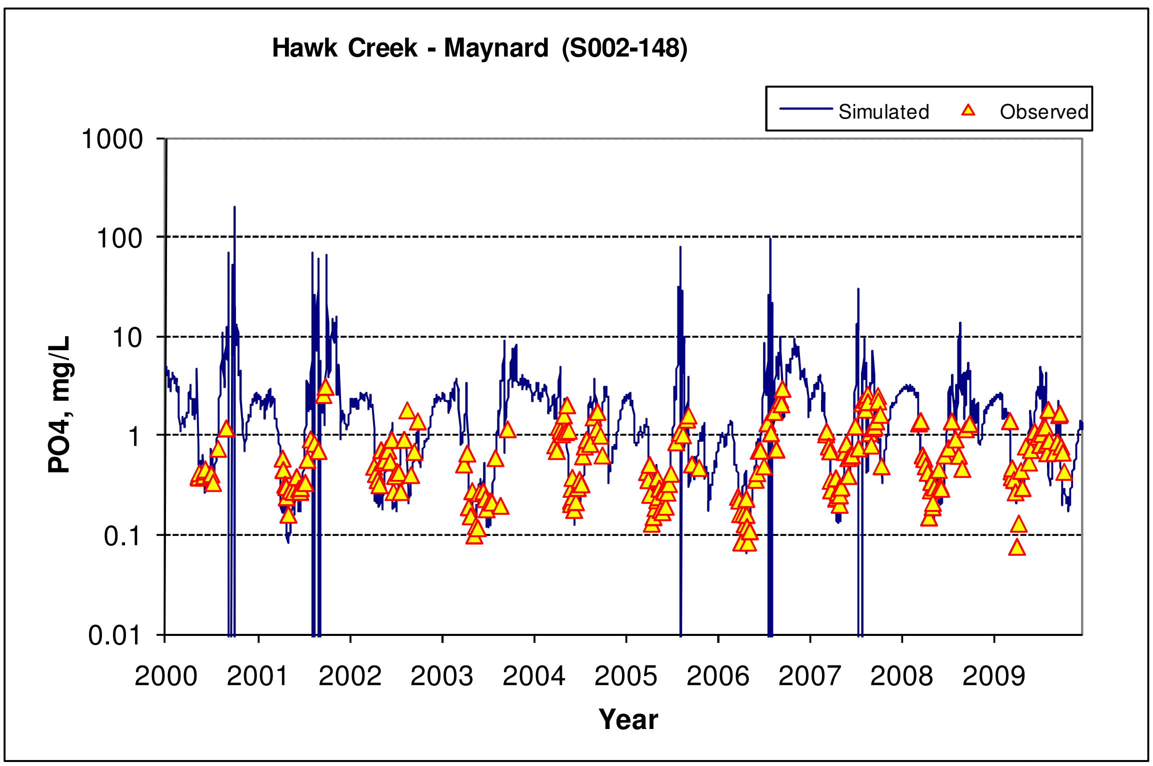
Hawk Creek - Maynard (S002-148)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

2.2 Orthophosphate (as P)

Parameter	1999 - 2005	2006 - 2009
Count	137	113
Conc Ave Error	65.68%	48.84%
Conc Median Error	-3.95%	-7.00%
Load Ave Error	-21.70%	-26.09%
Load Median Error	-1.76%	-6.15%
Paired t conc	0.03	0.03
Paired t load	0.45	0.25

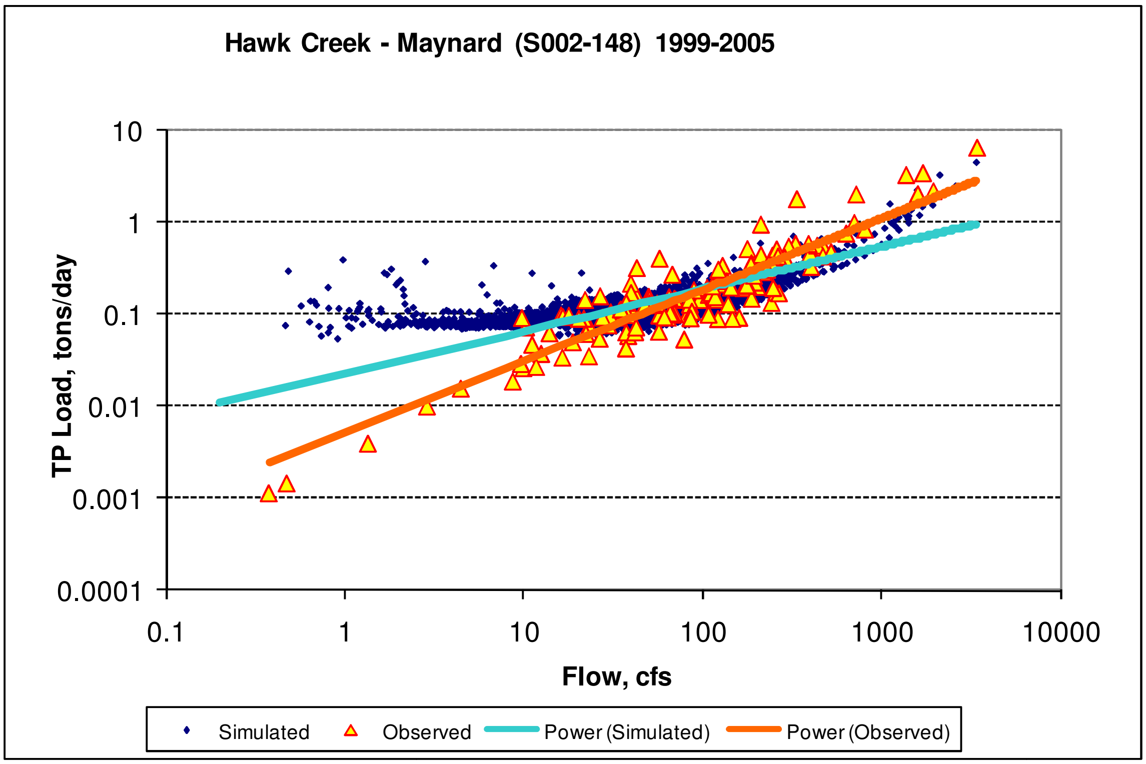


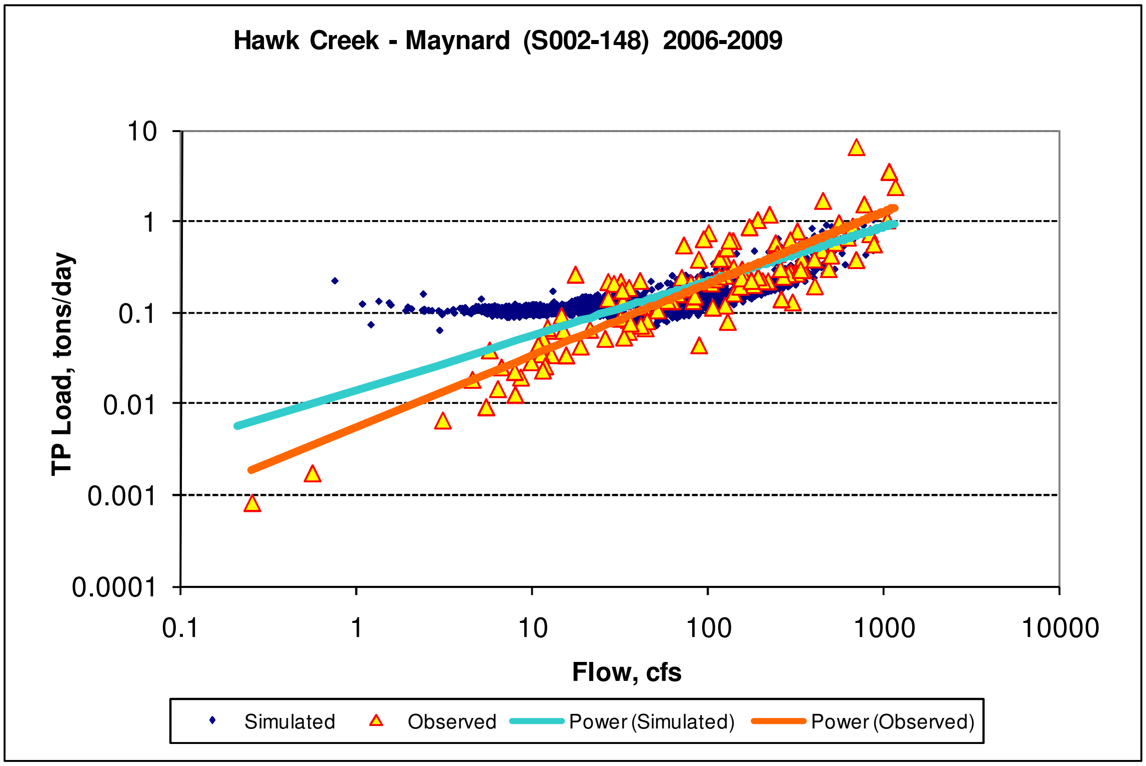

Hawk Creek - Maynard (S002-148) 2006-2009
PO4 Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

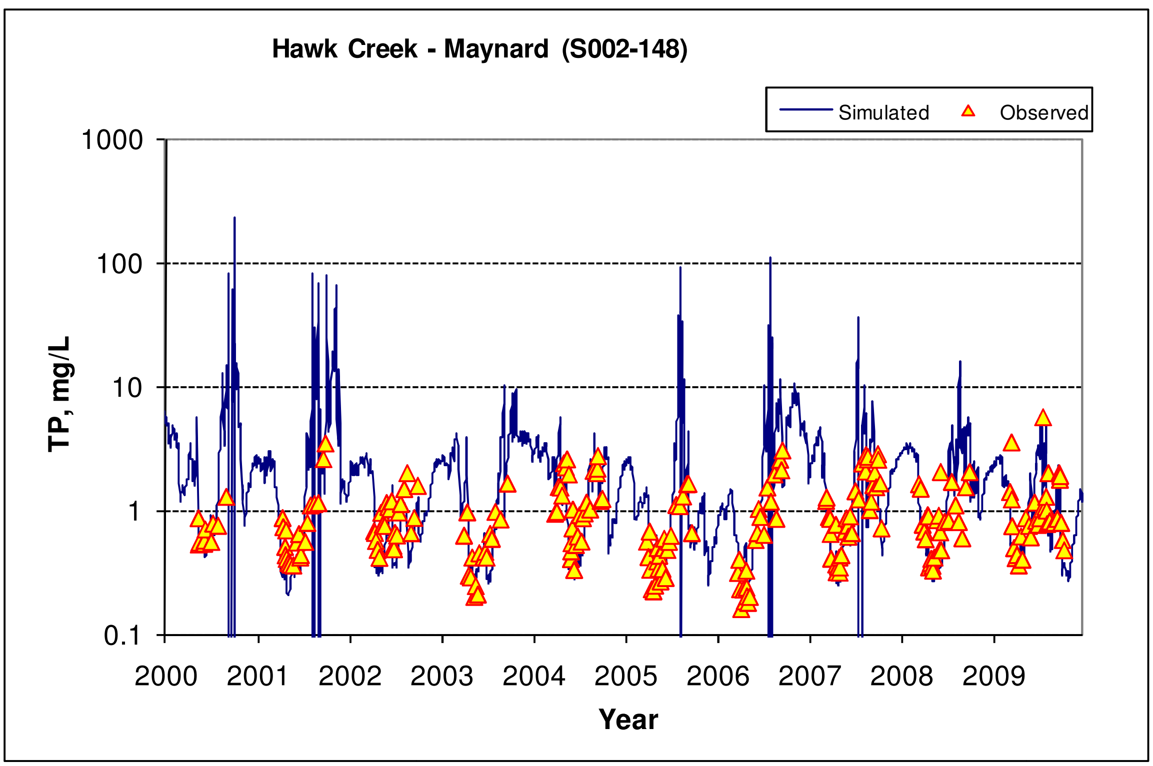

Hawk Creek - Maynard (S002-148)
Simulated
Observed
PO4, mg/L
1000
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

2.3 TOTAL PHOSPHORUS

Parameter	1999 - 2005	2006 - 2009
Count	140	120
Conc Ave Error	38.47%	28.72%
Conc Median Error	-9.78%	-9.00%
Load Ave Error	-28.93%	-38.85%
Load Median Error	-5.25%	-12.06%
Paired t conc	0.18	0.24
Paired t load	0.28	0.07

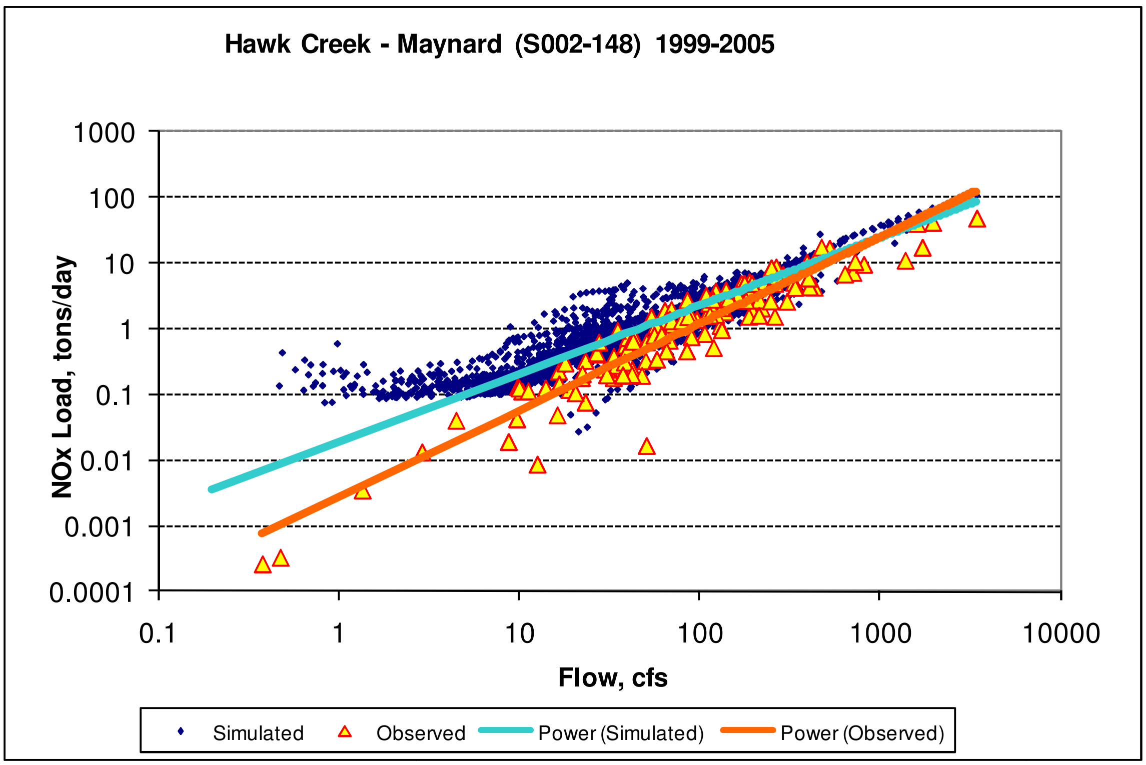


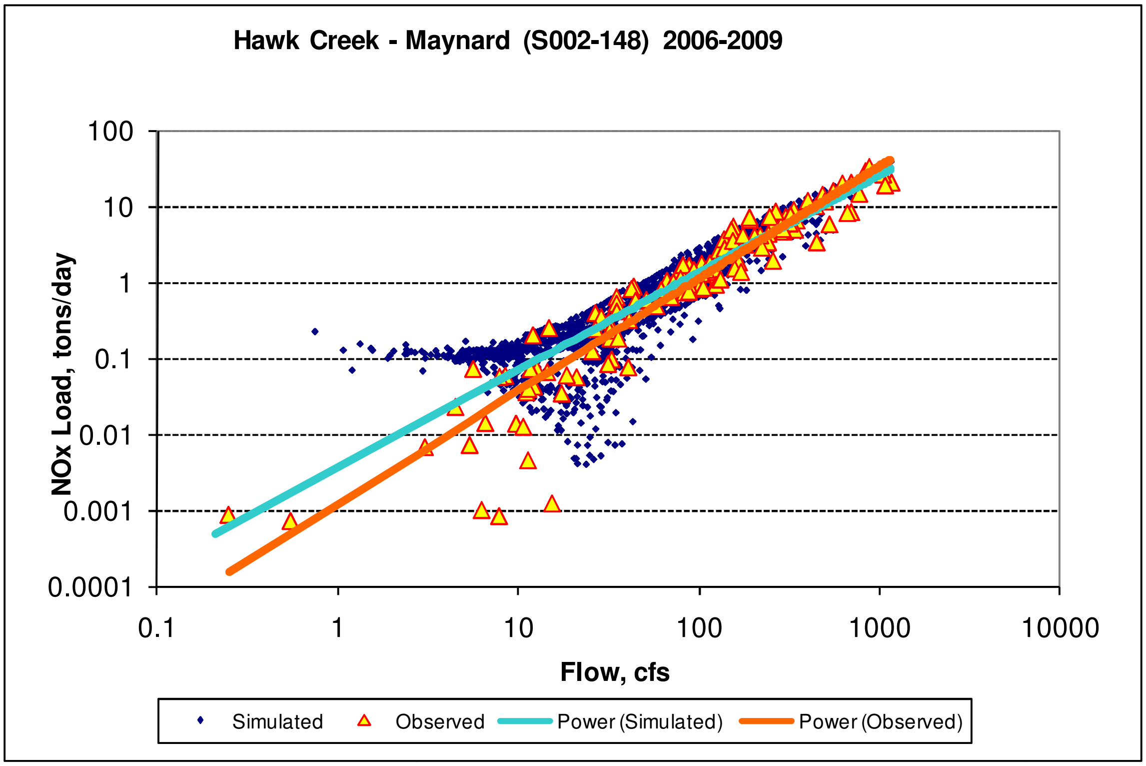

Hawk Creek - Maynard (S002-148) 2006-2009
10
1
0.1
0.01
0.001
0.0001
TP Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)


Hawk Creek - Maynard (S002-148)
Simulated
Observed
1000
100
10
1
0.1
TP, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

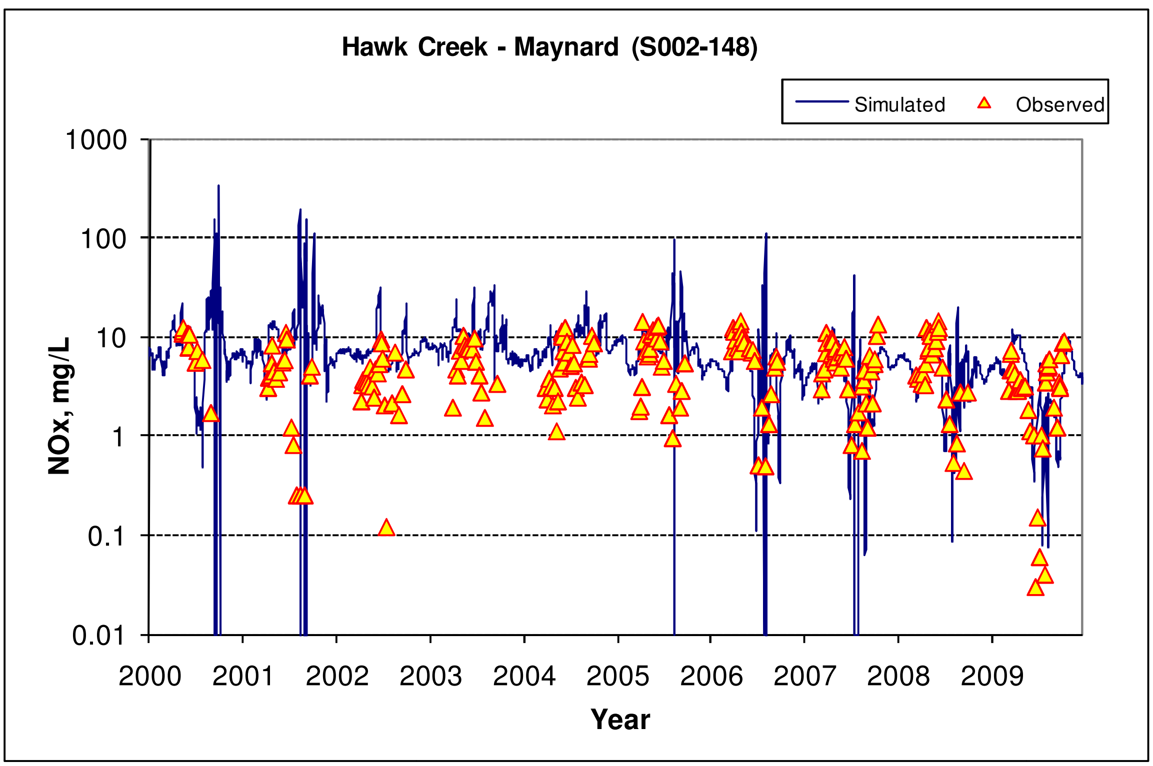
2.4 NITRATE PLUS NITRITE NITROGEN (AS N)

Parameter	1999 - 2005	2006 - 2009
Count	139	120
Conc Ave Error	100.95%	-3.11%
Conc Median Error	72.67%	-9.25%
Load Ave Error	64.02%	3.79%
Load Median Error	15.14%	-0.72%
Paired t conc	0.00	1.00
Paired t load	0.04	0.85





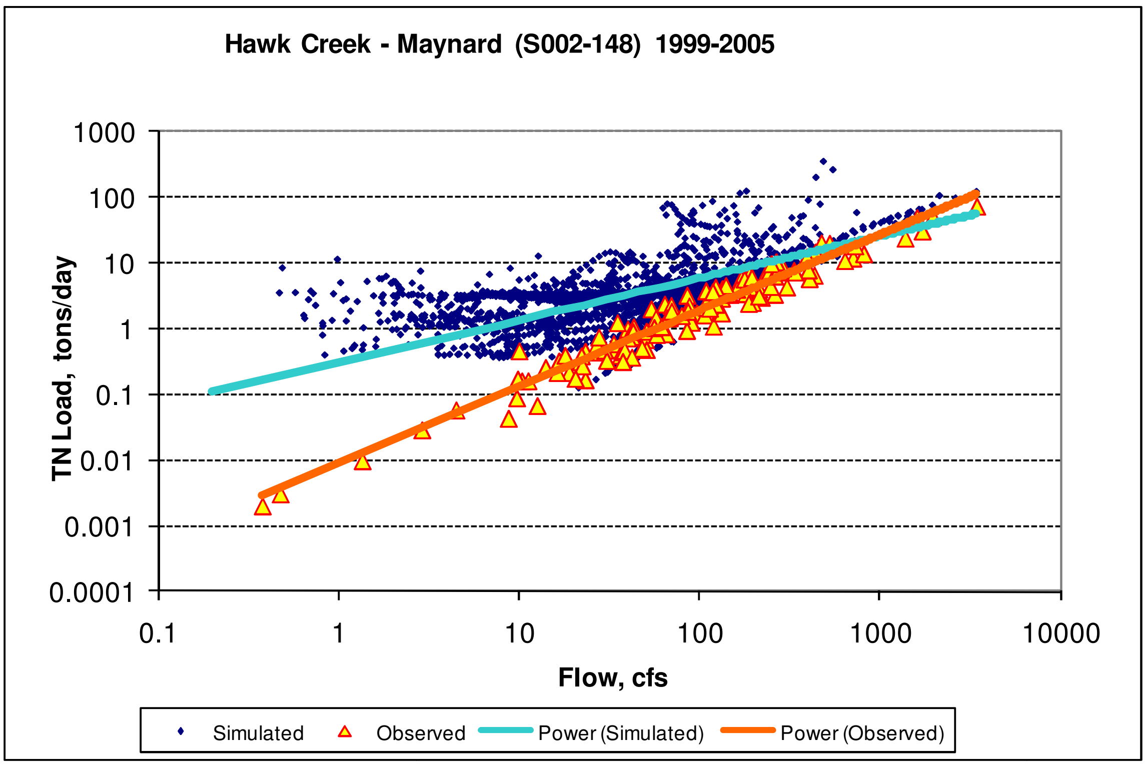
Hawk Creek - Maynard (S002-148) 2006-2009
100
10
1
0.1
0.01
0.001
0.0001
NOx Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

