# Hawk Creek 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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| **303(d) Listing Information** | There are impairments for 13 stream reaches, 13* listings for *E. coli* bacteria, and 5* listings for Turbidity (TSS). 4 lake impairments are listed for nutrient eutrophication; see Table 1.1<br>*Numbers are not cumulative | 13 |
| **Applicable Water Quality Standards/ Numeric Targets** | *See Section 2* | 16 |
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| **Wasteload Allocation** | *TMDL Summary, see Section 4.7* | 56 |
| **Load Allocation** | *TMDL Summary, see Section 4.7* | 56 |
| **Margin of Safety** | *E. coli*, turbidity (TSS), and lake nutrient eutrophication impairments: Explicit MOS of 10% used; *See Section 4.5* | 54 |
| **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*<br><br>Turbidity (TSS): Load duration curve methodology accounts for seasonal variation and the standard is developed for critical conditions; *See Section 4.6.2*<br><br>Nutrient eutrophication: Standard is developed for critical conditions; *See Section 4.6.3* | 56 |
| **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 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* | 66 |

| | | |
|---|---|---|
| **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* | 70 |
| **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* | 71 |
| **Public Participation** | Public participation in the Hawk Creek Watershed has been ongoing for the past two years. With respect to this specific TMDL: A public comment period was open from May 22, 2017 to June 21, 2017. There were four comment letters received and responded to as a result of the public comment period. *See Section 9* | 75 |

# Acronyms

| | |
|---|---|
| ARM | Agricultural Runoff Model |
| µg/L | Micrograms per Liter |
| AUID | Assessment Unit ID |
| AWQCP | Agricultural Water Quality Certification Program |
| BMP | Best Management Practice |
| BWSR | Board of Water and Soil Resources |
| 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 |
| GW | Groundwater |
| HSPF | Hydrological Simulation Program – FORTRAN |
| HUC | Hydrologic Unit Code |
| kg/ha | Kilograms per Hectare |
| LA | Load Allocation |
| lb(s) | Pound(s) |
| lbs/yr | Pounds per Year |
| lbs/day | Pounds per Day |
| LC | Loading Capacity |
| 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 |
| MOS | Margin of Safety |
| MPCA | Minnesota Pollution Control Agency |
| MS4 | Municipal Separate Storm Sewer System |
| NGP | Northern Glaciated Plains |
| NPDES | National Pollutant Discharge Elimination System |
| NPS | Nonpoint Source |
| NTU | Nephelometric Turbidity (TSS) Unit |
| org | Organisms |
| RR | Release Rate |
| SDS | State Disposal System |
| SSTS | Subsurface Sewage Treatment System |
| SWPPP | Stormwater Pollution Prevention Plan |

| | |
|---|---|
| TMDL | Total Maximum Daily Load |
| TP | Total Phosphorus |
| UAL | Unit-Area Load |
| WCBP | Western Corn Belt Plains |
| WLA | Wasteload Allocations |
| WRAPS | Watershed Restoration and Protection Strategies |
| WWTF | Wastewater Treatment Facilities |

# Executive Summary

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

This TMDL report addresses impairments for 13 stream reaches consisting of 13 *E. coli* and 5 turbidity (total suspended solids - TSS) impairments, as well as 4 lakes for nutrient eutrophication impairments, in the Hawk Creek 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 Hawk Creek Watershed is part of the Yellow Medicine River – Hawk Creek Major Watershed, comprised of two significant watersheds that do not have a hydrological connection and enter the Minnesota River from opposite sides. Hawk Creek Watershed covers approximately 626,000 acres in the Western Corn Belt Plains (WCBP) and North Central Hardwood Forest (NCHF) ecoregions and drains portions of three counties (Chippewa, Kandiyohi, and Renville) into the Minnesota River from the north. The Yellow Medicine River Watershed drains portions of five counties into the Minnesota River from the south, and has a previously completed TMDL report and Watershed Restoration and Protection Strategy (WRAPS) Report. This TMDL report addresses only the Hawk Creek portion.

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 Hydrological 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. Nonpoint sources (NPSs), primarily from agricultural land use and practices, will be the focus of implementation efforts. NPS contributions are currently not regulated and will need to be addressed 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 must be completed. The TMDL calculates the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and allocates pollutant loads across the sources of pollutants.

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 guide restoration and protection of streams, lakes, and wetlands across the watershed, including those for which TMDL calculations are not made.

The watershed approach started in the Hawk Creek Watershed in 2010 with intensive watershed monitoring and subsequent assessment, which resulted in 13 stream reaches and 4 lakes being listed as impaired for one or more water quality parameters (Table 1.1).

This document addresses Hawk Creek Watershed impairments identified in the 2010 monitoring and assessment cycle that have not been addressed in prior TMDLs, have an approved water quality standard, and have sufficient data for assessment. Refer to the prior TMDL webpage for more details on previously completed TMDLs: *Long and Ringo Lakes Excess Nutrients Total Maximum Daily Load* (MPCA 2011b). 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 applies to 22 separate impairment listings for 13 stream reaches and 4 lakes in the Hawk Creek and Watershed (Table 1.1). Supporting documentation for the proposed listing of the impairments can be found in:

*Hawk Creek Watershed Stressor ID Report* (MPCA 2012b)

*Minnesota River – Granite Falls Watershed Monitoring and Assessment Report* (MPCA 2012c)

Table 1.1: Hawk Creek Watershed 303(d) impairments addressed in this TMDL grouped by Aggregated HUC12 Watersheds

| Aggregated HUC12 Watershed | Stream Reach Description or Lake Name | Stream Use Class or Lake Ecoregion & Type | Assessment Unit ID or DNR Lake # | Affected Designated Use | Year Listed | Impairment |
|---|---|---|---|---|---|---|
| Beaver Creek | **East Fork Beaver Creek to Minnesota River** | **2B** | **07020004-528** | **Aquatic Recreation** | **2006** | **Fecal coliform** |
| | | | | **Aquatic Life** | **2006** | **Turbidity (TSS)** |
| Chetomba Creek | **Chetomba Creek to Spring Creek** | **2B** | **07020004-589** | **Aquatic Recreation** | **2010** | ***Escherichia coli*** |
| | | | | **Aquatic Life** | **2006** | **Turbidity (TSS)** |
| | **Lake Olson** | **NGP Shallow Lake** | **34-0266-00** | **Aquatic Recreation** | **2014** | **Nutrient Eutrophication** |
| County Ditch 11 | **Unnamed ditch to Hawk Creek** | **2B** | **07020004-689** | **Aquatic Recreation** | **2014** | ***Escherichia coli*** |
| East Fork Beaver Creek | **T115 R35W S35, North Line to West Fork Beaver Creek** | **2B** | **07020004-586** | **Aquatic Recreation** | **2014** | ***Escherichia coli*** |
| Lower Hawk Creek | **Spring Creek to Minnesota River** | **2B** | **07020004-587** | **Aquatic Recreation** | **2010** | ***Escherichia coli*** |
| | | | | **Aquatic Life** | **2004** | **Turbidity (TSS)** |
| | **Unnamed Creek to Unnamed Creek** | **2B** | **07020004-568** | **Aquatic Recreation** | **2006** | **Fecal coliform** |
| | | | | **Aquatic Life** | **2006** | **Turbidity (TSS)** |
| Sacred Heart Creek | **Headwaters to Minnesota River** | **2B** | **07020004-526** | **Aquatic Recreation** | **2010** | ***Escherichia coli*** |

| Aggregated HUC12 Watershed | Stream Reach Description or Lake Name | Stream Use Class or Lake Ecoregion & Type | Assessment Unit ID or DNR Lake # | Affected Designated Use | Year Listed | Impairment |
|---|---|---|---|---|---|---|
| Sacred Heart Creek - MN River | **Headwaters to Minnesota River** | **2B** | **07020004-525** | **Aquatic Recreation** | **2010** | ***Escherichia coli*** |
| | **CD 120 to Minnesota R** | **2C** | **07020004-615** | **Aquatic Recreation** | **2010** | ***Escherichia coli*** |
| | **T113 R35W S4, north line to Minnesota R** | **2C** | **07020004-617** | **Aquatic Recreation** | **2014** | ***Escherichia coli*** |
| Stony Run Creek - MN River | **Headwaters to Minnesota River** | **2B** | **07020004-534** | **Aquatic Recreation** | **2014** | ***Escherichia coli*** |
| Tributary to Hawk Creek | **St. John's Lake** | **NGP Shallow Lake** | **34-0283-00** | **Aquatic Recreation** | **2014** | **Nutrient Eutrophication** |
| | **West Solomon Lake** | **NGP Shallow Lake** | **34-0245-00** | **Aquatic Recreation** | **2014** | **Nutrient Eutrophication** |
| Upper Hawk Creek | **Swan Lake** | **NGP Shallow Lake** | **34-0186-00** | **Aquatic Recreation** | **2014** | **Nutrient Eutrophication** |
| West Fork Beaver Creek | **Headwaters to East Fork Beaver Creek** | **2B** | **07020004-530** | **Aquatic Recreation** | **2006** | **Fecal coliform** |
| | | | | **Aquatic Life** | **2006** | **Turbidity (TSS)** |
| Wood Lake Creek - MN River | **Unnamed Creek to Minnesota River** | **2B** | **07020004-648** | **Aquatic Recreation** | **2014** | ***Escherichia coli*** |

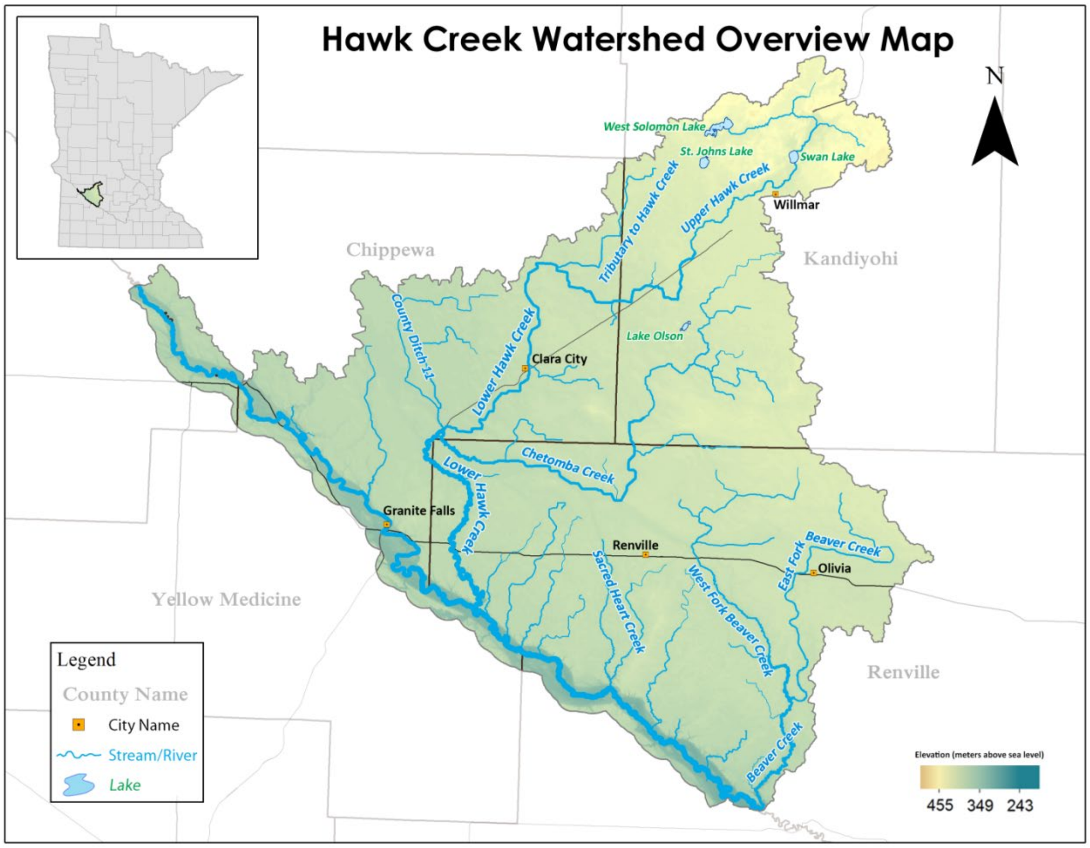



**Figure 1.1: Hawk Creek Watershed - HUC 07020004 and its location within Minnesota River Basin**

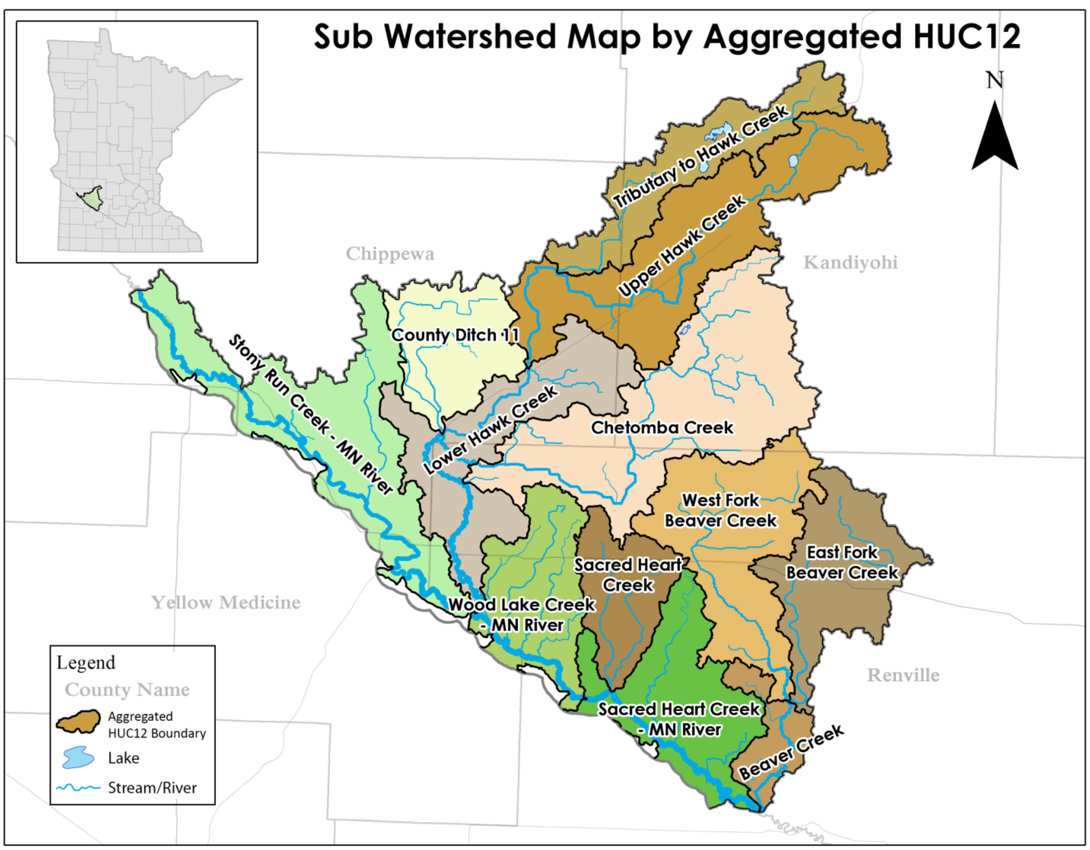



**Figure 1.2: Hawk Creek Aggregated HUC12 Subwatershed boundaries**

## 1.3 Priority Ranking

The MPCA's schedule for TMDL completions, as indicated on the 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. MPCA has aligned our TMDL priorities with the watershed approach and our WRAPS cycle. The schedule for TMDL completion corresponds to the WRAPS report completion on the 10-year cycle. MPCA developed a state plan Minnesota's TMDL Priority Framework Report to meet the needs of EPA's national measure (WQ-27) under EPA's Long-Term Vision for Assessment, Restoration and Protection under the Clean Water Act Section 303(d) Program. As part of these efforts, the MPCA identified water quality impaired segments that will be addressed by TMDLs by 2022. The Hawk Creek Watershed waters addressed by this TMDL are part of that MPCA prioritization plan to meet EPA's national measure.

# 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 targets for each parameter shown. For more detailed information refer to the *MPCA TMDL Protocols* (MPCA 2014b).

Table 2.1: Surface water quality standards for Hawk Creek Watershed stream reaches addressed in this TMDL

| 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 10$^{th}$ percentile | |
| TSS Class 2 waters | Not to Exceed 65 | mg/L | > 10% of total samples cannot exceed 65 mg/L | April 1 – September 30 |

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 Hawk Creek 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. 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 developed TSS criteria to replace the turbidity standards. These TSS criteria are regional in scope and based on a combination of both biotic sensitivities 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, the newly adopted 65 mg/L standard for Class 2B waters will be used to address the turbidity impairment listings in the Hawk Creek Watershed.

**Table 2.2: Lake water quality standards for lakes within the Hawk Creek Watershed**

| Ecoregion | Total Phosphorus Standard (µg/L) | Chlorophyll –a Standard (µg/L) | Secchi Depth (m) | Criteria | Period of Time Standard Applies |
|---|---|---|---|---|---|
| WCBP Shallow Lakes | < 90 | < 30 | > 0.7 | Summer average of all samples | June 1 – September 30 |

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). In addition to meeting phosphorus limits, chlorophyll-a (Chl-*a)*, and Secchi transparency standards must also be met.

Clear relationships were established between the causal factor total phosphorus (TP) and the response variables Chl-*a*, and Secchi transparency. Based on these relationships it is expected that by meeting the phosphorus target in each lake, the Chl-*a* and Secchi standards will likewise be met**.**

# 3. Watershed and Waterbody Characterization

Located in Southwestern Minnesota, the Hawk Creek Watershed covers approximately 626,000 acres in the WCBP and NCHF ecoregions and drains portions of three counties (Chippewa, Kandiyohi, and Renville). Willmar is the largest town in this largely rural watershed. Clara City, Renville, and Olivia are small towns within the study area. Land use statistics of the Hawk Creek Watershed are shown in Table 3.3. For more information on the Hawk Creek Watershed, refer to the *Minnesota River - Granite Falls Monitoring and Assessment Report* (MPCA 2012c).

The headwaters of Hawk Creek start in the NCHF ecoregion, but the majority of the watershed is in the WCBP ecoregion, and flows into the Minnesota River from the north. The Hawk Creek Watershed includes several smaller streams that are direct tributaries to the Minnesota River, including Chetomba, Beaver, Sacred Heart, Middle, Timm's, Brafees, Smith and Palmer Creeks. The upper portion in the northeastern part of the watershed has numerous lakes and rolling hills that form the headwaters of Hawk Creek. Hawk Creek originates at Eagle Lake north of Willmar and flows approximately 65 miles to its mouth at the Minnesota River near Granite Falls. Much of the watershed was originally covered by prairie. Significant portions of the watershed have been drained to increase agricultural and non-agricultural development. 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 beneath the entire field and drains water from upland areas down into the tile outlet.

Row crop agriculture is the primary land use in the watershed. The highly manipulated hydrology within the watershed has resulted in a very effective drainage system that allows agriculture, the region's primary land use, to thrive throughout much of the watershed.

## 3.1 Lakes

The impaired lakes addressed in the Hawk Creek Watershed TMDL are shallow, polymictic lakes in the WCBP ecoregion (Table 3.1).

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

| Aggregated HUC12 Subwatershed | Lake Name DNR Lake # | Surface Area (acres) | Average Depth (feet) | Max Depth (feet) | Lakeshed Area (acres) | Lakeshed Area : Surface Area Ratio | Littoral Area (%) |
|---|---|---|---|---|---|---|---|
| Chetomba Creek | Olson Lake 34-0266-00 | 126.6 | 2.0 | 3.0 | 492 | 4 : 1 | 100 |
| Tributary to Hawk Creek | St. John's Lake 34-0283-00 | 193 | 4 | 7 | 19,801 | 103 : 1 | 100 |
| | West Solomon Lake 34-0245-00 | 561 | 6.9 | 13 | 17,522 | 31 : 1 | 100 |
| Upper Hawk Creek | Swan Lake 34-0186-00 | 205 | 3.3 | 5 | 13,408 | 65 : 1 | 100 |

## 3.2 Streams

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

Table 3.2: Approximate watershed areas of impaired stream reaches

| Aggregated HUC12 | Stream Name | Reach Location Description | Assessment Unit ID # | Area (acres) |
|---|---|---|---|---|
| Beaver Creek | Beaver Creek | East Fork Beaver Creek to Minnesota River | 07020004-528 | 126,801 |
| Chetomba Creek | Chetomba Creek | Chetomba Creek to Spring Creek | 07020004-589 | 97,683 |
| County Ditch 11 | County Ditch 11 | Unnamed ditch to Hawk Creek | 07020004-689 | 37,095 |
| East Fork Beaver Creek | East Fork Beaver Creek | T115 R35W S35, North Line to West Fork Beaver Creek | 07020004-586 | 47,410 |
| Lower Hawk Creek | Hawk Creek | Unnamed Creek to Unnamed Creek | 07020004-568 | 206,059 |
| | Hawk Creek | Spring Creek to Minnesota River | 07020004-587 | 325,094 |
| Sacred Heart Creek | Sacred Heart Creek | Headwaters to Minnesota River | 07020004-526 | 29,048 |
| Sacred Heart Creek - MN River | Timms Creek | Headwaters to Minnesota River | 07020004-525 | 15,277 |
| Stony Run Creek - MN River | County Ditch 68 | Headwaters to Minnesota River | 07020004-534 | 21,574 |

| Aggregated HUC12 | Stream Name | Reach Location Description | Assessment Unit ID # | Area (acres) |
|---|---|---|---|---|
| West Fork Beaver Creek | West Fork Beaver Creek | Headwaters to East Fork Beaver Creek | 07020004-530 | 63,548 |
| Wood Lake Creek - MN River | County Ditch 119 | Unnamed Creek to Minnesota River | 07020004-648 | 10,716 |

## 3.3 Subwatersheds

Area within the watershed has been grouped together by aggregating Hydrologic Unit Code (HUC) 12 watersheds into subwatershed areas (See Figure 1.2). This was done in order to group together land area that drains into the individual branches and tributaries that flow into Hawk Creek and the direct tributaries of the Minnesota River. The beginning of the watershed consists of several lakes and tributaries, as well as the beginning of Hawk Creek. Hawk Creek then flows southwest toward the Minnesota River. Several smaller tributaries, such as County Ditch 11 and Chetomba Creek flow into Hawk Creek further down in the watershed. Tributaries that flow directly into the Minnesota River are also included in this TMDL. These direct tributary subwatersheds include Sacred Heart Creek, Stony Run Creek – Minnesota River, Wood Lake Creek – Minnesota River, Sacred Heart Creek – Minnesota River, and Beaver Creek.

## 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 Hawk Creek Watershed HUC12 Subwatersheds (MRLC 2011)

| Aggregated HUC-12 Subwatershed | Open Water | Developed | Barren/ Mining | Forest/ Shrub | Pasture/ Hay/ Grassland | Cropland | Wetland |
|---|---|---|---|---|---|---|---|
| Beaver Creek | 0.2% | 5.8% | 0.2% | 3.9% | 6.1% | 80% | 3.8% |
| Chetomba Creek | 0.1% | 5.5% | 0.1% | 1.1% | 1.1% | 88.9% | 3.2% |
| County Ditch 11 | 0.1% | 5.1% | 0.1% | 0.2% | 0.8% | 92.4% | 1.3% |
| East Fork Beaver Creek | 0.2% | 8% | 0.1% | 1.1% | 0.8% | 87.6% | 2.2% |
| Lower Hawk Creek | 0.3% | 6.4% | 0.1% | 1.5% | 2.4% | 85.7% | 3.6% |
| Sacred Heart Creek | 0.2% | 7.6% | 0.2% | 2.7% | 1.2% | 83.1% | 5% |
| Sacred Heart Creek – MN River | 1.1% | 4.7% | 0.1% | 5.2% | 5.1% | 79.4% | 4.4% |
| Stony Run Creek – MN River | 1.6% | 6% | 0.1% | 1.1% | 6.3% | 81.1% | 3.8% |
| Tributary to Hawk Creek | 12.2% | 4.9% | 0.1% | 4.2% | 8.3% | 65.5% | 4.8% |
| Upper Hawk Creek | 4% | 11% | 0.1% | 1.7% | 4.9% | 75.1% | 3.2% |
| West Fork Beaver Creek | 0.5% | 5.5% | 0.2% | 1.1% | 1.9% | 84.5% | 6.3% |
| Wood Lake Creek - MN River | 0.8% | 5.7% | 0% | 4.5% | 3% | 79.9% | 6.1% |

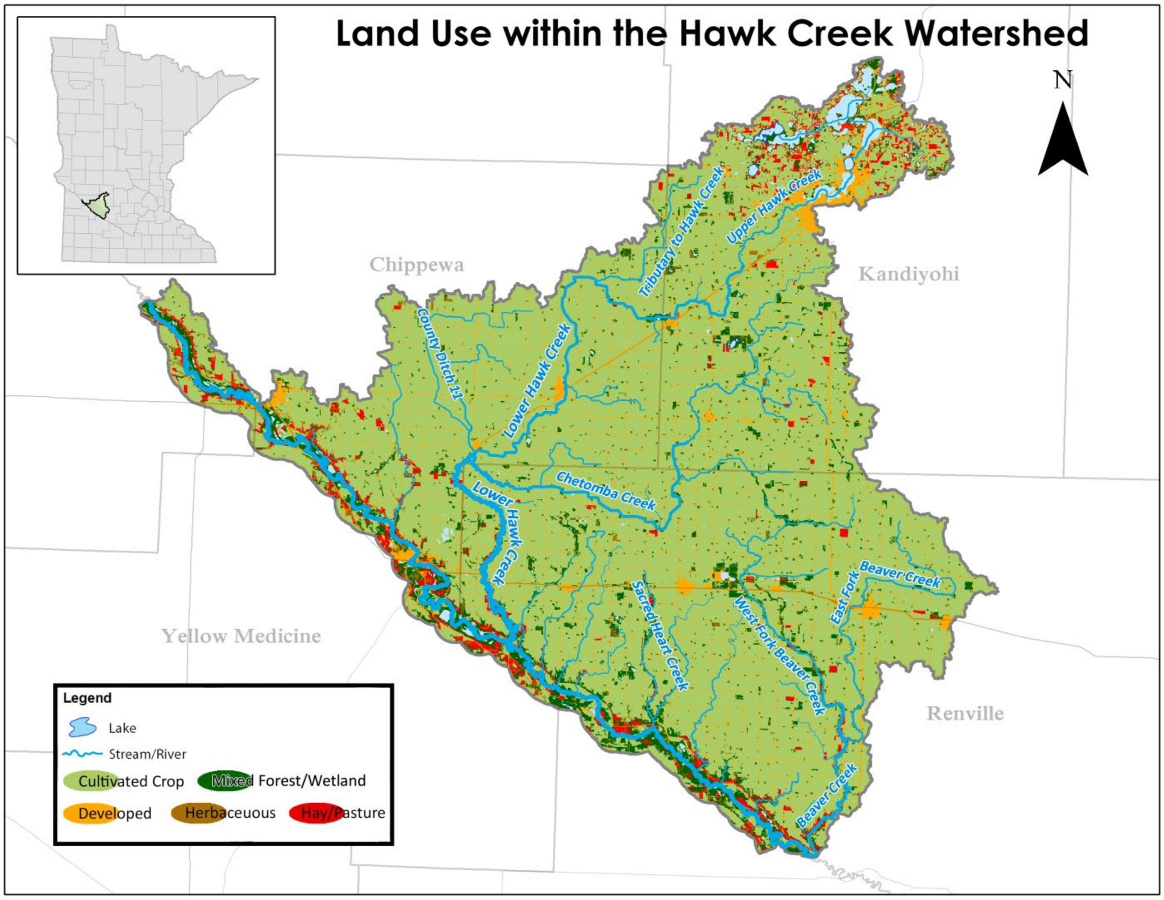



**Figure 3.1: Land use of the Hawk Creek Watershed**

## 3.5 Current/Historic Water Quality

A summary of current water quality is provided in this section related to the *E. coli*, Turbidity (TSS), and nutrient impairments addressed in this TMDL. 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 *Hawk Creek Watershed Biotic Stressor Identification Report* (MPCA 2012b).

### 3.5.1 Streams

#### 3.5.1.1 *E. coli*

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

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

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 Subwatershed<br>Stream Reach<br>AUID #<br>EQuIS Station ID | Range of Data (org/mL) | % of samples exceeding 1260 org/100mL | Geometric Mean (org/mL) [# of samples] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Apr | May | June | July | Aug | Sep | Oct |
| Beaver Creek<br>07020004-528<br>S000-666 | 7-7270 | June- 19%<br>July-11%<br>Aug- 14%<br>Sep- 21%<br>Oct- 30% | 65.7 [25] | 114.3 [27] | 452.7 [31] | 489.3 [18] | 426.3 [5] | 548 [19] | 681.8 [10] |
| Chetomba Creek<br>07020004-589<br>S002-152 | 1-3873 | April- 12%<br>June- 14%<br>Aug- 14%<br>Sep- 21%<br>Oct- 20% | 54.8 [26] | 63.3 [27] | 261.6 [29] | 124.6 [18] | 87.6 [21] | 129.6 [19} | 237.8 [10] |
| County Ditch 11<br>07020004-689<br>S002-147 | 50-2420 | - | - | - | 242.5 [5] | 159.5 [5] | 156.4 [5] | - | - |
| East Fork Beaver Creek<br>07020004-586<br>S000-404 | 55-1046 | - | - | - | 213.3 [5] | 276.7 [5] | 237.4 [5] | - | - |
| Lower Hawk Creek<br>07020004-587<br>S002-012 | 1-11199 | June- 14%<br>Sep- 21% | 38 [26] | 46.5 [27] | 174.1 [29] | 139.2 [18] | 99.1 [21] | 256.5 [19] | 176.2 [10] |

| Aggregated HUC12 Subwatershed Stream Reach AUID # EQuIS Station ID | Range of Data (org/mL) | % of samples exceeding 1260 org/100mL | Geometric Mean (org/mL) [# of samples] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Apr | May | June | July | Aug | Sep | Oct |
| Lower Hawk Creek 07020004-568 S002-148 | 4-3654 | April- 12% June- 20% July- 11% Sep- 17% | 60.9 [25] | 62.8 [27] | 310.2 [25] | 270.4 [18] | 257.9 [21] | 273.9 [18] | 192.9 [9] |
| Sacred Heart Creek 07020004-526 S001-341 | 3-2481 | June- 11% July- 11% Aug- 18% Sep- 13% | 37.8 [10] | 82.18 [17] | 294.3 [18] | 261.4 [9] | 493.1 [11] | 335.7 [8] | 1128 [2] |
| Sacred Heart Creek – MN River 07020004-525 S003-867 | 5-2481 | June- 22% July- 44% Aug- 36% Sep- 50% | 41.7 [12] | 195.3 [15] | 671.6 [18] | 933.6 [9] | 838.6 [11] | 800.8 [8] | 1117 [2] |
| Sacred Heart Creek – MN River 07020004-615 S004-691 | 68-1120 | - | - | - | 177.4 [5] | 406.6 [5] | 410.6 [5] | - | - |
| Sacred Heart Creek – MN River 07020004-617 S004-694 | 68-2420 | Aug- 20% | - | - | 160.3 [5] | 310.2 [5] | 473.9 [5] | - | - |

| Aggregated HUC12 Subwatershed Stream Reach AUID # EQuIS Station ID | Range of Data (org/mL) | % of samples exceeding 1260 org/100mL | Geometric Mean (org/mL) [# of samples] | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Apr | May | June | July | Aug | Sep | Oct |
| Stony Run Creek – MN River 07020004-534 S002-136 | 5-4800 | June- 31% July- 13% | 35.6 [11] | 149.6 [13] | 622.7 [16] | 265.8 [8] | 274.2 [11] | 263.7 [8] | 1359 [2] |
| West Fork Beaver Creek 07020004-530 S006-138 | 6-6100 | June- 28% July- 18% Aug- 28% Sep- 41% Oct- 14% | 51.7 [27] | 143.6 [26] | 627.2 [29] | 675.6 [17] | 861.5 [18] | 954.1 [17] | 551.2 [7] |
| Wood Lake Creek – MN River 07020004-648 S003-866 | 1-2420 | June- 17% Sep- 25% | 19.9 [12] | 65.4 [17] | 418.6 [16.7] | 625.3 [6] | 399.4 [5] | 367.3 [4] | - |

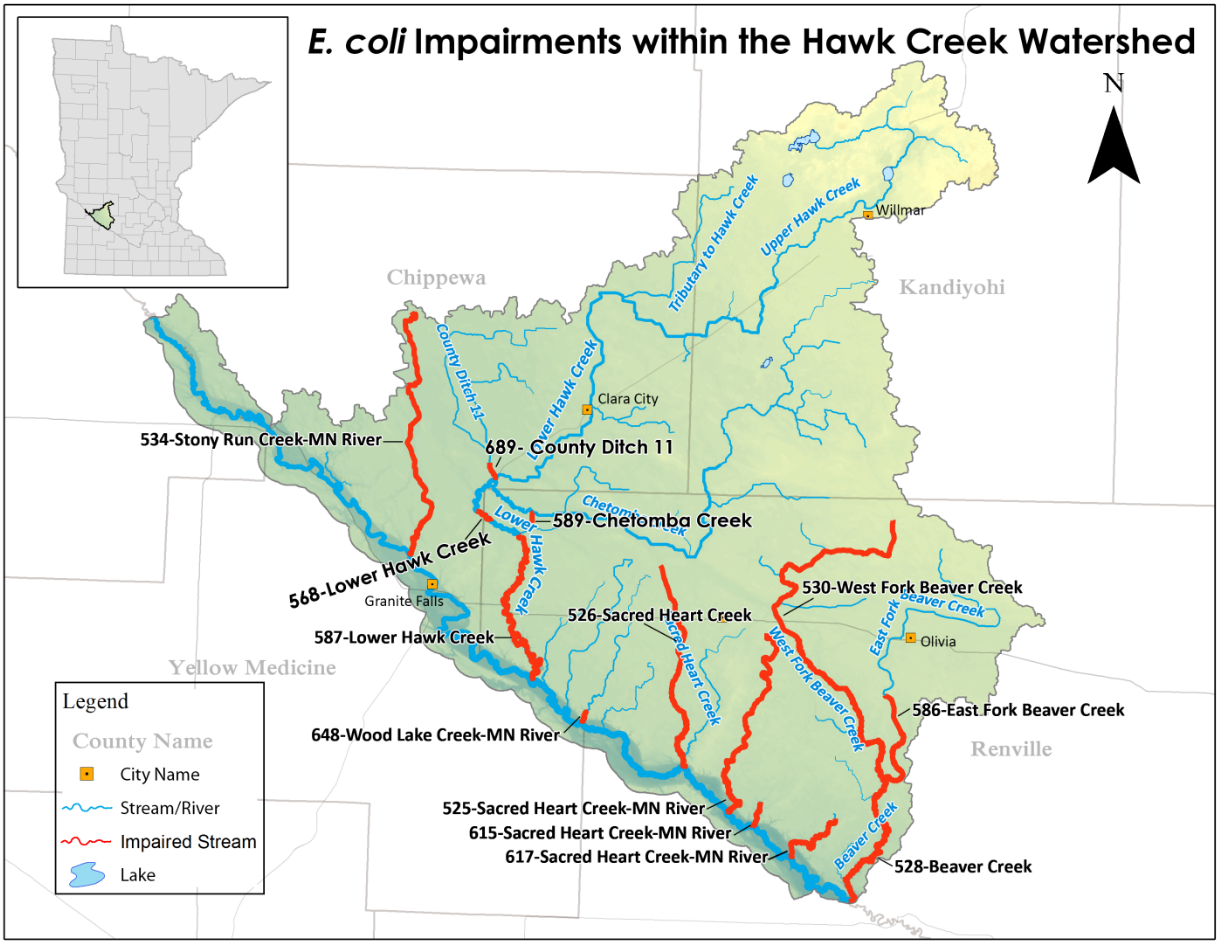



**Figure 3.2: *E. coli* stream reach impairments**

### 3.5.2 Turbidity

TSS data has been collected for multiple years in the Hawk Creek 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 Subwatershed<br>Stream Reach<br>AUID #<br>Station ID | Range of data (mg/L) | % of Monthly samples >65 mg/L [# of samples] | | | | | | % of Total Samples >65/L [# of samples] |
|---|---|---|---|---|---|---|---|---|
| | | Apr | May | Jun | Jul | Aug | Sep | |
| Beaver Creek<br>07020004-528<br>S000-666 | 2 - 793 | 21% [61] | 19% [69] | 56% [61] | 13% [47] | 25% [12] | 23% [44] | 23% [341] |

| Aggregated HUC12 Subwatershed<br>Stream Reach<br>AUID #<br>Station ID | Range of data (mg/L) | % of Monthly samples >65 mg/L [# of samples] | | | | | | % of Total Samples >65/L<br>[# of samples] |
|---|---|---|---|---|---|---|---|---|
| | | Apr | May | Jun | Jul | Aug | Sep | |
| Chetomba Creek<br>07020004-589<br>S002-152 | 1 - 748 | 11% [61] | 9.5% [63] | 67% [21] | 13% [31] | 10% [20] | 25% [20] | 12% [318] |
| Lower Hawk Creek<br>07020004-568<br>S002-148 | 2 - 644 | 20% [60] | 21% [63] | 41% [97] | 33% [43] | 21% [39] | 15% [39] | 30% [313] |
| West Fork Beaver Creek<br>07020004-530<br>S006-138<br>S000-405 | 4 - 355 | 2% [60] | 9.5% [63] | 23% [70] | 20% [41] | 22% [45] | 23% [30] | 16% [297] |
| Lower Hawk Creek<br>07020004-587<br>S002-012 | 3 - 680 | 65% [26] | 25% [61] | 49% [73] | 23% [44] | 11% [45] | 19% [42] | 28% [322] |

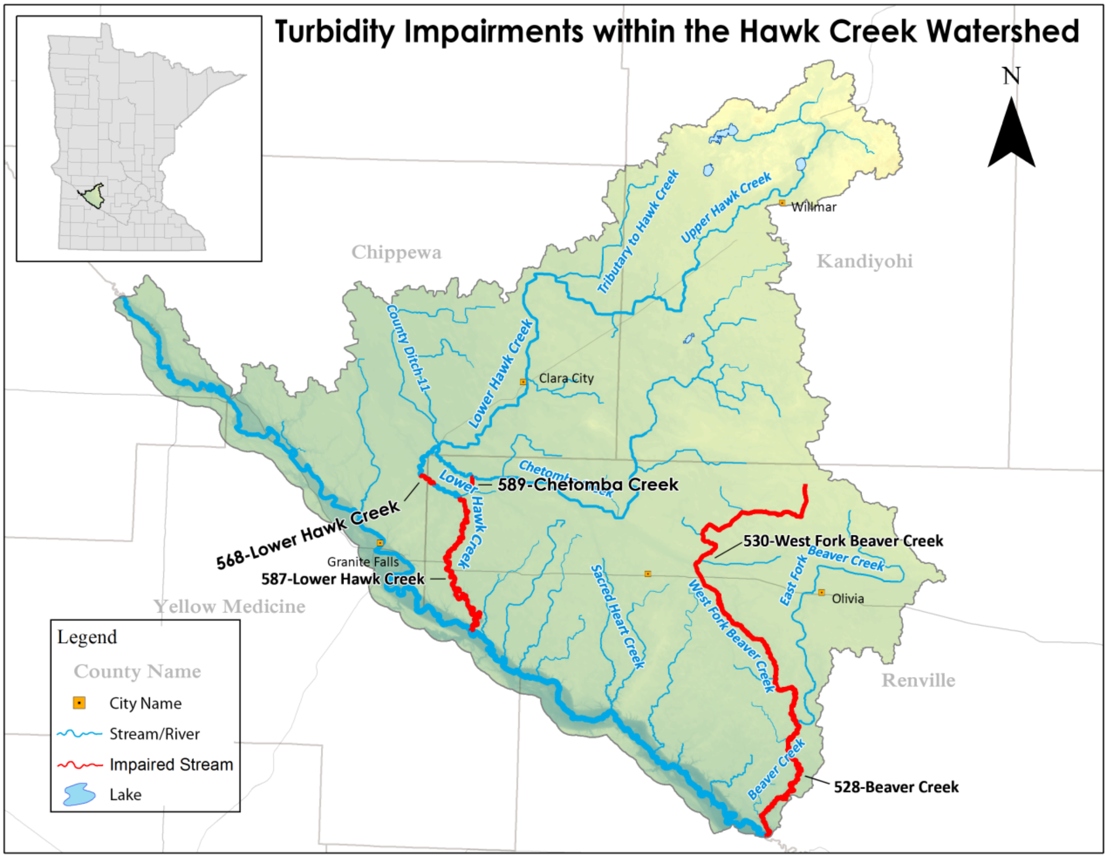



Figure 3.3: Turbidity (TSS) stream reach impairments

### 3.5.3 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.

Table 3.6: Summary of 2010-2011 June through September sampling for impaired lakes in the Hawk Creek Watershed. Mean value is listed in bold and the number of samples taken are listed in brackets

| Aggregated HUC12 Subwatershed | Lake Name DNR # | Average Total Phosphorus (µg/L) | Average Chlorophyll-a (µg/L) | Average Secchi Disk Transparency (m) |
|---|---|---|---|---|
| Chetomba Creek | Olson Lake 34-0266-00 | **121** [12] | **54** [11] | **0.4** [5] |
| Tributary to Hawk Creek | St. John's Lake 34-0283-00 | **155** [11] | **60** [9] | **1** [27] |
| | West Solomon Lake 34-0245-00 | **113** [12] | **45** [10] | **0.5** [31] |
| Upper Hawk Creek | Swan Lake 34-0186-00 | **111** [17] | **27.1** [16] | **0.4** [25] |

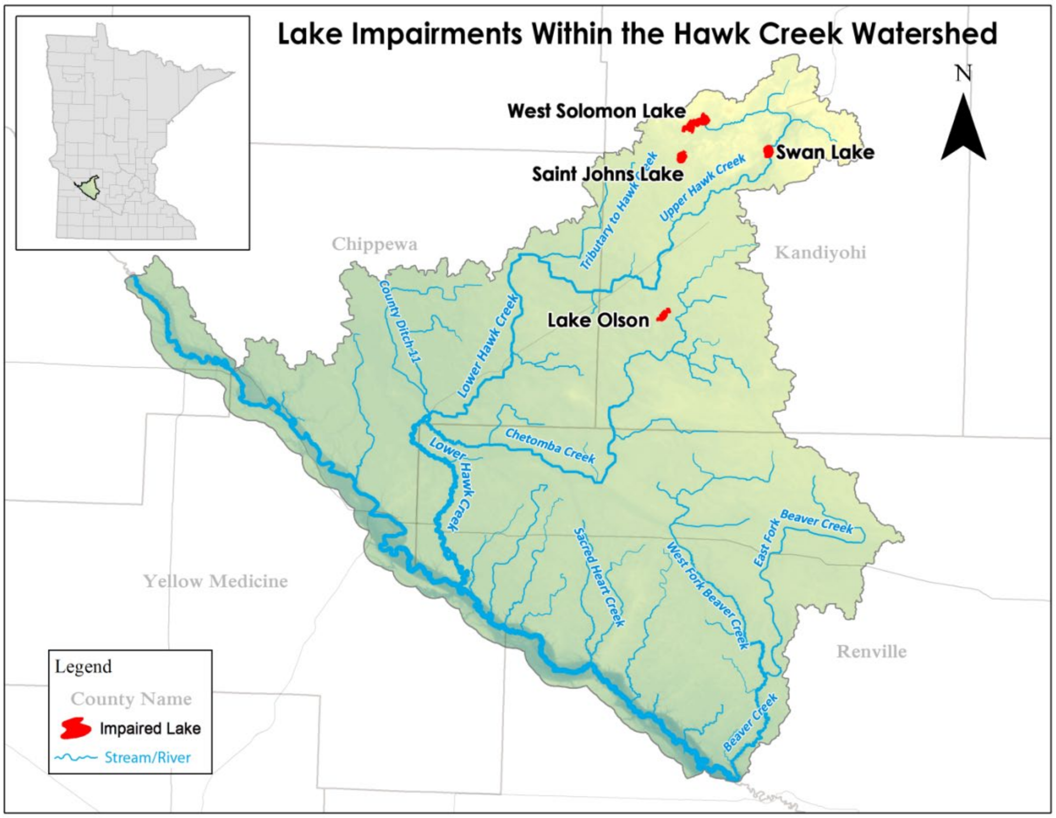



Figure 3.4: Lake nutrient eutrophication impairments as indicated from water monitoring data

## 3.6 Pollutant Source Summary

### 3.6.1 *E. coli*

Likely sources of bacteria in the Hawk Creek 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.

**Feedlot Facilities** –Feedlot facilities are present in the Hawk Creek Watershed. Livestock can contribute bacteria to the watershed through runoff from these feedlot facilities. Facility and livestock numbers by subwatershed, based on the MPCA record of registered feedlot facilities, are listed in the table below. These numbers include both county permitted and NPDES permitted feedlot facilities, both of which are not allowed to discharge animal waste into surface waters. The majority of the feedlots in the watershed are less than 500 animal units. Seventy percent of the feedlots are under 300 animal units (AU) (268 facilities). These sites generally have limited manure storage so manure application occurs on a more frequent basis. In addition, these sites are not required to have a manure management plan or test their soils for phosphorus. One hundred fifty-six of these sites are under 100 AU, which have even less restrictions under feedlot rules. In the Hawk Creek Watershed, there are approximately 28 feedlots located within 1000 feet of a lake or 300 feet of a stream or river, an area generally defined as shoreland. Twenty-six 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. One of the feedlots located within shoreland is operating under an Open Lot Agreement (OLA) with the MPCA.

These feedlot OLA 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. Manure from these feedlots is applied as fertilizer to agricultural fields and is discussed below.

Of the approximately of 383 feedlots in the Hawk Creek Watershed, there are 51 active NPDES permitted operations, 50 of which are classified as Concentrated Animal Feeding Operation (CAFOs). CAFO is an EPA definition that implies not only a certain number of animals but also specific animal types, e.g. 2500 swine is a CAFO, 1000 cattle are a CAFO, but a site with 2499 swine and 999 cattle is not a CAFO according to the EPA definition. The MPCA currently uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the term AU. In Minnesota, the following types of livestock facilities are issued, and must operate under, a NPDES Permit or a state issued State Disposal System (SDS) Permit: a) all federally defined CAFOs that have had a discharge, some of which are under 1000 AUs in size; and b) all CAFOs and non-CAFOs that have 1000 or more AUs. These feedlots must be designed to totally contain runoff, and manure management planning requirements are more stringent than for smaller feedlots. CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. All CAFOs (NPDES permitted, SDS permitted and not required to be permitted) are inspected by MPCA on a routine basis with an appropriate mix of field inspections, offsite monitoring and compliance assistance. Facility and livestock numbers by HUC12 subwatersheds, based on the MPCA record of registered feedlot facilities, are listed in the table below. These numbers include both county registered and NPDES or SDS permitted feedlot facilities.

**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 Hawk Creek Watershed with Direct Tributaries | 438 | Birds, Bovines, Deer/Elk, Goats/Sheep, Horses, Llamas/Alpacas, Pigs, Other | 145,729 |
| Beaver Creek | 17 | Birds, Bovines, Pigs | 2,405 |
| Chetomba Creek | 16 | Birds, Bovines, Goats/Sheep, Deer/Elk, Horses, Pigs, | 31,540 |
| County Ditch 11 | 18 | Birds, Bovines, Goats/Sheep, Horses, Pigs | 7,752 |
| East Fork Beaver Creek | 21 | Bovines, Goats/Sheep, Pigs | 6,608 |
| Lower Hawk Creek | 24 | Birds, Bovines, Goats/Sheep, Horses, Llamas/Alpacas, Pigs | 8,605 |
| Sacred Heart Creek | 22 | Birds, Bovines, Horses, Goats/Sheep, Pigs | 17,112 |
| Sacred Heart Creek – MN River | 40 | Birds, Bovines, Goats/Sheep, Horses, Pigs | 11,894 |
| Stony Run Creek – MN River | 12 | Bovines, Horses, Pigs | 1,428 |
| Tributary to Hawk Creek | 39 | Birds, Bovines, Goats/Sheep, Horses, Pigs | 23,260 |

| Aggregated HUC12 Subwatershed | # of Feedlot Facilities | Livestock Type | Animal Units |
|---|---|---|---|
| Upper Hawk Creek | 67 | Birds, Bovines, Goats/Sheep, Horses, Pigs | 16,413 |
| West Fork Beaver Creek | 51 | Birds, Bovines, Goats/Sheep, Horses, Pigs | 16,855 |
| Wood Lake Creek - MN River | 21 | Bovines, Horses, Pigs | 1,857 |

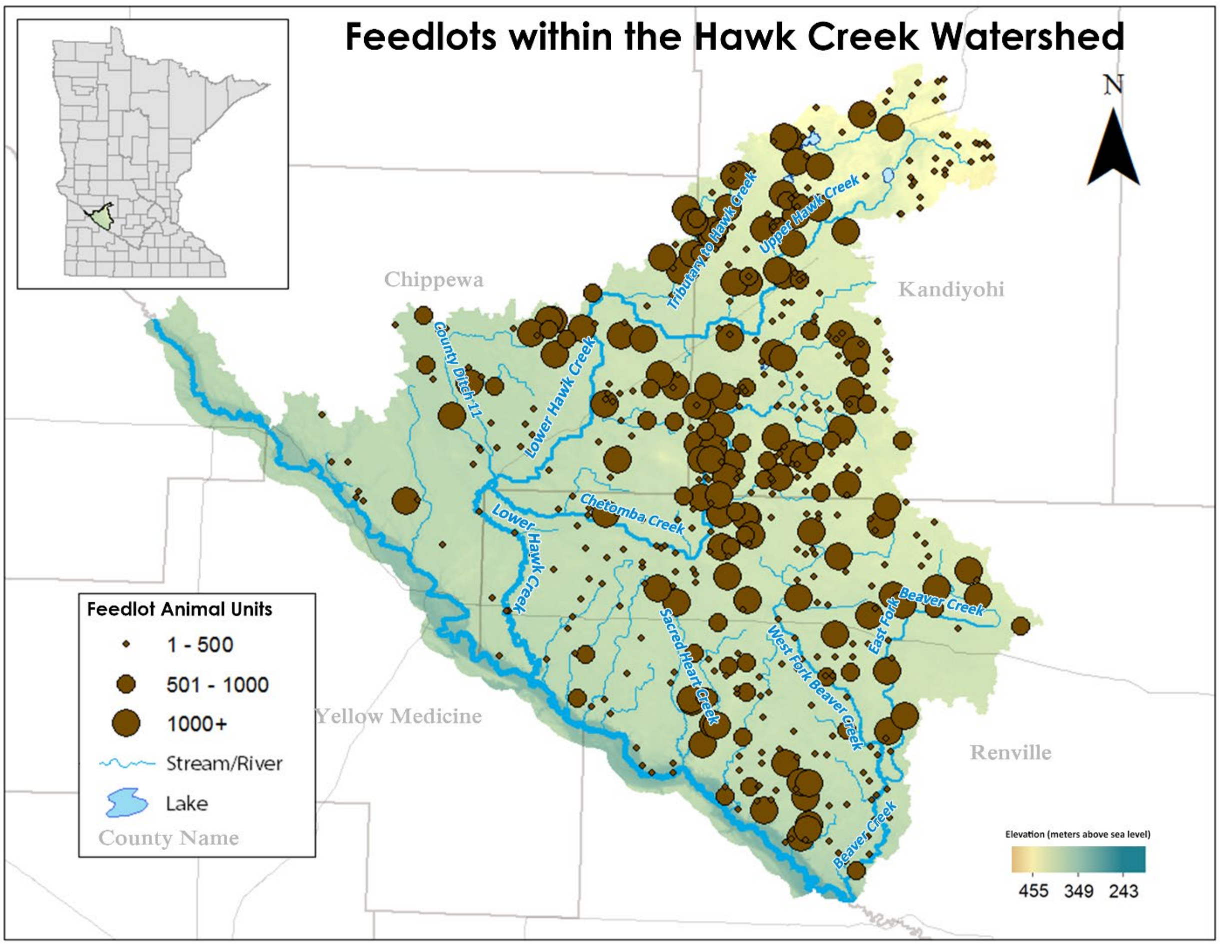



**Figure 3.5: Feedlot facility locations**

**Wastewater Treatment Facilities (WWTF)** – Human waste can be a significant source of *E. coli* during low flow periods. Twelve WWTFs discharge into the impaired stream reaches addressed in this TMDL report. These WWTFs are both controlled discharge pond systems and mechanical continuous discharge systems. There are six controlled discharge systems, which are allowed to discharge during higher flows. WWTF NPDES Permits include fecal coliform effluent limitations that require effective disinfection during the *E. coli* standard's effective period. These controlled discharge facilities are not likely to be a source during low flow periods. There are also six continuous discharge systems, which constantly release treated wastewater. WWTF NPDES Permits include fecal coliform effluent limitations, which require effective disinfection during the *E. coli* standard's effective period. 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 Hawk Creek Watershed range from 35% to 75% non-compliant. Some of these systems 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. Based on MPCA feedlot staff analysis of feedlot demographics, local knowledge and actual observation, 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. Contributing to the feedlot staff knowledge are two surveys, conducted by the Minnesota Department of Agriculture (MDA) 2010 Commercial Nitrogen and Manure Selection and Management Practices on Corn and Wheat in Minnesota (http://www.mda.state.mn.us/protecting/cleanwaterfund/gwdwprotection/~/media/Files/protecting/cwf/2010cornnitromgmt.pdf) and Commercial Nitrogen and Manure Fertilizer Section and Management Practices Associated with Minnesota's 2012 Corn Crop (https://www.mda.state.mn.us/sitecore/shell/Controls/Rich%20Text%20Editor/~/media/Files/protecting/cwf/2012nitrocorn.pdf ). While the results are not reported by specific watershed and only by general geographic area, they provide very similar information as used in the TMDL and WRAPS process.

Short-term stockpile sites are defined in Minn. R. 7020, and are considered temporary; any stockpile kept for longer than a year must be registered with the MPCA and would be identified as part of a feedlot facility. Because of the temporary status of the short-term stockpile sites, and the fact they are usually very near or at the land application area they are included in with the land applied manure.

**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 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 (Chandrasekaran et al. 2015). 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, a small percentage of *E. coli* may be present in the water from these sources.

### 3.6.2 Turbidity (TSS)

Likely sources of turbidity (TSS) in the Hawk Creek Watershed include atmospheric deposition, WWTFs, overland erosion from land practices, and hydrologic changes within the watershed. These are described in more detail below.

**Atmospheric Deposition**– Windblown sediment is likely a source of TSS in surface waters in the Hawk Creek Watershed. Dust from industrial and construction sites, bare soils, and developed areas can all contribute TSS to surface waters.

**Wastewater Treatment Facilities (WWTF)** – Human waste can be a source of TSS. Eleven WWTFs discharge into the impaired stream reaches addressed in this TMDL report. These WWTFs are both controlled discharge pond systems and mechanical continuous discharge systems. There are six controlled discharge systems, which are allowed to discharge during higher flows. These controlled discharge facilities are not likely to be a source during low flow periods. There are also five continuous discharge systems, which constantly release treated wastewater. WWTF NPDES Permit effluent limits are established at levels that ensure that discharges do not contribute to exceedances of the TSS water quality standard. 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 accelerated 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 other reasons, such as construction, mining, or insufficiently vegetated pastures.

**Hydrologic Changes** – Hydrological changes in the landscape can all lead to increased turbidity (TSS) in surface waters. Subsurface drainage tiling, channelization of waterways, riparian land cover alteration, and increases in impervious surfaces all decrease detention time and increase flows. 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 the land at a higher velocity and in a shorter amount of time. The straightening and ditching of natural rivers, for both agricultural drainage or diversions around cities, increases the slope of the original watercourse and moves water off of the land at a higher velocity in a shorter amount of time. These 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). Figure 3.6 shows the altered hydrology within the

Hawk Creek Watershed. Velocity changes associated with unpermitted 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 are modeled by shallow groundwater/interflow arriving at the receiving waterbody sooner than deeper groundwater/baseflow.

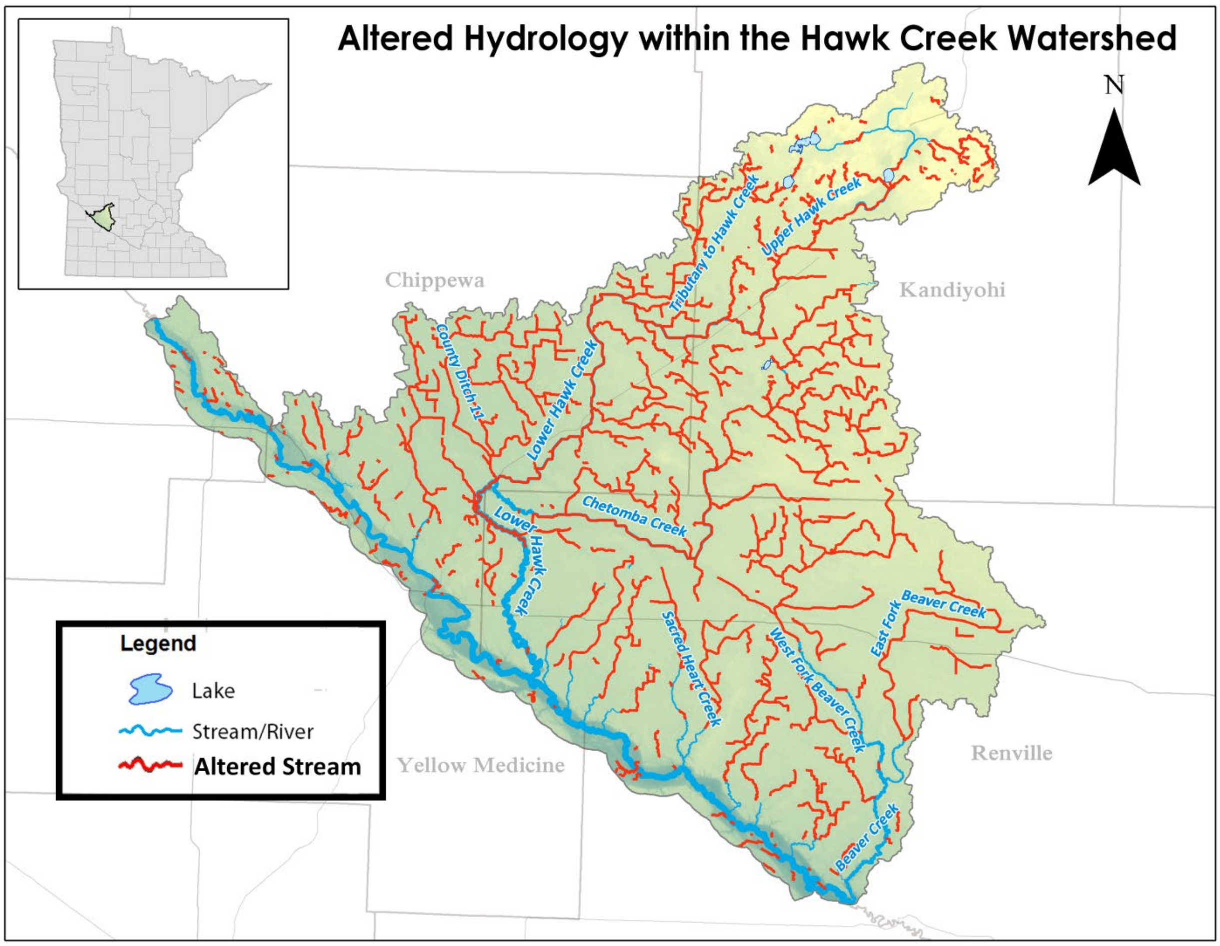



Figure 3.6: Altered hydrology of Hawk Creek Watershed

### 3.6.3 Nutrient Eutrophication

Phosphorus source categories, as well as runoff and phosphorus loads, were extracted from the Hawk Creek Watershed HSPF model. Likely sources of phosphorus in surface water of the Hawk Creek Watershed include atmospheric load, SSTS, manure application on agricultural fields, upland erosion, fertilizer application, streambank 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.

**Atmospheric Load** – Direct atmospheric deposition to the surface of the lakes was based on regional values (MPCA 2004). 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. County estimates range from 35% to 75% non-compliance. Phosphorus loads from septics 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 into 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 (%) |
|---|---|---|
| Olson Lake | 1.94 | 2 |
| St. John's Lake | 5.95 | 1.2 |
| West Solomon Lake | 20.5 | 1 |
| Swan Lake | 4.2 | 1 |

**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. Eroded soils can carry attached phosphorus to waterbodies.

**Fertilizer and Manure Application** – During precipitation events, runoff from fields can contain nutrients from applied fertilizer or manure. Due to overland flow runoff makes its way into open tile intakes, through a network of drainage tile, and eventually into surface waters. There is a significant amount of late winter solid manure application (before the ground thaws). High intensity precipitation often occurs during the spring, which can cause erosion of both the soil, fertilizer, and manure. During this time the runoff can be a source of phosphorus in lakes.

**Streambank 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. 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 0.29 (Olson Lake) – 2.45 (Saint John's 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 Hawk Creek Watershed 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 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 Hawk Creek 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. | 3.4 – 10.6 | < 1 – 1 |
| Cropland (Conventional and Conservation Tillage) | Runoff from agricultural lands can include applied manure, fertilizers, soil particles and organic material from agronomic crops. | 28 – 67.8 | 46 – 85 |
| Grassland/Pasture | Surface runoff can deliver phosphorus from vegetation, livestock and wildlife waste, and soil loss. | 3.7 – 21.7 | < 1 – 3.1 |
| 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. | 3.8 – 22.2 | 2.7 – 16.7 |
| Wetlands/ Open Water | Wetlands and open water can export phosphorus through suspended solids as well as organic debris that flow through waterways. | 1 – 47 | < 1 – 4.8 |

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

### Point Sources

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:

$$TMDL = LC = \sum WLA + \sum LA + MOS + RC$$

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 Hawk Creek Watershed impairments addressed in this TMDL, 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 Hydrological Simulation Program – FORTRAN (HSPF)

The HSPF model was used to simulate dissolved oxygen and flows from 1996-2012 in the Hawk Creek 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 land surfaces, runoff and constituent loading from 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 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 TMDL (Tables 4.12 through 4.14), 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 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 load capacity (LC). For example, for the “very high flow” zone, the LC is based on the flow value at the fifth 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 | $ft^3$ | à | ml | $ft^3$ | ml/sec |
| 3 | Multiply by # organisms<br>(Standard set at 126 MPN/100ml) | | | | = | organisms/sec |
| 4 | Divide by 100 ml | | | | | |
| 5 | Multiply by 60 sec/min to convert | seconds | à | minutes | = | organisms/min |
| 6 | Multiply by 60 min/hr to convert | minutes | à | hours | = | organisms/hour |
| 7 | Multiply by 24 hours/day to convert | hours | à | days | = | organisms/day |
| 8 | Divide by 1 Billion to convert | organisms | à | billion organisms | = | billion organisms/day |

Table 4.14 shows LCs and allocations 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 if the concentration of the water was exactly at 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 |
|---|---|---|---|
| Beaver Creek 07020004-528 | 566,069 [151] | 79,181 | 86% |
| Chetomba Creek 07020004-589 | 474,325 [150] | 70,545 | 85% |
| County Ditch 11 07020004-689 | 6,104 [15] | 1,139 | 81% |
| East Fork Beaver Creek 07020004-586 | 4,997 [15] | 2,073 | 59% |
| Lower Hawk Creek 07020004-568 | 892,868 [147] | 147,489 | 83% |
| Lower Hawk Creek 07020004-587 | 1,573,383 [150] | 242,189 | 85% |
| Sacred Heart Creek 07020004-526 | 13,967 [75] | 2,691 | 81% |
| Sacred Heart Creek – MN River 07020004-525 | 19,041 [75] | 2,956 | 85% |
| Sacred Heart Creek – MN River 07020004-615 | 761,780 [15] | 230,452 | 70% |
| Sacred Heart Creek – MN River 07020004-617 | 665,948 [15] | 264,200 | 60% |
| Stony Run Creek – MN River 07020004-534 | 33,061 [69] | 4,790 | 86% |
| West Fork Beaver Creek 07020004-530 | 242,765 [141] | 43,656 | 82% |

| Aggregated HUC12 Subwatershed<br>Stream Reach AUID # | Observed Load<br>(billion org)<br>[# of samples] | Load Set at 126 org /100mL Standard<br>(billion org) | Estimated Reduction Needed To Get<br>< 126 org/100 mL |
|---|---|---|---|
| Wood Lake Creek – MN River<br>07020004-648 | 13,051<br>[62] | 2,374 | 82% |

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 (TSS) impairments. For reasons explained in Section 2, the current southern streams region 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 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 0.01 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 $5^{th}$ 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 Appendix B.

**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 | $ft^3$ | à | ml | = | ml/sec |
| 3 | Multiply by # mg<br>(Standard set at 65 mg/L) | | | | = | mg/sec |
| 4 | Divide by 1000 ml | | | | | |
| 5 | Divide by 453,592 mg/lb to convert | mg | à | lbs | = | lbs/sec |
| 6 | Multiply by 60 sec/min to convert | seconds | à | minutes | = | lbs/min |
| 7 | Multiply by 60 min/hr to convert | minutes | à | hours | = | lbs/hour |
| 8 | Multiply by 24 hours/day to convert | hours | à | days | = | lbs/day |

| Load (tons/day) = Concentration (mg/1000mL) * Flow (cfs) * Factor | | | | | | |
|---|---|---|---|---|---|---|
| 9 | Divide by 2000 lbs/ton to convert | lbs | à | tons | = | tons/day |

Table 4.15 shows LCs and allocations 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 the Appendix.

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 if 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 |
|---|---|---|---|
| Beaver Creek 07020004-528 | 19,015 [341] | 9,972 | 48% |
| Chetomba Creek 07020004-589 | 13,938 [341] | 9,134 | 35% |
| Lower Hawk Creek 07020004-568 | 25,384 [339] | 17,514 | 31% |
| Lower Hawk Creek 07020004-587 | 66,683 [353] | 29,288 | 56% |

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 Hawk Creek 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. Flow data from 1996 through 2012 generated by the HSPF model was used to populate the BATHTUB models. For more detail on the Hawk Creek sources of model data, refer to the *Granite Falls – Minnesota River Watershed Monitoring and Assessment Report* (MPCA 2012d).

BATHTUB's Canfield Bachmann lake model was used to estimate loads to the impaired lakes. 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 Hawk Creek Watershed, lakes required additional internal loading (0.29 – 2.45 $mg*m^{-2}*day^{-1}$) 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 Hawk Creek 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 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 to 6 in

Table 4.5). This was achieved by reducing TP 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 TP 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 until the water quality standard was achieved. Using the modeled annual loads and the annual load capacities, the load reductions were calculated (Column 8 in Table 4.5).

**Table 4.5: Observed and modeled mean phosphorus conditions in Hawk Creek Watershed lakes; phosphorus load reduction necessary to meet the water quality standard**

| Lake Name<br>DNR Lake # | Observed Average TP (µg/L) | Modeled TP (µg/L) | TP Standard (µg/L) | Modeled Annual TP Load (lbs/yr) | Additional Annual Internal TP Load (lbs/yr) | Modeled Annual TP Load Capacity (lbs/yr) | Load Reduction to Achieve TP Standard |
|---|---|---|---|---|---|---|---|
| **Olson Lake 41-0034-00** | **121** | **121** | **90** | **214.7** | **116.8** | **132.1** | **38%** |
| **St. John's Lake 34-0283-00** | **155** | **155** | **90** | **2,587** | **1,538.8** | **1,287** | **50%** |
| **West Solomon Lake 34-0245-00** | **113** | **113** | **90** | **3,805** | **1,498.9** | **2,708.2** | **29%** |
| **Swan Lake 31-0171-00** | **111** | **111** | **90** | **2,240.1** | **735.2** | **1,739** | **22%** |

# 4.3 Wasteload Allocation Methodology

The WLAs are determined for a facility's operating permit (wastewater), or calculated in accordance with EPA guidance (EPA 2002) and presented as categorical WLAs for non-permitted sources. Categorical WLAs are pollutant loads that are equivalent for multiple permittees (several regulated Municipal Separate Storm Sewer System [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, national or 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 4.6: WWTF permitted facilities applicable to this TMDL

| City WWTF | Permit # | Facility | System Type | Impairment | Stream Reach AUID # |
|---|---|---|---|---|---|
| Bird island | MN0020737 | Municipal WWTP | Controlled Discharge | *E. coli*/Turbidity (TSS) | 07020004-528 |
| | | | | *E. coli* | 07020004-586 |
| Blomkest/Svea | MN0069388 | Municipal WWTP | Controlled Discharge | *E. coli*/Turbidity (TSS) | 07020004-587 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-589 |
| Clara City | MN0023035 | Municipal WWTP | Continuous Discharge | Fecal coliform /Turbidity (TSS) | 07020004-568 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-587 |
| Danube | MNG580057 | Municipal WWTP | Controlled Discharge | *E. coli*/Turbidity (TSS) | 07020004-528 |
| | | | | Fecal coliform /Turbidity (TSS) | 07020004-530 |
| Maynard | MN0056588 | Municipal WWTP | Continuous Discharge | Fecal coliform /Turbidity (TSS) | 07020004-568 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-587 |
| | | | | *E. coli* | 07020004-689 |
| Olivia | MN0020907 | Municipal WWTP | Continuous Discharge | *E. coli*/Turbidity (TSS) | 07020004-528 |
| | | | | *E. coli* | 07020004-586 |
| Pennock | MNG580104 | Municipal WWTP | Controlled Discharge | *E. coli*/Turbidity (TSS) | 07020004-568 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-587 |
| Prinsburg | MN0063932 | Municipal WWTP | Continuous Discharge | *E. coli*/Turbidity (TSS) | 07020004-587 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-589 |
| Raymond | MN0045446 | Municipal WWTP | Controlled Discharge | Fecal coliform /Turbidity (TSS) | 07020004-568 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-587 |
| Renville | MN0020737 | Municipal WWTP | Continuous Discharge | *E. coli* | 07020004-526 |

| City WWTF | Permit # | Facility | System Type | Impairment | Stream Reach AUID # |
|---|---|---|---|---|---|
| Roseland | MN0070092 | Municipal WWTP | Controlled Discharge | *E. coli*/Turbidity (TSS) | 07020004-587 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-589 |
| Willmar | MN0025259 | Municipal WWTP | Continuous Discharge | *E. coli*/Turbidity (TSS) | 07020004-568 |
| | | | | *E. coli*/Turbidity (TSS) | 07020004-587 |

For the *E. coli* impaired stream reaches, controlled discharge WWTF allocations were determined by multiplying the water quality standard 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 | B | C | A*B*C |
|---|---|---|---|---|
| | Permit Limit (org/100 mL) | Max Daily Flow or Max Permitted Discharge Flow (mgd) | Conversion factor | Load (billion org/day) |
| Bird island | 126 | 1.136 | 0.0379 | 5.42 |
| Blomkest/Svea | | 0.450 | | 2.14 |
| Clara City | | 0.46 | | 2.19 |
| Danube | | 0.645 | | 3.08 |
| Maynard | | 0.153 | | 0.73 |
| Olivia | | 0.98 | | 4.67 |
| Pennock | | 0.652 | | 3.11 |
| Prinsburg | | 0.0545 | | 0.26 |
| Raymond | | 1.417 | | 6.76 |
| Renville | | 0.853 | | 4.07 |
| Roseland | | 0.375 | | 1.79 |
| Willmar | | 7.51 | | 35.82 |

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 (TSS) impaired stream reaches, controlled discharge WWTF allocations were determined by multiplying the permit limit of 30 or 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 | B | C | A*B*C |
|---|---|---|---|---|
| | Permit Limit (mg/liter) | Max Daily Flow or Max Permitted Discharge Flow (mgd) | Conversion factor | Load (tons/day) |
| Bird island | 45 | 1.136 | 0.0041722 | 0.21 |
| Blomkest/Svea | 45 | 0.450 | | 0.08 |
| Clara City | 30 | 0.46 | | 0.06 |
| Danube | 45 | 0.645 | | 0.12 |
| Maynard | 30 | 0.153 | | 0.02 |
| Olivia | 30 | 0.98 | | 0.12 |
| Pennock | 45 | 0.652 | | 0.12 |
| Prinsburg | 30 | 0.0545 | | 0.01 |
| Raymond | 45 | 1.417 | | 0.27 |
| Roseland | 45 | 0.375 | | 0.07 |
| Willmar | 30 | 7.51 | | 0.94 |

The flow contribution from each of the WWTF exceeds the LC 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 (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

NPDES/SDS permitted facilities process wastewater from industrial processes. Relevant industrial facilities for impaired stream reaches are shown in Table 4.9. The LA from the Southern Minnesota Beet Sugar Plant WWTF exceeds the LC in several flow zones for stream reach 07020004-587. The discharged 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 (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 a significant contributor of *E. coli* or TSS and actual discharge concentrations are typically well below the standard.

