APPENDIX A – ASHLEY WATERSHED MODEL MODIFICATIONS

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TABLES

FIGURES

ACRONYMS

DEQ	Montana Department of Environmental Quality
FWP	Montana Department of Fish, Wildlife, and Parks
SWS	Subwatershed
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
USGS	U.S. Geological Survey (U.S. Department of the Interior)
TAG	Technical Advisory Group

UNITS OF MEASURE

lb/d	pound per day
mg/L	milligram per liter

A-1. ASHLEY CREEK WATERSHED MODIFICATIONS

The Ashley Creek watershed was originally included in the larger Flathead Lake LSPC watershed model, which was developed to support total maximum daily load (TMDL) planning for the region. A subset LSPC model of Ashley Creek (**Figure A-1**) was created from the Flathead Lake LSPC watershed model to facilitate development of the Ashley Creek TMDLs. Several revisions were made to the Flathead Lake LSPC model to address unique properties of the Ashley Creek watershed, which are detailed below.

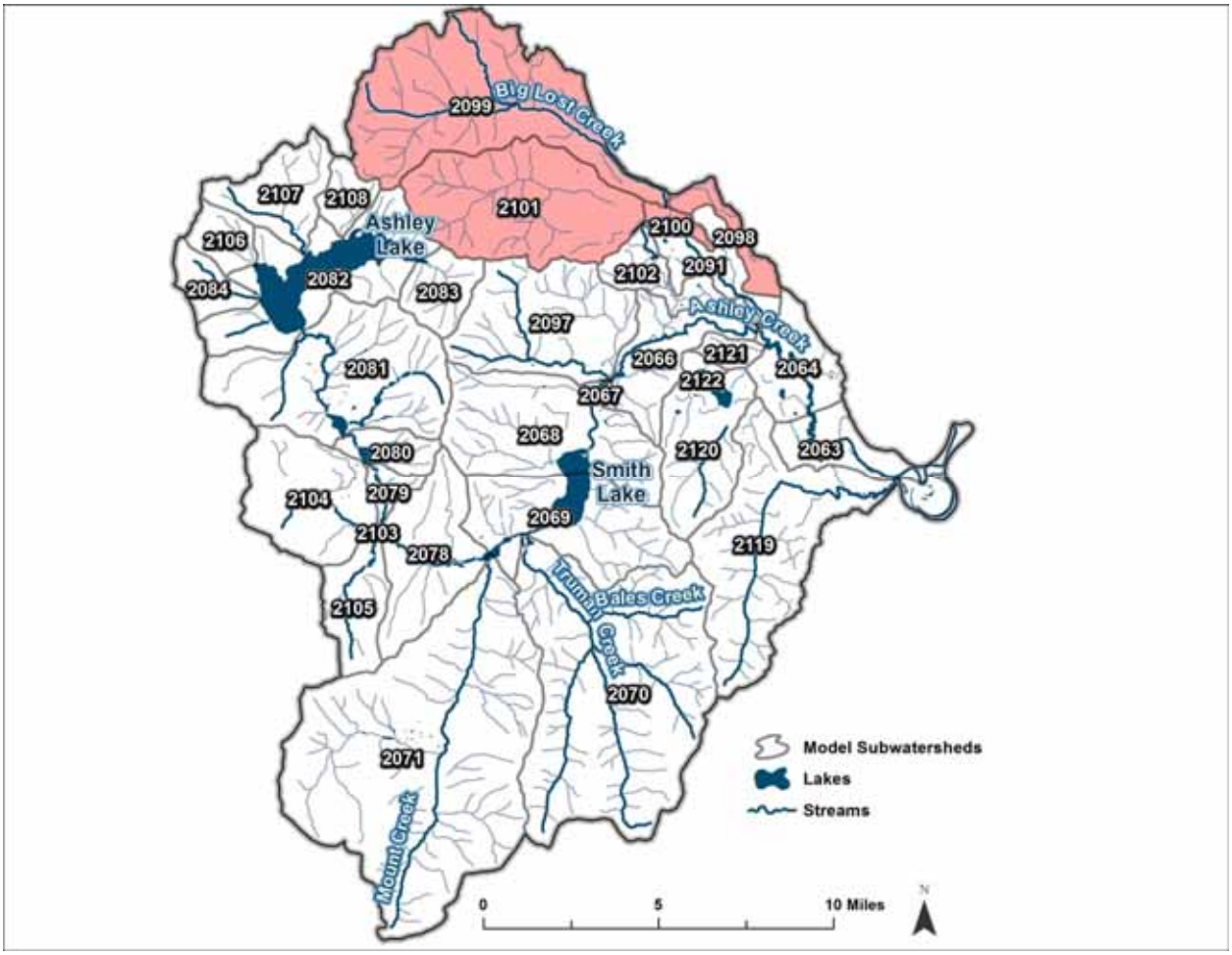


Figure A-1. Ashley Creek Watershed Model.