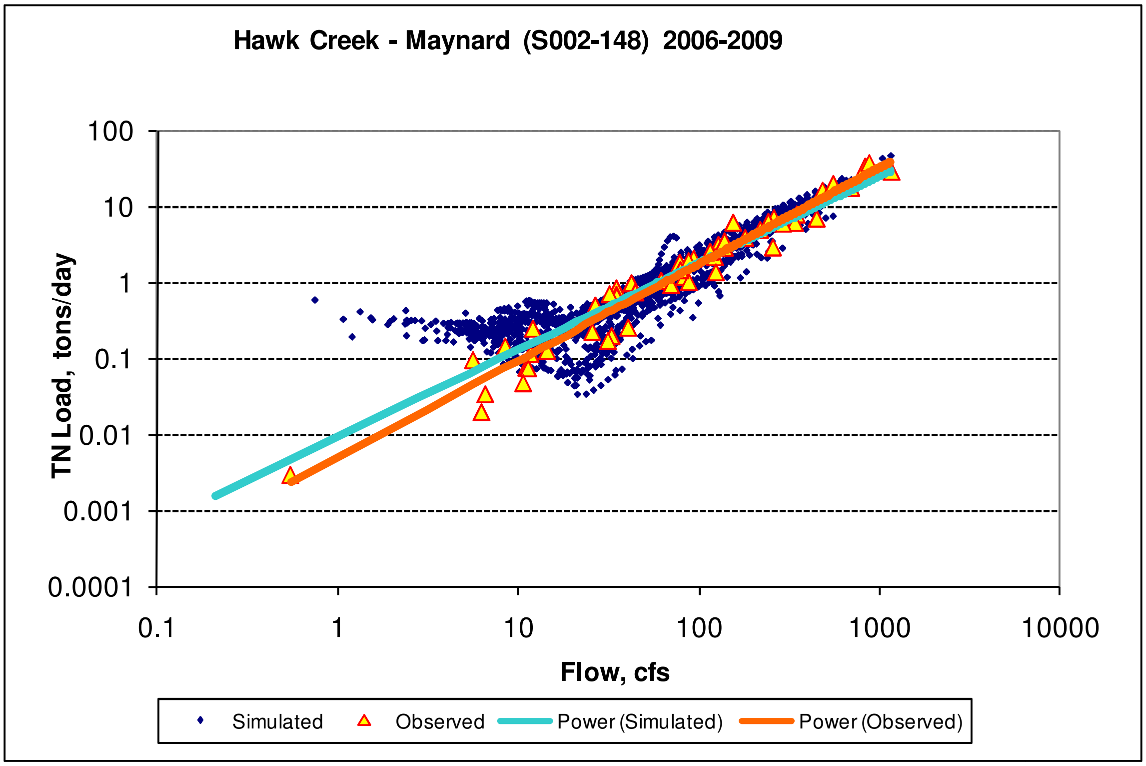


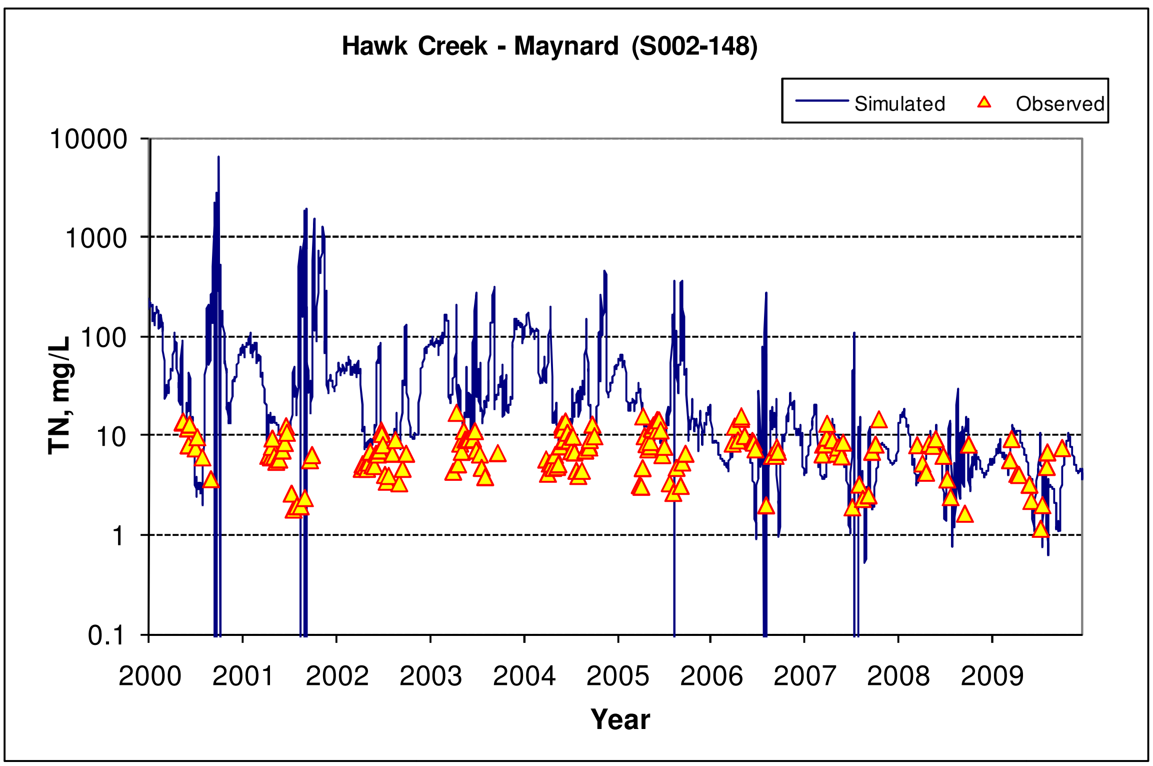
Hawk Creek - Maynard (S002-148)
Simulated
Observed
1000
100
10
1
0.1
0.01
NOx, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

2.5 TOTAL NITROGEN

Parameter	1999 - 2005	2006 - 2009
Count	137	53
Conc Ave Error	298.44%	-1.41%
Conc Median Error	104.03%	-8.81%
Load Ave Error	122.36%	-5.39%
Load Median Error	37.43%	-3.76%
Paired t conc	0.00	0.99
Paired t load	0.00	0.72



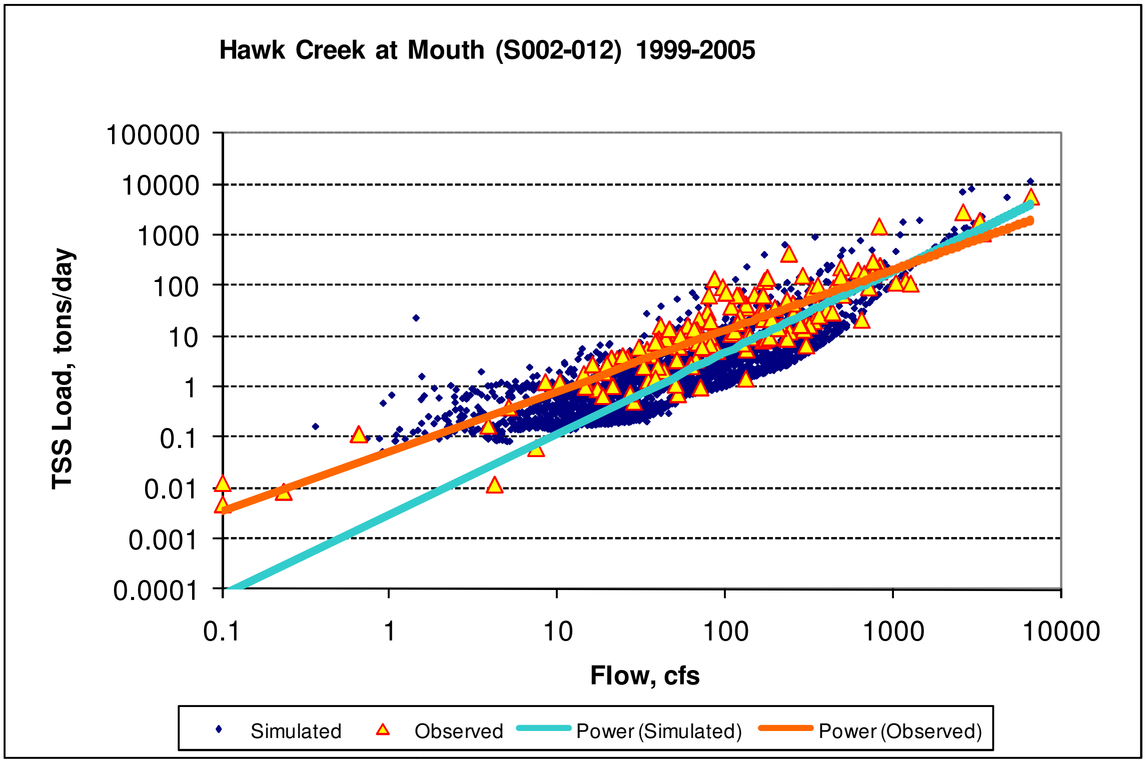

Hawk Creek - Maynard (S002-148) 2006-2009
TN Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

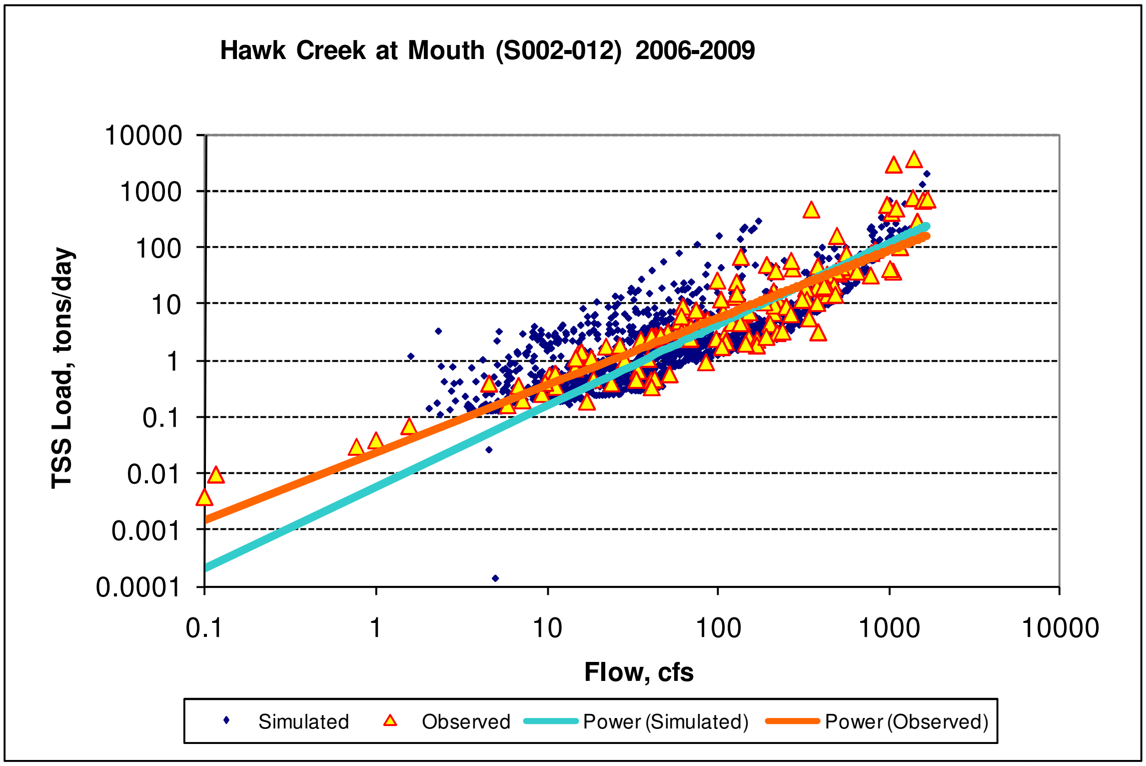

Hawk Creek - Maynard (S002-148)
Simulated
Observed
TN, mg/L
10000
1000
100
10
1
0.1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

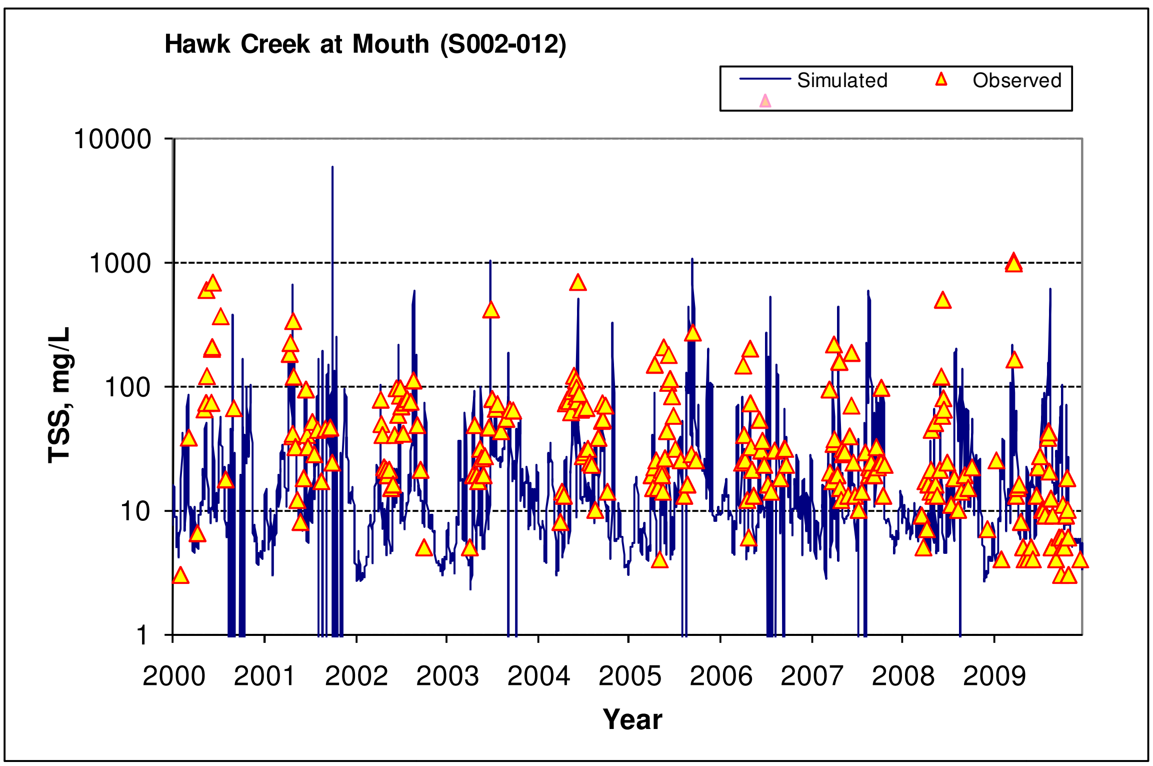
3 Hawk Creek at Mouth (S002-12)

3.1 TOTAL SUSPENDED SEDIMENT

Parameter	1999 - 2005	2006 - 2009
Count	149	127
Conc Ave Error	-43.02%	-0.73%
Conc Median Error	-20.68%	-1.96%
Load Ave Error	33.89%	-36.97%
Load Median Error	-3.16%	-0.03%
Paired t conc	0.02	0.84
Paired t load	0.40	0.29

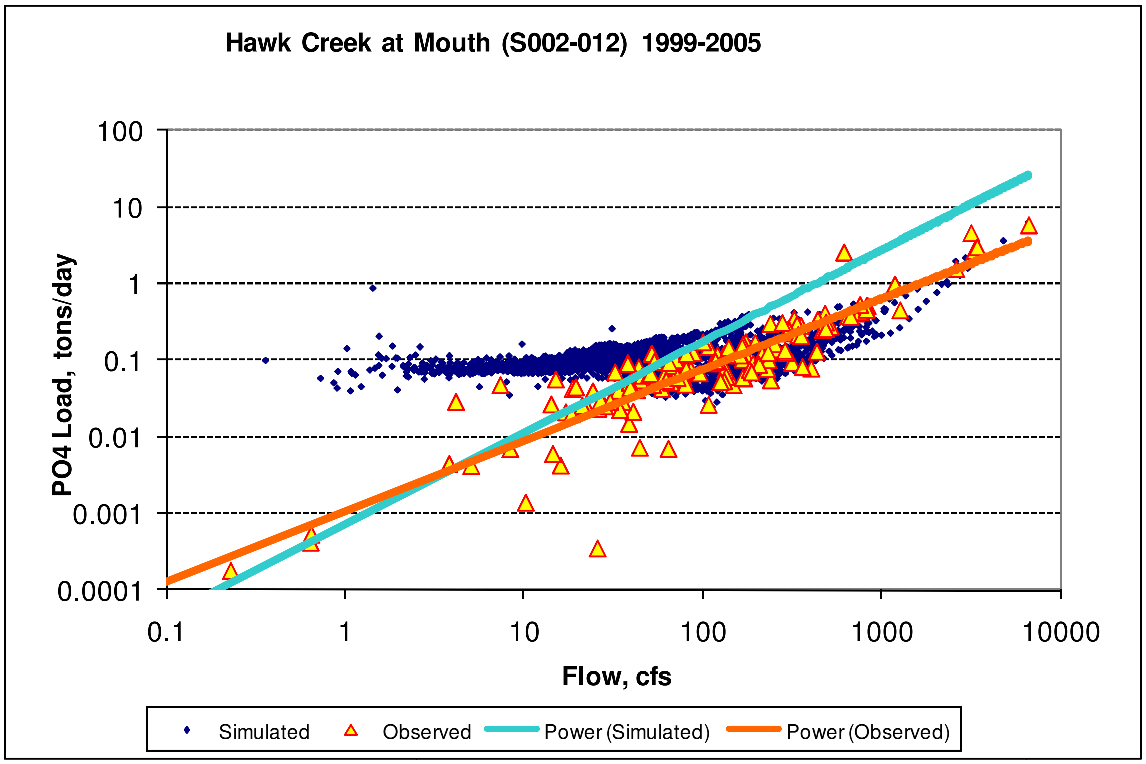


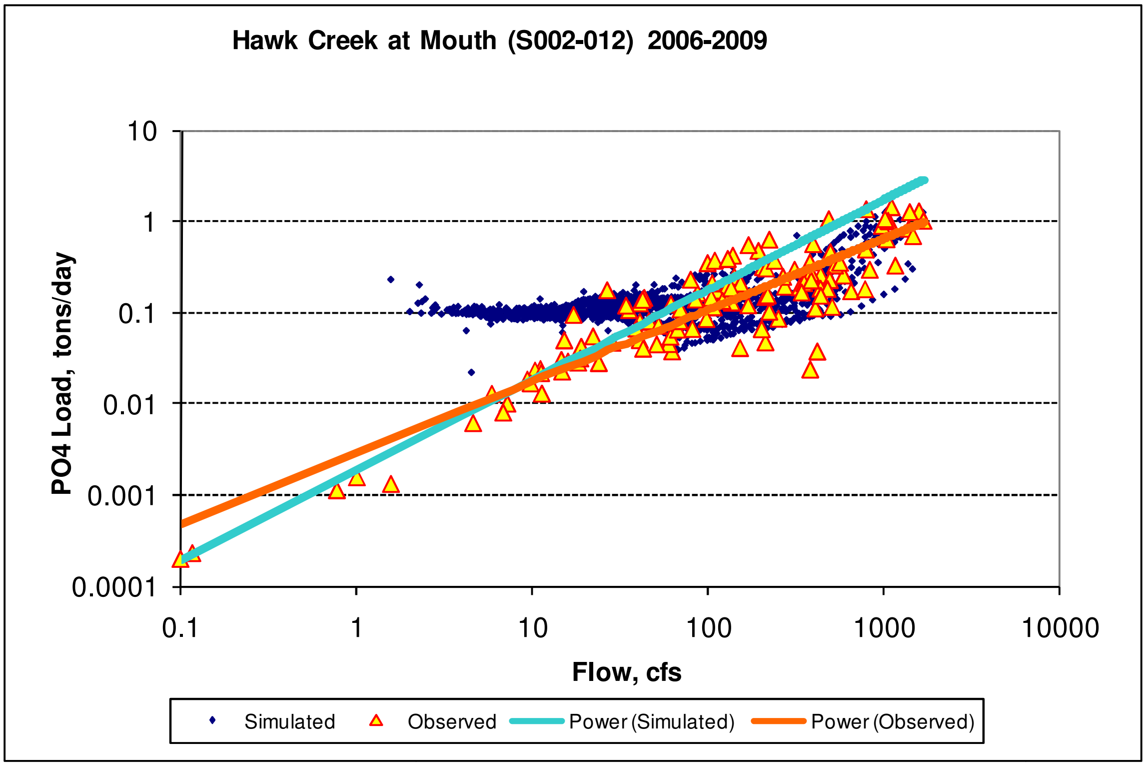

Hawk Creek at Mouth (S002-012) 2006-2009
TSS Load, tons/day
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

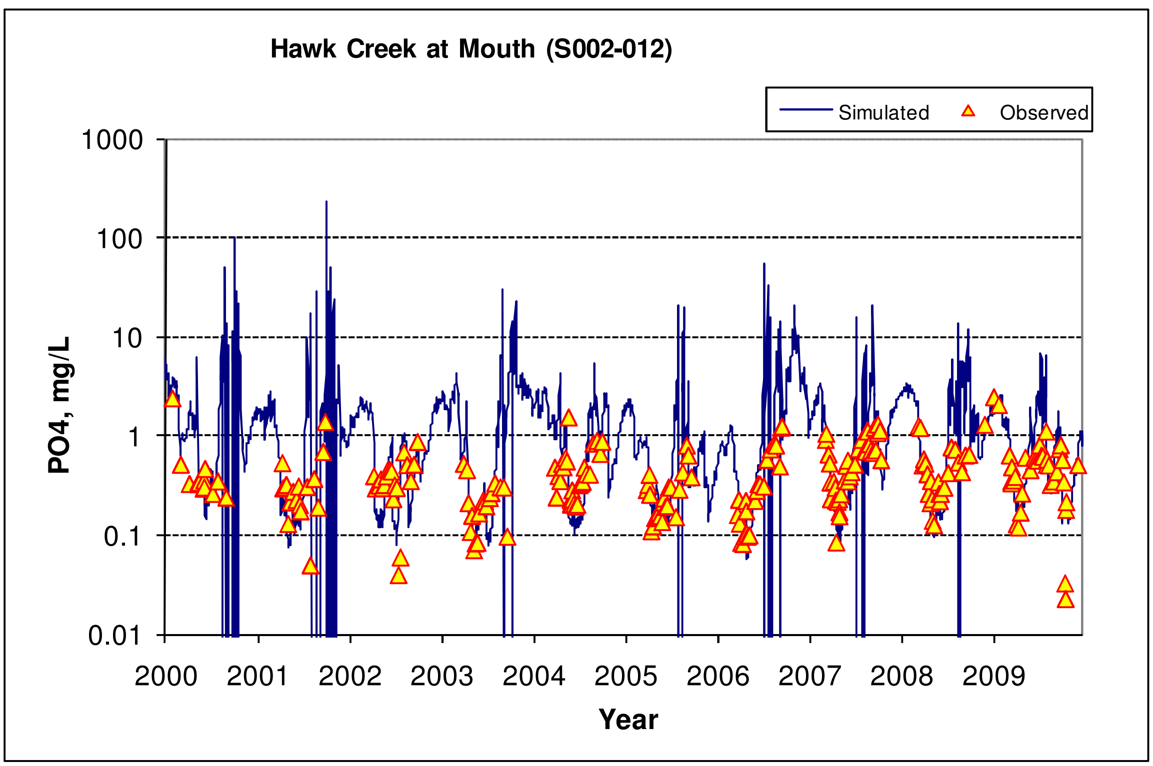

Hawk Creek at Mouth (S002-012)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

3.2 ORTHOPHOSPHATE (AS P)

Parameter	1999 - 2005	2006 - 2009
Count	144	121
Conc Ave Error	93.04%	148.28%
Conc Median Error	4.14%	-12.85%
Load Ave Error	-18.12%	-19.22%
Load Median Error	4.00%	-9.74%
Paired t conc	0.00	0.02
Paired t load	0.53	0.53

