Project	Mustinka/Bois de Sioux HSPF model	**Date**	10/15/2014
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Regarding	Water quality parameterization and calibration		

Introduction and approach

This memo documents the parameterization and calibration for water quality in the Mustinka/Bois de Sioux watersheds (MBdS) as per Objective 2, Tasks A and B of the project workplan.

Temperature, select nitrogen and phosphorus species, dissolved oxygen (DO), phytoplankton, and biological oxygen demand (BOD) were calibrated at three sites in the MBdS: Mustinka (near Wheaton), Bois de Sioux (BdS; near Doran) and Rabbit (near Campbell). Of these constituents, nitrate (NO_3), orthophosphate (Ortho-P) and total phosphorus (TP) *load* calibrations were the most rigorously calibrated and evaluated using numerical criteria. Calibrated constituent *concentrations* were evaluated based on graphical examination only due to the difficulty in successfully simulating periodic daily grab sample concentrations.

Nitrogen, given its low observed concentrations, is less important in the MBdS than phosphorus (and the latter's link to dissolved oxygen). Therefore, phosphorus was given greater weight for attaining accurate calibrations. Moreover, because of the lack of nitrate data at the Rabbit calibration site, nitrogen species were not calibrated in the Rabbit.

Guidance documentation for HSPF water quality (WQ) parameterization and calibration is relatively lacking compared to hydrology or sediment. As a result, the Minnesota River HSPF Calibration and Validation Report (Tetra Tech, 2009; hereafter referred to as the MNR-HSPF report) served as an important resource for setting initial parameter values and defining reasonable ranges. It was also used to set and constrain ratios between dependent parameter values as well as ratios between different PERLND segment parameter values. Guidance information from BASINS/HSPF training lectures and exercises were also used.

Monitoring Data

Considerable WQ monitoring data were available for calibration at the three major sites in the MBdS (See Table 1). Notable limitations of this dataset include a short sampling period (2001-2003) for several constituents, no ammonia (NH_3), total kjeldahl nitrogen (TKN) or chlorophyll-a (Chl-a) data at the BdS station and no BOD data at any station. Grab samples were used to compare and evaluate continuous simulated concentrations. In addition, EOR generated continuous time series for NO_3, TP and Ortho-P concentrations for comparison with simulated loads as these nutrients are a special focus in TMDL development and this approach allow for more quantitative evaluation of model performance.

Table 1. Available monitoring data for calibration. Yellow cells indicate limited date range and/or number of samples

		Mustinka River Wheaton, MN		Bois de Sioux River Doran, MN		Rabbit River Campbell, MN	
		S000-062		S000-553		S001-029	
		5049000		05051300		54017001	
		HSPF ID: 308		HSPF ID: 104		HSPF ID: 205	
Grab samples (MPCA)		**#**	**Date range**	**#**	**Date range**	**#**	**Date range**
	Temp (degF)	105	2001-2006	80	2001-2006	29	2001-2006
	NO_3 (mg/l)	79	2001-2006	54	2001-2006	13	2001-2006
	NH_3 (mg/l)	20	2001-2003	0		9	2001-2003
	TKN (mg/l)	20	2001-2003	0		15	2001-2003
	Total P (mg/l)	79	2001-2006	74	2001-2006	39	2001-2006
	Ortho P (mg/l)	90	2001-2006	70	2001-2006	37	2001-2006
	Chloro.-a (ug/l)	29	2001-2003	0		15	2001-2003
	DO (mg/l)	98	2001-2006	75	2001-2006	47	2001-2006
	BOD (mg/l)	0		0		0	
Cont. time series (EOR)							
	NO_3 (mg/l)		2001-2006		2001-2006		NA
	TP (mg/l)		2001-2006		2001-2006		2001-2006
	OP (mg/l)		2001-2006		2001-2006		2001-2006

Generation of continuous observed time series

Time series were developed in MS-Excel and statistical software using a methodology similar to FLUX or LOADEST software tools. Generally, higher flows in the MBdS result in higher Ortho-P and TP concentrations making high flow periods the most important for phosphorus loading. Often, NO_3 shows a similar trend with flow. However, quantifying statistically significant trends between flow and Ortho-P, TP and NO_3 is problematic due to the wide variability in grab sample measurements at all flow ranges. To determine trends, linear and non-linear regression were tested first; if significant trends with flow were determined to exist (using ~90% confidence or professional judgment), daily flows were used with the applicable regression equation to calculate an estimated daily concentration.

However, analysis of all MBdS calibration sites revealed weak flow regression relationships with P and N species due to high variability of observed concentrations under most flow regimes. This forced the use of a flow-weighted mean concentration (FWMC) approach. This approach entailed dividing the sum of the NO_3, Ortho-P, and TP loads (average daily concentration x daily flow volume) by the sum of the flow volume for discrete flow ranges defined by where Ortho-P, TP or NO_3 concentrations were visually observed to cluster. As discussed previously, the Rabbit had relatively few grab NO_3 samples (and even fewer at middle and higher flows). Therefore, no continuous NO_3 record was generated for the Rabbit and N species were not calibrated. The continuous time series FWMC methodologies for all three sites are presented in Table 2.

Table 2. Observed continuous time series FWMC methodology

Calibration Station	Constit.	Flow Range #1: FWMC mg/l	Flow Range #2: FWMC mg/l	Flow Range #3: FWMC mg/l	Flow Range #4: FWMC mg/l
Mustinka	Ortho-P	< 165 cfs: 0.07	166-500 cfs: 0.145	>500 cfs: 0.377	
Mustinka	TP	< 50 cfs: 0.2	51-100 cfs: 0.3	101-500 cfs: 0.41	> 500 cfs: 0.54
Bois de Sioux	Ortho-P	< 165 cfs: 0.06	166-630 cfs: 0.15	>630 cfs: 0.27	
Bois de Sioux	TP	< 100 cfs: 0.27	101-450 cfs: 0.36	>450 cfs: 0.43	
Rabbit	Ortho-P	< 168 cfs: 0.16	> 169 cfs: 0.37		
Rabbit	TP	< 168 cfs: 0.3	> 169 cfs: 0.47		

Point Sources

Eight WWTP point sources were incorporated into the model. Seven were located in the Mustinka watershed, one in the Rabbit/BdS watershed (See Figure 25). Point sources in North/South Dakota were not included in the model. Point source data was input into HSPF via the EXTERNAL SOURCES block and included (1) daily flow, (2) heat, (3) dissolved oxygen, (4) nitrate/nitrite, (5) phosphate, (6) organic N, (7) organic P, (8) ammonia, (9) BOD and (10) total organic carbon. Data were made available by Mike Vavricka at MPCA. Further details are included in the April 12, 2012 EOR memo entitled *Point Sources and Atmospheric Deposition per Task 3 of the Mustinka River (09020102) & Bois de Sioux River (09020101) HSPF Model Work Plan.*

Atmospheric Deposition

NO_3 and NH_4 inputs via wet and dry deposition are significant inputs in the MBdS. The daily rates for these four constituents were input into the HSPF EXTERNAL SOURCES block. Further details are included in the April 12, 2012 EOR memo entitled *Point Sources and Atmospheric Deposition per Task 3 of the Mustinka River (09020102) & Bois de Sioux River (09020101) HSPF Model Work Plan.*

Manure

Field application of livestock manure plays a significant role in agricultural nutrient management in the MBdS watersheds. However, it was challenging to acquire specific information on the amount of manure generated and when/where the manure is applied. EOR staff compiled a list of feedlots from MPCA sources and estimated the actual number of animal units present based on windshield surveys. To estimate the amount and spatial distribution of manure and parameterize the HSPF model the following procedure was used:

1. Calculate recoverable nitrogen and phosphorus per feedlot (based on per animal type/per day estimates from NRCS, 1992).

2. Overlay feedlot locations with HSPF subbasins using GIS to get the recoverable nitrogen and phosphorus generated per subbasin.

3. Determine row-crop area per subbasin with manure applied assuming an application rate of 150 lbs/acre/yr recoverable nitrogen.

4. Add new HSPF pervious land segment (PLS) for manured row-crops.

5. Update HSPF NETWORK block with new subbasin distributions of PLS areas.

Parameterization

HSPF water quality predictions are based on simulation of surface buildup/washoff, interflow and groundwater flow concentrations of modeled constituents (i.e., NH_3, NO_3, Ortho-P, and BOD). The parameters involved in these processes are implicit, difficult to estimate and are given considerable latitude for adjustment during calibration. Therefore, the MBdS model relied heavily on the MNR-HSPF report for starting values and constraining ratios between PLS types. Generally, the Chippewa watershed model was utilized for starting parameter values while the MNR-HSPF report provided procedures and guidelines for setting constraining values and ratios.

The principal areal landuse and pollutant source in the MBdS watersheds is row-crop agriculture (corn, soy and sugar beets). As such, parameterization was focused on these PLS's more so than forest, grassland, and wetland which comprise a small proportion of the watershed area, are predicted to result in less surface runoff and are assumed to have lower surface and subsurface concentrations of nutrients. Pervious and impervious urban landuse (which also comprise a small proportion of MBdS watershed area) were defaulted to parameter values contained in the MNR-HSPF report and not adjusted during calibration.

Surface buildup/washoff

Simulation of surface runoff pollutant concentrations is governed by one of two processes depending on whether the pollutant is transported in a dissolved form (NH_3 and NO_3) vs. adsorbed to sediment (Ortho-P and BOD).

Dissolved NH_3 and NO_3 concentrations in surface runoff are primarily governed by the ACCUM and SQOLIM parameters -- the daily rates of surface buildup/storage of the pollutant and the limiting storage of the pollutant at which the surface storage does not increase further, respectively. ACCUM and SQOLIM for both nitrogen forms were calibrated to be relatively small as it was assumed that NH_3 and NO_3 are accumulated a low rate and were "recycled" quickly e.g., (via leaching, chemical transformation, volatilization, etc.) so that during any given surface runoff event, the simulated flow concentrations were not excessive when compared to observed stream concentrations. Ratios of ACCUM to SQOLIM were set at 0.5 to 0.33 based on guidance in MNR-HSPF. Manured row-crop segments ACCUM and SQOLIM values were 50% higher than non-manured segments as per MNR-HSPF, which cited work by Mulla et al, 2001. ACCUM and SQOLIM were calibrated to be 5 to 10 times higher in April, May and June than during the rest of the year.