FLOW MODIFICATIONS

- There is an area in the northern part of the Ashley Creek watershed where streams are not hydraulically connected to Ashley Creek. In other words, the streams drain back into the stream beds and dry up without discharging to a downstream location. Identified creeks include Big Lost Creek and McMannamy Draw, among others. These subbasins are identified in **Figure A-1** as 2098, 2099, 2100, and 2101. Because these subbasins drain to groundwater and do not provide any surface water to Ashley Creek, they do not deliver any pollutant loads within the model or within the TMDL framework. In LSPC, they were manually disconnected from the routing network, based on recommendations from the Technical Advisory Group (TAG).

- The reach in subwatershed 2119 drains to Ashley Creek along the lower portion of the reach in subwatershed 2063. Since LSPC does not allow for connections in the middle of reaches, the flow from 2119 was rerouted to exit the watershed at the mouth of Ashley Creek, but is still included in the model.
- The Ashley Lake *F-Table* was modified based on a combination of outlet structure information and observed outflow data from Montana FWP (*F-Tables* are described further in Section 2.3 of the main report). The weir equation was used to estimate outflow based on the reported widths of the discharge gates above the normal pool elevation. Leekage flows were added to represent discharge seen in the flow monitoring data during periods when the lake level was below normal pool. The leekage values ranged from 1 cfs to 4 cfs depending on stage.
- The Smith Lake *F-Table* was modified based on downstream observed flow data and assumed loss to groundwater from the channel, along with anecdotal evidence regarding its depth. The modifications were based on changing the distribution of flow between surface and infiltration across a range of depths until a good fit was achieved to observed flow values.
- Reaches 2066 and 2064 incorporated infiltration to groundwater from the channel based on downstream observed flow data and personal communication with D. Sirucek (Flathead National Forest – retired, July 29, 2014). During the 10-year simulation period (WY2003 – WY2012), about 16% of the total flow volume was lost to channel infiltration between the two reaches.

WATER QUALITY/CHEMISTRY IMPROVEMENTS

- The septic system representation was revised to include increased phosphorus reduction for calcareous soils, which results in less total phosphorus (TP) delivered to streams, per recommendations from the TAG.
- Ashley Lake outflow concentrations were improved by modifying initial condition concentrations.
- Total nitrogen (TN) land-to-stream partitioning coefficients were revised.

- Synoptic data and discussions with stakeholders suggested that the upper Ashley Creek wetland complex adds nitrogen and phosphorus to the stream. This was not previously captured in the model. The model was revised to incorporate a “Wetland Flux” using a direct input time series of organic nitrogen and phosphorus into Smith Lake based on measured synoptic data that showed the simulated concentrations downstream of Smith Lake were significantly less than the measured data.
    - To better match the measured data 0.02 milligrams per liter (mg/L) of TP was added to the surface water entering Smith Lake, resulting in the addition of 9.35 pounds per day (lb/day) of TP into the lake.
    - To better match the measured data 0.5 mg/L of TN was added to the surface water entering Smith Lake, resulting in the addition of 233.8 lb/day of TN into the lake.

ADDITIONAL FLOW DATA AND LOCATIONS

Available flow data used for flow calibration are summarized in **Table A-1**. Ashley Lake has a small outlet control structure and lake levels are maintained by Montana Fish, Wildlife, and Parks (FWP). Tetra Tech received daily operational outflows for the model simulation period. These data were used to modify the Ashley Lake watershed *F-Table* to better represent outflow from Ashley Lake.

The Montana Department of Environmental Quality (DEQ) monitored flow on Ashley Creek for two water years (10/1/2006 – 9/30/2008) at two locations – a few miles downstream of Smith Lake and in cooperation with the U.S. Geological Survey (USGS) gage 12367800 at Kalispell (**Figure A-2**). These data were used to modify the Smith Lake watershed's *F-Table* to better match simulated and observed flows from Smith Lake. These data also suggested the presence of a losing stream in the alluvial reaches of Ashley Creek (between the monitoring locations), which was collaborated by local knowledge of a shallow gravel aquifer in the region (Personal communication with D. Sirucek (Flathead National Forest – retired, July 29, 2014). . As a result, the *F-Tables* were modified to allow loss to the aquifer between Smith Lake and Kalispell.