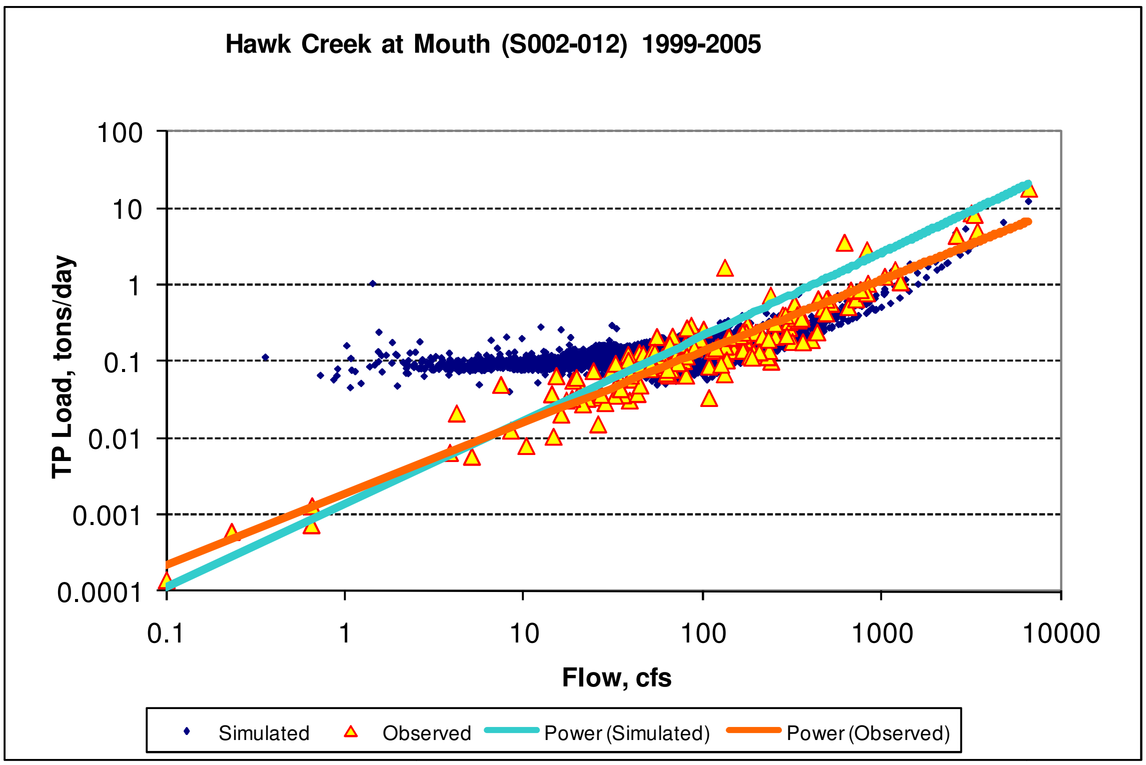


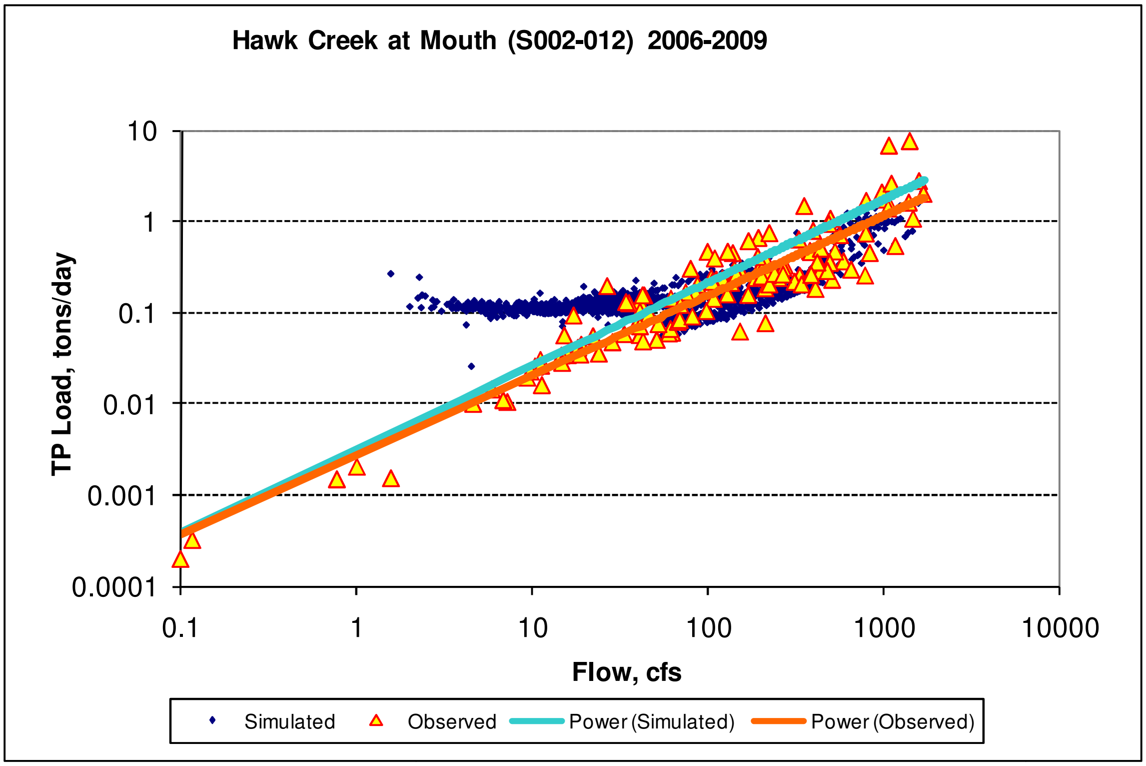

Hawk Creek at Mouth (S002-012) 2006-2009
PO4 Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)


Hawk Creek at Mouth (S002-012)
Simulated
Observed
PO4, mg/L
1000
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

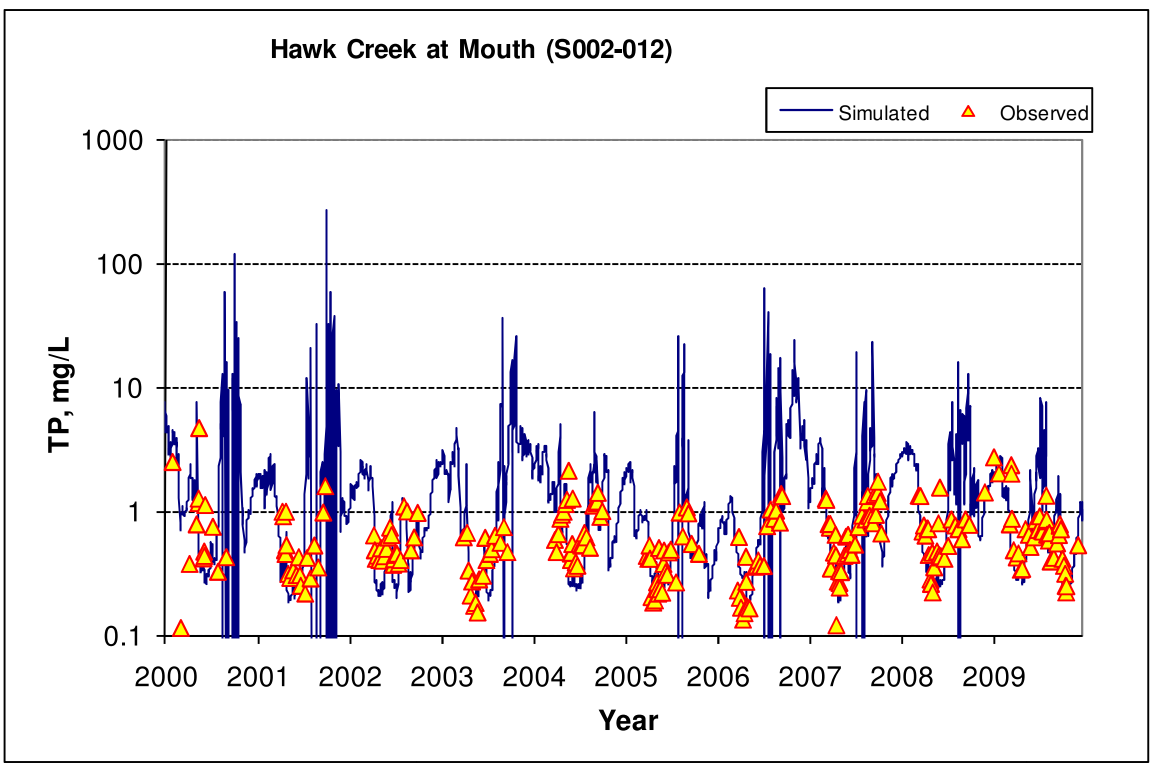
3.3 Total Phosphorus

Parameter	1999 - 2005	2006 - 2009
Count	150	128
Conc Ave Error	-38.38%	-113.82%
Conc Median Error	9.30%	13.47%
Load Ave Error	36.04%	39.19%
Load Median Error	2.43%	7.38%
Paired t conc	0.10	0.04
Paired t load	0.24	0.09





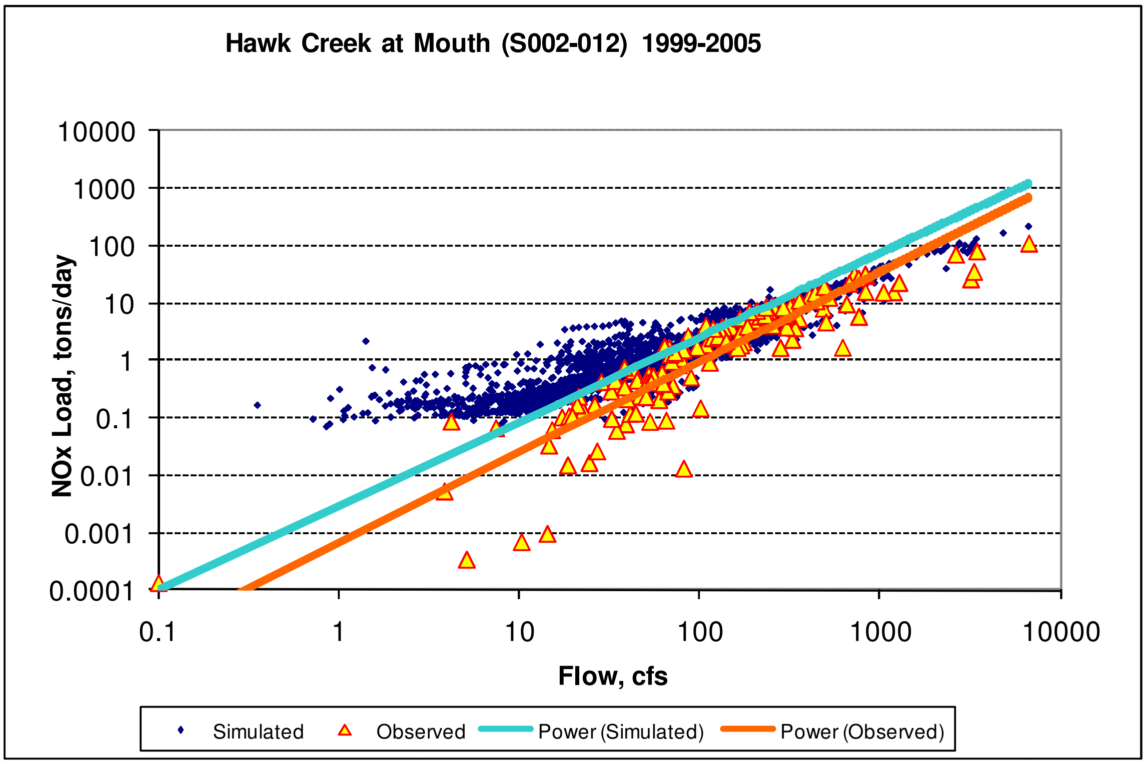
Hawk Creek at Mouth (S002-012) 2006-2009
TP Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

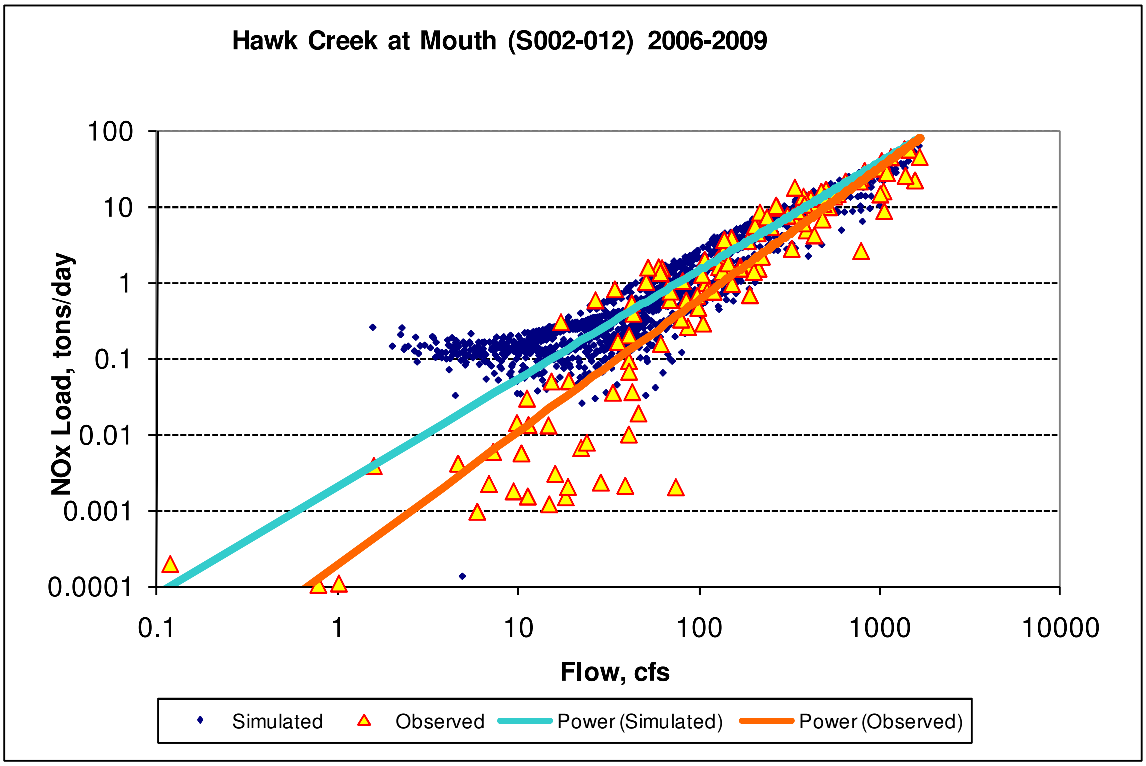


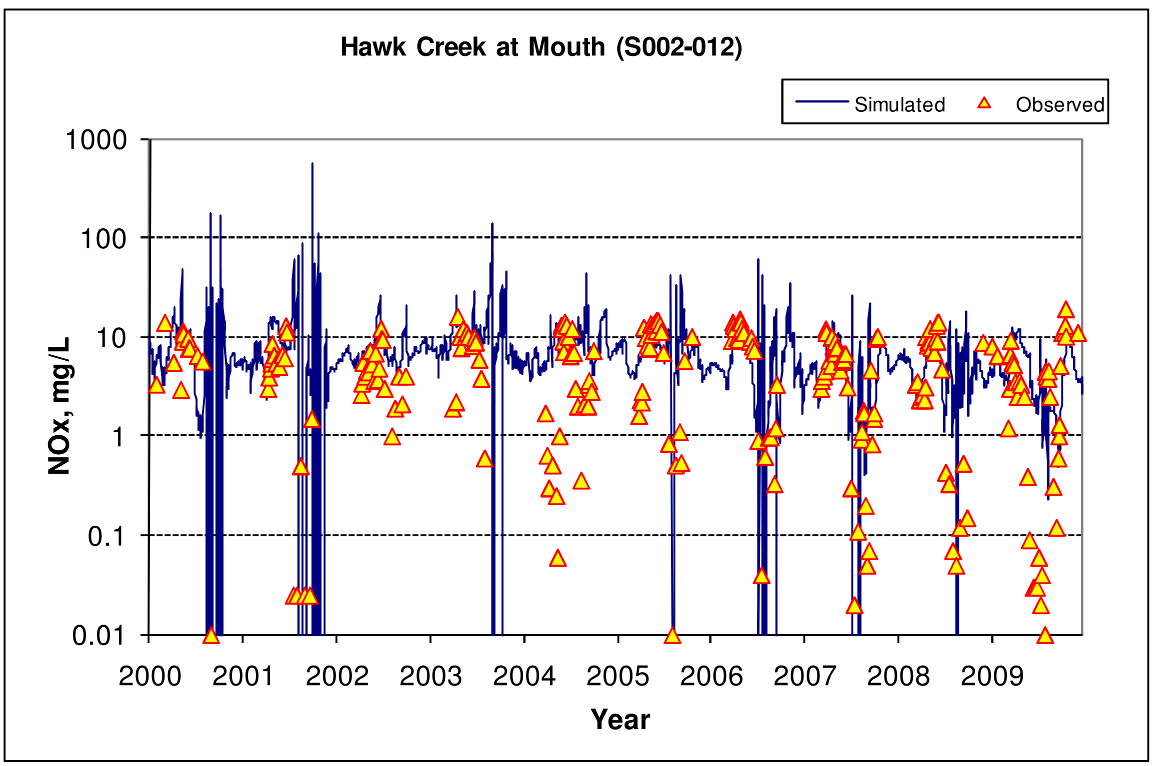
Hawk Creek at Mouth (S002-012)
Simulated
Observed
TP, mg/L
1000
100
10
1
0.1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

3.4 NITRATE PLUS NITRITE NITROGEN (AS N)

Count	142	128
Conc Ave Error	89.75%	12.74%
Conc Median Error	56.38%	3.14%
Load Ave Error	52.51%	4.07%
Load Median Error	10.92%	0.45%
Paired t conc	0.00	0.79
Paired t load	0.10	0.85

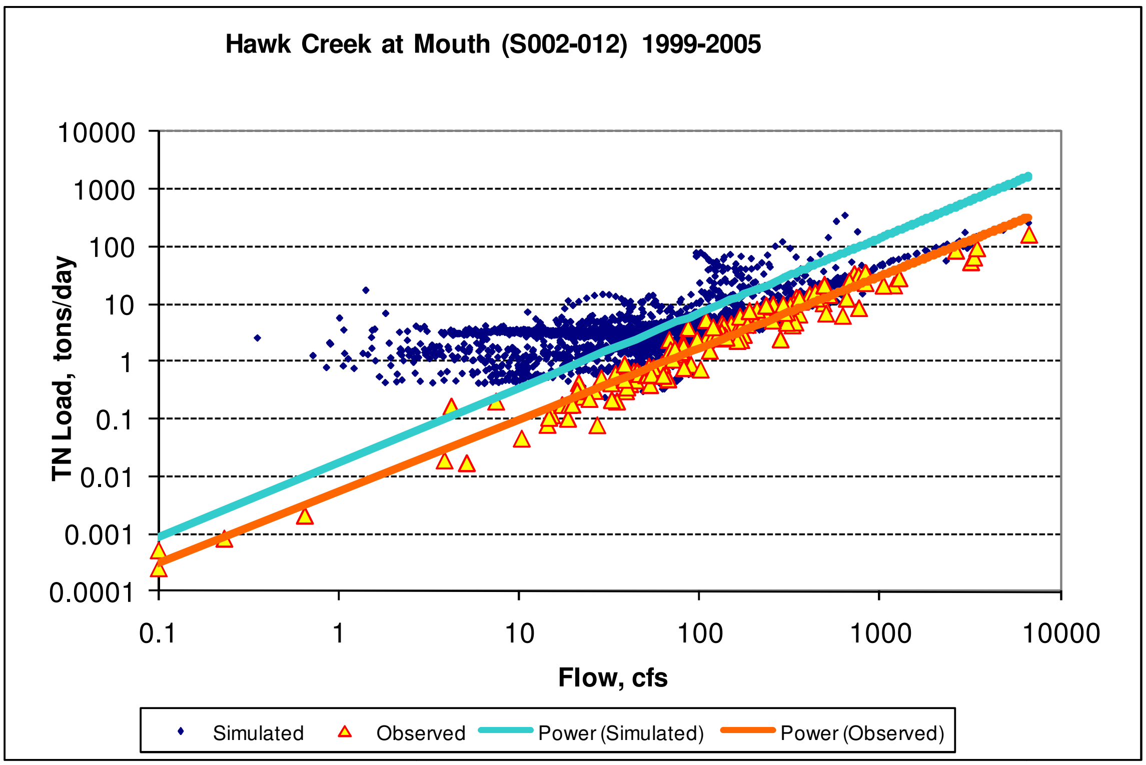


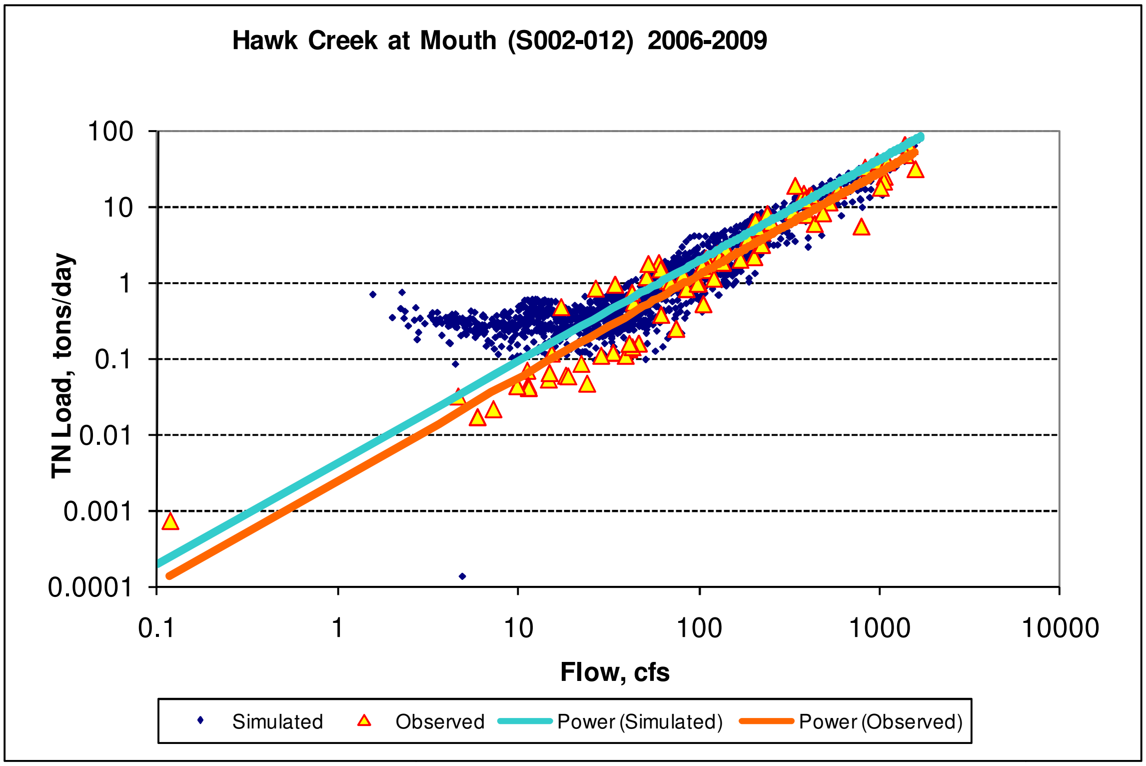

Hawk Creek at Mouth (S002-012) 2006-2009
100
10
1
0.1
0.01
0.001
0.0001
NOx Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

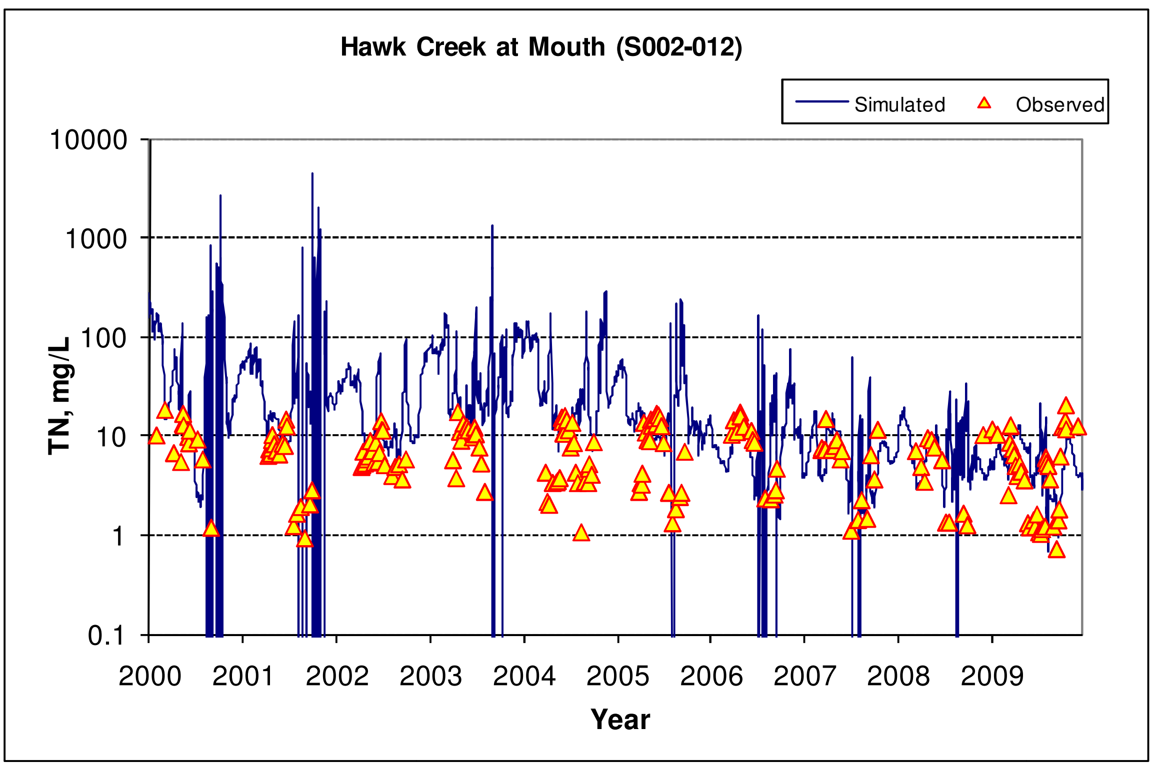

Hawk Creek at Mouth (S002-012)
Simulated
Observed
1000
100
10
1
0.1
0.01
NOx, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