Sediment bound Ortho-P and BOD rely on adjustment of potency factor parameters (POTFW) which control how much nutrient is transported with washed off sediment per unit sediment mass. POTFW was calibrated so as to match observed high flow Ortho-P with manured potencies 5.5 times higher than non-manured following the MNR-HSPF report citing Mulla et al, 2001. No observed BOD stream data were available for calibration so BOD potency was defaulted to that of the Chippewa HSPF model and manured BOD constrained to be 4 times higher than non-manured segments as per the MNR-HSPF.

Aside from direct parameterization, water quality response was heavily influenced by the depressional storage segmentation of row-crop landuse initiated during the hydrologic calibration. In depressional subbasins, simulated surface runoff is reduced significantly which in turn drives reductions of all surface water borne pollutants and to some degree, subsurface loading due to increased evapotranspiration. This creates an added level of subbasin detail is distributing simulated WQ response that is useful for TMDL analysis.

Interflow and Groundwater
Subsurface concentrations of NH_3, NO_3, Ortho-P, and BOD were defaulted to values in the Chippewa HSPF model. Corresponding with the manured vs. non-manured surface runoff parameters, subsurface NH_3 and NO_3 concentrations were set 1.5 times higher, Ortho-P was set 5.5 times higher and BOD was set 4 times higher than non-manured segments.

Calibration procedure

Water quality was calibrated at the Mustinka (Wheaton), Bois de Sioux (Doran) and Rabbit (Campbell) flow and WQ sampling stations. However, unlike the hydrology calibration, validation was not conducted for 1995-2000 and 1998-2000 in the BdS and Rabbit, respectively, because (1) no WQ grab samples were available prior to 2001 at any calibration station and, (2) model support for the 2001-2006 (and more recent) period is the focus for supporting TMDLs.

The Mustinka calibration period, because of limited observed flow data, was similar to that for the hydrologic calibration (2003-2006); however, periods of valid flow data from 2001-2002 were considered in the WQ calibration in an effort to stretch the calibration period as much as possible. Bois de Sioux and Rabbit used the period 2001-2006 although for the Rabbit, only growing season flow data were available.

Calibration followed a step-wise procedure as suggested in the project workplan and BASINS/HSPF training materials: (1) calibrate water temperature first, (2) followed by nitrogen and phosphorus species, and (3) finishing with dissolved oxygen, BOD and phytoplankton with the assumption that (2) and (3) will be iteratively repeated given the inter-dependence of the nutrient cycling processes involved.

Evaluation of calibration was based on a weight-of-evidence approach consisting of the following components:

(1) Numerical performance statistics (i.e., goodness-of-fit [GOF]) of observed vs. simulated continuous time series *loads* (NO_3, Ortho-P, TP)
(2) Visual comparison of continuous observed vs simulated *loads* using load duration curves and monthly and annual time series (NO_3, Ortho-P, TP)
(3) Visual comparison of observed grab sample *concentrations* graphed with simulated time series (all constituents).

Because of the spatial and temporal complexity of landscape and stream nutrient processes as well as uncertainties in observed data, simulated water quality is generally judged by lower GOF standards and at longer temporal scales than flow (monthly and annually vs. daily). Numerical model performance criteria were estimated from the MPCA Guidance doc (ATC, 2013). However, statistics and performance criteria for water quality calibration were not specified in model guidance documentation except in the case of evaluation of percent difference; by comparing the thresholds (*very good, good, fair, poor*) between these criteria for flow vs. water quality, reasonable criteria for NSE and R^2 were estimated. A summary of the evaluation approach is presented in Table 3.

Calibration statistics and graphical output were generated using a custom HSPF framework programmed by EOR using the R statistical software platform (R Core Team, 2014). This framework allows for very flexible, automated and efficient data processing as well as statistics calculation and graph generation in support of HSPF projects.

Table 3. Model Calibration Evaluation Methodology

Site	Calibration Period	Numerical Evaluation Statistics	Numerical Ratings and Criteria	Graphical Evaluation
Mustinka	2001-2006	(1) Monthly NSE* of average daily load (2) Monthly R^2 of average daily load (3) Percent diff. in simulated vs. observed total load for entire period	<u>NSE*, R^2</u> Very Good: > 0.75 Good: 0.65 - 0.75 Fair: 0.55 – 0.65 <u>Percent Difference</u> Very good: <15% Good: 15-25% Fair: 25-35%	(1) Monthly/annual simulated vs. observed loads (2) Daily simulated time-series vs. observed grab sample concentrations** (3) Simulated vs. observed load duration curves
Bois de Sioux	2001-2006			
Rabbit	2001-2006			

* Nash-Sutcliffe Efficiency coefficient: index of cumulative error between daily observed and simulated values. Range: -∞ to 1.0 (1.0 indicates perfect agreement between observed and simulated)

** Calibrated temperature, dissolved oxygen, Chlorophyll-a and N and P concentrations were evaluated based on graphical examination only

Calibration of Ortho-P and TP were given more emphasis than nitrate and other nitrogen forms because observed nitrate concentrations in the MBdS are far below the threshold for impairment (approximately an order of magnitude or more lower than agricultural watersheds in the Mississippi and Minnesota River basins). In other words, there was a higher priority in ensuring accurate phosphorus simulations across all flow regimes than with nitrogen because of existing impairment priorities. That stated, the same performance criteria were used for nitrogen and phosphorus forms.

Calibration Results and Discussion

Numerical results of NO_3, Ortho-P and TP are presented below in Table 4. Graphical results are presented thereafter following each constituent calibration summary.

Table 4. NO_3, TP and Ortho-P daily load calibration statistics and ratings

Site	Constit.	Monthly NSE	Monthly R^2	Percent Diff.
Mustinka	NO_3	0.79 (Very Good)	0.89 (Very Good)	-19% (Good)
	TP	0.72 (Good)	0.73 (Good)	-7% (Very Good)
	Ortho-P	0.60 (Fair)	0.69 (Good)	+17% (Good)
Bois de Sioux	NO_3	0.69 (Good)	0.71 (Good)	-26% (Fair)
	TP	0.62 (Fair)	0.60 (Fair)	-27% (Fair)
	Ortho-P	0.75 (Very Good)	0.79 (Very Good)	+16% (Good)
Rabbit	NO_3	NA	NA	NA
	TP	0.64 (Fair)	0.65 (Good)	-17% (Good)
	Ortho-P	0.61 (Fair)	0.65 (Good)	+7% (Very Good)

Temperature

Temperature was calibrated at the three sites using a robust set of observed data. HSPF's temperature algorithms appear to be very accurate – despite setup using default parameters -- as no additional calibration at any site was necessary. See Figures 1-3. However, it is not clear to what extent temperature may be over-predicted in smaller, shallower streams of the MBdS. HSPF produced warnings in several lower order reaches during summer, low flow periods indicating simulated temperature exceeded reasonable values (a common warning in the HSPF model simulations). Adjusting the ADCALC activity flag to "2" remedied some but not all of these warnings.

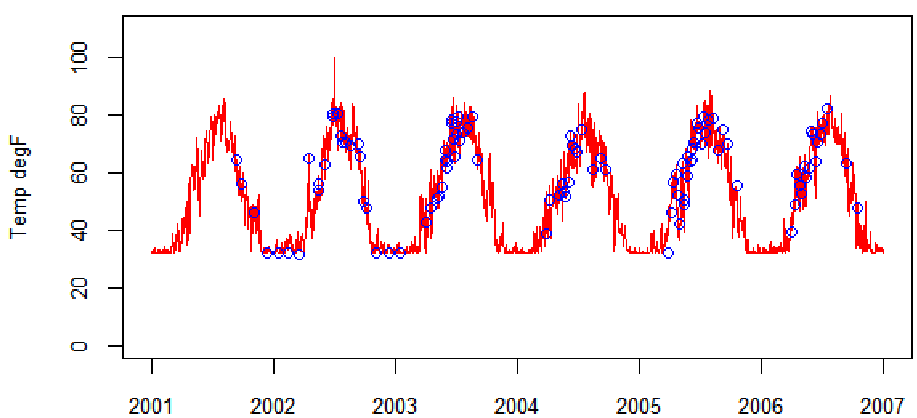


Figure 1. Temperature calibration results for Mustinka

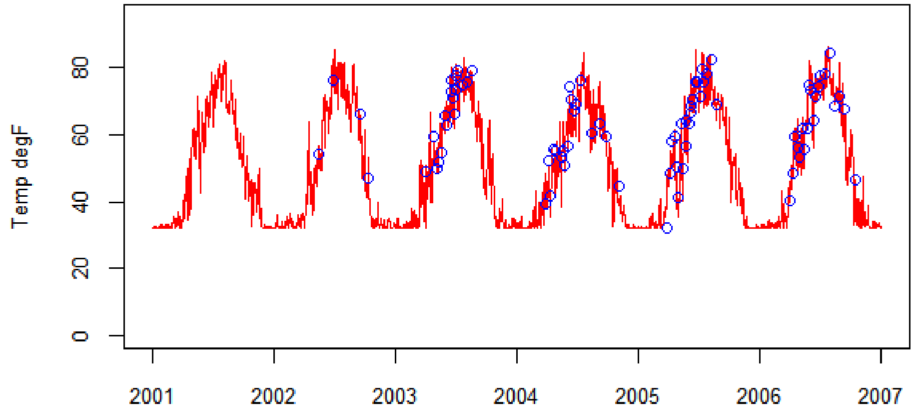


Figure 2. Temperature calibration results for Bois de Sioux

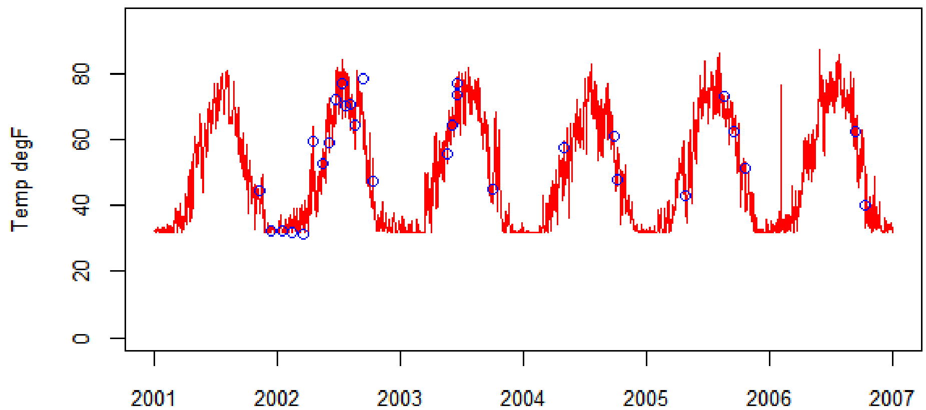


Figure 3. Temperature calibration results for Rabbit

Nitrogen

As discussed above, the MBdS watersheds (along with the Red River basin on the whole) are somewhat unique in that, unlike most central/southern MN agricultural watersheds, they exhibit relatively low river NO_3 loads; in most cases, concentrations are roughly an order of magnitude lower than similarly managed (i.e., fertilizer, tillage, etc.) agricultural watersheds in the Minnesota River basin (MPCA, 2010). Chuck Regan of MPCA (personal communication, 2014) confirmed that in his experience the upper Red River basin has substantially lower NO_3 concentrations and somewhat higher NH_3 relative to the Minnesota River basin. He speculates that high water tables create a highly reducing soil environment which drives pronounced denitrification and ammonification processes. These observations made calibration of nitrogen more challenging given the reliance on the MNR-HSPF report for parameter guidance given that the MBdS responds differently than Minnesota River watersheds.