**Table 4.9: Industrial permits applicable to this TMDL**

| Industrial Facility | Permit # | Facility | System Type | Impairment | Stream Reach AUID # |
|---|---|---|---|---|---|
| Southern Minnesota Beet Sugar – SD009 | MN0040665 | Beet Sugar Plant | Periodic/Seasonal Discharge | *E. coli* | 07020004-526 |
| Southern Minnesota Beet Sugar – SD001 | MN0040665 | Beet Sugar Plant | Periodic/Seasonal Discharge | Turbidity (TSS) | 07020004-528 |
| Southern Minnesota Beet Sugar – SD001 | MN0040665 | Beet Sugar Plant | Periodic/Seasonal Discharge | Turbidity (TSS) | 07020004-530 |
| Granite Falls Energy LLC | MN0066800 | Ethanol Plant | Continuous Discharge | Turbidity (TSS) | 07020004-587 |

**Table 4.10: Individual industrial facility *E. coli* WLA**

| Industrial Facility | Permitted Load (billion org/day) |
|---|---|
| Southern Minnesota Beet Sugar – SD009 | 10.78 |

**Table 4.11: Individual industrial facility TSS WLA**

| Industrial Facility | Permitted Load (tons/day) |
|---|---|
| Southern Minnesota Beet Sugar – SD001 | 0.06 |
| Granite Falls Energy LLC | 0.02 |

### 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 stream 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, municipality MS4 Permits, and industrial facilities. The city of Willmar's MS4 impacts two stream reaches impaired for both TSS and bacteria: 07020004-568 and 07020004-587. The upstream reach, 07020004-568, has a drainage area of 206,059 acres. Approximately 9,531 acres of the city of Willmar are within the Hawk Creek Watershed. Of these 9,531 acres, approximately 3,758.24 acres were categorized as developed (MRLC 2011), which is 1.8% of the drainage area of reach 07020004-568. The allocation to this category is made after the MOS is subtracted from the total LC. This 1.8% of the total average daily LC for stream reach 07020004-568 is the more restrictive value and is therefore used for stream reach 07020004-587.

**Table 4.12: Municipal MS4 permits applicable to this TMDL**

| Industrial Facility | Permit # | Type | Impairment | Stream Reach AUID # |
|---|---|---|---|---|
| City of Willmar | MS400272 | Stormwater | TSS/ Fecal coliform | 07020004-568 |
| | | | TSS/ *E. coli* | 07020004-587 |

**Construction and Industrial** – 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

TSS and phosphorus WLAs for stormwater discharges from sites where there is construction activity reflect 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. Bacteria WLAs for regulated construction stormwater (permit #MNR100001) were not developed, since *E. coli* is not a typical pollutant from construction sites. Industrial stormwater receives a WLA only if the pollutant is part of benchmark monitoring for an industrial site in the watershed of an impaired water body. There are no bacteria or *E. coli* benchmarks associated with any of the industrial stormwater permits (permit #MNR050000) in these watersheds and therefore no industrial stormwater *E. coli* WLAs were assigned.

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 handling material. 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. Applicable TSS and phosphorus WLAs for stormwater discharges from sites where there is industrial activity reflect the number of sites in the impaired 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.

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. 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. 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 LC for applicable TSS and Nutrient Eutrophication TMDLs 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** – 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. There are 51 livestock facilities with NPDES permits located within the Hawk Creek Watershed as shown in Table 4.13. 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 4.13: NPDES permitted livestock CAFOs by subwatershed**

| Aggregated HUC12 Subwatershed | Feedlot Permit Number | Feedlot Name | Total Animal Units |
|---|---|---|---|
| Chetomba Creek | MNG440187 | Country Pork Inc | 1440 |
| | MNG440432 | Gorans Bros Inc | 676 |
| | MNG440432 | Gorans Bros Inc | 1152 |
| | MNG440111 | Gorans Bros Inc | 2378 |
| | MNG440432 | Gorans Bros Inc | 100 |
| | MNG440432 | Gorans Bros Inc | 2160 |
| | MNG440535 | Huisinga Farms Inc | 1760 |

| Aggregated HUC12 Subwatershed | Feedlot Permit Number | Feedlot Name | Total Animal Units |
|---|---|---|---|
| | MNG440841 | J&C Swine | 1920 |
| | MNG440191 | Prinsburg Farmers Co-op | 1400 |
| | MNG440889 | Prinsburg Farmers Co-op | 1440 |
| | MNG440893 | Prinsburg Farmers Co-op | 497.5 |
| | MNG440838 | Roger Mulder | 1095 |
| | MNG440744 | Willmar Poultry Co Inc | 500 |
| | MNG440745 | Willmar Poultry Co Inc | 600 |
| County Ditch 11 | MNG441067 | Christensen Farms Midwest LLC | 1344 |
| East Fork Beaver Creek | MNG440418 | Steve Peterson | 1152 |
| | MNG440520 | Teri Kubesh | 1248 |
| Lower Hawk Creek | MNG440782 | Christensen Farms Midwest LLC | 2208 |
| | MNG441055 | JAM Farms Inc | 1253.3 |
| | MNG440840 | Justin Ulferts | 1225 |
| | MNG440784 | Kleene Farms Inc | 750 |
| | MNG440473 | Lone Tree Farm LLC | 1203.8 |
| | MNG440925 | Lone Tree Farm LLC | 1200 |
| | MNG440829 | Riverview LLP | 1176 |
| | MNG440471 | Ruschen Turkey Inc | 820 |
| | MNG440440 | Taatjes Farms Inc | 1200 |
| Sacred Heart Creek | MNG441068 | Christensen Farms Midwest LLC | 1378 |
| | MNG440491 | Clay & Lisa Bryan | 2850 |
| | MNG440750 | Clay & Lisa Bryan | 990 |
| | MNG440484 | Christensen Family LLC | 848 |

| Aggregated HUC12 Subwatershed | Feedlot Permit Number | Feedlot Name | Total Animal Units |
|---|---|---|---|
| | MNG441069 | Christensen Farms Midwest LLC | 1378 |
| | MNG440452 | Country Pork Inc | 1296 |
| | MNG440188 | Country Pork Inc | 1440 |
| | MNG440816 | Kevin Rosendahl | 900 |
| | MNG440192 | Rembrandt Enterprises Inc | 6105.6 |
| | MNG440488 | Rosendahl Feedlots | 1200 |
| Sacred Heart Creek - MN River | MNG440478 | Kevin & Sandra Malecek Farm – Kevin Site | 1440 |
| | MNG440478 | Kevin & Sandra Malecek Farm – Sandra Site | 1152 |
| | MNG440913 | Randall Dolezal Farm | 840 |
| | MNG440474 | The Pullet Connection | 1572 |
| Tributary to Hawk Creek | MNG441065 | Meadow Star Dairy LLP | 8880 |
| | MNG440116 | Willmar Poultry Co Inc | 2250 |
| | MNG440117 | Willmar Poultry Company Diagnostic Labra | 711 |
| Upper Hawk Creek | MNG440595 | Jennie-O Turkey Store Inc | 380 |
| | MNG440112 | Sunnyside Turkeys Inc | 1170 |
| | MNG440743 | Willmar Poultry Co Inc | 625 |
| | MNG440119 | Willmar Poultry Company Diagnostic Labra | 540 |
| West Fork Beaver Creek | MNG440433 | Christensen Farms & Feedlots Inc | 1248 |
| | MNG440524 | Huisinga Farms Inc | 1200 |
| | MNG440483 | Roger D Kingstrom | 2808 |
| | MNG440841 | James Hebrink Farm | 1230 |

### 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 and subtracted from the LC, the remaining pollutant load was allocated to the LA. The LA includes nonpoint pollution sources that are not subject to NPDES Permit requirements, as well as "natural background" sources. "Natural background" is defined in both Minnesota rule and statute: Minn. R. 7050.0150, subp. 4 "Natural causes' means the multiplicity of factors that determine the physical, chemical or biological conditions that would exist in the absence of measurable impacts from human activity or influence." The Clean Water Legacy Act (Minn. Stat. § 114D.10, subd. 10) defines natural background as "characteristics of the water body resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics that affect the physical, chemical or biological conditions in a water body, but does not include measurable and distinguishable pollution that is attributable to human activity or influence."

Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion (Section 3.6) of this study. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, urban stormwater, WWTFs, failing SSTSs and other anthropogenic sources. Separate LAs were not determined for natural background sources in this report due to the factors outlined below, as well as a lack of research or data that would be required to differentiate between nonpoint and natural background sources of the pollutants.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest natural background sources are a major driver of any of the water body impairments and/or affect their ability to meet state water quality standards. For all impairments addressed in this study, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

*E. coli* natural background evaluation

The relationship between bacterial sources and bacterial concentrations found in streams is complex, involving precipitation and flow, temperature, livestock management practices, wildlife activities, survival rates, land use practices, and other environmental factors. Two Minnesota studies described the potential for the presence of "naturalized or indigenous" *E. coli* in watershed soils (Ishii et al. 2006), ditch sediment, and water (Chandrasekaran et al. 2015). Chandrasekaran et al. (2015) conducted DNA fingerprinting of *E. coli* in sediment and water samples from Seven Mile Creek, located in south-central Minnesota. They concluded that roughly 63.5% were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36.5% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. The authors suggested that 36% might be used as a rough indicator of "background" levels of bacteria at this site during the study period but results might not be transferable to other locations without further study. Although the result may not be transferable to other locations, they do suggest the presence of background *E. coli* and a fraction of *E. coli* may be present regardless of the control measures taken by traditional implementation strategies.

TSS natural background evaluation

The MPCA uses the year 1830 as a reference point for measuring the beginning of anthropogenic effects on the TSS loads, based on estimates from Lake Pepin sediment cores. This period is prior to European settlement, which introduced dramatic changes to the landscape. These changes consisted primarily of converting more than 90% of native prairie and wetlands to agriculture through tillage and artificial drainage, along with the introduction of annual row crops. From the Lake Pepin core samples an estimation for "natural background" of TSS was established for each of the river basins (Upper Mississippi, Minnesota, St. Croix and Cannon) that drain to Lake Pepin during the development of the South Metro Mississippi River TSSs TMDL (MPCA 2015). However, the method used to develop these "natural background" loads for each basin does not allow them to be extrapolated into the watersheds located in each basin. Because of the way sediment moves in the stream and the unknown river flows and stream dynamic of the Minnesota River in 1830, attempting to allocate a portion of the Minnesota River "natural background" load to the Hawk Creek Watershed will lead to a potential margin of error that in itself may be more than the estimated allocation.

The decision not to include all forms of erosion as natural background can be summed up as Schottler explains, the land form that creates the potential for high erosion rates is natural, but today's high rates of erosion and sediment concentration are not natural:

*"Because of geologic history, non-field sources such as bluffs and large ravines are natural and prevalent features in some watersheds. Consequently these watersheds are predisposed to high erosion rates. However, it would be highly inaccurate to label this phenomenon as natural. Post-settlement increases in sediment accumulation rates in Lake Pepin, the Redwood Reservoir…and numerous lakes in agricultural watersheds … clearly show that rates of sediment erosion have increased substantially over the past 150 years. Coupling these observations with the non-field sediment yields determined in this study, demonstrates that the rate of non-field erosion must also have increased. The features and potential for non-field erosion may be natural, but the rate is not."* (Schottler et al. 2010, Page 32)

Nutrient Eutrophication natural background evaluation

The TMDL does not attempt to quantify the natural background load as a separate component of the LA for the impaired lakes. Natural background load is likely a very small part of the LA for lakes in the Hawk Creek Watershed. Studies indicate runoff load of nutrients and other pollutants from urban, agricultural and other developed or disturbed lands is generally at least an order of magnitude greater than runoff loads from natural landscapes (Barr Engineering 2004). Any estimate of natural background as a separate component of the LA would be very difficult to derive and would have a large potential for error without expensive, special studies such as paleolimnological analysis of sediment cores. Given the highly altered landscape in which the Hawk Creek lakes are located, it is unlikely natural background is a major component of phosphorus loading.

## 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. Appendix C shows the hydrologic calibration and validation for the Hawk Creek/Yellow Medicine HSPF model. The calibration report indicates that the HSPF model estimated storm flow values and the observed flow values for all impaired stream reaches are within the explicit

10% MOS (+/- 10%). The MPCA believes that the model is an accurate representation of the hydrologic conditions present within the watershed and that the MOS is adequate to account for the models uncertainty and variability. The use of an explicit MOS accounted for environmental variability in pollutant loading, variability in water quality data (i.e., collected water quality monitoring data), calibration and validation processes of modeling efforts, uncertainty in modeling outputs, and conservative assumptions made during the modeling efforts.

### 4.5.1 *E. coli*

The Hawk Creek Watershed HSPF model was calibrated and validated using 17 years (1996 through 2012) of flow data from flow stations S002-12 at the Hawk Creek outlet, S002-140 near Priam, S002-148 at Maynard, S002-152 in Chetomba Creek, S000-666 in Beaver Creek at Beaver Falls, and S000-405 in the West Fork Beaver Creek, 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. See Appendix C of this TMDL for the HSPF model calibration and validation results. The *E. coli* Load Duration Curves were developed using HSPF modeled daily flow data from April through October. 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 Hawk Creek Watershed HSPF model was calibrated and validated using 17 years (1996 through 2012) of flow data from flow stations S002-12 at the Hawk Creek outlet, S002-140 near Priam, S002-148 at Maynard, S002-152 in Chetomba Creek, S000-666 in Beaver Creek at Beaver Falls, and S000-405 in the West Fork Beaver Creek, 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 TMDL for the HSPF model calibration and validation results. The TSS stream Load Duration Curves were developed using HSPF modeled daily flow data from April through September. 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 Hawk Creek Watershed HSPF model was calibrated and validated using 17 years (1996 through 2012) of flow data from flow stations S002-12 at the Hawk Creek outlet, S002-140 near Priam, S002-148 at Maynard, S002-152 in Chetomba Creek, S000-666 in Beaver Creek at Beaver Falls, and S000-405 in the West Fork Beaver Creek, and 11 years (1999 through 2009) of water chemistry data. 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 TMDL 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 data 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 TP 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, 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.

## 4.6 Seasonal Variation

### 4.6.1 Streams, *E. coli*

Concentrations of *E. coli* vary throughout the summer in the Hawk Creek Watershed. The standard is based on a monthly geometric mean and must be met for the months of 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 duration curve approach was developed using April through October 1996 through 2012, daily average flow data provided by the Hawk Creek Watershed HSPF model. The applicable time period of the standard will provide sufficient water quality protection during the critical summer period.

### 4.6.2 Streams, Turbidity (TSS)

TSS data was collected in the Hawk Creek Watershed. Elevated TSS is prevalent throughout much of the year in all of the streams. There are likely differing sources contributing to TSS in different parts of the watershed and in different years. The duration curve approach was developed using April through September 1996 through 2012 daily average flow data provided by the Hawk Creek Watershed HSPF model. The allocations generated from the duration curve approach will provide sufficient water quality protection throughout the applicable time period.

### 4.6.3 Lakes, Nutrient Eutrophication

Water quality monitoring in Olson, St. John's, West Solomon, and Swan 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 also 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 4.14: *E. coli* loading capacities and allocations for stream reaches**

| ***E. coli*** | | | | | |
|---|---|---|---|---|---|
| **Beaver Creek<br>East Fork Beaver Creek to Minnesota River<br>AUID # 07020004-528** | **MID-POINT OF FLOW ZONE** | | | | |
| | **Very High** | **High** | **Mid** | **Low** | **Very Low** |
| | **Billion organisms per day** | | | | |
| **Average Daily Loading Capacity** | **949.4** | **237.2** | **79.4** | **17.1** | **0.03** |
| **Margin of Safety** | **95** | **23.7** | **8** | **1.7** | **0.003** |

| *E. coli* | | | | | | |
|---|---|---|---|---|---|---|
| **Wasteload Allocation** | | | | | | |
| Wastewater Treatment Facilities | Bird Island | 1.1136 | 1.1136 | 1.1136 | 1.1136 | ** |
| | Danube | 0.645 | 0.645 | 0.645 | 0.645 | ** |
| | Olivia | 0.98 | 0.98 | 0.98 | 0.98 | ** |
| Communities Subject to MS4 NPDES Requirements | | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| **Load Allocation** | | 851.6614 | 210.7614 | 68.6614 | 12.6614 | # |

| Chetomba Creek<br>Chetomba Creek to Spring Creek<br>AUID # 07020004-589 | MID-POINT OF FLOW ZONE | | | | | |
|---|---|---|---|---|---|---|
| | | Very High | High | Mid | Low | Very Low |
| | | Billion organisms per day | | | | |
| Average Daily Loading Capacity | | 962.1 | 190.1 | 56 | 11.8 | 0.03 |
| Margin of Safety | | 96.2 | 19 | 5.6 | 1.2 | 0.003 |
| **Wasteload Allocation** | | | | | | |
| Wastewater Treatment Facilities | Blomkest/Svea | 2.14 | 2.14 | 2.14 | 2.14 | ** |
| | Prinsburg | 0.26 | 0.26 | 0.26 | 0.26 | ** |
| | Roseland | 1.79 | 1.79 | 1.79 | 1.79 | ** |
| Communities Subject to MS4 NPDES Requirements | | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| **Load Allocation** | | 861.71 | 166.91 | 46.21 | 6.41 | # |

| County Ditch 11<br>Unnamed Ditch to Hawk Creek<br>AUID # 07020004-689 | MID-POINT OF FLOW ZONE | | | | |
|---|---|---|---|---|---|
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 109 | 23.1 | 4.5 | 1 | 0.03 |
| Margin of Safety | 10.9 | 2.3 | 0.5 | 0.1 | 0.003 |
| **Wasteload Allocation** | | | | | |
| Maynard Wastewater Treatment Facility | 0.73 | 0.73 | 0.73 | 0.73 | ** |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |

| *E. coli* | | | | | | |
|---|---|---|---|---|---|---|
| Load Allocation | | 97.37 | 20.07 | 3.27 | 0.17 | # |
| East Fork Beaver Creek<br>T115 R35W S35, north line to W Fk Beaver Creek<br>AUID # 07020004-586 | | MID-POINT OF FLOW ZONE | | | | |
| | | Very High | High | Mid | Low | Very Low |
| | | Billion organisms per day | | | | |
| Average Daily Loading Capacity | | 259.9 | 95.8 | 35.3 | 10.4 | 0.6 |
| Margin of Safety | | 26 | 9.6 | 3.5 | 1 | 0.06 |
| Wasteload Allocation | | | | | | |
| Wastewater Treatment Facilities | Bird Island | 5.42 | 5.42 | 5.42 | ** | ** |
| | Olivia | 4.67 | 4.67 | 4.67 | ** | ** |
| Communities Subject to MS4 NPDES Requirements | | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | | 223.81 | 76.11 | 21.71 | # | # |
| Lower Hawk Creek<br>Unnamed Creek to Unnamed Creek<br>AUID # 07020004-568 | | MID-POINT OF FLOW ZONE | | | | |
| | | Very High | High | Mid | Low | Very Low |
| | | Billion organisms per day | | | | |
| Average Daily Loading Capacity | | 1,776.2 | 505.7 | 150.5 | 40.4 | 7.2 |
| Margin of Safety | | 177.6 | 50.6 | 15.1 | 4 | 0.7 |
| Wasteload Allocation | | | | | | |
| Wastewater Treatment Facilities | Clara City | 2.19 | 2.19 | 2.19 | ** | ** |
| | Maynard | 0.73 | 0.73 | 0.73 | ** | ** |
| | Pennock | 3.11 | 3.11 | 3.11 | ** | ** |
| | Raymond | 6.76 | 6.76 | 6.76 | ** | ** |
| | Willmar | 35.82 | 35.82 | 35.82 | ** | ** |
| City of Willmar MS4 NPDES Requirements 1.8% | | 31.9 | 9.1 | 2.4372 | 0.6552 | 0.117 |
| Livestock facilities requiring NPDES permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | | 1,518.09 | 397.39 | 84.09 | # | # |
| Lower Hawk Creek<br>Spring Creek to Minnesota River<br>AUID # 07020004-587 | | MID-POINT OF FLOW ZONE | | | | |
| | | Very High | High | Mid | Low | Very Low |
| | | Billion organisms per day | | | | |

| *E. coli* | | | | | | |
|---|---|---|---|---|---|---|
| Average Daily Loading Capacity | | 2,934.1 | 762.7 | 218.4 | 46 | 0.03 |
| Margin of Safety | | 293.4 | 76.3 | 21.8 | 4.6 | 0.003 |
| Wasteload Allocation | | | | | | |
| Wastewater Treatment Facilities | Blomkest/Svea | 2.14 | 2.14 | 2.14 | 2.14 | ** |
| | Prinsburg | 0.26 | 0.26 | 0.26 | 0.26 | ** |
| | Roseland | 1.79 | 1.79 | 1.79 | 1.79 | ** |
| City of Willmar MS4 NPDES Requirements | | 31.9 | 9.1 | 2.4372 | 0.6552 | **** |
| Livestock facilities requiring NPDES permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | | 2,604.61 | 673.11 | 189.97 | 36.55 | # |

| Sacred Heart Creek<br>Headwaters to Minnesota River<br>AUID # 07020004-526 | MID-POINT OF FLOW ZONE | | | | |
|---|---|---|---|---|---|
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 78.2 | 19 | 5.6 | 1 | 0.03 |
| Margin of Safety | 7.8 | 1.9 | 0.6 | 0.1 | 0.003 |
| Wasteload Allocation | | | | | |
| Renville Wastewater Treatment Facility | 4.07 | 4.07 | 4.07 | ** | ** |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |
| Southern Minnesota Beet Sugar – SD009 | 10.78 | 10.78 | *** | *** | *** |
| Load Allocation | 55.55 | 2.25 | # | # | # |

| Sacred Heart Creek – MN River<br>Headwaters to Minnesota River<br>AUID # 07020004-525 | MID-POINT OF FLOW ZONE | | | | |
|---|---|---|---|---|---|
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 82.8 | 20.1 | 5.8 | 1.1 | 0.03 |
| Margin of Safety | 8.3 | 2 | 0.6 | 0.1 | 0.003 |
| Wasteload Allocation | | | | | |
| Permitted Wastewater Treatment Facilities | * | * | * | * | * |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |

| *E. coli* | | | | | |
|---|---|---|---|---|---|
| Load Allocation | 74.5 | 18.1 | 5.2 | 1 | 0.027 |
| Stony Run Creek – MN River<br>Headwaters to Minnesota River<br>AUID # 07020004-534 | MID-POINT OF FLOW ZONE | | | | |
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 153.6 | 31.8 | 6.5 | 1.4 | 0.03 |
| Margin of Safety | 15.4 | 3.2 | 0.7 | 0.1 | 0.003 |
| Wasteload Allocation | | | | | |
| Permitted Wastewater Treatment Facilities | * | * | * | * | * |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | 138.2 | 28.6 | 5.8 | 1.3 | 0.027 |
| West Fork Beaver Creek<br>Headwaters to East Fork Beaver Creek<br>AUID # 07020004-530 | MID-POINT OF FLOW ZONE | | | | |
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 502.6 | 118.8 | 38.8 | 8.9 | 0.03 |
| Margin of Safety | 50.26 | 11.88 | 3.88 | 0.89 | 0.003 |
| Wasteload Allocation | | | | | |
| Danube Wastewater Treatment Facility | 3.08 | 3.08 | 3.08 | 3.08 | ** |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | 449.26 | 103.84 | 31.84 | 4.93 | # |
| Wood Lake Creek-MN River<br>Unnamed Creek to Minnesota R<br>AUID # 07020004-648 | MID-POINT OF FLOW ZONE | | | | |
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 78.5 | 16.1 | 3.3 | 0.6 | 0.03 |
| Margin of Safety | 7.9 | 1.6 | 0.3 | 0.06 | 0.003 |
| Wasteload Allocation | | | | | |
| Permitted Wastewater Treatment Facilities | * | * | * | * | * |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |

| *E. coli* | | | | | |
|---|---|---|---|---|---|
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | 70.6 | 14.5 | 3 | 0.54 | 0.027 |
| Sacred Heart Creek-MN River CD 120 to Minnesota R AUID # 07020004-615 | MID-POINT OF FLOW ZONE | | | | |
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 9,098 | 3,639 | 1,451 | 568 | 141 |
| Margin of Safety | 909.8 | 363.9 | 145.7 | 56.8 | 14.1 |
| Wasteload Allocation | | | | | |
| Permitted Wastewater Treatment Facilities | * | * | * | * | * |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | 8,188.2 | 3,275.1 | 1,305.3 | 511.2 | 126.9 |
| Sacred Heart Creek-MN River T113 R35W S4, north line to Minnesota R AUID # 07020004-617 | MID-POINT OF FLOW ZONE | | | | |
| | Very High | High | Mid | Low | Very Low |
| | Billion organisms per day | | | | |
| Average Daily Loading Capacity | 31,615 | 12,615 | 5,234 | 2,018 | 571 |
| Margin of Safety | 3,161.5 | 1,261.5 | 523.4 | 201.8 | 57.1 |
| Wasteload Allocation | | | | | |
| Permitted Wastewater Treatment Facilities | * | * | * | * | * |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |
| Load Allocation | 28,453.5 | 11,353.5 | 4,710.6 | 1,816.2 | 513.9 |

# LC exceeded by point source WLA
* None located within watershed
** WWTF design/discharge flow exceeds the LC, therefore allocation = (flow contribution from a given source) x (126 org/100ml). See section 4.3.1 for details.
*** Industrial design/discharge flow exceeds the LC, therefore allocation = (flow contribution from a given source) x (126 org/100ml). See section 4.3.2 for details.

**** MS4 LA exceeds the LC, MS4 storm sewer systems typically do not discharge during very low flow conditions.

### 4.7.2 Turbidity (TSS) Impaired Stream Reach Loading Capacities

Table 4.15: Loading capacities and allocations for stream reaches

<table>
<tr><th colspan="7">TSS</th></tr>
<tr><td colspan="2" rowspan="3">Beaver Creek<br>East Fork Beaver Creek to Minnesota River<br>AUID # 07020004-528</td><td colspan="5">MID-POINT OF FLOW ZONE</td></tr>
<tr><td>Very High</td><td>High</td><td>Mid</td><td>Low</td><td>Very Low</td></tr>
<tr><td colspan="5">TSS (tons per day)</td></tr>
<tr><td colspan="2">Average Daily Loading Capacity</td><td>57.6</td><td>14.8</td><td>5.1</td><td>1.3</td><td>0.03</td></tr>
<tr><td colspan="2">Margin of Safety</td><td>5.8</td><td>1.5</td><td>0.5</td><td>0.1</td><td>0.003</td></tr>
<tr><td colspan="7">Wasteload Allocation</td></tr>
<tr><td rowspan="3">Wastewater Treatment Facilities</td><td>Bird Island</td><td>0.21</td><td>0.21</td><td>0.21</td><td>0.21</td><td>**</td></tr>
<tr><td>Danube</td><td>0.12</td><td>0.12</td><td>0.12</td><td>0.12</td><td>**</td></tr>
<tr><td>Olivia</td><td>0.12</td><td>0.12</td><td>0.12</td><td>0.12</td><td>**</td></tr>
<tr><td colspan="2">Communities Subject to MS4 NPDES Requirements</td><td>*</td><td>*</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Livestock facilities requiring NPDES permits</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">“Straight Pipe” Septic Systems</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Construction and Industrial storm water 1%</td><td>0.518</td><td>0.133</td><td>0.046</td><td>0.012</td><td>0.00027</td></tr>
<tr><td colspan="2">Southern Minnesota Beet Sugar – SD001</td><td>0.06</td><td>0.06</td><td>0.06</td><td>0.06</td><td>***</td></tr>
<tr><td colspan="2">Load Allocation</td><td>50.772</td><td>12.657</td><td>4.044</td><td>0.678</td><td>#</td></tr>
<tr><td colspan="2" rowspan="3">Chetomba Creek<br>Chetomba Creek to Spring Creek<br>AUID # 07020004-589</td><td colspan="5">MID-POINT OF FLOW ZONE</td></tr>
<tr><td>Very High</td><td>High</td><td>Mid</td><td>Low</td><td>Very Low</td></tr>
<tr><td colspan="5">TSS (tons per day)</td></tr>
<tr><td colspan="2">Average Daily Loading Capacity</td><td>58.2</td><td>12.1</td><td>3.7</td><td>1</td><td>0.03</td></tr>
<tr><td colspan="2">Margin of Safety</td><td>5.8</td><td>1.2</td><td>0.4</td><td>0.1</td><td>0.003</td></tr>
<tr><td colspan="7">Wasteload Allocation</td></tr>
<tr><td rowspan="3">Wastewater Treatment Facilities</td><td>Blomkest/Svea</td><td>0.08</td><td>0.08</td><td>0.08</td><td>0.08</td><td>**</td></tr>
<tr><td>Prinsburg</td><td>0.01</td><td>0.01</td><td>0.01</td><td>0.01</td><td>**</td></tr>
<tr><td>Roseland</td><td>0.07</td><td>0.07</td><td>0.07</td><td>0.07</td><td>**</td></tr>
<tr><td colspan="2">Communities Subject to MS4 NPDES Requirements</td><td>*</td><td>*</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td colspan="2">Livestock facilities requiring NPDES permits</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">“Straight Pipe” Septic Systems</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td colspan="2">Construction and Industrial storm water 1%</td><td>0.524</td><td>0.109</td><td>0.033</td><td>0.009</td><td>0.00027</td></tr>
<tr><td colspan="2">Load Allocation</td><td>51.716</td><td>10.631</td><td>3.107</td><td>0.731</td><td>#</td></tr>
<tr><td colspan="2">Lower Hawk Creek</td><td colspan="5">MID-POINT OF FLOW ZONE</td></tr>
</table>

| TSS | | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Unnamed Creek to Unnamed Creek<br>AUID # 07020004-568 | | Very High | High | Mid | Low | Very Low |
| | | TSS (tons per day) | | | | |
| Average Daily Loading Capacity | | 109.3 | 30.9 | 9.8 | 2.9 | 0.4 |
| Margin of Safety | | 10.9 | 3.1 | 1 | 0.3 | 0.04 |
| Wasteload Allocation | | | | | | |
| Wastewater Treatment Facilities | Clara City | 0.06 | 0.06 | 0.06 | 0.06 | ** |
| | Maynard | 0.02 | 0.02 | 0.02 | 0.02 | ** |
| | Pennock | 0.12 | 0.12 | 0.12 | 0.12 | ** |
| | Raymond | 0.27 | 0.27 | 0.27 | 0.27 | ** |
| | Willmar | 0.94 | 0.94 | 0.94 | 0.94 | ** |
| Willmar MS4 NPDES Requirements 1.8% | | 1.9 | 0.6 | 0.2 | 0.04 | 0.00648 |
| Livestock facilities requiring NPDES permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| Construction and Industrial storm water 1% | | 1.0 | 0.3 | 0.07 | 0.01 | 0.0036 |
| Load Allocation | | 94.09 | 25.49 | 7.12 | 1.14 | # |
| Lower Hawk Creek<br>Spring Creek to Minnesota River<br>AUID # 07020004-587 | | MID-POINT OF FLOW ZONE | | | | |
| | | Very High | High | Mid | Low | Very Low |
| | | TSS (tons per day) | | | | |
| Average Daily Loading Capacity | | 181.7 | 47.5 | 14.3 | 3.5 | 0.002 |
| Margin of Safety | | 18.2 | 4.8 | 1.4 | 0.4 | 0.0002 |
| Wasteload Allocation | | | | | | |
| Wastewater Treatment Facilities | Blomkest/Svea | 0.08 | 0.08 | 0.08 | 0.08 | ** |
| | Prinsburg | 0.01 | 0.01 | 0.01 | 0.01 | ** |
| | Roseland | 0.07 | 0.07 | 0.07 | 0.07 | ** |
| Willmar MS4 NPDES Upstream Requirements | | 1.9 | 0.6 | 0.2 | 0.04 | **** |
| Granite Falls Energy LLC Industrial Wastewater | | 0.02 | 0.02 | 0.02 | 0.02 | *** |
| Livestock facilities requiring NPDES permits | | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | | 0 | 0 | 0 | 0 | 0 |
| Construction and Industrial storm water 1% | | 1.6 | 0.4 | 0.1 | 0.1 | 0.1 |
| Load Allocation | | 159.82 | 41.52 | 12.42 | 2.78 | # |
| West Fork Beaver Creek | | MID-POINT OF FLOW ZONE | | | | |

| TSS | | | | | |
|---|---|---|---|---|---|
| Headwaters to East Fork Beaver Creek AUID # 07020004-530 | Very High | High | Mid | Low | Very Low |
| | TSS (tons per day) | | | | |
| Average Daily Loading Capacity | 30.9 | 7.5 | 2.5 | 0.7 | 0.002 |
| Margin of Safety | 3.1 | 0.8 | 0.3 | 0.07 | 0.0002 |
| Wasteload Allocation | | | | | |
| Danube Wastewater Treatment Facility | 0.12 | 0.12 | 0.12 | 0.12 | ** |
| Communities Subject to MS4 NPDES Requirements | * | * | * | * | * |
| Livestock facilities requiring NPDES permits | 0 | 0 | 0 | 0 | 0 |
| "Straight Pipe" Septic Systems | 0 | 0 | 0 | 0 | 0 |
| Construction and Industrial storm water 1% | 0.3 | 0.07 | 0.02 | 0.005 | 0.00002 |
| Southern Minnesota Beet Sugar – SD001 | 0.06 | 0.06 | 0.06 | 0.06 | *** |
| Load Allocation | 27.32 | 6.45 | 2 | 0.445 | # |

# LC exceeded by point source WLA
* None located within watershed
** WWTF design/discharge flow exceeded low flow, therefore allocation = (flow contribution from a given source) x (65 mg/1000ml). See section 4.3.1 for details.
*** Industrial design/discharge flow exceeded low flow, therefore allocation = (flow contribution from a given source) x (65 mg/1000ml). See section 4.3.2 for details.
**** MS4 LA exceeds the LC, MS4 storm sewer systems typically do not discharge during very low flow conditions.

### 4.7.3 Impaired Lake Loading Capacities

**Table 4.16: Total phosphorus loading capacities and allocations for impaired lakes within the Hawk Creek Watershed**

| Olson Lake 34-0266-00 | TP lbs/day |
|---|---|
| Loading Capacity** | 0.362 |
| Margin of Safety | 0.036 |
| Wasteload Allocation* | |
| Construction and industrial storm water | 0.003 |
| Industrial process wastewater | 0 |
| Livestock facilities requiring NPDES permits | 0 |
| "Straight pipe" septic systems | 0 |
| Load Allocation | 0.323 |

| Swan Lake 34-0186-00 | TP lbs/day |
|---|---|
| Loading Capacity** | 4.76 |
| Margin of Safety | 0.476 |
| Wasteload Allocation* | |
| Construction and industrial storm water | 0.043 |
| Industrial process wastewater | 0 |
| Livestock facilities requiring NPDES permits | 0 |
| "Straight pipe" septic systems | 0 |
| Load Allocation | 4.24 |

| | |
|---|---|
| Watershed and internal load | 0.233 |
| Atmospheric load | 0.09 |
| **St. John's Lake** 34-0283-00 | TP lbs/day |
| Loading Capacity** | 3.53 |
| Margin of Safety | 0.353 |
| Wasteload Allocation* | |
| Construction and industrial storm water | 0.032 |
| Industrial process wastewater | 0 |
| Livestock facilities requiring NPDES permits | 0 |
| "Straight pipe" septic systems | 0 |
| Load Allocation | 3.145 |
| Watershed and internal load | 3.005 |
| Atmospheric load | 0.14 |

| | |
|---|---|
| Watershed and internal load | 4.09 |
| Atmospheric load | 0.15 |
| **West Solomon Lake** 34-0245-00 | TP lbs/day |
| Loading Capacity** | 7.42 |
| Margin of Safety | 0.742 |
| Wasteload Allocation* | |
| Construction and industrial storm water | 0.067 |
| Industrial process wastewater | 0 |
| Livestock facilities requiring NPDES permits | 0 |
| "Straight pipe" septic systems | 0 |
| Load Allocation | 6.61 |
| Watershed and internal load | 6.2 |
| Atmospheric load | 0.41 |

* No Communities Subject to MS4 NPDES requirements or Industrial process wastewater discharges located in the watershed
**Values may be rounded

# 5 Future Growth Considerations

Potential changes in population and land use over time in the Hawk Creek 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 in-stream 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 Hawk Creek 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

A TMDL needs to provide reasonable assurance that water quality targets will be achieved through the specified combination of point and nonpoint source reductions reflected in the LAs and WLAs. According to EPA guidance (EPA 2002b), "When a TMDL is developed for waters impaired by both point and nonpoint sources, and the WLA is based on an assumption that nonpoint-source load reductions will occur… the TMDL should provide reasonable assurances that nonpoint-source control measures will achieve expected load reductions in order for the TMDL to be approvable. This information is necessary for the EPA to determine that the TMDL, including the LA and WLAs, has been established at a level necessary to achieve water quality standards". In the Hawk Creek Watershed, considerable reductions in nonpoint sources are required.

The MPCA will adopt portions of the Chesapeake Bay Reasonable Assurance framework, with some modifications as follows:

- Evaluate existing programmatic, funding, and technical capacity to implement basin and watershed strategies.
- Identify gaps in current programs, funding, and local capacity to achieve the needed controls.
- Build program capacity for short-term and long-term goals. Demonstrate increased implementation and/or pollutant reductions.
- Commit to track/monitor/assess and report progress at set regular times.

TSS impairments in this TMDL will not include further reductions to point sources by reducing their WLAs, for permitted MS4s or permitted WWTF. These are minor sources of TSS to the Hawk Creek Watershed and reductions in their WLAs will not help to accomplish the goals of the TMDL.

Additional requirements could be implemented if nonpoint source targets are not met and will focus on nonpoint sources themselves. They could take the form of:

- Review of statewide nonpoint source control programs and policies by state agencies and their implementation by local agencies
- Requirements to comply with existing nonpoint source authorities, including but not limited to:
    - 50-foot buffer required for the shore impact zone of streams classified as protected waters (Minn. Stat. § 103F.201) for agricultural land uses
    - Protecting highly erodible land within the 300-foot shoreland district (Minn. Stat. § 103F.201)
    - Buffers on public drainage ditches (Minn. Stat. § 103E.021)
    - Excessive soil loss statute (Minn. Stat. § 103F.415)
    - Nuisance nonpoint source pollution (Minn. R. 7050.0210, subp. 2)
    - Other measures that may be identified in the WRAPS Report or the One Watershed One Plan

The targeting of BMPs and ongoing research to pinpoint sediment sources and measure the effectiveness of nonpoint source remediation measures will provide some assurance of achieving the LA of this TMDL. In addition, inter-agency work groups formed to direct the state's new Clean Water Fund will help to ensure that nonpoint source load reductions will be addressed. These groups have developed guidance related to monitoring, implementation, research, and identification of measures and outcomes. Within this framework of implementation, reasonable assurance will be provided with regard to nonpoint sources through commitments of funding, watershed planning, and use of existing regulatory authorities. The Clean Water Legacy Act (2006) provided the MPCA authority and direction for carrying out section 303(d) of the CWA, in addition to one-time funding to initiate a comprehensive 10-year process of assessment and TMDL development in Minnesota.

In November 2008, Minnesotans voted in support of the Clean Water, Land and Legacy Amendment to the state constitution. Through this historic vote, about $5.5 billion is dedicated to the protection and restoration of water and land over 25 years. One third of the annual proceeds from sales tax revenue, an estimated $80 to $90 million, will be devoted to a Clean Water Fund to protect, enhance and restore water quality of lakes, rivers, streams, and groundwater. The Amendment specifies that this funding must supplement and not replace traditional funding. Approximately two-thirds of the annual proceeds will be earmarked for water quality protection and restoration.

Reasonable assurance for permitted sources such as stormwater and wastewater is provided primarily via compliance with the respective NPDES Permit programs, which have been described in Section 3.6.

Point sources were not identified as a primary source of *E. coli*, TSS, or TP in the Hawk Creek Watershed. The permitted facilities in the watershed discharge at concentrations that meet the applicable water quality standards; therefore, no additional need for further point source reductions have been identified within the Hawk Creek Watershed. Point source permitting staff work closely with facilities to implement limits set by the MPCA's Effluent Limits Unit.

SSTS, commonly known as septic systems, are regulated by Minn. Stat. §§ 115.55 and 115.56. Counties and other local units of government (LUGs) that regulate SSTS must meet the requirements for local SSTS programs in Minn. R. ch. 7082. Counties and other LUGs must adopt and implement SSTS ordinances in compliance with Minn. R. ch. 7080 to 7083.

These regulations detail:

- Minimum technical standards for individual and mid-size SSTS;
- A framework for local units of government to administer SSTS programs and;
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

Counties and other LUGs enforce Minn. R. chs. 7080 to 7083 through their local SSTS ordinances and issue permits for systems designed with flows up to 10,000 gallons per day. There are approximately 200 LUGs across Minnesota, and depending on the location, an LUG may be a county, city, township, or sewer district. LUG SSTS ordinances vary across the state. Some require SSTS compliance inspections prior to property transfer, require permits for SSTS repair and septic tank maintenance, and/or may have other requirements, which are stricter than state regulations. Minn. R. 7082.0500, requires compliance inspections by Counties and other LUGs for all new construction and for existing systems if the LUG issues a permit for the addition of a bedroom.

The MPCA has worked with counties through the SSTS Implementation and Enforcement Task Force (SIETF) to identify the most beneficial way to use funds to accelerate SSTS compliance statewide. In order to increase the number of compliance inspections, the MPCA has developed and administers several grants to LUGs for various ordinances, actions, and plans within the LUG jurisdictional boundaries. These include a base grant that all counties receive, and counties have the option to apply for additional funds for septic system upgrades. Several other grants are available to counties that have additional provisions in their ordinances above the minimum program requirements. As of 2015, total dollar amounts given to counties for these additional provisions are listed below.

- Compliance inspection for property transfer – ($123,000 awarded)
- Compliance inspection for any (all) permit-countywide – ($27,000 awarded)
- Plan to improve compliance, like records catalog or inventory (past, ongoing or future) – ($32,500 awarded)
- Plan to address unsewered Areas – ($12,500 awarded)

The MPCA Staff keeps a statewide database of known imminent threats public health and safety (ITPHS) that include "straight pipe systems". Straight pipe systems are reported to the counties or the MPCA by the public or discovered through county compliance inspections. Upon confirmation of a straight pipe system, the county sends out a notification of non-compliance, which starts a 10-month deadline to fix the system and bring it into compliance. From 2006 to 2017, 742 straight pipes have been tracked by the MPCA. 701 of those were abandoned, fixed, or were found not to be a straight pipe system as defined in Minn. Stat 115.55, subd. 1. There have been 17 Administrative Penalty Orders issued and docketed in court. The remaining straight pipe systems received a notification of non-compliance and are currently within the 10-month deadline.

Southwest Minnesota is the leader in addressing unsewered communities. Unsewered communities can be a source of nutrients and pathogens to surface waters. Since 1996, the MPCA Southwest Wastewater staff have helped seven small communities throughout the Hawk Creek Watershed: Gluek, George Lake, Henderson Lake, Roseland, Svea, Blomkest, and country courts, build soil or pond wastewater treatment systems. Five unsewered communities in the watershed: Bunde, Wegdahl, St. Johns Lake, South Long Lake, and Countryside Acres are all addressing their wastewater treatment through SSTS upgrades regulated by county ordinances.

Funding for SSTS upgrades and replacements from various sources are available and have been utilized by all three counties within the Hawk Creek watershed. The Clean Water Fund provides money to counties for low-Income SSTS upgrade grants. These grants are awarded through a competitive application process hosted by the MPCA. These funds are awarded based on issuance of a Notice of Noncompliance for systems deemed ITPHS, or for systems failing to protect groundwater. The Clean Water Partnership (CWP) State Revolving Fund (SRF) and the MDA's Ag BMP Loan Programs have money available to award low-interest loans for individual SSTS upgrades.

In order for the impaired waters to meet water quality standards the majority of pollutant reductions in the Hawk Creek Watershed will need to come from NPS contributors. Due to lack of existing state and federal regulations for NPSs and the monetary incentives for practices that can degrade water quality, agricultural drainage and surface runoff are major contributors of both nutrients and increased flows throughout the watershed. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce nutrient runoff, as well as streambank and overland erosion. Agencies, organizations, local units of government, and citizens alike need to recognize that resigning waters to an impaired condition is not acceptable.

See Table 14A of the *Hawk Creek WRAPS Report* for 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 developed by the WRAPS Workshop Team. The strategies identified 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. The implementation strategies described in this plan have demonstrated effectiveness in reducing nutrient loading to lakes and streams. Table 14B of the Hawk Creek WRAPS Report presents the estimated adoption rates to meet the 10-year watershed-wide targets with information most relevant for local planning efforts including the specific strategies, actions, and responsibilities for BMP implementation.

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. The watershed's citizens and communities will need to voluntarily adopt the practices at the necessary scale and rates to achieve the 10-year targets presented in Table 14B of the *Hawk Creek WRAPS Report*. Refer to Section 9 for citizen engagement that has occurred in the Hawk Creek Watershed. 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 BMP implementation will be led by local units of government, the Hawk Creek Watershed Project (HCWP), county SWCDs, county planning and zoning with guidance and support from multiple state agencies (MPCA, Board of Water and Soil Resources (BWSR), Minnesota Department of Natural Resources (DNR), MDA, Minnesota Department of Health (MDH). 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 CWA Section 319 grant programs, BWSR implementation funding, and NRCS incentive programs. Programs and activities are also occurring at the local government level, where county staff, commissioners, and residents work 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 toward 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 Hawk Creek 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 Hawk Creek Watershed in 2020.

*Watershed Pollutant Load Monitoring Network* (MPCA 2013a) 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 Hawk Creek Watershed, there is an annual site near the outlet of the Hawk Creek and one seasonal (spring through fall) subwatershed site.

*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 weekly to monthly lake and river measurements. This will allow the MPCA to re-assess previously listed impairments. Approximately 15 citizen-monitoring locations exist in the Hawk Creek 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. 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. The baseline years in the applicable reaches for implementation are listed below (Table 8.1). The years listed are the median of the data years used for development of the percent pollutant reductions (Table 4.4). 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 a MS4’s load reductions. If a BMP implementation occurred 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.

Table 8.1: Baseline years for impaired stream reaches addressed in this report

| Impaired Reach AUID # | Impairments | Data Years | Baseline Year |
|---|---|---|---|
| 07020004-528 | *Escherichia coli* | 2007-2011 | 2009 |
| | Turbidity (TSS) | 2007-2011 | 2009 |
| 07020004-589 | *Escherichia coli* | 2007-2011 | 2009 |
| | Turbidity (TSS) | 1999-2012 | 2005 |
| 07020004-689 | *Escherichia coli* | 2010-2011 | 2010 |
| 07020004-586 | *Escherichia coli* | 2010-2011 | 2010 |
| 07020004-587 | *Escherichia coli* | 2007-2011 | 2009 |
| | Turbidity (TSS) | 2002-2011 | 2007 |
| 07020004-568 | *Escherichia coli* | 2007-2011 | 2009 |
| | Turbidity (TSS) | 2002-2011 | 2007 |
| 07020004-526 | *Escherichia coli* | 2007-2011 | 2009 |
| 07020004-525 | *Escherichia coli* | 2007-2011 | 2010 |
| 07020004-615 | *Escherichia coli* | 2010-2011 | 2010 |
| 07020004-617 | *Escherichia coli* | 2010-2011 | 2010 |
| 07020004-534 | *Escherichia coli* | 2007-2011 | 2009 |
| 07020004-530 | *Escherichia coli* | 2007-2011 | 2010 |
| | Turbidity (TSS) | 2002-2011 | 2007 |
| 07020004-648 | *Escherichia coli* | 2007-2011 | 2010 |
| 34-0283-00 | Nutrient Eutrophication | 2010-2011 | 2010 |
| 34-0245-00 | Nutrient Eutrophication | 2010-2011 | 2010 |
| 34-0186-00 | Nutrient Eutrophication | 2010-2011 | 2010 |
| 34-0266-00 | Nutrient Eutrophication | 2010-2011 | 2010 |

### 8.1.4 Wastewater

The MPCA issues permits for WWTF's 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 protecting public health and aquatic life and 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 Hawk Creek WRAPS Report. These strategies, adopted at generally wide-scale and integrated in suites, are expected to bring waters in the Hawk Creek Watershed into a supporting status. Refer to Tables 14A and 14B in the ***Hawk Creek WRAPS Report*** for details of BMPs and adoption rates to meet interim water quality targets. Below is a summary of the recommended strategies.

- 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)
- 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
- Changes in policy and increased funding and other support
- Protect currently higher quality areas

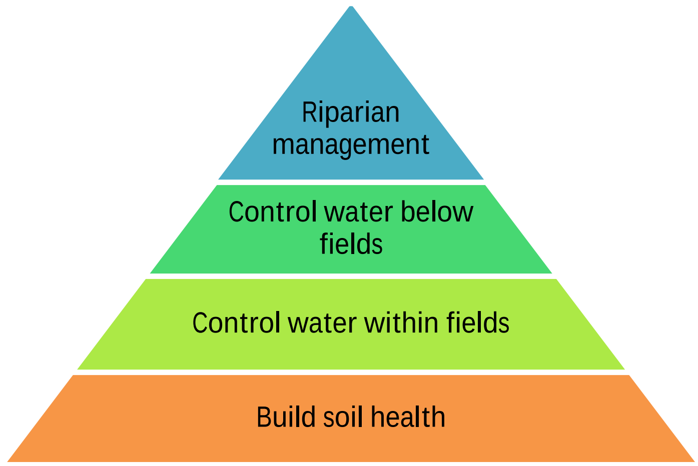



Figure 8.1: This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impounds, etc., and then 4) riparian management: buffers, stabilization, restoration, etc.

To fully address the widespread water quality impairments in agriculturally-dominated watersheds such as the Hawk Creek 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).

Additional strategies can be found by utilizing the MDA's Minnesota Agriculture Water Quality Certification Program (MAWQCP; http://www.mda.state.mn.us/awqcp), a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality. If producers within the watershed enroll in the MAWQCP, their fields will be evaluated to determine if they are eligible to become a "certified" farm.

## 8.3 Cost

Estimating the cost of bringing waters in the Hawk Creek Watershed into a status of supporting beneficial water uses 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 Hawk Creek WRAPS Report.

The estimated cost of agricultural BMPs to meet the Hawk Creek WRAPS 10-year water quality targets is roughly $160 million. The 10-year targets represent pollutant (or stressor) reductions that range from 5% to 27%. This number can be very roughly extrapolated by (considering the ratio of the total goal to the 10-year target) a factor of five to roughly $800 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 $150 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.

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.

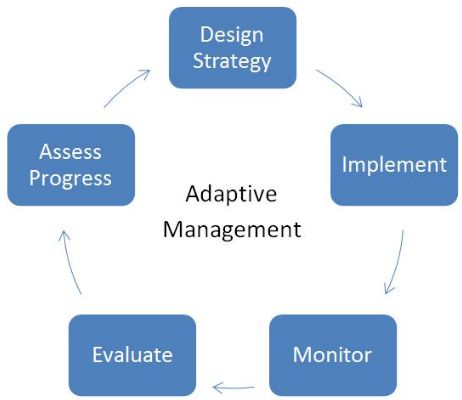



Figure 8.2: A Adaptive Management


Figure 8.3: Minnesota water quaility framework

# 9 Public Participation

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

## 9.1 Hawk Creek Watershed

The *Hawk Creek Watershed Project Advisory Committee* 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

Several civic engagement opportunities were sponsored by the HCWP and the MPCA. The HCWP created and distributed four newsletters from 2010 to 2016 with Watershed Approach information to watershed citizens. The HCWP also hosted 15 public meetings from 2010 to 2016 to present information on and to provide opportunities for citizens to provide input on the Watershed Approach. 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 was published for public comments on May 22, 2017 to June 21, 2017.

# 10 Literature Cited


Barr Engineering. 2004. "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" Prepared for Minnesota Pollution Control Agency, by Barr Engineering Company, Minneapolis, MN. http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/phosphorus/detailed-assessments-of-phosphorus-sources-to-minnesota-watersheds.html.

Environmental and Natural Resources Trust Fund (ENRTF), 2013. "Project Proposal: Demonstrating Farmer Led Conservation in the Elm Creek Watershed" http://www.lccmr.leg.mn/proposals/2014/pre-presentation_by_category/047-b.pdf

Environmental Protection Agency, United States (EPA), 1999. "Protocol for Developing Sediment TMDLs, First Edition" EPA 841-B-99-004 https://owpubauthor.epa.gov/lawsregs/lawsguidance/cwa/tmdl/upload/1999_12_08_tmdl_sediment_sediment.pdf

Environmental Protection Agency, United States (EPA), 2002a. "Establishing Total Maximum Daily Load Wasteload Allocations for stormwater Sources and NPDES Permit Requirements Based on Those WLAs" http://www.epa.gov/npdes/pubs/final-wwtmdl.pdf

Environmental Protection Agency, United States (EPA), 2002b. "Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992" EPA 841-B-99-004 https://www.epa.gov/sites/production/files/2015-10/documents/2002_06_04_tmdl_guidance_final520021.pdf

Environmental Protection Agency, United States (EPA), 2007. "An Approach for Using Load Duration Curves in the Development of TMDLs" EPA 841-B-07-006 https://www.epa.gov/sites/production/files/2015-07/documents/2007_08_23_tmdl_duration_curve_guide_aug2007.pdf

Hoverson, D. 2008. Phosphorus Release from sediments in Shawano Lake, Wisconsin College of Natural resources, University of Wisconsin - Stevens Point. http://www.uwsp.edu/cnrap/watershed/Documents/hoverson.pdf

Ishii, S., W.B. Ksoll, R.E. Hicks, M.J. Sadowsky. 2006. Presence and Growth of Naturalized Escherichia coli in Temperate Soils from Lake Superior Watersheds. Applied and Environmental Microbiology. Vol. 72:612-621. Prairie, Y.T. and J. Kalff. 1986. Effect of catchment size on phosphorus export. Wat. Resour. Bull. 22(3) 465-470.

Minnesota Pollution Control Agency (MPCA). 2004. "Detailed Assessment of Phosphorus Sources to Minnesota Watersheds" https://www.pca.state.mn.us/sites/default/files/pstudy-2007updatememo.pdf. Prepared by Barr Engineering.

Minnesota Pollution Control Agency (MPCA), 2005. "Minnesota Lake Water Quality Assessment report: Developing Nutrient Criteria, 3rd Edition" http://www.pca.state.mn.us/index.php/view-document.html?gid=6503. September 2005.

Minnesota Pollution Control Agency (MPCA), 2007. "Statewide Mercury TMDL" http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html

Minnesota Pollution Control Agency (MPCA), 2008. "Small Community Wastewater Needs in Minnesota" http://www.pca.state.mn.us/index.php/view-document.html?gid=5192

Minnesota Pollution Control Agency (MPCA), 2011. "Minnesota's Water Quality Monitoring Strategy" http://www.pca.state.mn.us/index.php/view-document.html?gid=10228

Minnesota Pollution Control Agency (MPCA), 2011b. "Long and Ringo Lakes Excess Nutrients Total Maximum Daily Load" http://www.pca.state.mn.us/index.php/view-document.html?gid=16013

Minnesota Pollution Control Agency (MPCA), 2012a. "Intensive Watershed Monitoring" http://www.pca.state.mn.us/index.php?option=com_k2&view=item&id=1197

Minnesota Pollution Control Agency (MPCA), 2012b. "Hawk Creek Watershed Biotic Stressor identification report" https://www.pca.state.mn.us/sites/default/files/wq-ws5-07020004b.pdf

Minnesota Pollution Control Agency (MPCA), 2012d. "Minnesota River – Granite Falls Watershed Monitoring and Assessment Report" http://www.pca.state.mn.us/index.php/view-document.html?gid=19934

Minnesota Pollution Control Agency (MPCA) 2012e. "Zumbro Watershed Turbidity (TSS) Total Maximum Daily Load" http://www.pca.state.mn.us/index.php/view-document.html?gid=17902

Minnesota Pollution Control Agency (MPCA), 2013a. "Watershed Pollutant Load Monitoring Network" http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/streams-and-rivers/watershed-pollutant-load-monitoring-network.html

Minnesota Pollution Control Agency (MPCA), 2013b. "Volunteer Surface Water Monitoring" http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/volunteer-water-monitoring/volunteer-surface-water-monitoring.html

Minnesota Pollution Control Agency (MPCA), 2013c. "Minnesota Nutrient Reduction Strategy" http://www.pca.state.mn.us/index.php/view-document.html?gid=20213

Minnesota Pollution Control Agency (MPCA), 2014a. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List. http://www.pca.state.mn.us/index.php/view-document.html?gid=16988

Minnesota Pollution Control Agency (MPCA), 2014b. "TMDL Policy and Guidance" http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/project-resources/tmdl-policy-and-guidance.html

Minnesota Pollution Control Agency (MPCA), 2014c. "Environmental Data" http://www.pca.state.mn.us/index.php/data/environmental-data-access.html

Minnesota Pollution Control Agency (MPCA) and MSUM. 2009. State of the Minnesota River, Summary of Surface Water Quality Monitoring 2000-2008. http://mrbdc.mnsu.edu/sites/mrbdc.mnsu.edu/files/public/reports/basin/state_08/2008_fullreport1109.pdf

Multi-Resolution Land Characteristics Consortium (MRLC), 2011. "National Land Cover Database" http://www.mrlc.gov/nlcd2011.php

Nürnberg Gertrud K., 1984. "Prediction of annual and seasonal phosphorus concentrations in stratified and polymictic lakes" American Society of Limnology and Oceanography, 43(7), 1998, 1544-1552. http://aslo.org/lo/toc/vol_43/issue_7/1544.pdf

Pierce, Samuel C., R. Kröger, and R. Pezeshki, 2012. "Managing Artificially Drained Low-Gradient Agricultural Headwaters for Enhanced Ecosystem Functions". Biology, 1(3), 794-856, Dec. 10, 2012. http://www.mdpi.com/2079-7737/1/3/794

Chandrasekaran R, Hamilton MJ, Wang P, Staley C, Matteson S, Birr A, Sadowsky MJ. 2015. Geographic isolation of Escherichia coli genotypes in sediments and water of the Seven Mile Creek - A constructed riverine watershed. Sci. Total Environ. 538:78-85

Schottler, S.P, Jason Ulrich, Patrick Belmont, Richard Moore, J. Wesley Lauer, Daniel R. Engstrom, and James E. Almendinger, 2012. "Twentieth century agricultural drainage creates more erosive rivers" Hydrological Processes, 28(4):1951-1961, Feb. 15, 2014. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021703.pdf

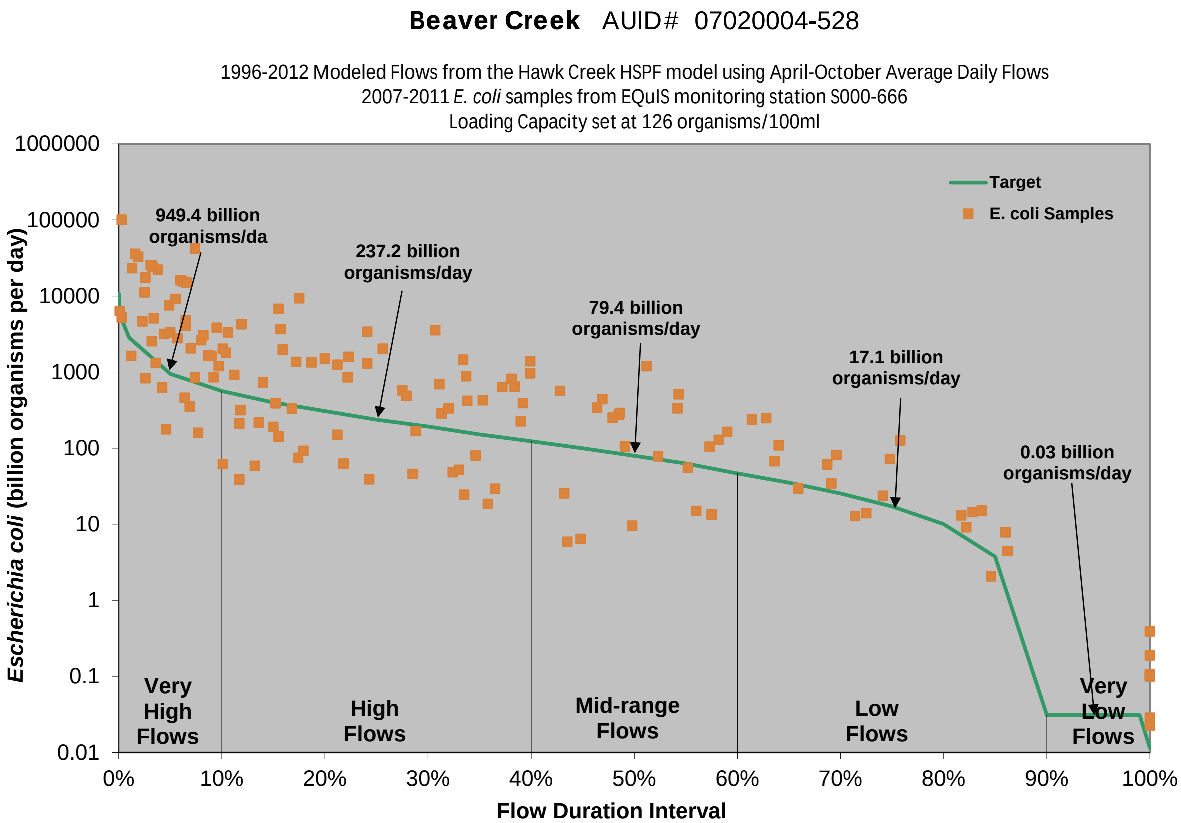
Tomer, Mark D., Sarah A. Porter, David E. James, Kathleen M.B. Boomer, Jill A. Kostel, and Eileen McLellan, 2013. "Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning" Journal of Soil and Water Conservation, 68(5):113A-120A http://www.jswconline.org/content/68/5/113A.full.pdf+html

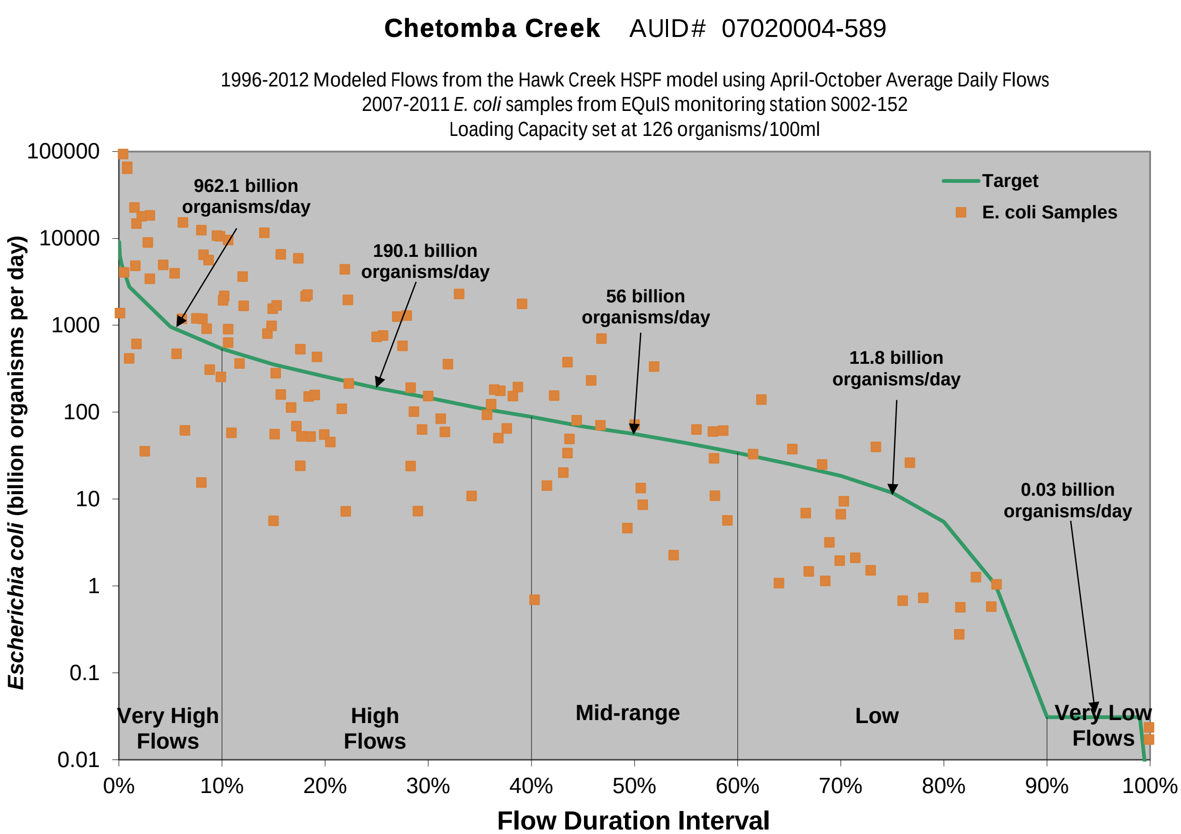
Walker, William, 1999. "Simplified Procedures for Eutrophication Assessment and Prediction: User Manual" https://wiki.umn.edu/pub/Nieber/WebHome/FLUX-BATHTUB_MANUAL_IR-W-96_2.pdf

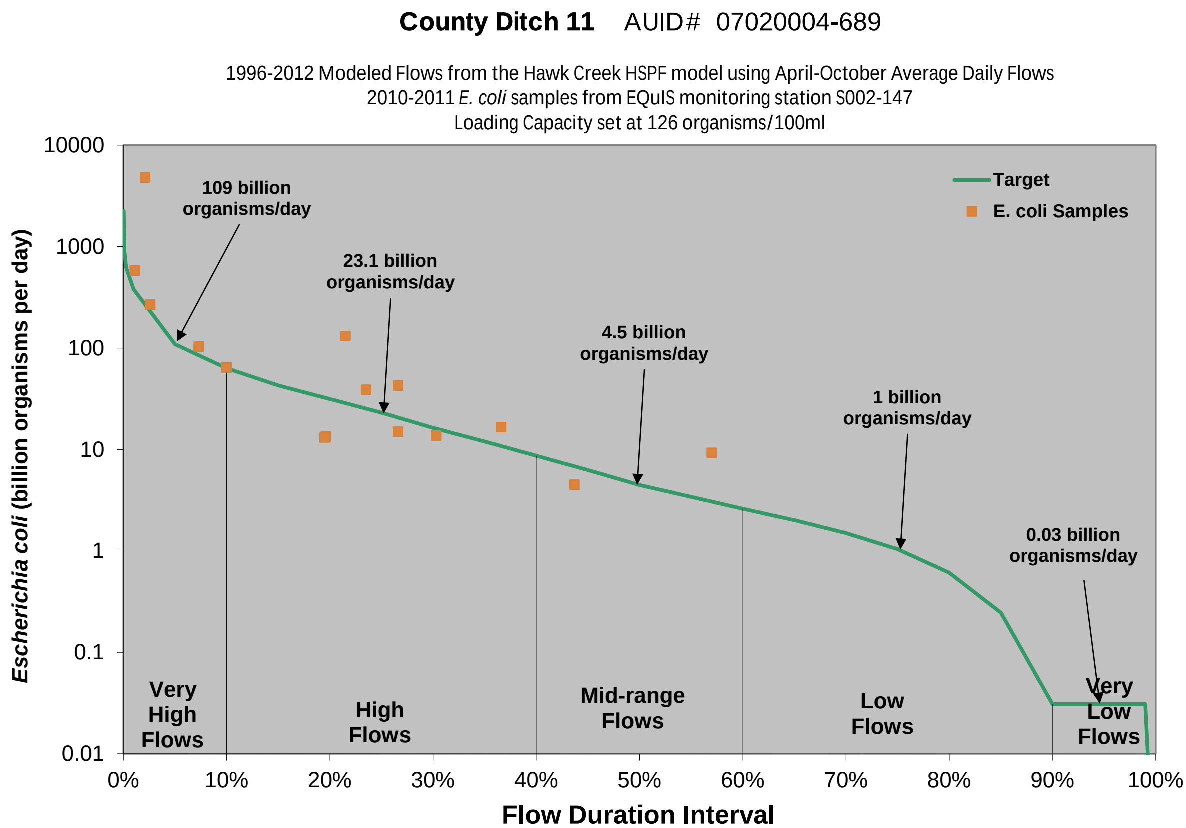
Hawk Creek Watershed District. http://www.hawkcreekwatershed.org/