3.5 TOTAL NITROGEN

Parameter	1999 - 2005	2006 - 2009
Count	139	81
Conc Ave Error	265.30%	8.28%
Conc Median Error	73.46%	-5.75%
Load Ave Error	79.03%	-3.10%
Load Median Error	17.56%	-0.01%
Paired t conc	0.00	0.93
Paired t load	0.01	0.81



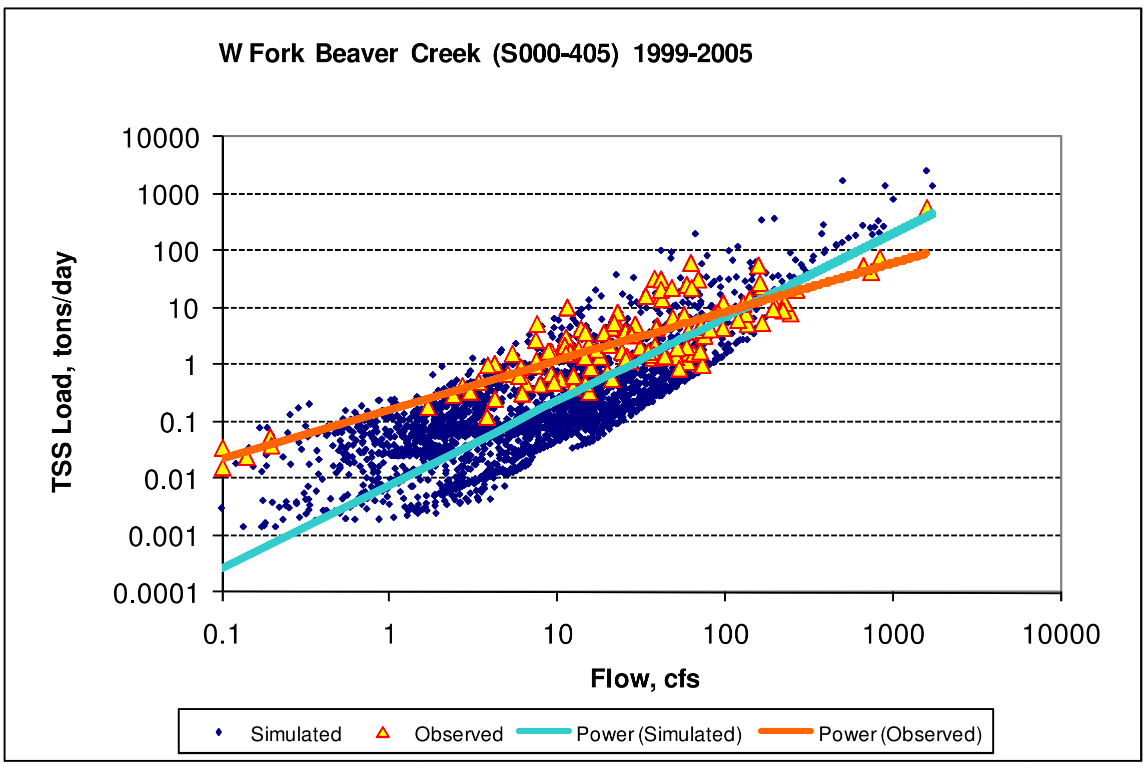

Hawk Creek at Mouth (S002-012) 2006-2009
100
10
1
0.1
0.01
0.001
0.0001
TN Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

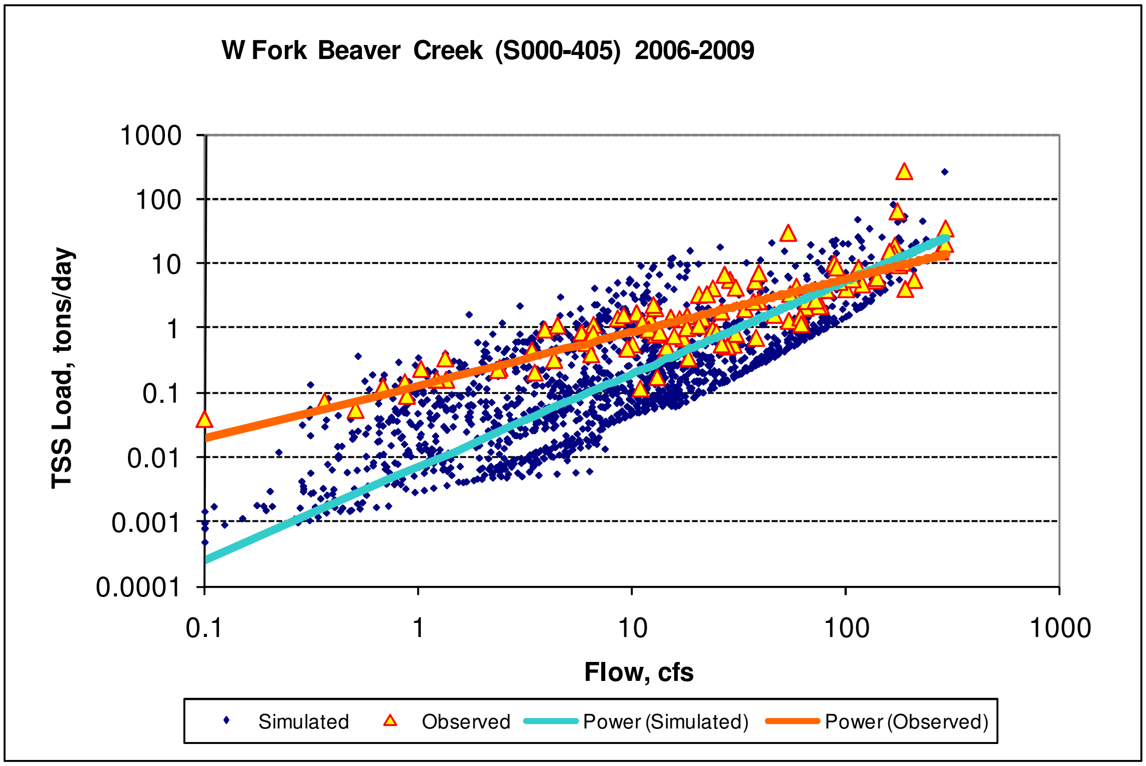

Hawk Creek at Mouth (S002-012)
Simulated
Observed
10000
1000
100
10
1
0.1
TN, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

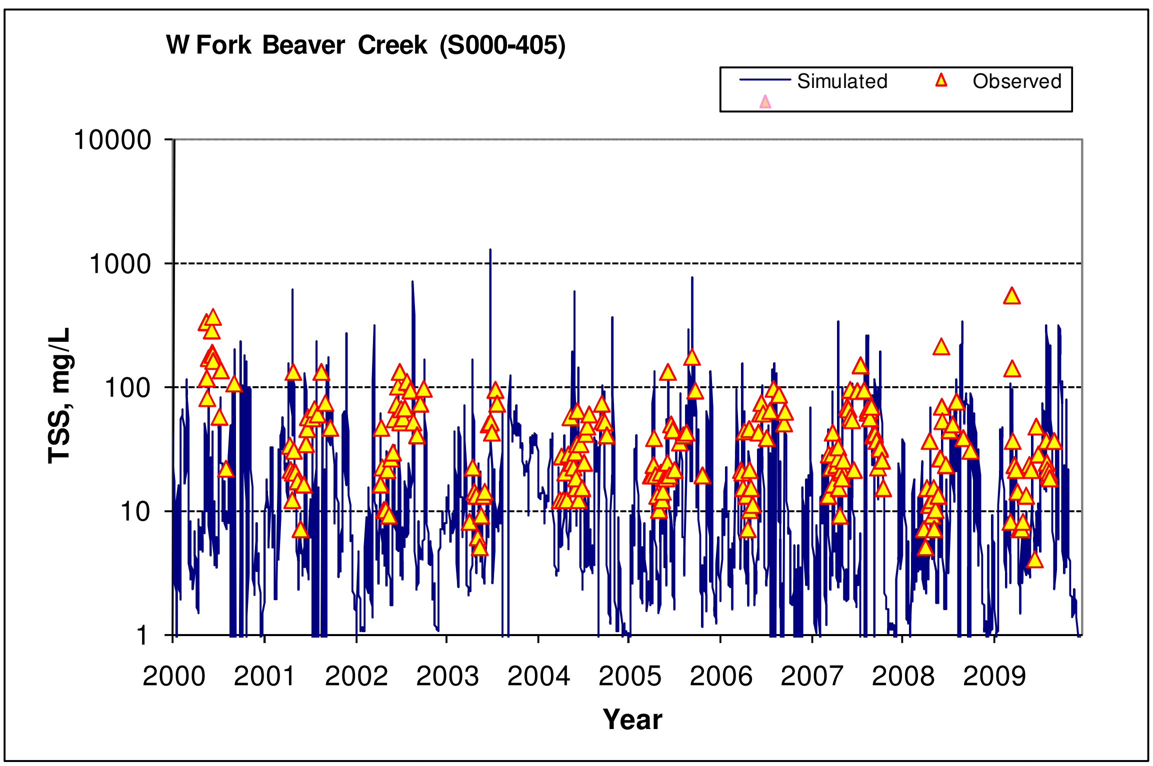
4 West Fork Beaver Creek (S000-405)

4.1 TOTAL SUSPENDED SEDIMENT

Parameter	1999 - 2005	2006 - 2009
Count	130	104
Conc Ave Error	-10.71%	-1.93%
Conc Median Error	-23.48%	-13.18%
Load Ave Error	205.97%	9.58%
Load Median Error	-5.38%	-3.13%
Paired t conc	0.72	0.90
Paired t load	0.08	0.60

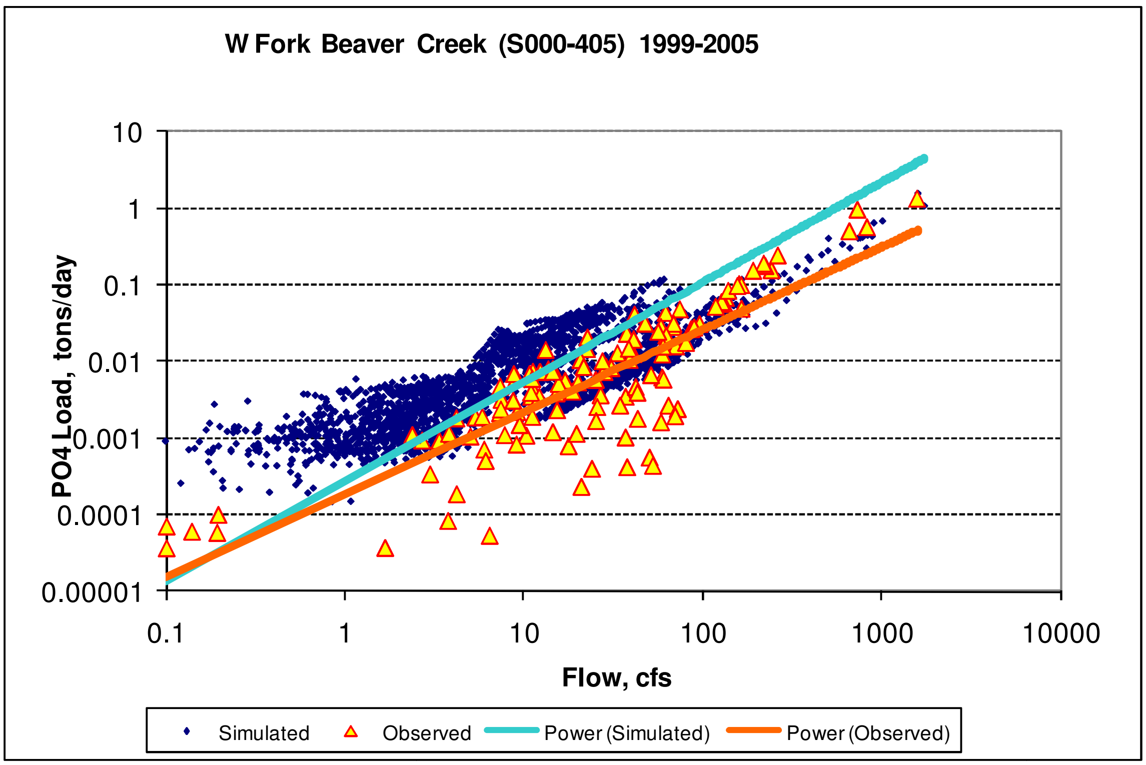


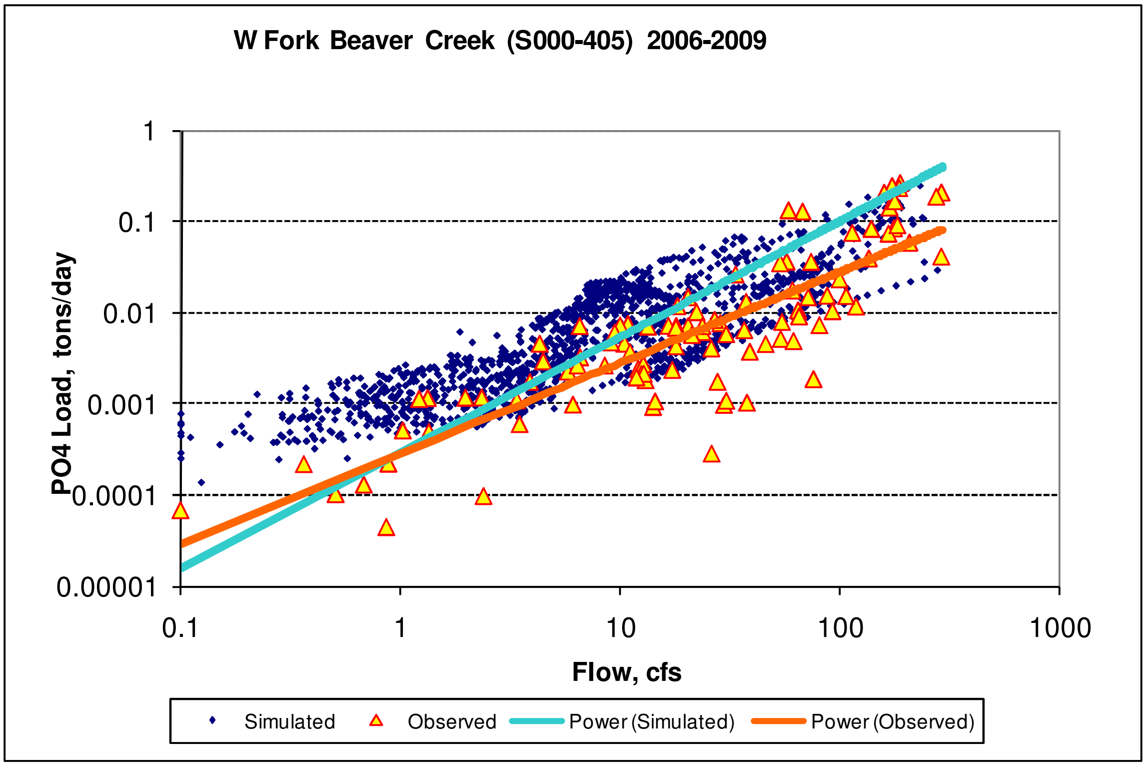

W Fork Beaver Creek (S000-405) 2006-2009
TSS Load, tons/day
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

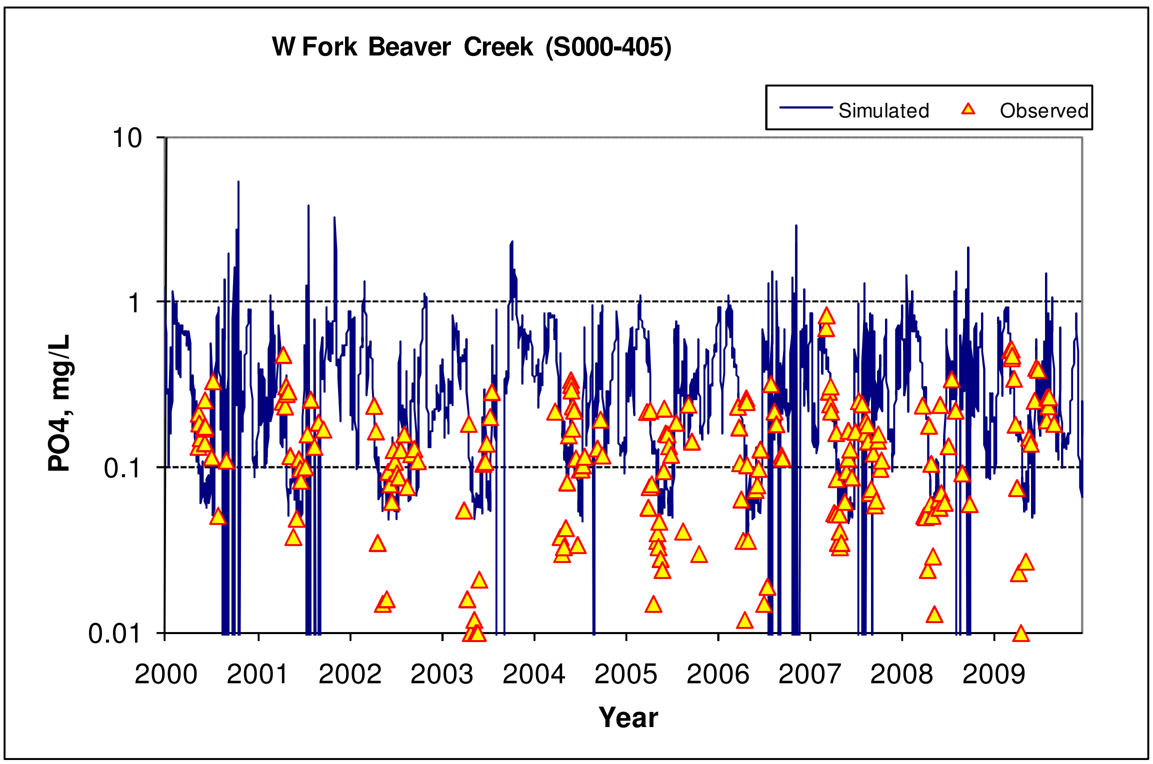

W Fork Beaver Creek (S000-405)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

4.2 ORTHOPHOSPHATE (AS P)

Parameter	1999 - 2005	2006 - 2009
Count	126	100
Conc Ave Error	33.64%	40.09%
Conc Median Error	6.55%	19.08%
Load Ave Error	-20.19%	-16.36%
Load Median Error	0.58%	5.39%
Paired t conc	0.06	0.03
Paired t load	0.50	0.59

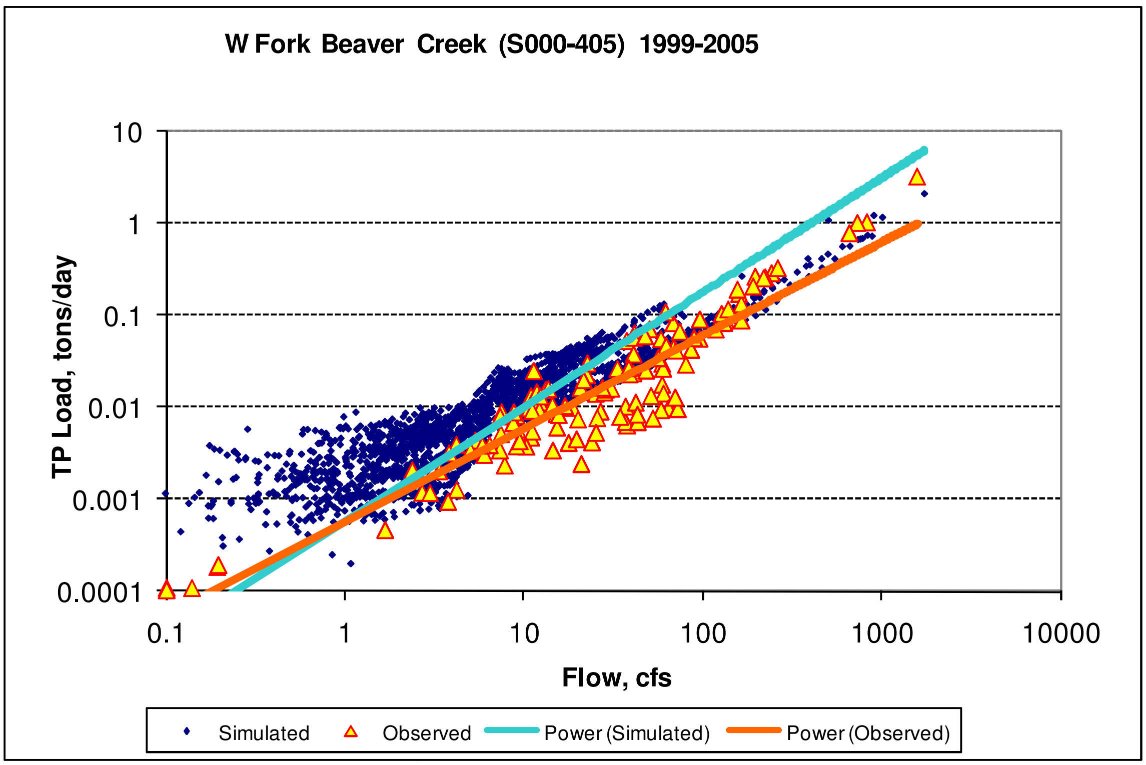


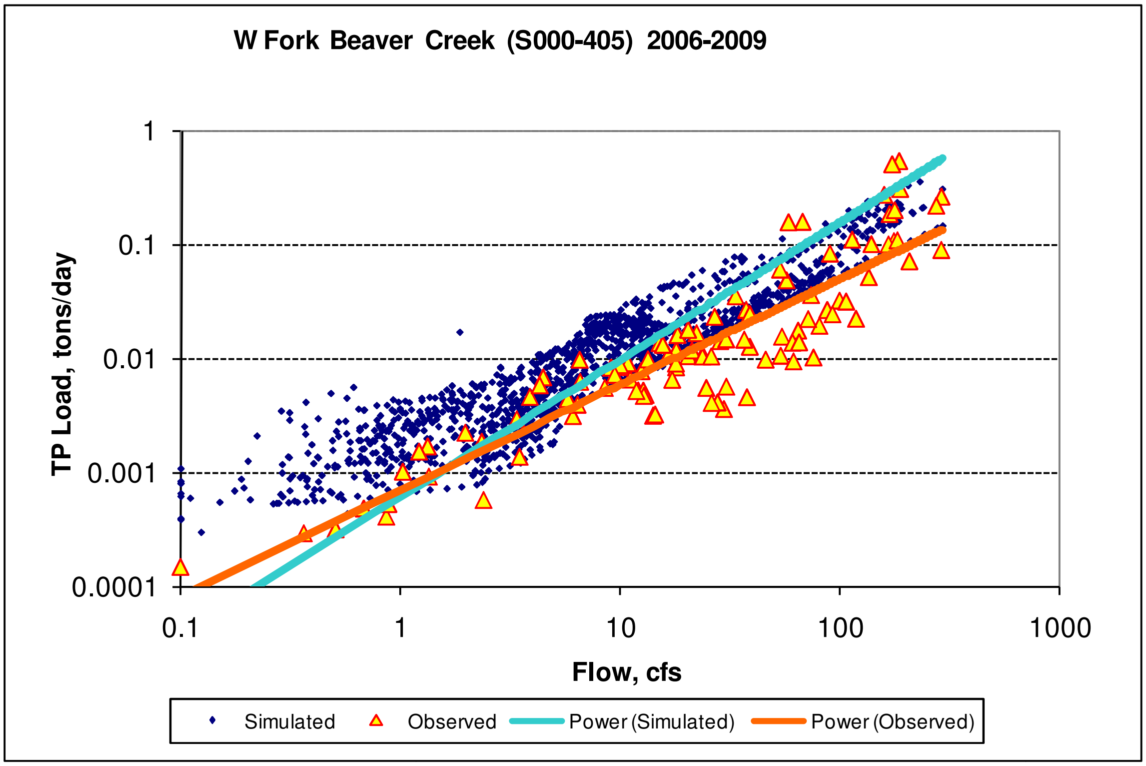

W Fork Beaver Creek (S000-405) 2006-2009
PO4 Load, tons/day
1
0.1
0.01
0.001
0.0001
0.00001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