Nitrate (NO_3)

Low observed NO_3 concentrations at the two calibration sites necessitated a pronounced decrease in the surface runoff component of NO_3 transport to prevent over-prediction of simulated concentrations during high flow periods. Daily accumulation and storage limits (ACCUM, SQOLIM) were decreased to reduce the storm event concentration peaks. Low flow

NO_3 was calibrated by adjustment of interflow and groundwater concentrations. Calibrated subsurface concentrations were calibrated to be notably higher during the months of April, May and June where observed concentrations are generally higher.

Mustinka NO_3 numerical calibration results were *good* to *very good* (See Table 4). Percent difference in cumulative loads over the entire period were *good* with an under-prediction bias of ~20%. Review of the load duration curve shows the NO_3 calibration is representative at all flow ranges. Simulation of concentrations appears adequate but with some simulated peaks during non-spring periods that are likely not representative of actual conditions (See Figures 4-6).

Bois de Sioux NO_3 numerical calibration results were *fair* to *good* (See Table 4) with the load duration curve indicating a good calibration on the highest loading days (which is driving the strength of numerical GOF statistics) but correspondence with the observed data in most other flow ranges was . Percent difference in cumulative loads over the entire period were *fair* with an under-prediction bias of 27%. Daily simulated concentrations appear *very good* but, similar to Mustinka, most likely over-predicting some peak flow concentrations (See Figures 7-9).

Total Ammonia (NH_3)

Mustinka NH_3 concentrations were simulated and compared with periodic grab samples (See Figure 10). HPSF most likely over-predicted high flow peak concentrations (ranging from ~0.5 mg/l to ~1.0 mg/l) but overall, the median of the simulated time series compared well to the median grab sample concentration (0.034 vs. 0.038 mg/l, respectively). While Rabbit NH_3 was not rigorously calibrated for any nitrogen forms, simulated vs. observed median concentrations compared well there also (0.109 vs. 0.095, respectively).

Total Kjeldahl Nitrogen (TKN)

TKN is the sum of NH_3 and organic nitrogen and served as the proxy for evaluating total nitrogen. Overall, the simulations substantially under-predicted observed grab sample TKN concentrations (See Figure 11). Comparison of simulated vs. observed medians exhibited a poor correlation as well (0.72 vs. 1.72 mg/l respectively). Because of the lesser weight given to calibrating nitrogen species in general, this under-prediction was not investigated beyond adjustment of BOD surface potency and subsurface concentrations.