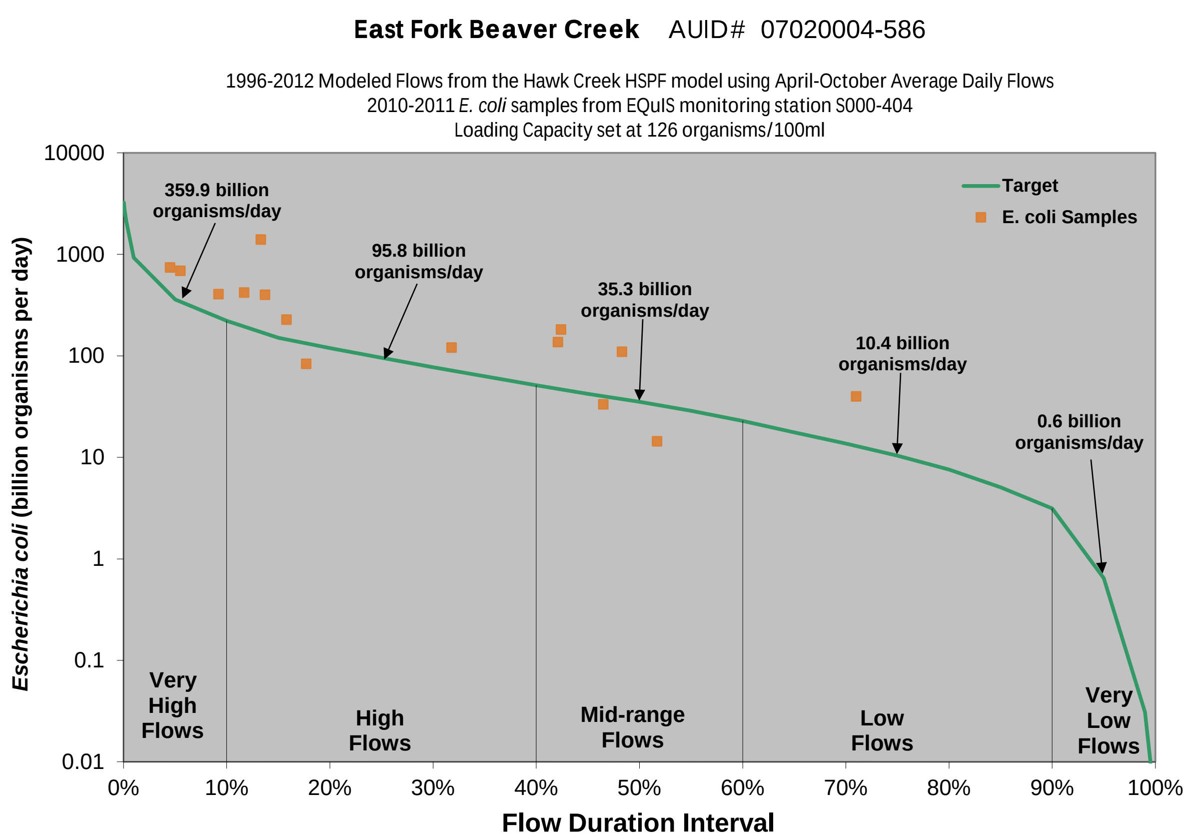
## Appendix A

**Load duration curves for *E. coli* bacteria stream reach impairments**




County Ditch 11 AUID# 07020004-689
1996-2012 Modeled Flows from the Hawk Creek HSPF model using April-October Average Daily Flows
2010-2011 E. coli samples from EQuIS monitoring station S002-147
Loading Capacity set at 126 organisms/100ml
Target
E. coli Samples
109 billion organisms/day
23.1 billion organisms/day
4.5 billion organisms/day
1 billion organisms/day
0.03 billion organisms/day
Very High Flows
High Flows
Mid-range Flows
Low Flows
Very Low Flows
Escherichia coli (billion organisms per day)
10000
1000
100
10
1
0.1
0.01
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Flow Duration Interval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2010-2011 E. coli samples from EQuIS monitoring station S000-404
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Target
E. coli Samples
359.9 billion organisms/day
95.8 billion organisms/day
35.3 billion organisms/day
10.4 billion organisms/day
0.6 billion organisms/day
Very High Flows
High Flows
Mid-range Flows
Low Flows
Very Low Flows
Escherichia coli (billion organisms per day)
10000
1000
100
10
1
0.1
0.01
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Flow Duration Interval

**Lower Hawk Creek** AUID# 07020004-568

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2007-2011 *E. coli* samples from EQuIS monitoring station S002-148
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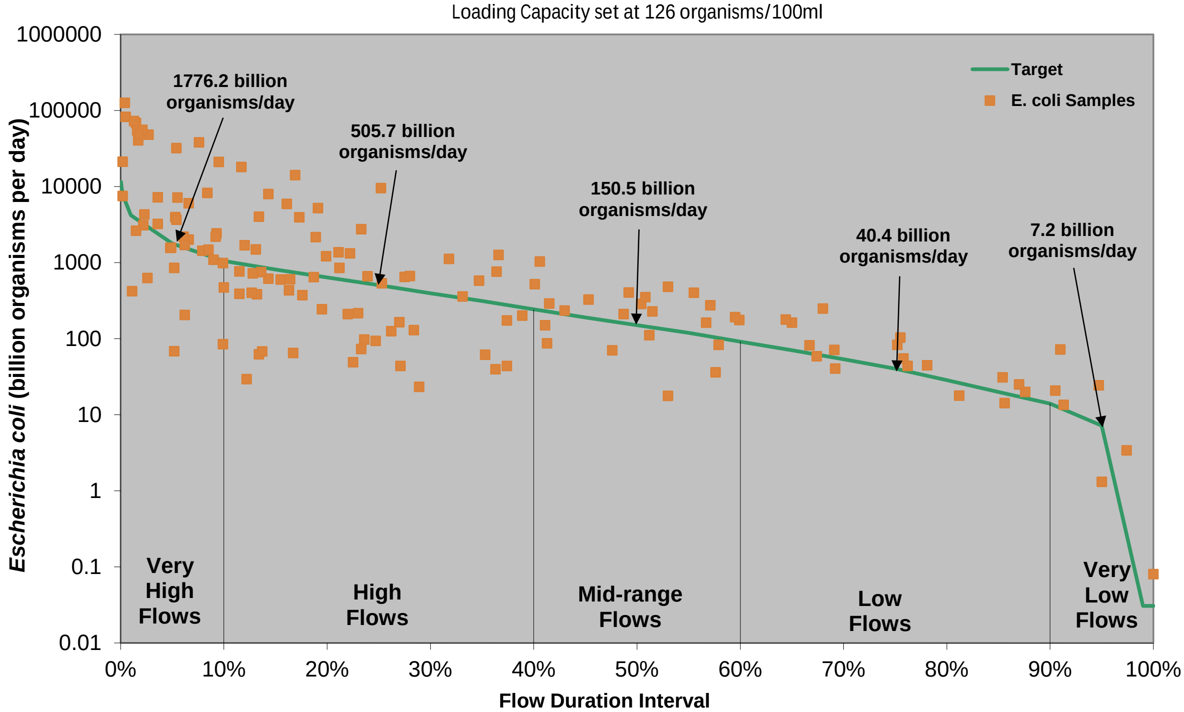
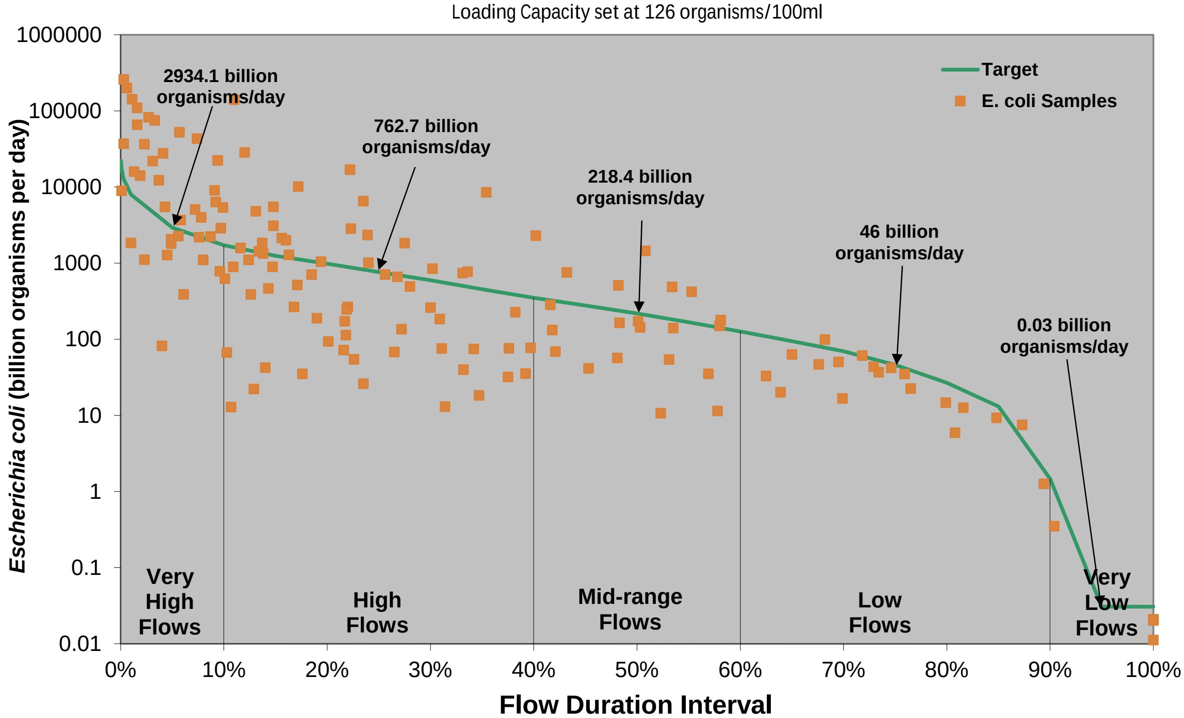



**Lower Hawk Creek** AUID# 07020004-587

1996-2012 Modeled Flows from the Hawk Creek HSPF model using April-October Average Daily Flows
2007-2011 *E. coli* samples from EQuIS monitoring station S002-012
Loading Capacity set at 126 organisms/100ml



**Middle Creek** AUID# 07020004-615

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2010-2011 *E. coli* samples from EQuIS monitoring station S004-691
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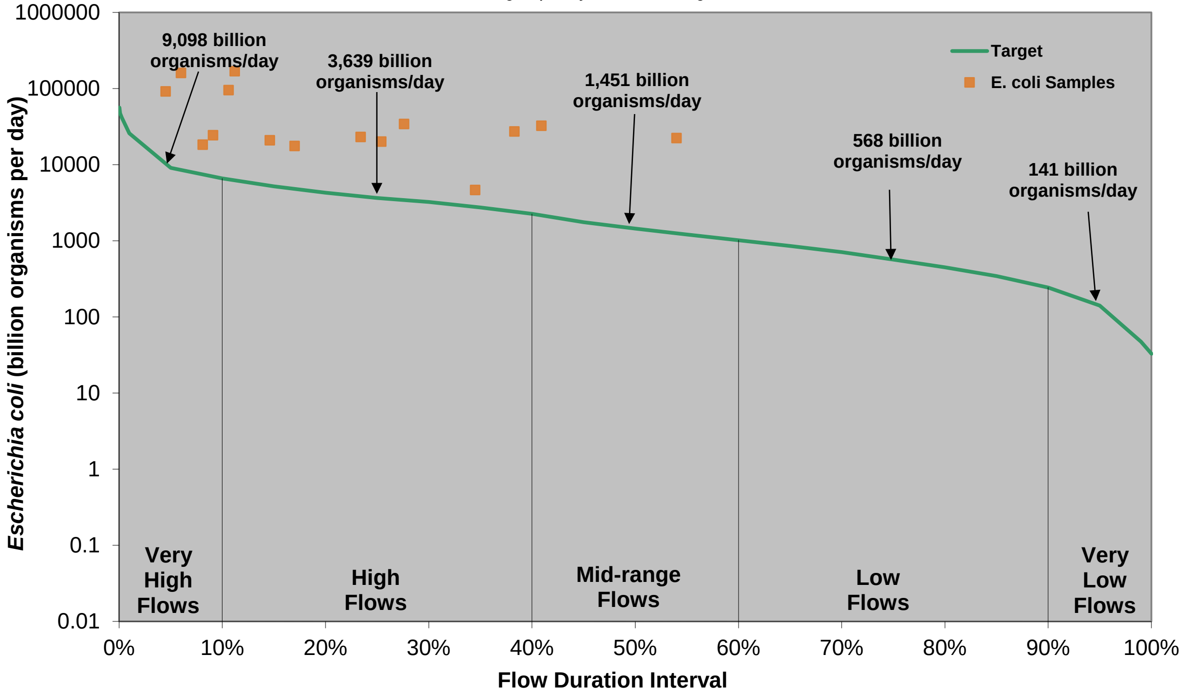


**Smith Creek** AUID# 07020004-617

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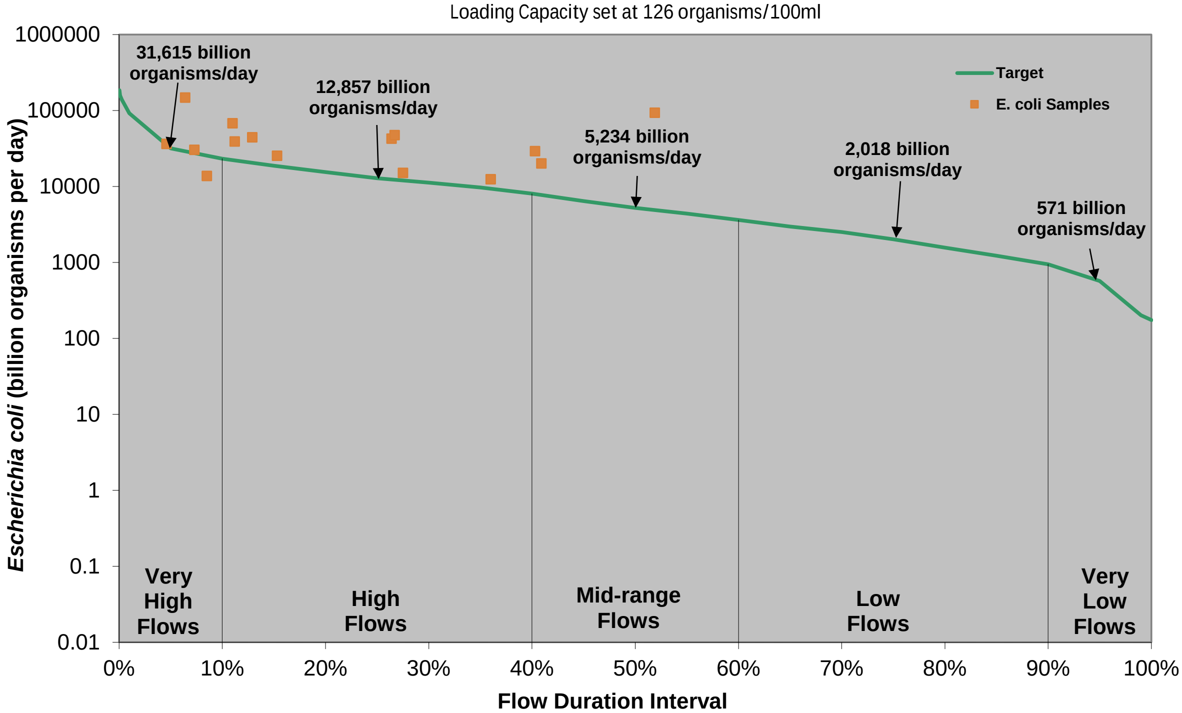
2010-2011 *E. coli* samples from EQuIS monitoring station S004-694
Loading Capacity set at 126 organisms/100ml



**Sacred Heart Creek** AUID# 07020004-526

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2007-2011 *E. coli* samples from EQuIS monitoring station S001-341
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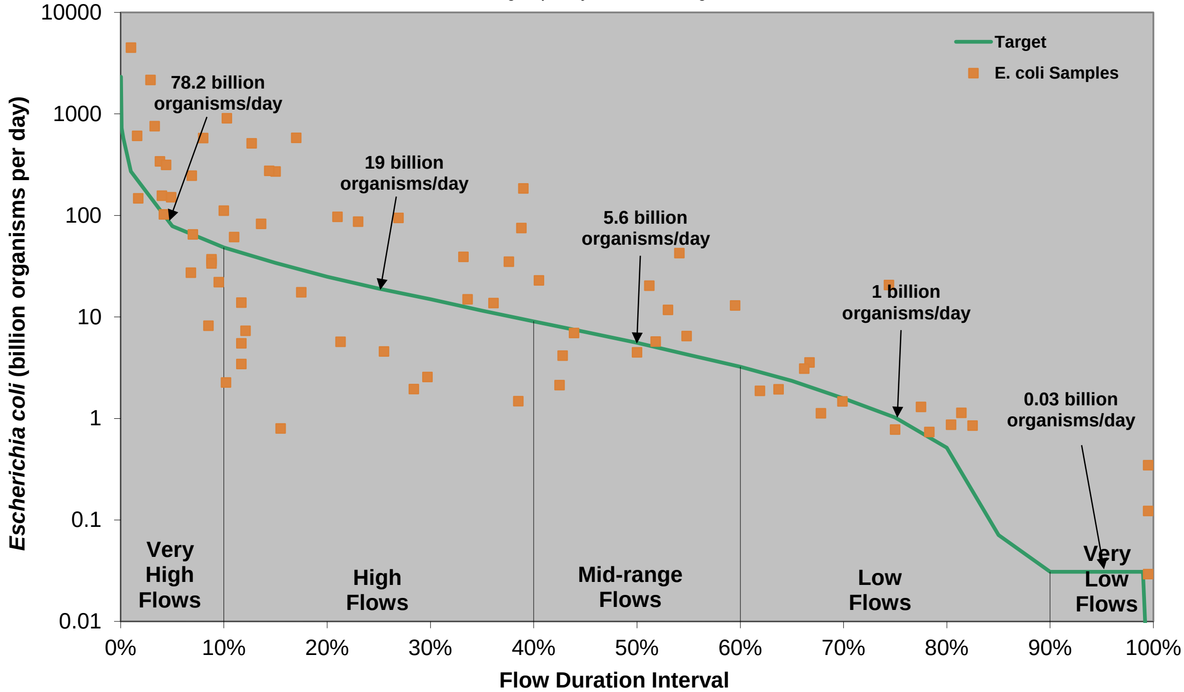
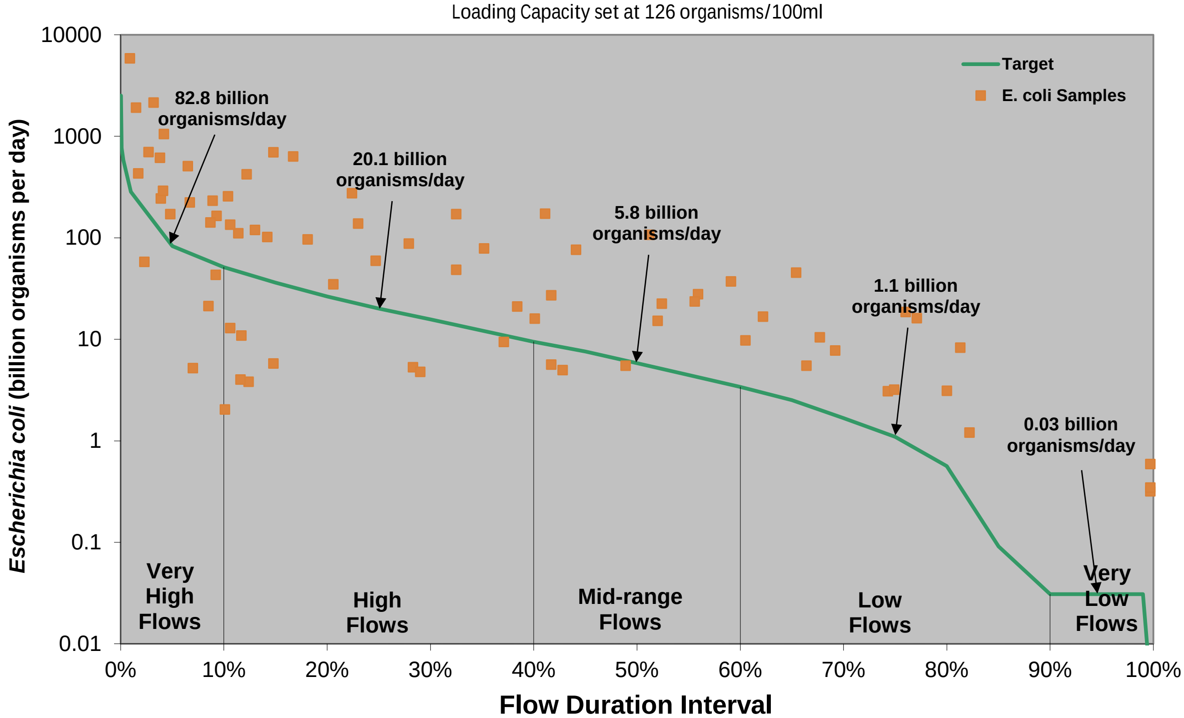



**Sacred Heart Creek - MN River** AUID# 07020004-525

1996-2012 Modeled Flows from the Hawk Creek HSPF model using April-October Average Daily Flows
2007-2011 *E. coli* samples from EQuIS monitoring station S003-867
Loading Capacity set at 126 organisms/100ml



**Stony Run Creek - MN River** AUID# 07020004-534

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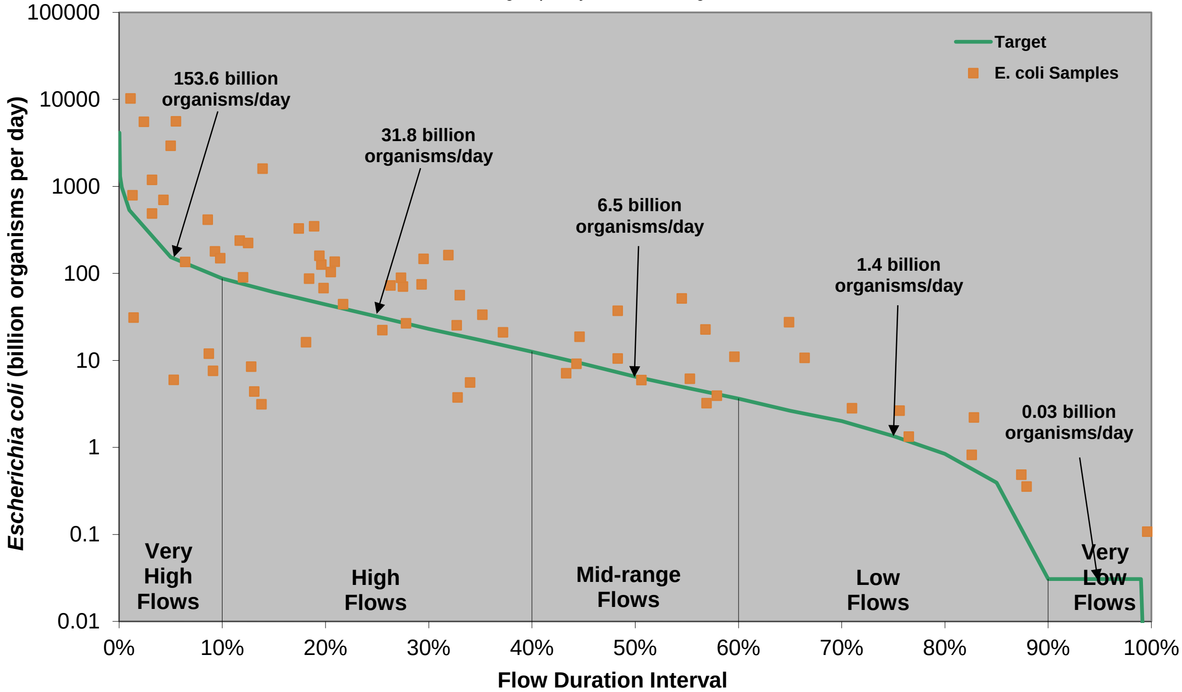


**West Fork Beaver Creek** AUID# 07020004-530

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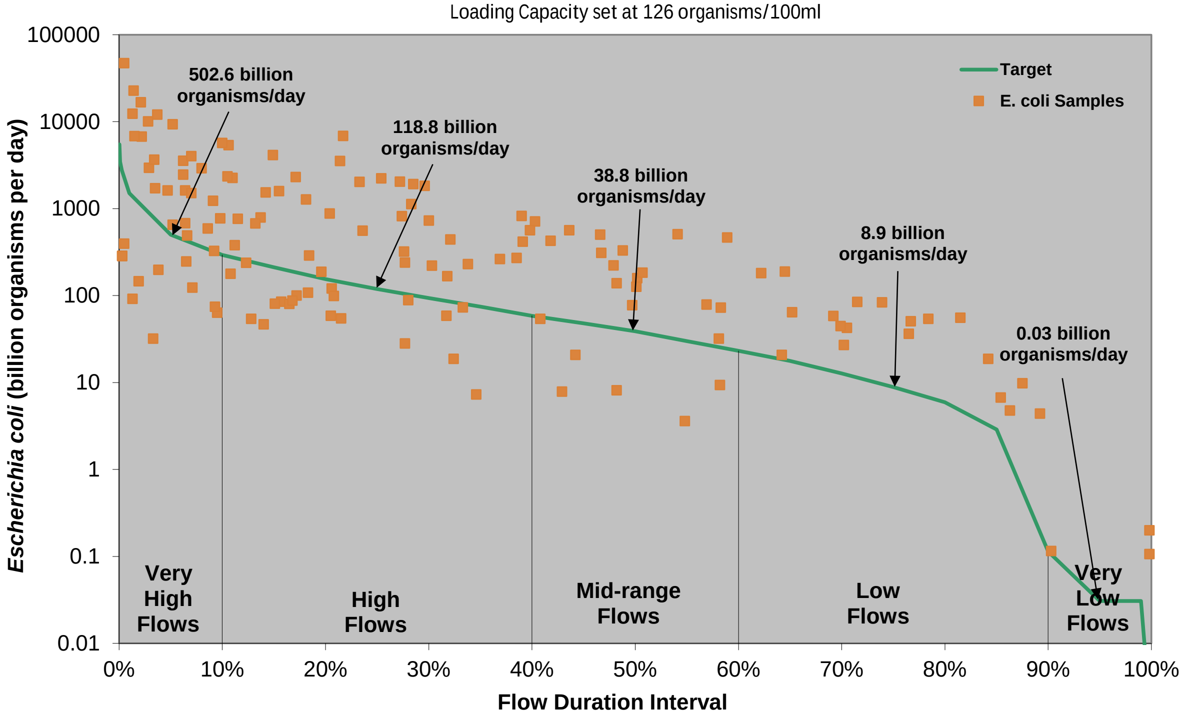
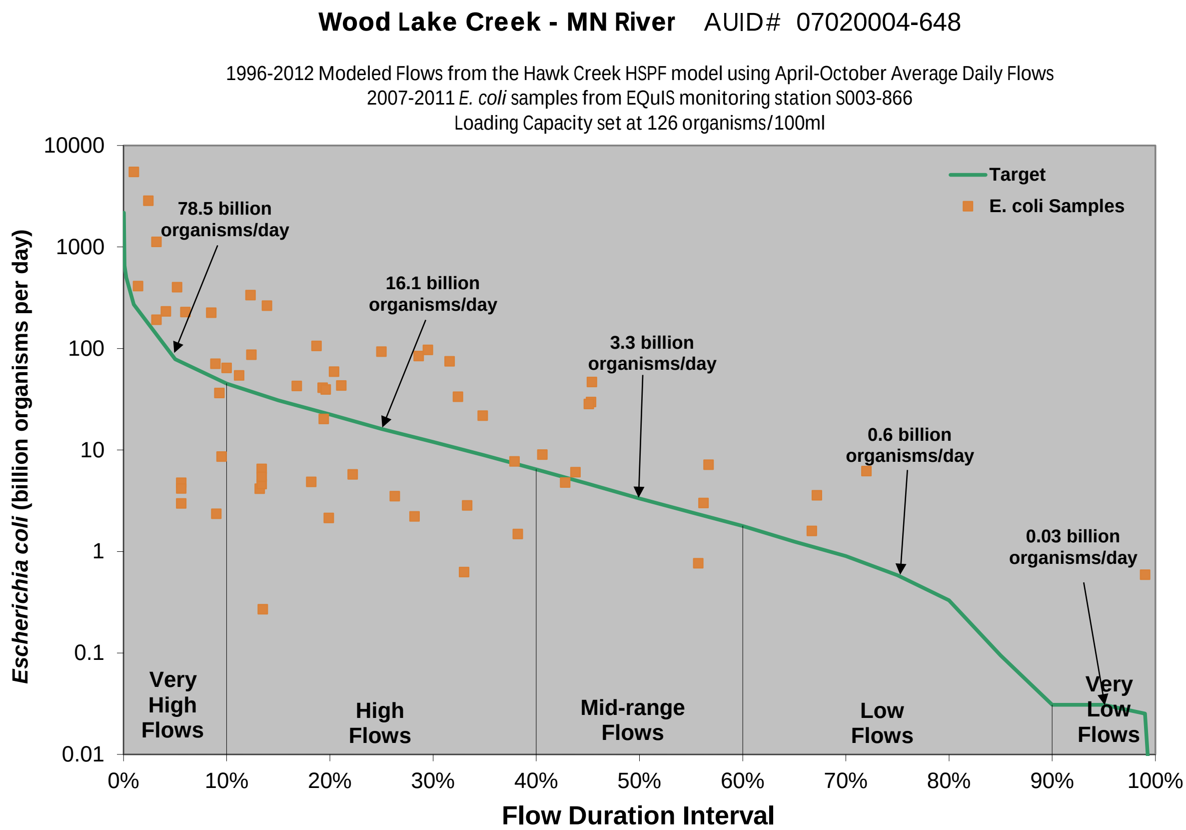
2007-2011 *E. coli* samples from EQuIS monitoring stations S006-138 and S000-405
Loading Capacity set at 126 organisms/100ml




Wood Lake Creek - MN River AUID# 07020004-648
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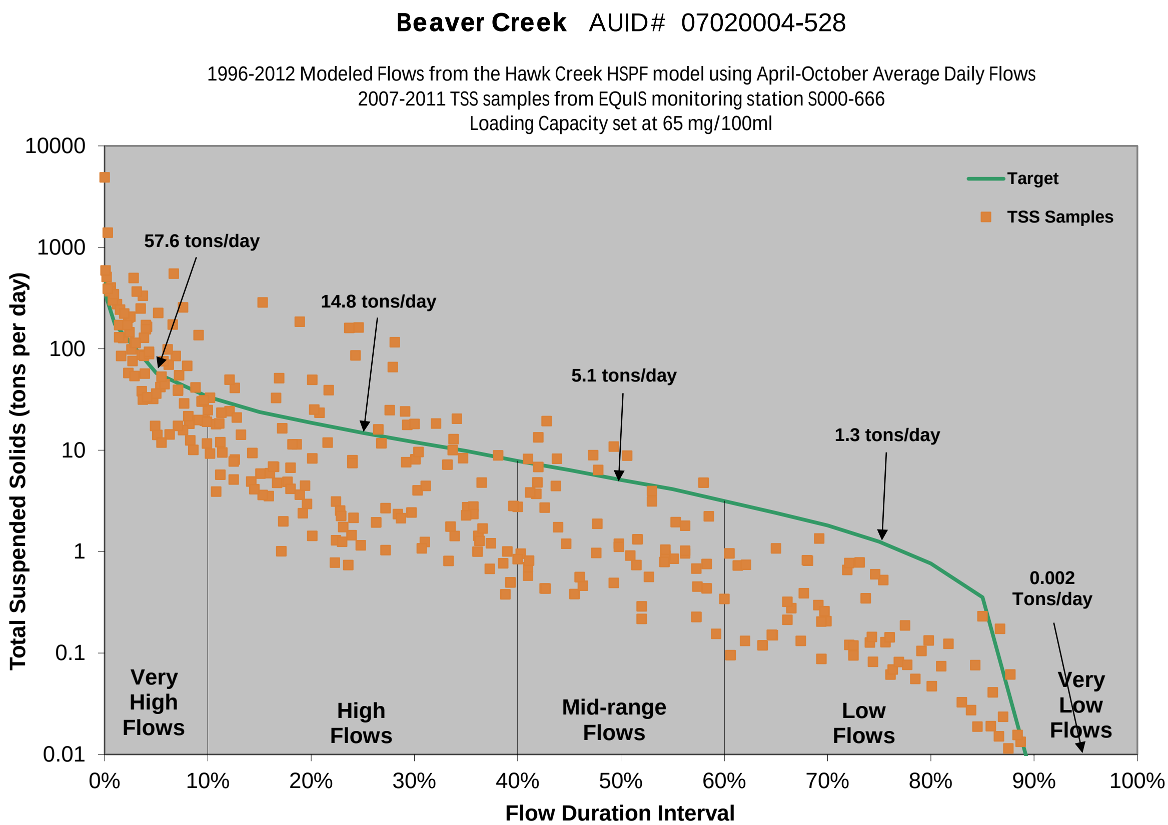
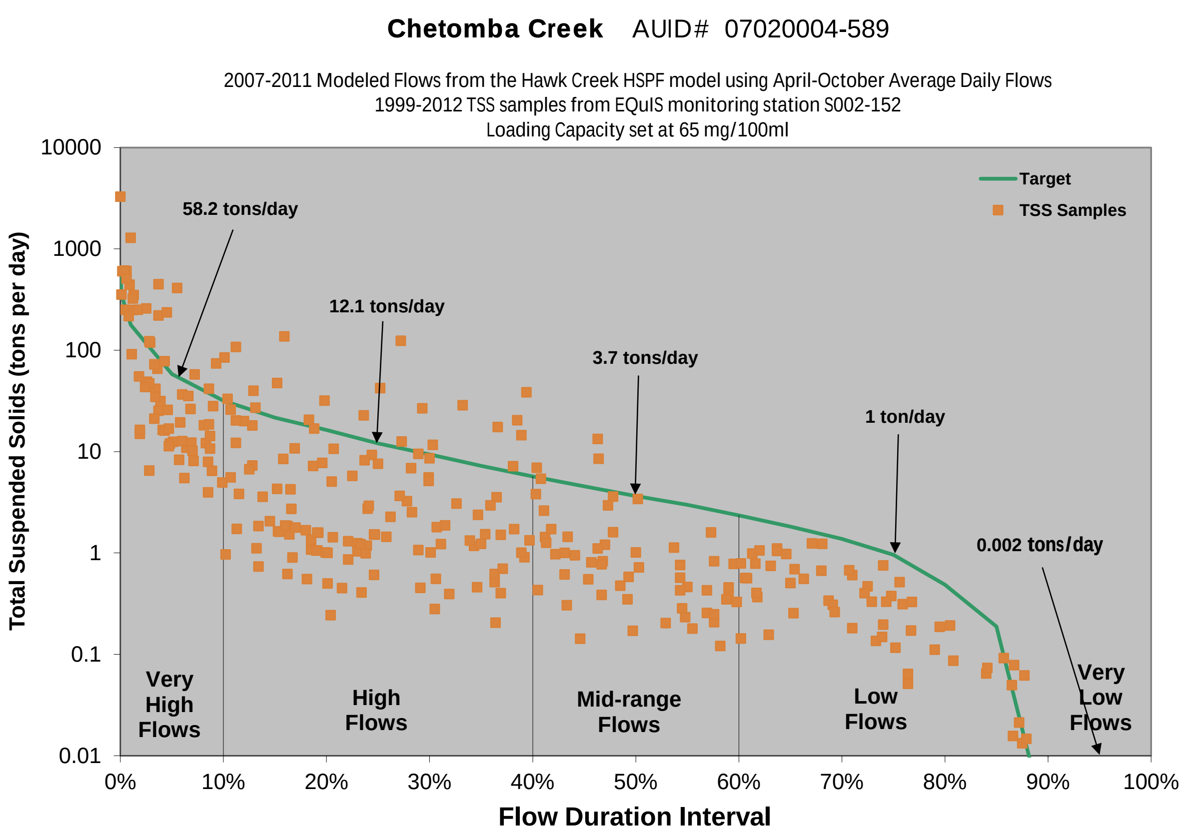
2007-2011 E. coli samples from EQuIS monitoring station S003-866
Loading Capacity set at 126 organisms/100ml
Target
E. coli Samples
78.5 billion organisms/day
16.1 billion organisms/day
3.3 billion organisms/day
0.6 billion organisms/day
0.03 billion organisms/day
Very High Flows
High Flows
Mid-range Flows
Low Flows
Very Low Flows
10000
1000
100
10
1
0.1
0.01
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Escherichia coli (billion organisms per day)
Flow Duration Interval

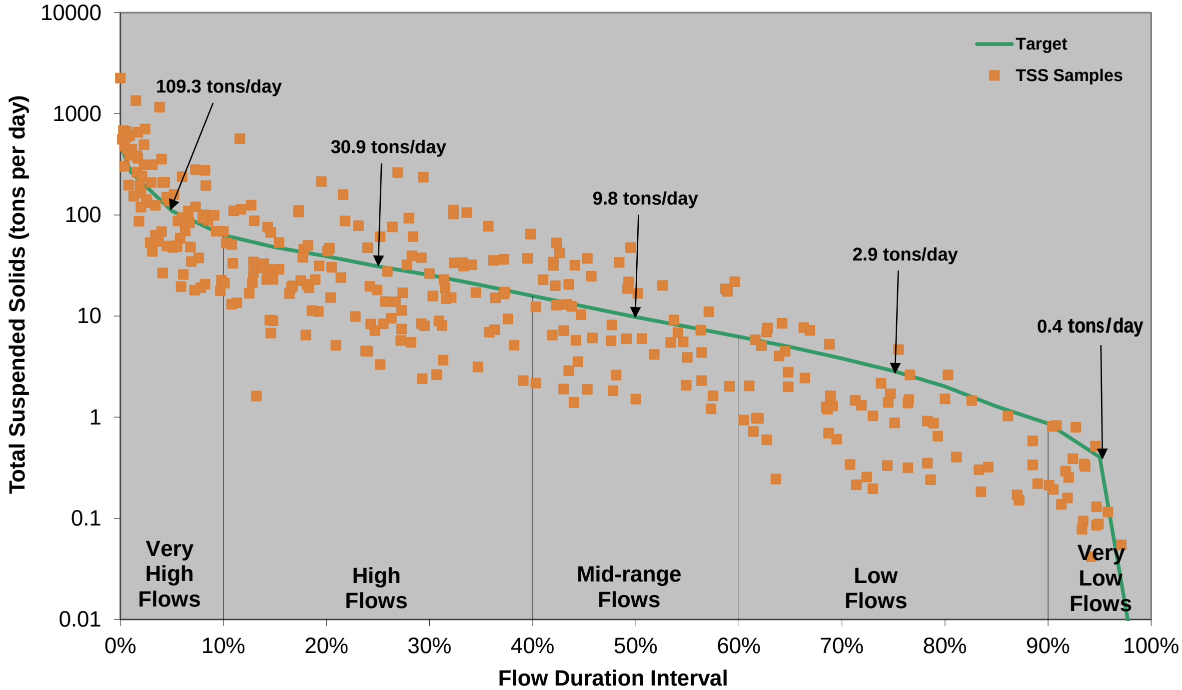
**Load duration curves for *TSS* stream reach impairments**



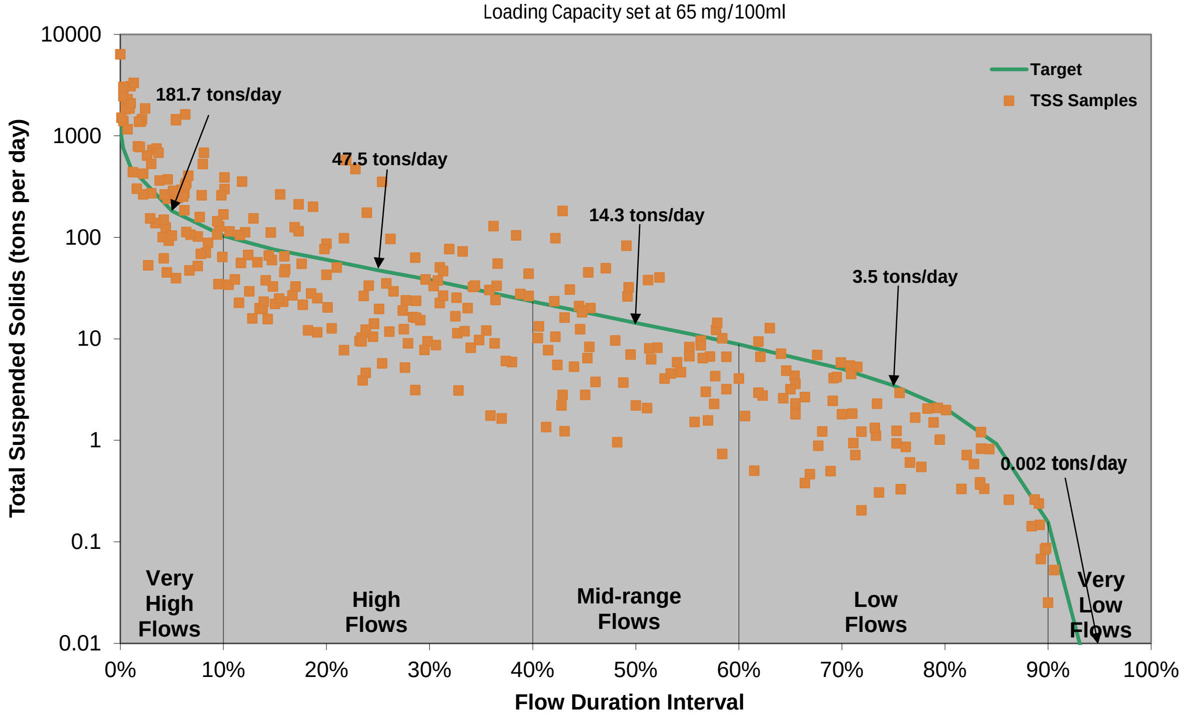
**Lower Hawk Creek** AUID# 07020004-568

1996-2012 Modeled Flows from the Hawk Creek HSPF model using April-October Average Daily Flows
2002-2011 TSS samples from EQuIS monitoring station S002-148
Loading Capacity set at 65 mg/100ml



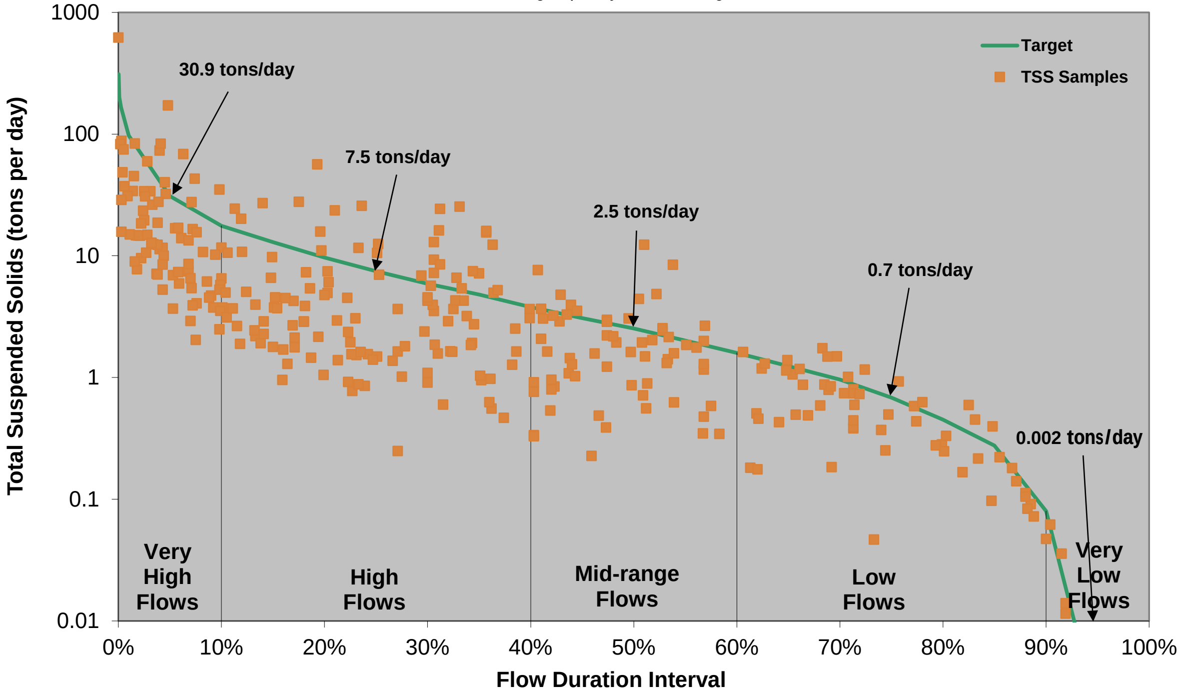

**Lower Hawk Creek** AUID# 07020004-587

1996-2012 Modeled Flows from the Hawk Creek HSPF model using April-October Average Daily Flows
2002-2011 TSS samples from EQuIS monitoring station S002-012
Loading Capacity set at 65 mg/100ml



**West Fork Beaver Creek** AUID# 07020004-530

1996-2012 Modeled Flows from the Hawk Creek HSPF model using April-October Average Daily Flows
2002-2011 TSS samples from EQuIS monitoring stations S000-405 and S006-138
Loading Capacity set at 65 mg/100ml



## Olson 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 | Olson Lake Shed | | 0.2 | 0.00E+00 | 0.00 | |
| PRECIPITATION | | | | 0.5 | 0.4 | 0.00E+00 | 0.00 | 0.72 |
| TRIBUTARY INFLOW | | | | | 0.0 | 0.00E+00 | 0.00 | |
| NONPOINT INFLOW | | | | | 0.2 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 0.5 | 0.6 | 0.00E+00 | 0.00 | 1.17 |
| ADVECTIVE OUTFLOW | | | | 0.5 | 0.1 | 0.00E+00 | 0.00 | 0.23 |
| ***TOTAL OUTFLOW | | | | 0.5 | 0.1 | 0.00E+00 | 0.00 | 0.23 |
| ***EVAPORATION | | | | | 0.5 | 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 | SSTS | 0.9 | 0.9% | 0.00E+00 | | 0.00 | 88.4 | |
| 2 | 2 | 1 | Olson Lake Shed | 28.5 | 29.3% | 0.00E+00 | | 0.00 | 131.3 | |
| PRECIPITATION | | | | 15.0 | 15.4% | 5.63E+01 | 100.0% | 0.50 | 41.7 | 30.0 |
| INTERNAL LOAD | | | | 53.0 | 54.4% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | | 0.9 | 0.9% | 0.00E+00 | | 0.00 | 88.4 | |
| NONPOINT INFLOW | | | | 28.5 | 29.3% | 0.00E+00 | | 0.00 | 131.3 | |
| ***TOTAL INFLOW | | | | 97.4 | 100.0% | 5.63E+01 | 100.0% | 0.08 | 165.9 | 194.8 |
| ADVECTIVE OUTFLOW | | | | 14.2 | 14.5% | 2.86E+01 | | 0.38 | 121.2 | 28.3 |
| ***TOTAL OUTFLOW | | | | 14.2 | 14.5% | 2.86E+01 | | 0.38 | 121.2 | 28.3 |
| ***RETENTION | | | | 83.2 | 85.5% | 7.49E+01 | | 0.10 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 0.2 | Nutrient Resid. Time (yrs) | 0.3733 |
| Hydraulic Resid. Time (yrs) | 2.5675 | Turnover Ratio | 2.7 |
| Reservoir Conc (mg/m3) | 121 | Retention Coef. | 0.855 |

## Olson 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 | Olson Lake Shed | | 0.2 | 0.00E+00 | 0.00 | |
| PRECIPITATION | | | | 0.5 | 0.4 | 0.00E+00 | 0.00 | 0.72 |
| TRIBUTARY INFLOW | | | | | 0.0 | 0.00E+00 | 0.00 | |
| NONPOINT INFLOW | | | | | 0.2 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 0.5 | 0.6 | 0.00E+00 | 0.00 | 1.17 |
| ADVECTIVE OUTFLOW | | | | 0.5 | 0.1 | 0.00E+00 | 0.00 | 0.23 |
| ***TOTAL OUTFLOW | | | | 0.5 | 0.1 | 0.00E+00 | 0.00 | 0.23 |
| ***EVAPORATION | | | | | 0.5 | 0.00E+00 | 0.00 | |

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

**Component:** — **TOTAL P**

| Trb | Type | Seg | Name | Load kg/yr | Load %Total | Load Variance (kg/yr)$^2$ | Load Variance %Total | CV | Conc mg/m$^3$ | Export kg/km$^2$/yr |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 1 | Olson Lake Shed | 18.0 | 30.1% | 0.00E+00 | | 0.00 | 83.0 | |
| PRECIPITATION | | | | 15.0 | 25.0% | 5.63E+01 | 100.0% | 0.50 | 41.7 | 30.0 |
| INTERNAL LOAD | | | | 26.8 | 44.8% | 0.00E+00 | | 0.00 | | |
| NONPOINT INFLOW | | | | 18.0 | 30.1% | 0.00E+00 | | 0.00 | 83.0 | |
| ***TOTAL INFLOW | | | | 59.9 | 100.0% | 5.62E+01 | 100.0% | 0.13 | 102.1 | 119.8 |
| ADVECTIVE OUTFLOW | | | | 10.5 | 17.5% | 1.51E+01 | | 0.37 | 89.9 | 21.0 |
| ***TOTAL OUTFLOW | | | | 10.5 | 17.5% | 1.51E+01 | | 0.37 | 89.9 | 21.0 |
| ***RETENTION | | | | 49.4 | 82.5% | 5.91E+01 | | 0.16 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 0.2 | Nutrient Resid. Time (yrs) | 0.4501 |
| Hydraulic Resid. Time (yrs) | 2.5675 | Turnover Ratio | 2.2 |
| Reservoir Conc (mg/m3) | 90 | Retention Coef. | 0.825 |

## Saint John's 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 | Saint John's Lake Shed | | 1.1 | 0.00E+00 | 0.00 | |
| 3 | 1 | 1 | R:209 | | 2.5 | 0.00E+00 | 0.00 | |
| PRECIPITATION | | | | 0.8 | 0.6 | 0.00E+00 | 0.00 | 0.72 |
| TRIBUTARY INFLOW | | | | | 2.5 | 0.00E+00 | 0.00 | |
| NONPOINT INFLOW | | | | | 1.1 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 0.8 | 4.2 | 0.00E+00 | 0.00 | 5.35 |
| ADVECTIVE OUTFLOW | | | | 0.8 | 3.4 | 0.00E+00 | 0.00 | 4.41 |
| ***TOTAL OUTFLOW | | | | 0.8 | 3.4 | 0.00E+00 | 0.00 | 4.41 |
| ***EVAPORATION | | | | | 0.7 | 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)$^2$ | %Total | CV | Conc mg/m$^3$ | Export kg/km$^2$/yr |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | SSTS | 2.7 | 0.2% | 0.00E+00 | | 0.00 | 273.5 | |
| 2 | 2 | 1 | Saint John's Lake Shed | 268.3 | 22.9% | 0.00E+00 | | 0.00 | 245.1 | |
| 3 | 1 | 1 | R:209 | 181.2 | 15.4% | 0.00E+00 | | 0.00 | 72.4 | |
| PRECIPITATION | | | | 23.4 | 2.0% | 1.37E+02 | 100.0% | 0.50 | 41.4 | 30.0 |
| INTERNAL LOAD | | | | 698.0 | 59.5% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | | 183.9 | 15.7% | 0.00E+00 | | 0.00 | 73.3 | |
| NONPOINT INFLOW | | | | 268.3 | 22.9% | 0.00E+00 | | 0.00 | 245.1 | |
| ***TOTAL INFLOW | | | | 1173.6 | 100.0% | 1.37E+02 | 100.0% | 0.01 | 281.4 | 1504.6 |
| ADVECTIVE OUTFLOW | | | | 531.3 | 45.3% | 1.66E+04 | | 0.24 | 154.6 | 681.1 |
| ***TOTAL OUTFLOW | | | | 531.3 | 45.3% | 1.66E+04 | | 0.24 | 154.6 | 681.1 |
| ***RETENTION | | | | 642.3 | 54.7% | 1.66E+04 | | 0.20 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 4.4 | Nutrient Resid. Time (yrs) | 0.1336 |
| Hydraulic Resid. Time (yrs) | 0.2950 | Turnover Ratio | 7.5 |
| Reservoir Conc (mg/m3) | 155 | Retention Coef. | 0.547 |

## Saint John's 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 | Saint John's Lake Shed | | 1.1 | 0.00E+00 | 0.00 | |
| 3 | 1 | 1 | R:209 | | 2.5 | 0.00E+00 | 0.00 | |
| PRECIPITATION | | | | 0.8 | 0.6 | 0.00E+00 | 0.00 | 0.72 |
| TRIBUTARY INFLOW | | | | | 2.5 | 0.00E+00 | 0.00 | |
| NONPOINT INFLOW | | | | | 1.1 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 0.8 | 4.2 | 0.00E+00 | 0.00 | 5.35 |
| ADVECTIVE OUTFLOW | | | | 0.8 | 3.4 | 0.00E+00 | 0.00 | 4.41 |
| ***TOTAL OUTFLOW | | | | 0.8 | 3.4 | 0.00E+00 | 0.00 | 4.41 |
| ***EVAPORATION | | | | | 0.7 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 1 | Saint John's Lake Shed | 129.7 | 22.2% | 0.00E+00 | | 0.00 | 118.5 | |
| 3 | 1 | 1 | R:209 | 181.2 | 31.0% | 0.00E+00 | | 0.00 | 72.4 | |
| PRECIPITATION | | | | 23.4 | 4.0% | 1.37E+02 | 100.0% | 0.50 | 41.4 | 30.0 |
| INTERNAL LOAD | | | | 249.6 | 42.7% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | | 181.2 | 31.0% | 0.00E+00 | | 0.00 | 72.2 | |
| NONPOINT INFLOW | | | | 129.7 | 22.2% | 0.00E+00 | | 0.00 | 118.5 | |
| ***TOTAL INFLOW | | | | 583.9 | 100.0% | 1.37E+02 | 100.0% | 0.02 | 140.0 | 748.6 |
| ADVECTIVE OUTFLOW | | | | 310.9 | 53.2% | 4.18E+03 | | 0.21 | 90.4 | 398.6 |
| ***TOTAL OUTFLOW | | | | 310.9 | 53.2% | 4.18E+03 | | 0.21 | 90.4 | 398.6 |
| ***RETENTION | | | | 273.0 | 46.8% | 4.21E+03 | | 0.24 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 4.4 | Nutrient Resid. Time (yrs) | 0.1571 |
| Hydraulic Resid. Time (yrs) | 0.2950 | Turnover Ratio | 6.4 |
| Reservoir Conc (mg/m3) | 90 | Retention Coef. | 0.468 |

## Swan 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 | Swan Lake Shed | | 1.1 | 0.00E+00 | 0.00 | |
| 3 | 1 | 1 | R:215 | 46.1 | 4.8 | 0.00E+00 | 0.00 | 0.10 |
| PRECIPITATION | | | | 0.8 | 0.6 | 0.00E+00 | 0.00 | 0.74 |
| TRIBUTARY INFLOW | | | | 46.1 | 4.8 | 0.00E+00 | 0.00 | 0.10 |
| NONPOINT INFLOW | | | | | 1.1 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 47.0 | 6.5 | 0.00E+00 | 0.00 | 0.14 |
| ADVECTIVE OUTFLOW | | | | 47.0 | 5.7 | 0.00E+00 | 0.00 | 0.12 |
| ***TOTAL OUTFLOW | | | | 47.0 | 5.7 | 0.00E+00 | 0.00 | 0.12 |
| ***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 | %Total | CV | Conc mg/m³ | Export kg/km²/yr |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | SSTS | 1.9 | 0.2% | 0.00E+00 | | 0.00 | 189.0 | |
| 2 | 2 | 1 | Swan Lake Shed | 244.1 | 24.0% | 0.00E+00 | | 0.00 | 229.2 | |
| 3 | 1 | 1 | R:215 | 411.7 | 40.5% | 0.00E+00 | | 0.00 | 86.3 | 8.9 |
| PRECIPITATION | | | | 24.9 | 2.5% | 1.55E+02 | 100.0% | 0.50 | 40.8 | 30.0 |
| INTERNAL LOAD | | | | 333.5 | 32.8% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | | 413.6 | 40.7% | 0.00E+00 | | 0.00 | 86.5 | 9.0 |
| NONPOINT INFLOW | | | | 244.1 | 24.0% | 0.00E+00 | | 0.00 | 229.2 | |
| ***TOTAL INFLOW | | | | 1016.1 | 100.0% | 1.55E+02 | 100.0% | 0.01 | 157.4 | 21.6 |
| ADVECTIVE OUTFLOW | | | | 629.2 | 61.9% | 1.14E+04 | | 0.17 | 110.9 | 13.4 |
| ***TOTAL OUTFLOW | | | | 629.2 | 61.9% | 1.14E+04 | | 0.17 | 110.9 | 13.4 |
| ***RETENTION | | | | 386.9 | 38.1% | 1.14E+04 | | 0.28 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 6.8 | Nutrient Resid. Time (yrs) | 0.0906 |
| Hydraulic Resid. Time (yrs) | 0.1463 | Turnover Ratio | 11.0 |
| Reservoir Conc (mg/m3) | 111 | Retention Coef. | 0.381 |

## Swan 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 | Swan Lake Shed | | 1.1 | 0.00E+00 | 0.00 | |
| 3 | 1 | 1 | R:215 | 46.1 | 4.8 | 0.00E+00 | 0.00 | 0.10 |
| PRECIPITATION | | | | 0.8 | 0.6 | 0.00E+00 | 0.00 | 0.74 |
| TRIBUTARY INFLOW | | | | 46.1 | 4.8 | 0.00E+00 | 0.00 | 0.10 |
| NONPOINT INFLOW | | | | | 1.1 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 47.0 | 6.5 | 0.00E+00 | 0.00 | 0.14 |
| ADVECTIVE OUTFLOW | | | | 47.0 | 5.7 | 0.00E+00 | 0.00 | 0.12 |
| ***TOTAL OUTFLOW | | | | 47.0 | 5.7 | 0.00E+00 | 0.00 | 0.12 |
| ***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)$^2$ | %Total | CV | Conc mg/m$^3$ | Export kg/km$^2$/yr |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 1 | Swan Lake Shed | 135.5 | 17.2% | 0.00E+00 | | 0.00 | 127.3 | |
| 3 | 1 | 1 | R:215 | 411.7 | 52.2% | 0.00E+00 | | 0.00 | 86.3 | 8.9 |
| PRECIPITATION | | | | 24.9 | 3.2% | 1.55E+02 | 100.0% | 0.50 | 40.8 | 30.0 |
| INTERNAL LOAD | | | | 216.6 | 27.5% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | | 411.7 | 52.2% | 0.00E+00 | | 0.00 | 86.1 | 8.9 |
| NONPOINT INFLOW | | | | 135.5 | 17.2% | 0.00E+00 | | 0.00 | 127.3 | |
| ***TOTAL INFLOW | | | | 788.8 | 100.0% | 1.55E+02 | 100.0% | 0.02 | 122.2 | 16.8 |
| ADVECTIVE OUTFLOW | | | | 509.7 | 64.6% | 6.49E+03 | | 0.16 | 89.8 | 10.9 |
| ***TOTAL OUTFLOW | | | | 509.7 | 64.6% | 6.49E+03 | | 0.16 | 89.8 | 10.9 |
| ***RETENTION | | | | 279.1 | 35.4% | 6.48E+03 | | 0.29 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 6.8 | Nutrient Resid. Time (yrs) | 0.0945 |
| Hydraulic Resid. Time (yrs) | 0.1463 | Turnover Ratio | 10.6 |
| Reservoir Conc (mg/m3) | 90 | Retention Coef. | 0.354 |

## West Solomon 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 | West Solomon Shed | | 4.0 | 0.00E+00 | 0.00 | |
| 3 | 1 | 1 | R:210 | 33.9 | 0.3 | 0.00E+00 | 0.00 | 0.01 |
| PRECIPITATION | | | | 2.3 | 1.6 | 0.00E+00 | 0.00 | 0.72 |
| TRIBUTARY INFLOW | | | | 33.9 | 0.3 | 0.00E+00 | 0.00 | 0.01 |
| NONPOINT INFLOW | | | | | 4.0 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 36.1 | 6.0 | 0.00E+00 | 0.00 | 0.17 |
| ADVECTIVE OUTFLOW | | | | 36.1 | 3.9 | 0.00E+00 | 0.00 | 0.11 |
| ***TOTAL OUTFLOW | | | | 36.1 | 3.9 | 0.00E+00 | 0.00 | 0.11 |
| ***EVAPORATION | | | | | 2.1 | 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)$^2$ | %Total | CV | Conc mg/m$^3$ | Export kg/km$^2$/yr |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | SSTS | 9.6 | 0.6% | 0.00E+00 | | 0.00 | 960.3 | |
| 2 | 2 | 1 | West Solomon Shed | 955.3 | 55.3% | 0.00E+00 | | 0.00 | 237.0 | |
| 3 | 1 | 1 | R:210 | 13.3 | 0.8% | 0.00E+00 | | 0.00 | 43.8 | 0.4 |
| PRECIPITATION | | | | 68.1 | 3.9% | 1.16E+03 | 100.0% | 0.50 | 41.4 | 30.0 |
| INTERNAL LOAD | | | | 679.9 | 39.4% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | | 23.0 | 1.3% | 0.00E+00 | | 0.00 | 72.9 | 0.7 |
| NONPOINT INFLOW | | | | 955.3 | 55.3% | 0.00E+00 | | 0.00 | 237.0 | |
| ***TOTAL INFLOW | | | | 1726.2 | 100.0% | 1.16E+03 | 100.0% | 0.02 | 288.2 | 47.8 |
| ADVECTIVE OUTFLOW | | | | 434.2 | 25.2% | 2.05E+04 | | 0.33 | 112.6 | 12.0 |
| ***TOTAL OUTFLOW | | | | 434.2 | 25.2% | 2.05E+04 | | 0.33 | 112.6 | 12.0 |
| ***RETENTION | | | | 1292.1 | 74.8% | 2.13E+04 | | 0.11 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 1.7 | Nutrient Resid. Time (yrs) | 0.3110 |
| Hydraulic Resid. Time (yrs) | 1.2364 | Turnover Ratio | 3.2 |
| Reservoir Conc (mg/m3) | 113 | Retention Coef. | 0.748 |

## West Solomon Lake BATHTUB Model Run – Modeled to Phosphorus Standard

**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 | West Solomon Shed | | 4.0 | 0.00E+00 | 0.00 | |
| 3 | 1 | 1 | R:210 | 33.9 | 0.3 | 0.00E+00 | 0.00 | 0.01 |
| PRECIPITATION | | | | 2.3 | 1.6 | 0.00E+00 | 0.00 | 0.72 |
| TRIBUTARY INFLOW | | | | 33.9 | 0.3 | 0.00E+00 | 0.00 | 0.01 |
| NONPOINT INFLOW | | | | | 4.0 | 0.00E+00 | 0.00 | |
| ***TOTAL INFLOW | | | | 36.1 | 6.0 | 0.00E+00 | 0.00 | 0.17 |
| ADVECTIVE OUTFLOW | | | | 36.1 | 3.9 | 0.00E+00 | 0.00 | 0.11 |
| ***TOTAL OUTFLOW | | | | 36.1 | 3.9 | 0.00E+00 | 0.00 | 0.11 |
| ***EVAPORATION | | | | | 2.1 | 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2 | 1 | West Solomon Shed | 467.0 | 38.0% | 0.00E+00 | | 0.00 | 115.9 | |
| 3 | 1 | 1 | R:210 | 13.3 | 1.1% | 0.00E+00 | | 0.00 | 43.8 | 0.4 |
| PRECIPITATION | | | | 68.1 | 5.5% | 1.16E+03 | 100.0% | 0.50 | 41.4 | 30.0 |
| INTERNAL LOAD | | | | 679.9 | 55.3% | 0.00E+00 | | 0.00 | | |
| TRIBUTARY INFLOW | | | | 13.3 | 1.1% | 0.00E+00 | | 0.00 | 42.4 | 0.4 |
| NONPOINT INFLOW | | | | 467.0 | 38.0% | 0.00E+00 | | 0.00 | 115.9 | |
| ***TOTAL INFLOW | | | | 1228.4 | 100.0% | 1.16E+03 | 100.0% | 0.03 | 205.1 | 34.0 |
| ADVECTIVE OUTFLOW | | | | 346.4 | 28.2% | 1.20E+04 | | 0.32 | 89.8 | 9.6 |
| ***TOTAL OUTFLOW | | | | 346.4 | 28.2% | 1.20E+04 | | 0.32 | 89.8 | 9.6 |
| ***RETENTION | | | | 882.0 | 71.8% | 1.28E+04 | | 0.13 | | |

| | | | |
|---|---|---|---|
| Overflow Rate (m/yr) | 1.7 | Nutrient Resid. Time (yrs) | 0.3486 |
| Hydraulic Resid. Time (yrs) | 1.2364 | Turnover Ratio | 2.9 |
| Reservoir Conc (mg/m3) | 90 | Retention Coef. | 0.718 |