DEQ also conducted numerous synoptic flow surveys on Ashley Creek in 2003, 2004 and 2005 (**Figure A-2**). These data were compared to the simulation and were used to confirm the overall calibration of the Ashley Creek watershed.

Table A-1. Summary of Monitoring Data Used for Hydrology Calibration

Station	Agency	Data Type	Begin	End	No. of flows	Min	Max
Ashley Lake outlet	FWP	C	1/1/1995	12/31/2013	6,940	0.50	160
AC-1	DEQ	I	5/21/2003	9/21/2005	17	1.80	30.27
AC-2	DEQ	I	5/21/2003	9/21/2005	16	2.54	33.23
AC-3	DEQ	I	5/21/2003	9/21/2005	17	2.71	33.23
AC-5	DEQ	I	5/21/2003	9/21/2005	17	2.86	47.92
	DEQ	C	10/1/2006	9/30/2008	731	0.2	107
AC-6	DEQ	I	6/17/2003	9/21/2005	16	5.52	43.30*
AC-7	DEQ	I	6/17/2003	9/21/2005	17	4.15	46.90
AC-9	DEQ	I	6/17/2003	9/21/2005	16	6.20	57.60
12367800	DEQ	C	10/1/2006	9/30/2008	731	3.1	126

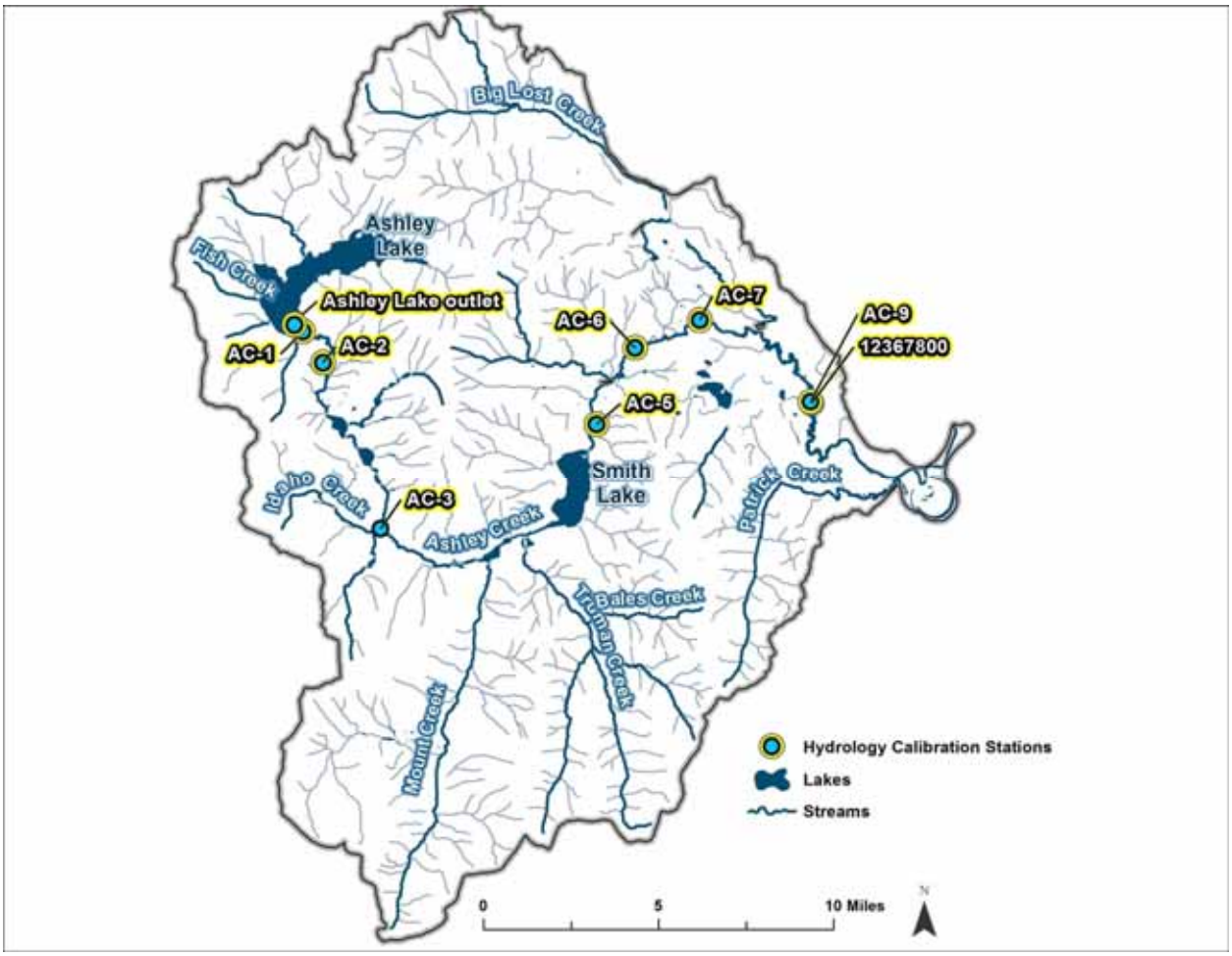


Figure A-2. Location of Hydrology Calibration Stations in the Ashley Creek Watershed.

ADDITIONAL WATER QUALITY DATA AND LOCATIONS

Water quality monitoring data were available for multiple locations along the Ashley Creek mainstem (**Figure A-3**). Periods of record, measured parameters, and data counts varied widely among the stations. Some stations did not have monitoring data during the simulation time period. In other cases, there were insufficient data to perform a meaningful statistical or graphical analysis for calibration. A few stations were excluded because they were located where model output was not available. Data collected on the same day were averaged into a single value for comparison to daily model output. Stations and data counts used in the calibration analysis are detailed in **Table A-2**. In some cases, stations were located in close proximity to each other or were in the same model subwatershed, so data were grouped as follows:

- C11AHLYC04 and C11AHLYC05 were grouped with AC-5
- C11AHLYC02 was grouped with 12367800
- C11AHLYC01 was grouped with FBC05003