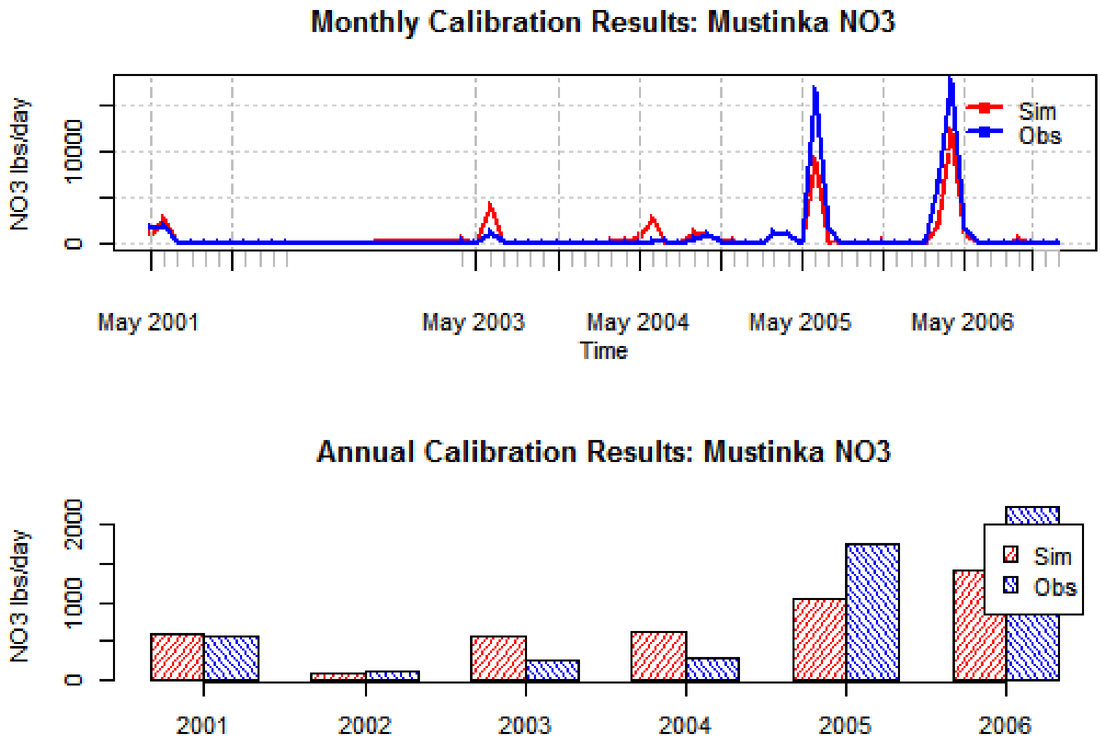


Figure 4. Simulated vs. observed monthly and yearly NO_3 loads for Mustinka

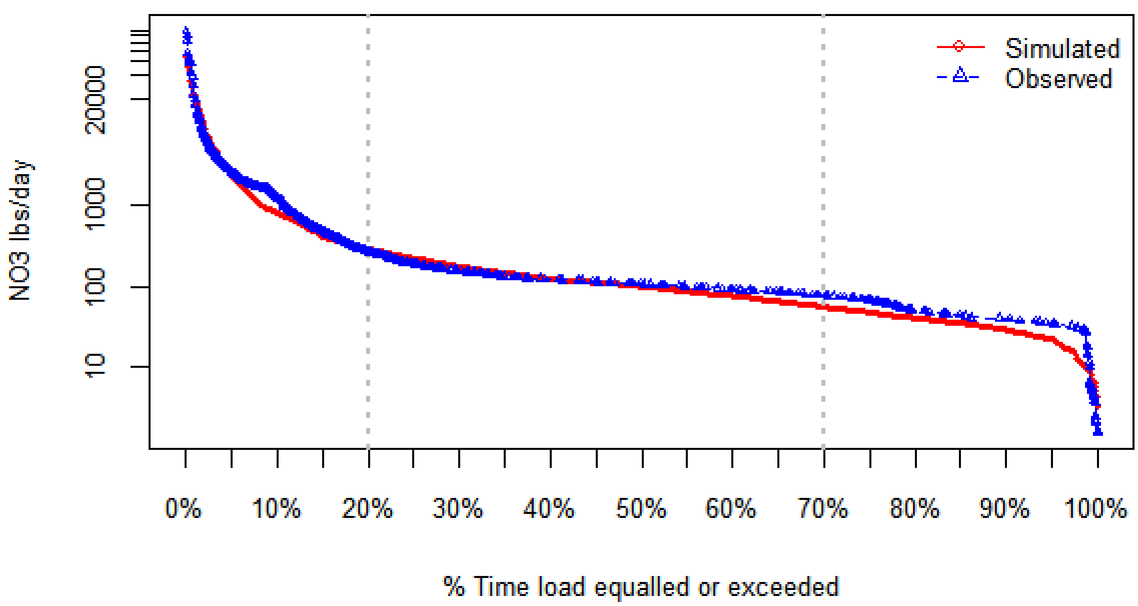


Figure 5. Simulated vs. observed daily NO_3 load duration curves for Mustinka

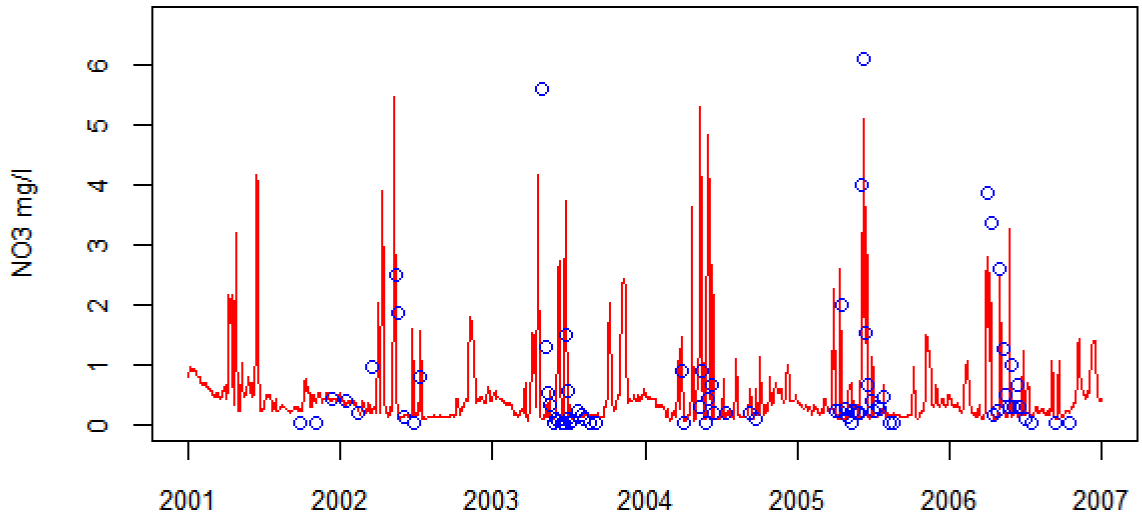


Figure 6. Simulated vs. observed daily NO_3 concentrations for Mustinka

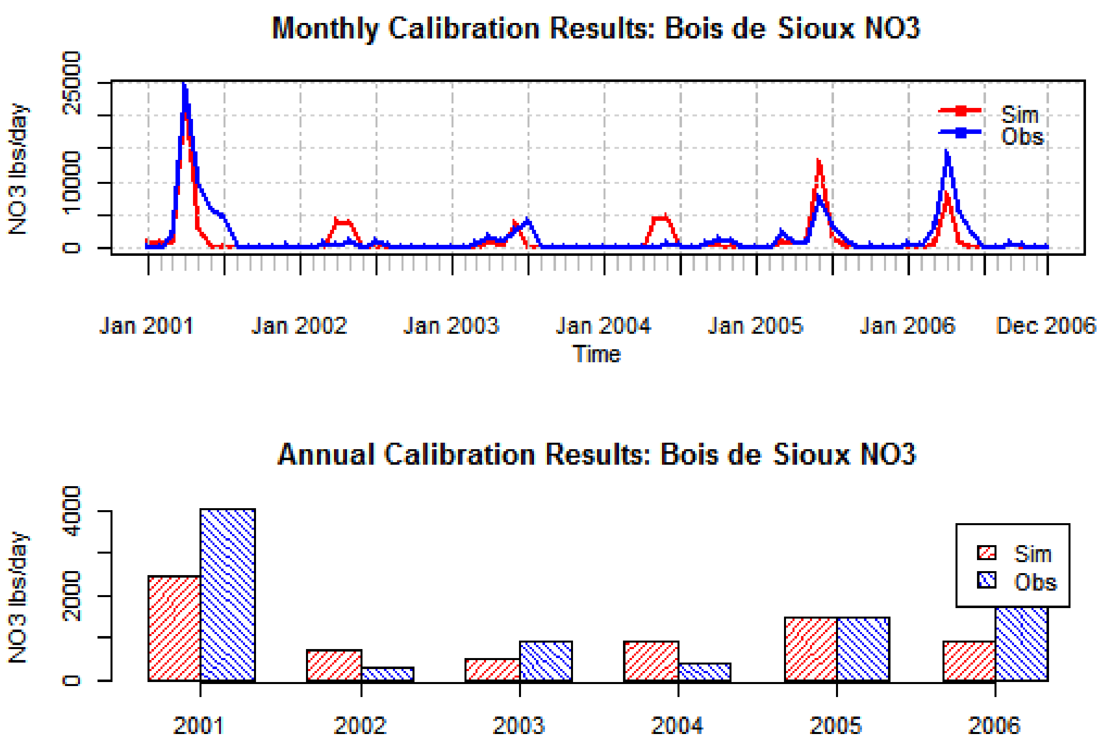


Figure 7. Simulated vs. observed monthly and yearly NO_3 loads for Bois de Sioux

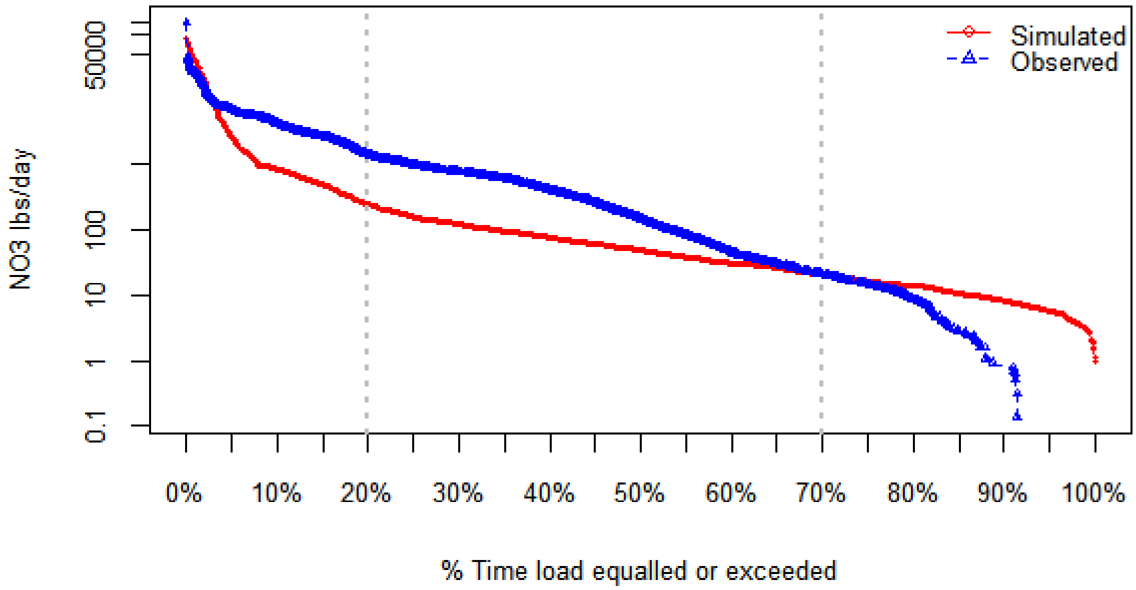


Figure 8. Simulated vs. observed daily NO_3 load duration curves for Bois de Sioux

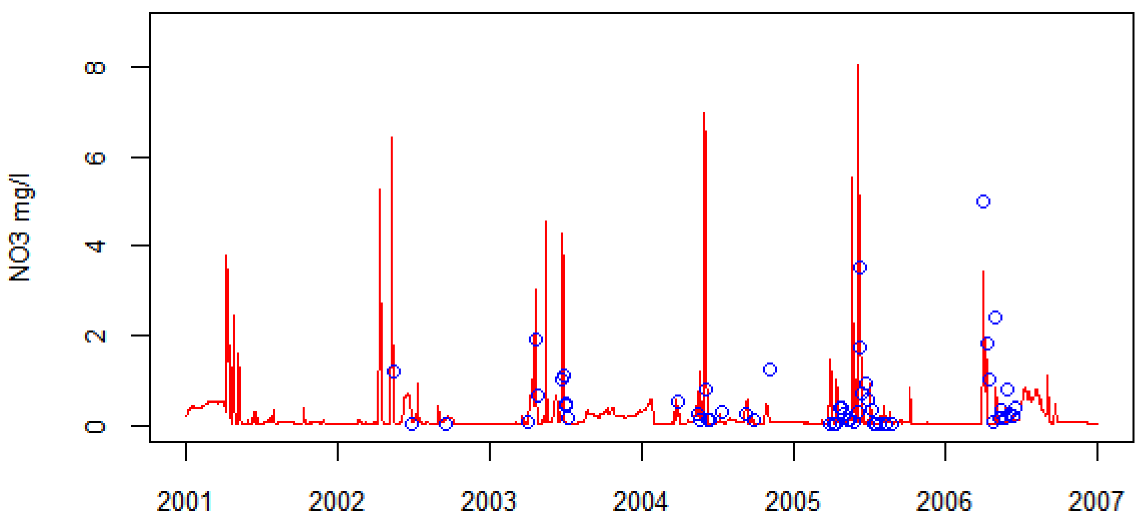


Figure 9. Simulated vs. observed daily NO_3 concentrations for Bois de Sioux

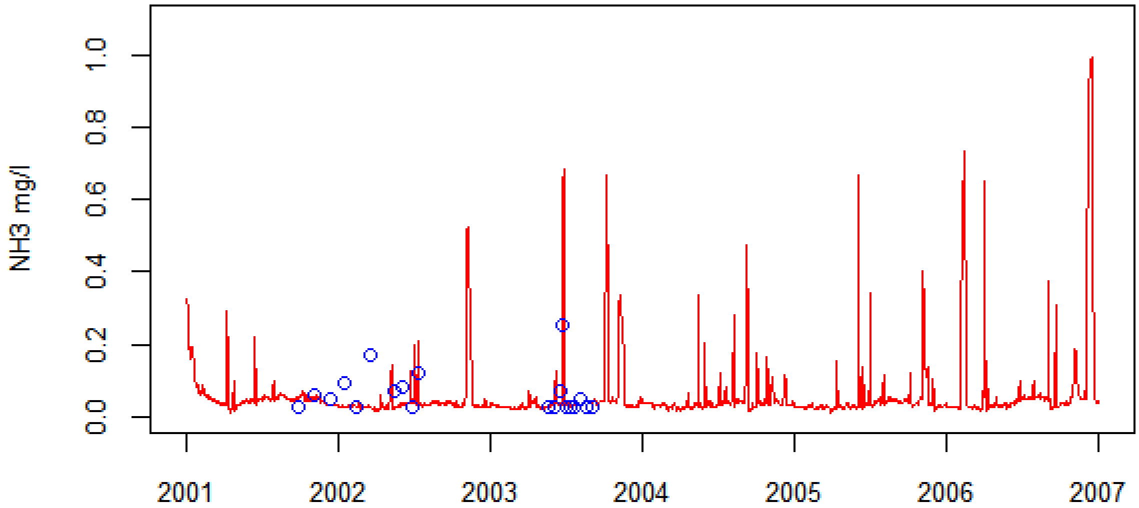


Figure 10. Simulated vs. observed daily ammonia (NH_3) concentrations for Mustinka