# 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

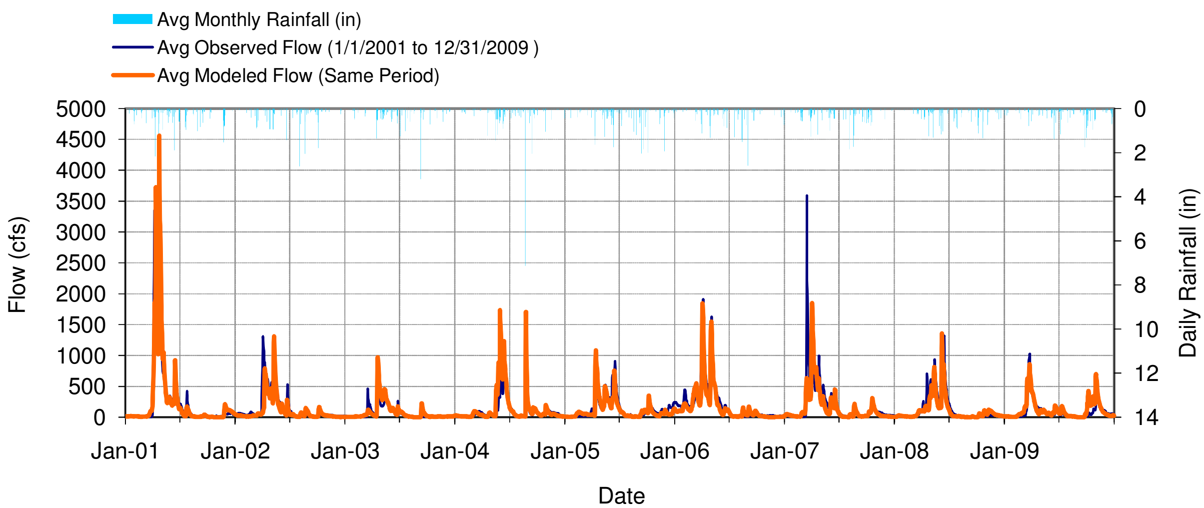



**Figure 1. Mean daily flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

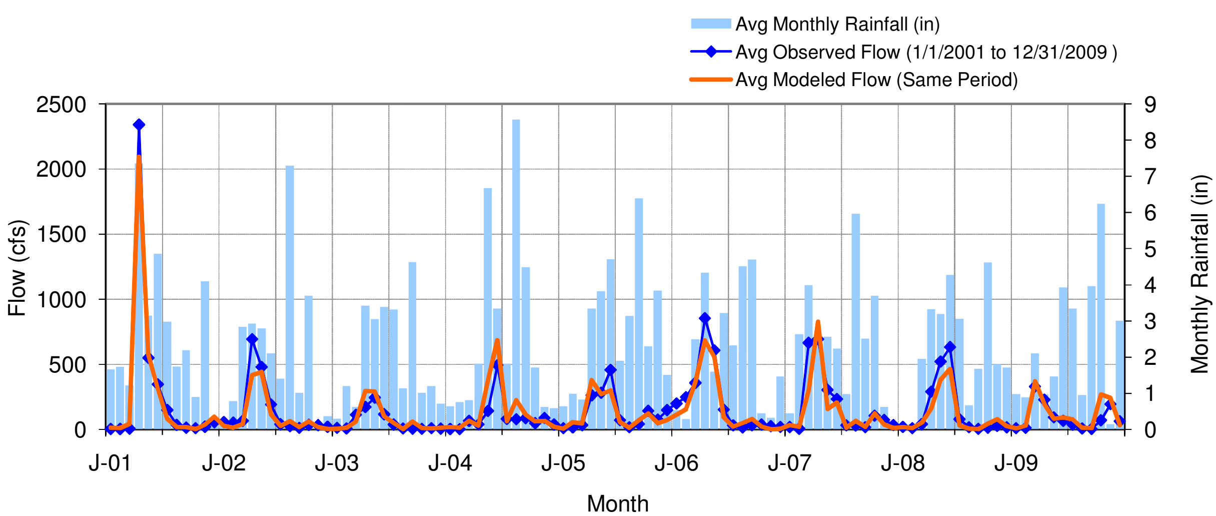



**Figure 2. Mean monthly flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

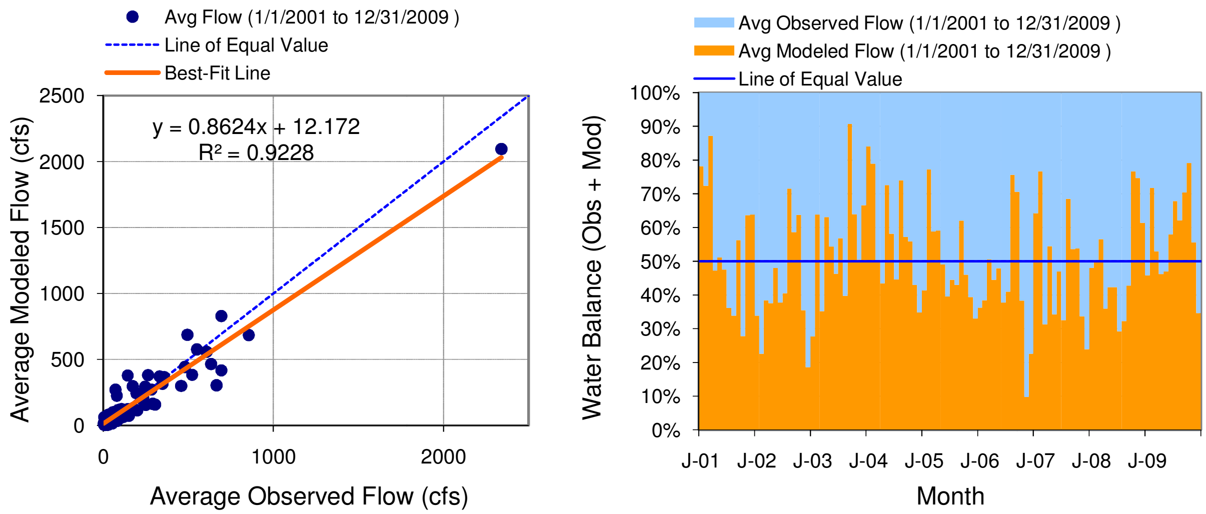



**Figure 3. Monthly flow regression and temporal variation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

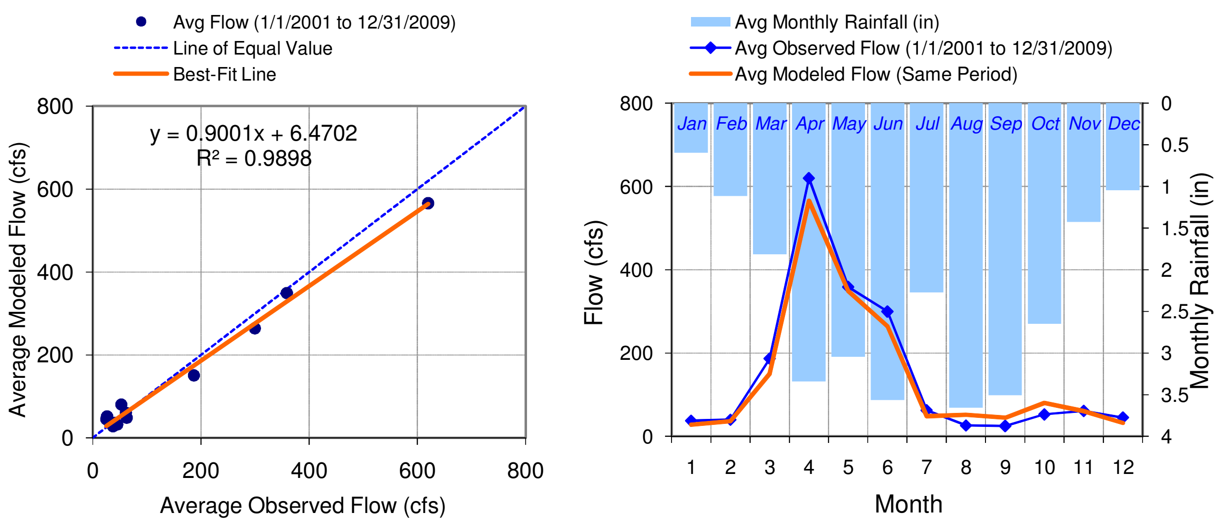



**Figure 4. Seasonal regression and temporal aggregate: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

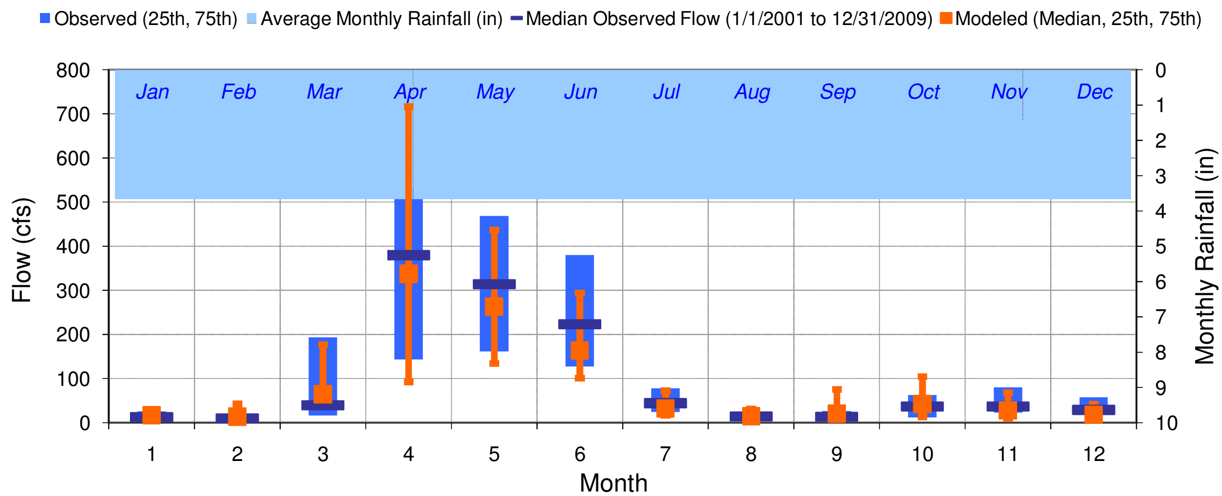



**Figure 5. Seasonal medians and ranges: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

**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 |

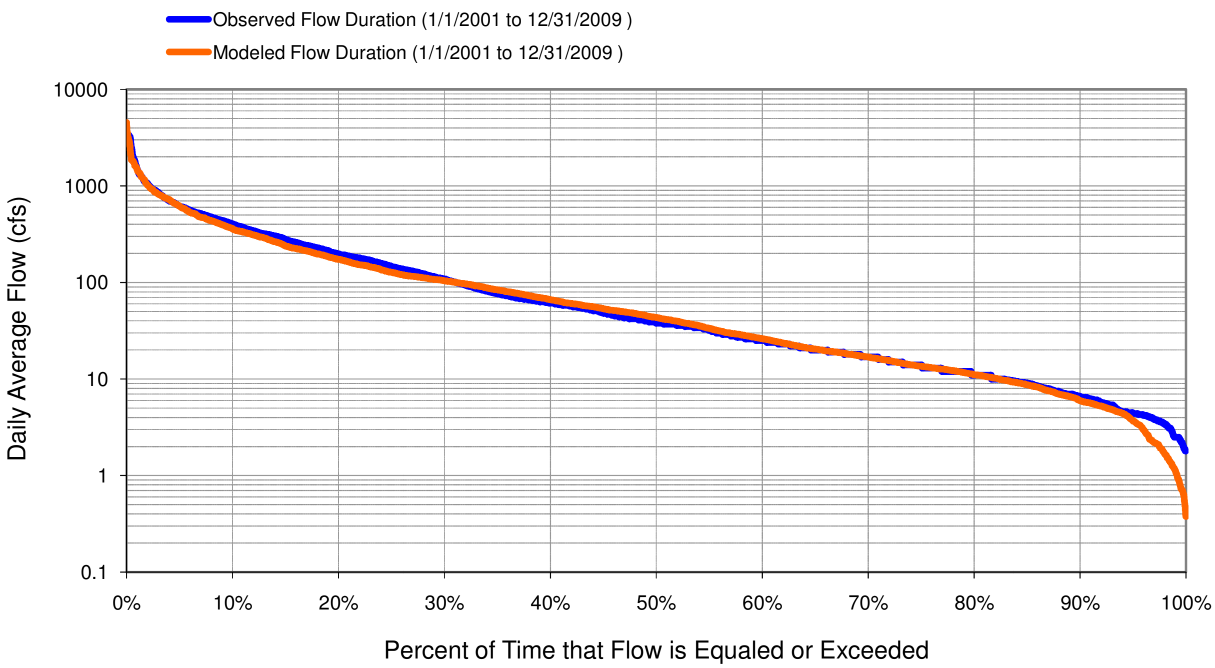



**Figure 6. Flow exceedence: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

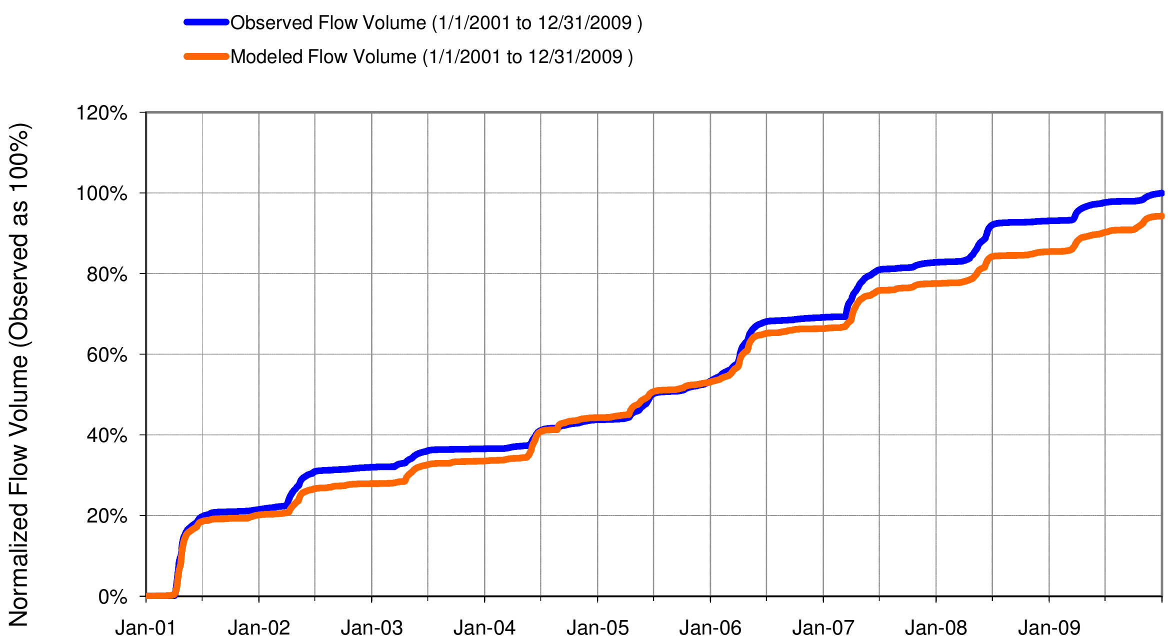



**Figure 7. Flow accumulation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN**

**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<br><br>9-Year Analysis Period: 1/1/2001 - 12/31/2009<br>Flow volumes are (inches/year) for upstream drainage area | | USGS 05313500 YELLOW MEDICINE RIVER NEAR GRANITE FALLS, MN<br><br>Hydrologic Unit Code: 7020004<br>Latitude: 44.72166667<br>Longitude: -95.5188889<br>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

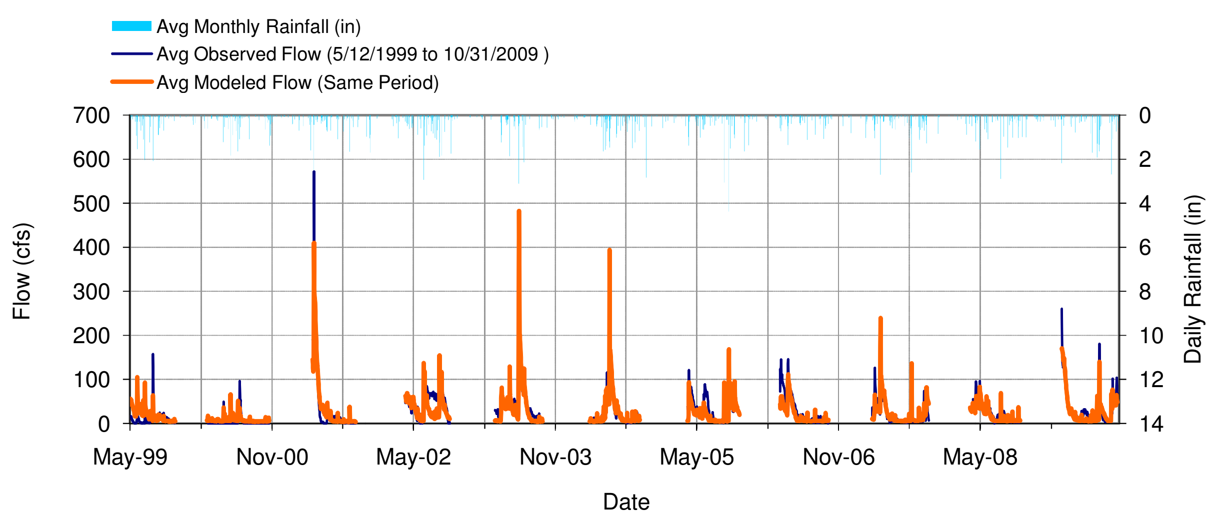



**Figure 8. Mean daily flow: Model DSN 700 vs. Hawk Creek - Priam (S002-140)**

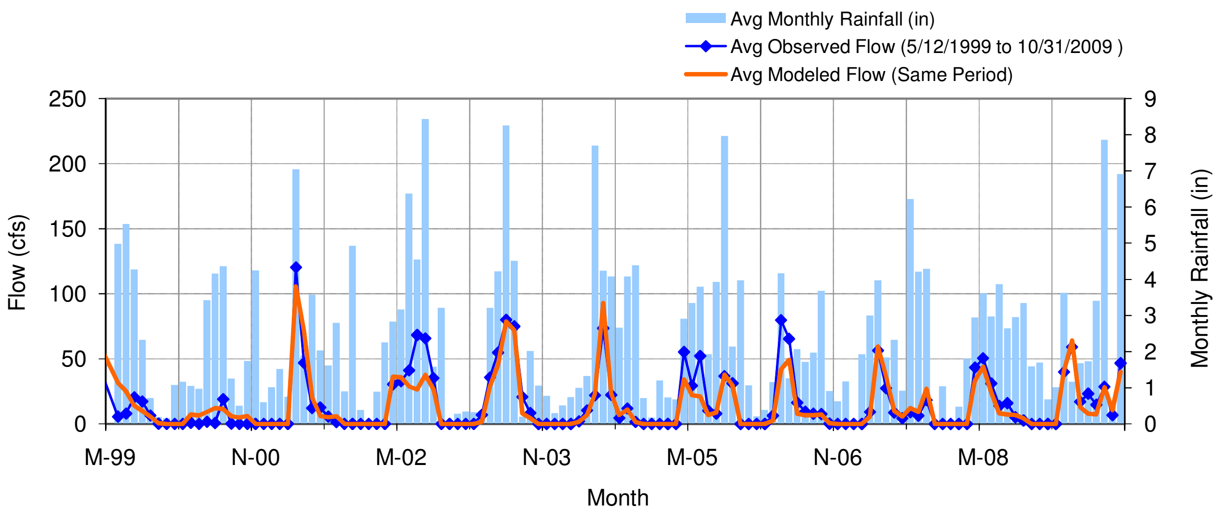
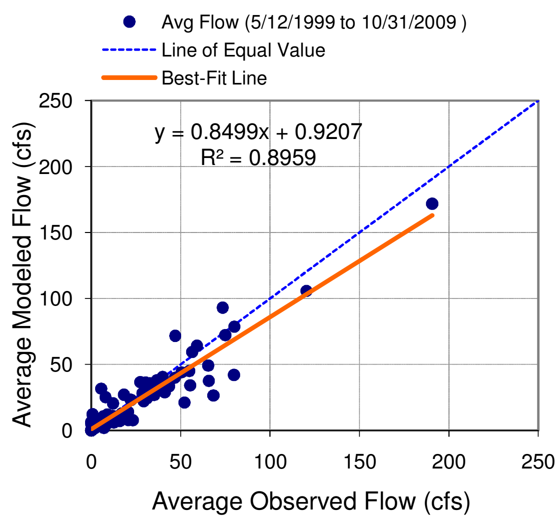



**Figure 9. Mean monthly flow: Model DSN 700 vs. Hawk Creek - Priam (S002-140)**



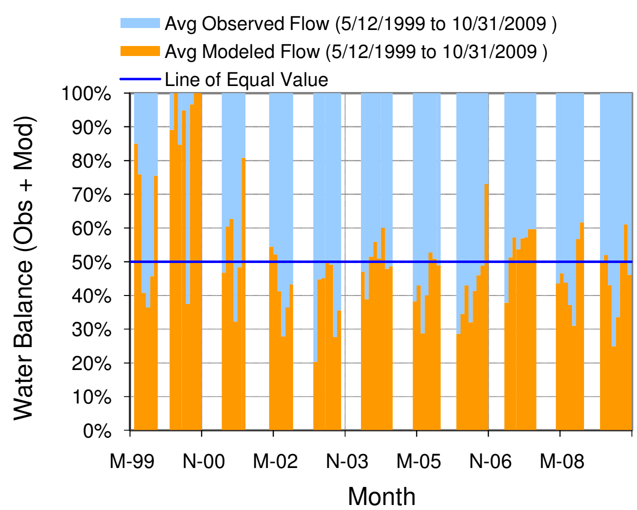




**Figure 10. Monthly flow regression and temporal variation: Model DSN 700 vs. Hawk Creek - Priam (S002-140)**

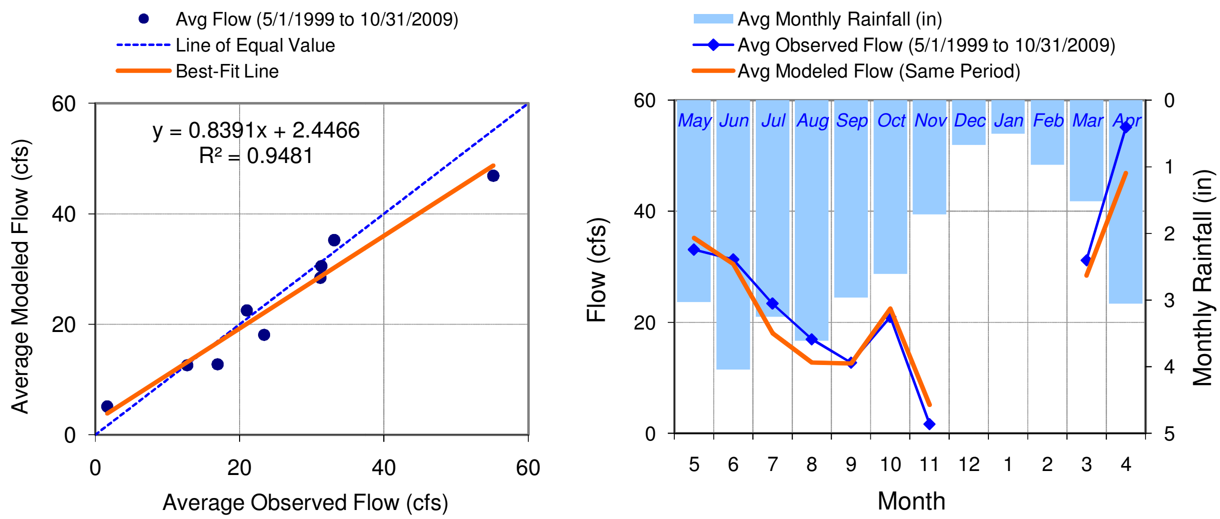



**Figure 11. Seasonal regression and temporal aggregate: Model DSN 700 vs. Hawk Creek - Priam (S002-140)**

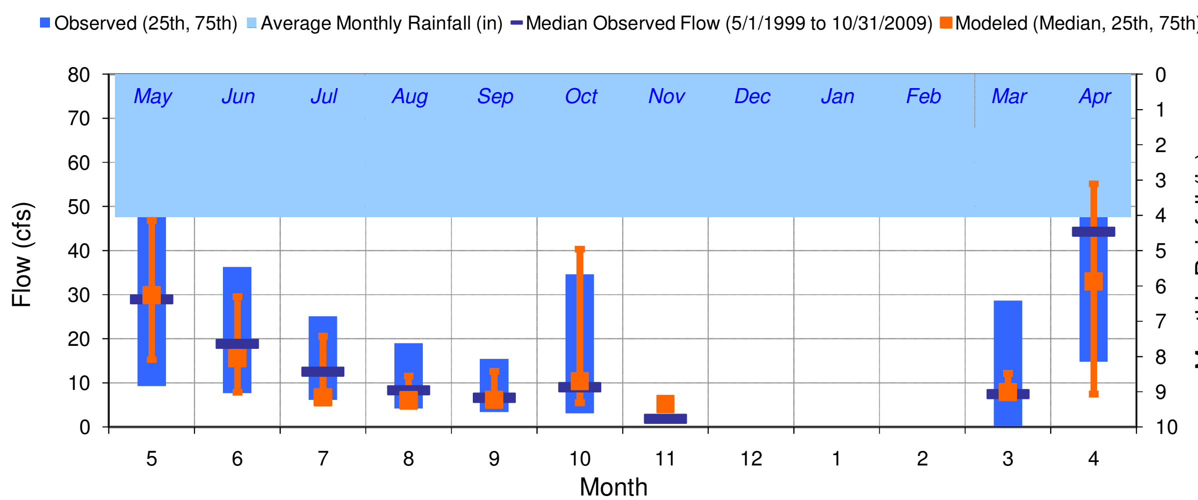



**Figure 12. Seasonal medians and ranges: Model DSN 700 vs. Hawk Creek - Priam (S002-140)**

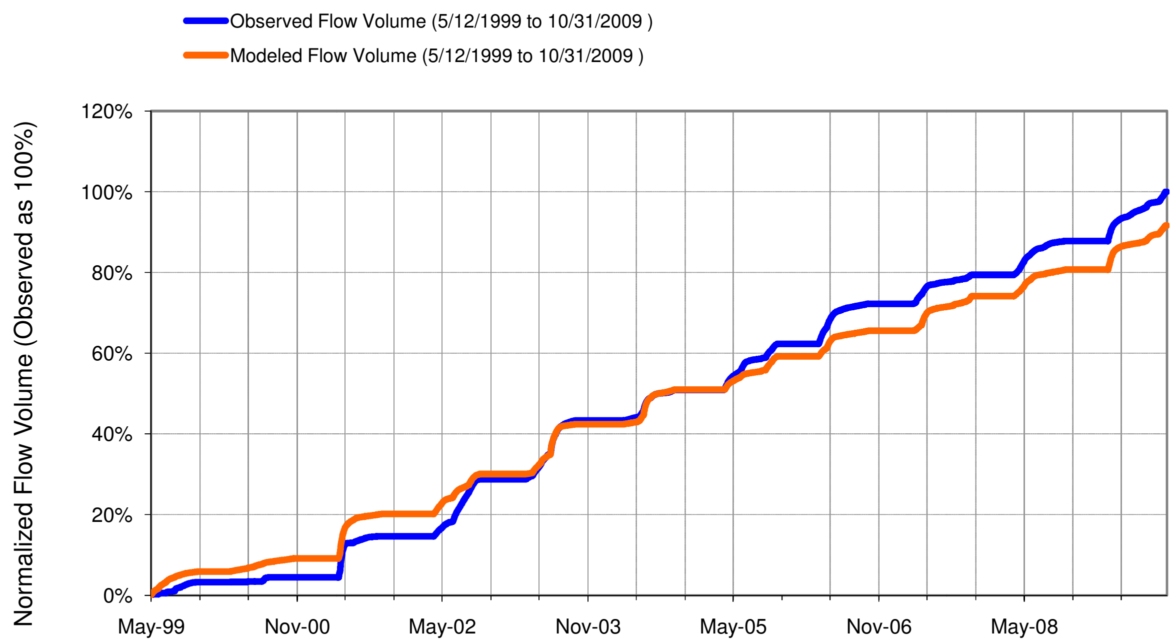



**Figure 13. Flow accumulation: Model DSN 700 vs. Hawk Creek - Priam (S002-140)**

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

| **HSPF Simulated Flow** | | **Observed Flow Gage** | |
|---|---|---|---|
| **REACH OUTFLOW FROM DSN 700**<br>10.48-Year Analysis Period: 5/1/1999 - 10/31/2009<br>Flow volumes are (inches/year) for upstream drainage area | | **Hawk Priam (S002-140)**<br>Manually Entered Data<br>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

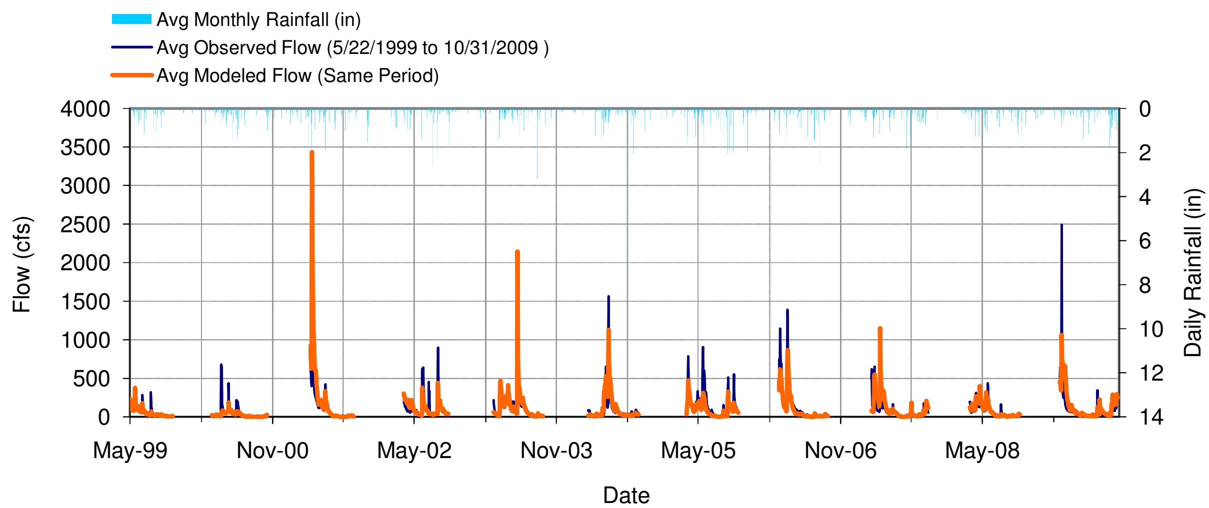



**Figure 14. Mean daily flow: Model DSN 800 vs. Hawk - Maynard (S002-148)**

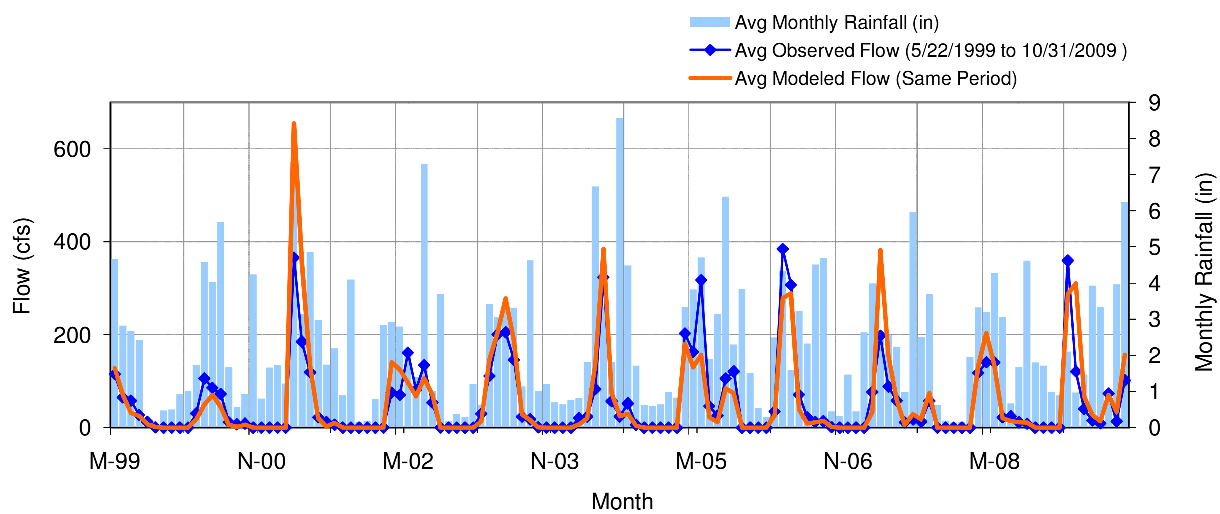



**Figure 15. Mean monthly flow: Model DSN 800 vs. Hawk - Maynard (S002-148)**

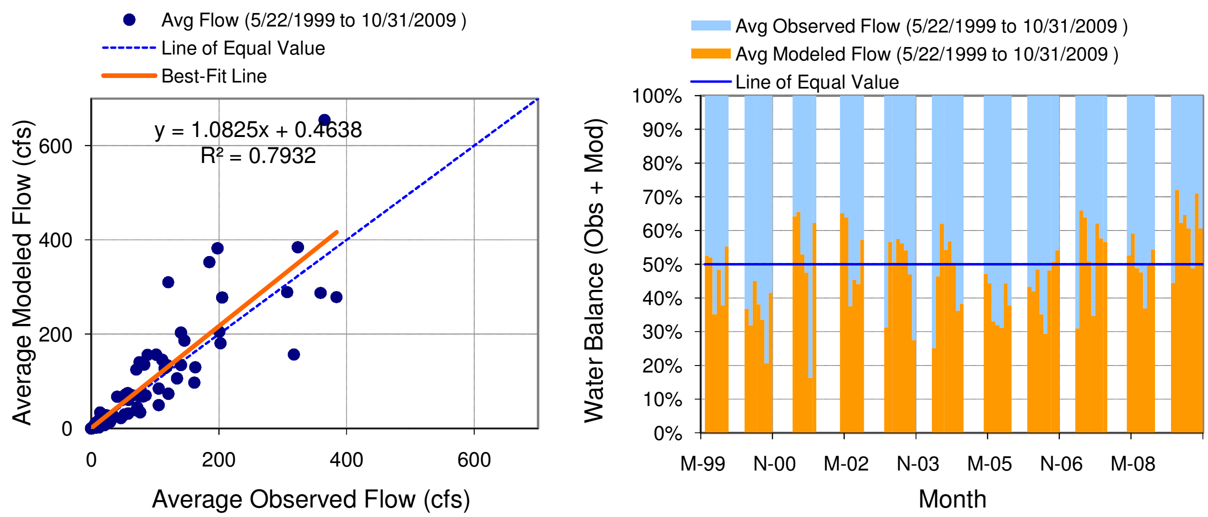



**Figure 16. Monthly flow regression and temporal variation: Model DSN 800 vs. Hawk - Maynard (S002-148)**

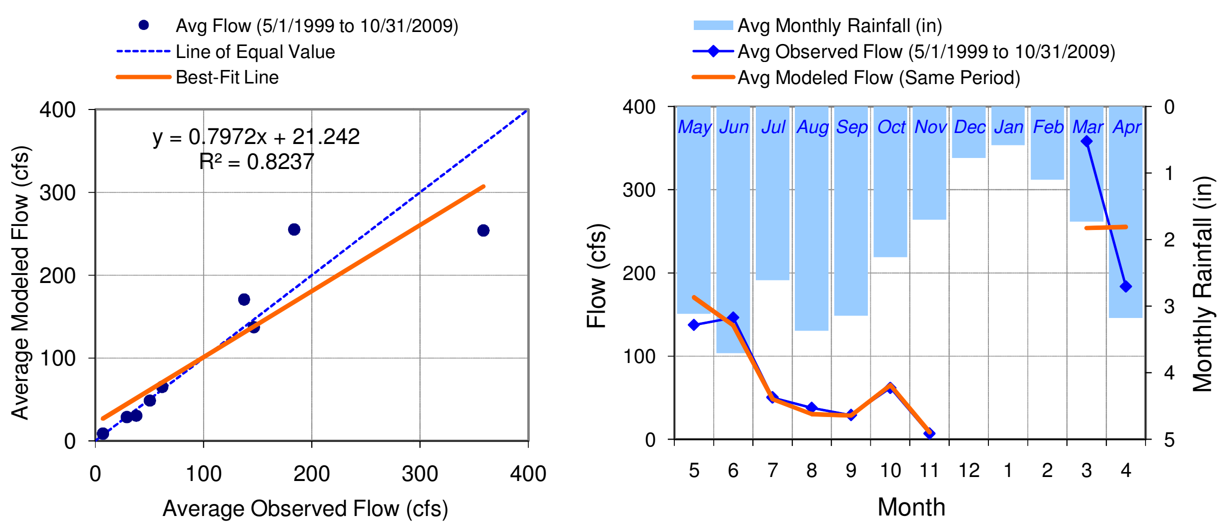



**Figure 17. Seasonal regression and temporal aggregate: Model DSN 800 vs. Hawk - Maynard (S002-148)**

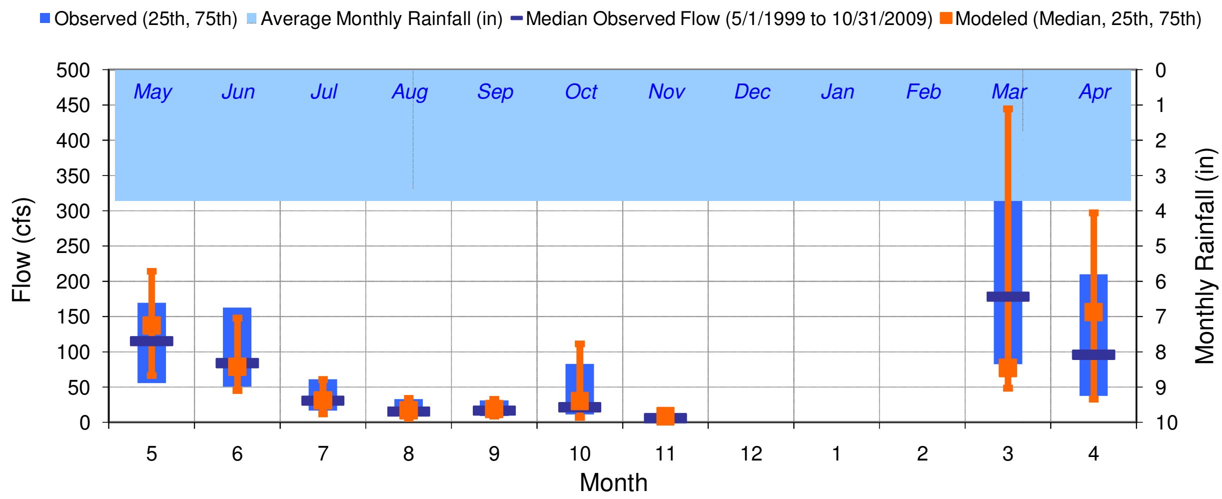



**Figure 18. Seasonal medians and ranges: Model DSN 800 vs. Hawk - Maynard (S002-148)**

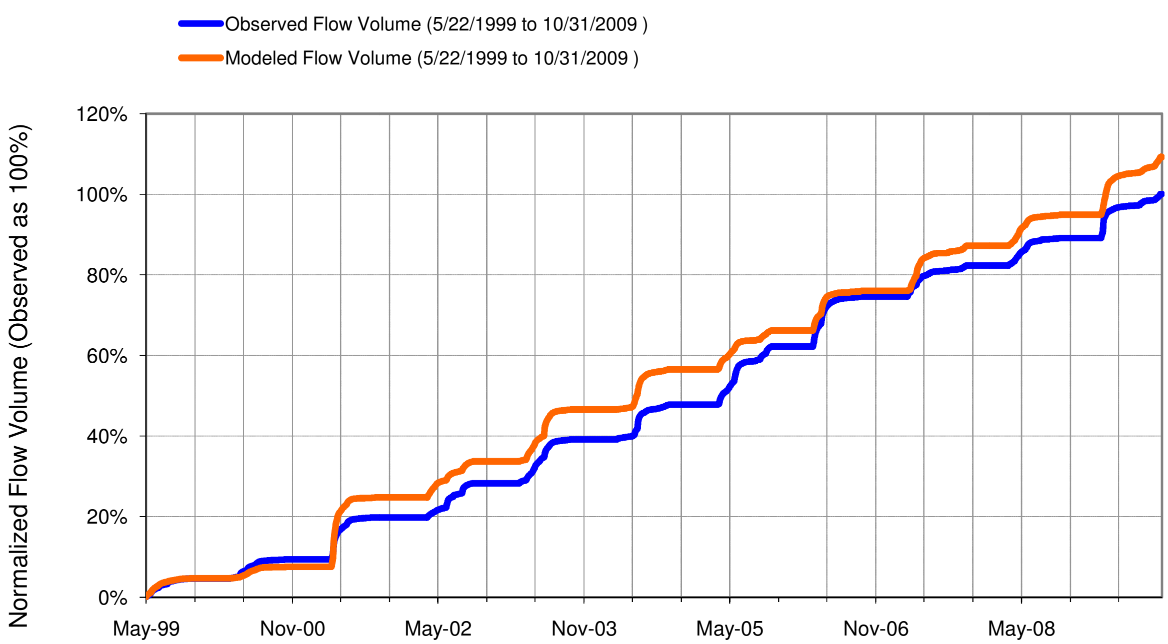



**Figure 19. Flow accumulation: Model DSN 800 vs. Hawk - Maynard (S002-148)**

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

| HSPF Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM DSN 800<br><br>10.45-Year Analysis Period: 5/1/1999 - 10/31/2009<br>Flow volumes are (inches/year) for upstream drainage area | | Hawk Maynard (S002-148)<br><br>Manually Entered Data<br><br>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 | |
| Baseline adjusted coefficient (Garrick), E': | 0.484 | as E or E' approaches 1.0 | |
| Monthly NSE | 0.921 | | |

# 4 Chetomba Creek

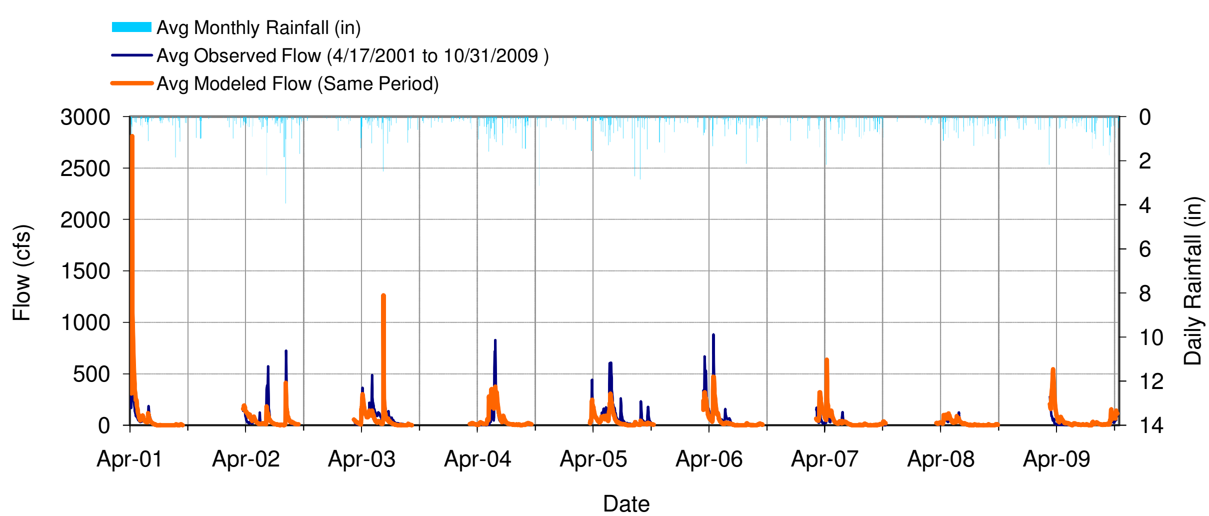



**Figure 20. Mean daily flow: Model DSN 900 vs. Chetomba Creek (S002-152)**

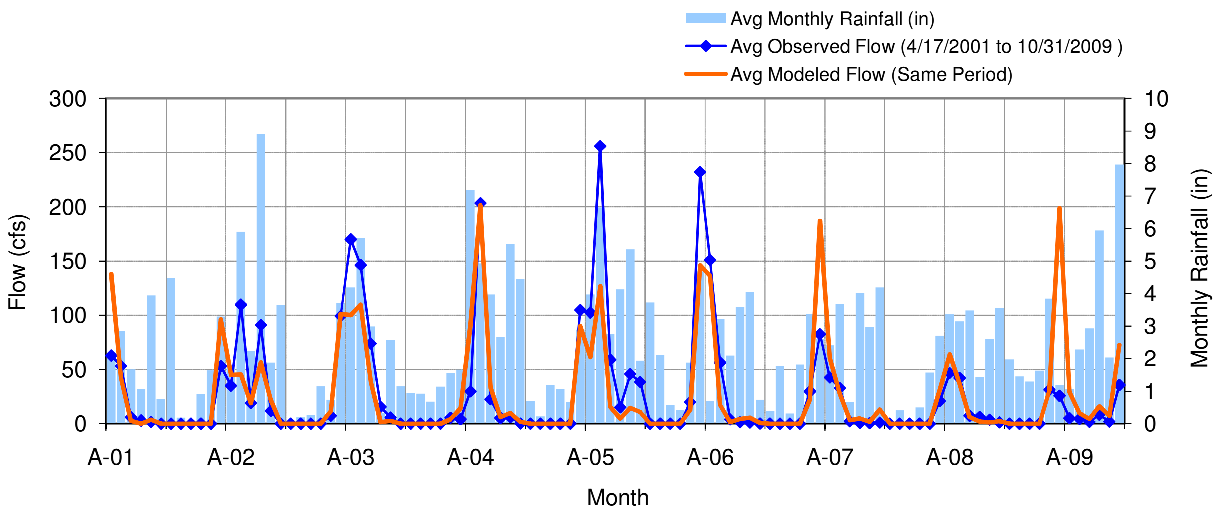



**Figure 21. Mean monthly flow: Model DSN 900 vs. Chetomba Creek (S002-152)**

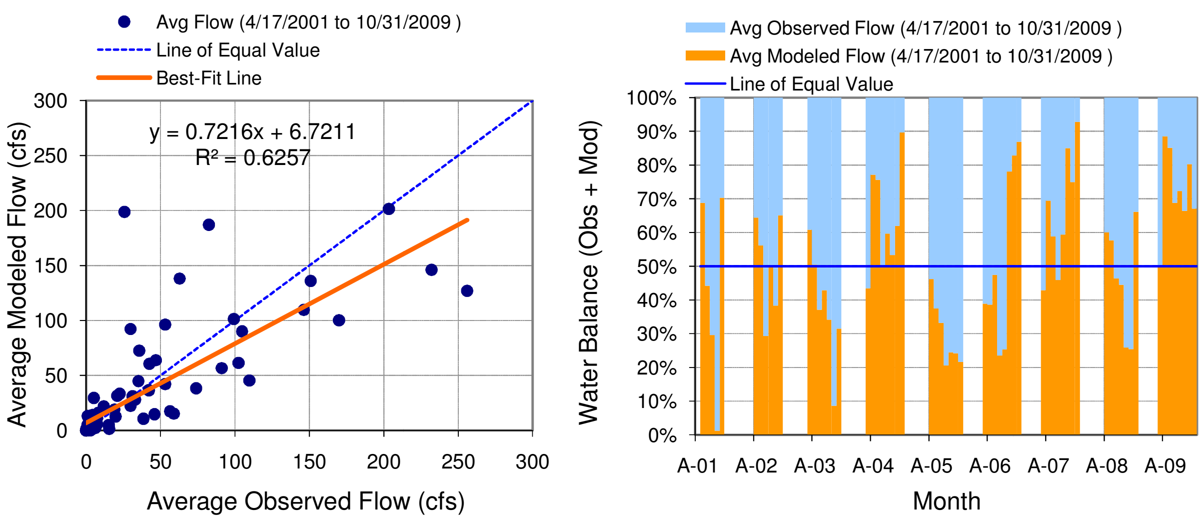



**Figure 22. Monthly flow regression and temporal variation: Model DSN 900 vs. Chetomba Creek (S002-152)**

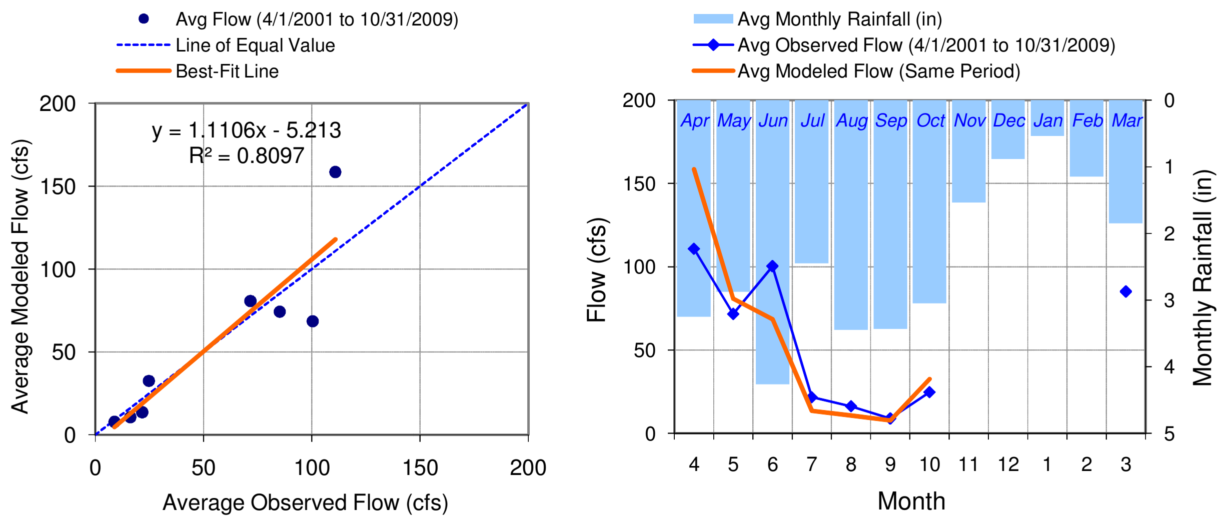



**Figure 23. Seasonal regression and temporal aggregate: Model DSN 900 vs. Chetomba Creek (S002-152)**

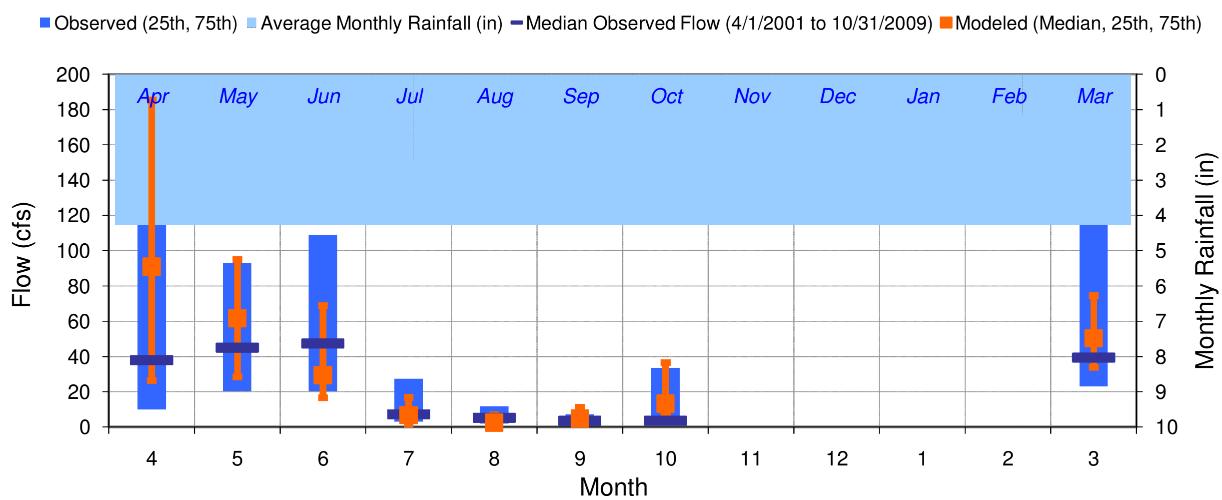



**Figure 24. Seasonal medians and ranges: Model DSN 900 vs. Chetomba Creek (S002-152)**

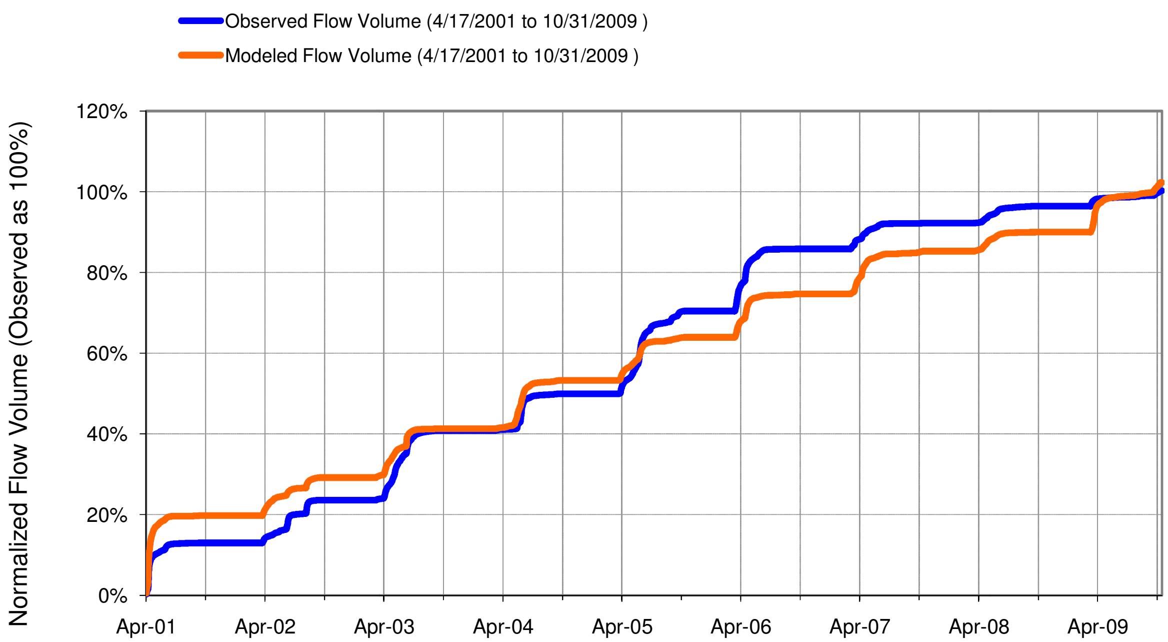



**Figure 25. Flow accumulation: Model DSN 900 vs. Chetomba Creek (S002-152)**

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

| HSPF Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM DSN 900<br>8.54-Year Analysis Period: 4/1/2001 - 10/31/2009<br>Flow volumes are (inches/year) for upstream drainage area | | Chetomba (S002-152)<br>Manually Entered Data<br>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

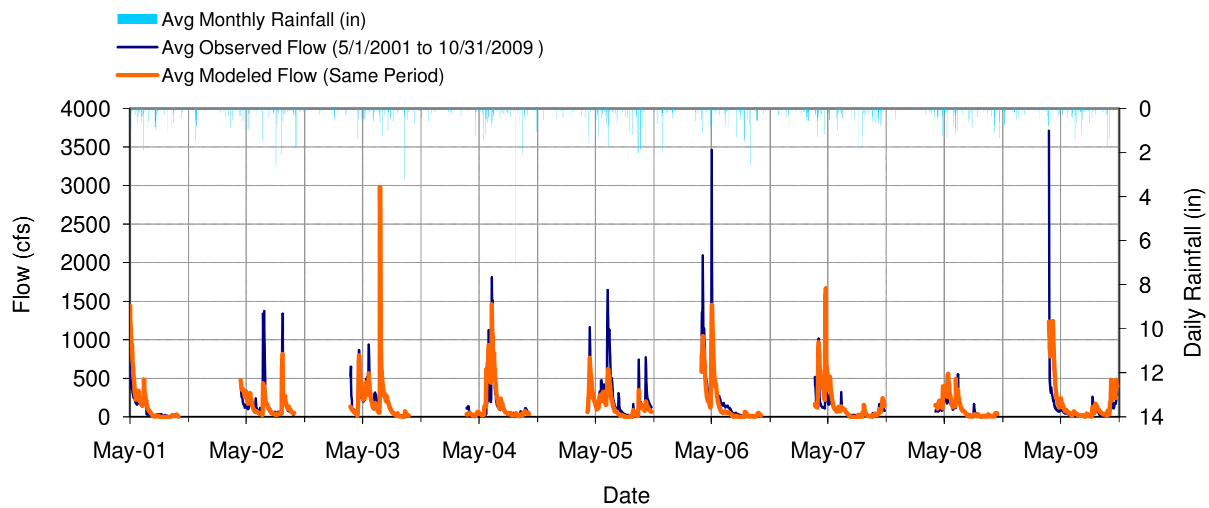



**Figure 26. Mean daily flow: Model DSN 600 vs. Hawk - Outlet (S002-12)**

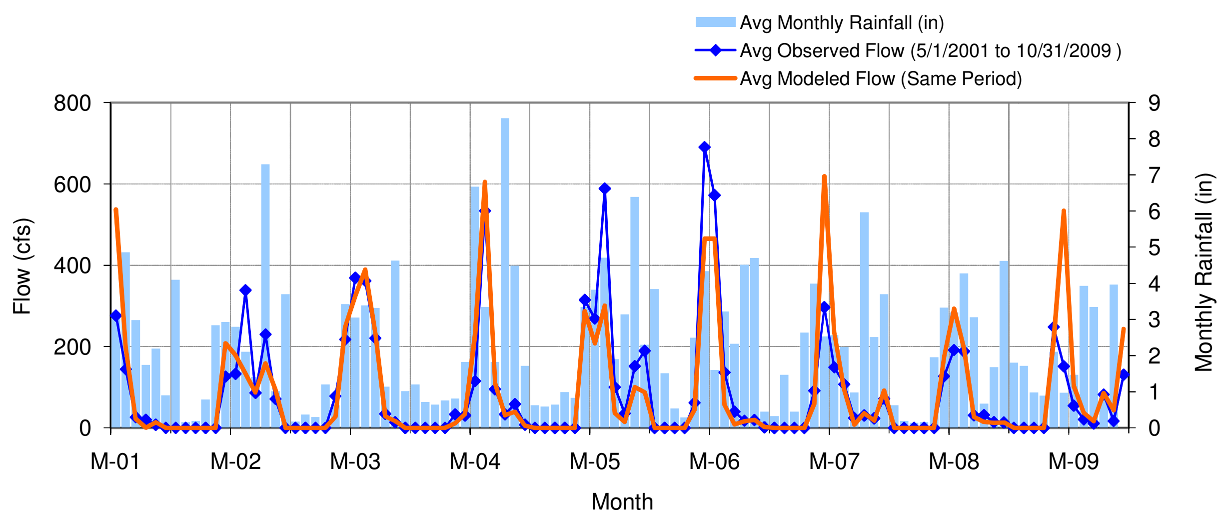



**Figure 27. Mean monthly flow: Model DSN 600 vs. Hawk - Outlet (S002-12)**

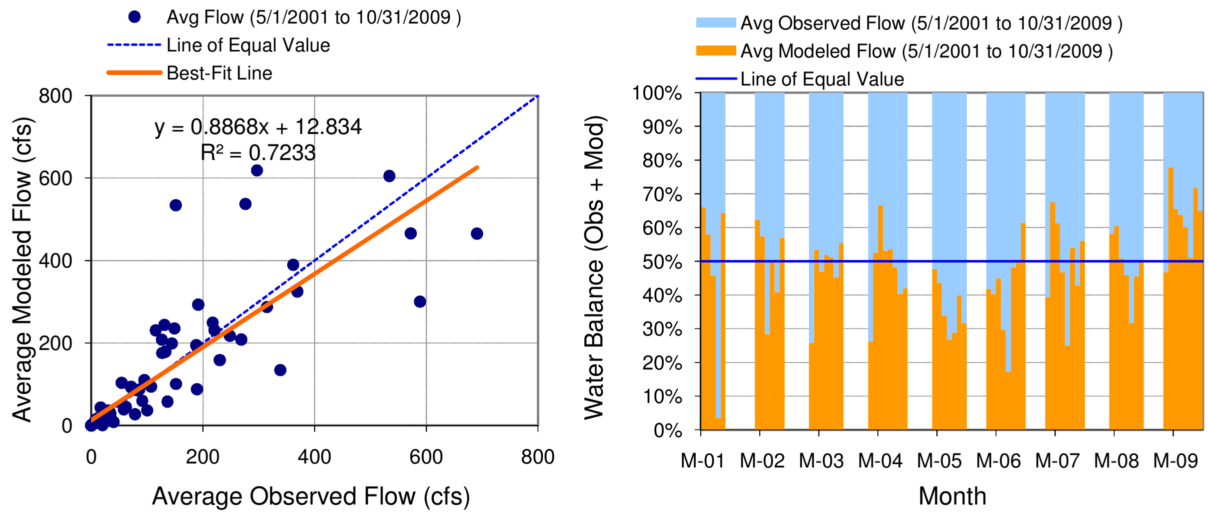



**Figure 28. Monthly flow regression and temporal variation: Model DSN 600 vs. Hawk - Outlet (S002-12)**

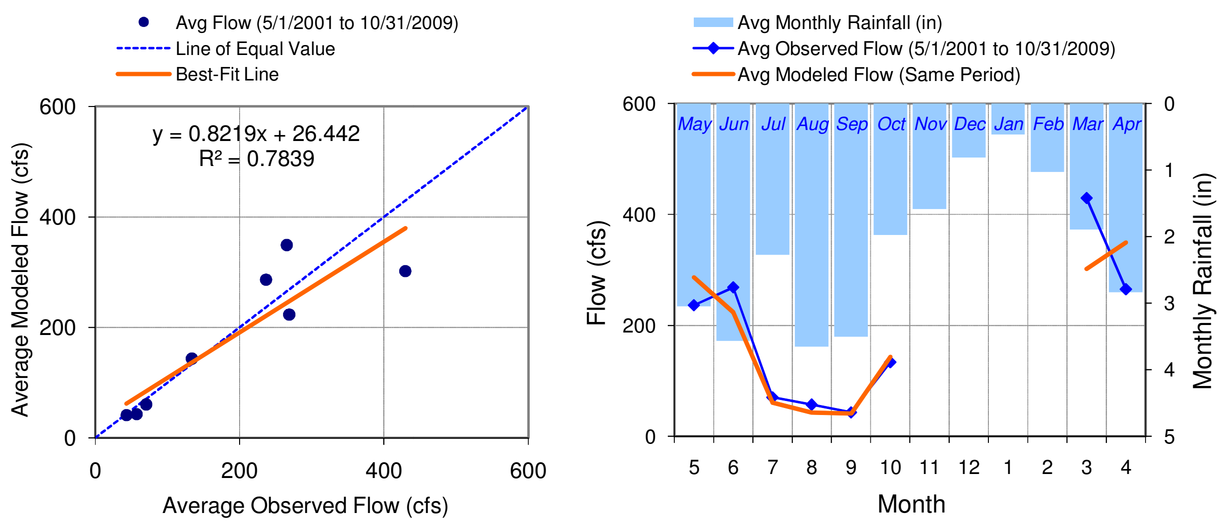



**Figure 29. Seasonal regression and temporal aggregate: Model DSN 600 vs. Hawk - Outlet (S002-12)**

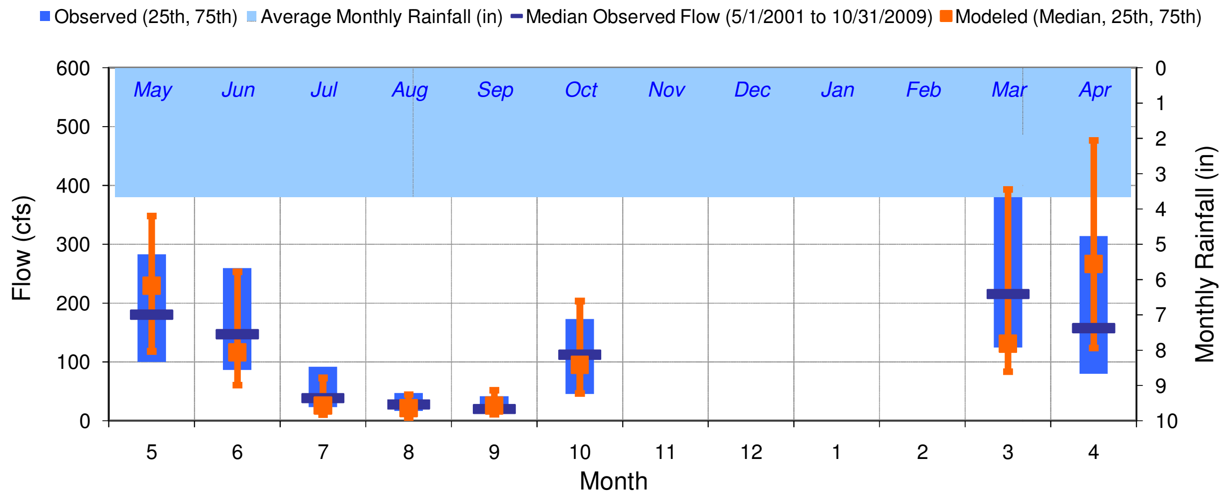



**Figure 30. Seasonal medians and ranges: Model DSN 600 vs. Hawk - Outlet (S002-12)**

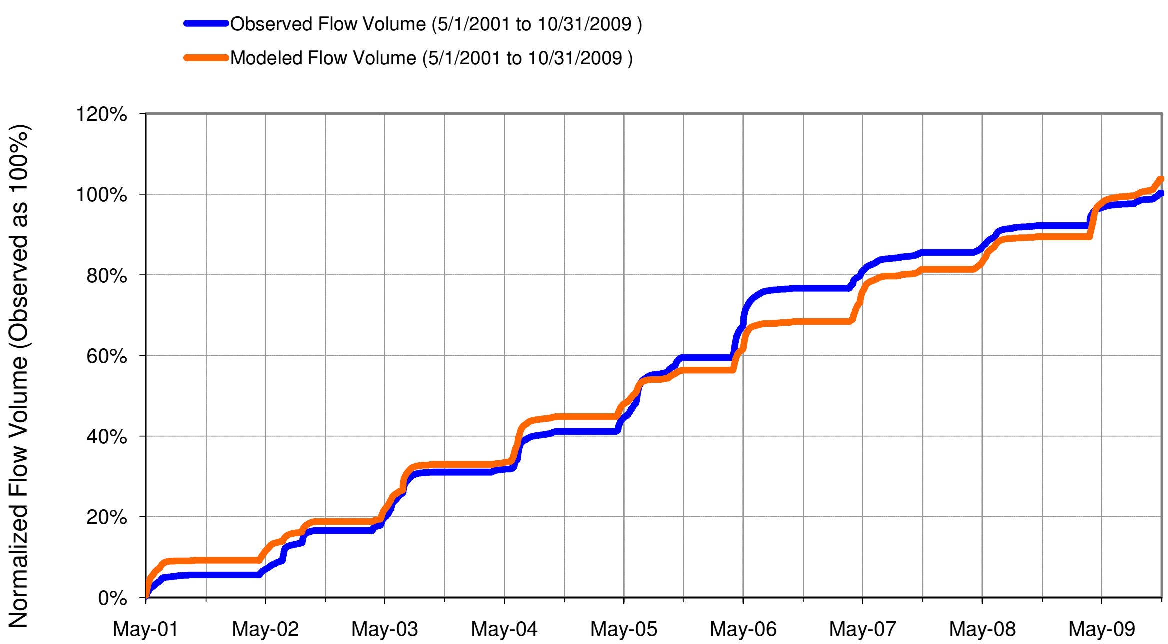



**Figure 31. Flow accumulation: Model DSN 600 vs. Hawk - Outlet (S002-12)**

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

| HSPF Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM DSN 600<br>8.5-Year Analysis Period: 5/1/2001 - 10/31/2009<br>Flow volumes are (inches/year) for upstream drainage area | | Hawk Outlet (S002-12)<br>Manually Entered Data<br>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 as E or E' approaches 1.0 | | |
| Baseline adjusted coefficient (Garrick), E': | 0.458 | | | |
| Monthly NSE | 0.898 | | | |