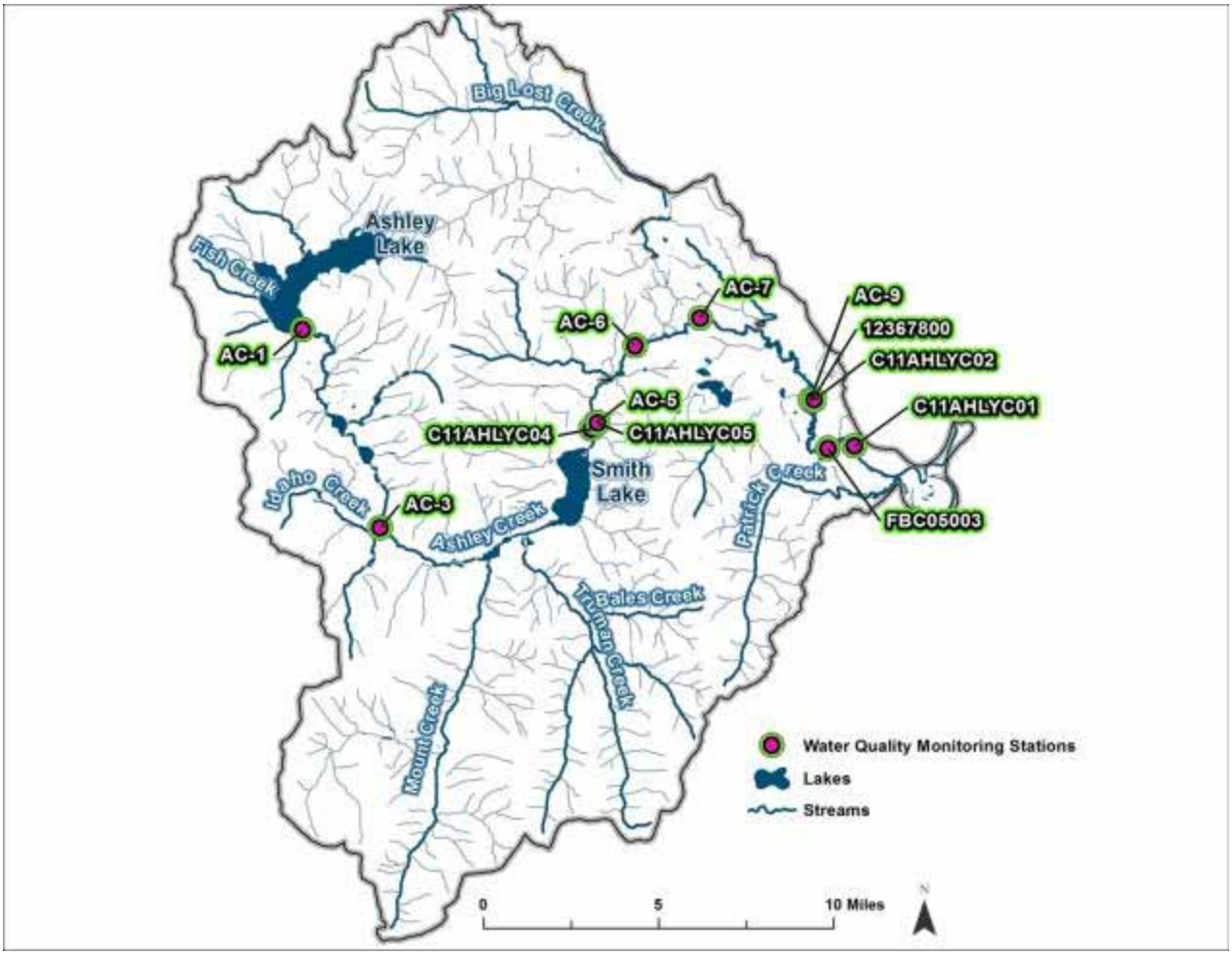


Figure A-3. Location of Water Quality Monitoring Stations in the Ashley Creek Watershed.

Table A-2. Summary of Monitoring Data Used for Water Quality Calibration

Station	Agency	TSS count	TN count	TP count
AC-1	DEQ	N/A	19	18
AC-3	DEQ	N/A	19	18
AC-5	DEQ	N/A	19	18
C11AHLYC04	DEQ	6	6	6
C11AHLYC05	DEQ	10	10	10
AC-6	DEQ	N/A	17	17
AC-7	DEQ	N/A	15	15
AC-9	DEQ	N/A	17	17
12367800	USGS	20	20	20
C11AHLYC02	DEQ	N/A	1	1
FBC05003	FLBS	15	102	102
C11AHLYC01	DEQ	N/A	4	5

DEQ = Montana Department of Environmental Quality; FLBS = Flathead Lake Biological Station; USGS = U.S. Geological Survey.

A-2. HYDROLOGY CALIBRATION RESULTS

As described above and summarized in **Table A-1**, long-term, continuous flow data are only available at one location (Ashley Lake Dam). Two years of continuous flow data are available at two-locations, AC-5 (just downstream of Smith Lake) and 12367800. The remainder of the available flow data is from grab samples. As discussed below, the available data drive the approach for calibration and presentation of calibration results.

Ashley Lake Dam

Given the available data, a thorough statistical and graphical analysis of simulated versus observed flow was conducted at this monitoring location. Results of the Ashley Lake flow calibration are shown in **Figure A-4** through **Figure A-8** and in **Table A-3**. FWP actively manages the seasonal lake level by manipulating the outlet control structure, something which LSPC cannot model directly without detailed information on gate operations. Given the limitations of the model for representing frequent flow modification, the quality of the calibration is considered reasonable. The results are discussed below.

A flow-duration plot (plot of flow versus percent-of-time exceeded, **Figure A-4**) shows good agreement across the entire range of flows. Monthly observed and modeled flows are plotted along with reported monthly rainfall (**Figure A-5**). The monthly totals track well in terms of overall trend, though there is some variation between observed and modeled monthly flows due in part to seasonal variation in lake level due to FWP management not captured in the model. A plot of flow accumulation (**Figure A-6**) shows that the model begins under-predicting flow volume during 2005. It is unclear why this deviation occurs, however, accumulated flows are nearly equal by the end of the simulation. Diagnostic plots of the distribution of observed and simulated flows by month are shown in **Figure A-7**. The bar ranges indicate the range between the 25th and 75th percentile, while the center point is the median. Medians and the interquartile range are in general agreement, though there is some variation which is likely attributable to seasonal management of the lake stage. **Figure A-8** shows a regression of average monthly modeled versus observed flow and a monthly time series of modeled versus observed flow. The regression shows good general agreement across a range of flows, while the monthly time series tracks the distributions shown in **Figure A-7**.