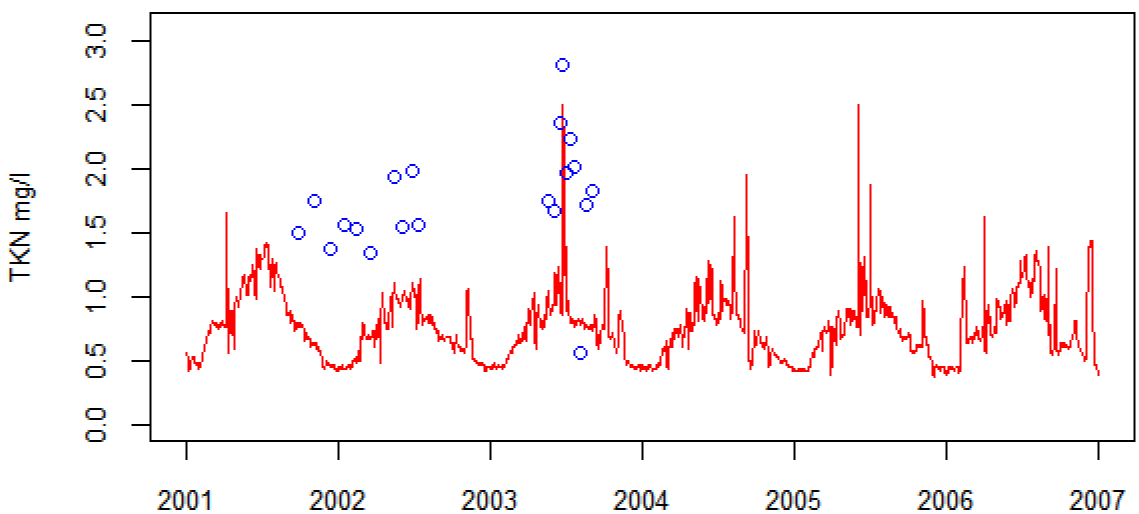


Figure 11. Simulated vs. observed daily total kjeldahl nitrogen (TKN) concentrations for Mustinka

Phosphorus
Calibration of phosphorus was the principal focus of the model calibration given its importance in TMDL impairments in the MBdS and was calibrated at all three sites.

HSPF simulates Ortho-P as the sum of particulate and dissolved phosphate forms. TP is simulated as the sum of Ortho-P and organic P present in stream plankton. Ortho-P was calibrated by adjusting the POTFW (surface runoff sediment Ortho-P potency factor) and monthly interflow and groundwater Ortho-P concentrations, while maintaining the ratios between manured and non-manured row-crop segments and non-row-crop segments (as discussed in the *Parameterization* section). After Ortho-P was calibrated, the resulting TP calibration was reviewed but did not require adjustment of parameters governing the organic P fractions.

Phosphorus calibration results are presented in Table 4. Performance statistics were rated *fair* to *very good* at all three calibration sites. Percent difference in cumulative loads exhibited a consistent trend across all three sites with Ortho-P over-predicted and TP under-predicted although all differences are rated *fair* to *very good*. Graphical results for TP are shown below in Figures 12-20. Ortho-P graphical results were very similar to that of TP and were omitted for conciseness.

<u>Mustinka</u>

Phosphorus calibration goodness-of-fit (GOF) and percent difference statistics were *fair* to *good* for Ortho-P and *good* to *very good* for TP indicating generally good monthly/yearly agreement between simulated and observed phosphorus. Comparison of load duration curves indicate good agreement in the upper 15% of flows where most TP loading occurs during the model period, but an over-prediction at medium flows. Simulated TP concentrations vs. observed grab samples appear to represent periodic grab samples well (See Figures 12-14).

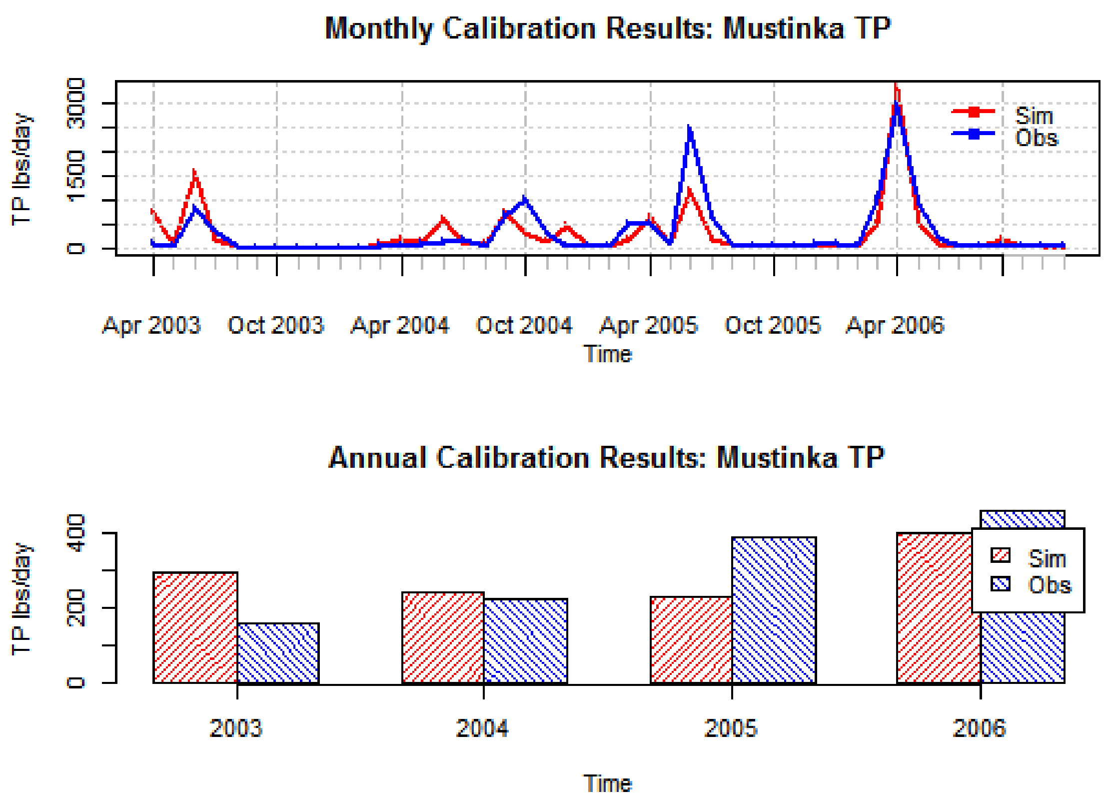


Figure 12. Simulated vs. observed monthly and yearly TP loads for Mustinka

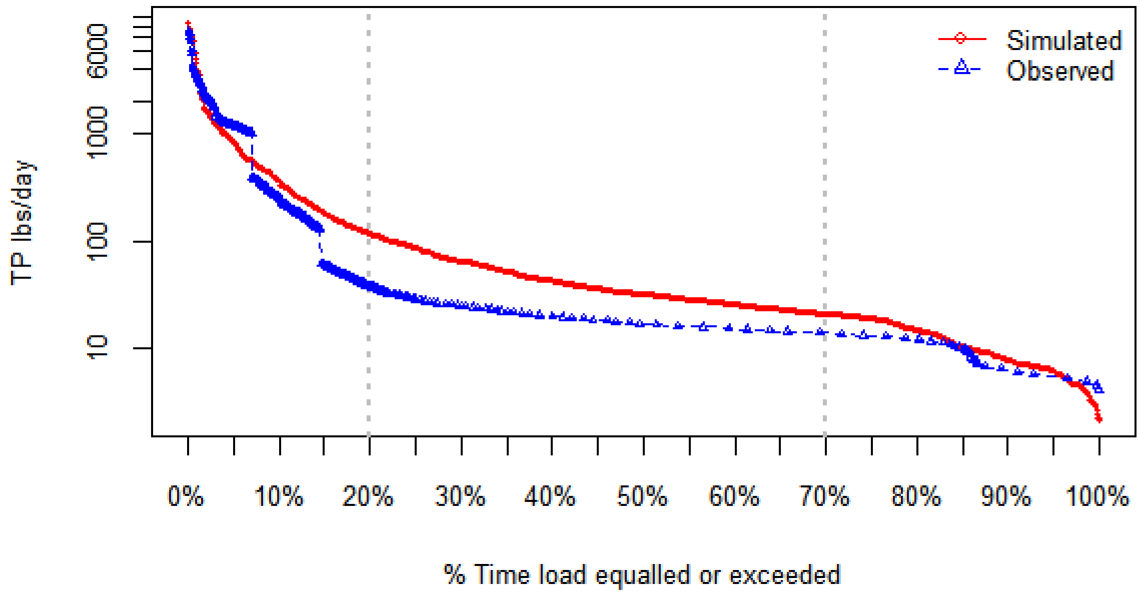


Figure 13. Simulated vs. observed daily TP load duration curves for Mustinka

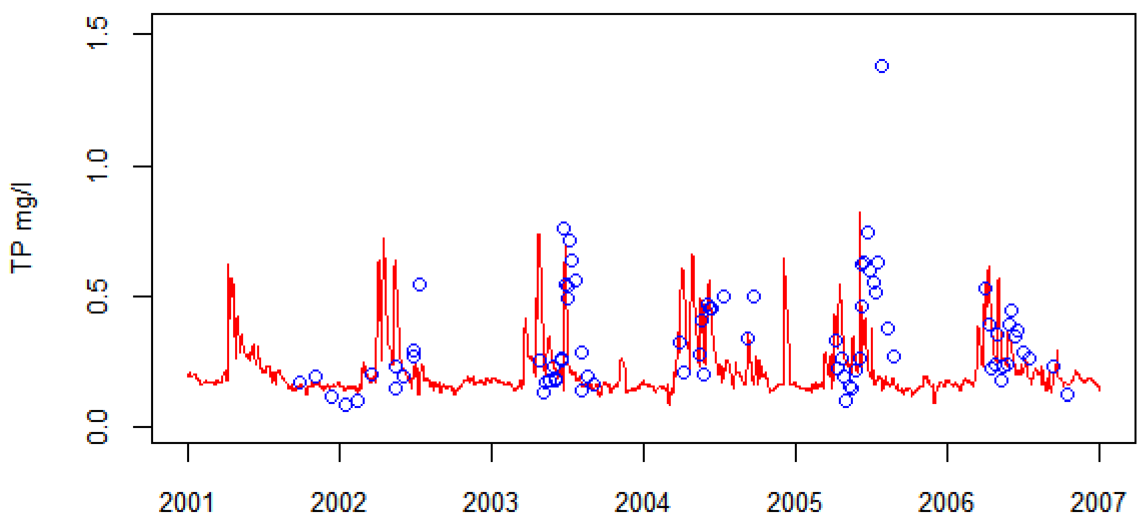


Figure 14. Simulated vs. observed daily TP concentrations for Mustinka

<u>Bois de Sioux</u>
Phosphorus calibration results yielded goodness-of-fit (GOF) and percent difference statistics that were *good* to *very good* for Ortho-P and *fair* for TP indicating generally good monthly/yearly agreement between simulated and observed phosphorus. Comparison of load duration curves indicate good agreement in the upper 50% of flows but an over-prediction in the lower 50% of flows, where loads are off roughly one order of magnitude. Simulated TP concentrations vs. observed grab samples appear to represent periodic grab samples adequately but exhibit significant over-prediction error during 2004 and likely excessive peak flow concentrations throughout. (See Figures 15-17).