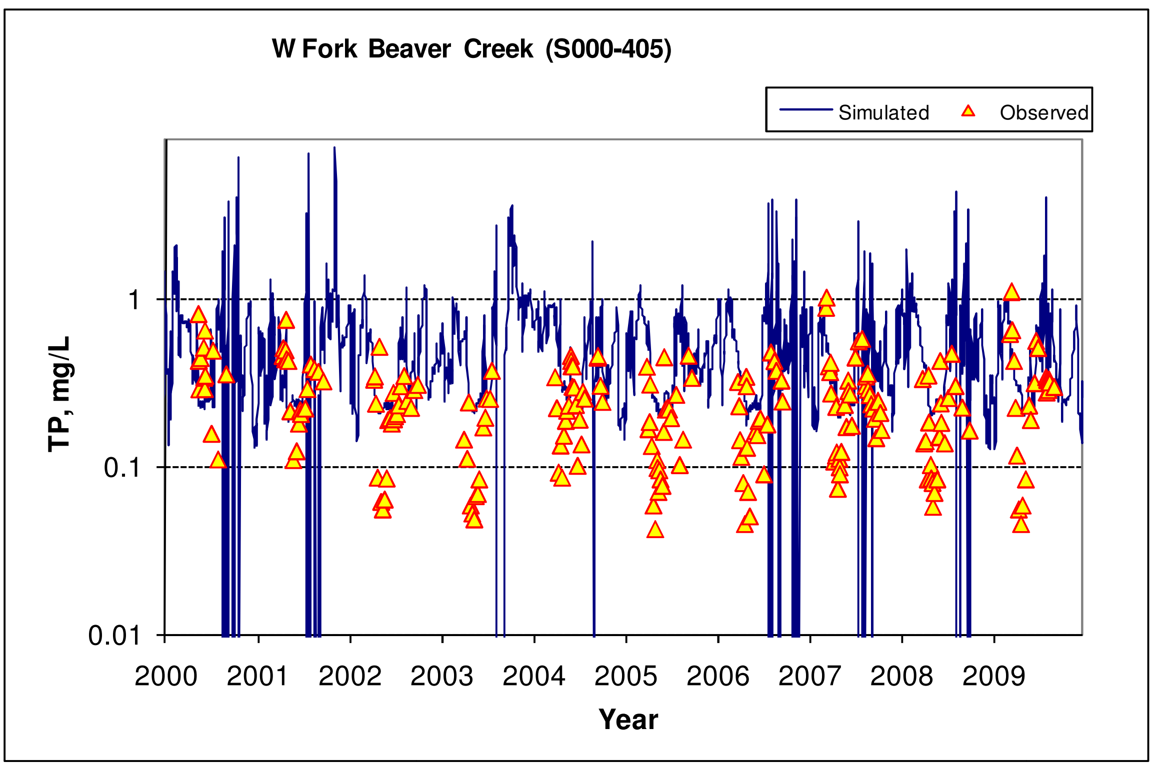

W Fork Beaver Creek (S000-405)
Simulated
Observed
PO4, mg/L
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

4.3 TOTAL PHOSPHORUS

Parameter	1999 - 2005	2006 - 2009
Count	129	105
Conc Ave Error	25.65%	57.72%
Conc Median Error	21.51%	40.73%
Load Ave Error	-10.02%	-0.19%
Load Median Error	3.94%	9.95%
Paired t conc	0.15	0.00
Paired t load	0.62	0.88

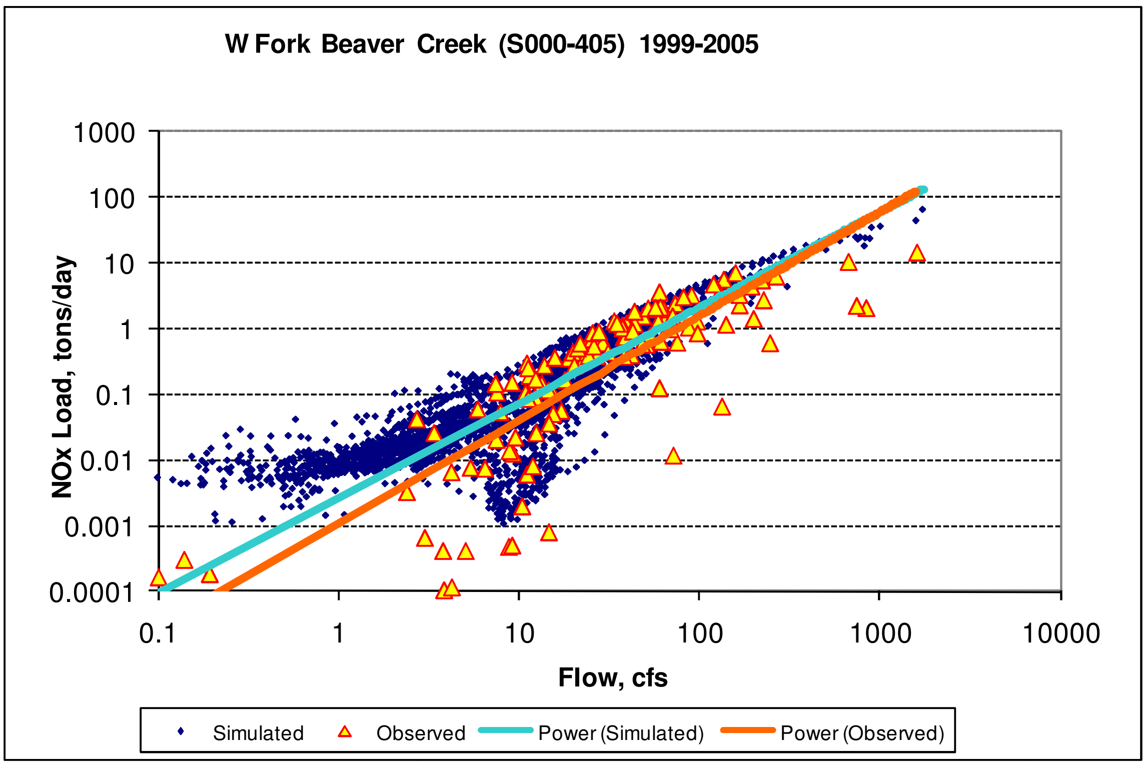


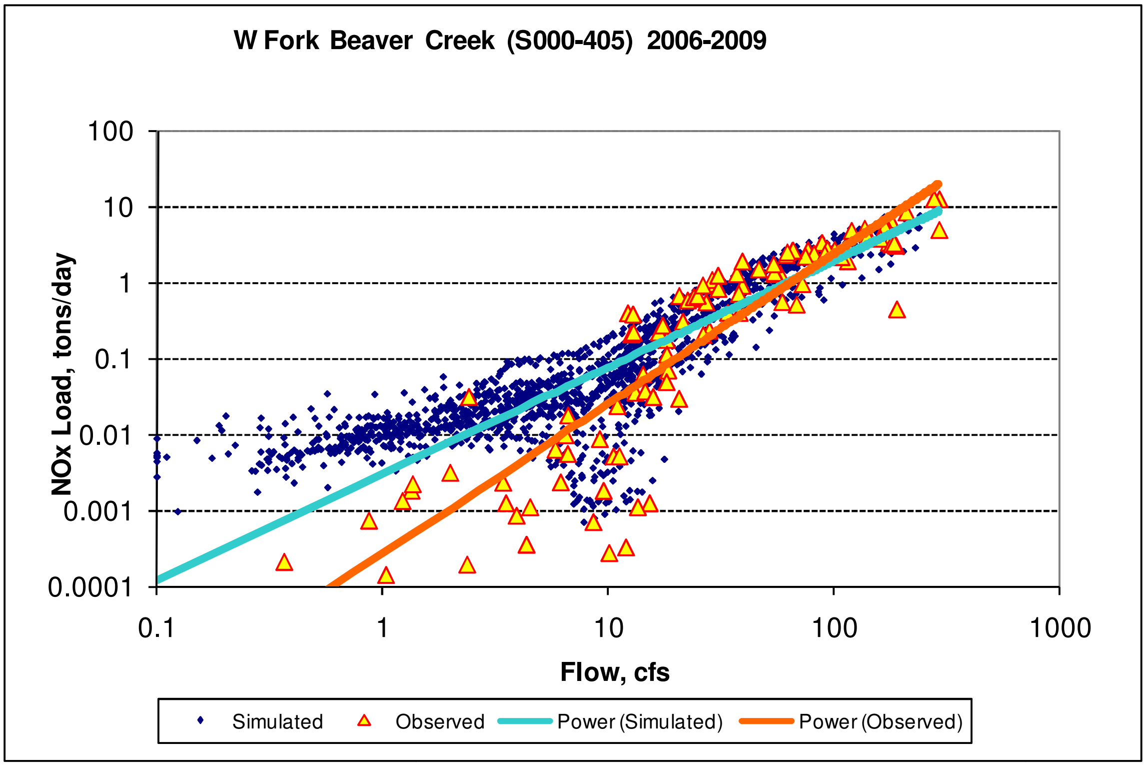

W Fork Beaver Creek (S000-405) 2006-2009
TP Load, tons/day
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

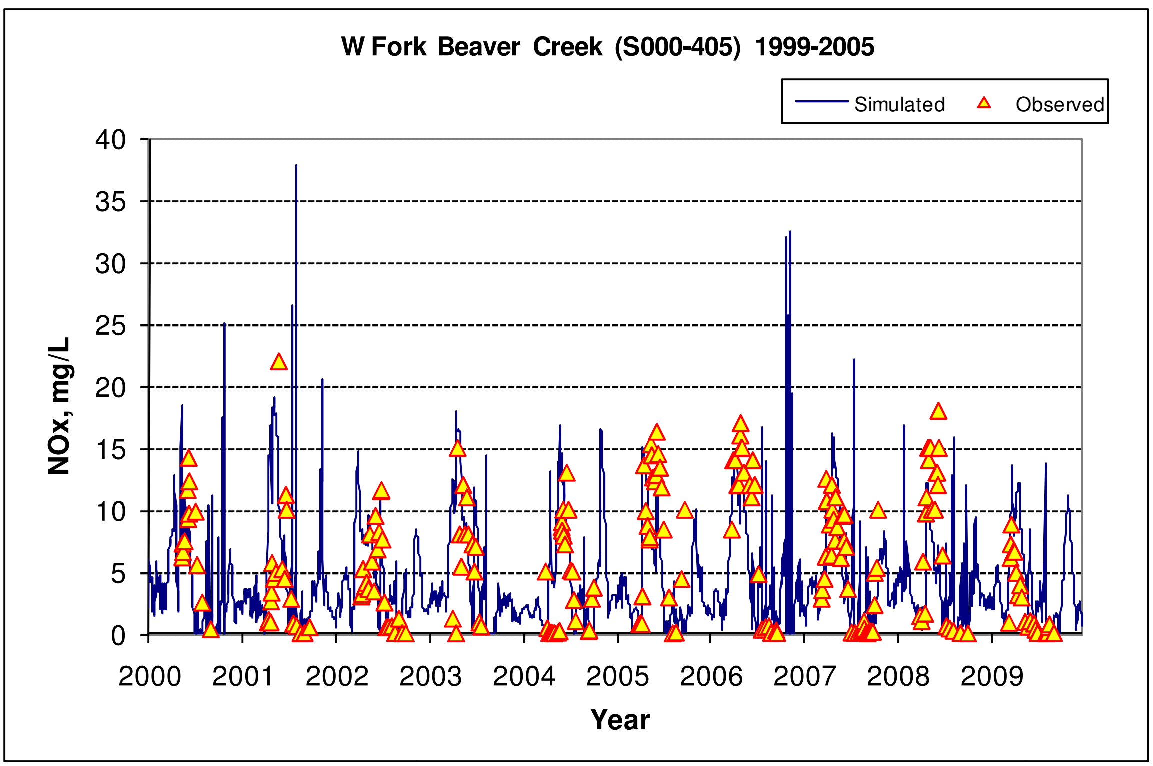

W Fork Beaver Creek (S000-405)
Simulated
Observed
TP, mg/L
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

4.4 Nitrate plus Nitrite Nitrogen (as N)

Parameter	1999 - 2005	2006 - 2009
Count	128	105
Conc Ave Error	8.60%	-0.49%
Conc Median Error	0.48%	5.20%
Load Ave Error	96.21%	1.43%
Load Median Error	0.12%	0.41%
Paired t conc	0.94	0.99
Paired t load	0.01	0.88

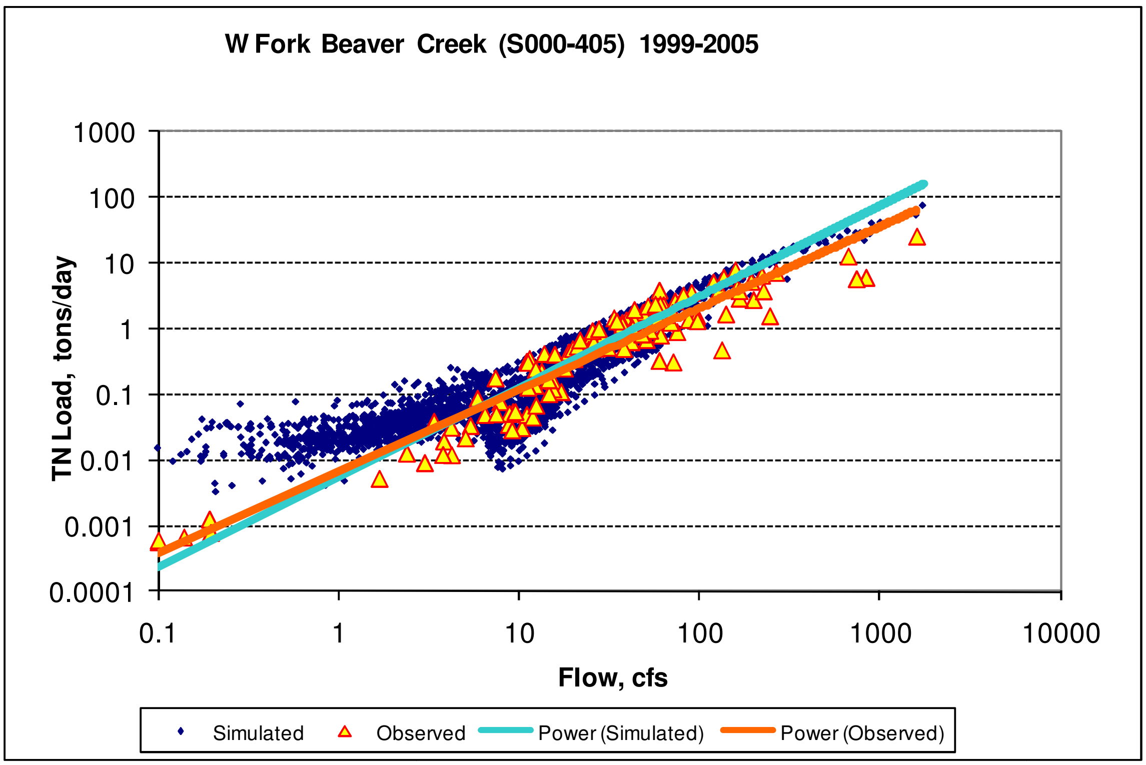


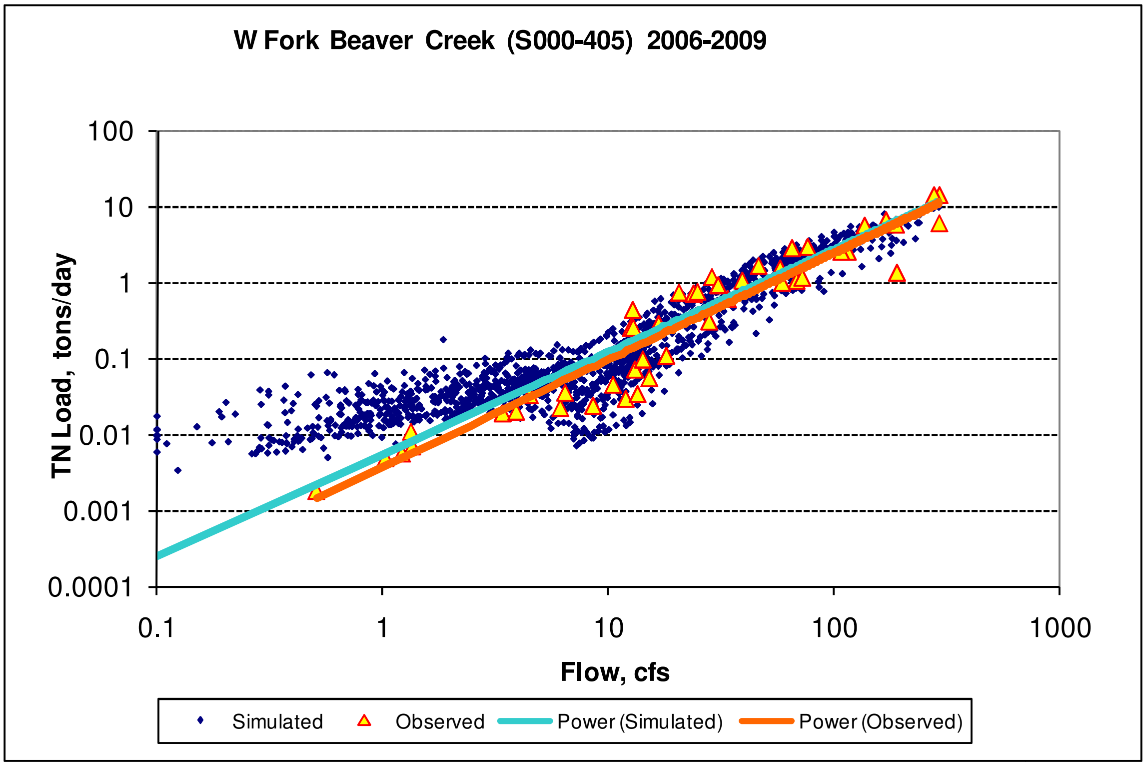

W Fork Beaver Creek (S000-405) 2006-2009
NOx Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

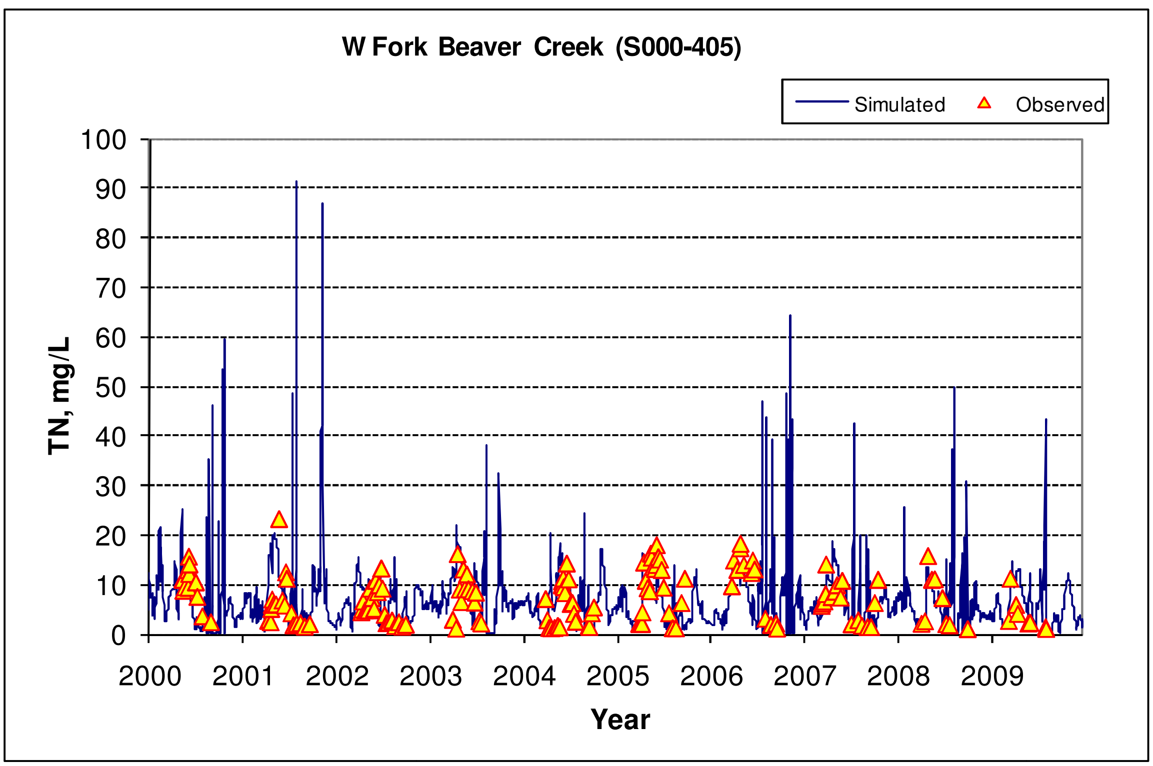

W Fork Beaver Creek (S000-405) 1999-2005
Simulated
Observed
NOx, mg/L
40
35
30
25
20
15
10
5
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

4.5 TOTAL NITROGEN

Parameter	1999 - 2005	2006 - 2009
Count	121	47
Conc Ave Error	11.71%	12.47%
Conc Median Error	-4.58%	6.06%
Load Ave Error	75.71%	3.01%
Load Median Error	-0.04%	0.43%
Paired t conc	0.91	0.76
Paired t load	0.04	0.73



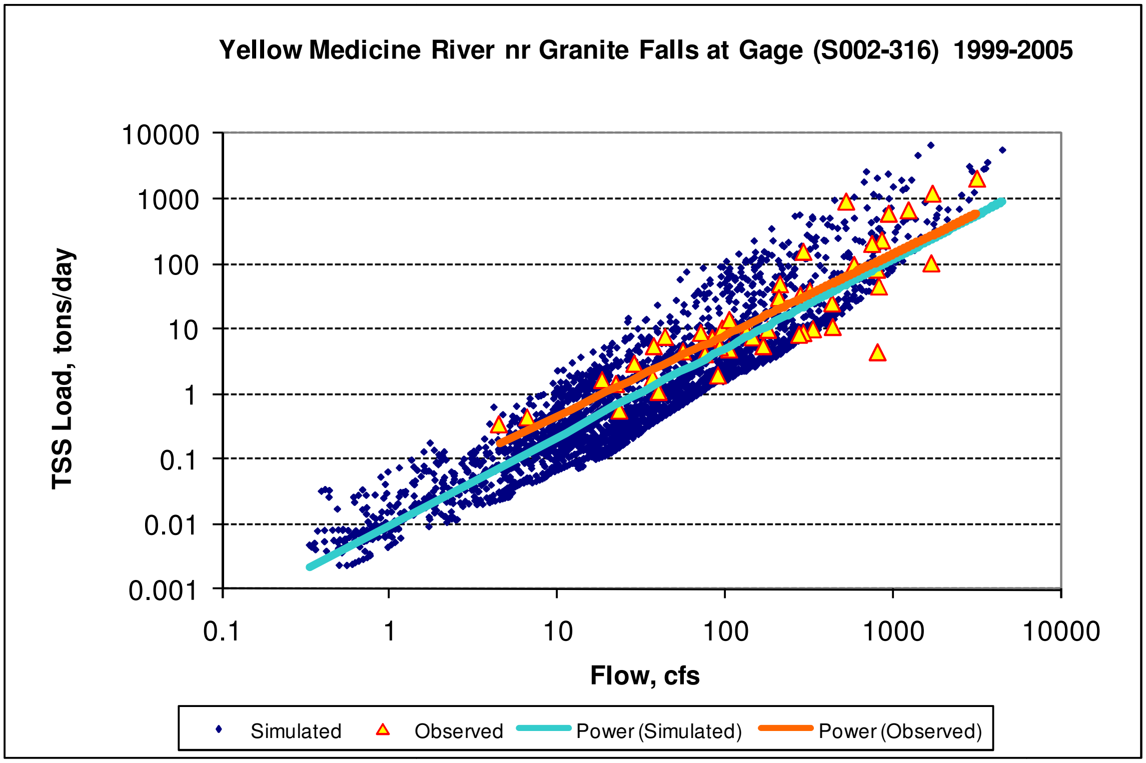

W Fork Beaver Creek (S000-405) 2006-2009
TN Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