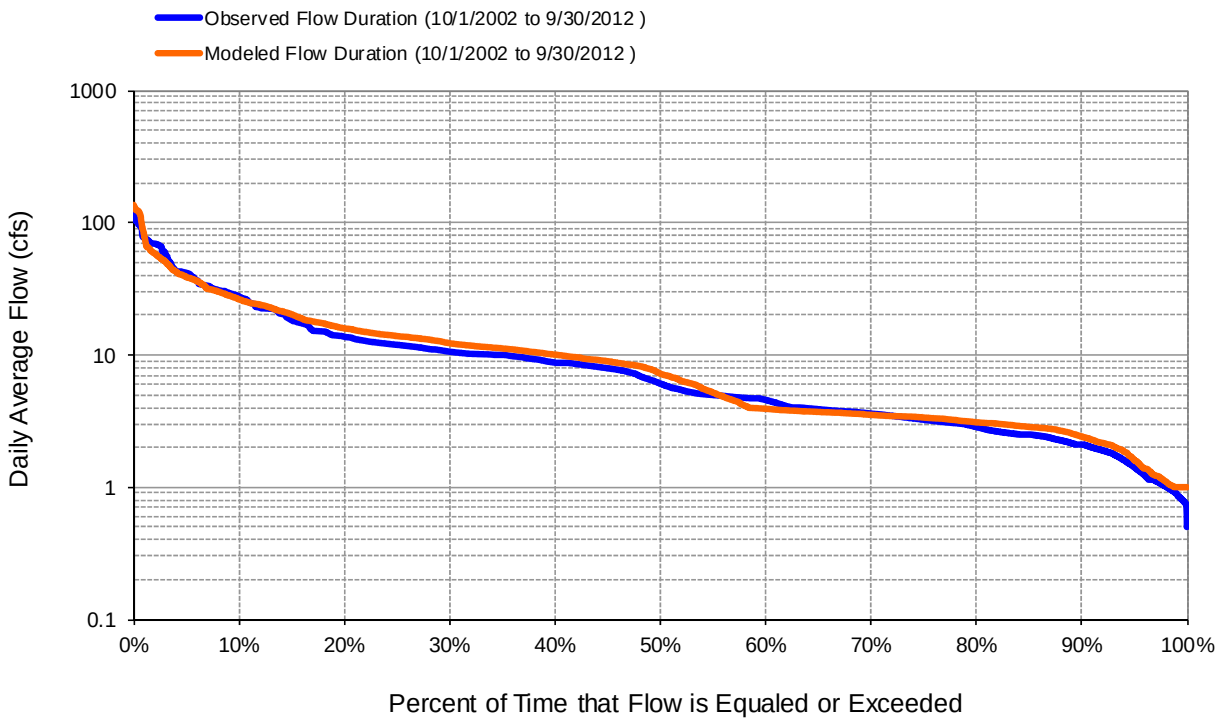


Figure A-4. FWP Observed and Modeled Flow-Duration, Ashley Lake Dam Outflow.

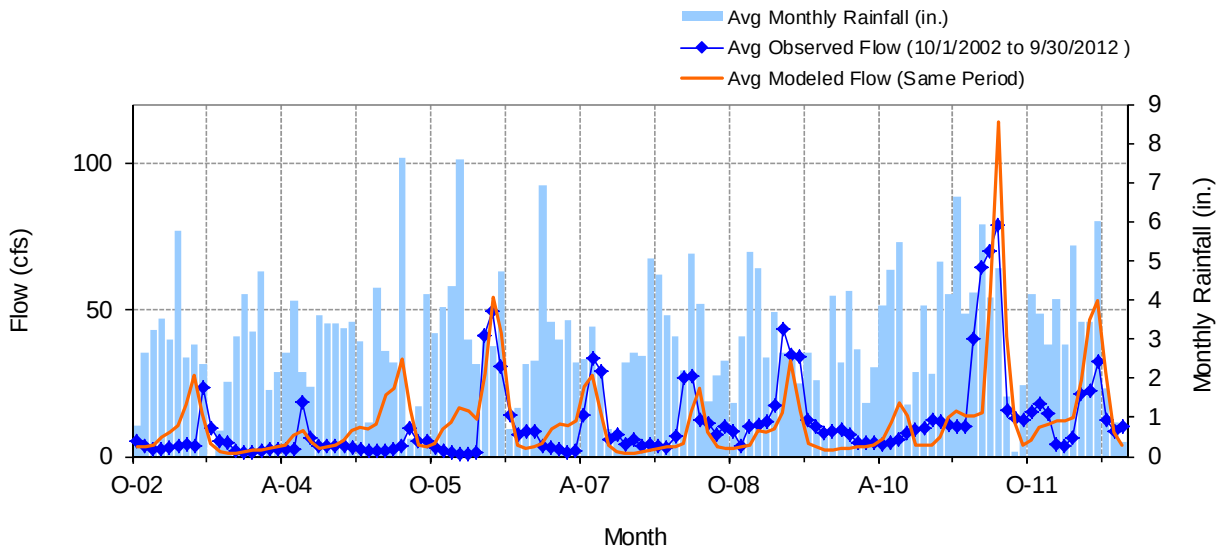


Figure A-5. Time Series of FWP Observed and Modeled Monthly Flows and Monthly Rainfall, Ashley Lake Dam Outflow.