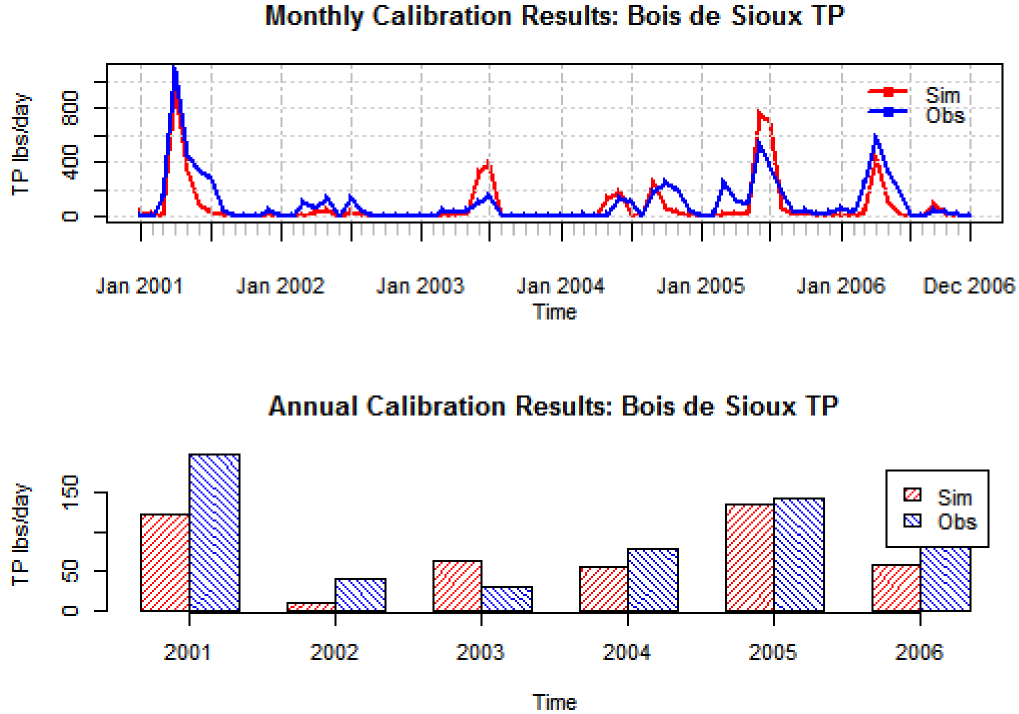


Figure 15. Simulated vs. observed monthly and yearly TP loads for Bois de Sioux

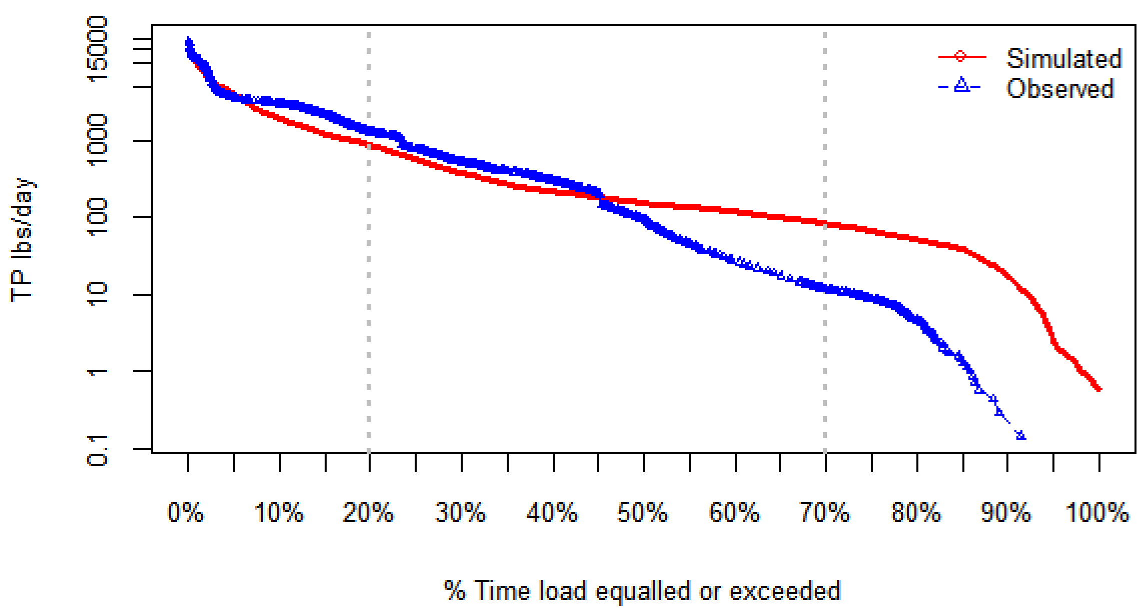


Figure 16. Simulated vs. observed daily TP load duration curves for Bois de Sioux

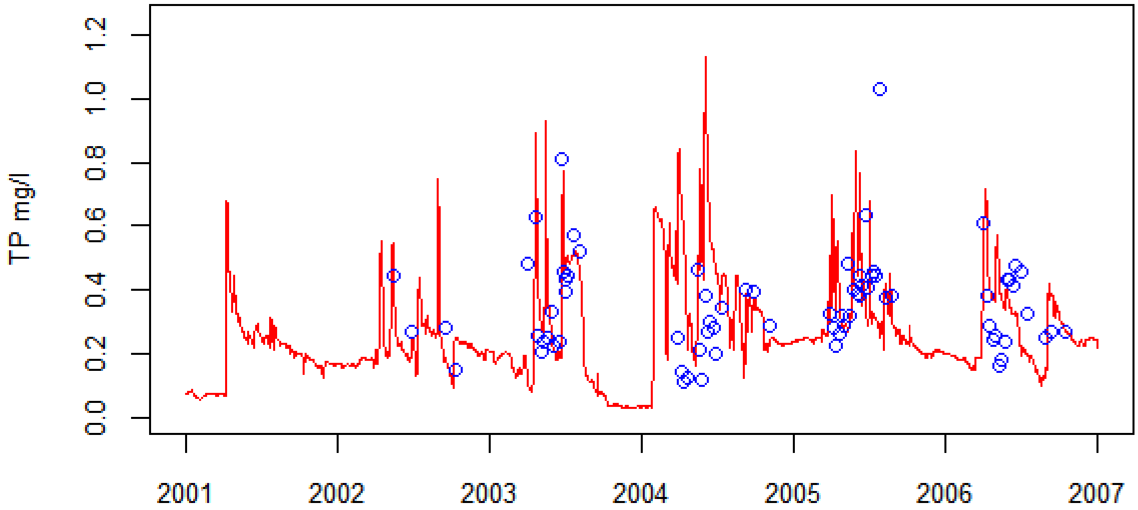
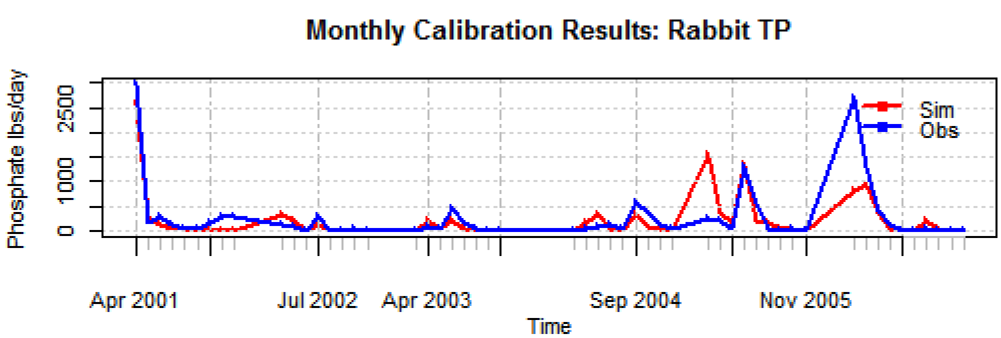


Figure 17. Simulated vs. observed daily TP concentrations for Bois de Sioux

Rabbit

Phosphorus calibration GOF results were *fair* to *good* for Ortho-P and TP but the overall percent differences were *very good* and *good,* respectively. Comparison of load duration curves show very good agreement in the majority of flow ranges (upper 70-90%). Simulated TP concentrations vs. observed grab samples appear to represent periodic grab samples adequately but indicate probable high flow/peak flow over-predictions. (See Figures 18-20).