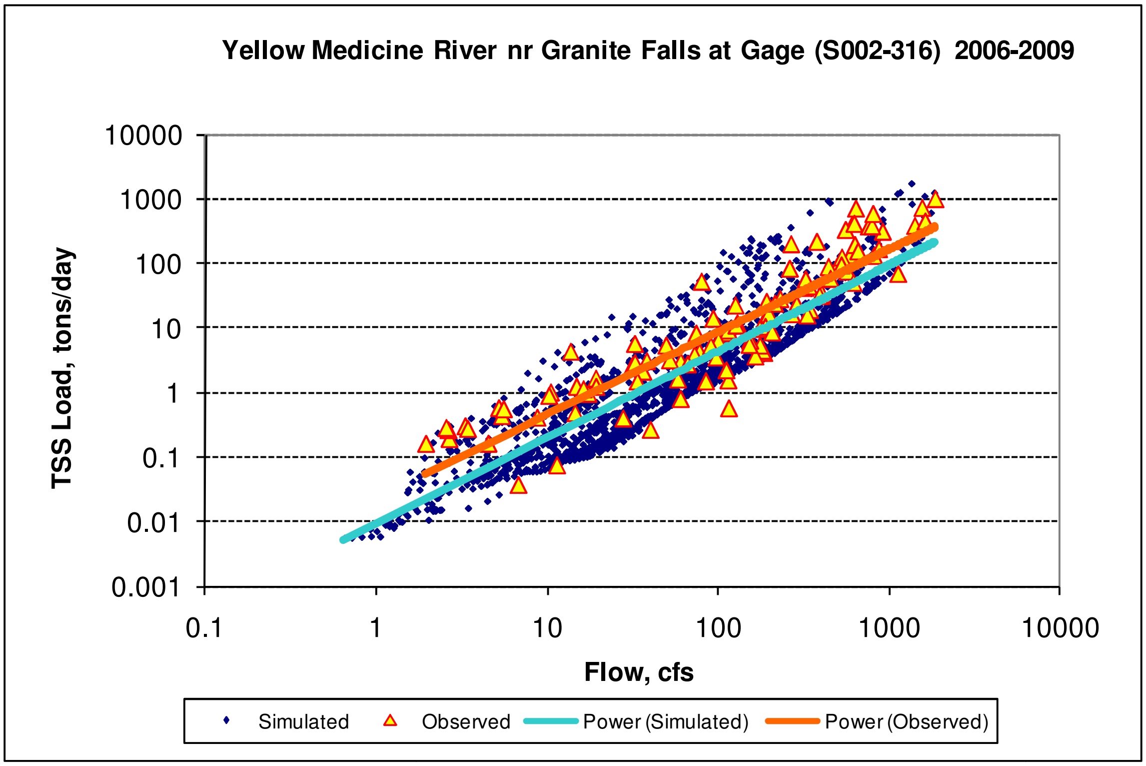

W Fork Beaver Creek (S000-405)
Simulated
Observed
TN, mg/L
100
90
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

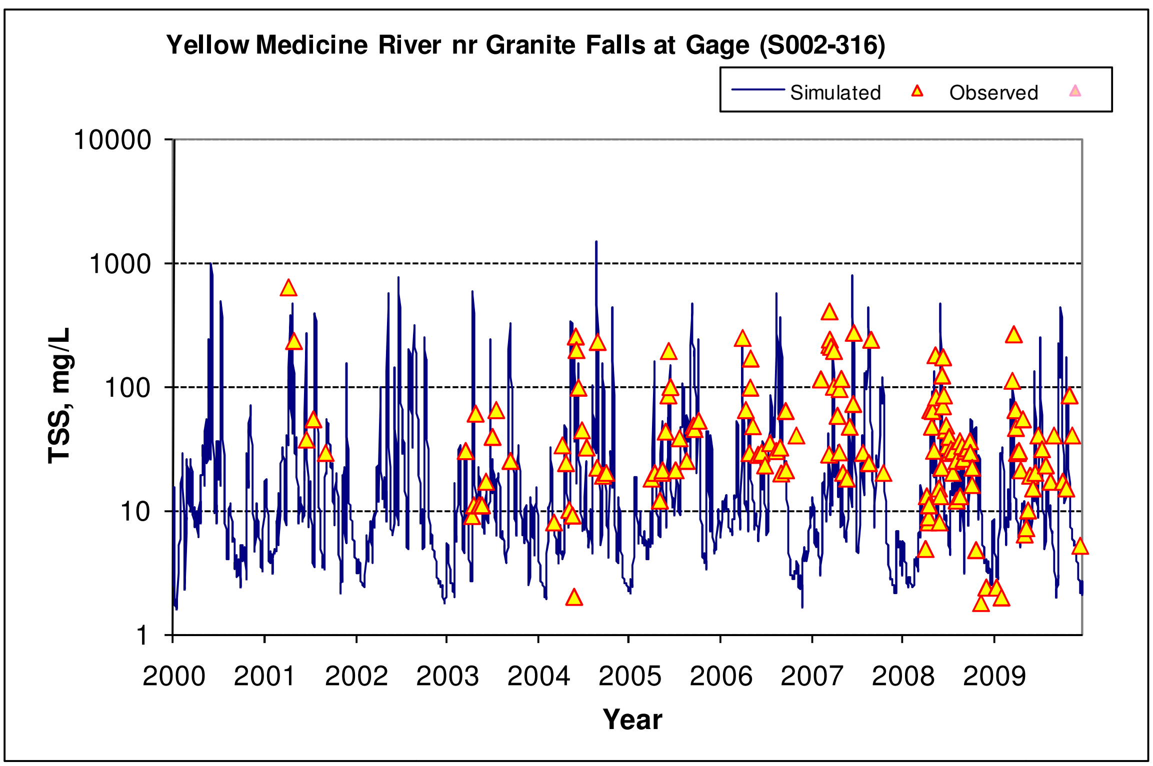
5 Yellow Medicine River at Gage (S002-316)

5.1 Total Suspended Sediment

Parameter	1999 - 2005	2006 - 2009
Count	45	107
Conc Ave Error	107.53%	-1.73%
Conc Median Error	-8.53%	-17.38%
Load Ave Error	140.15%	-1.53%
Load Median Error	-0.28%	-0.65%
Paired t conc	0.03	0.88
Paired t load	0.08	0.79

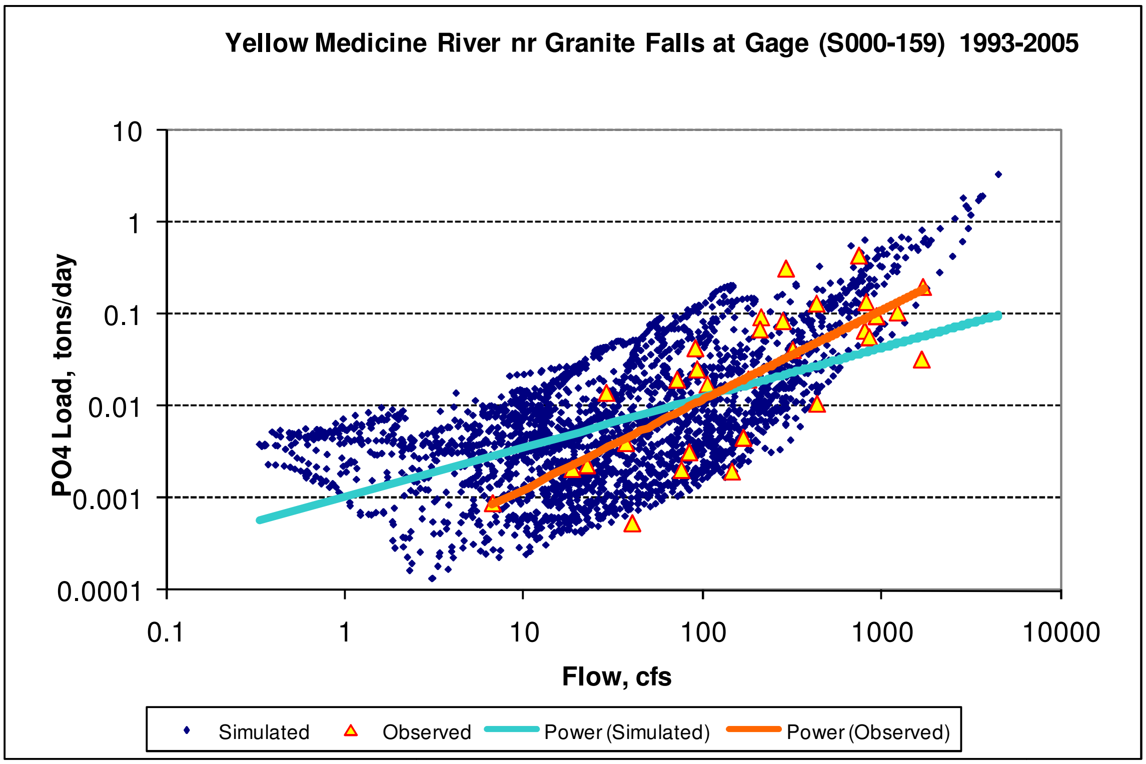


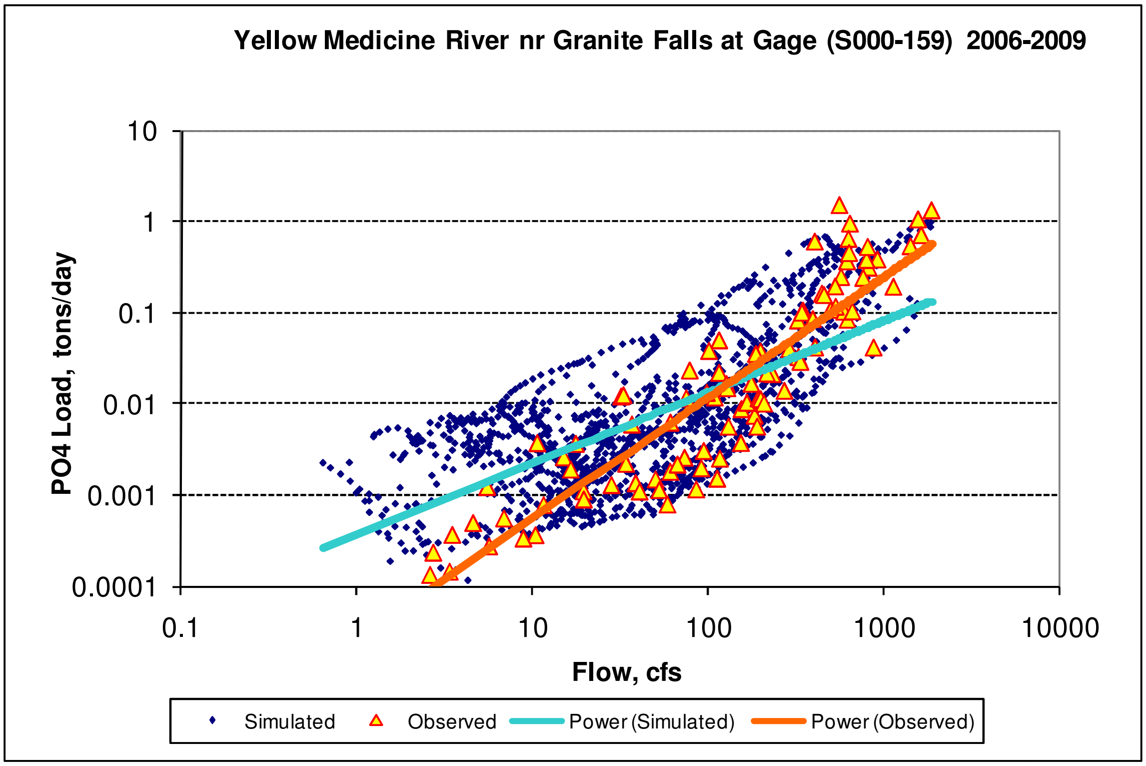

Yellow Medicine River nr Granite Falls at Gage (S002-316) 2006-2009
TSS Load, tons/day
10000
1000
100
10
1
0.1
0.01
0.001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

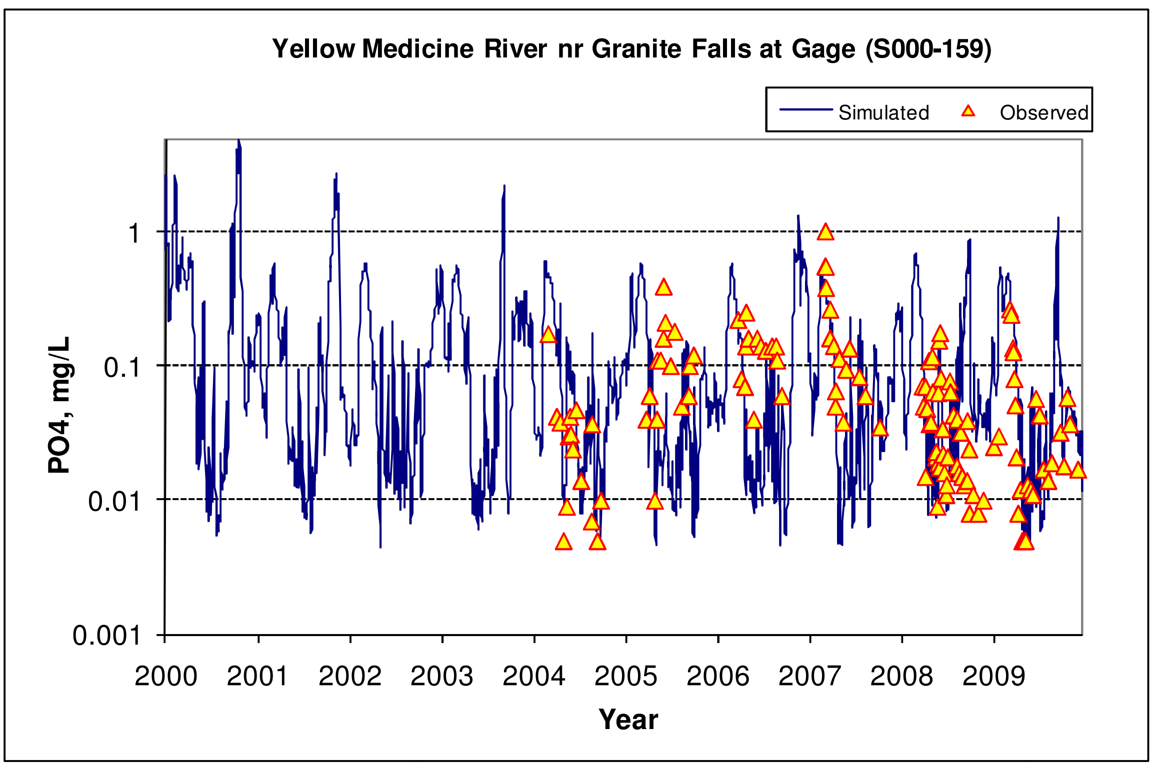

Yellow Medicine River nr Granite Falls at Gage (S002-316)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

5.2 ORTHOPHOSPHATE (AS P)

Parameter	1999 - 2005	2006 - 2009
Count	30	98
Conc Ave Error	12.69%	3.93%
Conc Median Error	0.32%	-2.76%
Load Ave Error	76.87%	-29.90%
Load Median Error	0.29%	-0.21%
Paired t conc	0.63	0.87
Paired t load	0.10	0.29

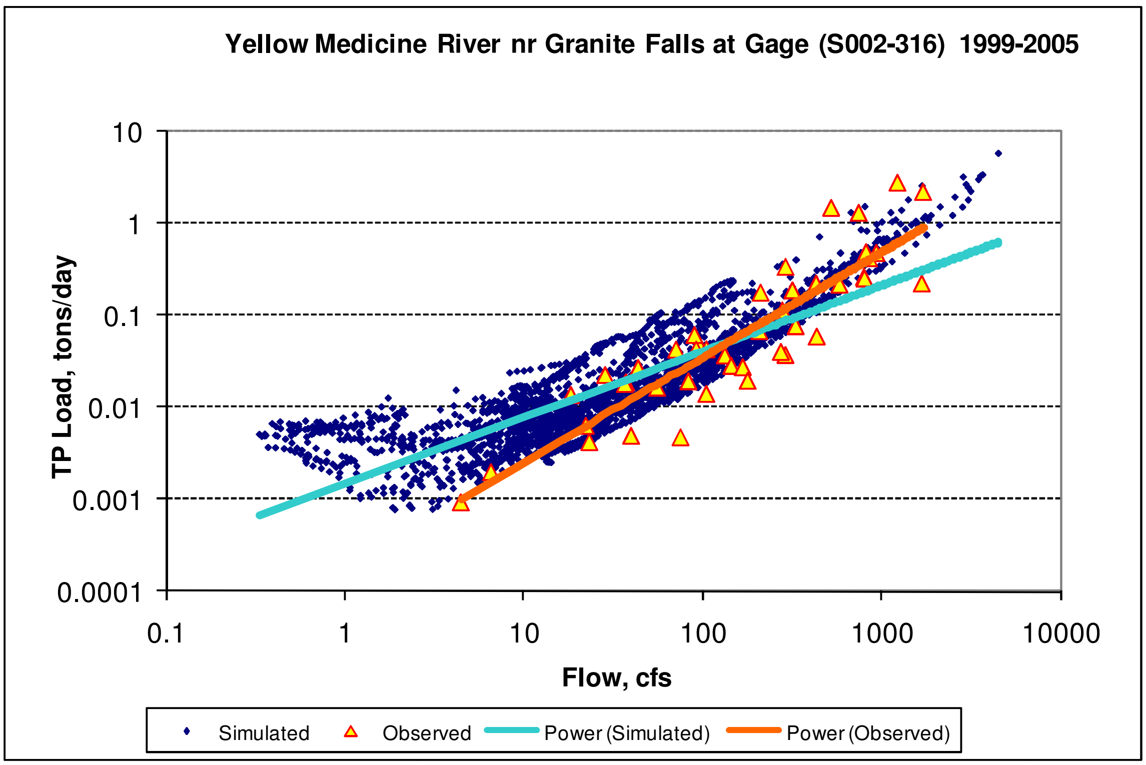


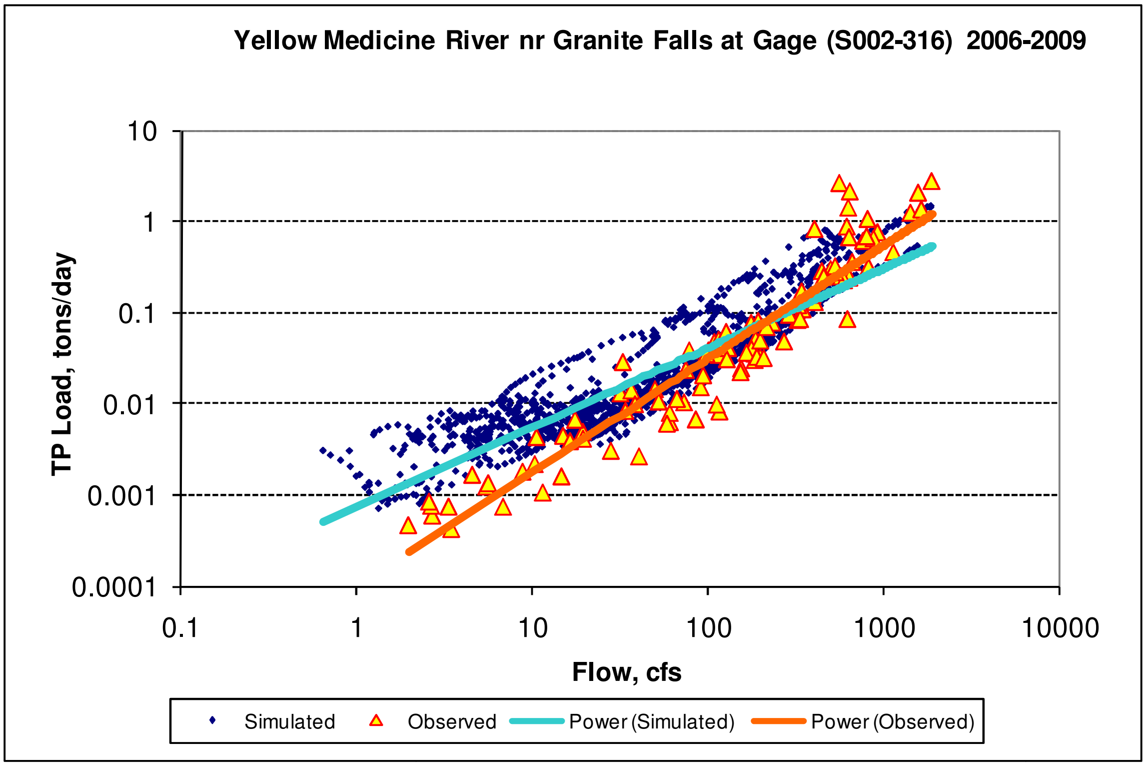

Yellow Medicine River nr Granite Falls at Gage (S000-159) 2006-2009
PO4 Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

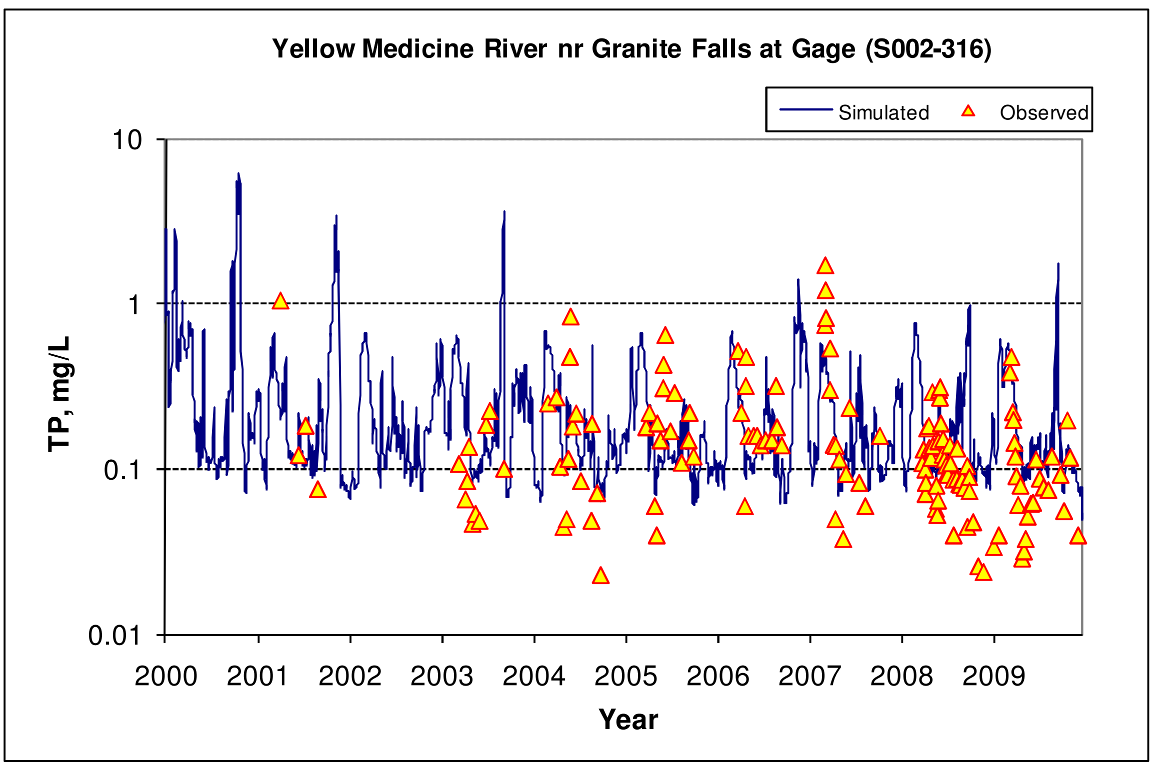

Yellow Medicine River nr Granite Falls at Gage (S000-159)
Simulated
Observed
PO4, mg/L
1
0.1
0.01
0.001
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