# 6 West Fork Beaver Creek

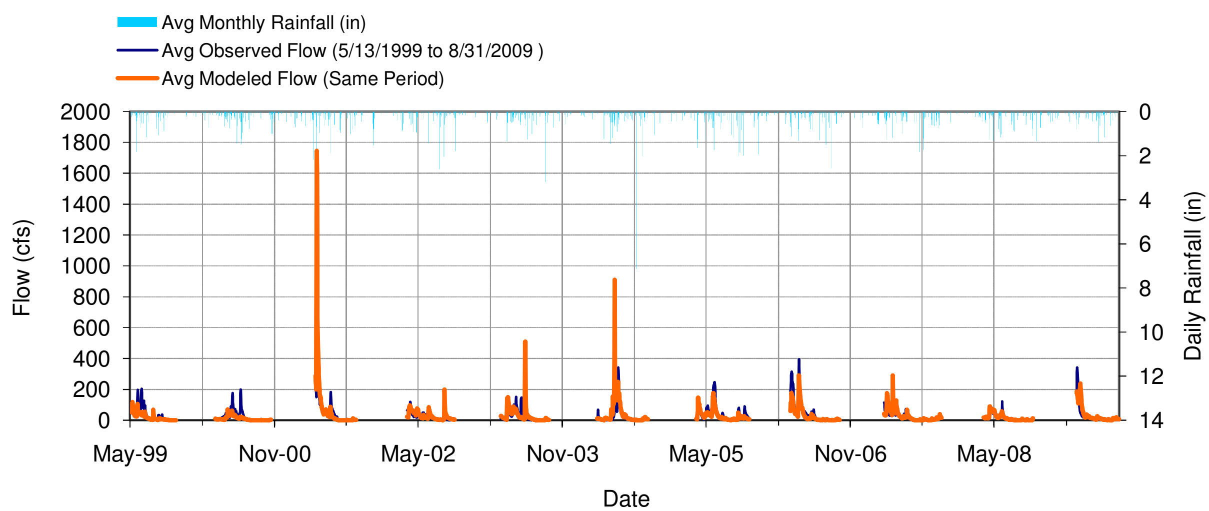



**Figure 32. Mean daily flow: Model DSN 300 vs. West Fork Beaver Creek (S000-405)**

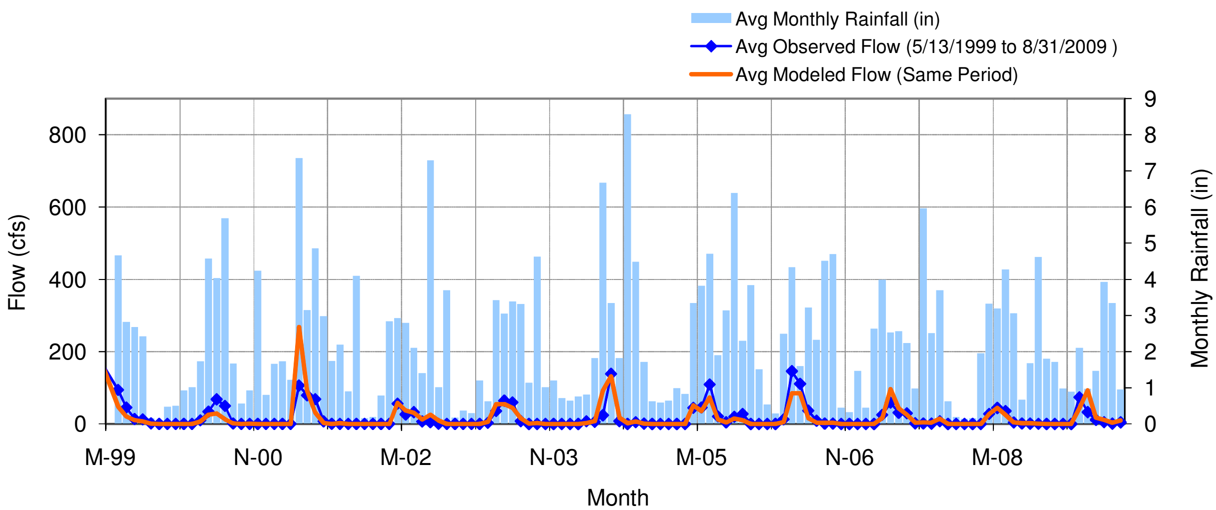



**Figure 33. Mean monthly flow: Model DSN 300 vs. West Fork Beaver Creek (S000-405)**

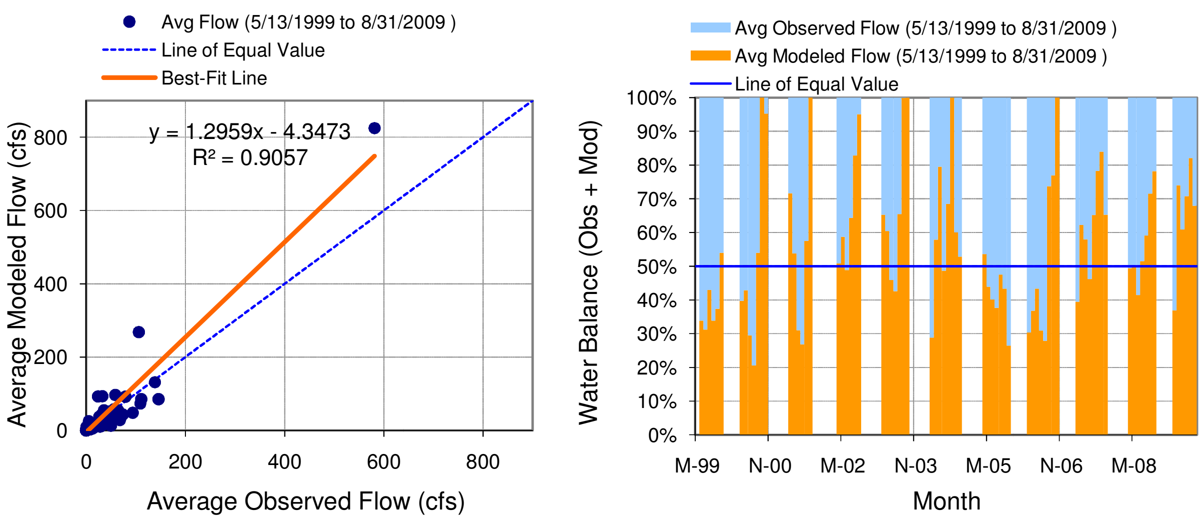



**Figure 34. Monthly flow regression and temporal variation: Model DSN 300 vs. West Fork Beaver Creek (S000-405)**

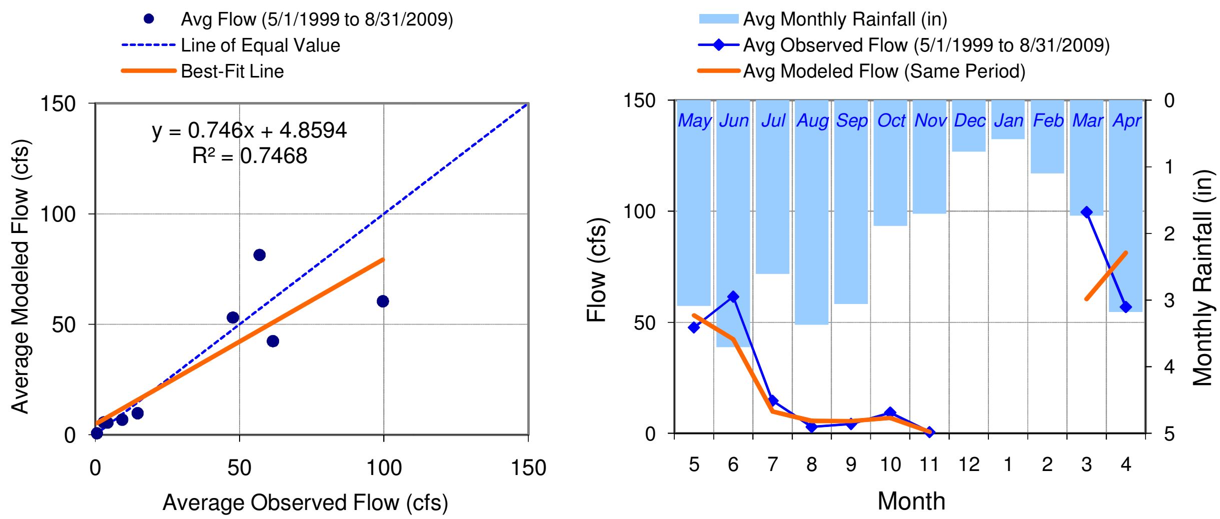



**Figure 35. Seasonal regression and temporal aggregate: Model DSN 300 vs. West Fork Beaver Creek (S000-405)**

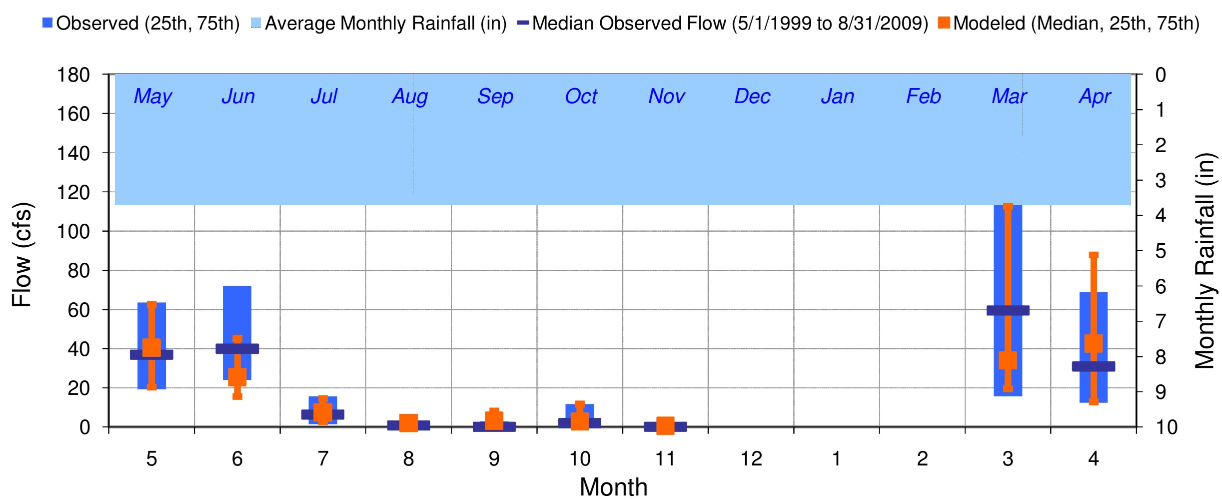



**Figure 36. Seasonal medians and ranges: Model DSN 300 vs. West Fork Beaver Creek (S000-405)**

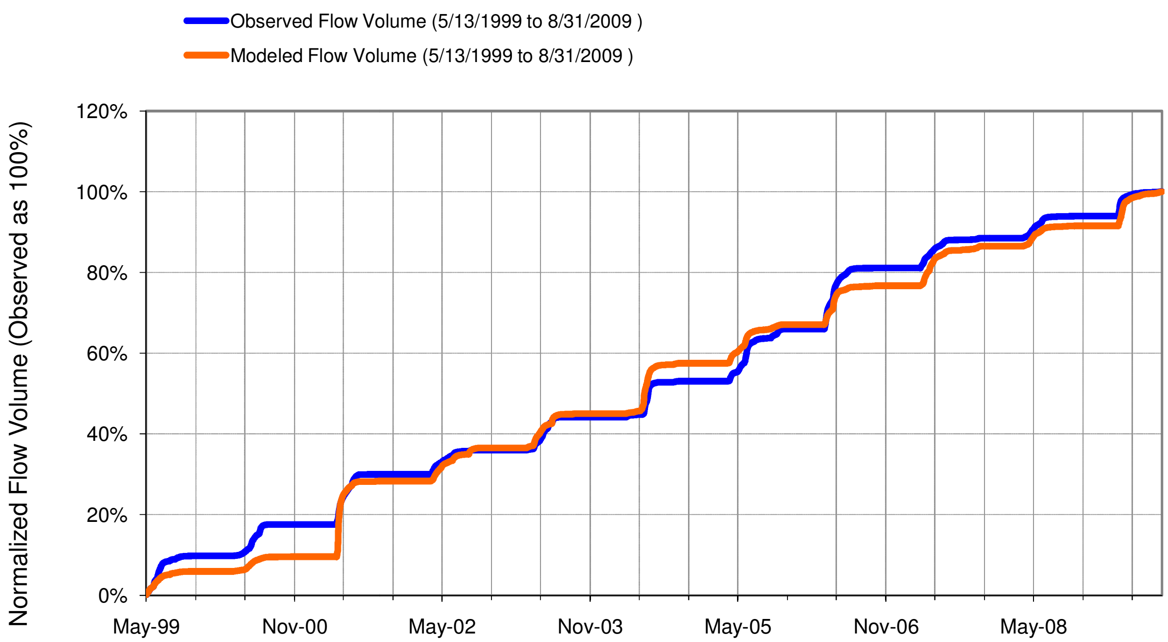



**Figure 37. Flow accumulation: Model DSN 300 vs. West Fork Beaver Creek (S000-405)**

**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**<br>10.31-Year Analysis Period: 5/1/1999 - 8/31/2009<br>Flow volumes are (inches/year) for upstream drainage area | | **WF Beaver (S000-405)**<br>Manually Entered Data<br>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

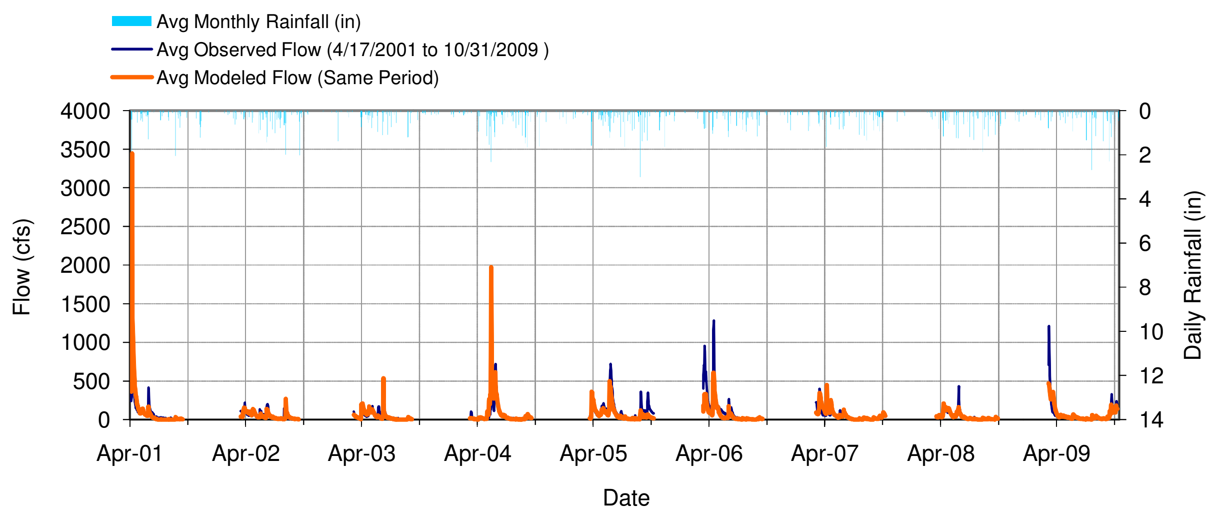



**Figure 38. Mean daily flow: Model DSN 400 vs. Beaver Falls (S000-666)**

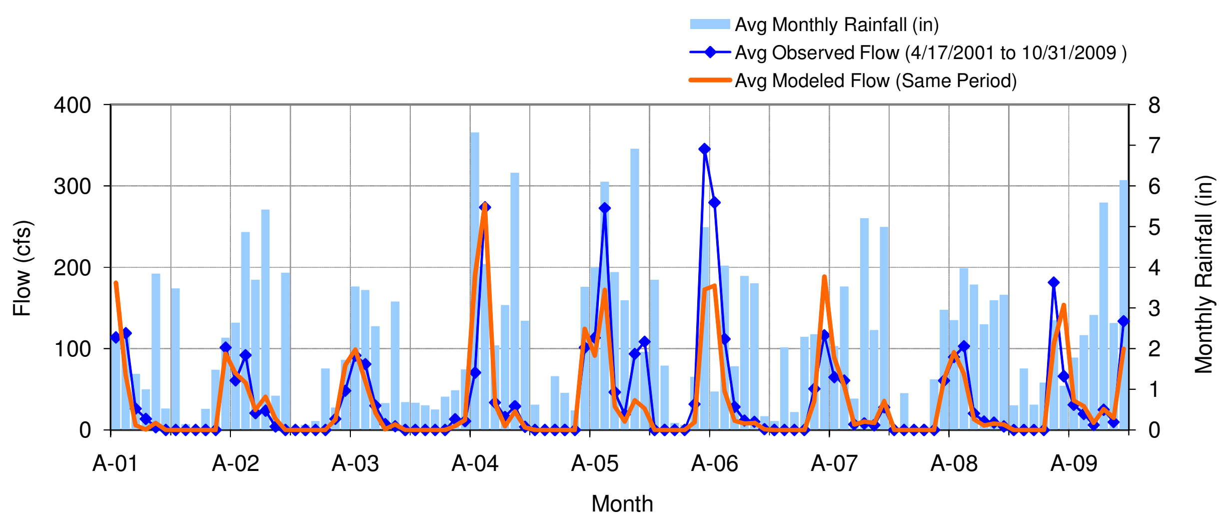
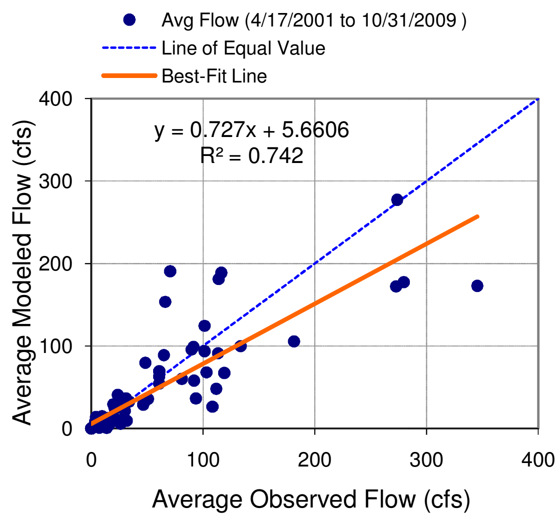



**Figure 39. Mean monthly flow: Model DSN 400 vs. Beaver Falls (S000-666)**



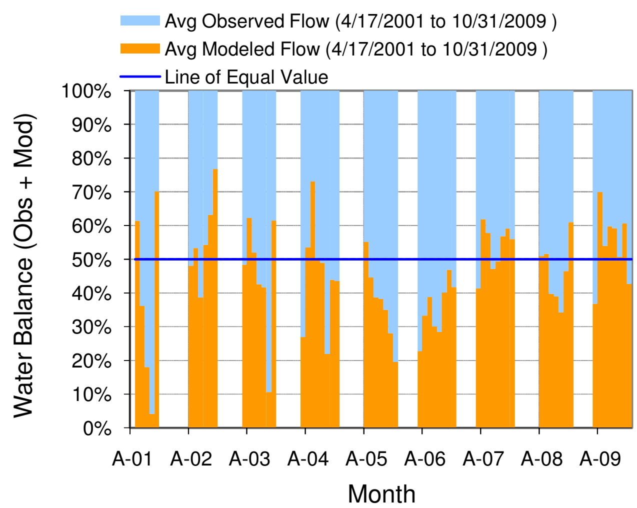
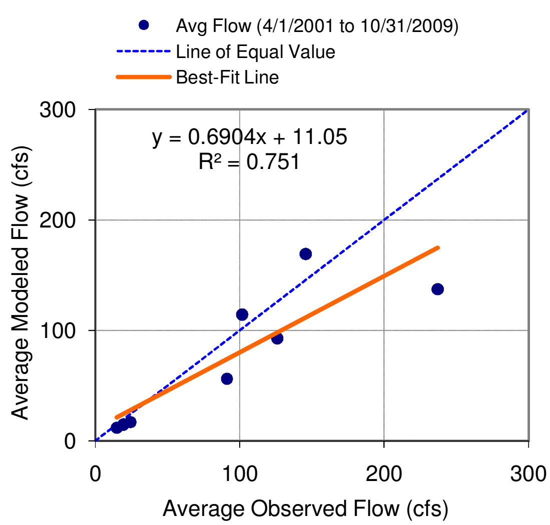




**Figure 40. Monthly flow regression and temporal variation: Model DSN 400 vs. Beaver Falls (S000-666)**



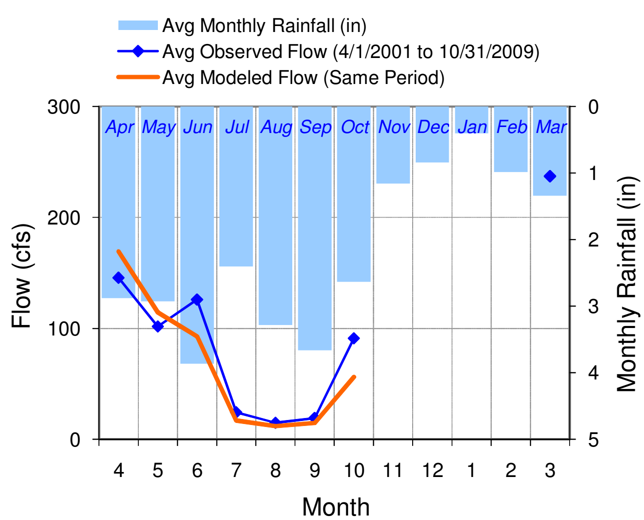




**Figure 41. Seasonal regression and temporal aggregate: Model DSN 400 vs. Beaver Falls (S000-666)**

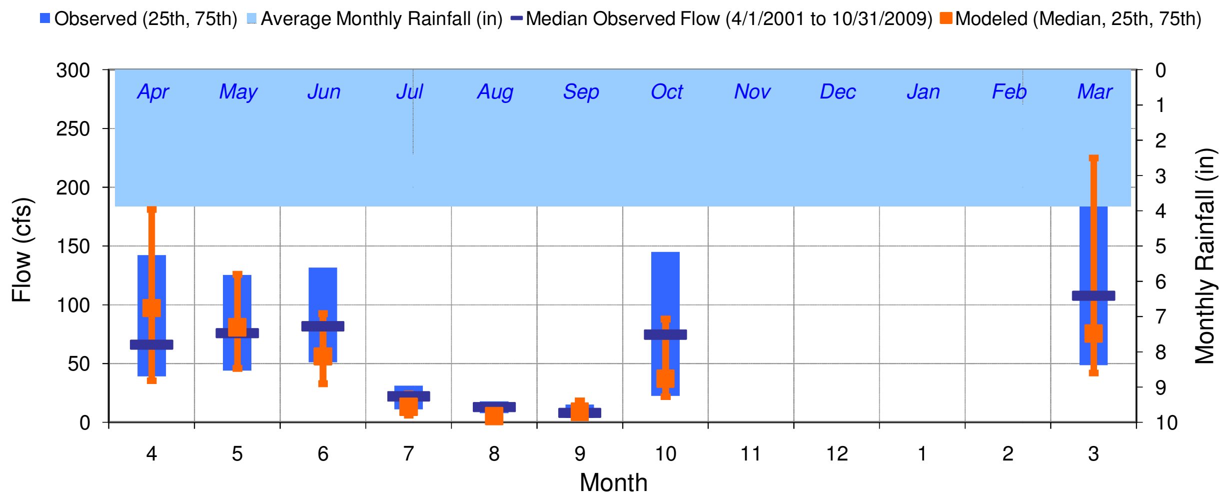



**Figure 42. Seasonal medians and ranges: Model DSN 400 vs. Beaver Falls (S000-666)**

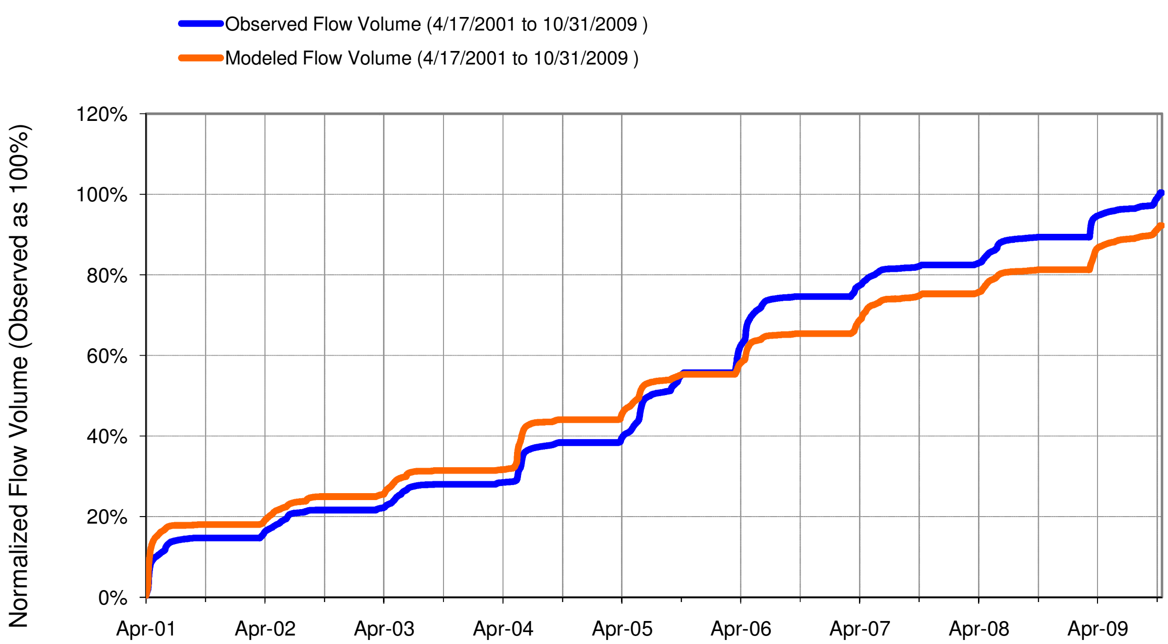



**Figure 43. Flow accumulation: Model DSN 400 vs. Beaver Falls (S000-666)**

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

| HSPF Simulated Flow | | Observed Flow Gage | | |
|---|---|---|---|---|
| REACH OUTFLOW FROM DSN 400<br>8.54-Year Analysis Period: 4/1/2001 - 10/31/2009<br>Flow volumes are (inches/year) for upstream drainage area | | Beaver Falls (S000-666)<br>Manually Entered Data<br>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

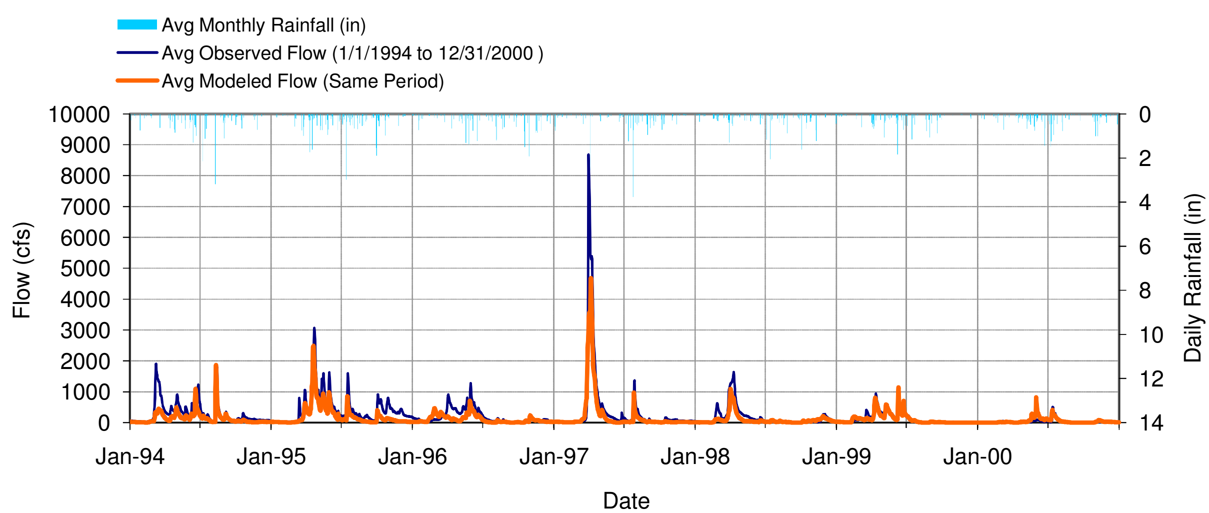



**Figure 44. Mean daily flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000**

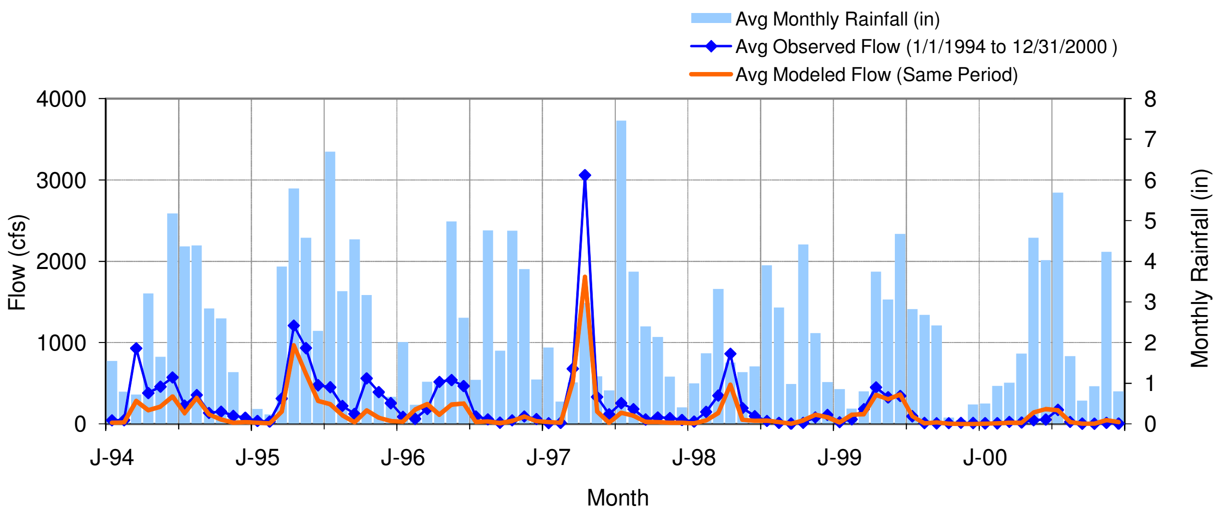



**Figure 45. Mean monthly flow: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000**

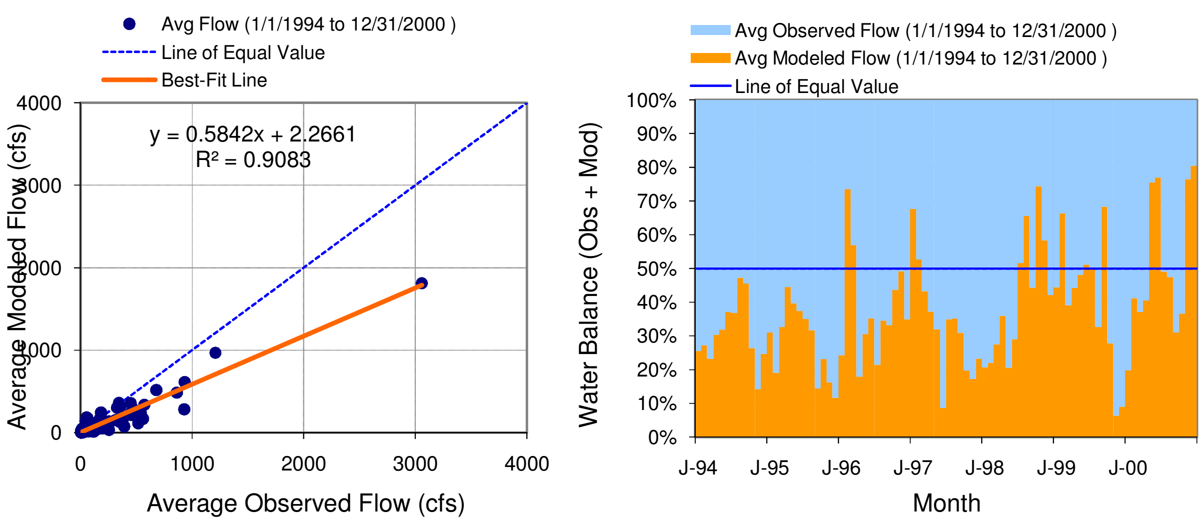



**Figure 46. Monthly flow regression and temporal variation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000**

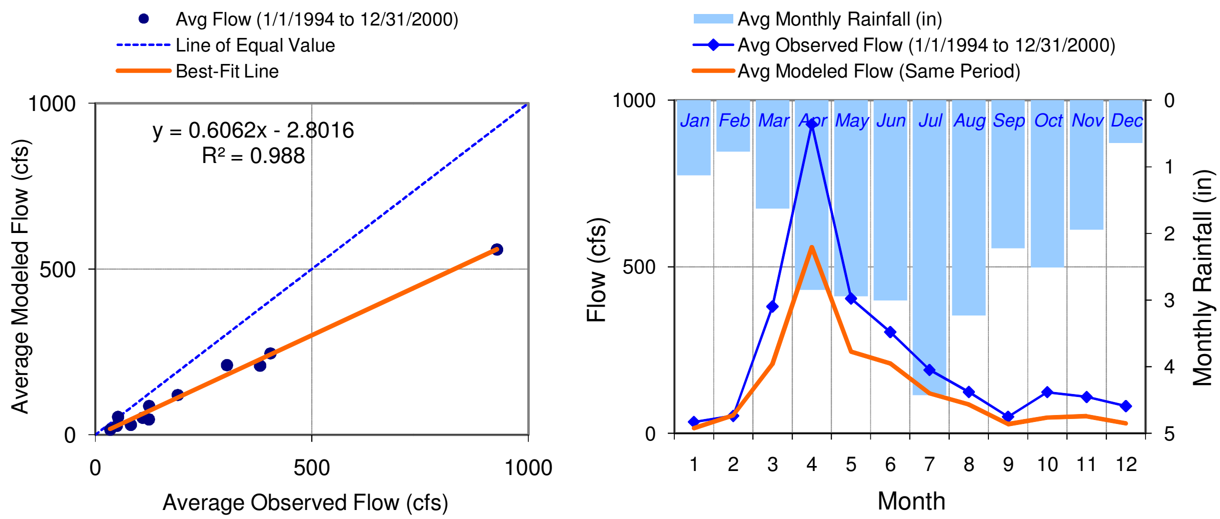



**Figure 47. Seasonal regression and temporal aggregate: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000**

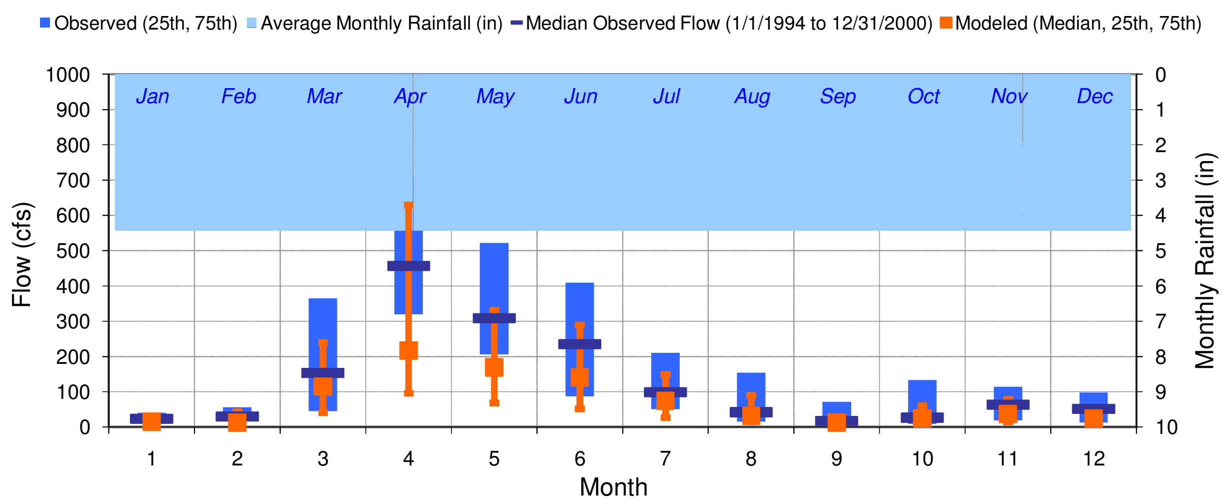



**Figure 48. Seasonal medians and ranges: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000**

**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 |

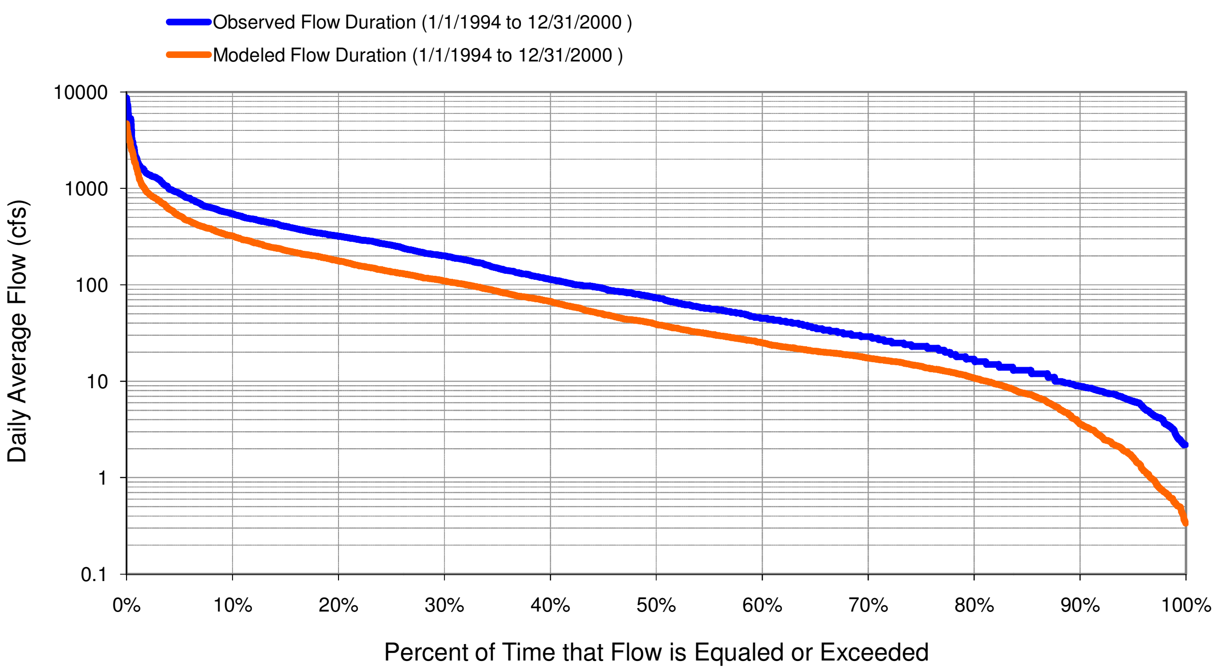



**Figure 49. Flow exceedence: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000**

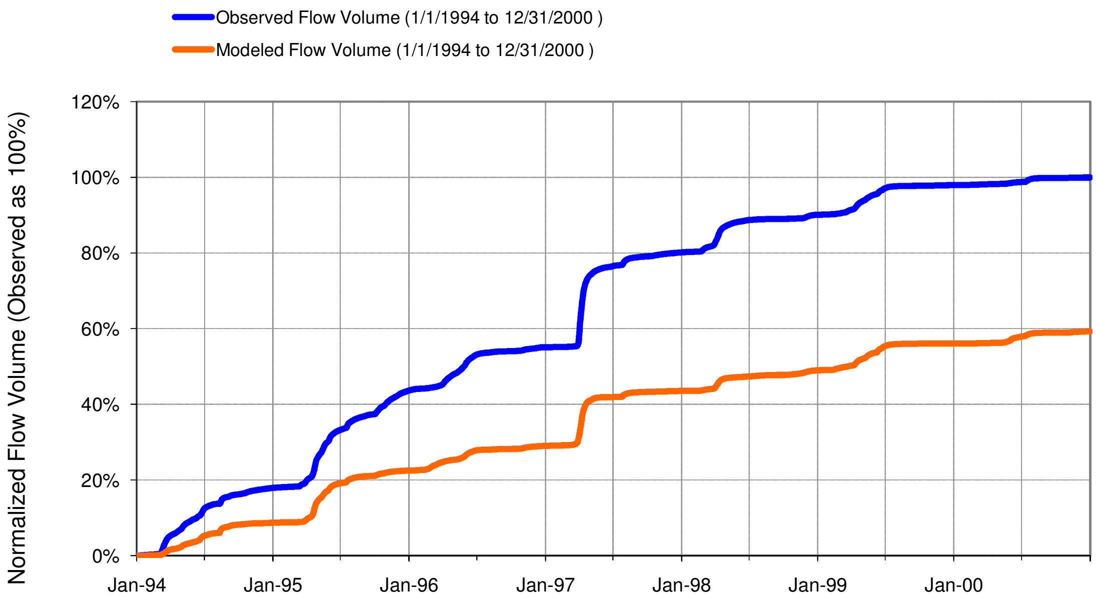



**Figure 50. Flow accumulation: Model DSN 100 vs. USGS 05313500 Yellow Medicine River near Granite Falls, MN, 1994-2000**

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

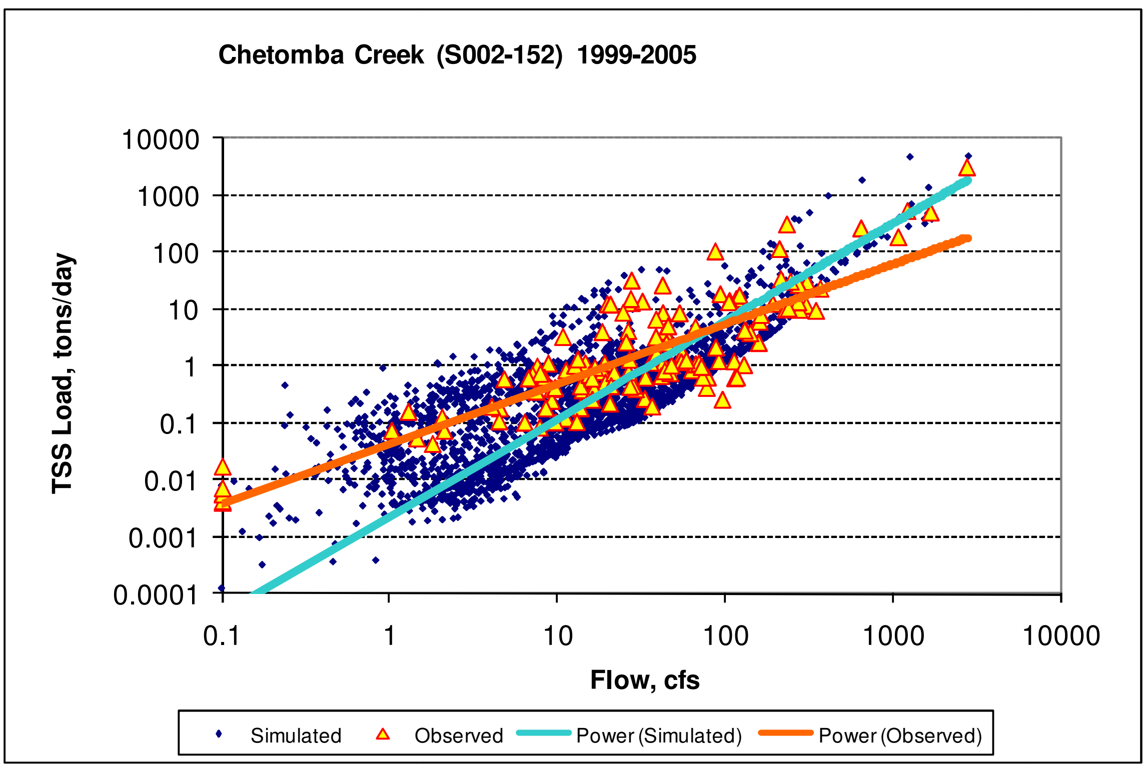
| HSPF Simulated Flow | | Observed Flow Gage | |
|---|---|---|---|
| REACH OUTFLOW FROM DSN 100<br>7-Year Analysis Period: 1/1/1994 - 12/31/2000<br>Flow volumes are (inches/year) for upstream drainage area | | USGS 05313500 YELLOW MEDICINE RIVER NEAR GRANITE FALLS, MN<br>Hydrologic Unit Code: 7020004<br>Latitude: 44.72166667<br>Longitude: -95.5188889<br>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 | | |

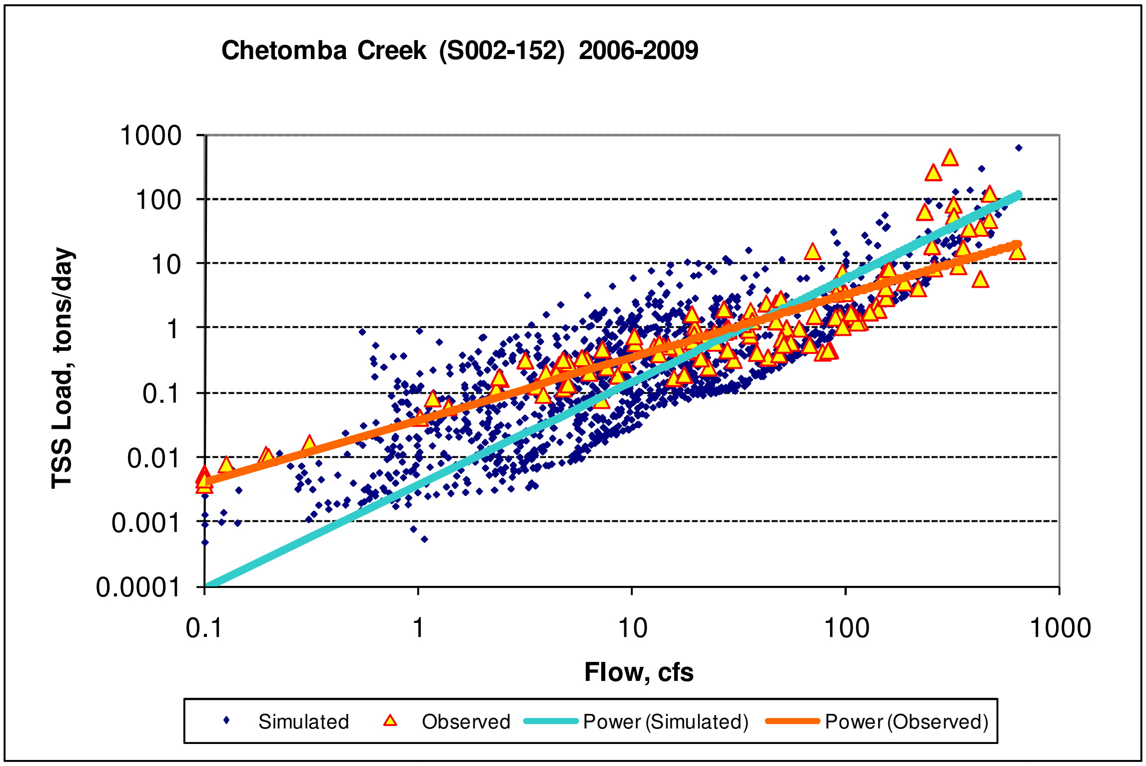
# Water Quality Calibration and Validation for the Hawk Creek/Yellow Medicine HSPF Model

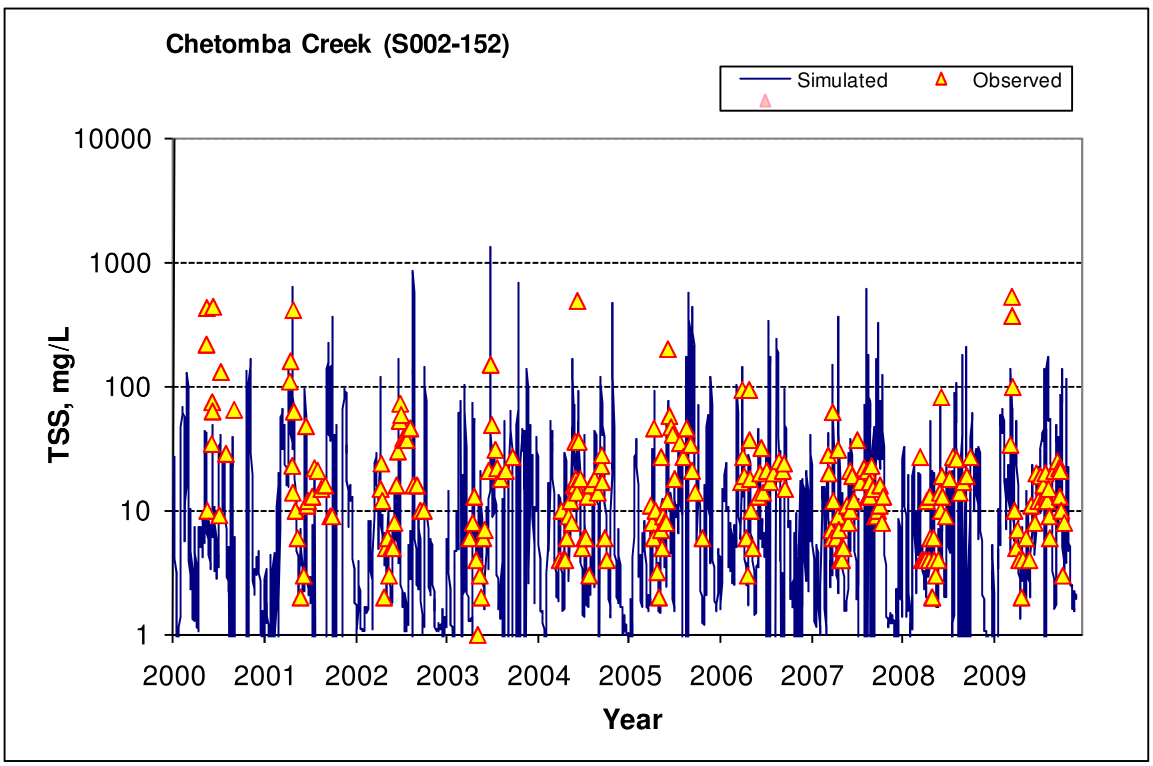
# 1 Chetomba Creek (S002-152)

## 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 |

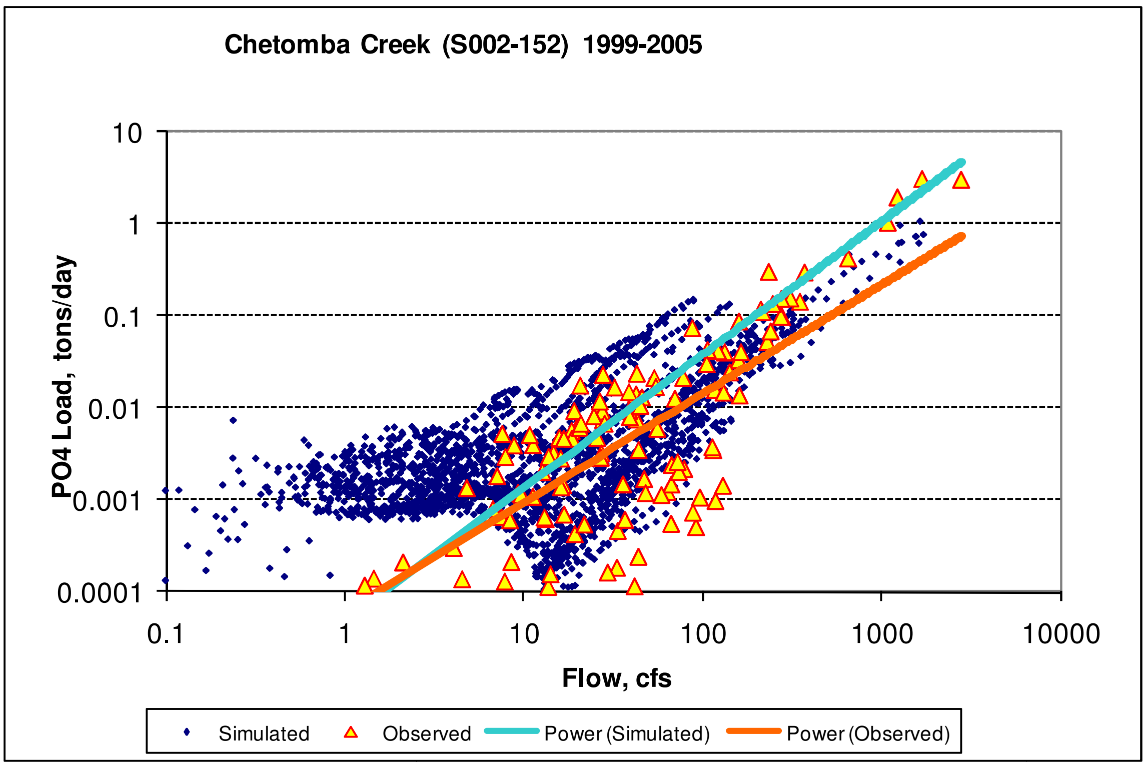


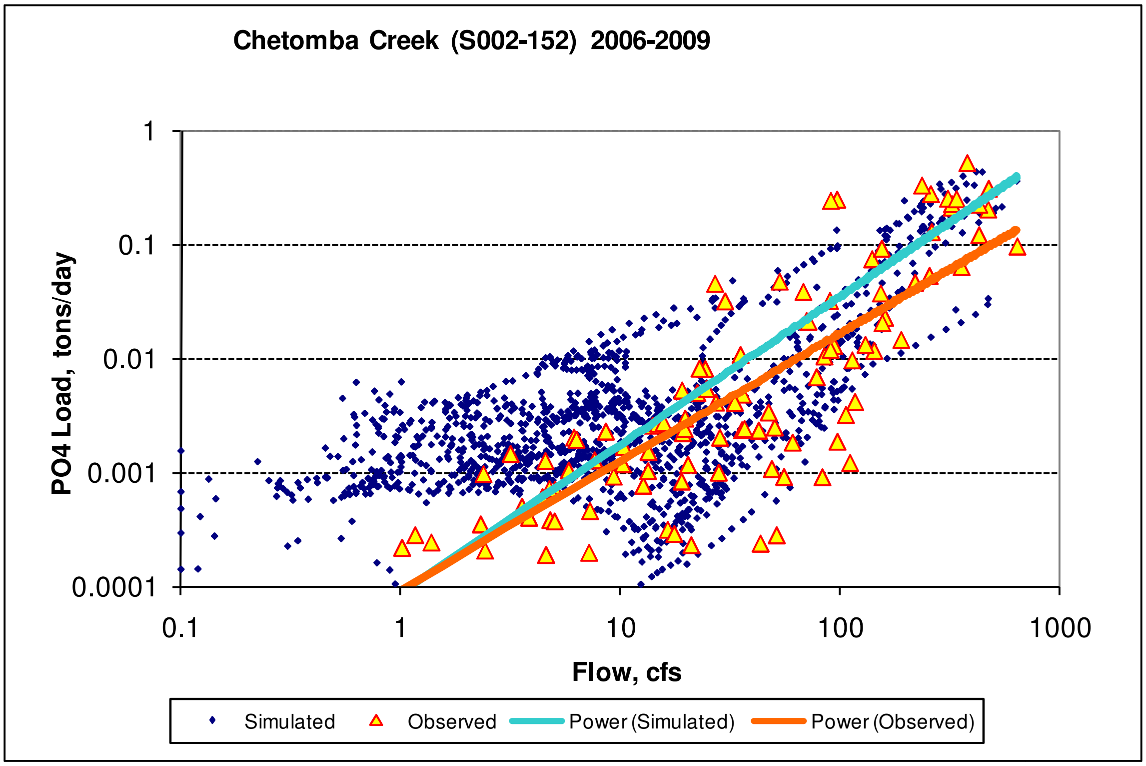

Chetomba Creek (S002-152) 2006-2009
TSS Load, tons/day
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

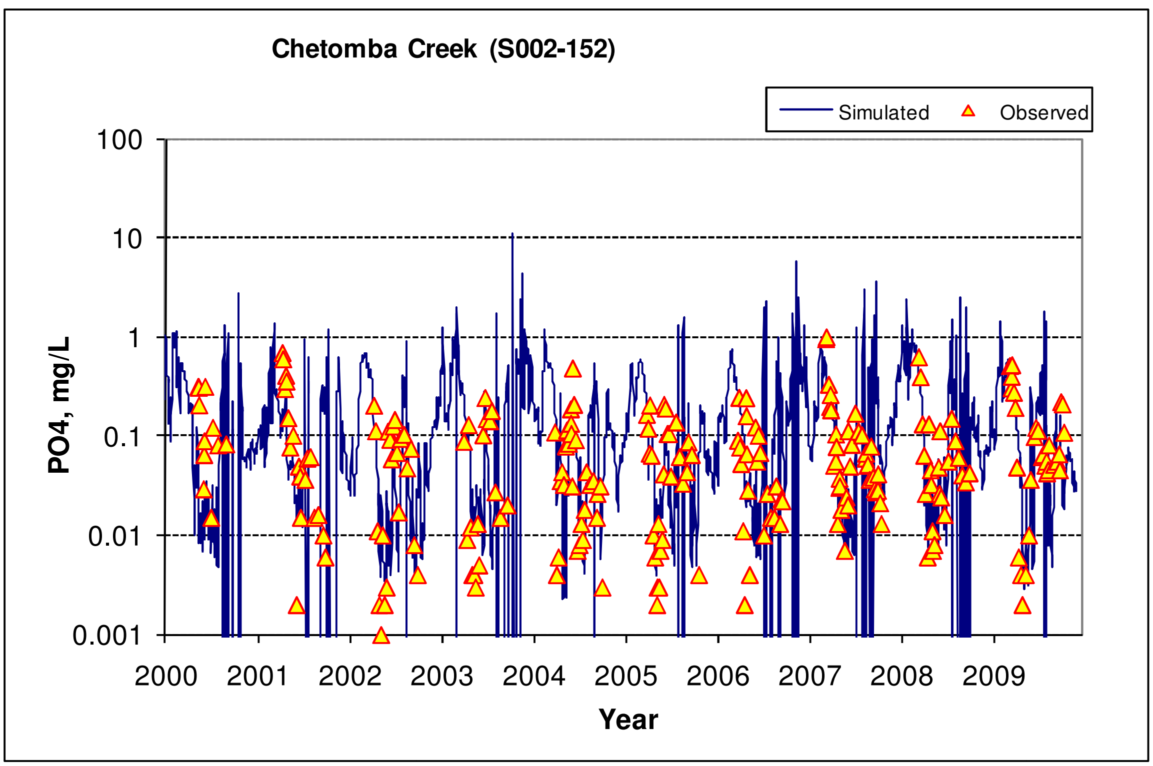

Chetomba Creek (S002-152)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

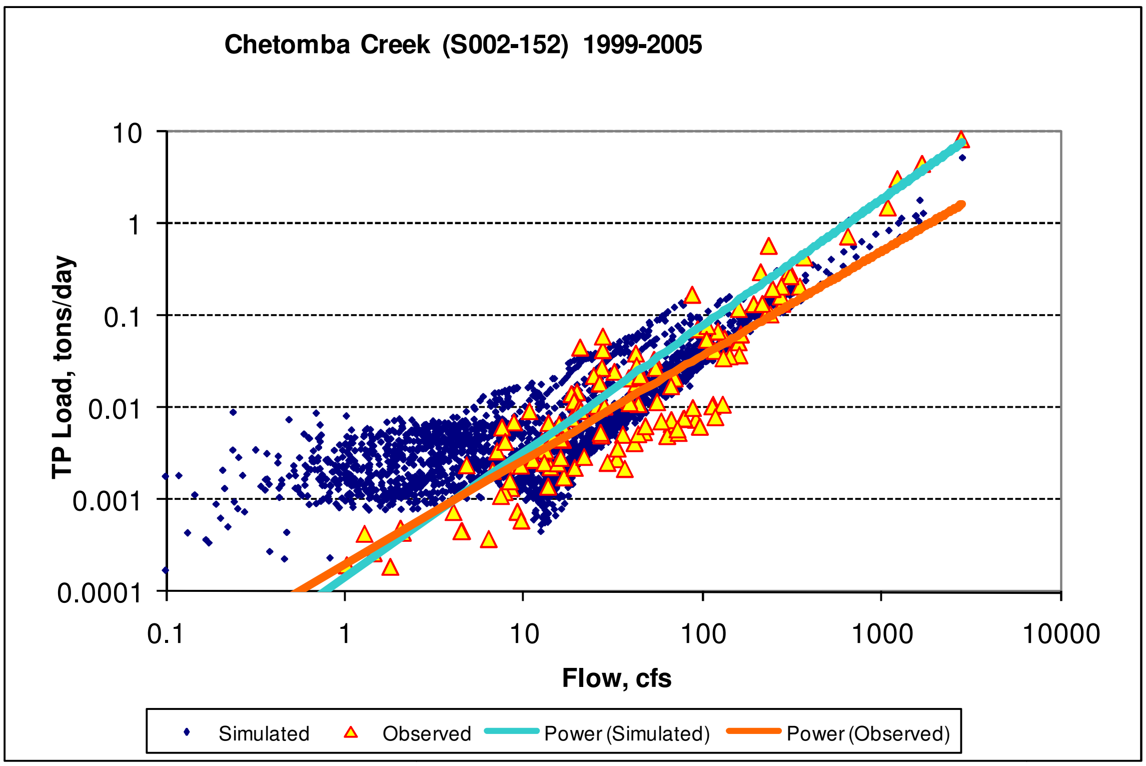


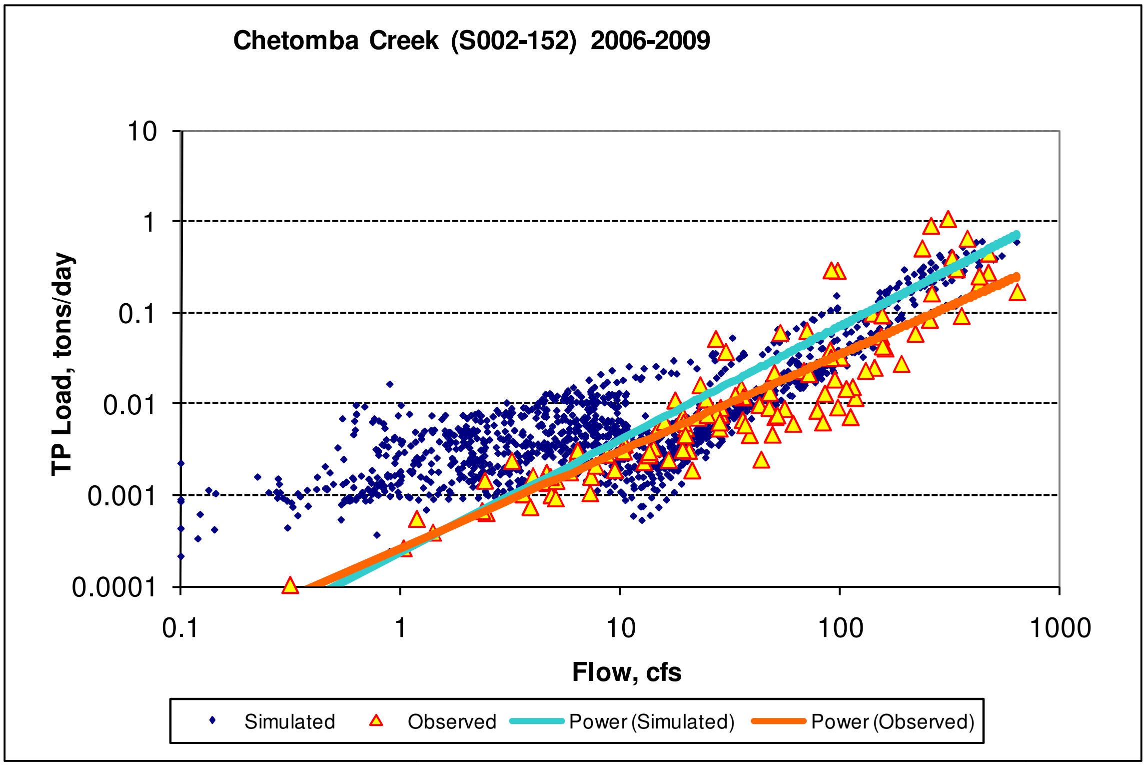

Chetomba Creek (S002-152) 2006-2009
PO4 Load, tons/day
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)


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

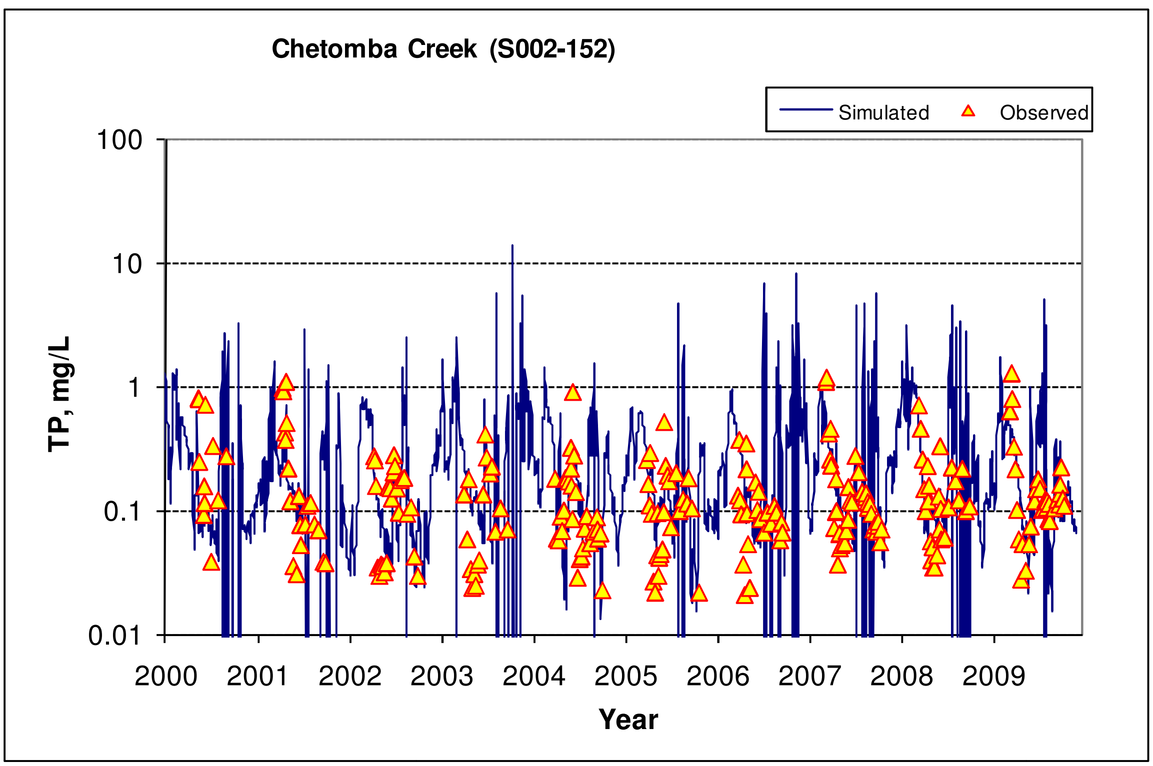
## 1.3 TOTAL PHOSPHORUS

| 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 |





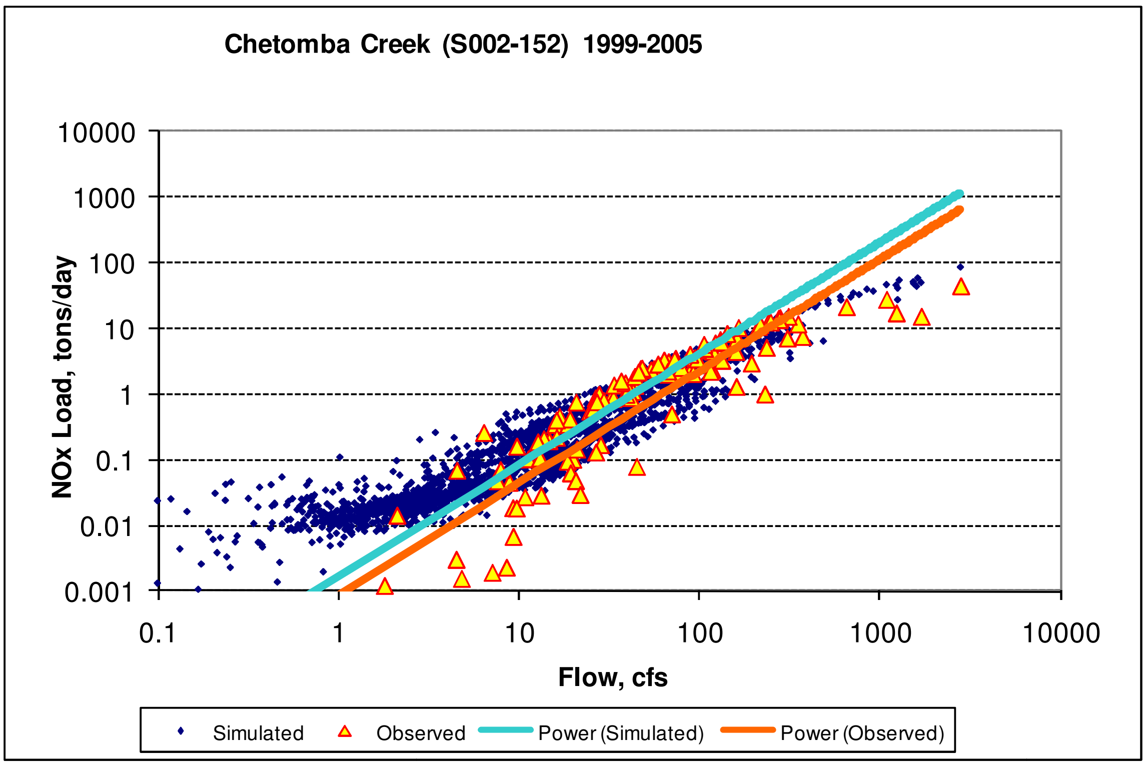
Chetomba Creek (S002-152) 2006-2009
TP Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

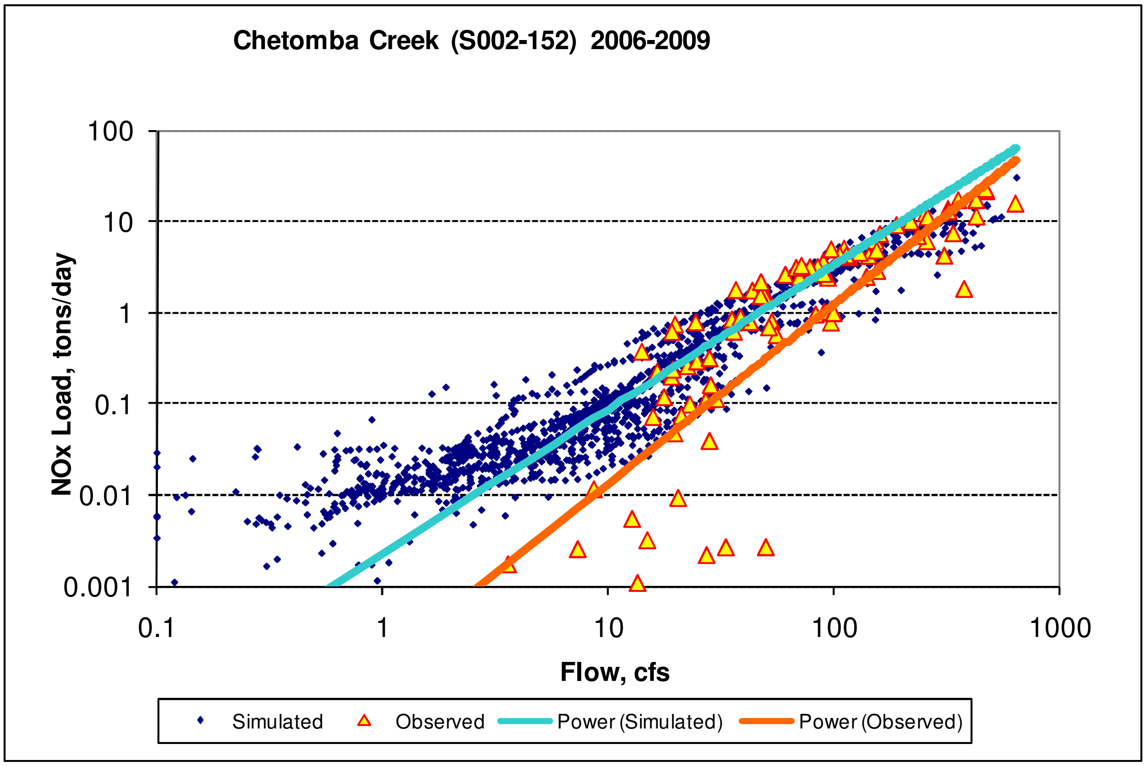



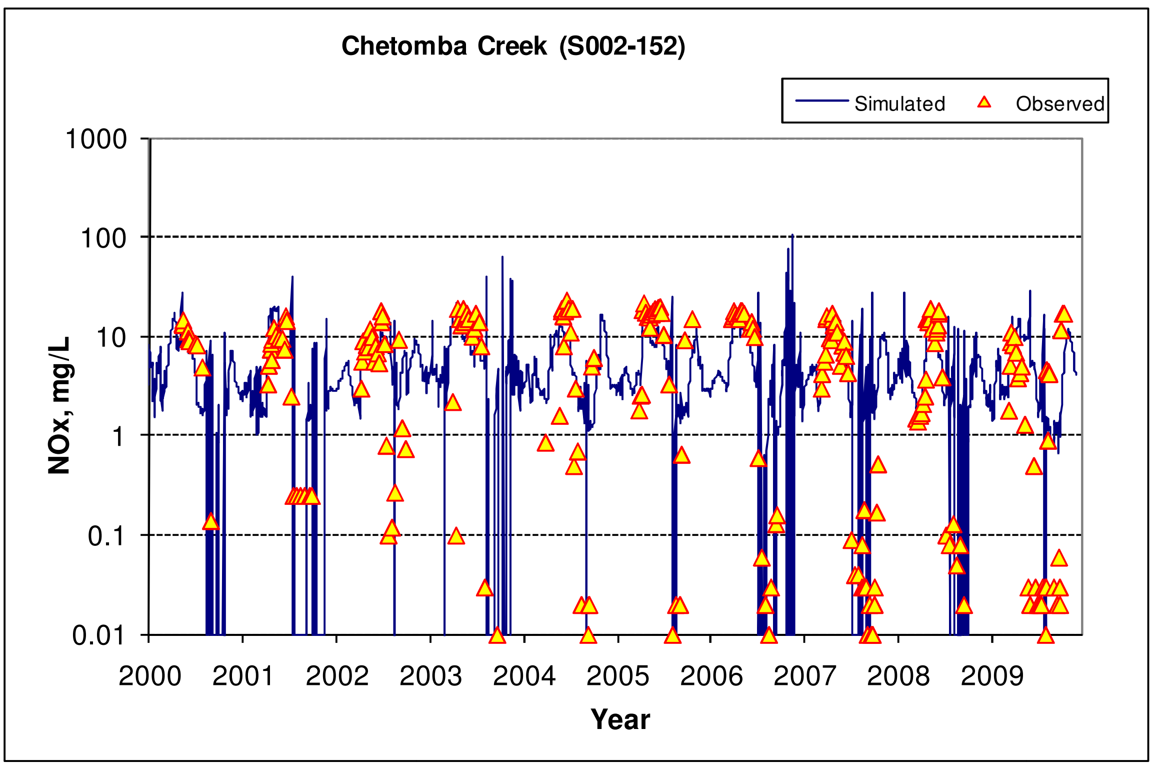
Chetomba Creek (S002-152)
Simulated
Observed
TP, mg/L
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