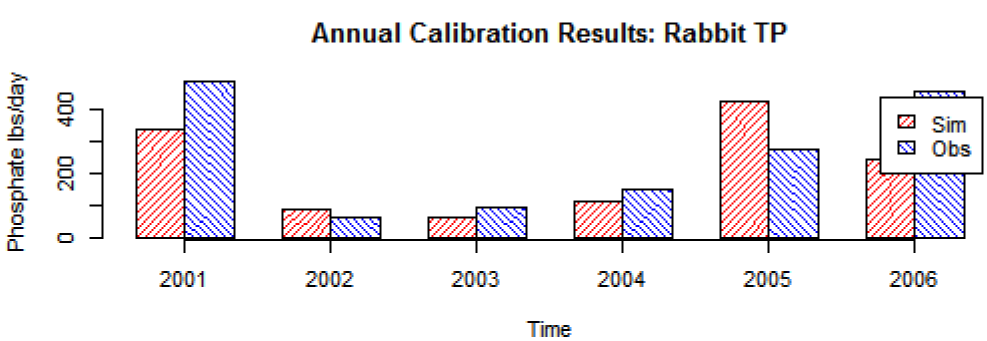


Figure 18. Simulated vs. observed monthly and yearly TP loads for Rabbit

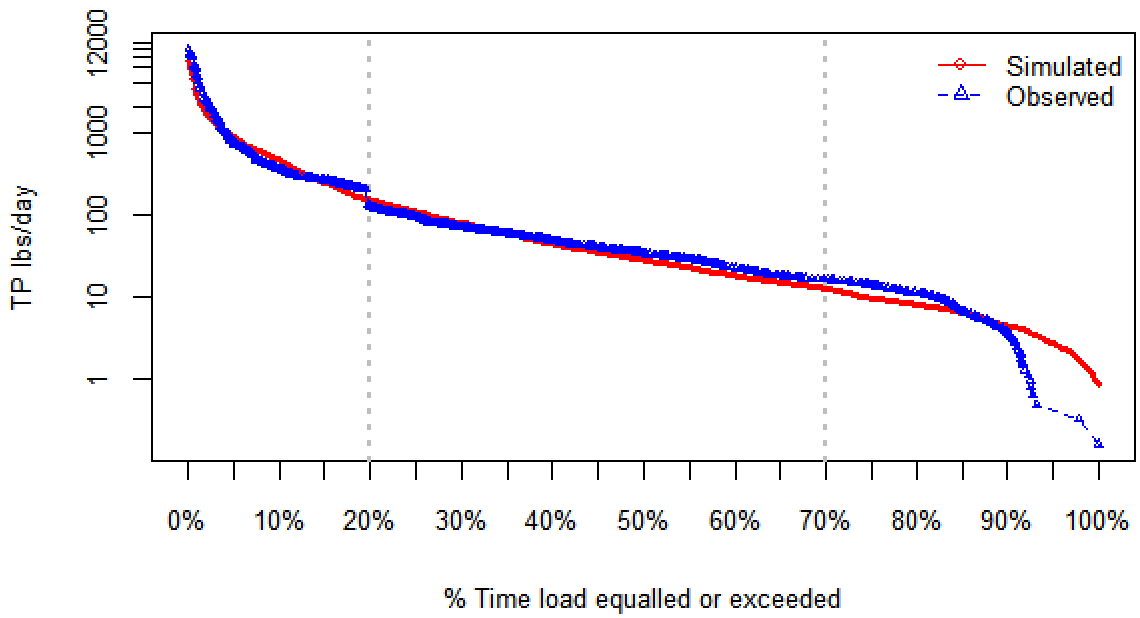


Figure 19. Simulated vs. observed daily TP load duration curves for Rabbit

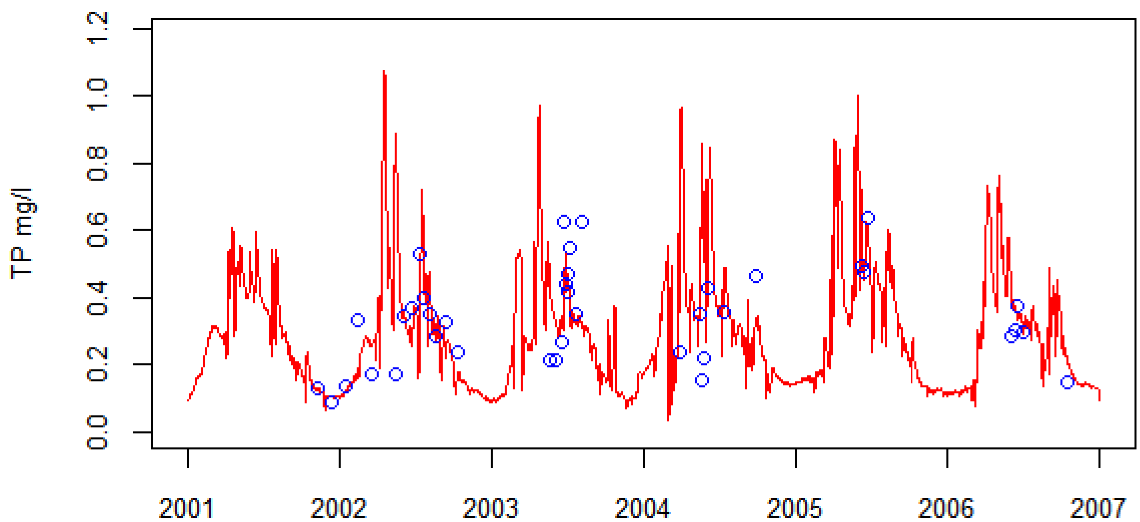


Figure 20. Simulated vs. observed daily TP concentrations for Rabbit

Dissolved Oxygen

Despite similar observed DO ranges at the three calibration stations and identical initial HSPF parameterization, initial simulated results varied widely with the BdS needing little or no calibration, Mustinka somewhat over-predicting and Rabbit significantly over-predicting DO during the low DO summer months. DO was calibrated graphically via adjustments to KBOD20 and REAK parameters (BOD decay O2 consumption rate and reaeration rate, respectively). Visual inspection indicates a reasonable DO calibration at all sites. See Figures 20-22.

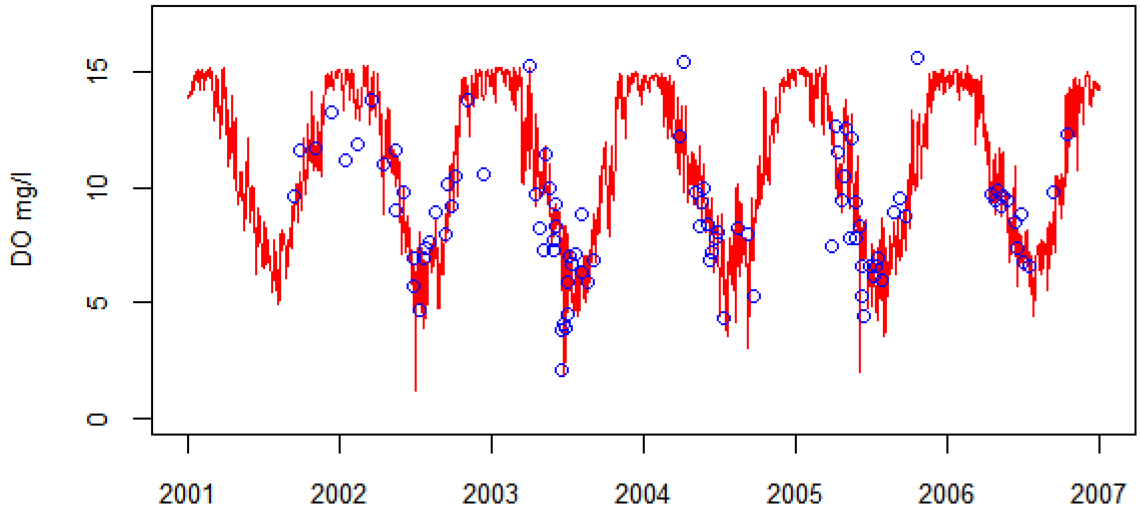


Figure 20. Simulated vs. observed daily DO concentrations for Mustinka

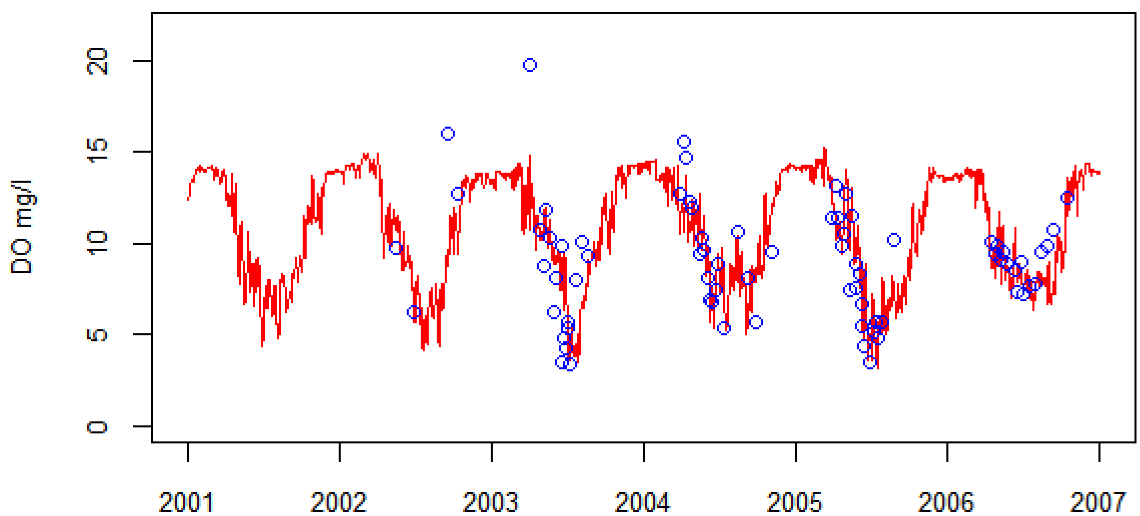


Figure 21. Simulated vs. observed daily DO concentrations for Bois de Sioux

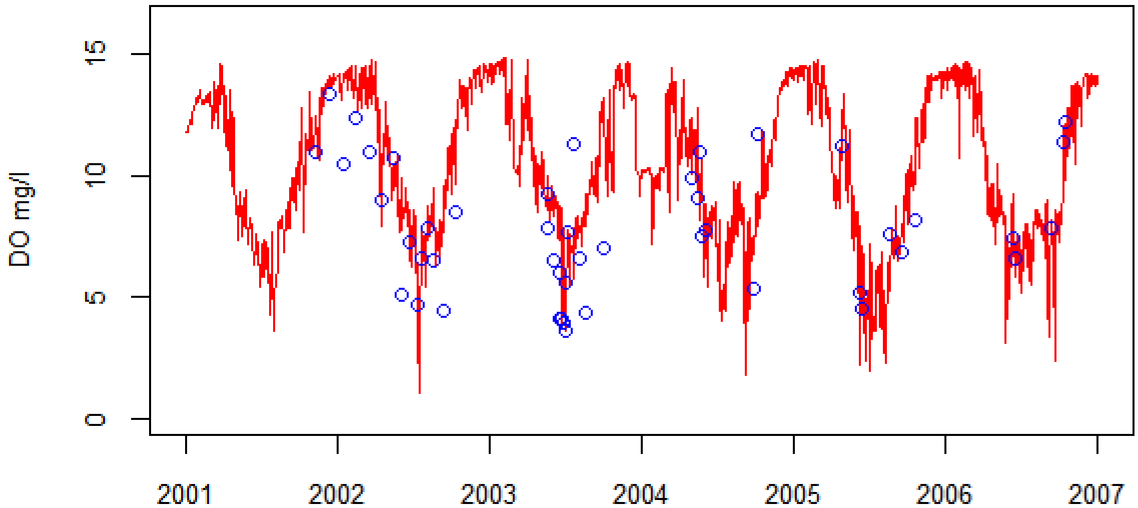


Figure 22. Simulated vs. observed daily DO concentrations for Rabbit

Biological Oxygen Demand
Calibrating BOD was problematic because of the dearth of observed data available at all three calibration sites. Initial parameter values for sediment potency and interflow/groundwater concentrations were set based on Tetra Tech, 2009. It was then assumed, given the tight interdependence between BOD and most other biological and chemical processes, that the reasonableness of the BOD calibration could be judged by the performance of the interdependent nutrient calibrations. Minor tweaks to the POTFW and interflow/groundwater concentration parameters were made to increase simulated organic N and P concentrations.