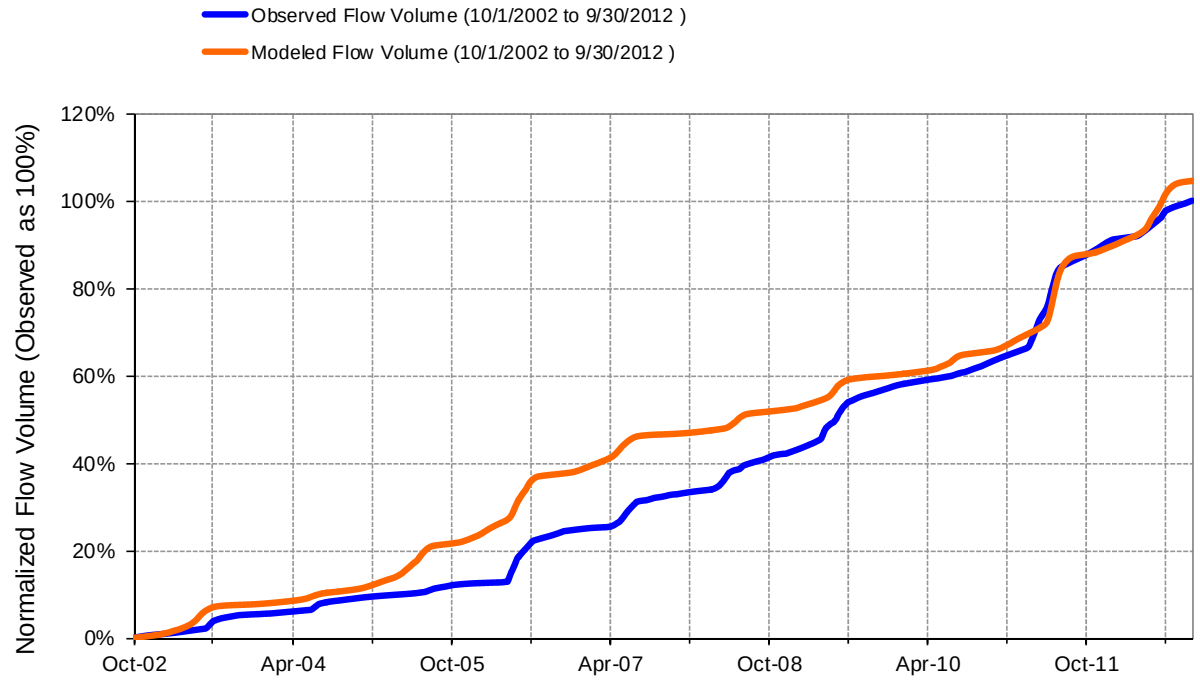


Figure A-6. Cumulative FWP Observed and Modeled Flow Volume, Ashley Lake Dam Outflow.

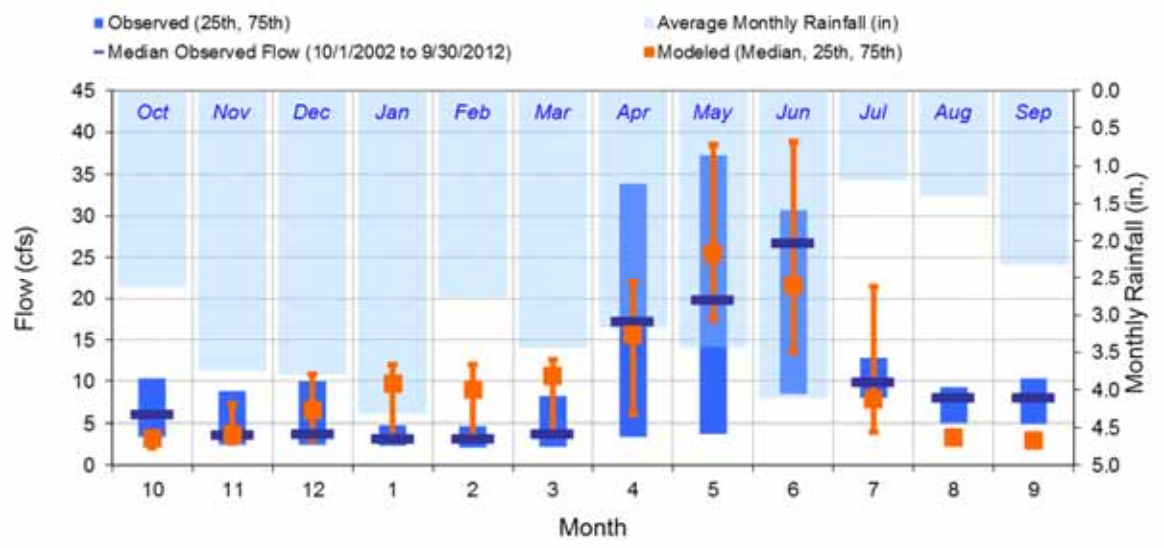


Figure A-7. FWP Observed and Modeled Monthly Flow Distributions with Monthly Rainfall, Ashley Lake Dam Outflow.