5.3 Total Phosphorus

Parameter	1999 - 2005	2006 - 2009
Count	44	100
Conc Ave Error	6.52%	-4.36%
Conc Median Error	-12.67%	-16.18%
Load Ave Error	16.84%	32.90%
Load Median Error	-1.89%	-1.06%
Paired t conc	0.85	0.93
Paired t load	0.54	0.22

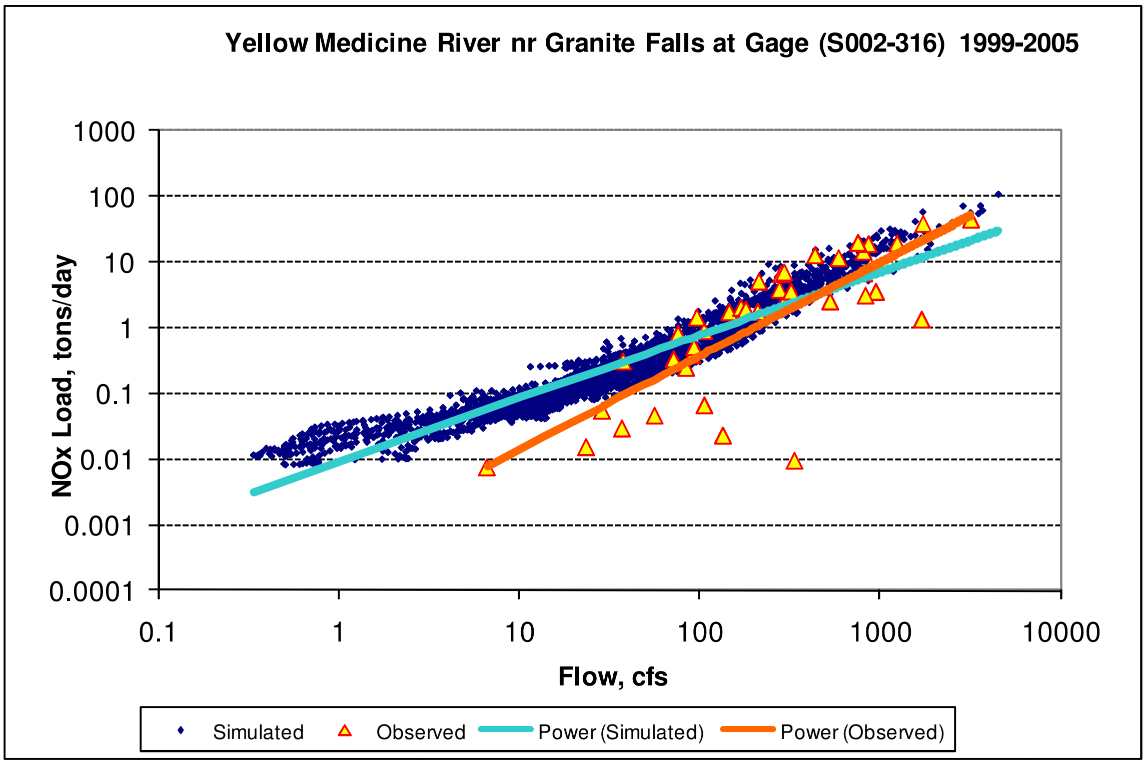


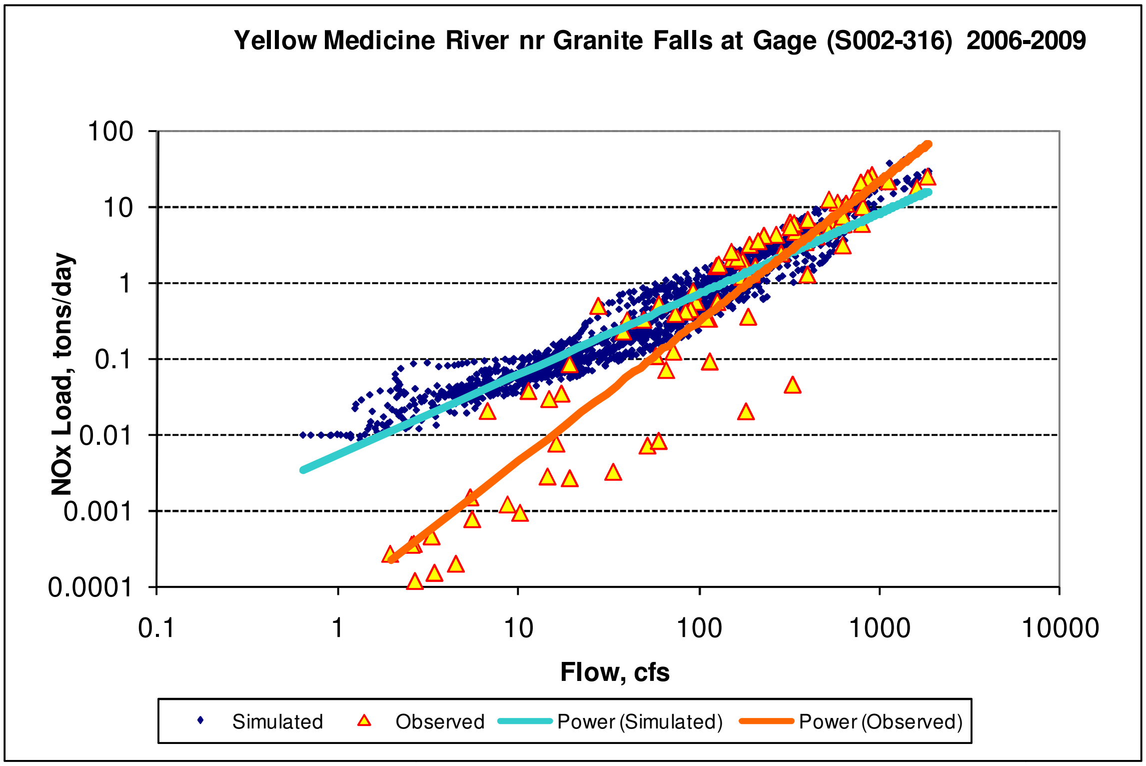

Yellow Medicine River nr Granite Falls at Gage (S002-316) 2006-2009
TP Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

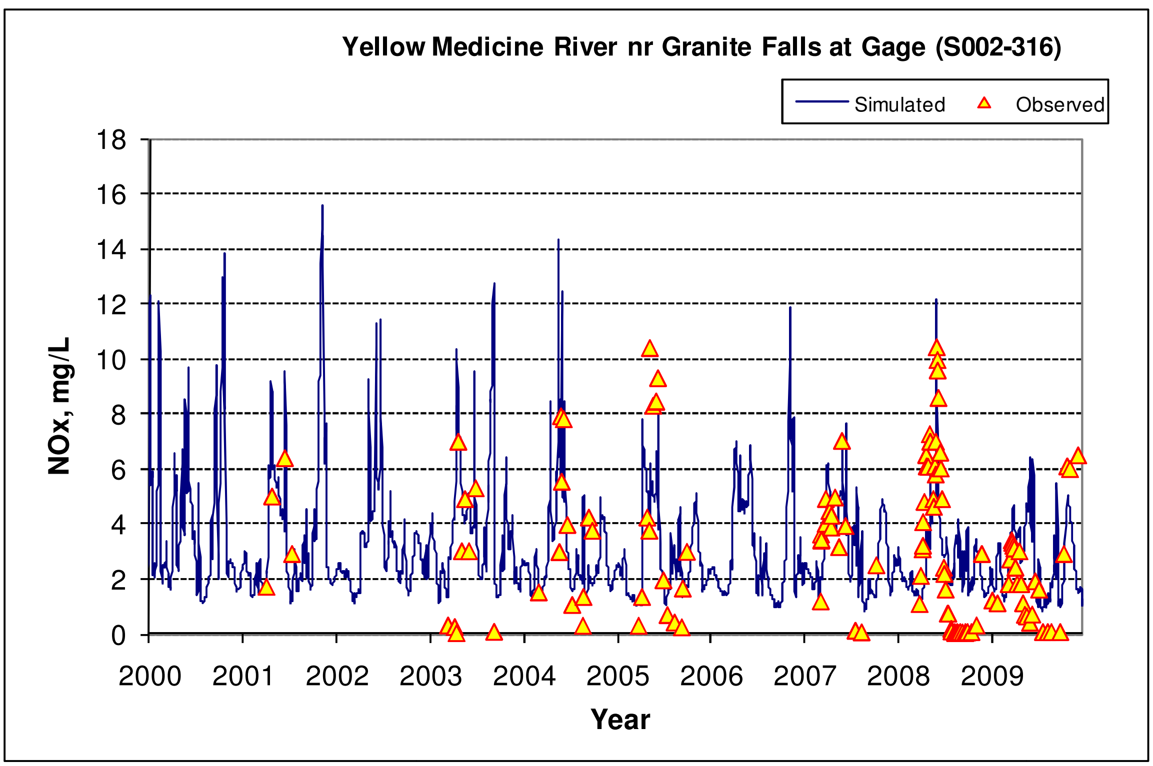

Yellow Medicine River nr Granite Falls at Gage (S002-316)
Simulated
Observed
TP, mg/L
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

5.4 NITRATE PLUS NITRITE NITROGEN (AS N)

Parameter	1999 - 2005	2006 - 2009
Count	39	86
Conc Ave Error	22.89%	11.70%
Conc Median Error	16.41%	26.56%
Load Ave Error	40.40%	-5.68%
Load Median Error	1.54%	0.76%
Paired t conc	0.41	0.84
Paired t load	0.26	0.79

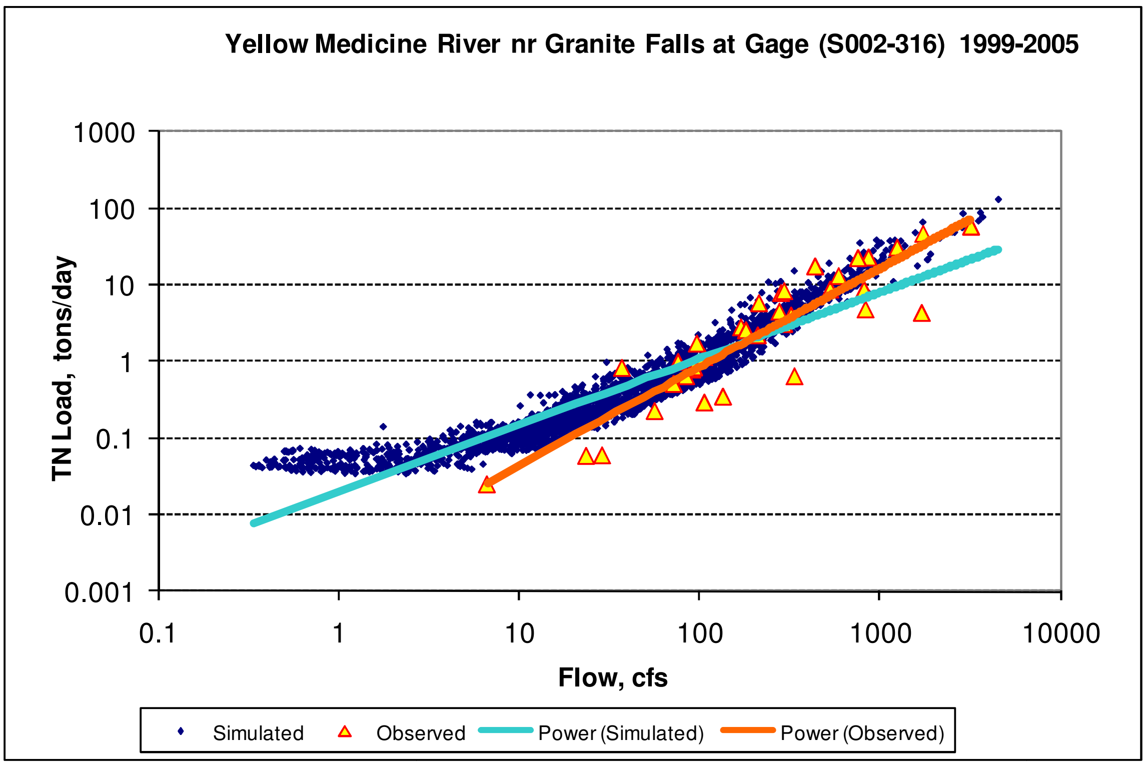


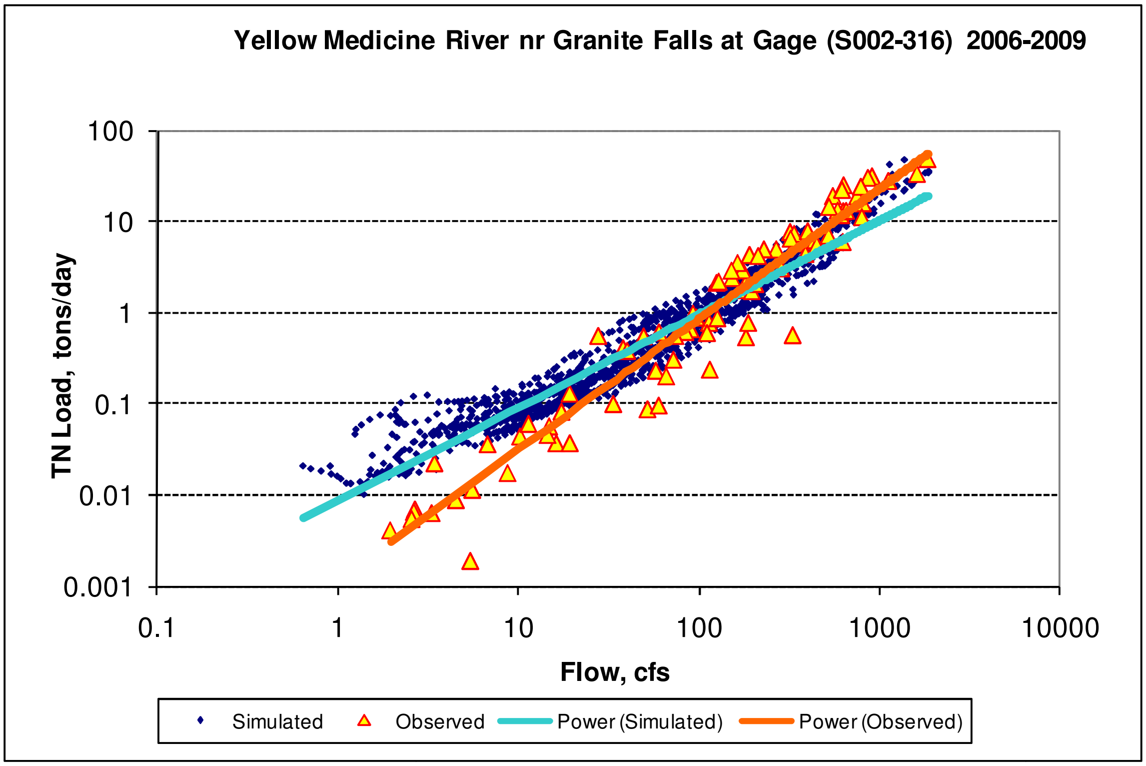

Yellow Medicine River nr Granite Falls at Gage (S002-316) 2006-2009
100
10
1
0.1
0.01
0.001
0.0001
NOx Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

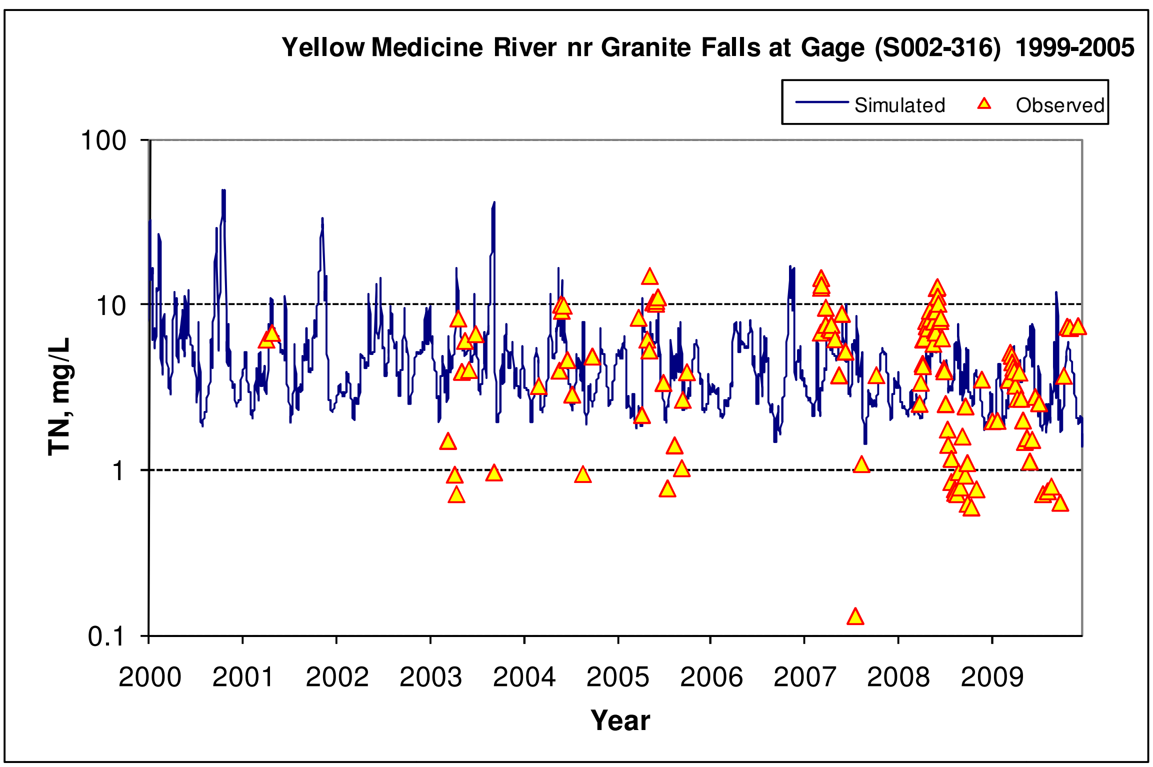

Yellow Medicine River nr Granite Falls at Gage (S002-316)
Simulated
Observed
18
16
14
12
10
8
6
4
2
0
NOx, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

5.5 TOTAL NITROGEN

Parameter	1999 - 2005	2006 - 2009
Count	35	86
Conc Ave Error	14.97%	-5.91%
Conc Median Error	-4.25%	-2.49%
Load Ave Error	27.51%	-25.06%
Load Median Error	-0.83%	-0.35%
Paired t conc	0.67	0.98
Paired t load	0.41	0.37



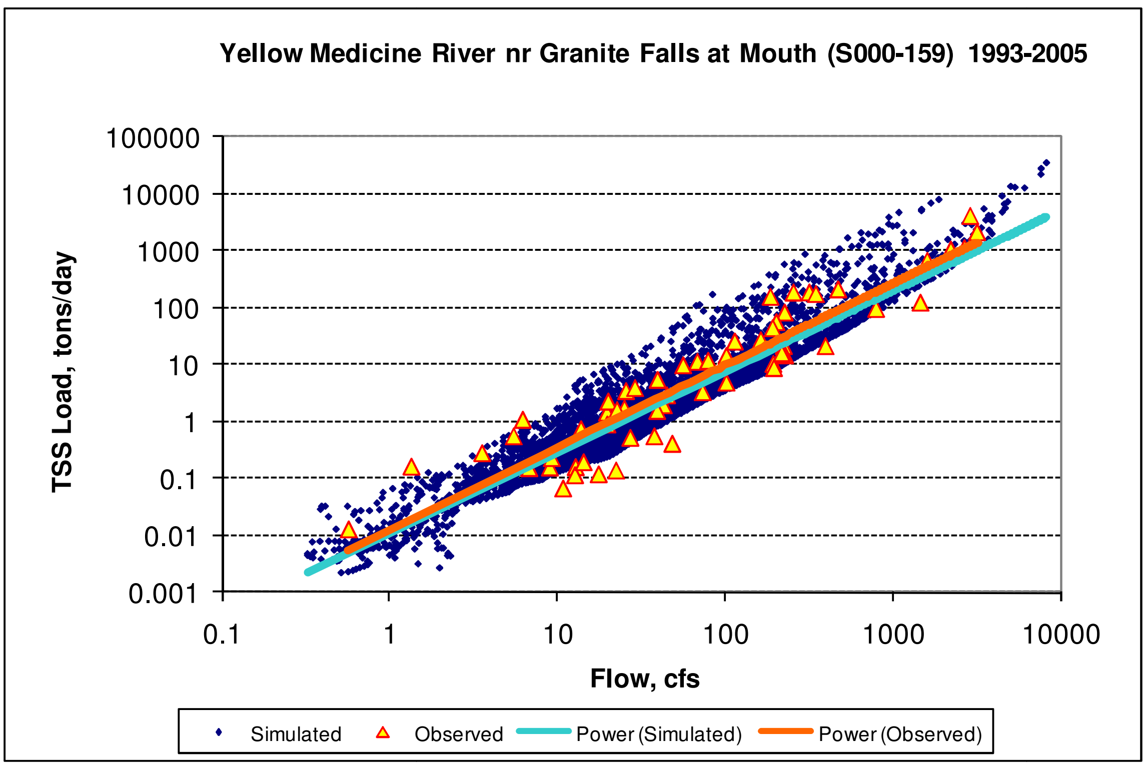

Yellow Medicine River nr Granite Falls at Gage (S002-316) 2006-2009
TN Load, tons/day
100
10
1
0.1
0.01
0.001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

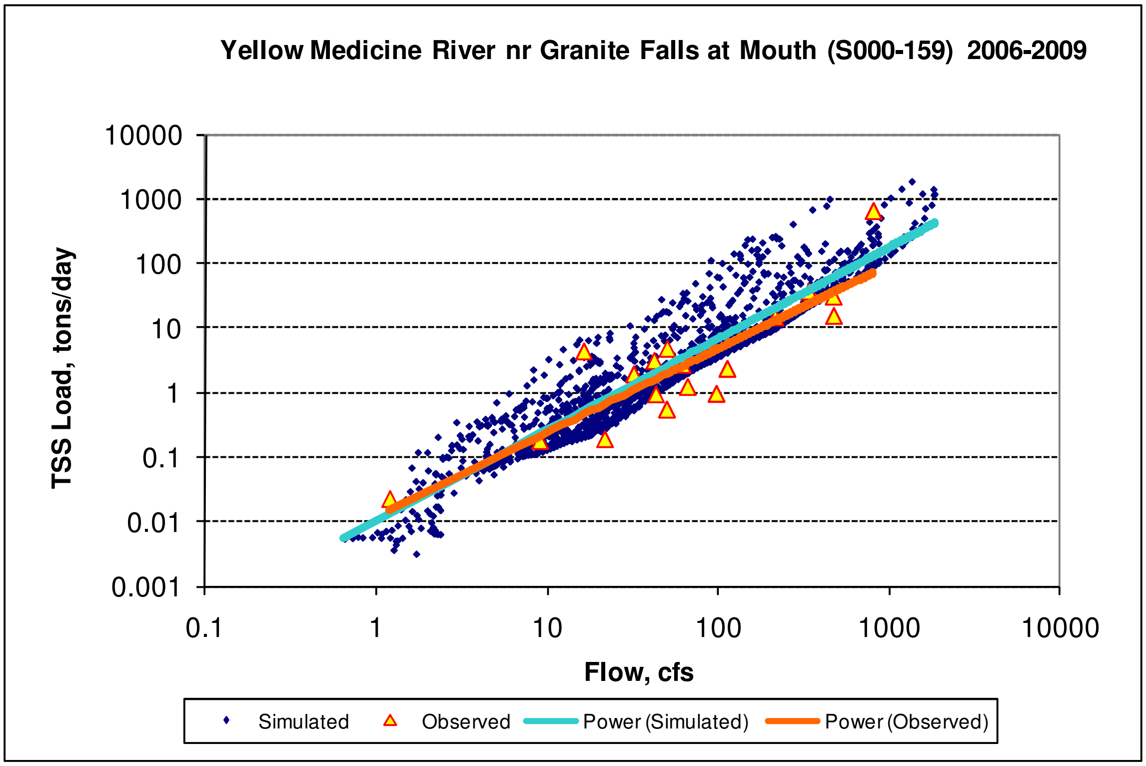

Yellow Medicine River nr Granite Falls at Gage (S002-316) 1999-2005
Simulated
Observed
TN, mg/L
100
10
1
0.1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