Phytoplankton
Phytoplankton densities were calibrated based on graphical comparison with Chl-A grab samples at Mustinka and Rabbit sites. A reasonable calibration was achieved through manipulation of the MALGR parameter in HSPF although performance evaluation was limited to 2001-2003. See Figures x and x. The Mustinka observed concentrations vary widely over the growing season; HSPF could not simulate this variability but efforts were made to achieve a, representative mean concentration. Observed Rabbit concentrations varied less than those of the Mustinka and consequently calibration results were better.

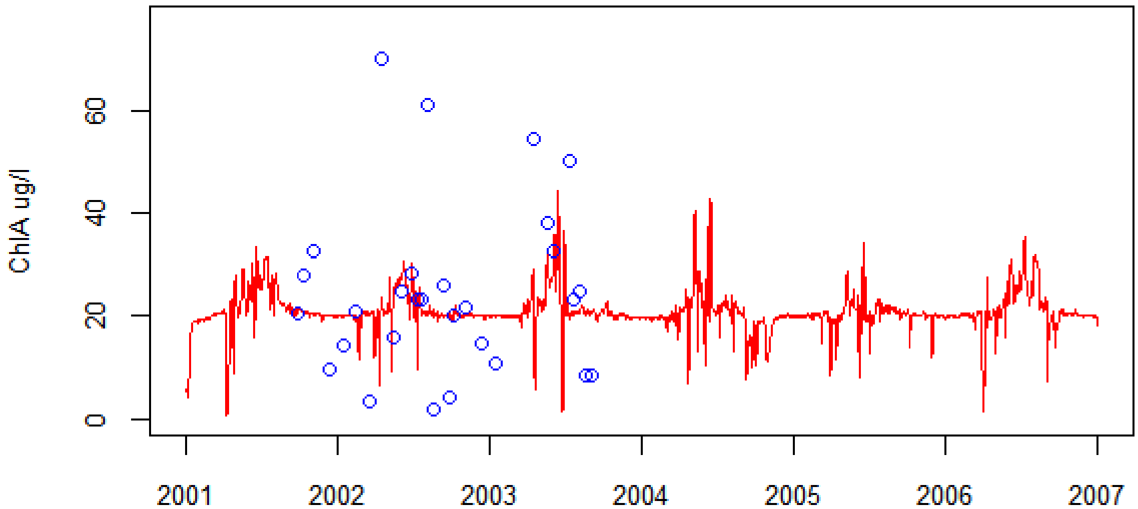


Figure 23. Simulated vs. observed daily chlorophyll-a concentrations for Mustinka

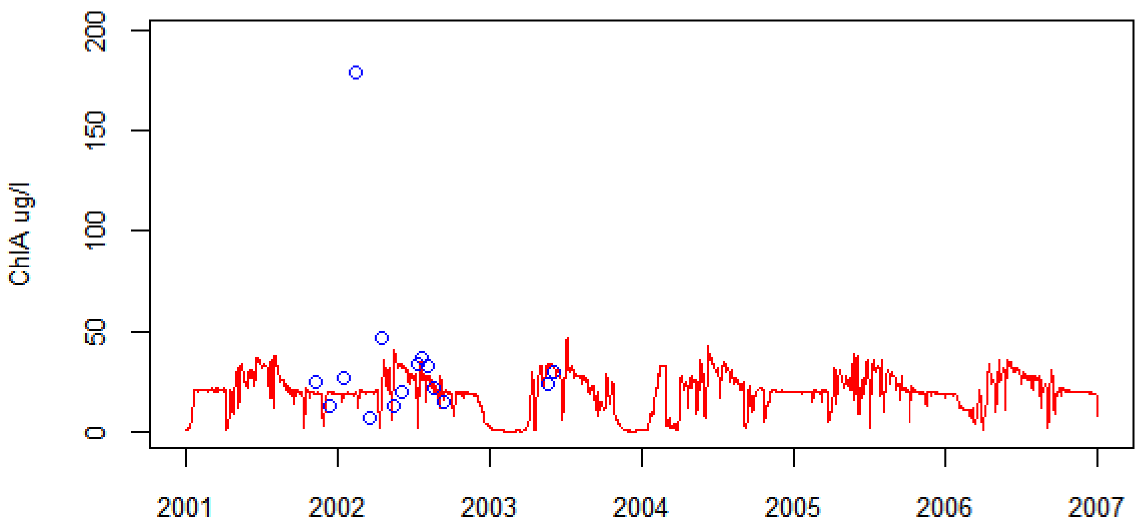


Figure 24. Simulated vs. observed daily chlorophyll-a concentrations for Rabbit

Model Uncertainties and TMDL support suitability

The calibrated MBdS HSPF model, judged by the weight-of-evidence approach taken, can be considered a good representation of hydrologic and water quality processes and is able to support TMDL activities in the watersheds. However, sources of uncertainty -- if assessed objectively -- are significant in all watershed modeling projects of this scope. Further, individual sources of uncertainty usually compound. Compounding error begins with errors in observed flow measurements (usually relatively small) plus the error in hydrologic calibration. This combined error is passed on to the sediment calibration phase where it is compounded by large errors (measurement error and variability per flow regime) in sediment measurements plus the resulting calibration error. Finally, sediment-dependent constituents – most importantly, phosphorus – receive this cumulative error where observed measurement and calibration errors add yet again another layer of uncertainty.

The MBdS model calibration focused on *loads* rather than *concentrations* because calibrated loads – being a function of flow and concentration – can smooth out calibrated flow errors to some degree. If the flow simulation is off, it can be offset by adjusting simulated concentration to some extent and vice versa. Additionally, focusing on loads ensures that periods with the highest daily mass of pollutants are prioritized for calibration first before trying to match concentrations on any given day.

Overall, the uncertainty in the MBdS model is driven primarily by the relatively short calibration period. The short period limits the number of WQ samples that can be used to generate representative flow and loading relationships with concentration. It also limits the number of discrete observed flow events available for calibration and thus limits the sample size and variability of boundary conditions that heavily influence flow and WQ response such as short- and long-term antecedent moisture condition, coincident agricultural management events and seasonal vegetative characteristics. Updates to the model that add more climate data as well as utilize the increase in sampling frequency and spatial distribution of WQ sampling that has occurred since the end of the modeling period (2006) would greatly enhance the certainty and utility of the model.

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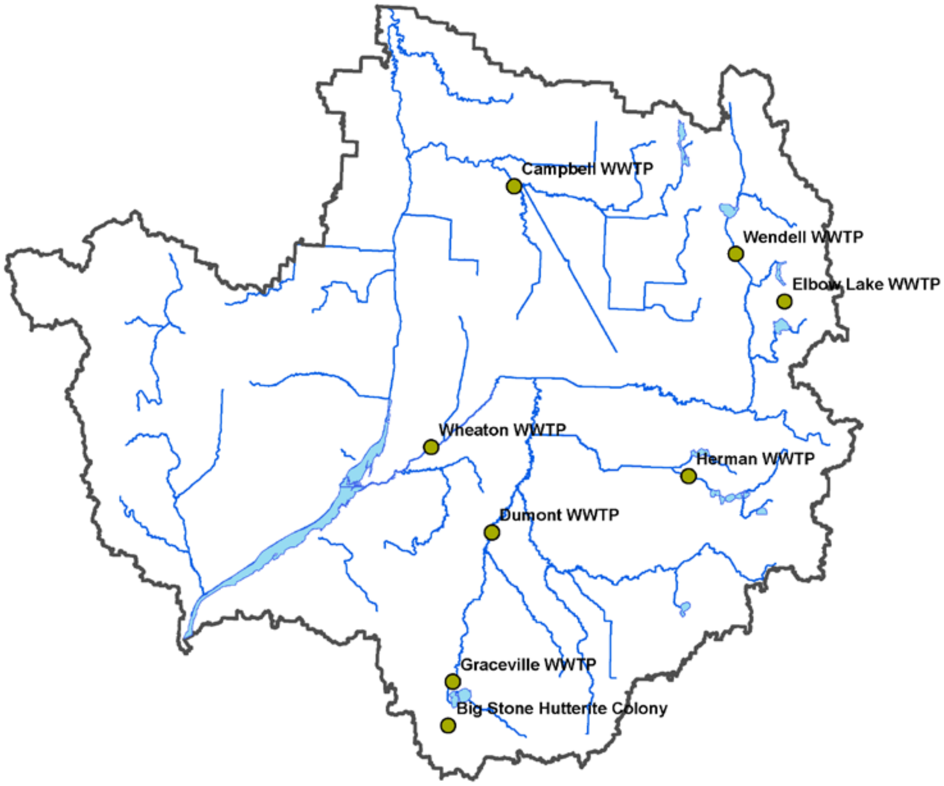

Figure 25. Map of WWTP point sources incorporated in the Mustinka/Bois de Sioux HSPF model.