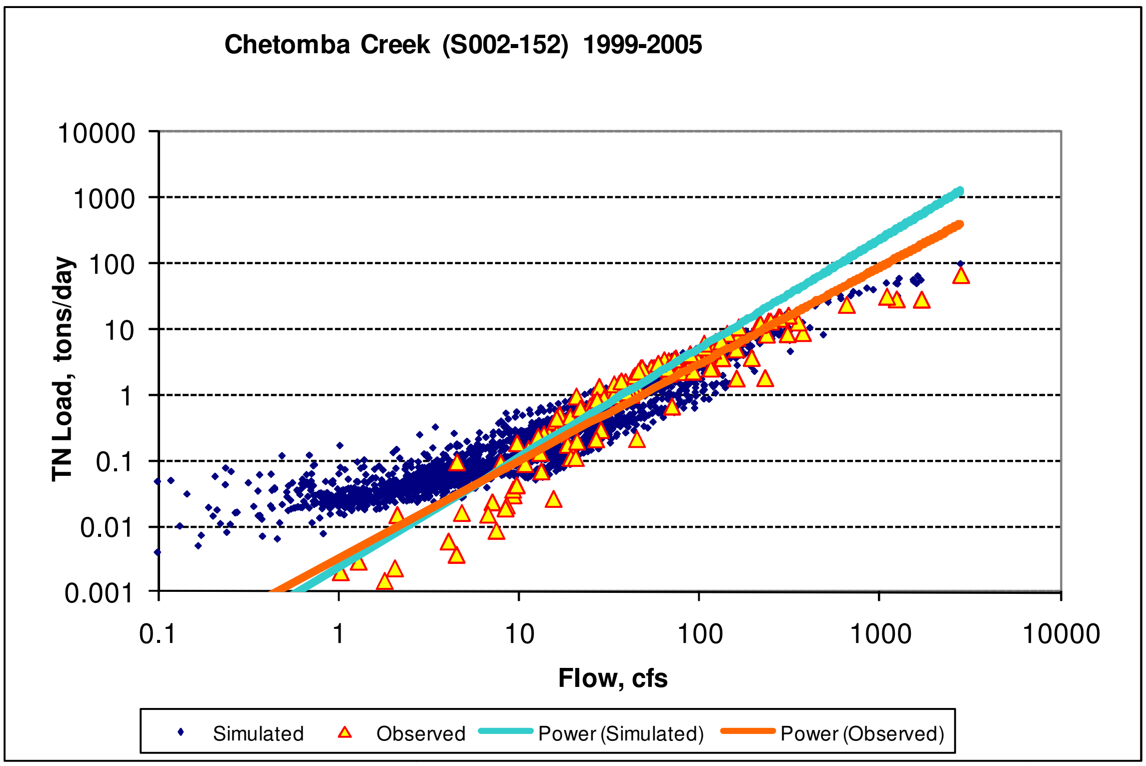


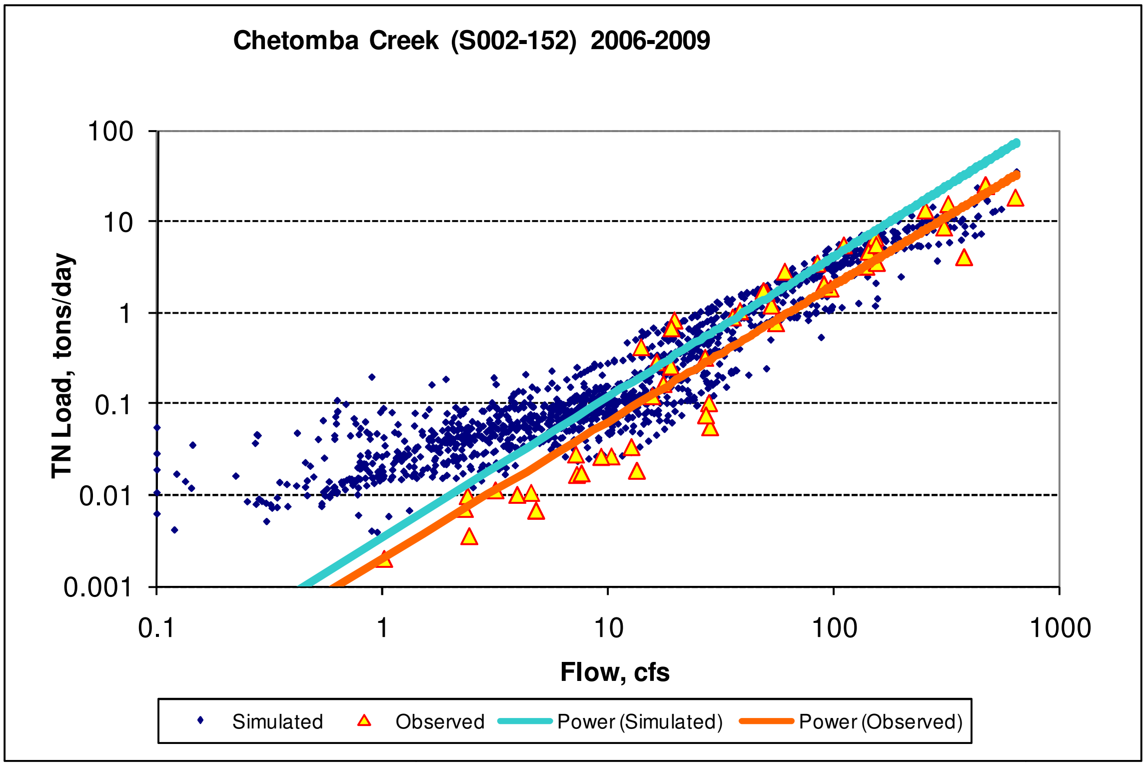

Chetomba Creek (S002-152) 2006-2009
NOx Load, tons/day
100
10
1
0.1
0.01
0.001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

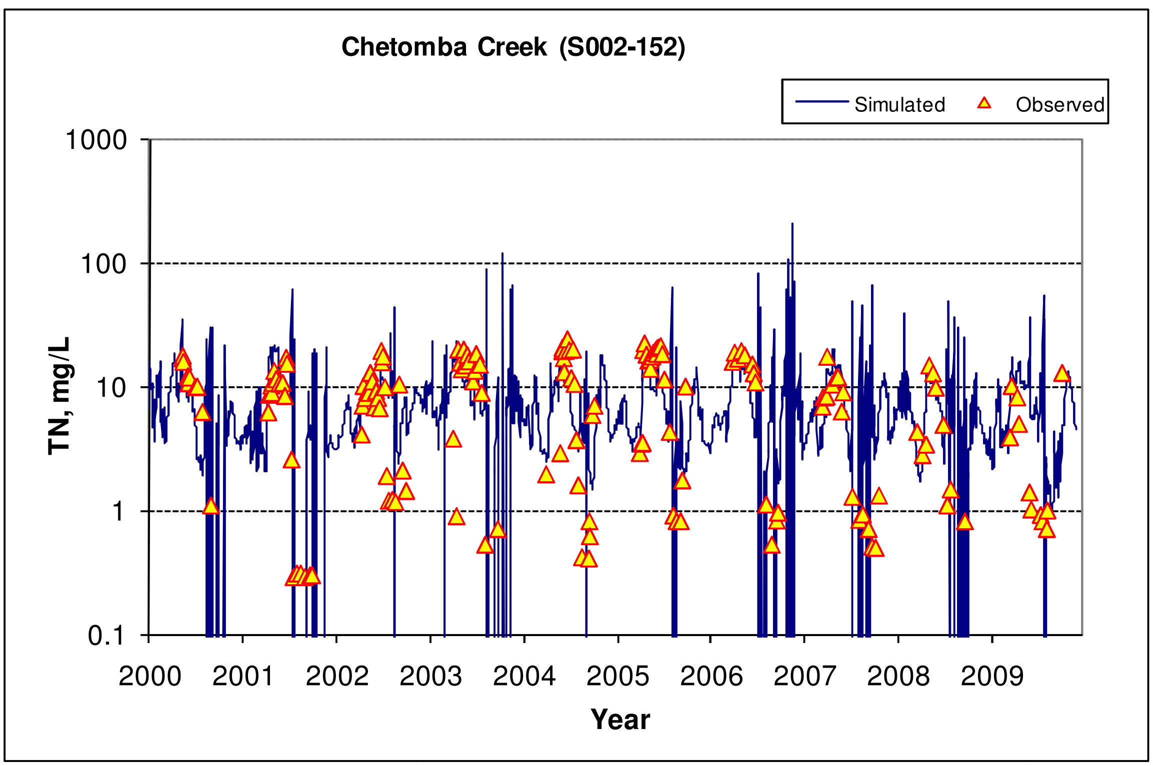

Chetomba Creek (S002-152)
Simulated
Observed
NOx, mg/L
1000
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |



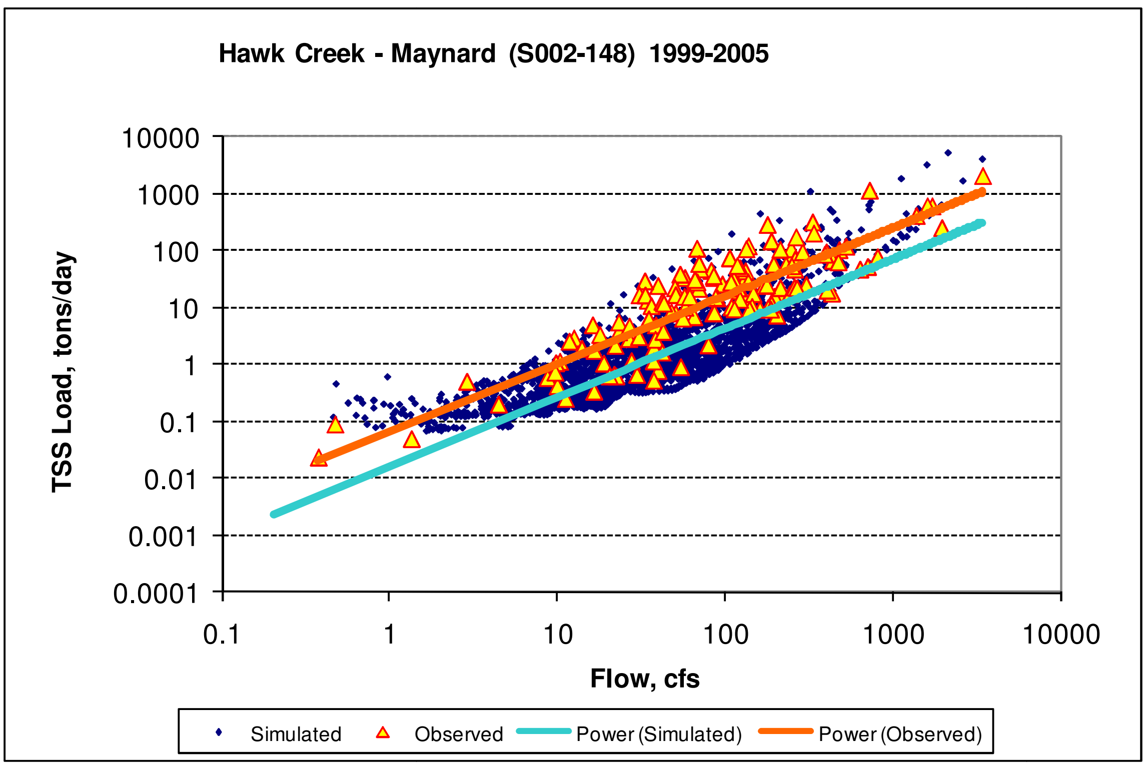

Chetomba Creek (S002-152) 2006-2009
TN Load, tons/day
100
10
1
0.1
0.01
0.001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

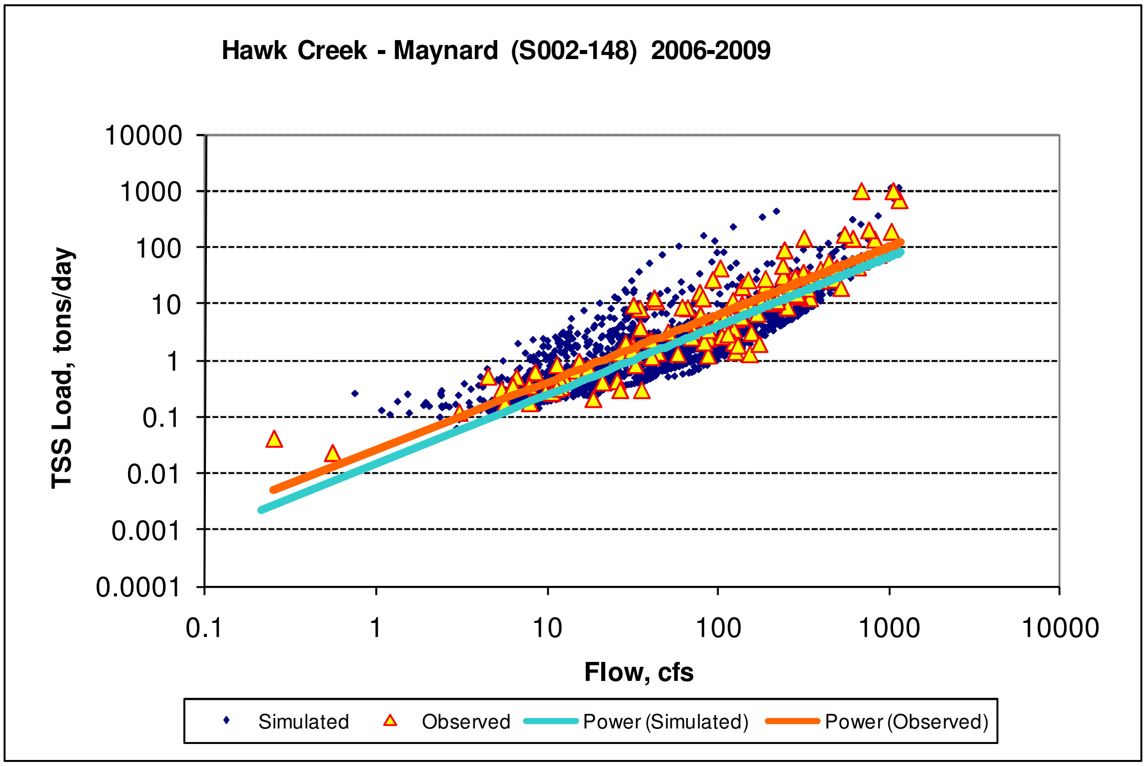

Chetomba Creek (S002-152)
Simulated
Observed
TN, mg/L
1000
100
10
1
0.1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

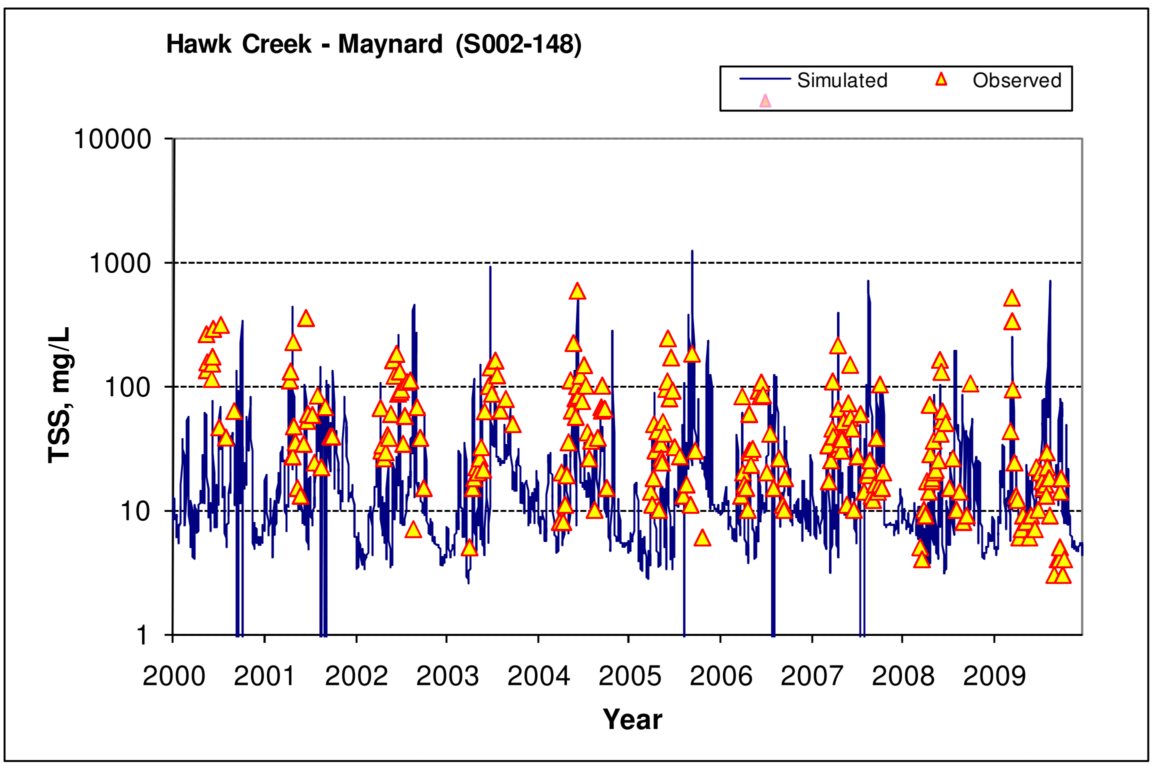
# 2 Hawk Creek at Maynard (S002-148)

## 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 |

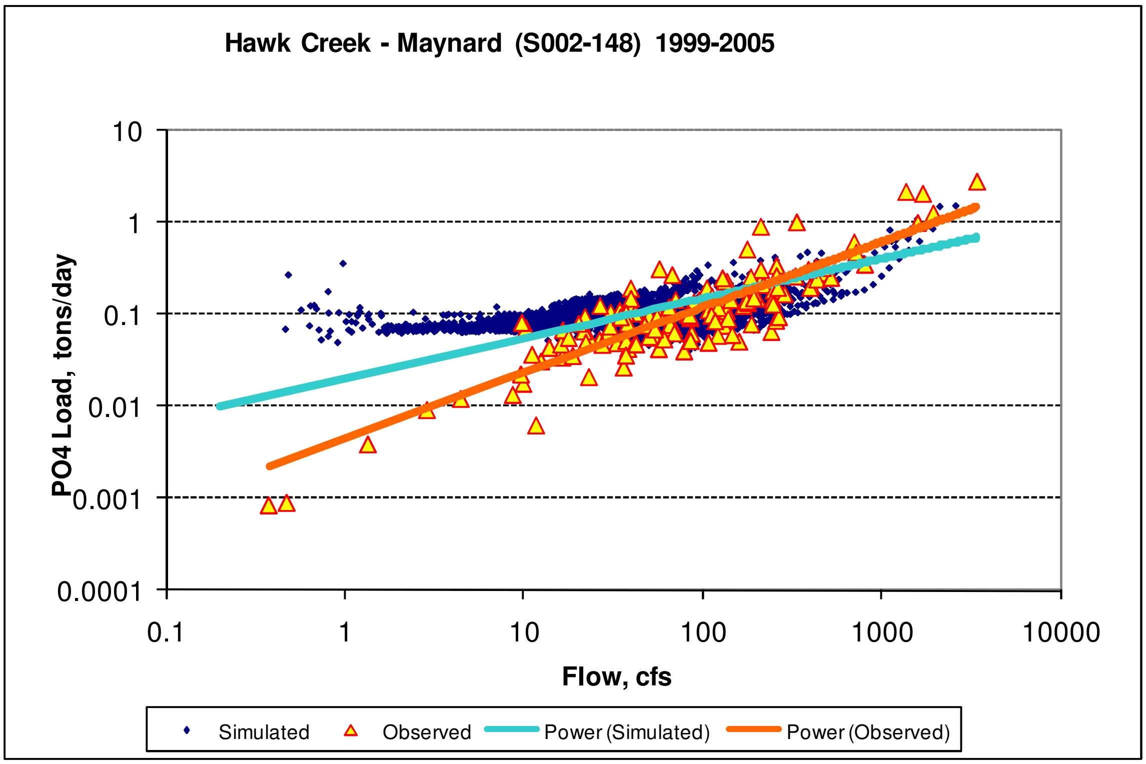


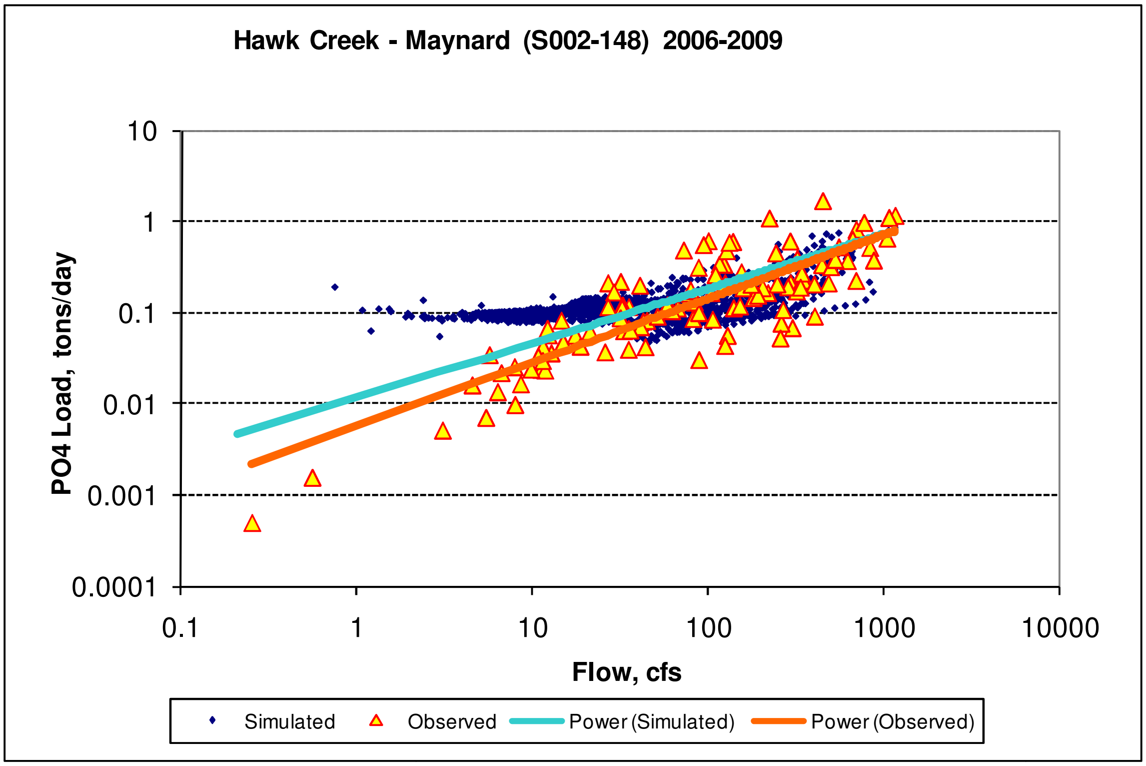

Hawk Creek - Maynard (S002-148) 2006-2009
TSS Load, tons/day
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)


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

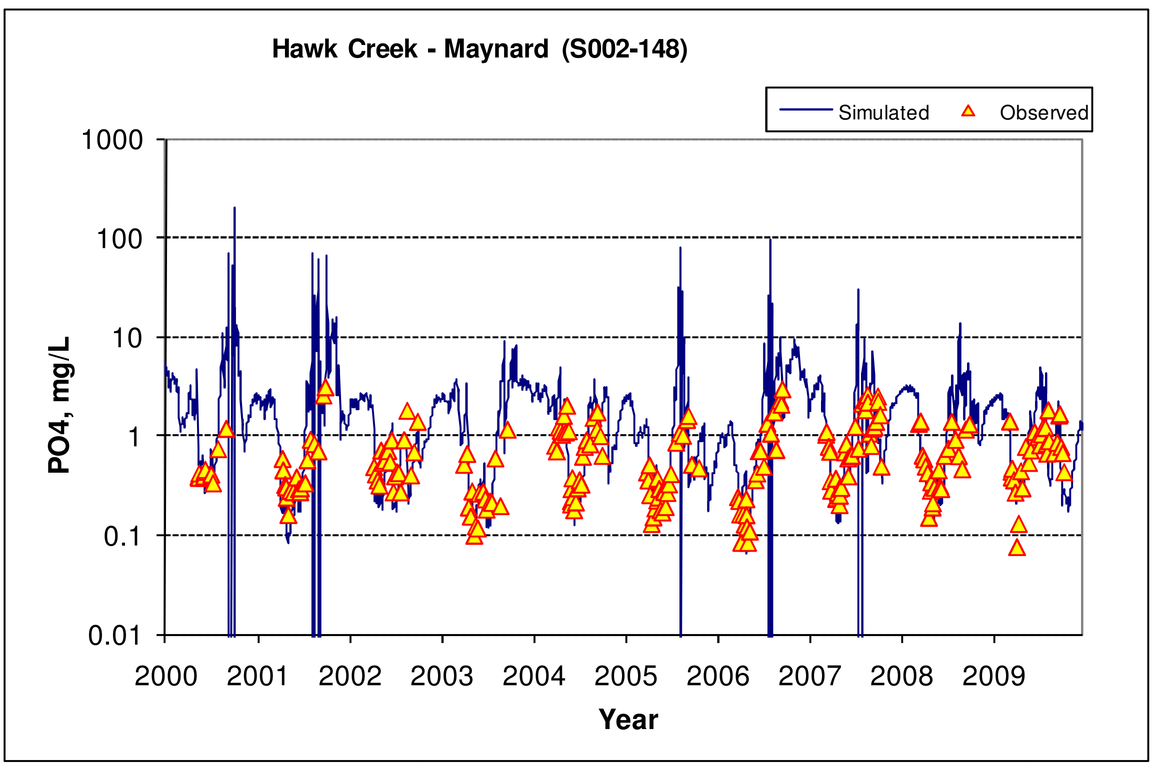
## 2.2 ORTHOPHOSPHATE (AS P)

| 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 |





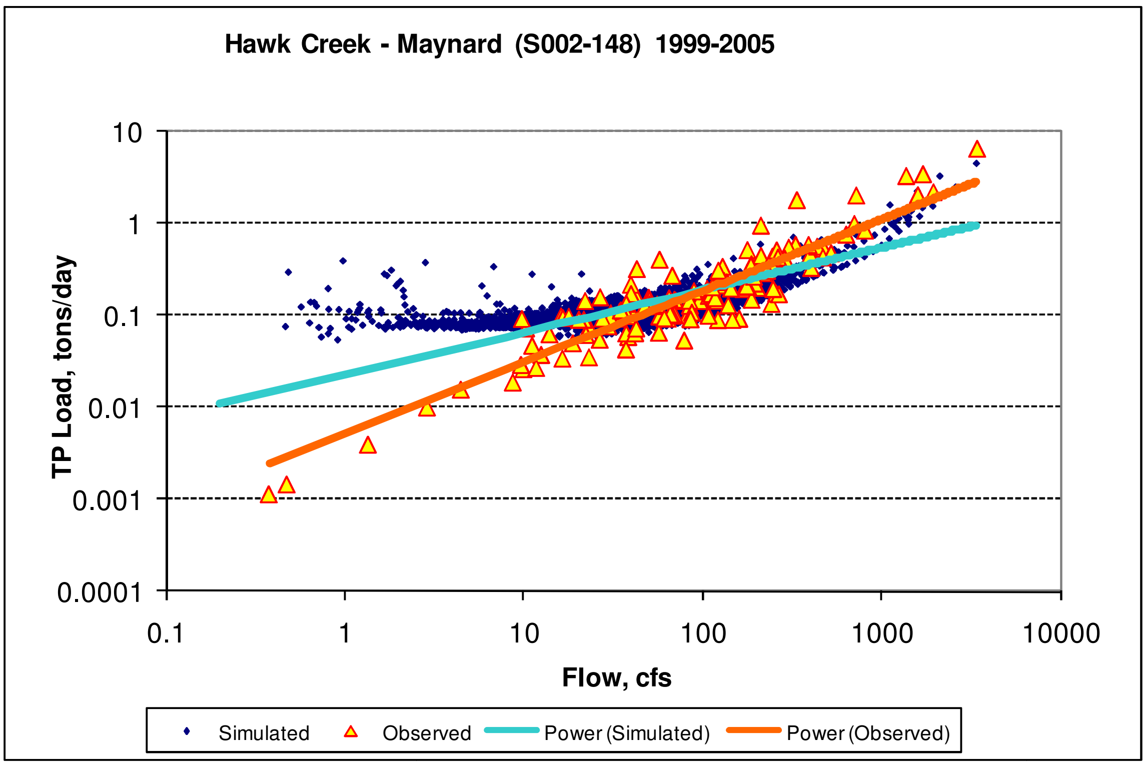
Hawk Creek - Maynard (S002-148) 2006-2009
PO4 Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

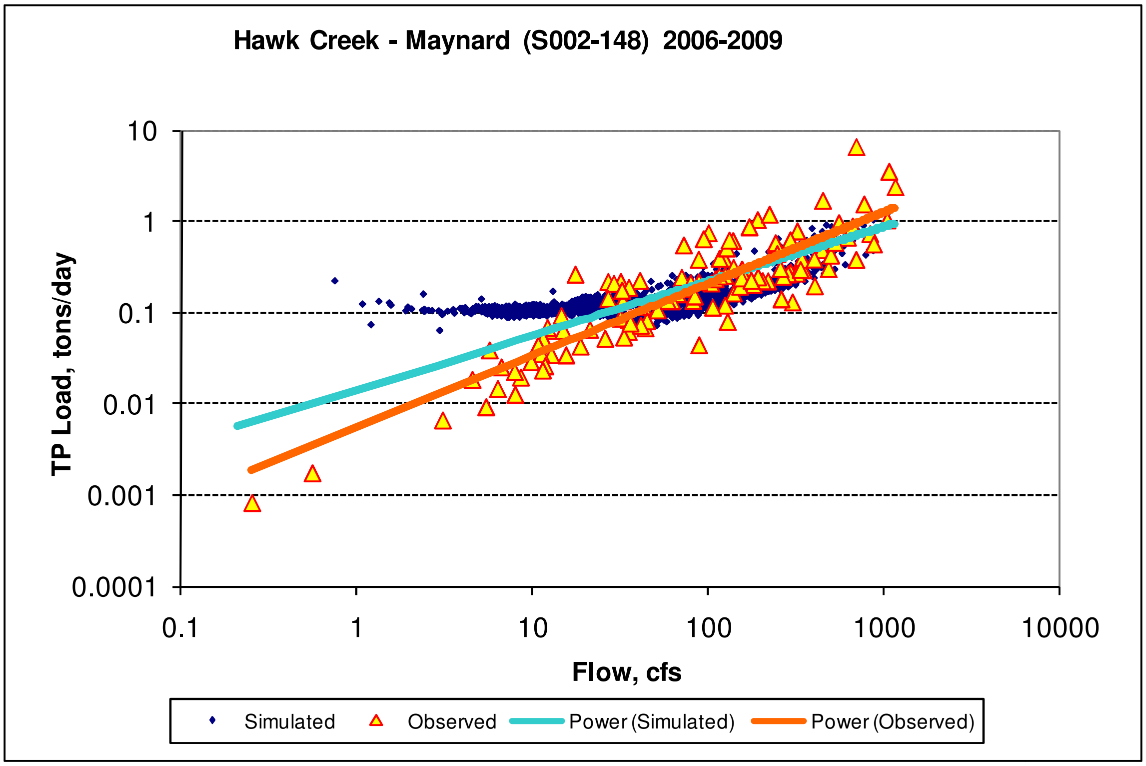



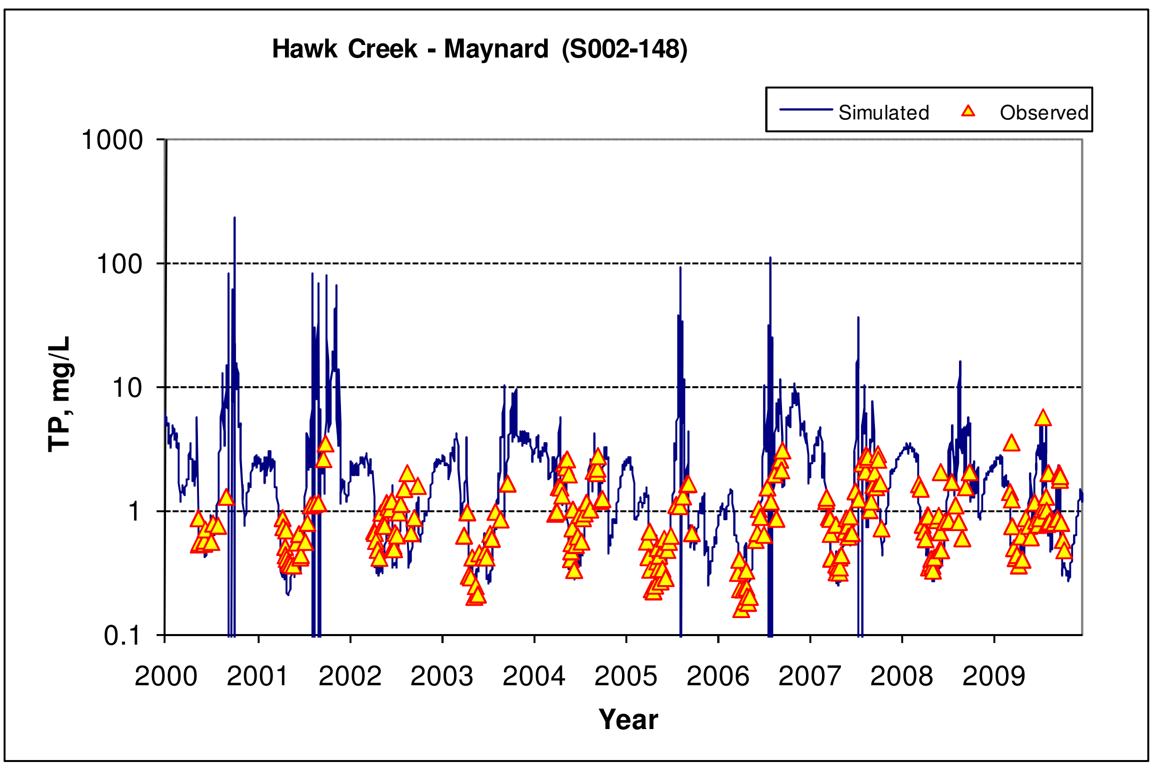
Hawk Creek - Maynard (S002-148)
Simulated
Observed
PO4, mg/L
1000
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

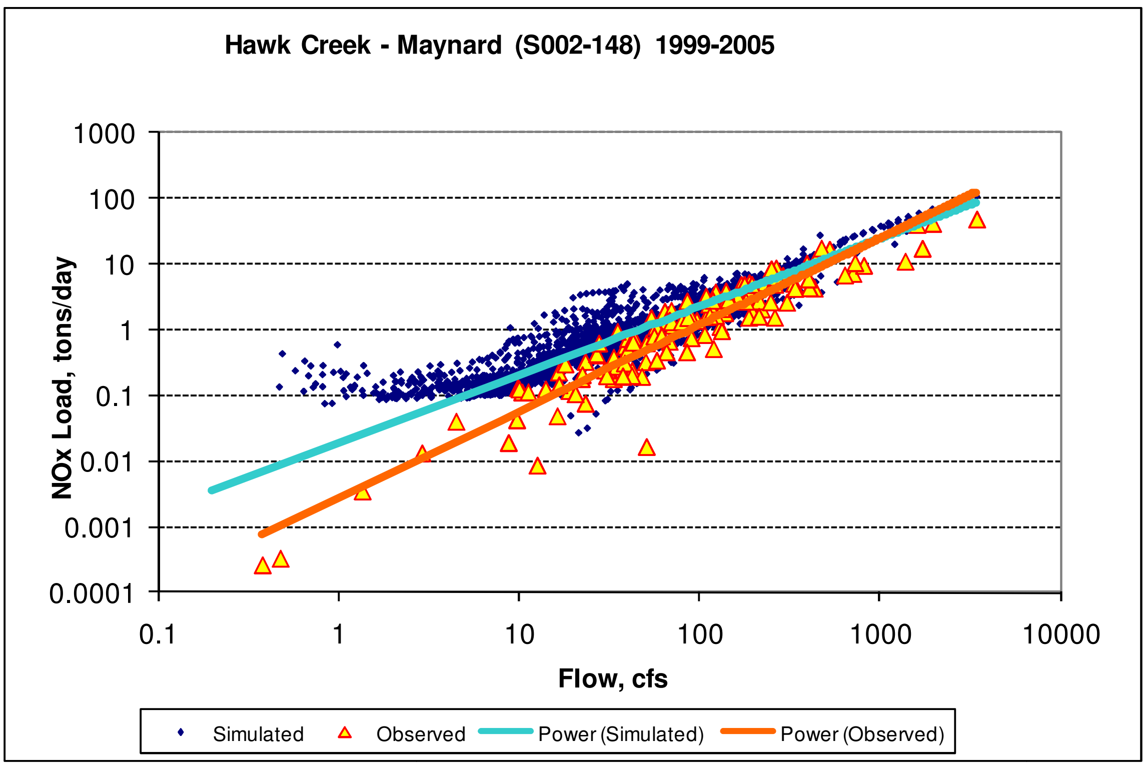


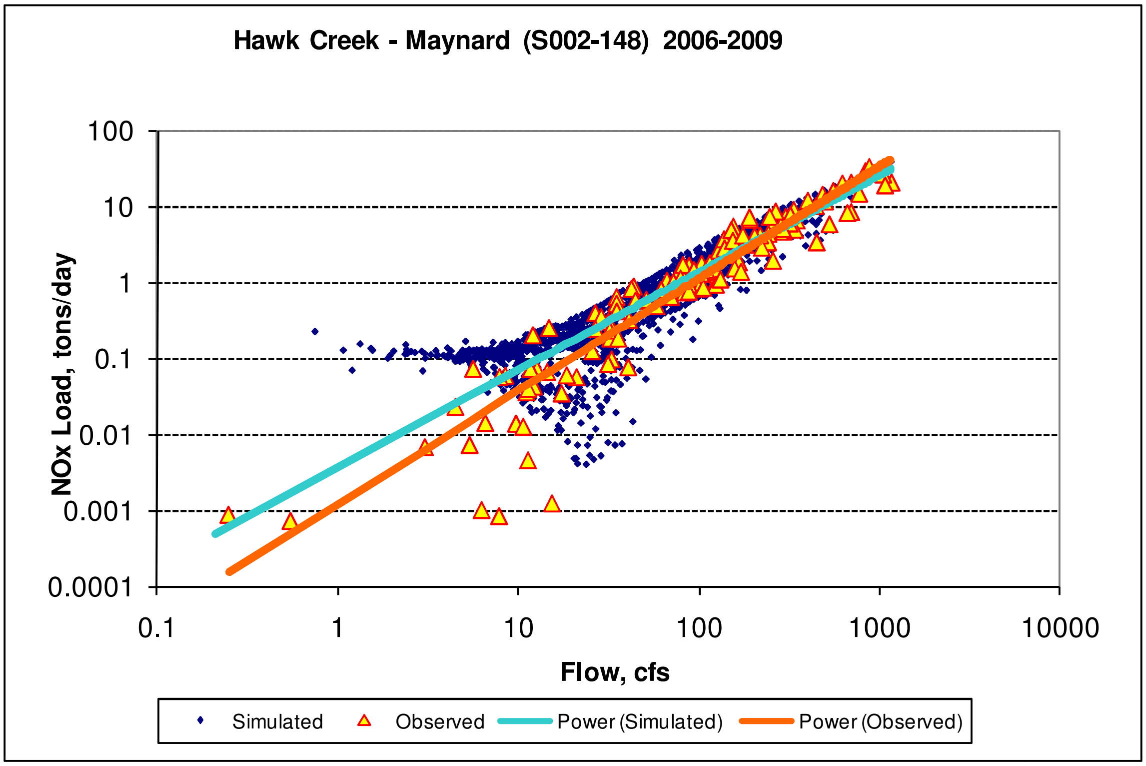

Hawk Creek - Maynard (S002-148) 2006-2009
TP Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

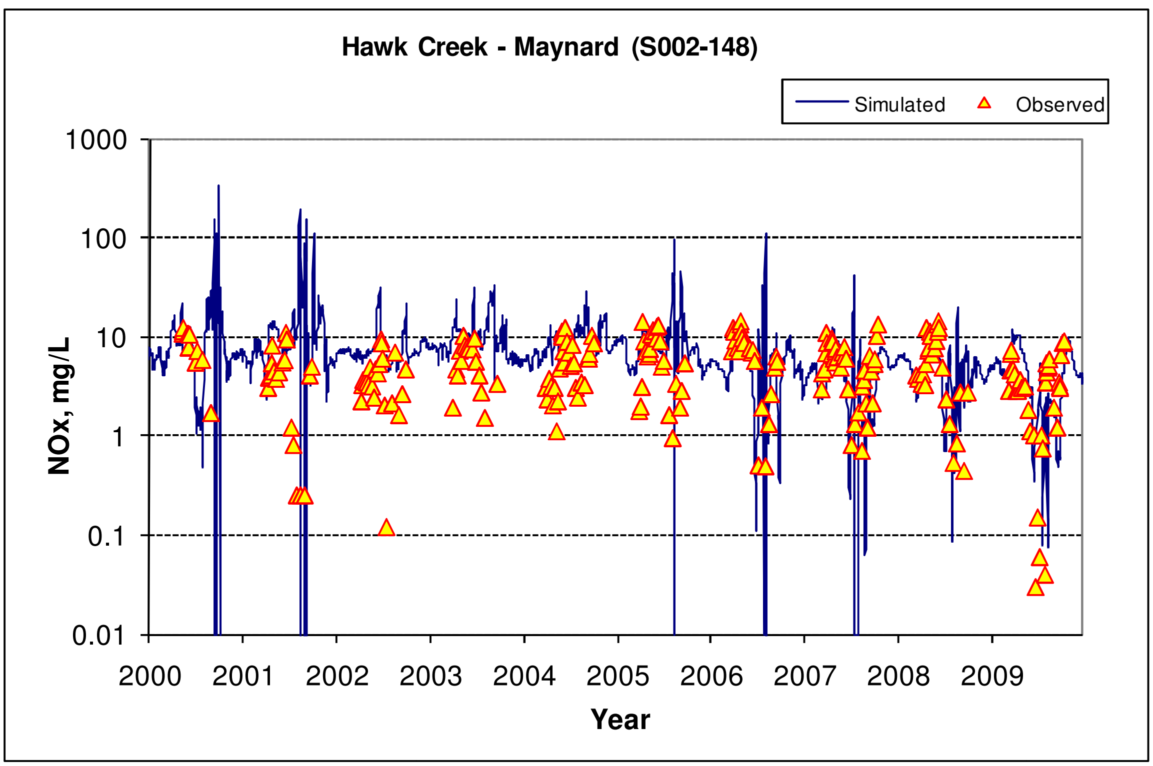

Hawk Creek - Maynard (S002-148)
Simulated
Observed
TP, mg/L
1000
100
10
1
0.1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

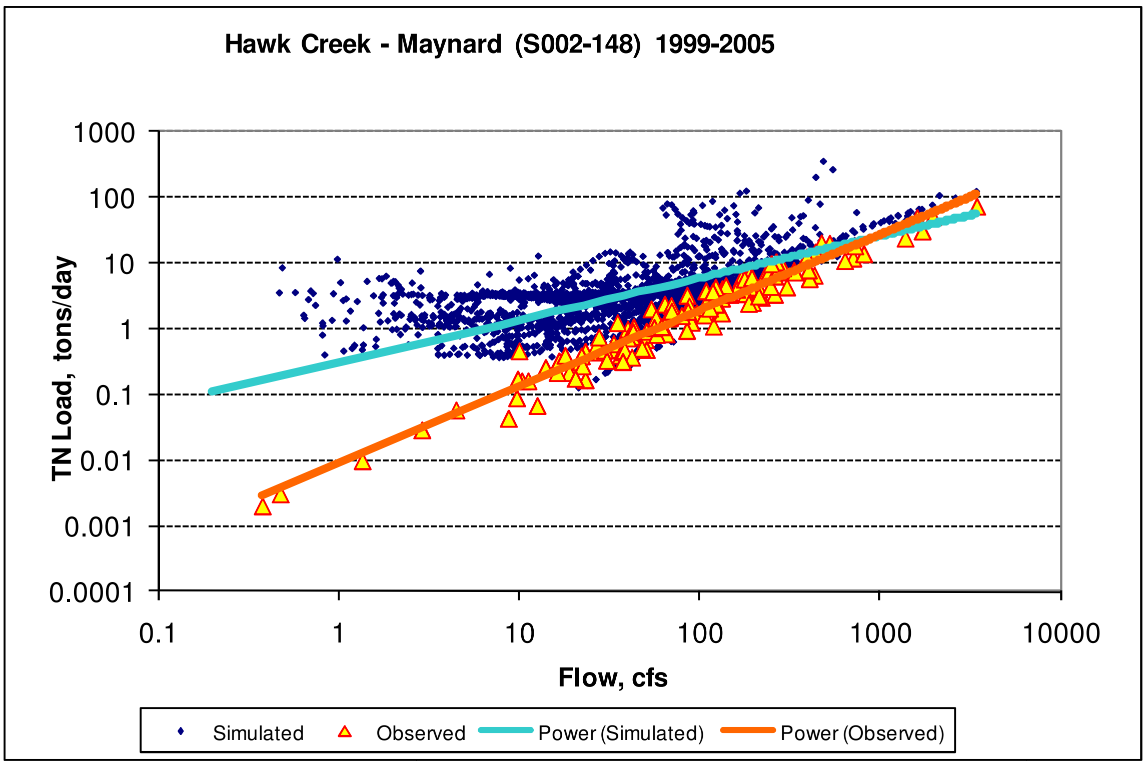


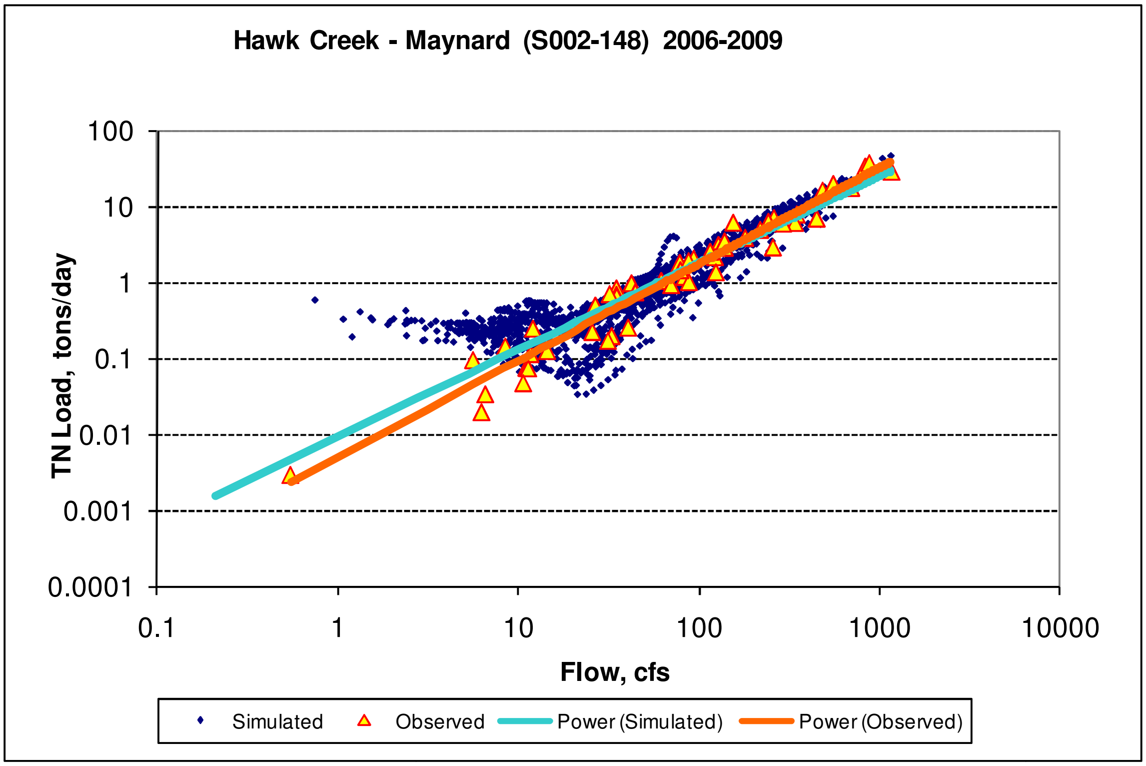

Hawk Creek - Maynard (S002-148) 2006-2009
NOx Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

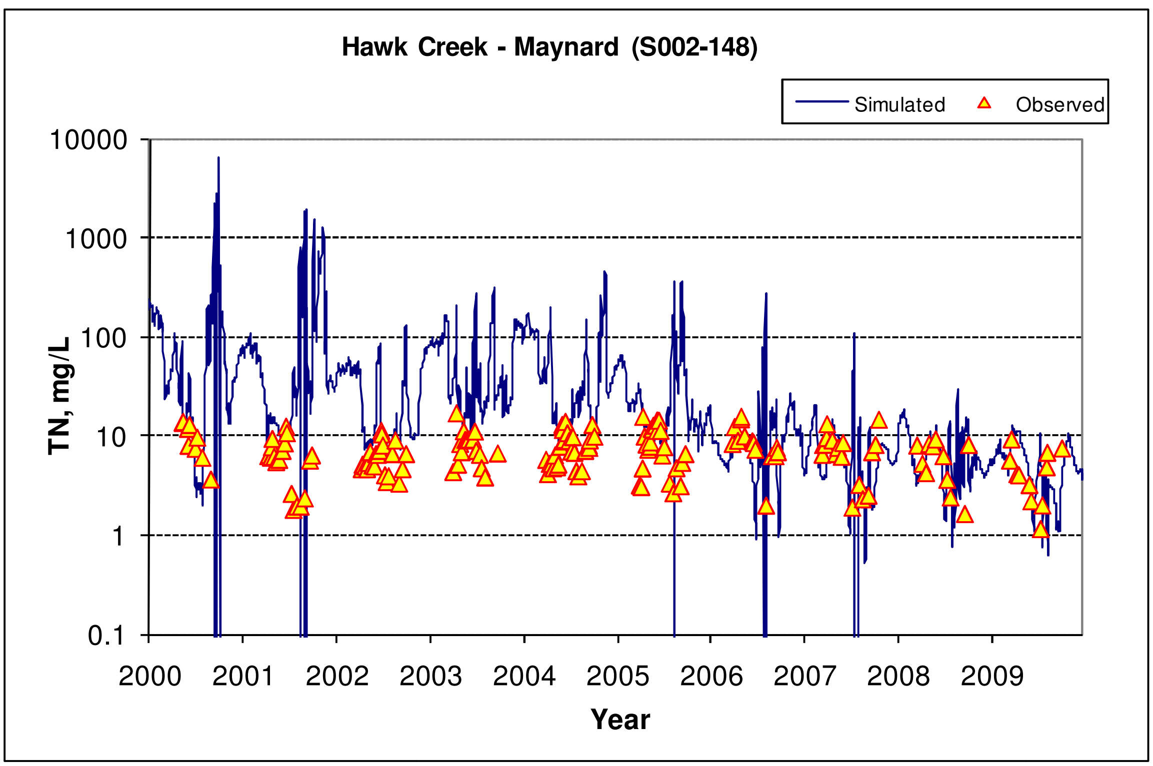

Hawk Creek - Maynard (S002-148)
Simulated
Observed
NOx, mg/L
1000
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |



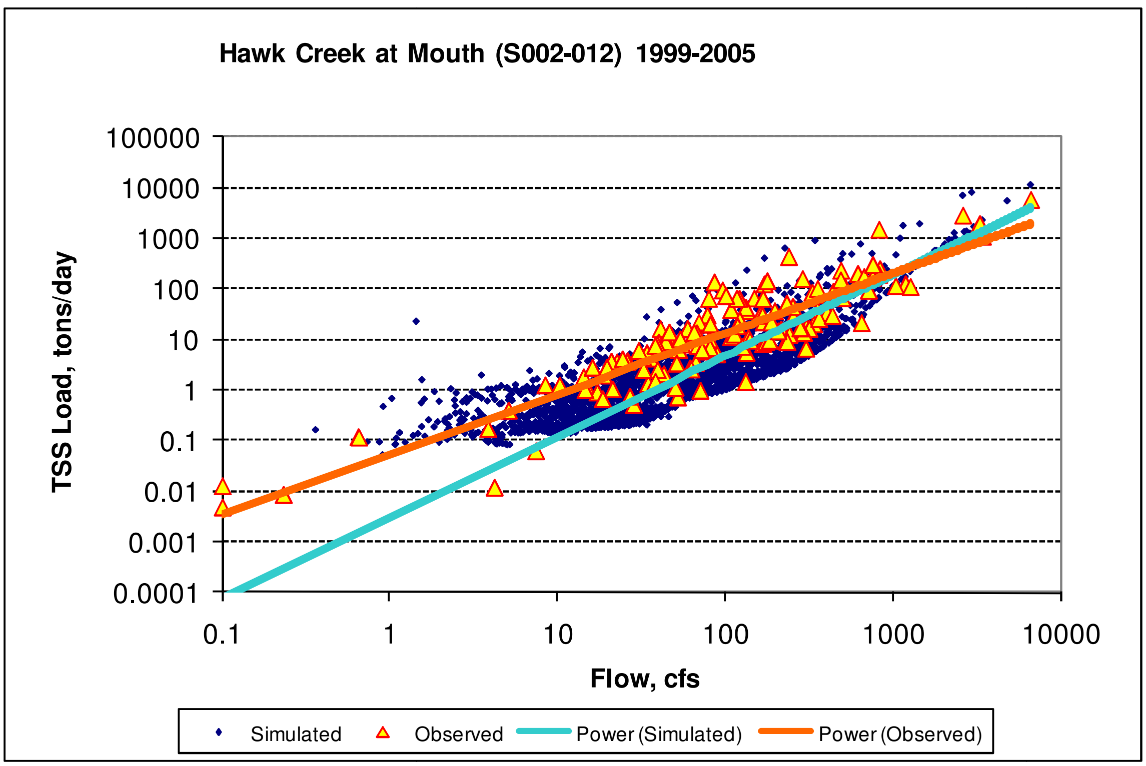

Hawk Creek - Maynard (S002-148) 2006-2009
TN Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

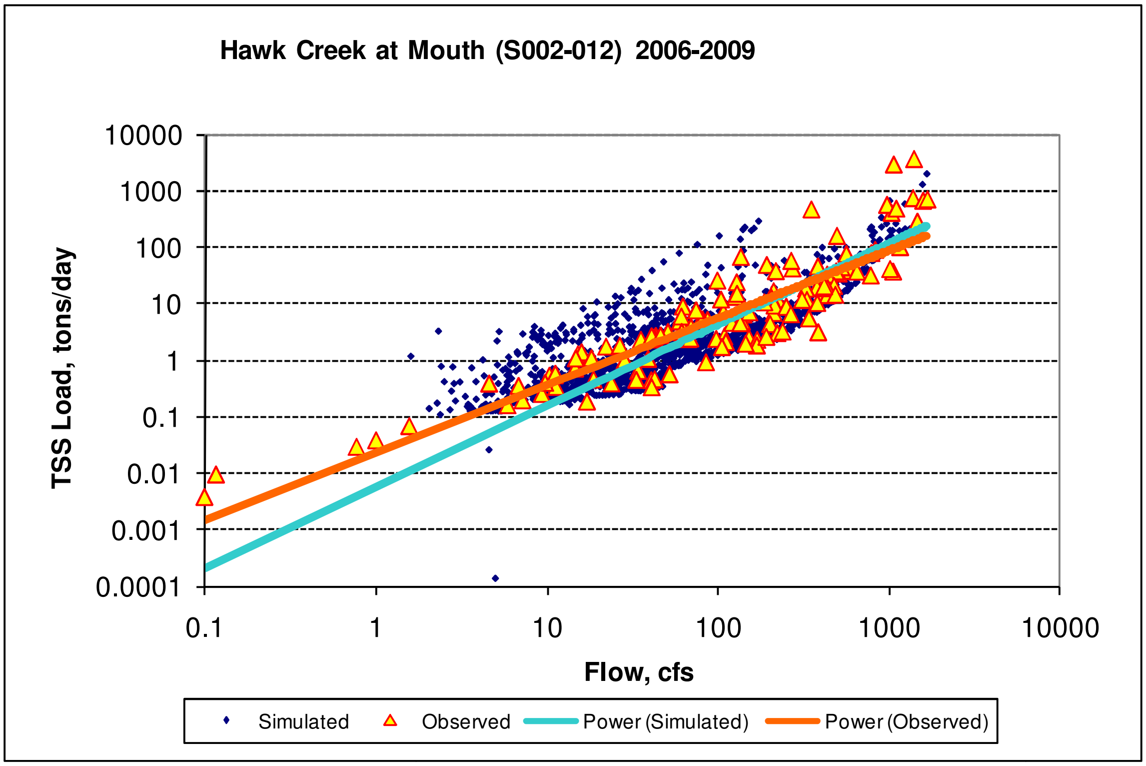

Hawk Creek - Maynard (S002-148)
Simulated
Observed
TN, mg/L
10000
1000
100
10
1
0.1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

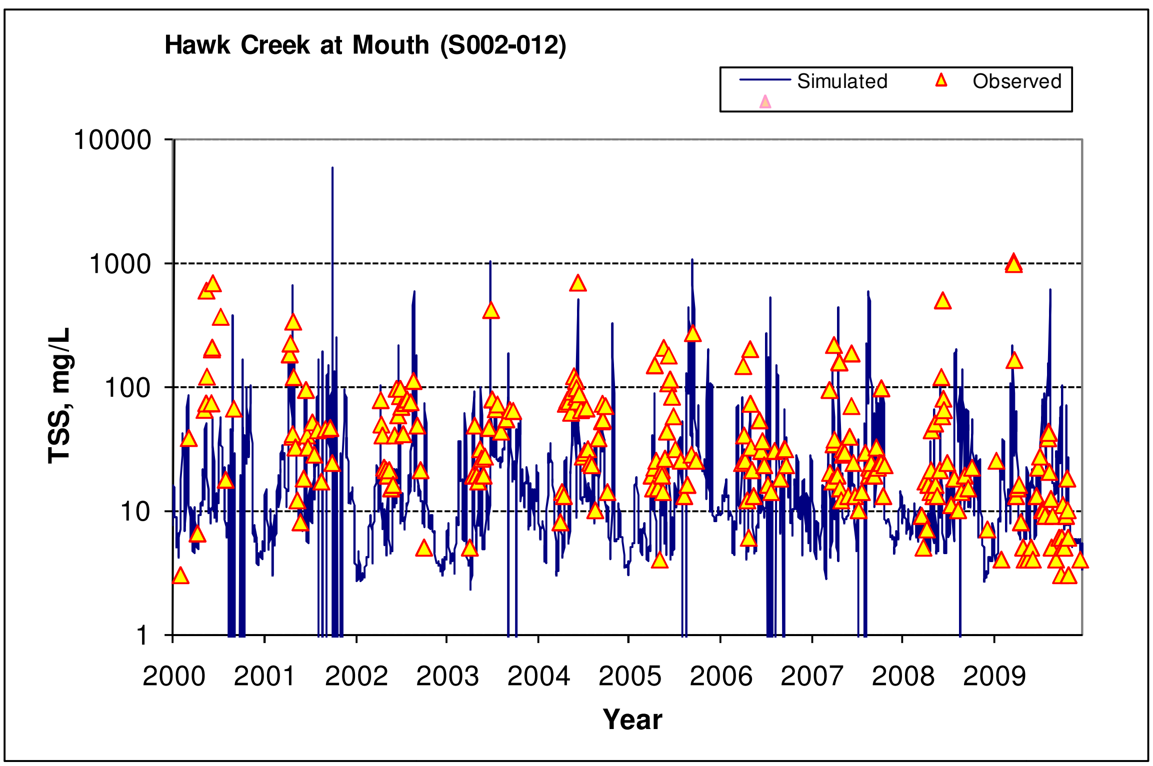
# 3 Hawk Creek at Mouth (S002-12)

## 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 |

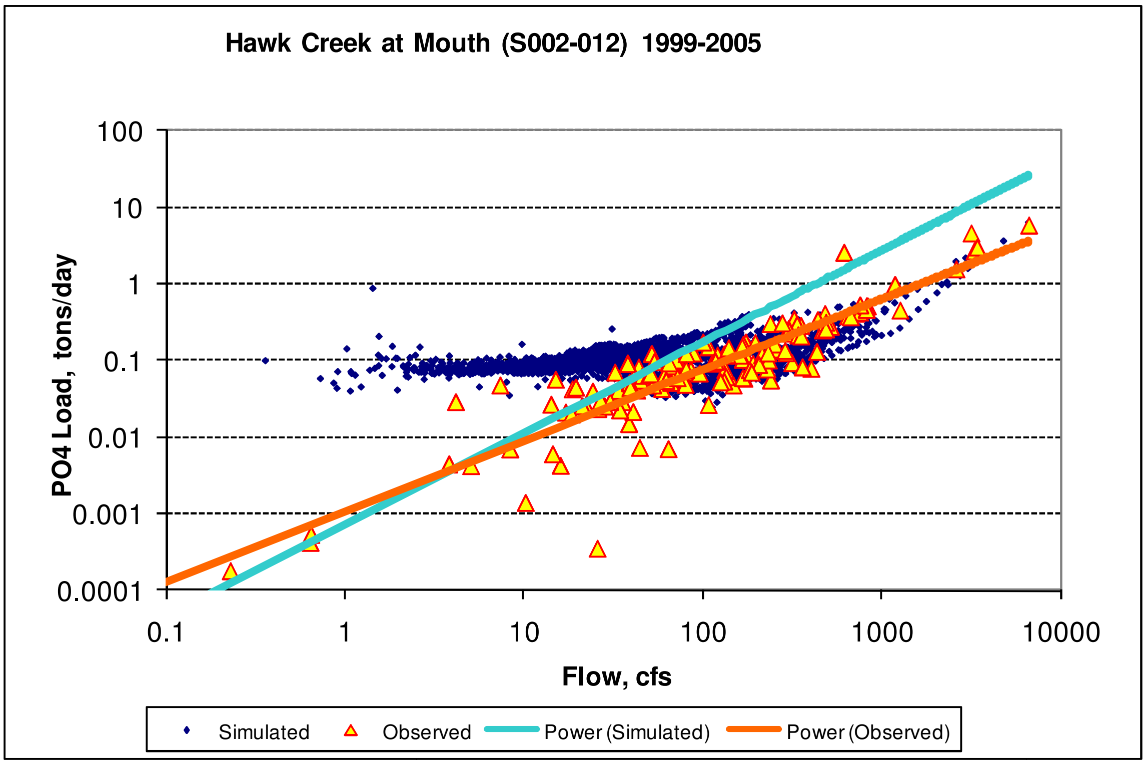


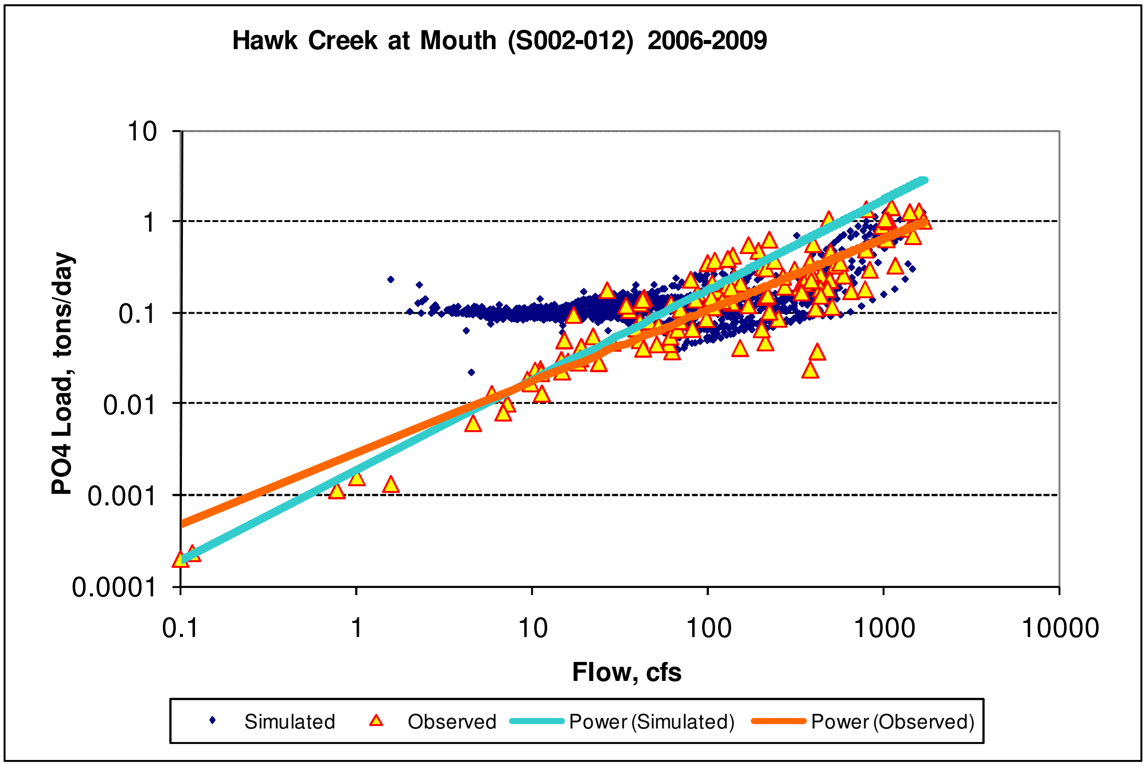

Hawk Creek at Mouth (S002-012) 2006-2009
TSS Load, tons/day
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

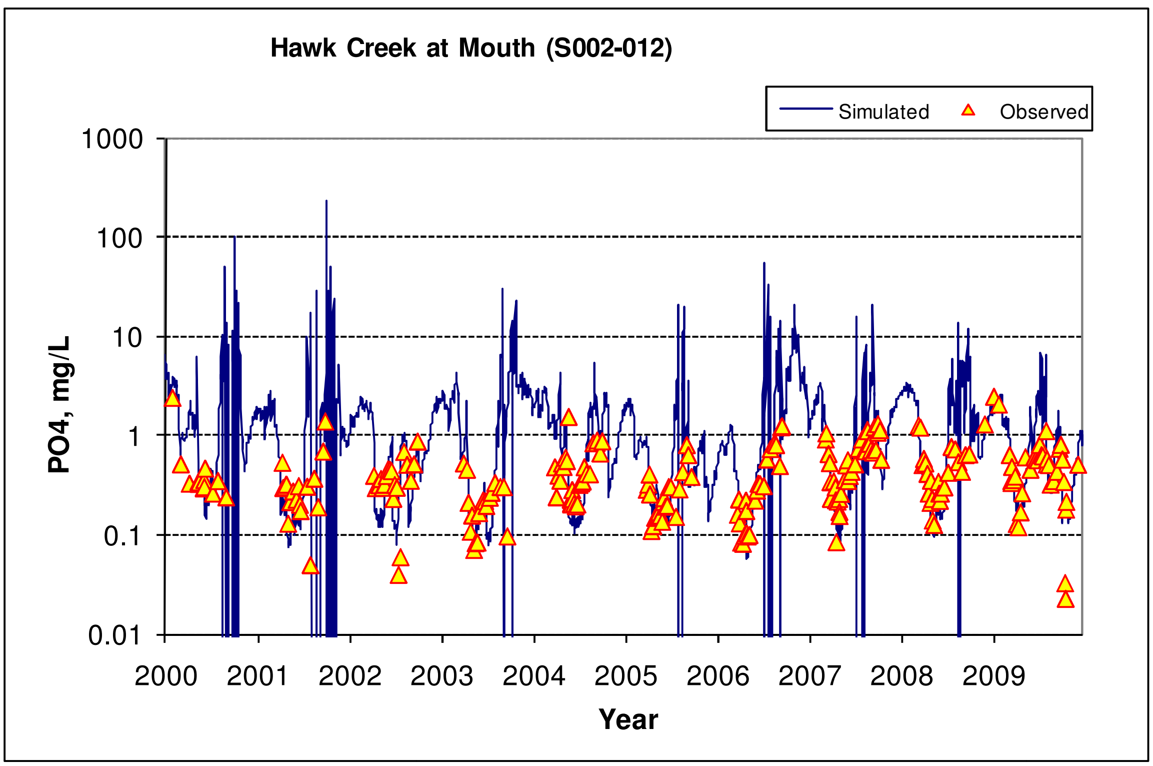

Hawk Creek at Mouth (S002-012)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