6 Yellow Medicine River at Mouth (S000-159)

6.1 Total Suspended Sediment

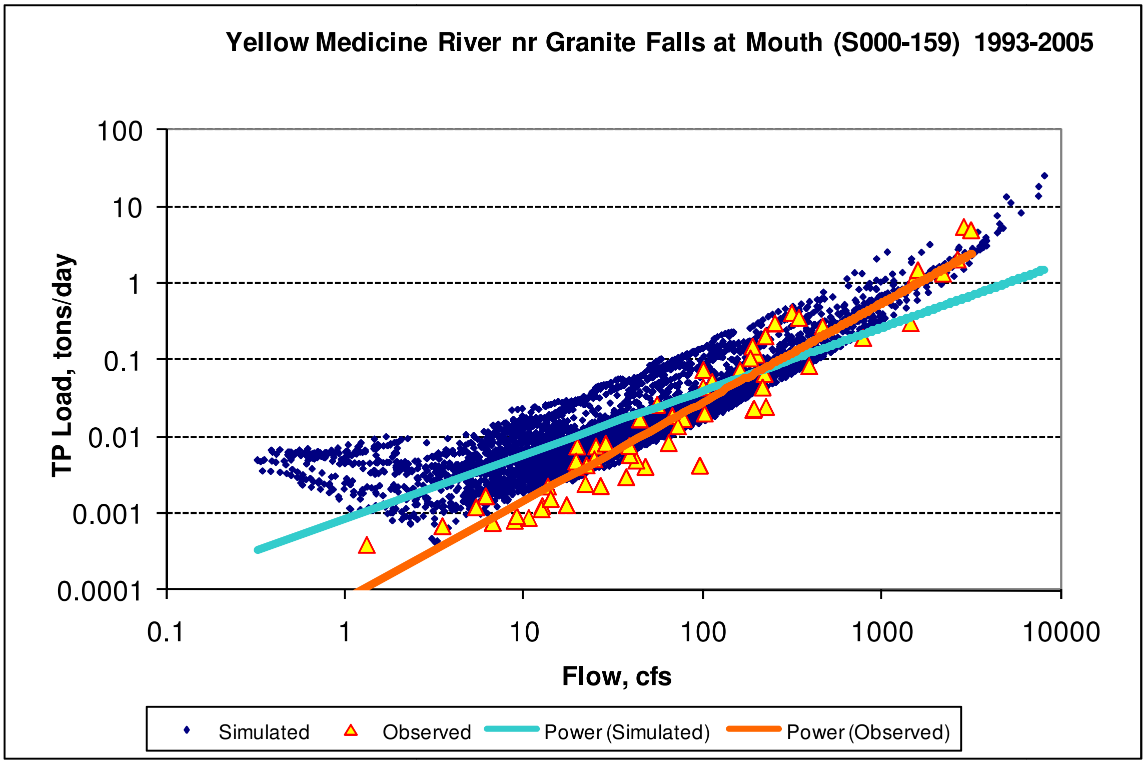
Parameter	1993 - 2005	2006 - 2009
Count	60	18
Conc Ave Error	-14.08%	20.66%
Conc Median Error	10.93%	-9.71%
Load Ave Error	-27.50%	53.18%
Load Median Error	0.21%	-1.33%
Paired t conc	0.58	0.49
Paired t load	0.44	0.30



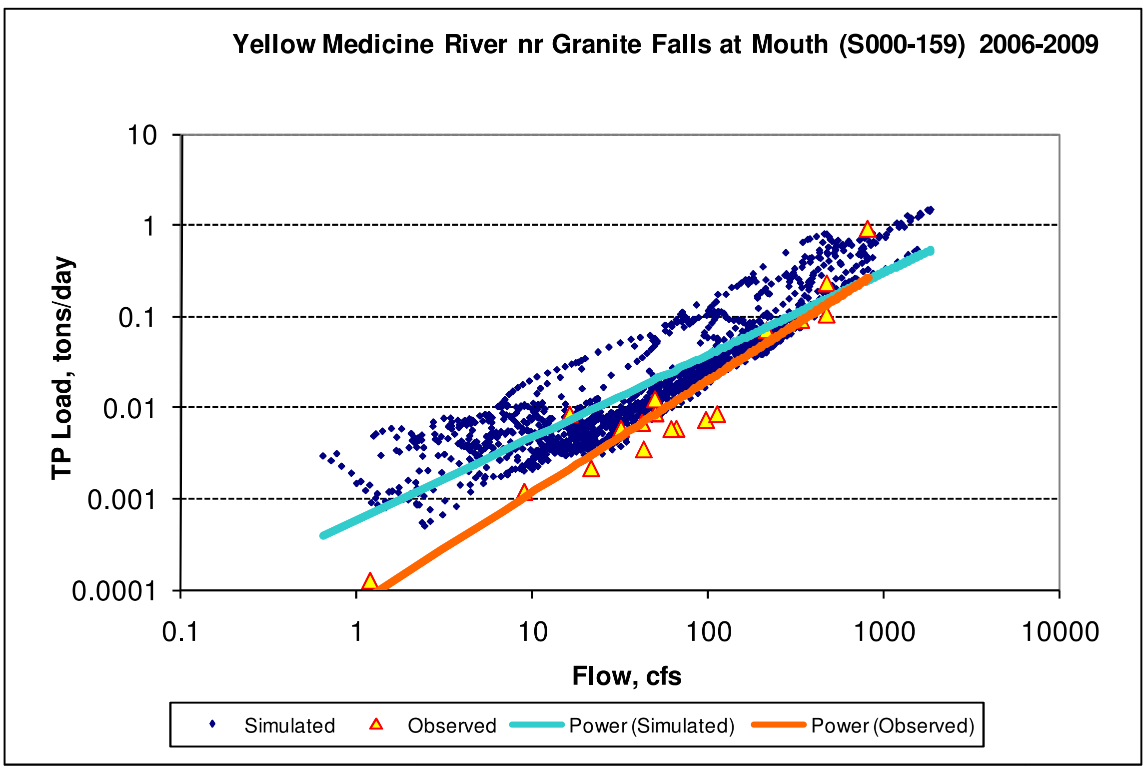


6.2 TOTAL PHOSPHORUS

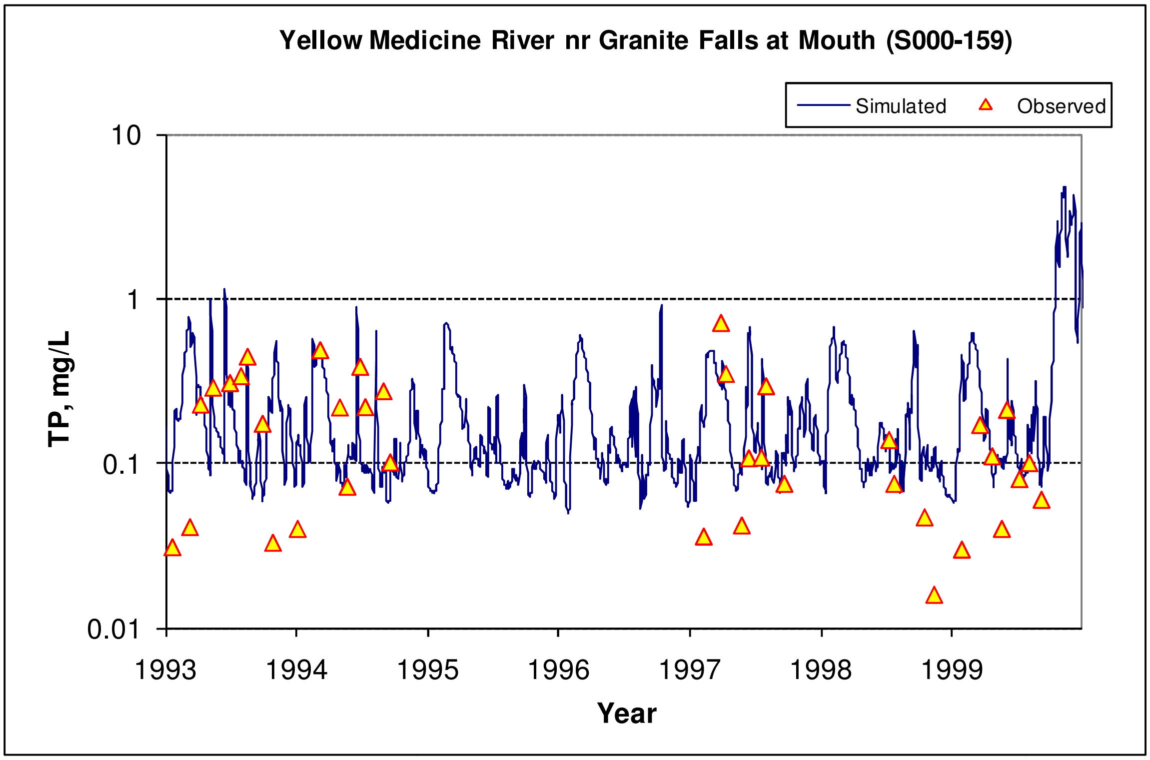
Parameter	1993 - 2005	2006 - 2009
Count	62	18
Conc Ave Error	-69.10%	-92.89%
Conc Median Error	-25.66%	-51.99%
Load Ave Error	21.50%	-36.38%
Load Median Error	-0.80%	-6.07%
Paired t conc	0.07	0.02
Paired t load	0.48	0.40

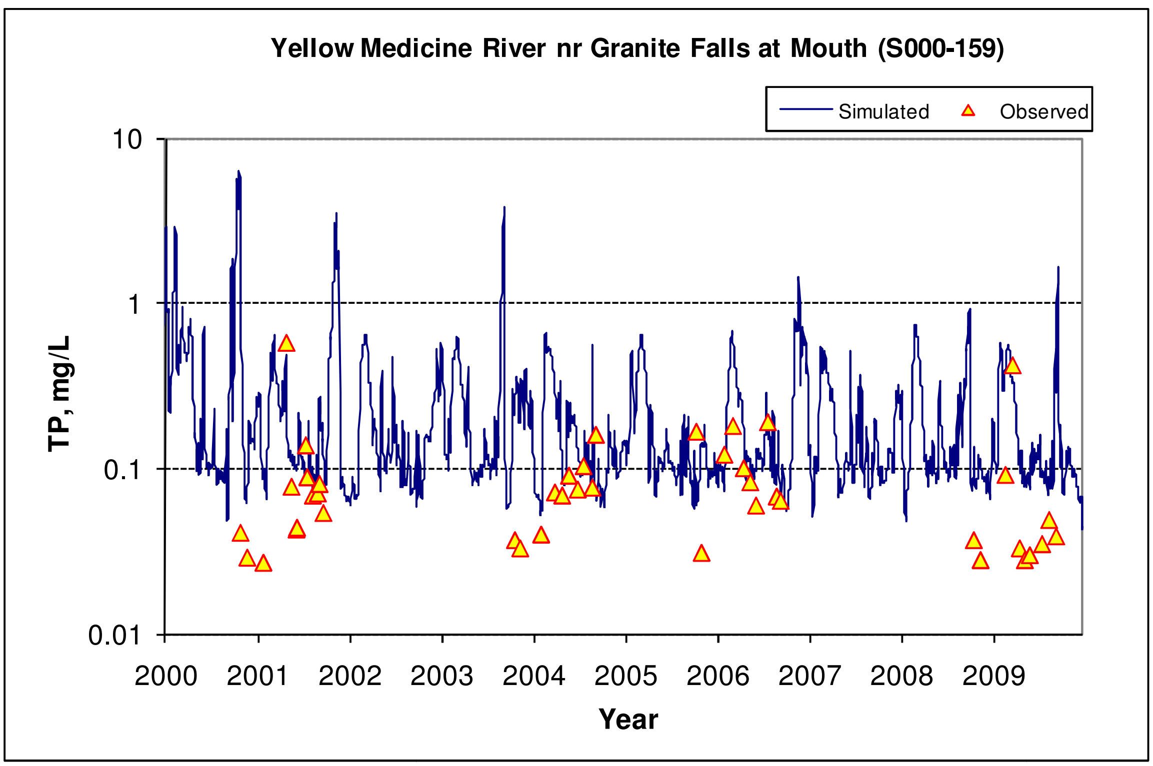


Yellow Medicine River nr Granite Falls at Mouth (S000-159) 1993-2005
100
10
1
0.1
0.01
0.001
0.0001
TP Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)



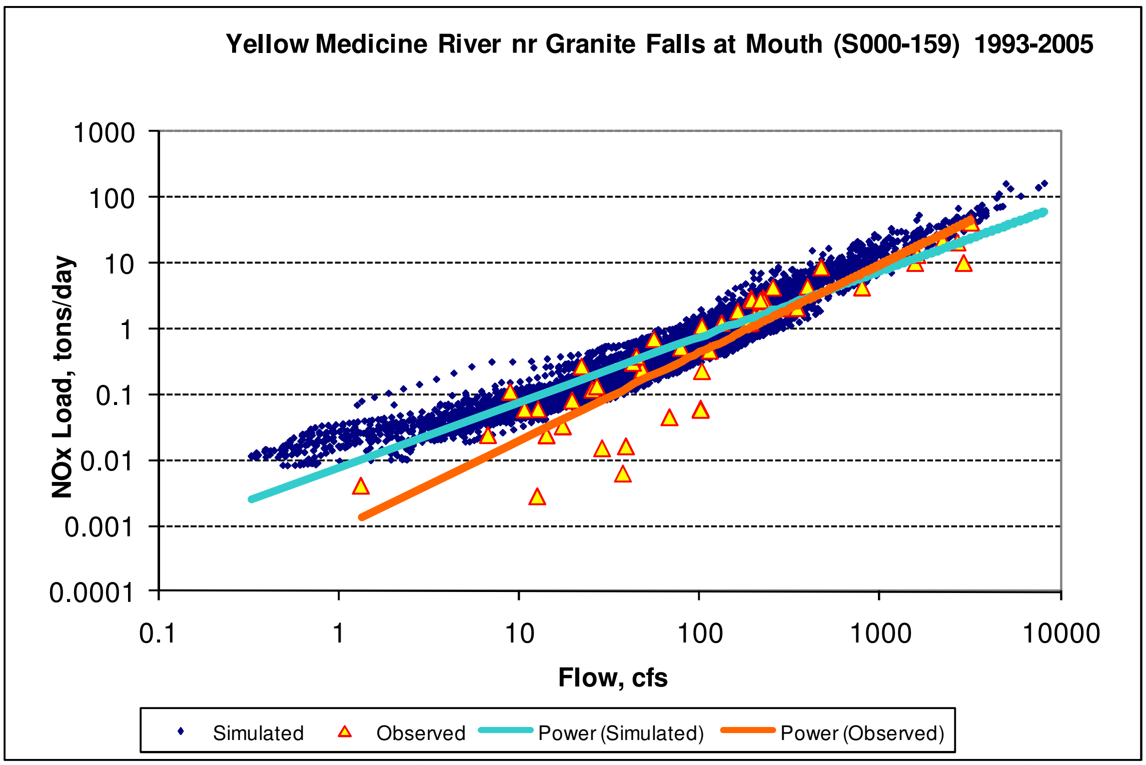
Yellow Medicine River nr Granite Falls at Mouth (S000-159) 2006-2009
10
1
0.1
0.01
0.001
0.0001
TP Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

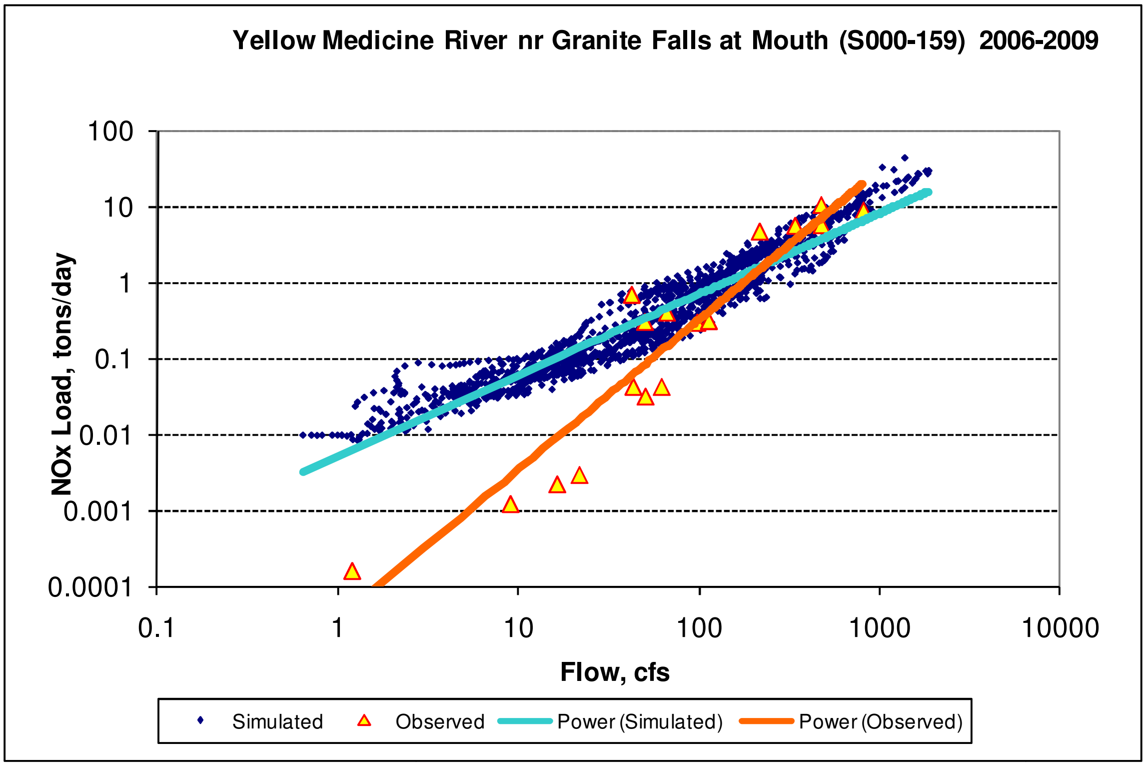

Yellow Medicine River nr Granite Falls at Mouth (S000-159)
Simulated
Observed
10
1
0.1
0.01
TP, mg/L
1993
1994
1995
1996
1997
1998
1999
Year


Yellow Medicine River nr Granite Falls at Mouth (S000-159)
Simulated
Observed
10
1
0.1
0.01
TP, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

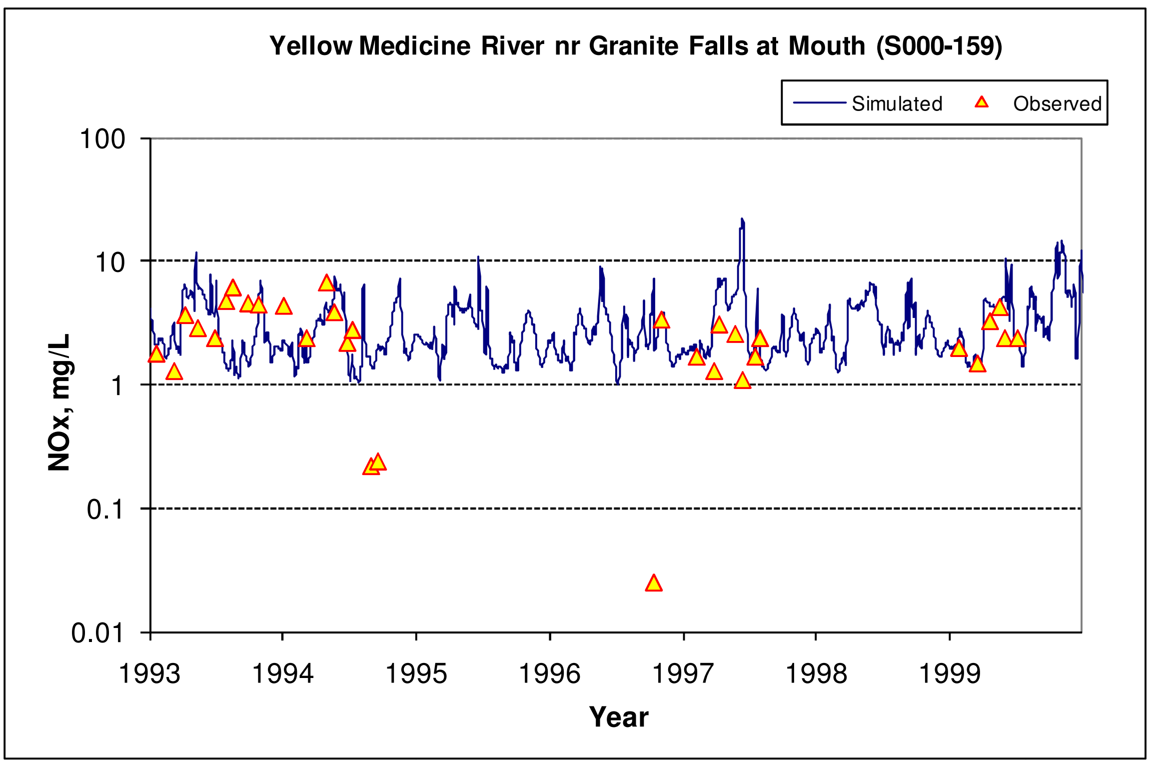
6.3 NITRATE PLUS NITRITE NITROGEN (AS N)

Parameter	1993 - 2005	2006 - 2009
Count	50	17
Conc Ave Error	45.26%	13.31%
Conc Median Error	30.64%	28.83%
Load Ave Error	62.46%	-27.58%
Load Median Error	1.54%	2.66%
Paired t conc	0.04	0.61
Paired t load	0.16	0.41

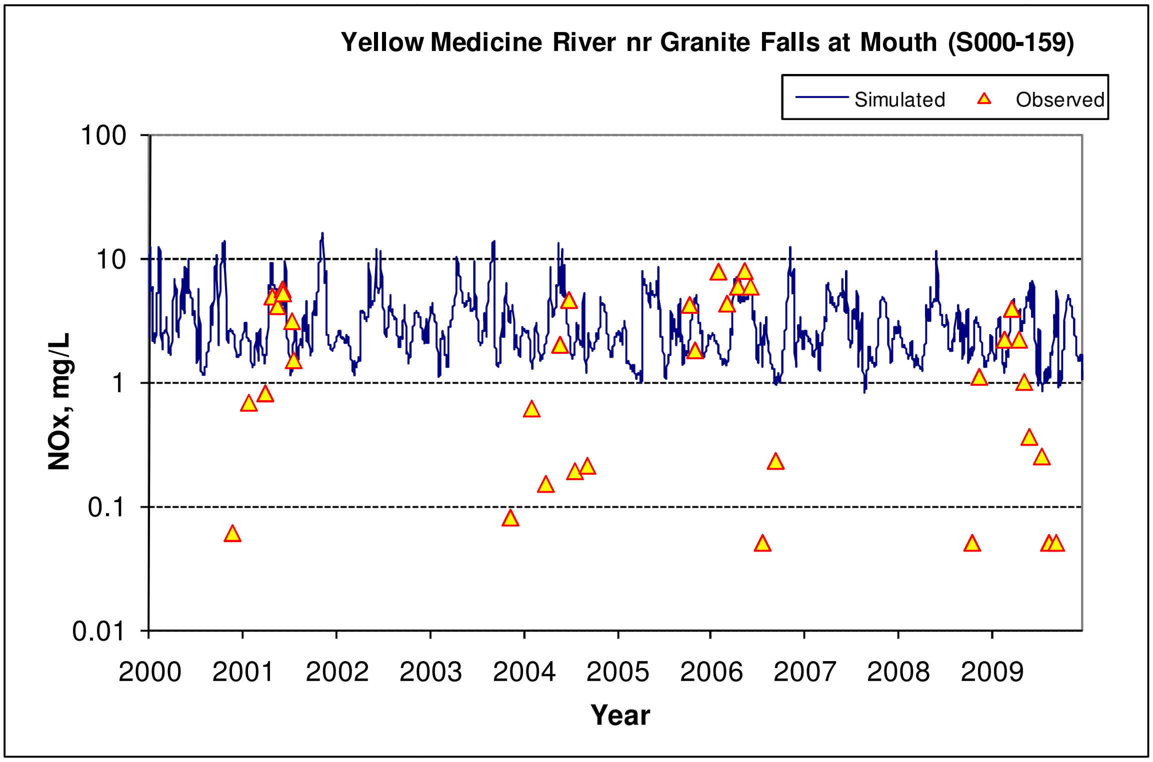




Yellow Medicine River nr Granite Falls at Mouth (S000-159) 2006-2009
100
10
1
0.1
0.01
0.001
0.0001
NOx Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)



Yellow Medicine River nr Granite Falls at Mouth (S000-159)
Simulated
Observed
100
10
1
0.1
0.01
NOx, mg/L
1993
1994
1995
1996
1997
1998
1999
Year


Yellow Medicine River nr Granite Falls at Mouth (S000-159)
Simulated
Observed
100
10
1
0.1
0.01
NOx, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year