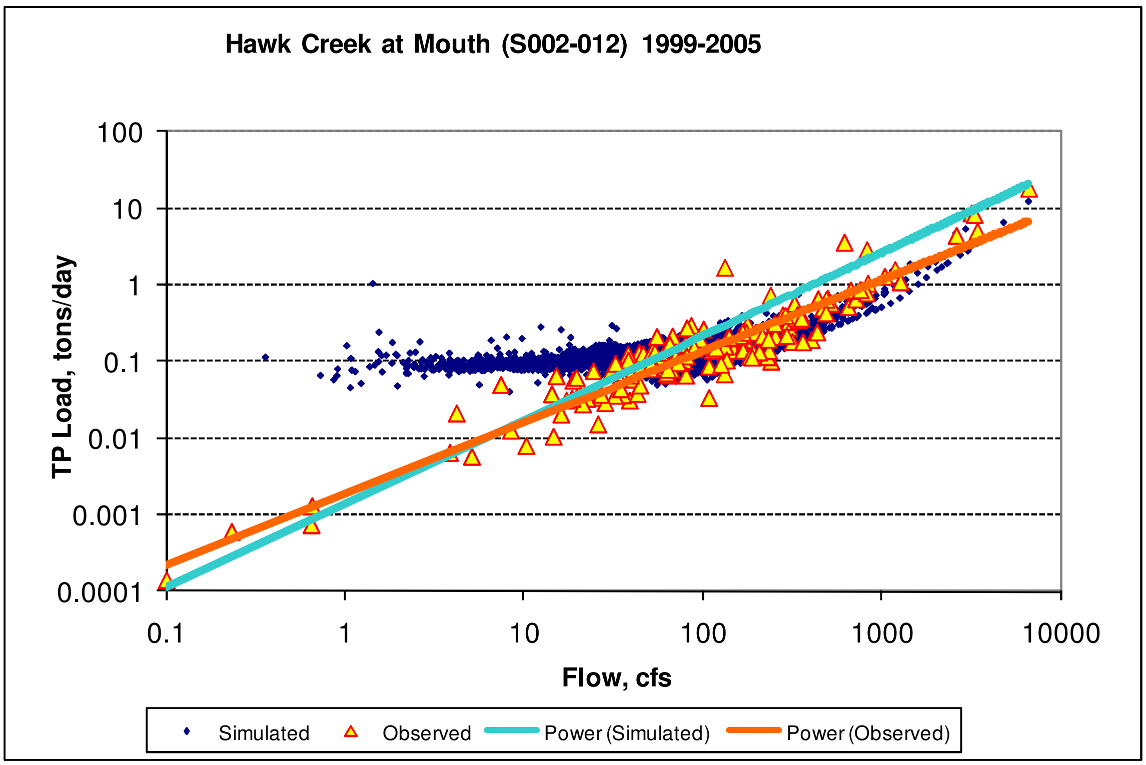


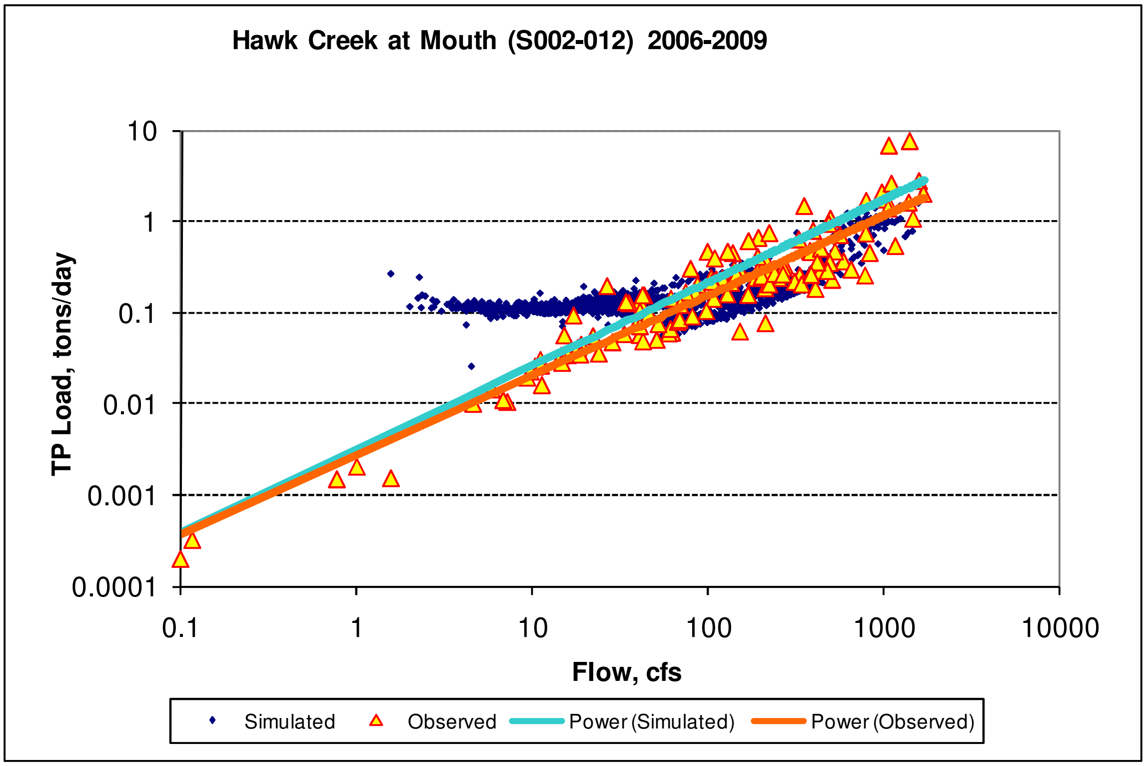

Hawk Creek at Mouth (S002-012) 2006-2009
PO4 Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

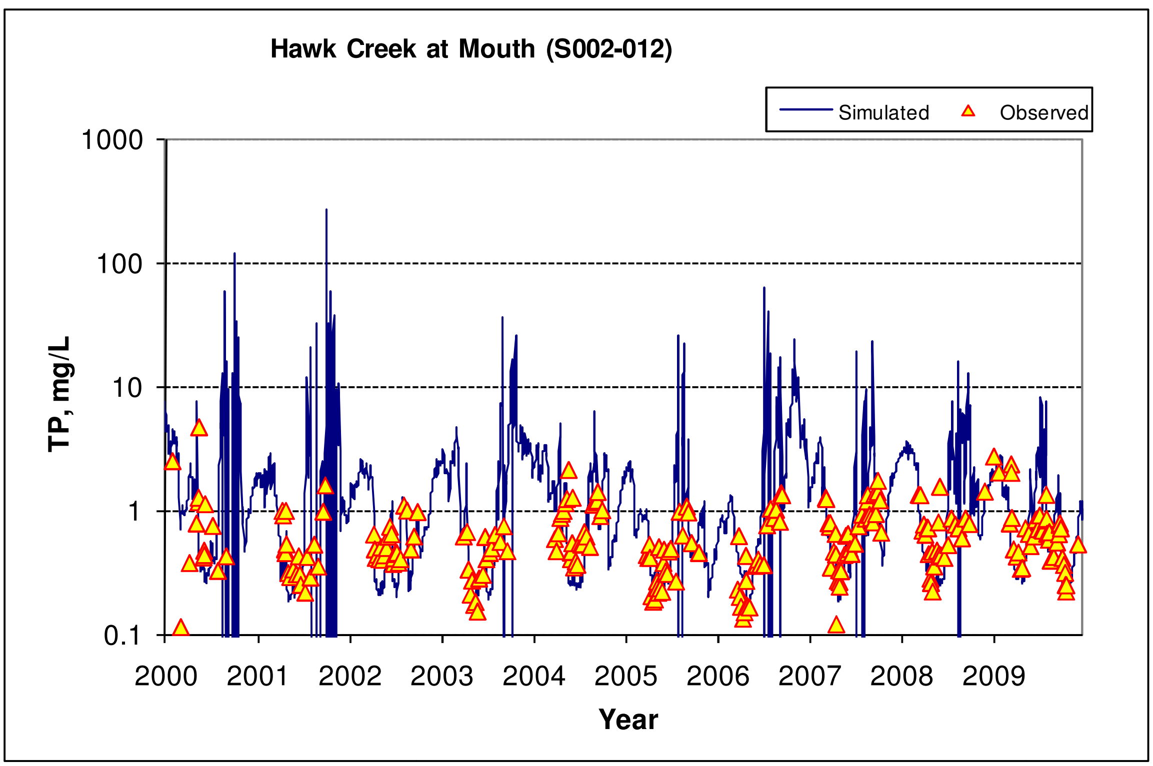

Hawk Creek at Mouth (S002-012)
Simulated
Observed
PO4, mg/L
1000
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

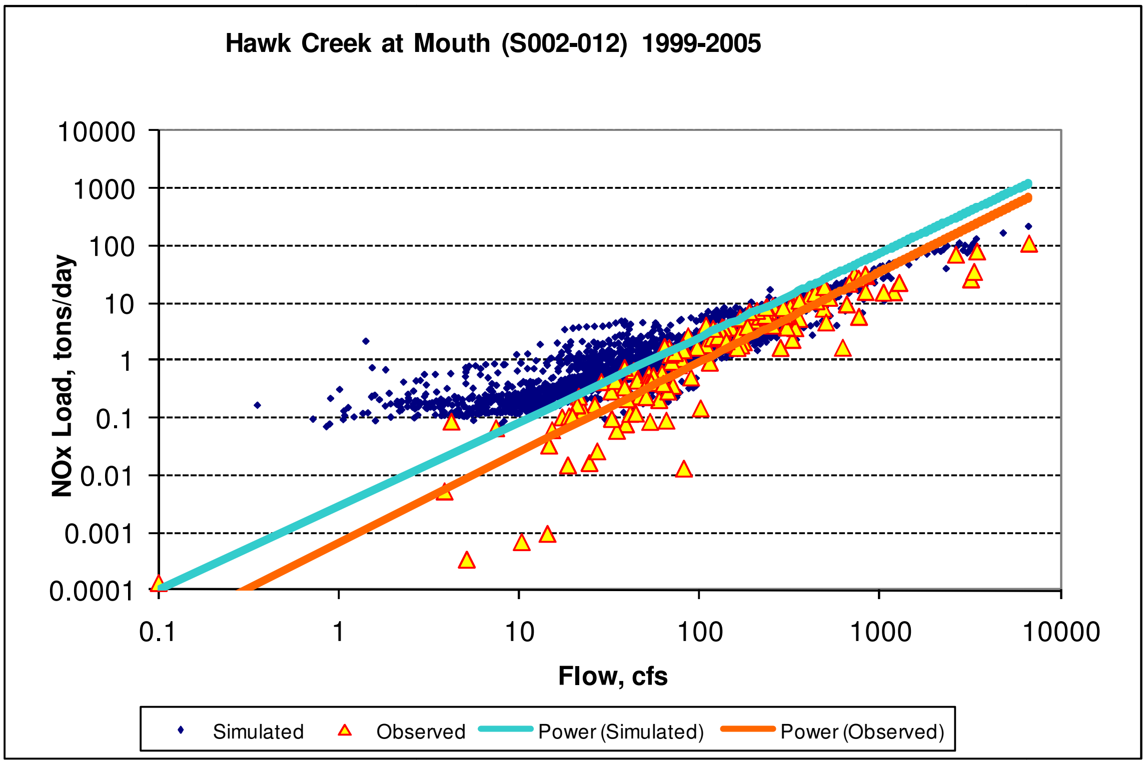


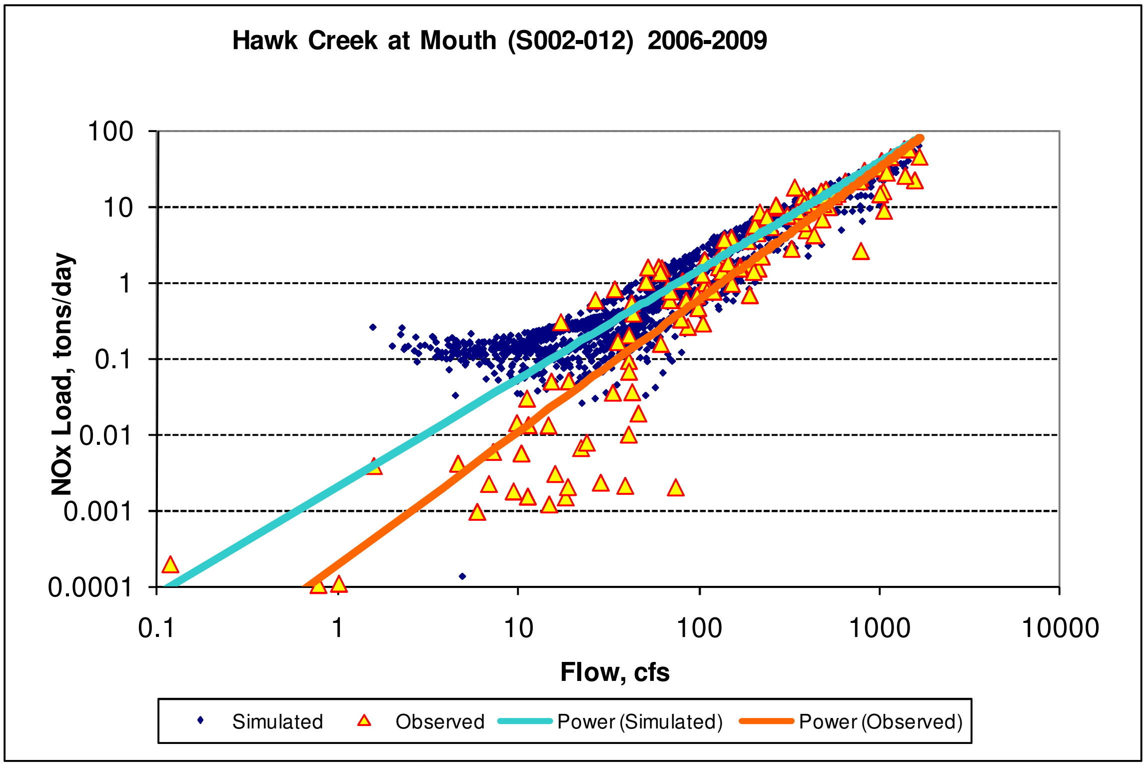

Hawk Creek at Mouth (S002-012) 2006-2009
TP Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)


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

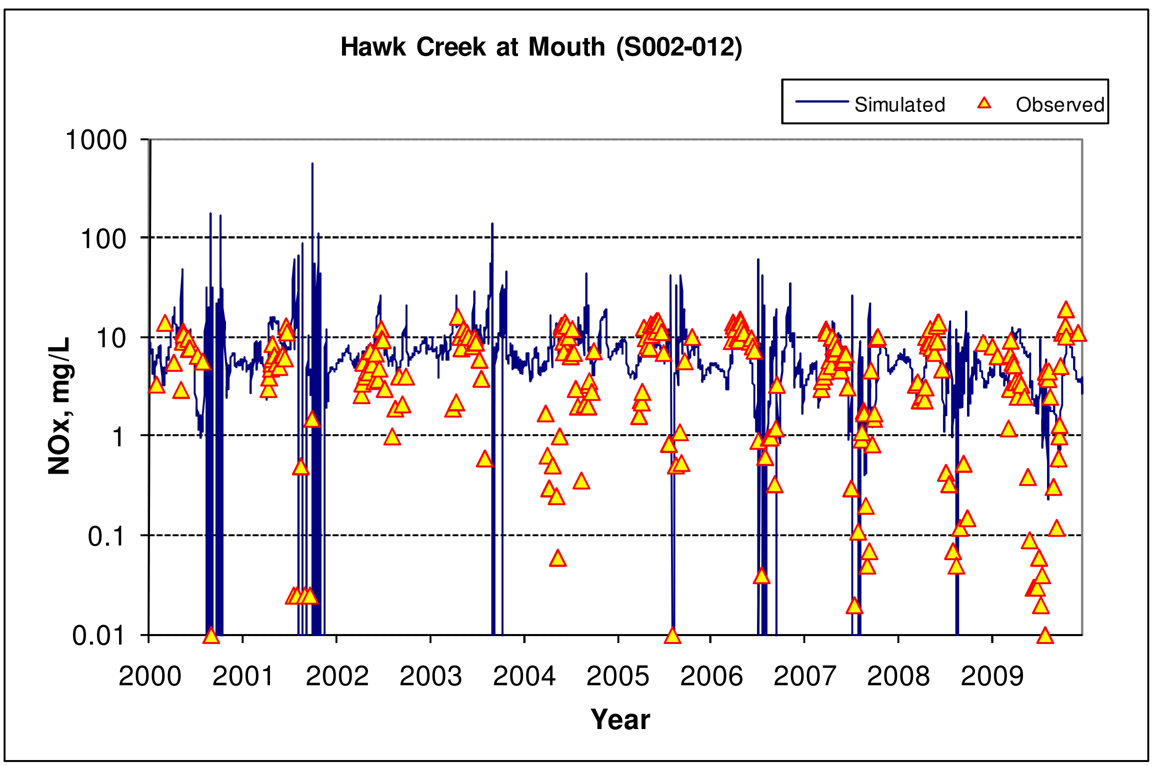
## 3.4 NITRATE PLUS NITRITE NITROGEN (AS N)

| | | |
|---|---|---|
| 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 |





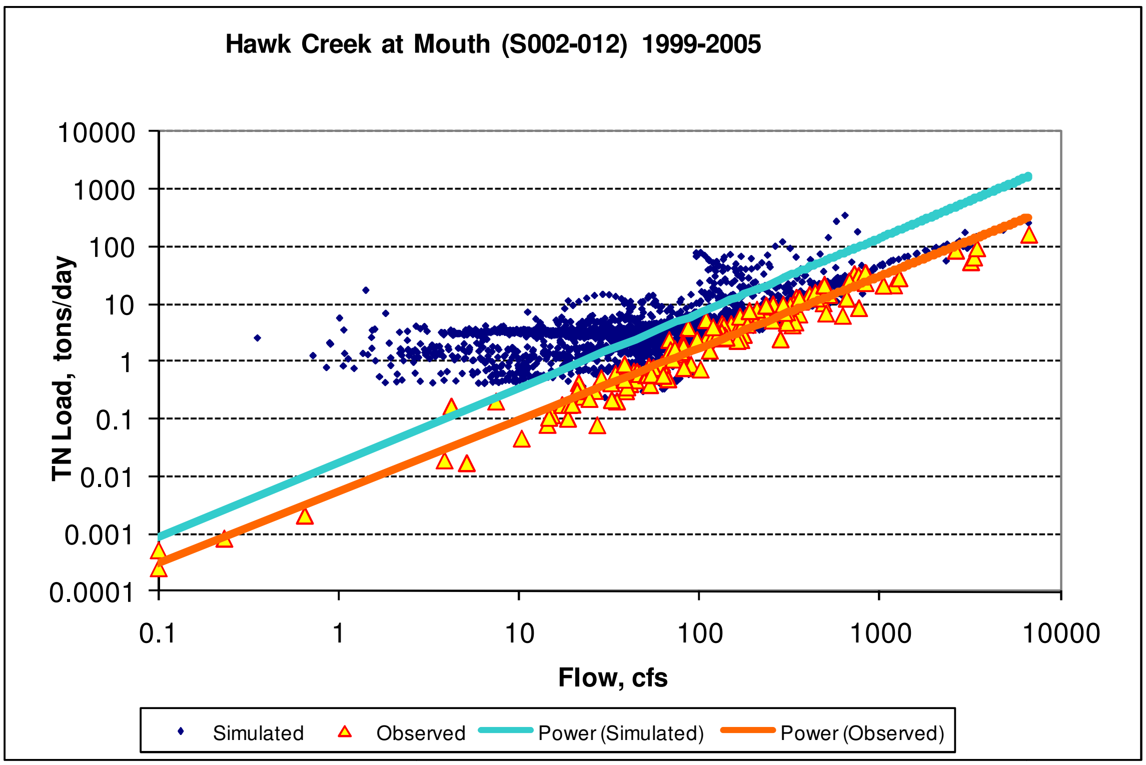
Hawk Creek at Mouth (S002-012) 2006-2009
NOx Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

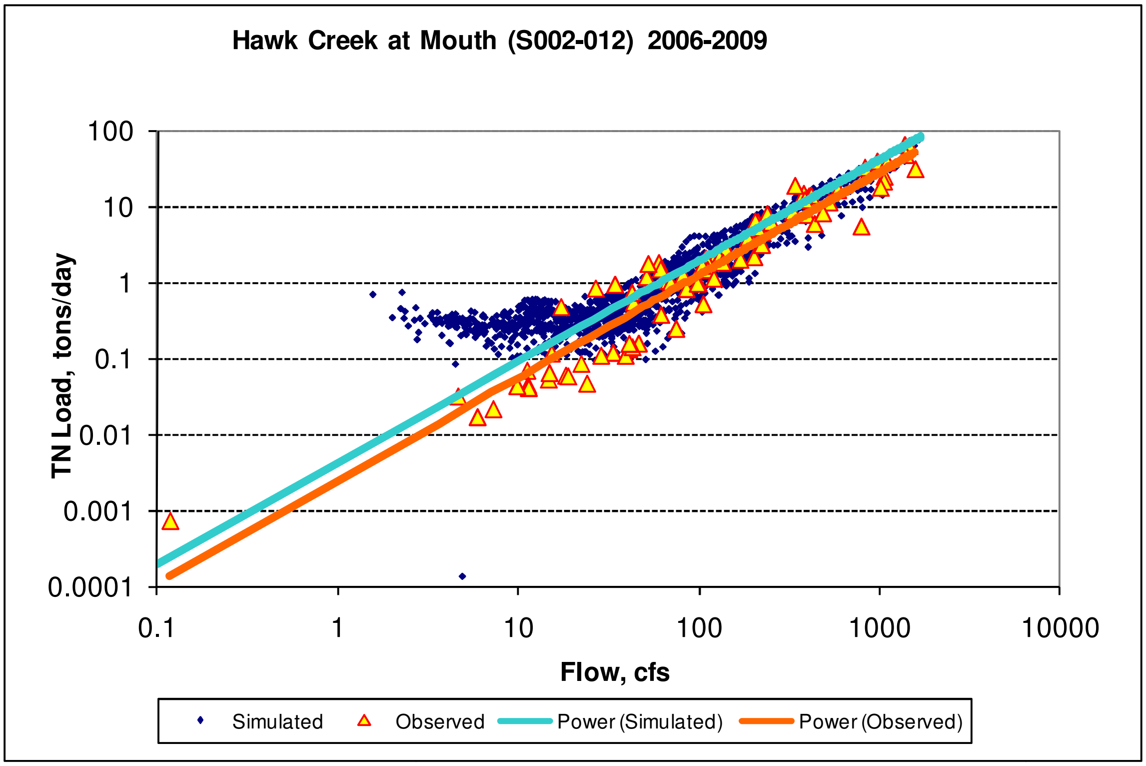



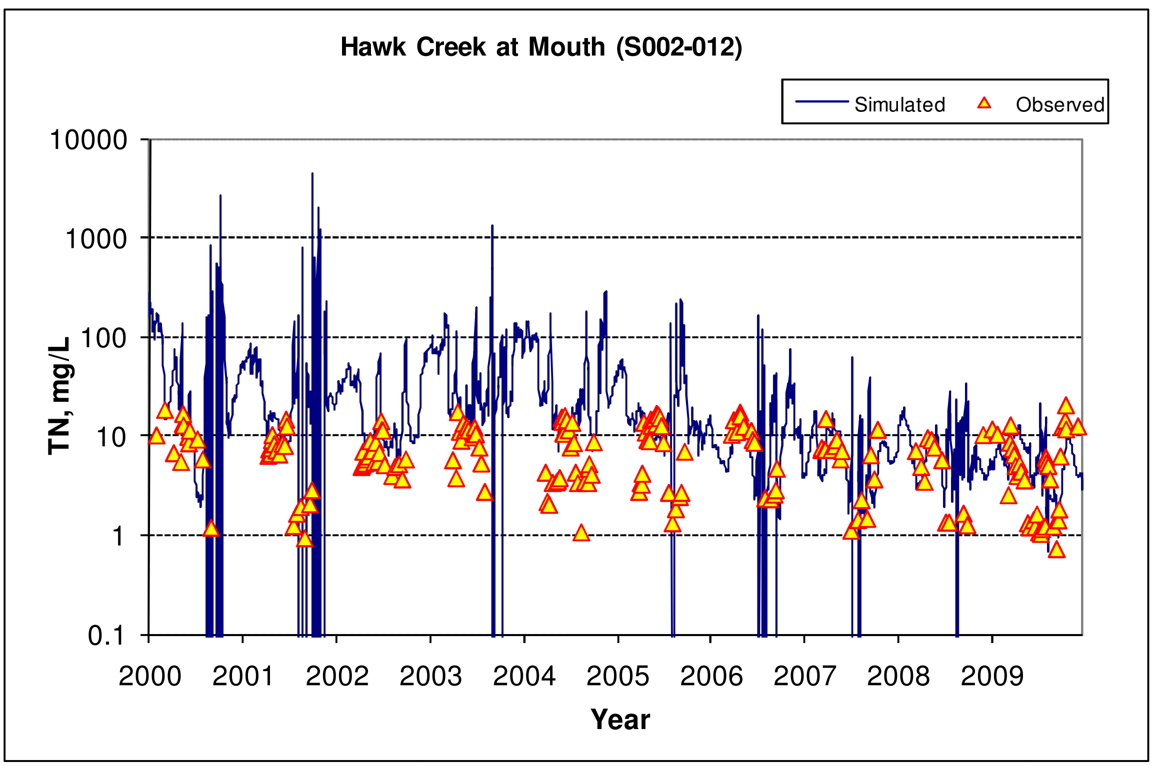
Hawk Creek at Mouth (S002-012)
Simulated
Observed
NOx, mg/L
1000
100
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |



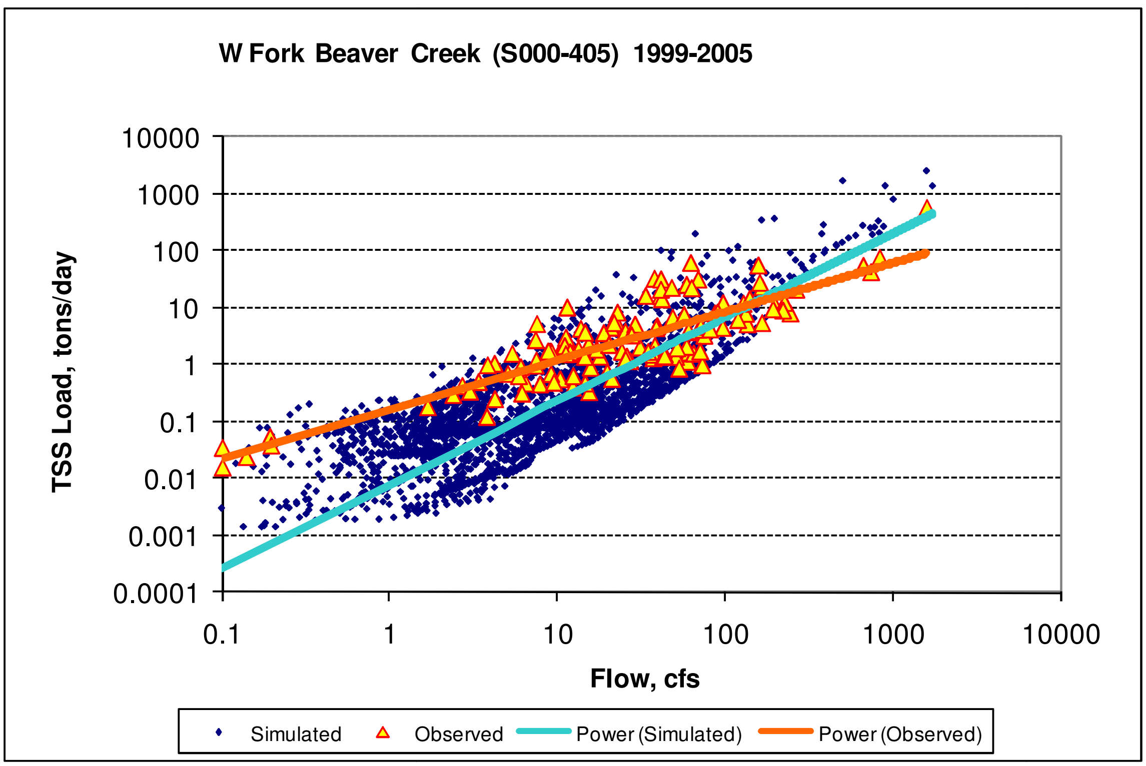

Hawk Creek at Mouth (S002-012) 2006-2009
TN Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

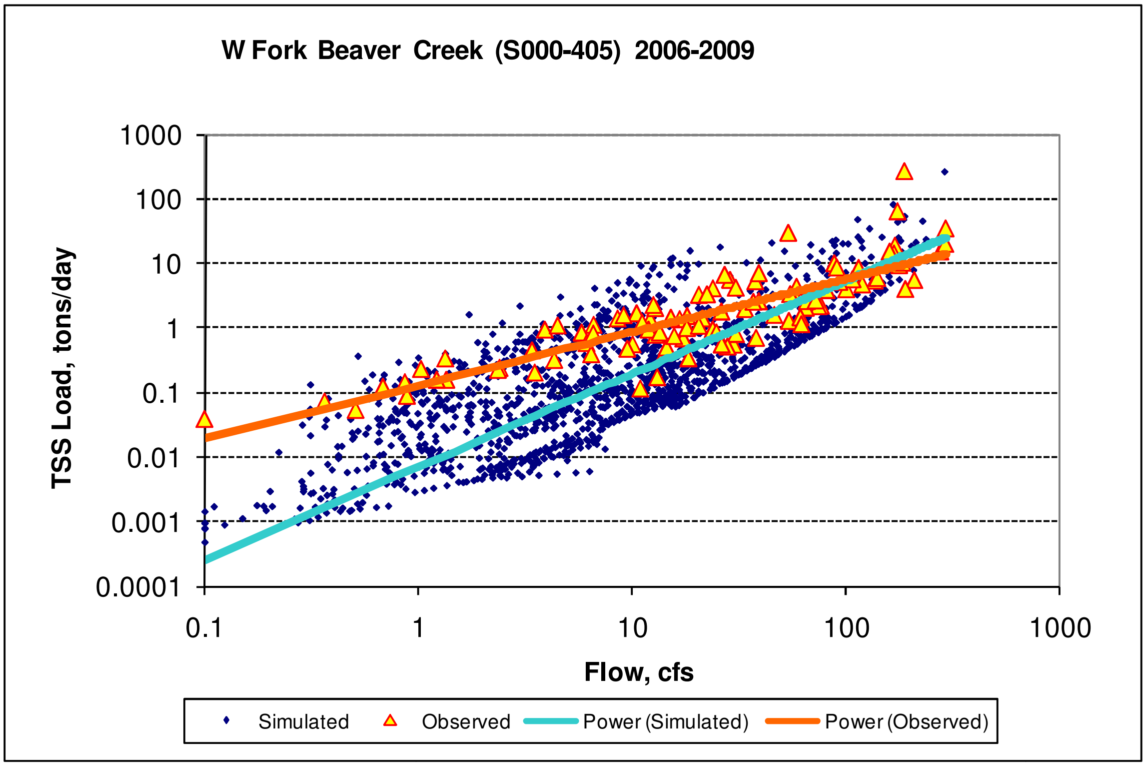

Hawk Creek at Mouth (S002-012)
Simulated
Observed
TN, mg/L
10000
1000
100
10
1
0.1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

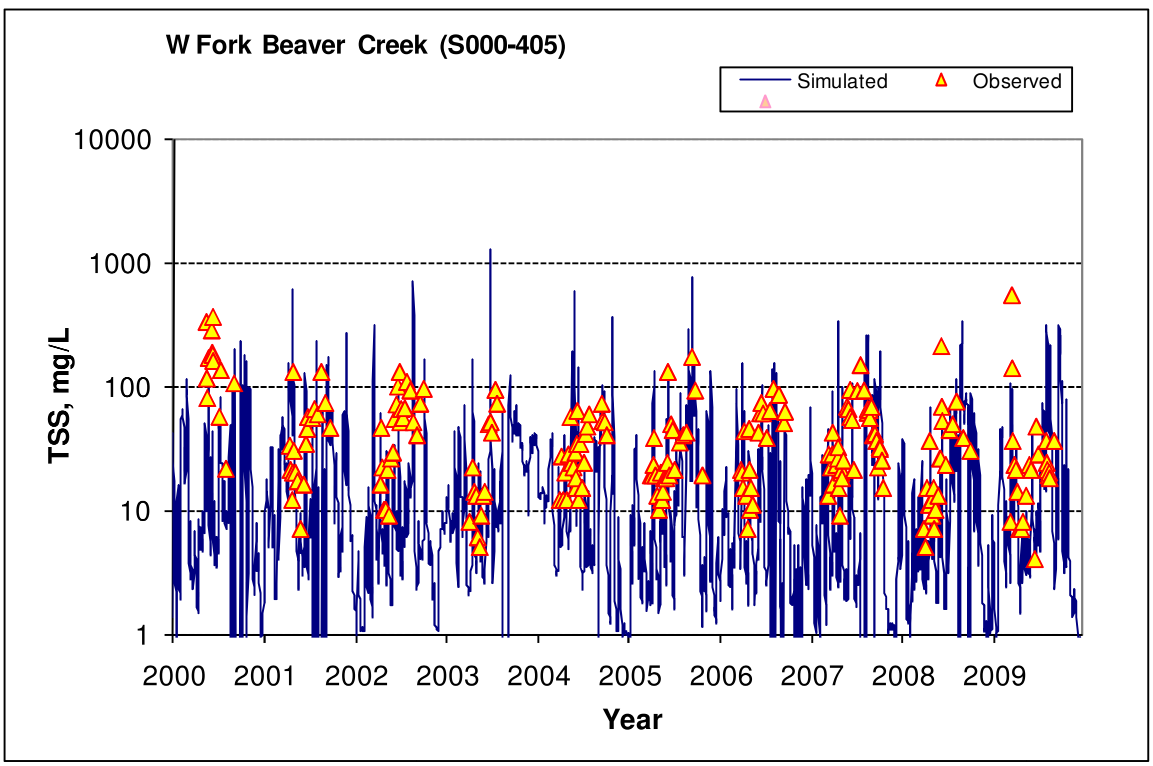
# 4 West Fork Beaver Creek (S000-405)

## 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 |

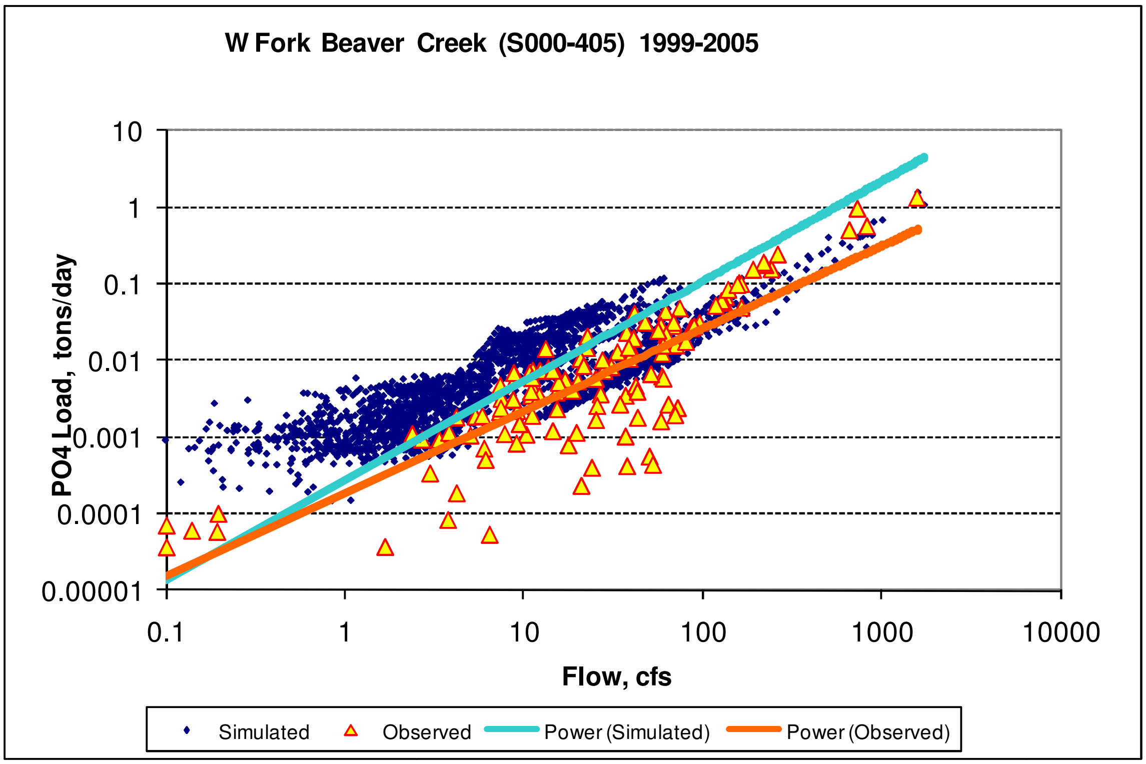


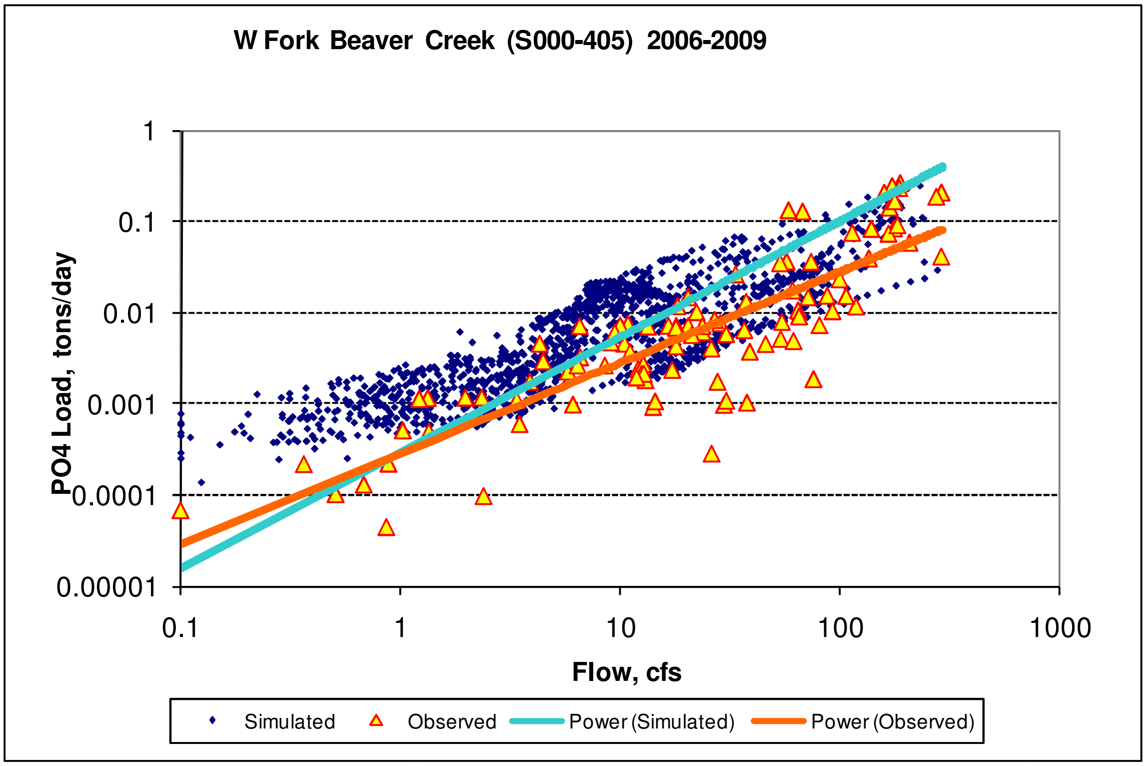

W Fork Beaver Creek (S000-405) 2006-2009
TSS Load, tons/day
1000
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

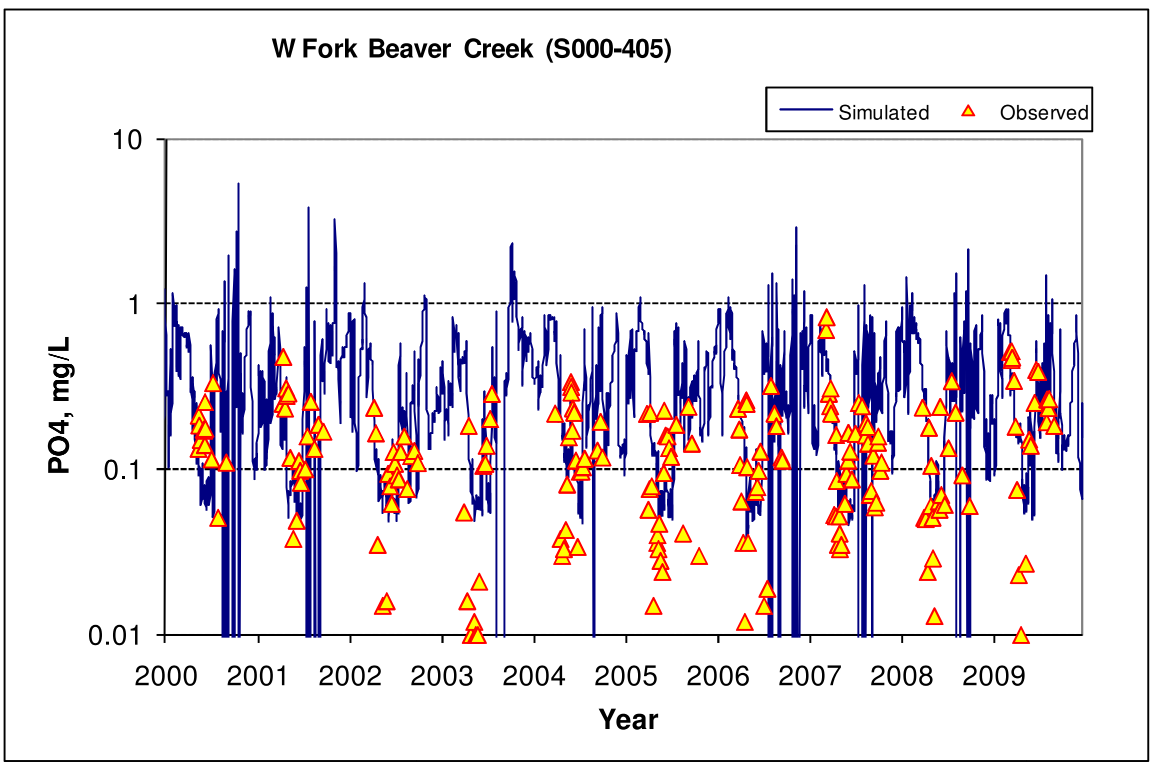

W Fork Beaver Creek (S000-405)
Simulated
Observed
TSS, mg/L
10000
1000
100
10
1
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

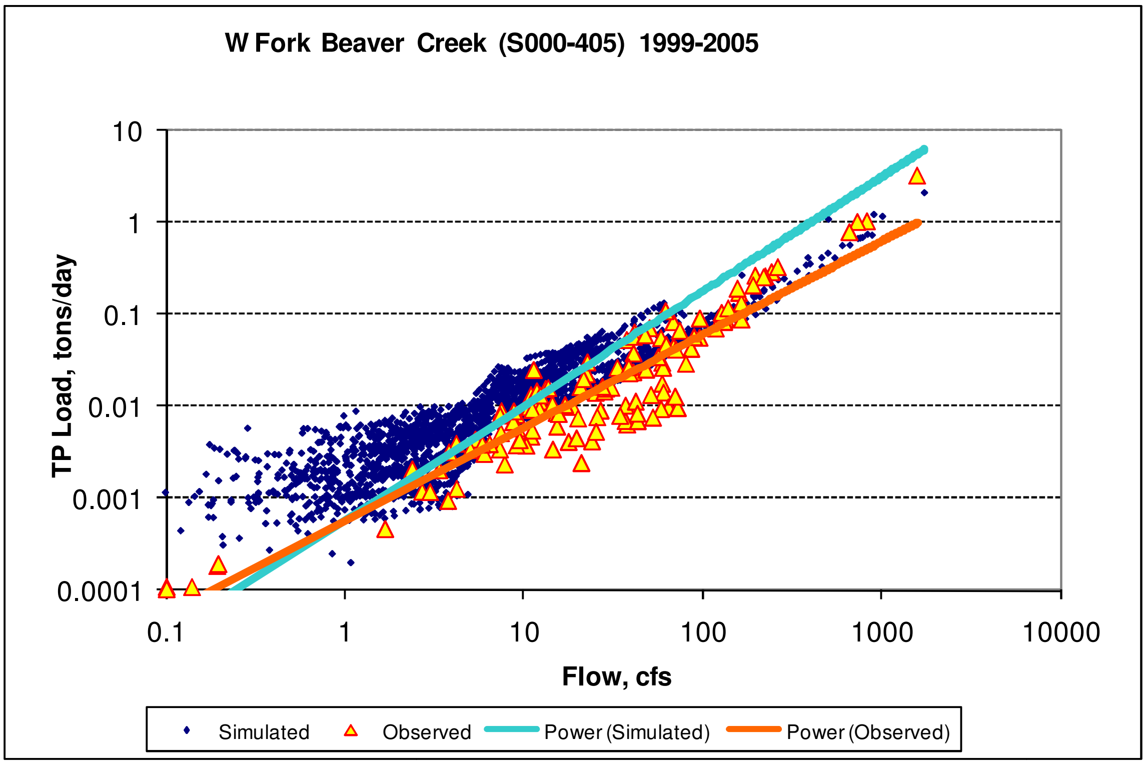


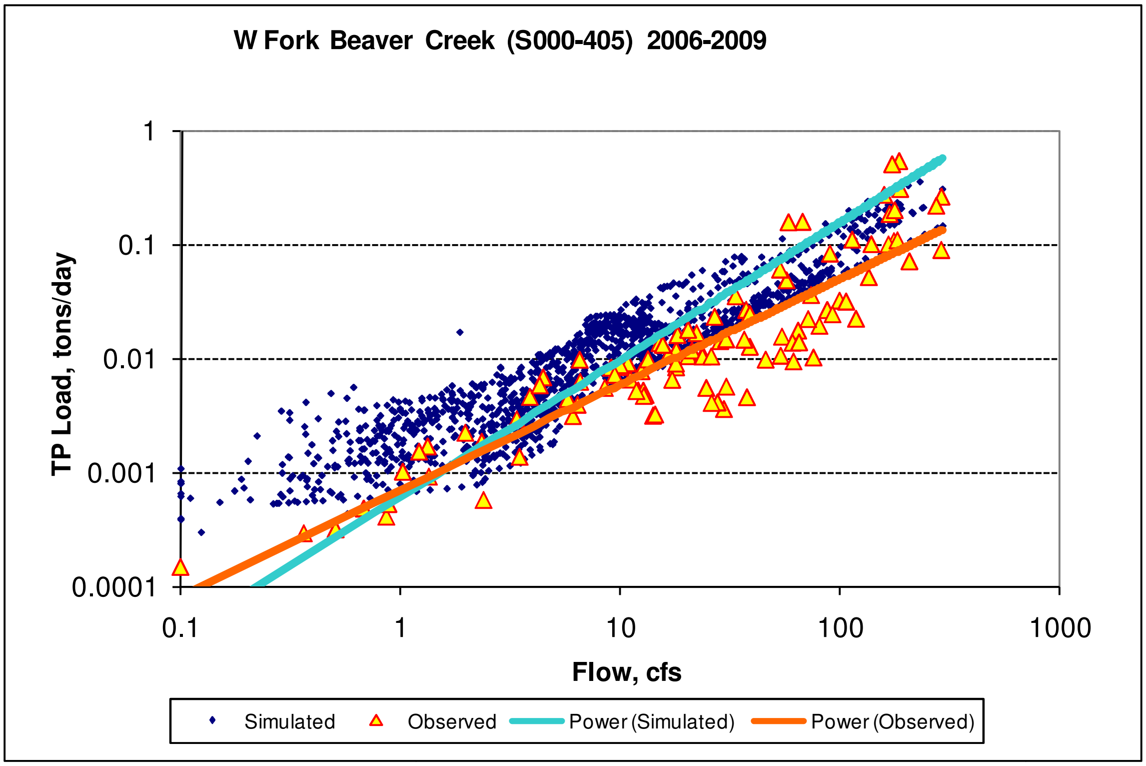

W Fork Beaver Creek (S000-405) 2006-2009
PO4 Load, tons/day
1
0.1
0.01
0.001
0.0001
0.00001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

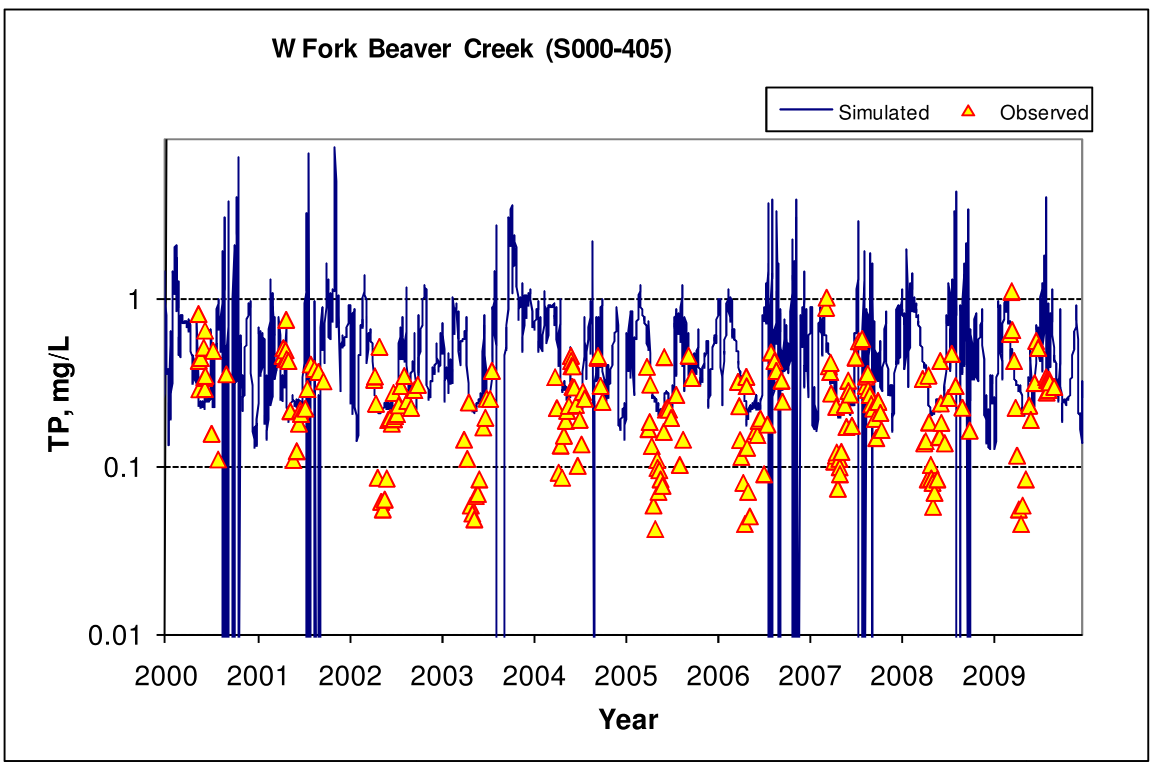

W Fork Beaver Creek (S000-405)
Simulated
Observed
PO4, mg/L
10
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

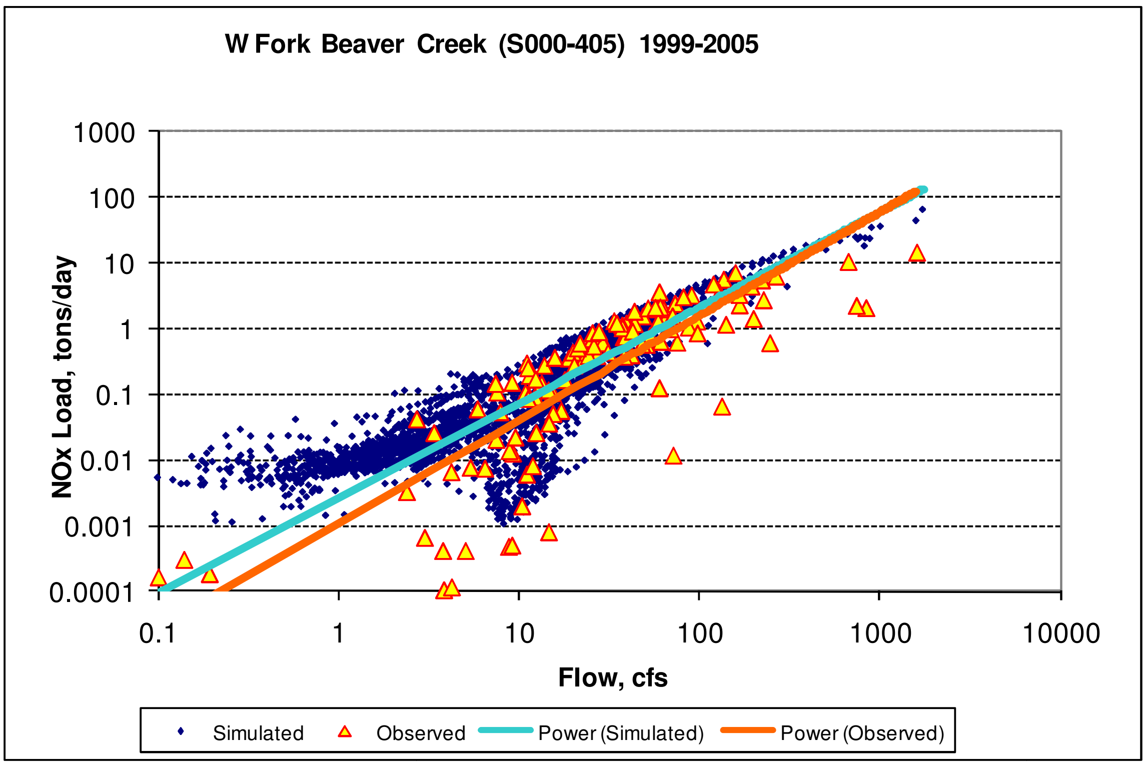


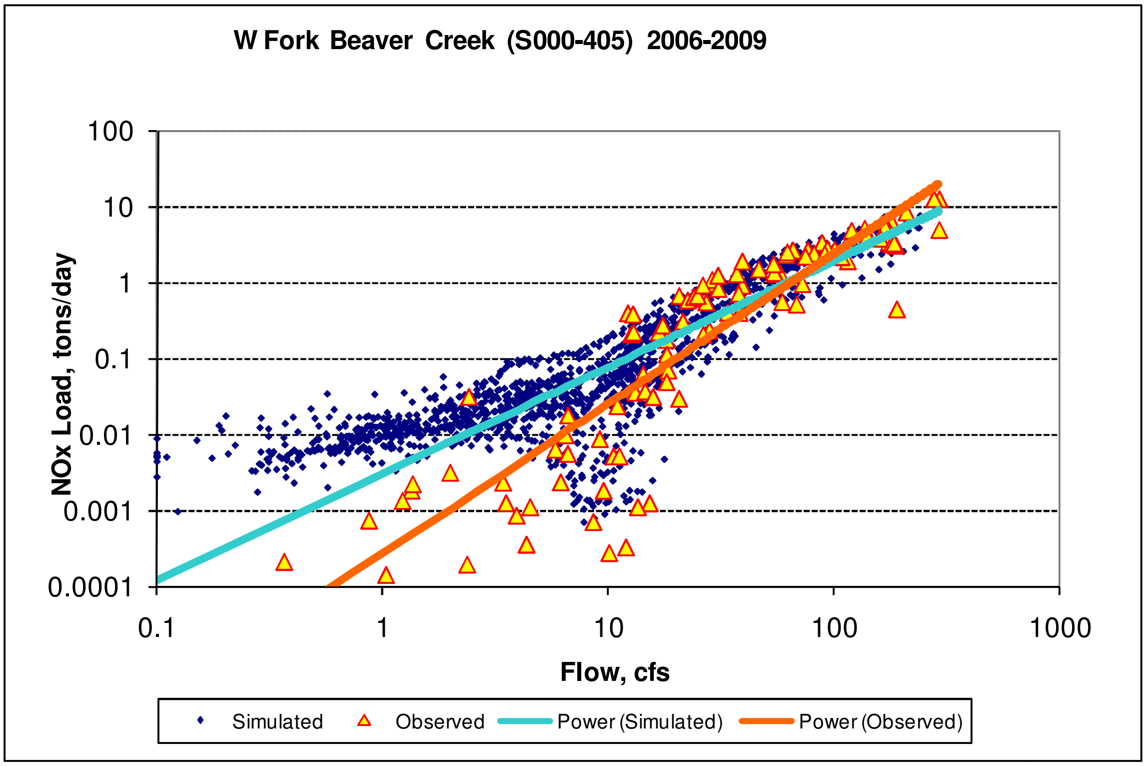

W Fork Beaver Creek (S000-405) 2006-2009
TP Load, tons/day
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

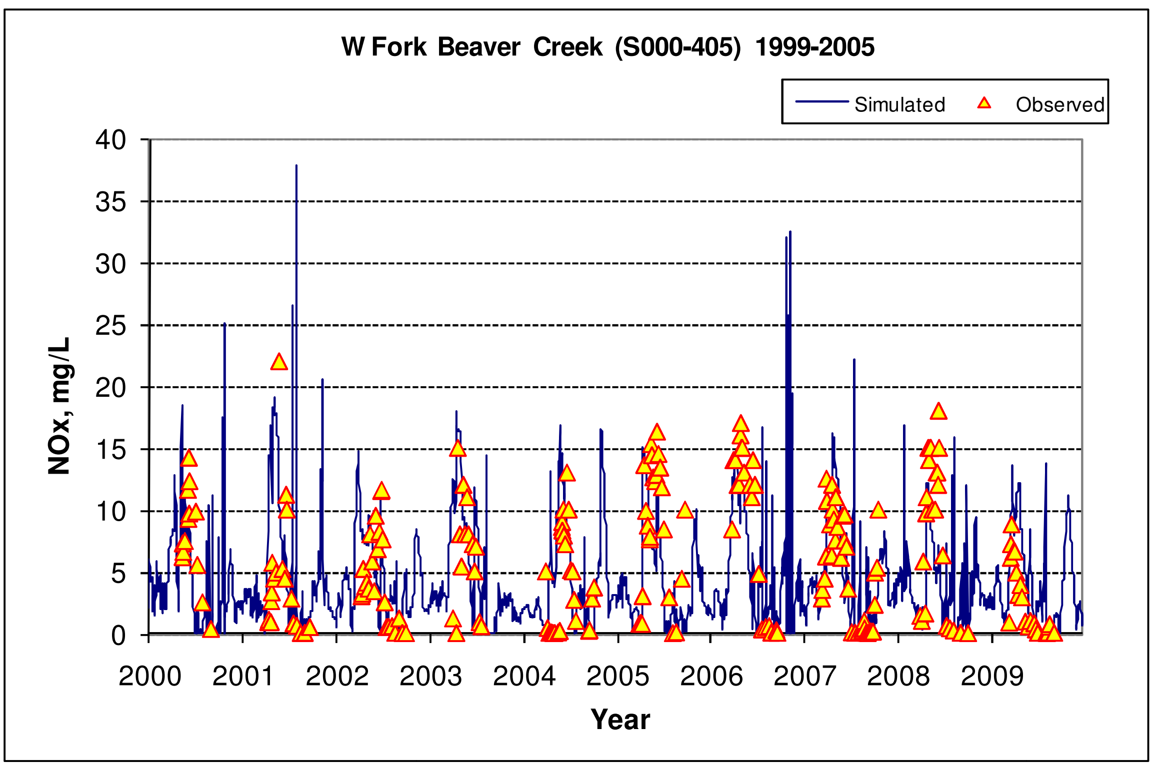

W Fork Beaver Creek (S000-405)
Simulated
Observed
TP, mg/L
1
0.1
0.01
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

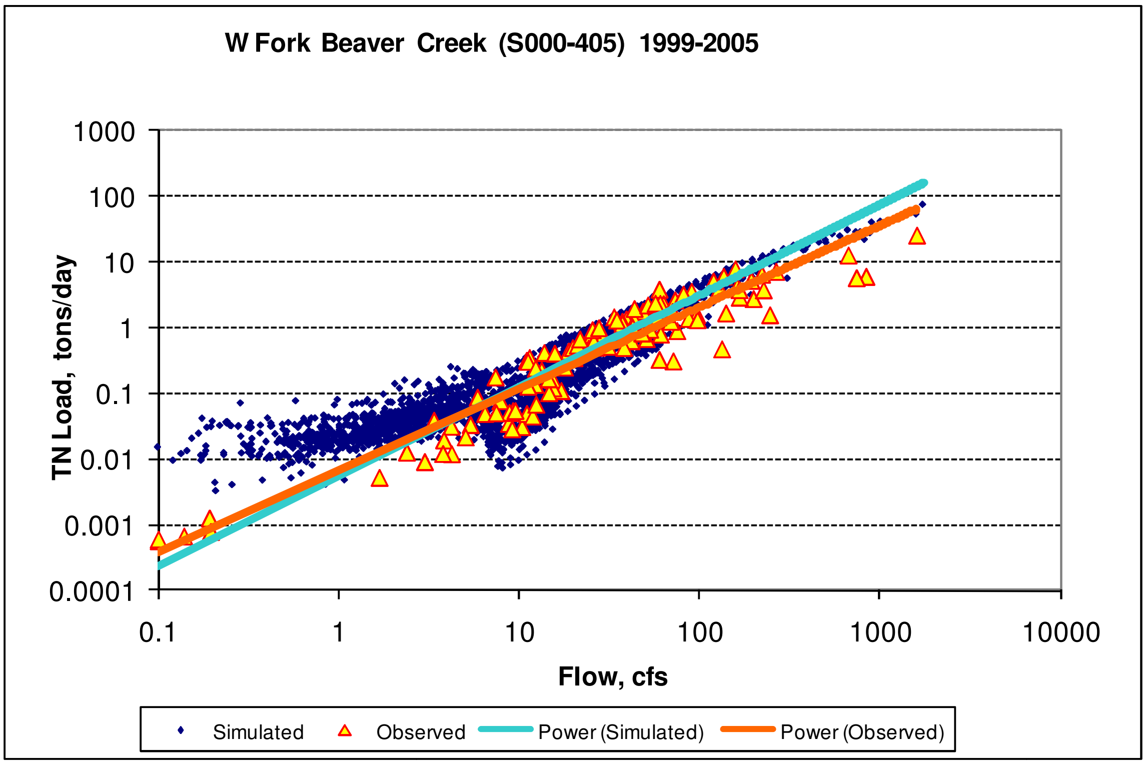


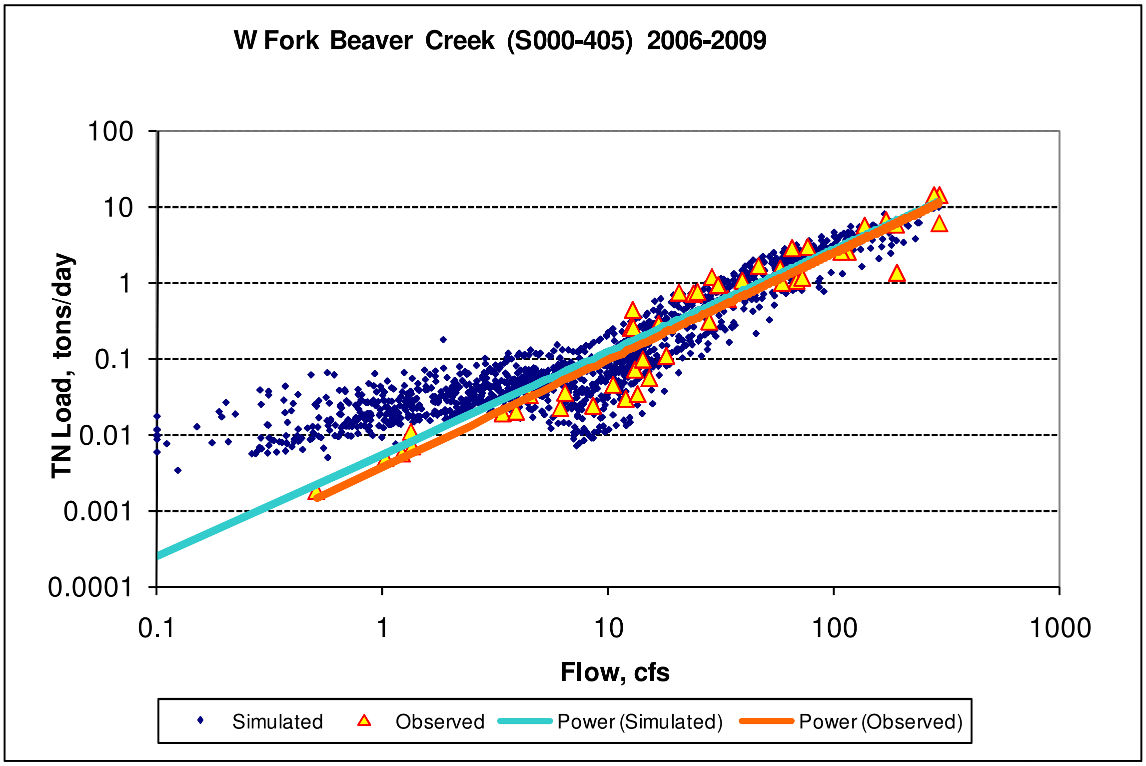

W Fork Beaver Creek (S000-405) 2006-2009
NOx Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

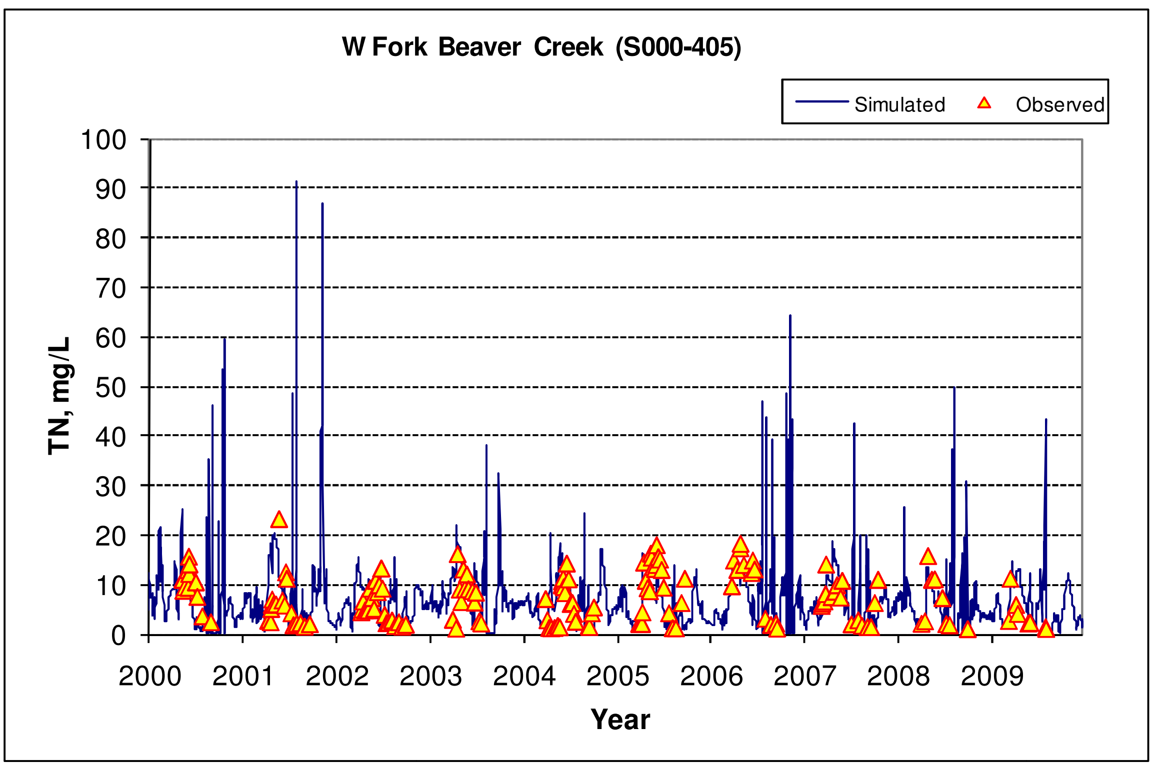

W Fork Beaver Creek (S000-405) 1999-2005
Simulated
Observed
NOx, mg/L
40
35
30
25
20
15
10
5
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |



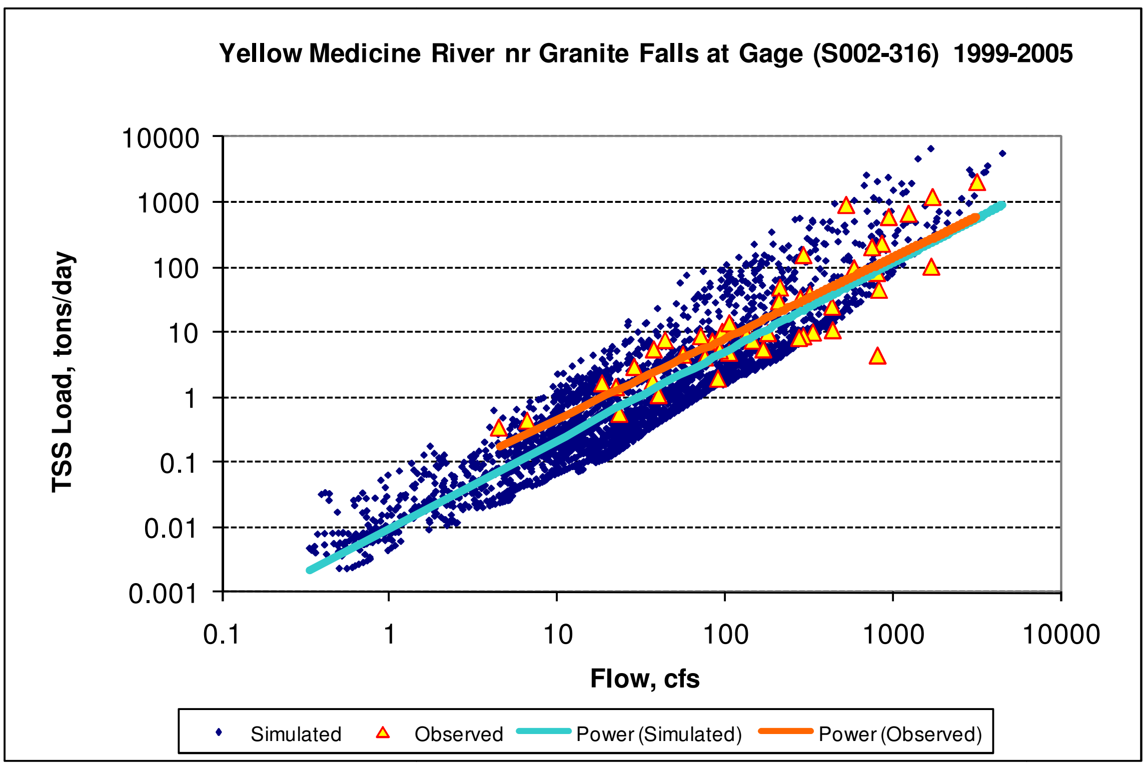

W Fork Beaver Creek (S000-405) 2006-2009
TN Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

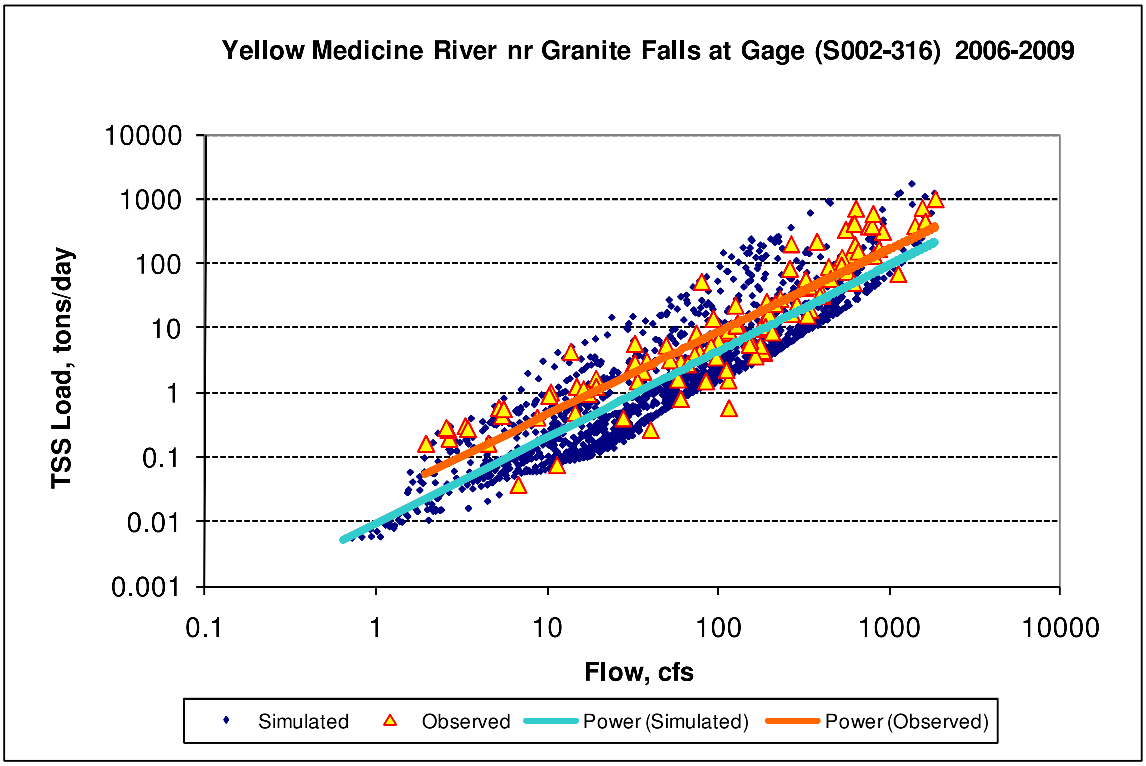

W Fork Beaver Creek (S000-405)
Simulated
Observed
TN, mg/L
100
90
80
70
60
50
40
30
20
10
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

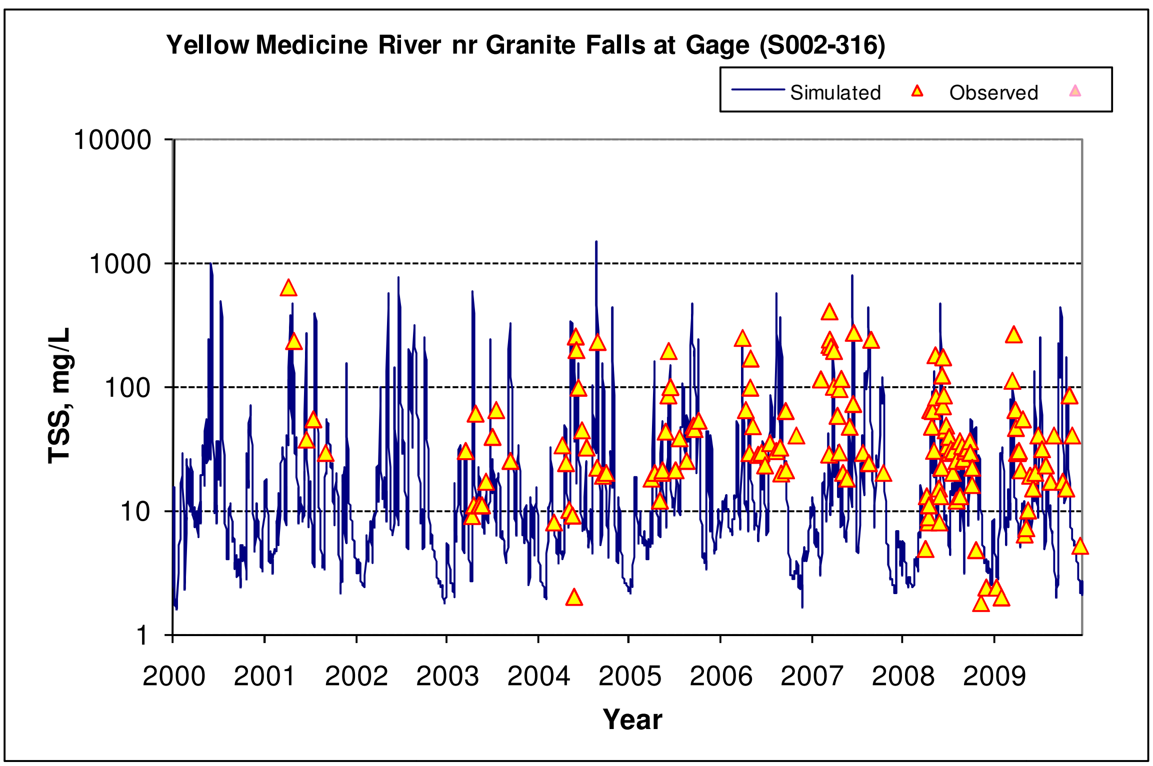
# 5 Yellow Medicine River at Gage (S002-316)

## 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 |



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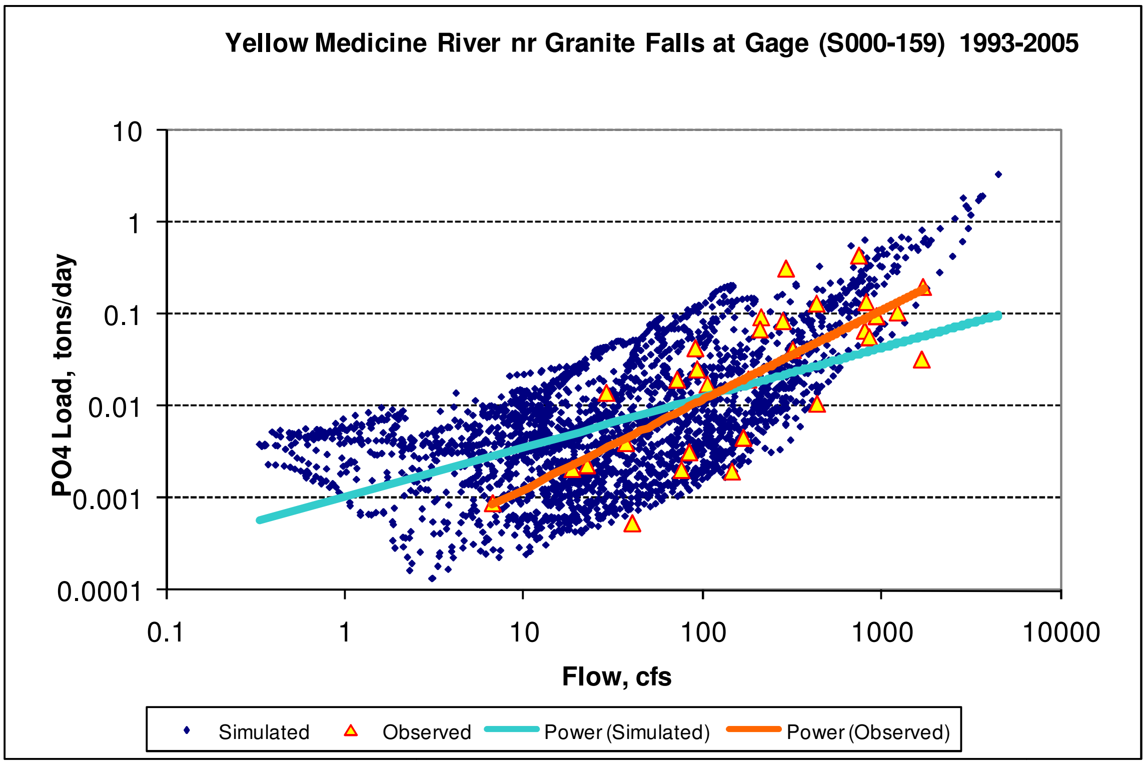
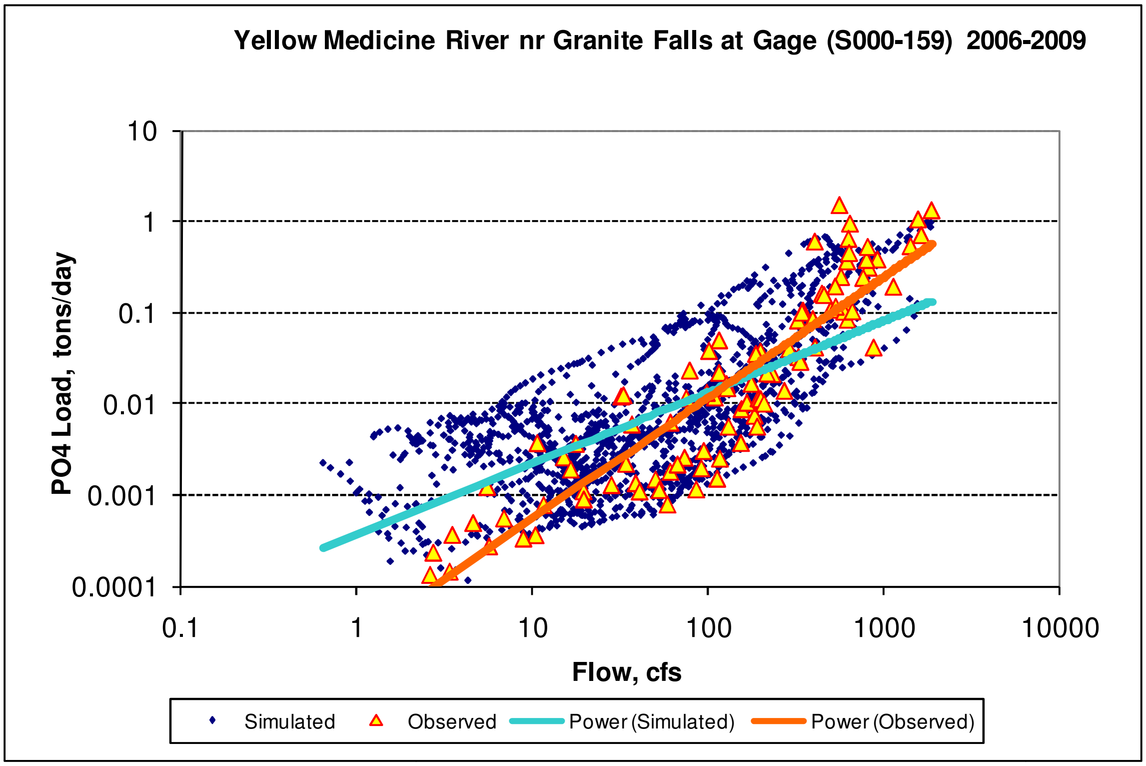
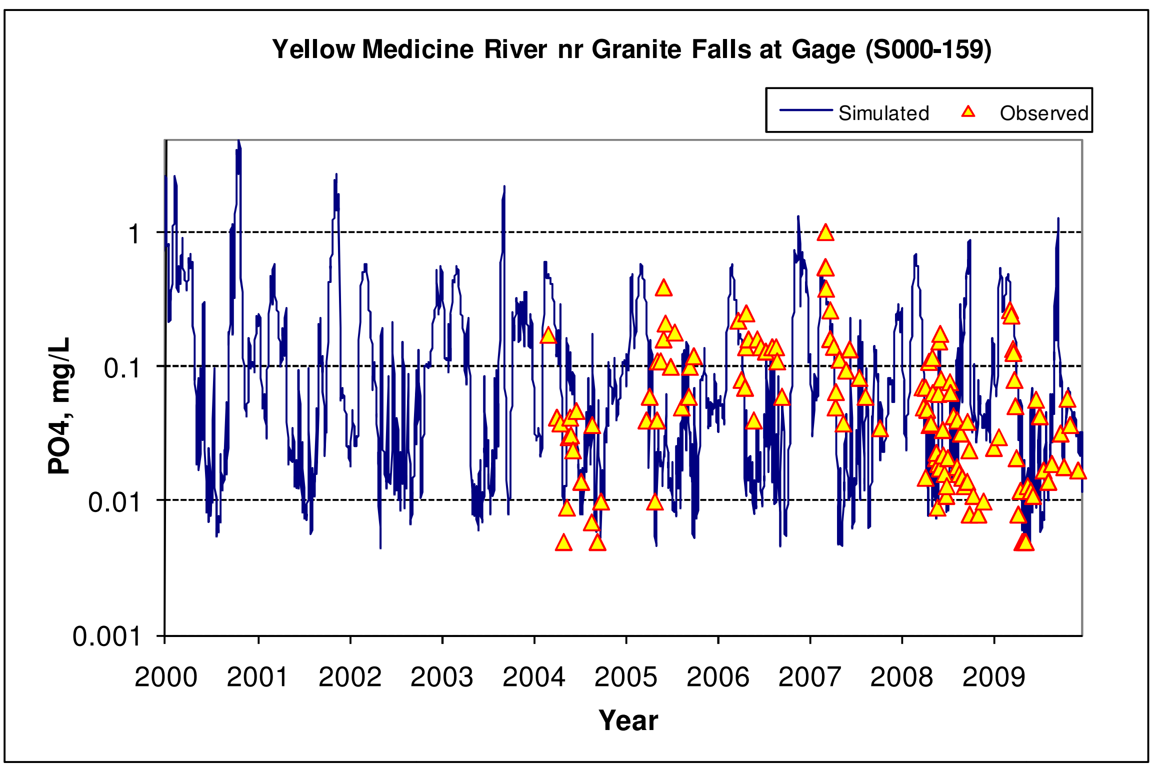
## 5.2 ORTHOPHOSPHATE (AS P)

| 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 |

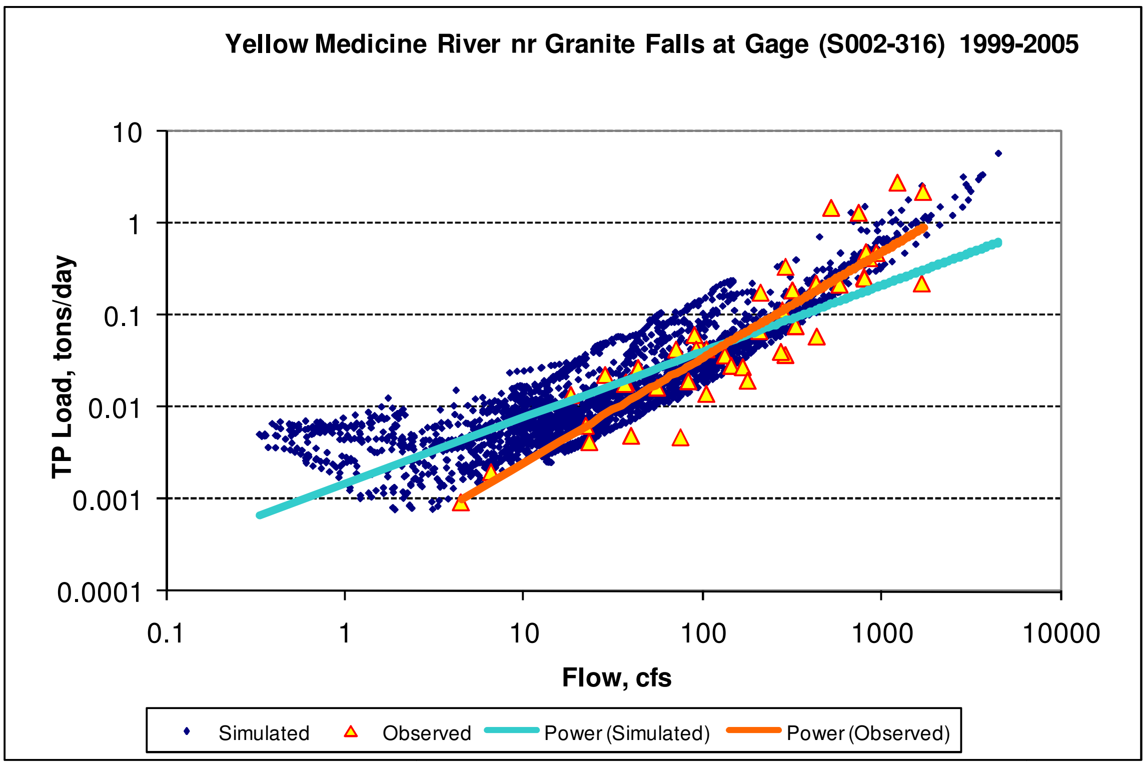


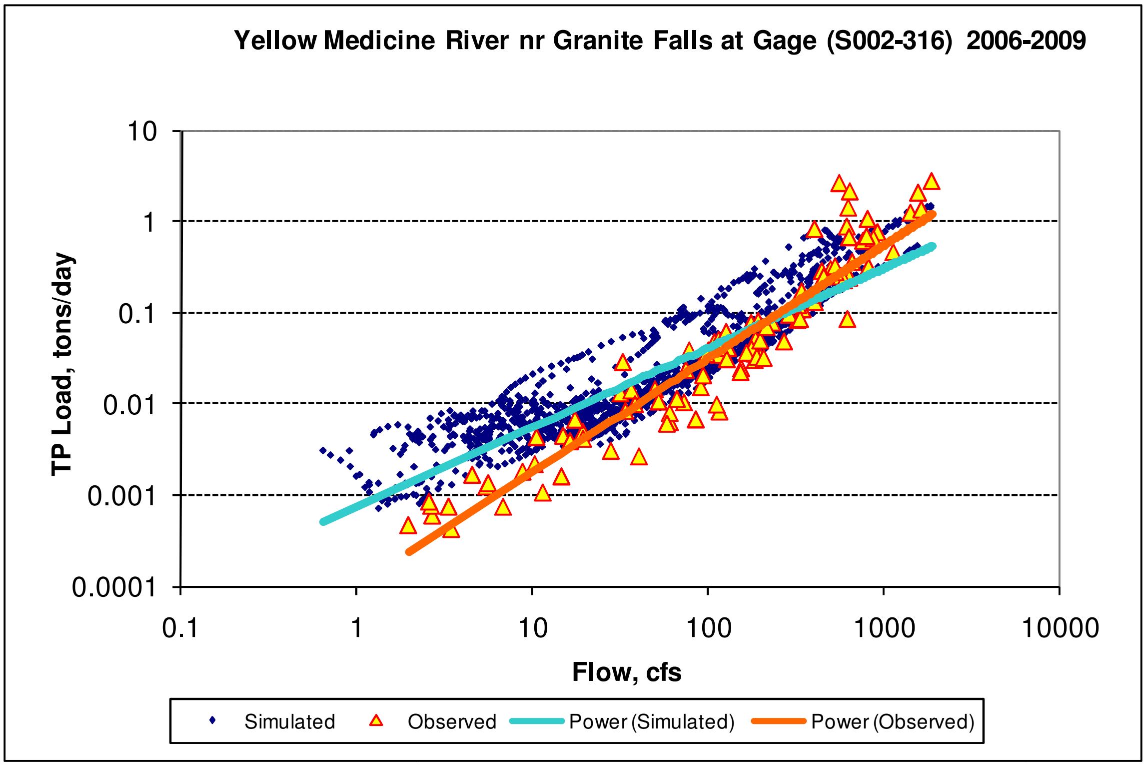

Yellow Medicine River nr Granite Falls at Gage (S000-159) 2006-2009
PO4 Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

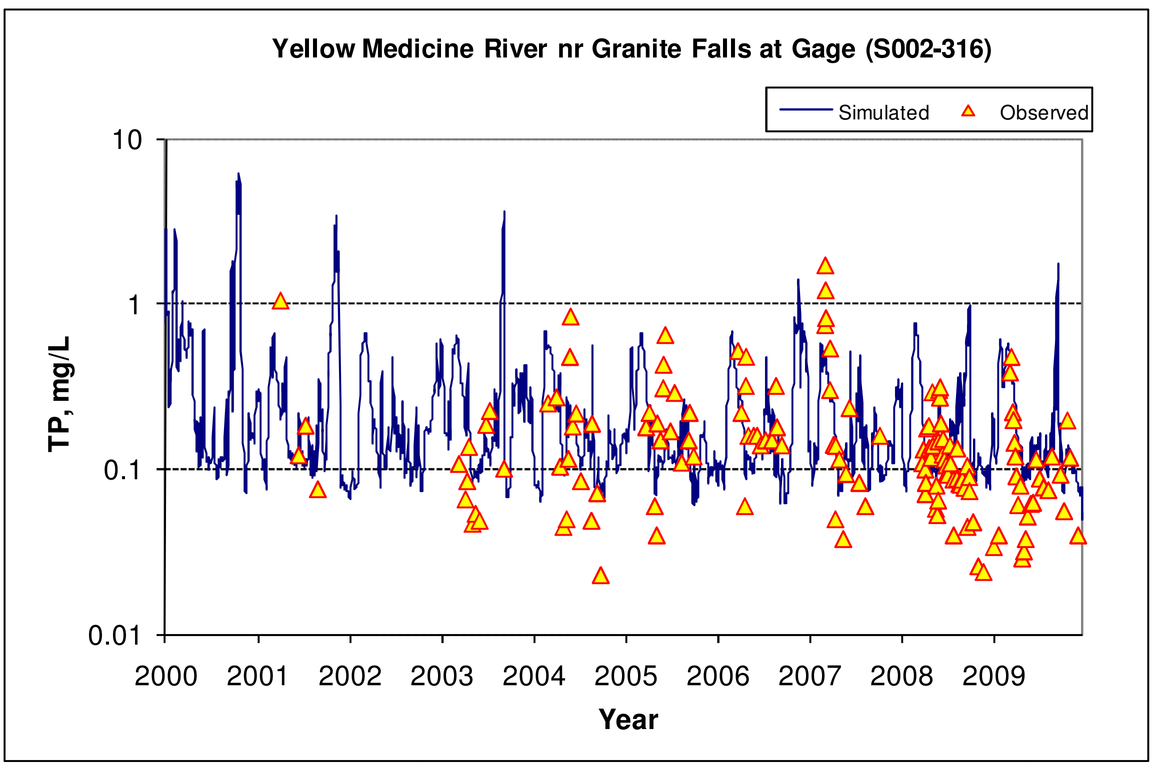

Yellow Medicine River nr Granite Falls at Gage (S000-159)
Simulated
Observed
PO4, mg/L
1
0.1
0.01
0.001
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

## 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 |

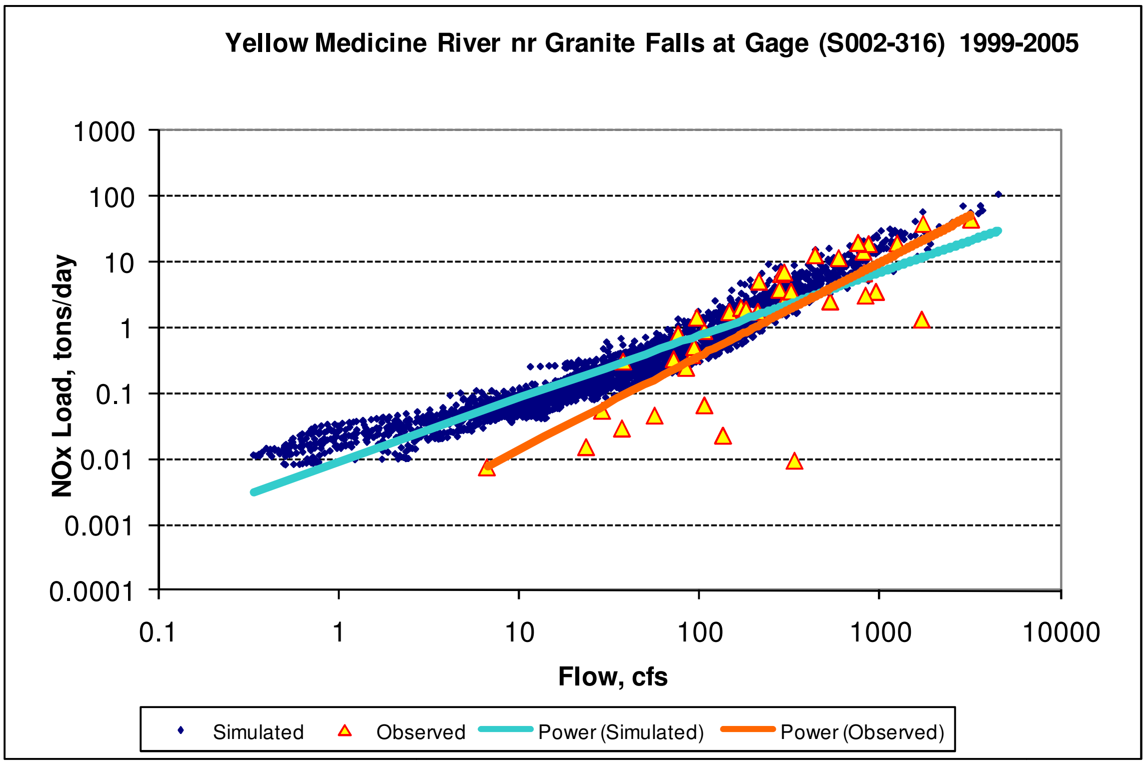


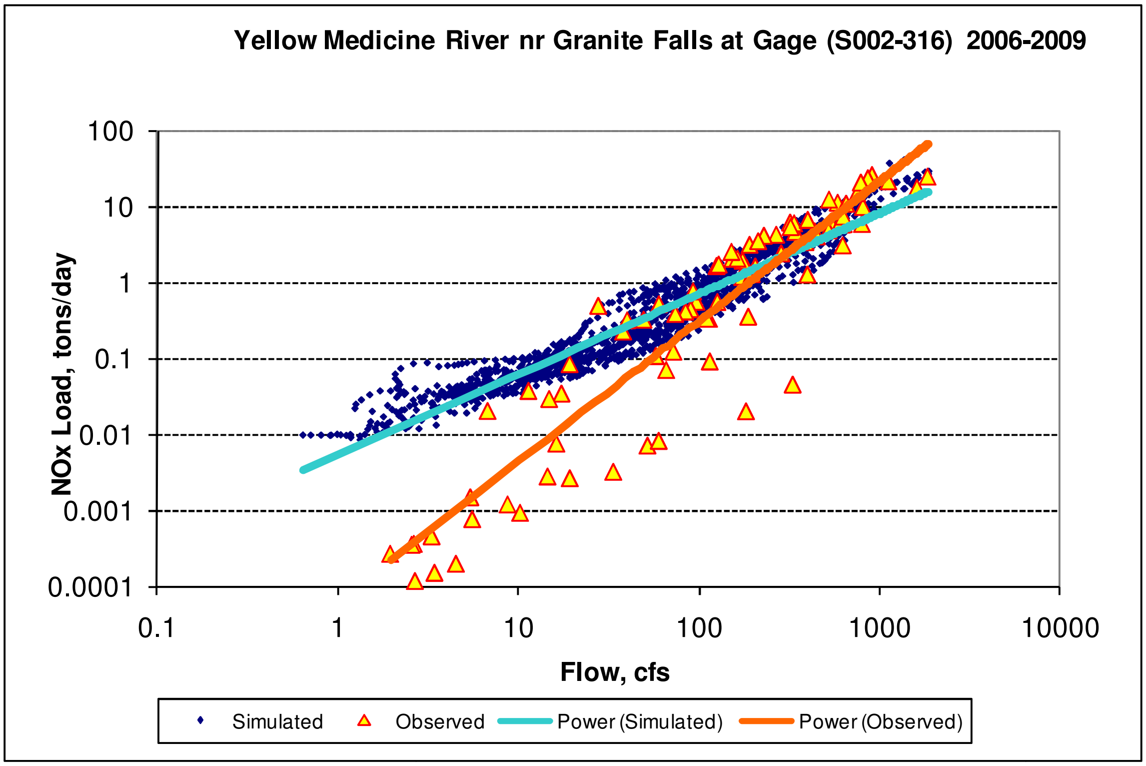

Yellow Medicine River nr Granite Falls at Gage (S002-316) 2006-2009
TP Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)


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

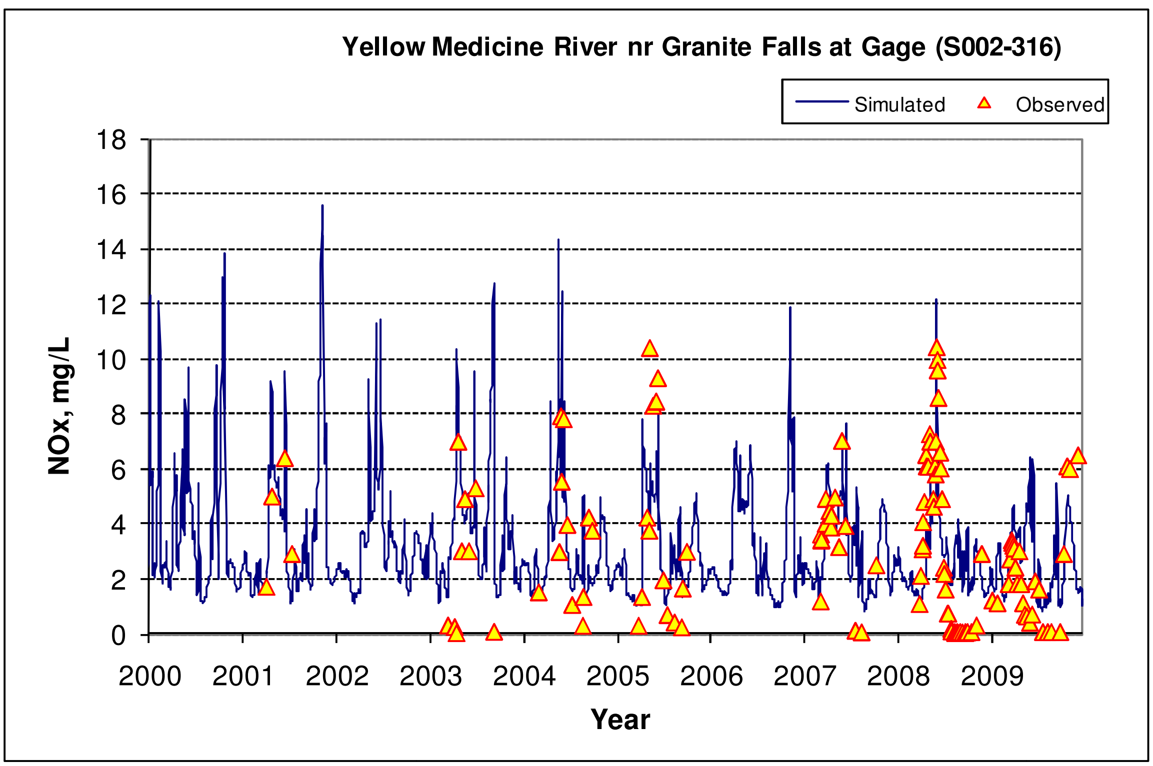
## 5.4 NITRATE PLUS NITRITE NITROGEN (AS N)

| 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 |





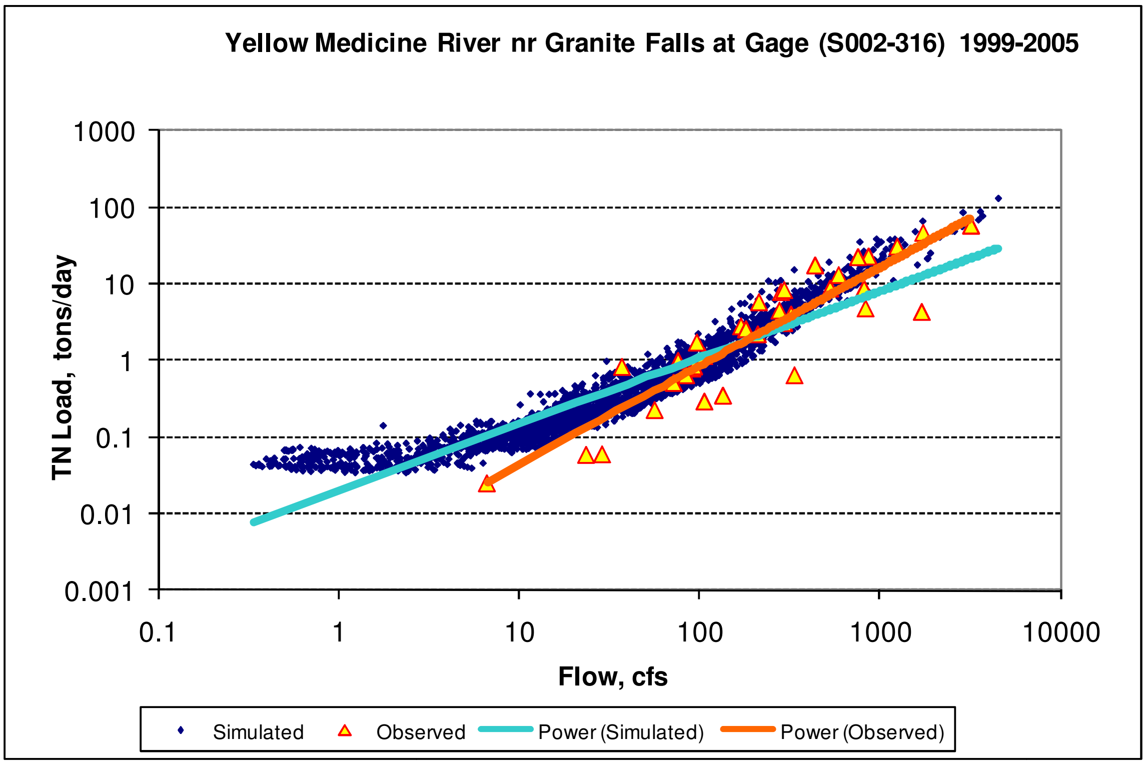
Yellow Medicine River nr Granite Falls at Gage (S002-316) 2006-2009
100
10
1
0.1
0.01
0.001
0.0001
NOx Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

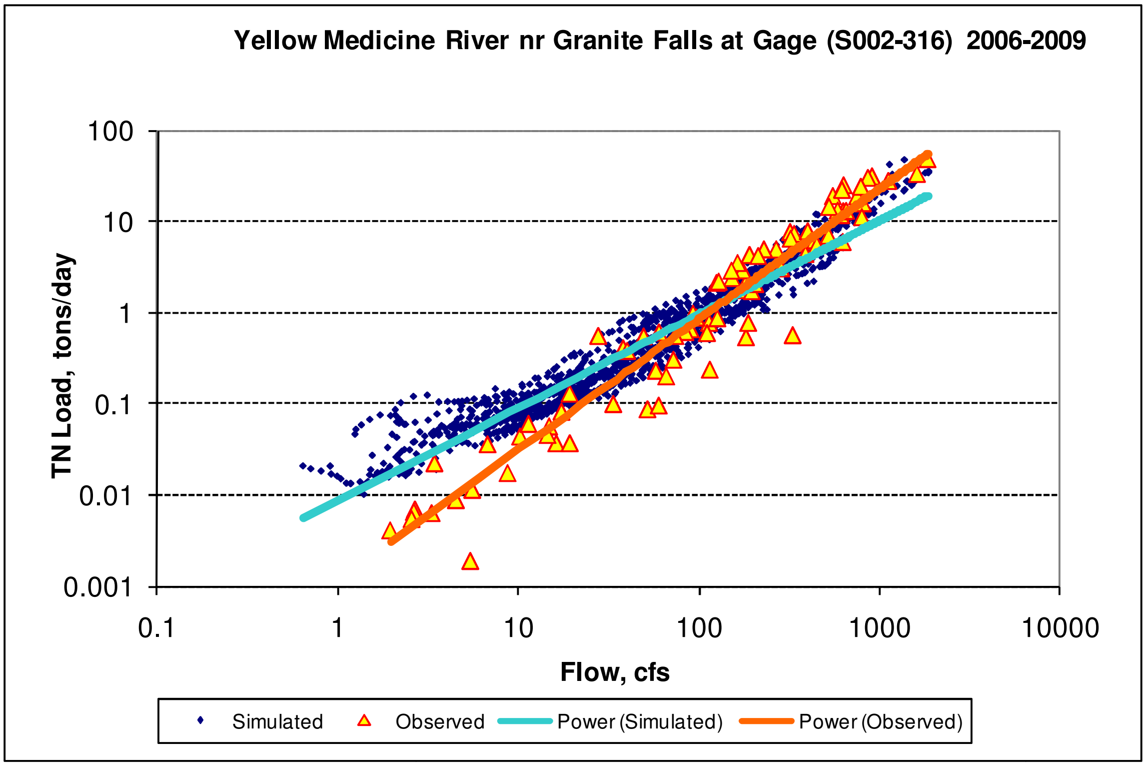



Yellow Medicine River nr Granite Falls at Gage (S002-316)
Simulated
Observed
18
16
14
12
10
8
6
4
2
0
NOx, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

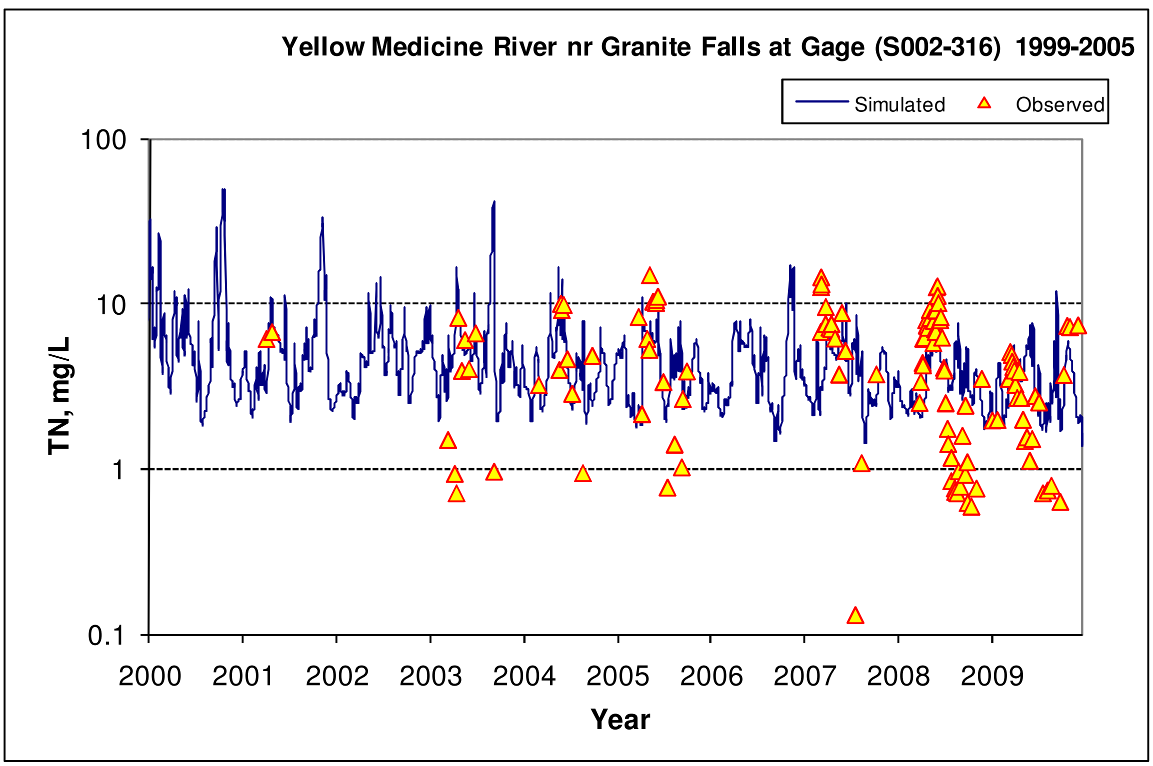
## 5.5 TOTAL NITROGEN

| 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
100
10
1
0.1
0.01
0.001
TN Load, tons/day
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

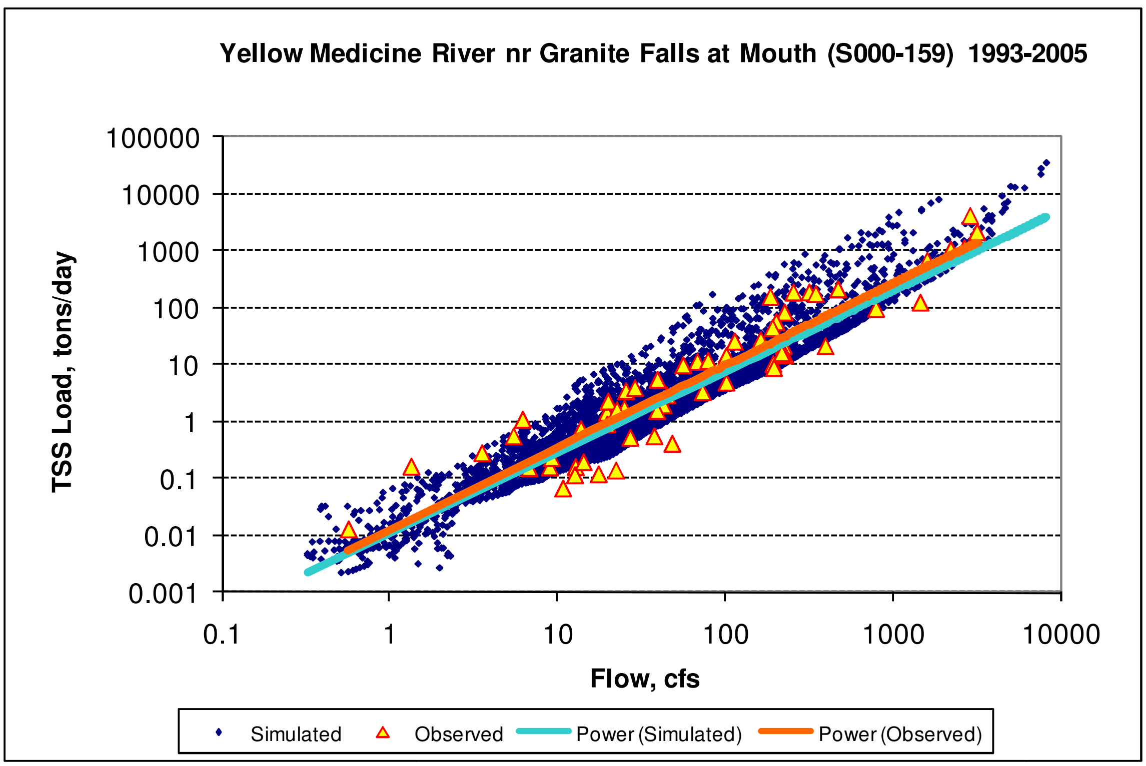



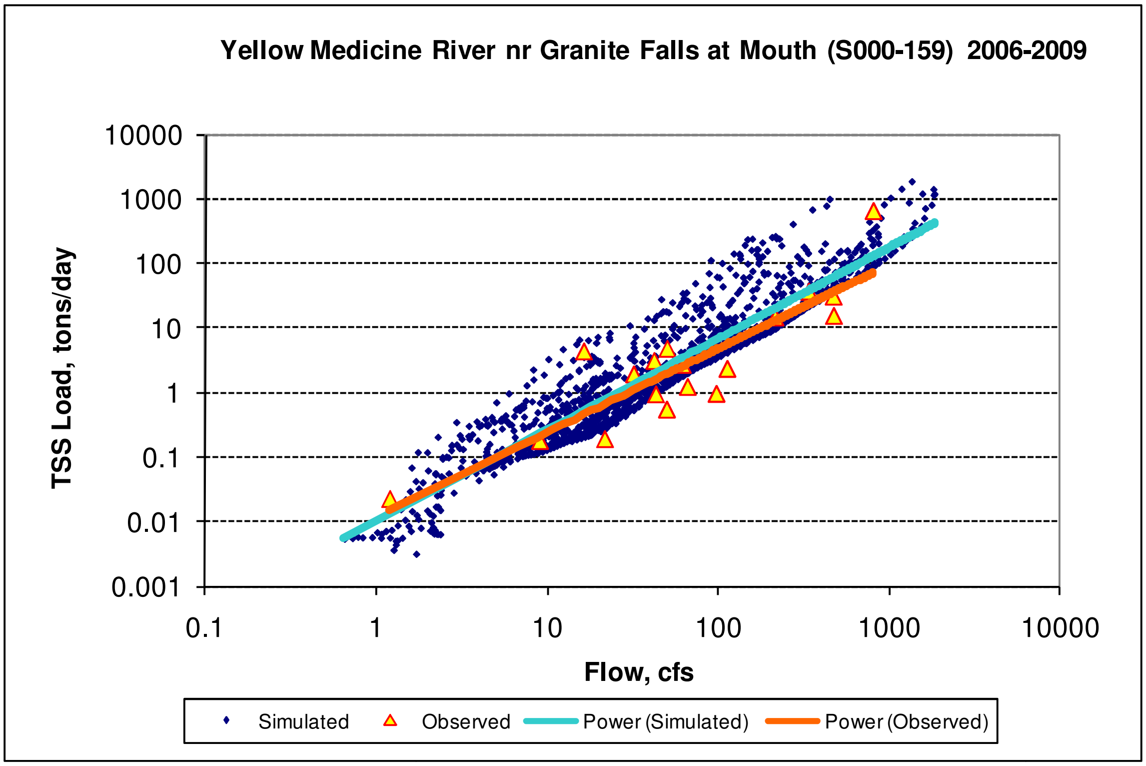
Yellow Medicine River nr Granite Falls at Gage (S002-316) 1999-2005
Simulated
Observed
100
10
1
0.1
TN, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

# 6 Yellow Medicine River at Mouth (S000-159)

## 6.1 Total Suspended Sediment

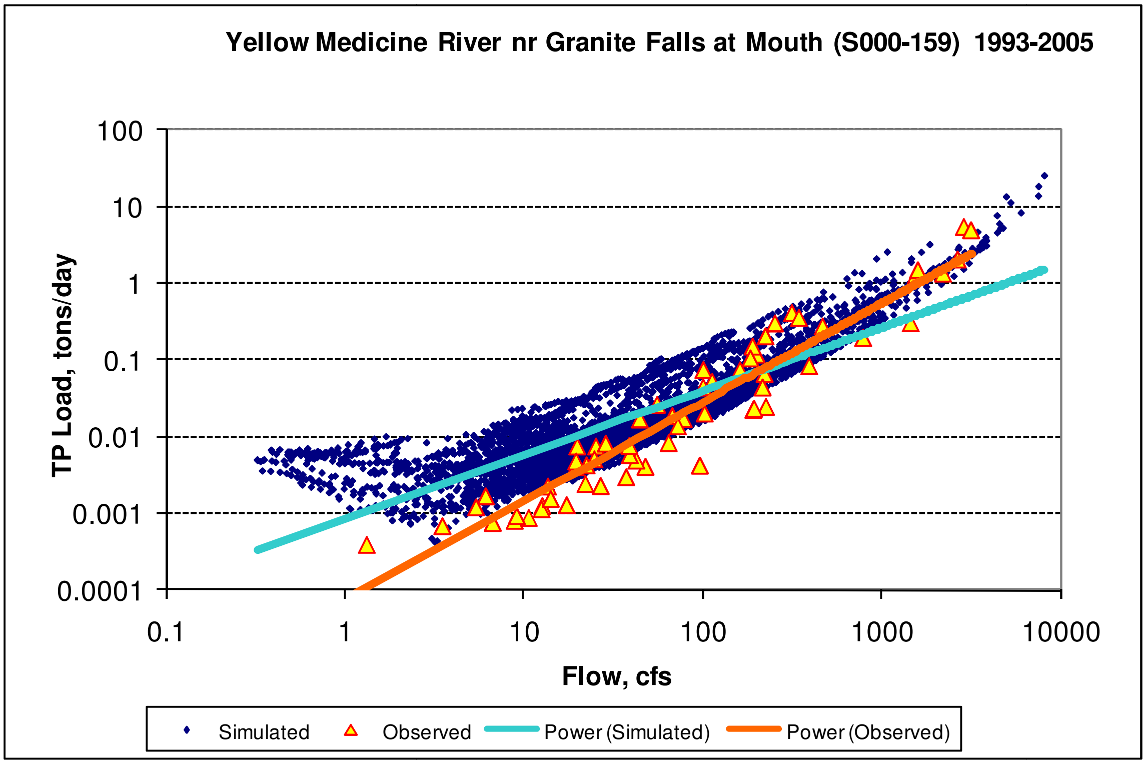
| Parameter | 1993 - 2005 | 2006 - 2009 |
|---|---|---|
| Count | 60 | 18 |
| Conc Ave Error | -14.08% | 20.66% |
| Conc Median Error | 10.93% | -9.71% |
| Load Ave Error | -27.50% | 53.18% |
| Load Median Error | 0.21% | -1.33% |
| Paired t conc | 0.58 | 0.49 |
| Paired t load | 0.44 | 0.30 |



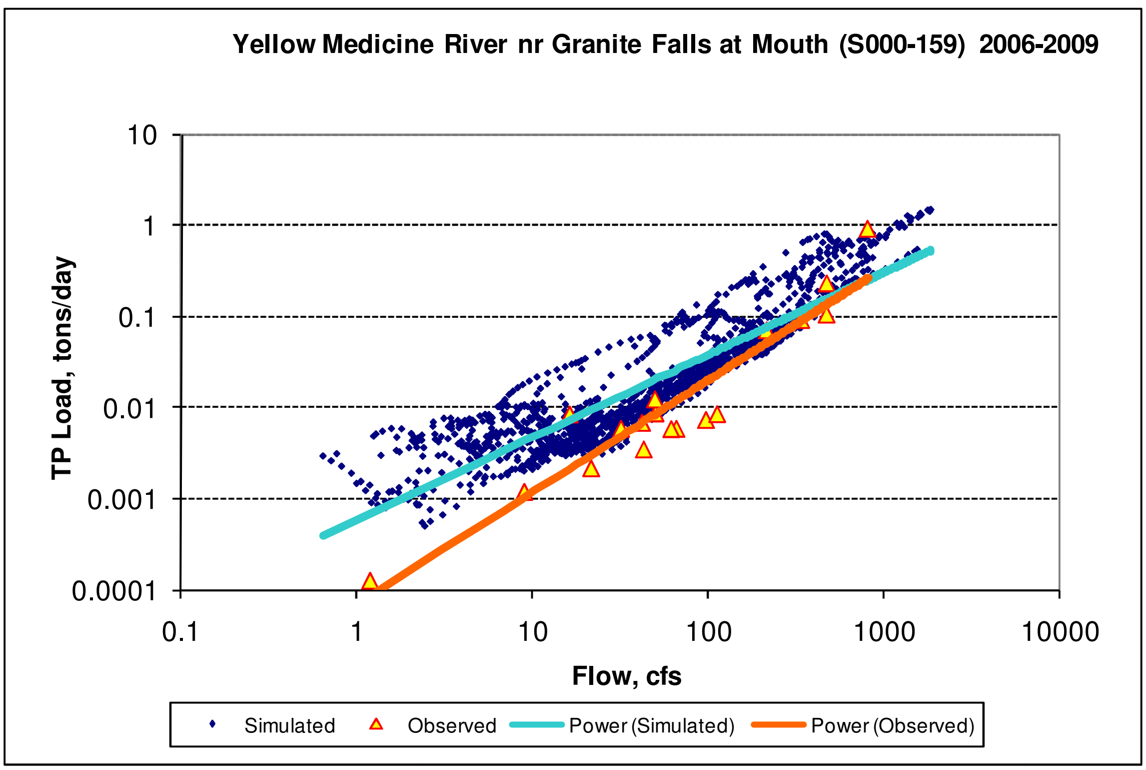



## 6.2 TOTAL PHOSPHORUS

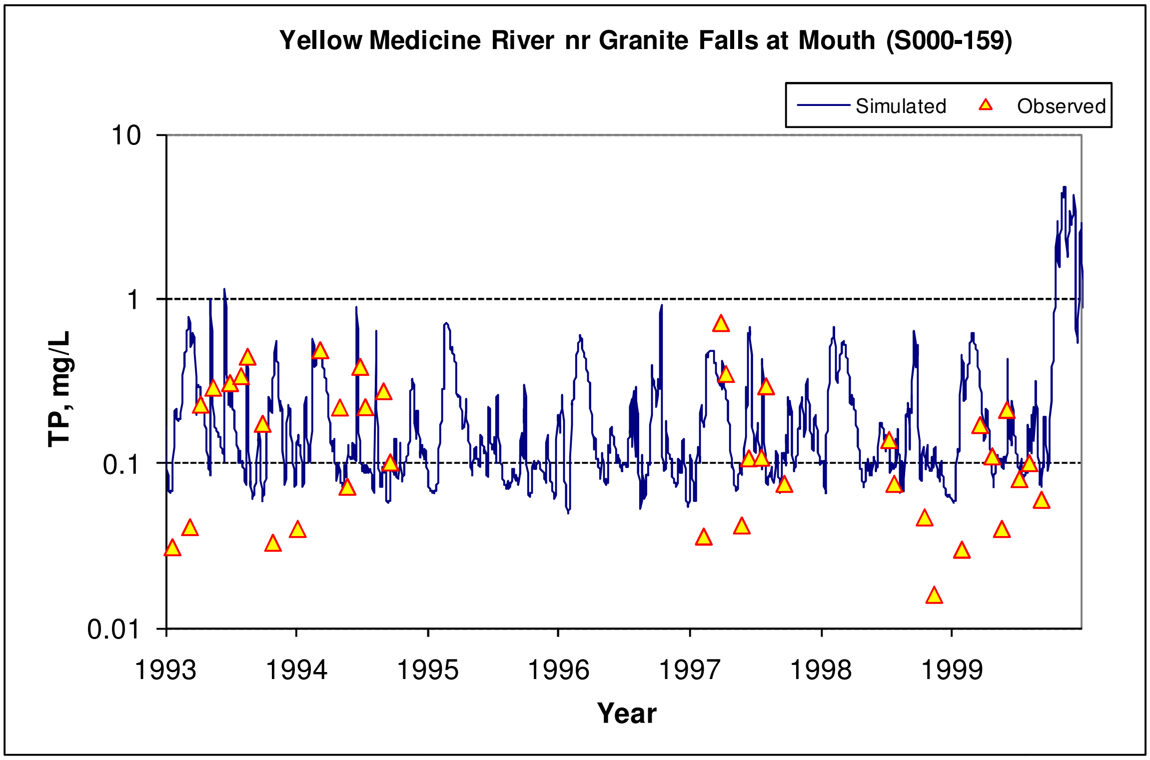
| Parameter | 1993 - 2005 | 2006 - 2009 |
|---|---|---|
| Count | 62 | 18 |
| Conc Ave Error | -69.10% | -92.89% |
| Conc Median Error | -25.66% | -51.99% |
| Load Ave Error | 21.50% | -36.38% |
| Load Median Error | -0.80% | -6.07% |
| Paired t conc | 0.07 | 0.02 |
| Paired t load | 0.48 | 0.40 |

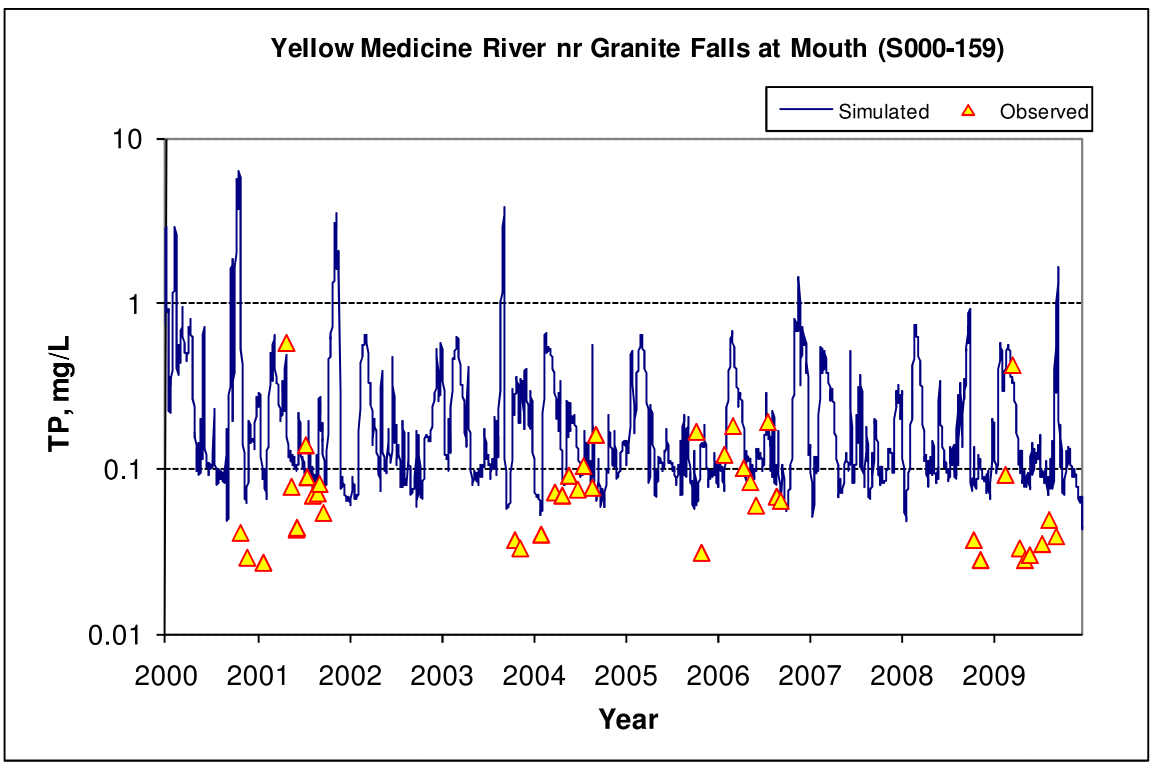


Yellow Medicine River nr Granite Falls at Mouth (S000-159) 1993-2005
TP Load, tons/day
100
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

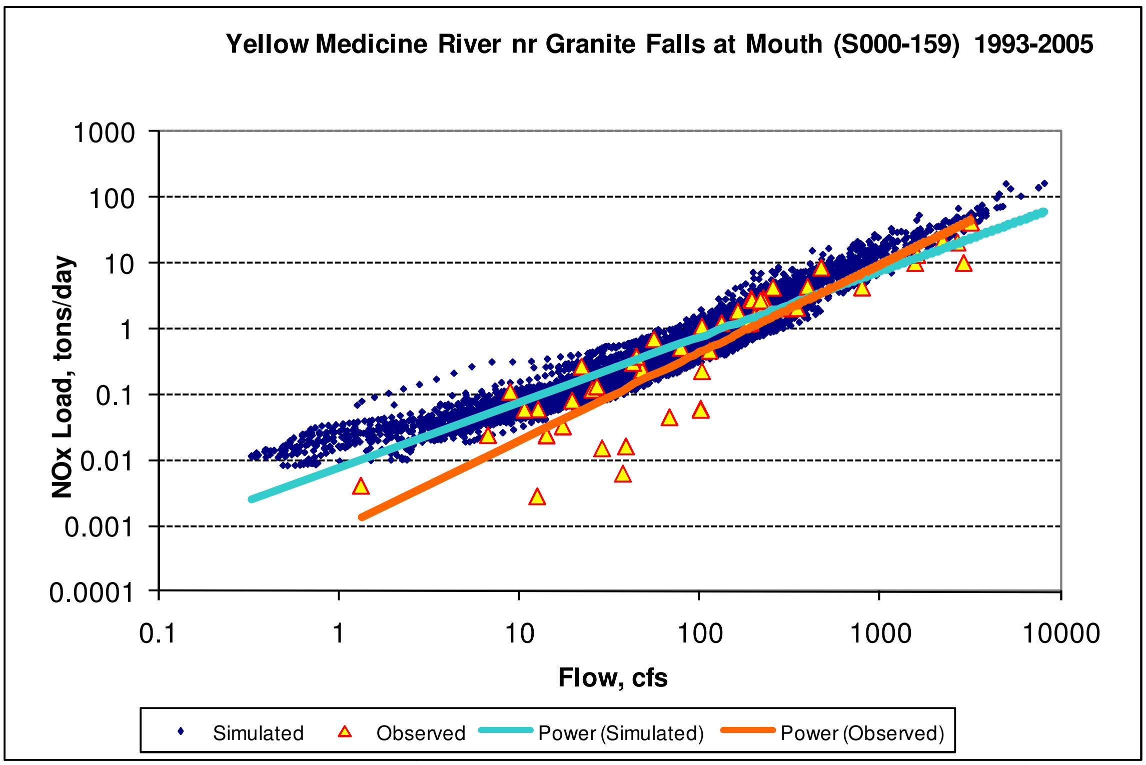
Yellow Medicine River nr Granite Falls at Mouth (S000-159) 2006-2009
TP Load, tons/day
10
1
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
10000
Flow, cfs
Simulated
Observed
Power (Simulated)
Power (Observed)

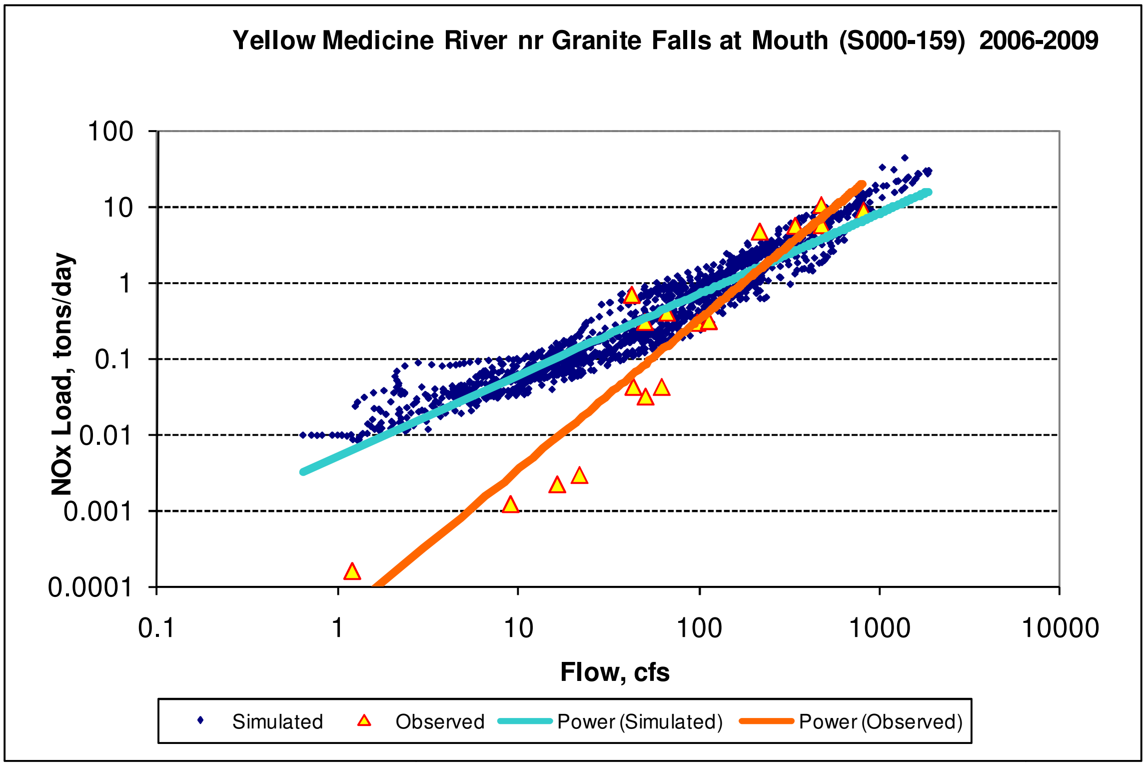

Yellow Medicine River nr Granite Falls at Mouth (S000-159)
Simulated
Observed
10
1
0.1
0.01
TP, mg/L
1993
1994
1995
1996
1997
1998
1999
Year

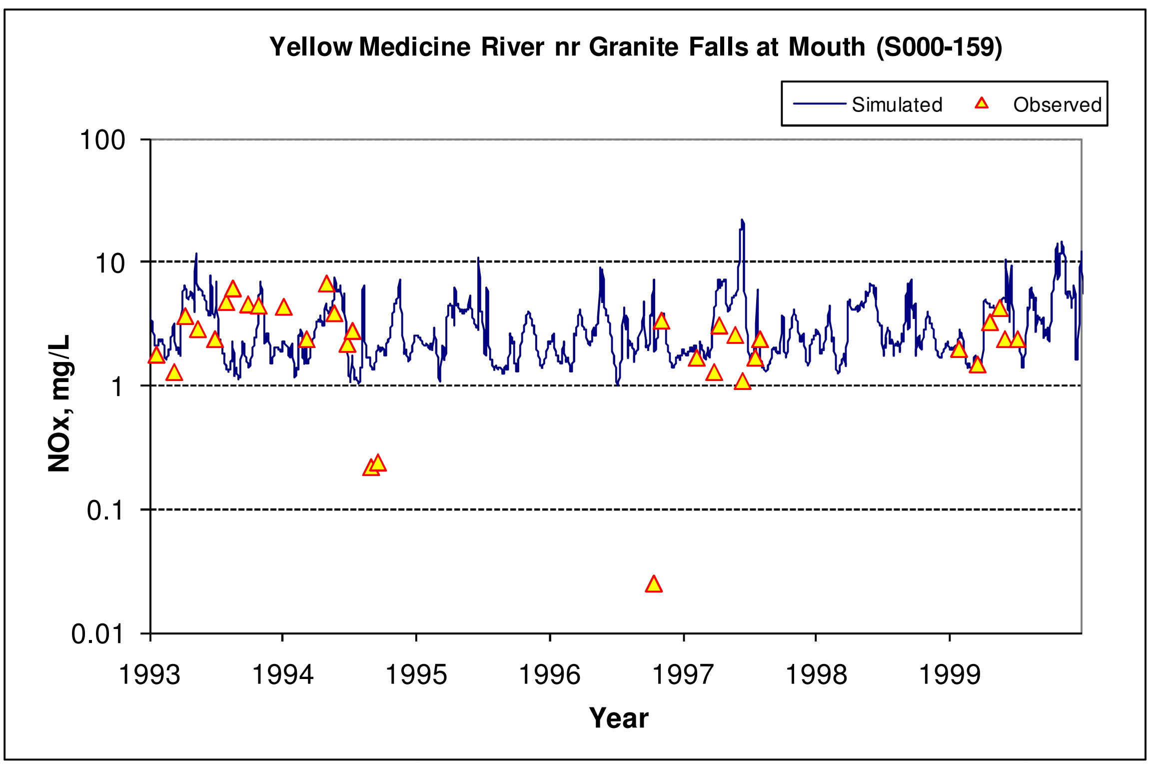

Yellow Medicine River nr Granite Falls at Mouth (S000-159)
Simulated
Observed
10
1
0.1
0.01
TP, mg/L
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Year

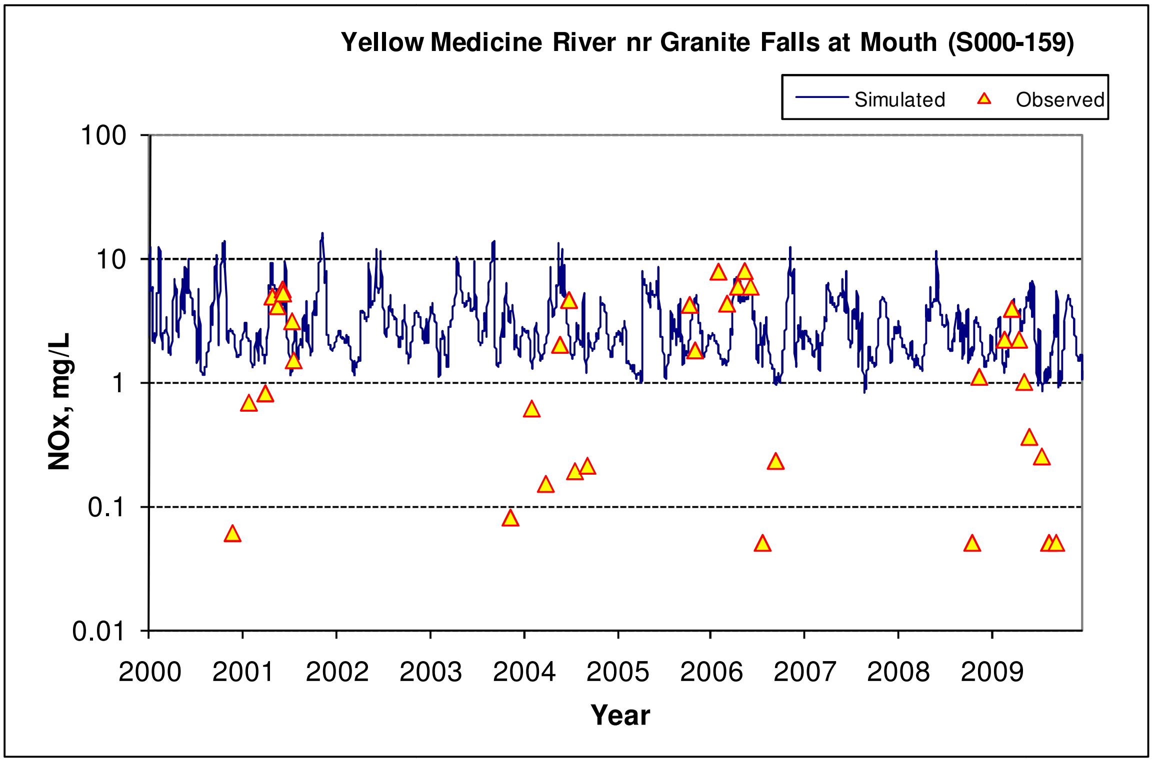
## 6.3 NITRATE PLUS NITRITE NITROGEN (AS N)

| 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
NOx 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)


Yellow Medicine River nr Granite Falls at Mouth (S000-159)
Simulated
Observed
NOx, mg/L
100
10
1
0.1
0.01
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