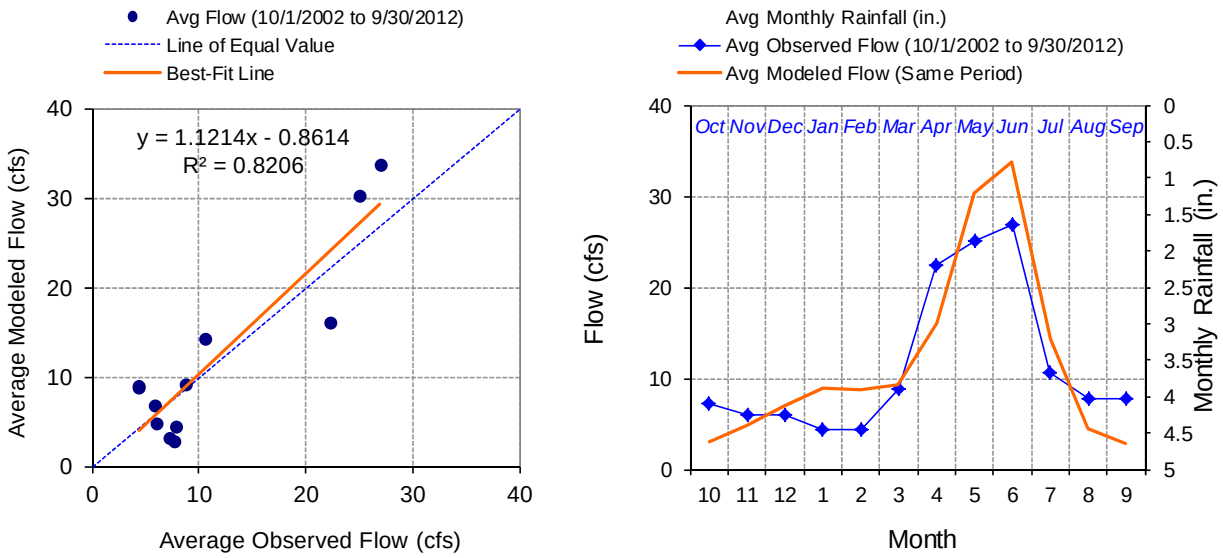


Figure A-8. FWP Observed and Modeled Monthly Average Flow with Monthly Rainfall, Ashley Lake Dam Outflow.

Statistics for the hydrologic calibration are shown in **Table A-3** and compared to performance targets documented by Donigian et al. (1984), Lumb et al. (1994), and Donigian (2000) shown below. All measures rated "Good" or "Very Good", except for winter seasonal volume, monthly R^2, and daily R^2, all of which rated "Poor". The daily R^2 fit is influenced heavily by day-to-day outflow management, while the monthly R^2 fit is influenced by seasonal lake stage management. The winter seasonal volume error is likely affected by difficulties representing gate leakage during winter months which is probably reduced due to frozen conditions.

Table A-3. FWP Observed and Modeled Summary Statistics: Ashley Lake Dam Outflow

Model Component	Error Statistic
1. Error in total volume	**4.53**
2. Error in 50% lowest flow volumes	**4.17**
3. Error in 10% highest flow volumes	**-2.52**
4. Error in storm volume	**-13.69**
5. Winter volume error	**52.80**
6. Spring volume error	**8.05**
7. Summer volume error	**-17.62**
8. Fall volume error	**-22.51**
9. R^2 daily values	**0.447**
10. R^2 monthly values	**0.494**

Very Good **Good** **Fair** **Poor**

Downstream of Smith Lake and Near Kalispell

Approximately two years of continuous flow data were collected at site AC-5 and **USGS 12367800**; however there were insufficient data to perform the statistical and graphical analysis used above for the Ashley Lake Dam. Time series of simulated versus observed flows are shown in **Figure A-9** and **Figure A-10**, respectively for the location downstream of Smith Lake and at the USGS gage in Kalispell, and show a good fit across the range of seasons and flows.

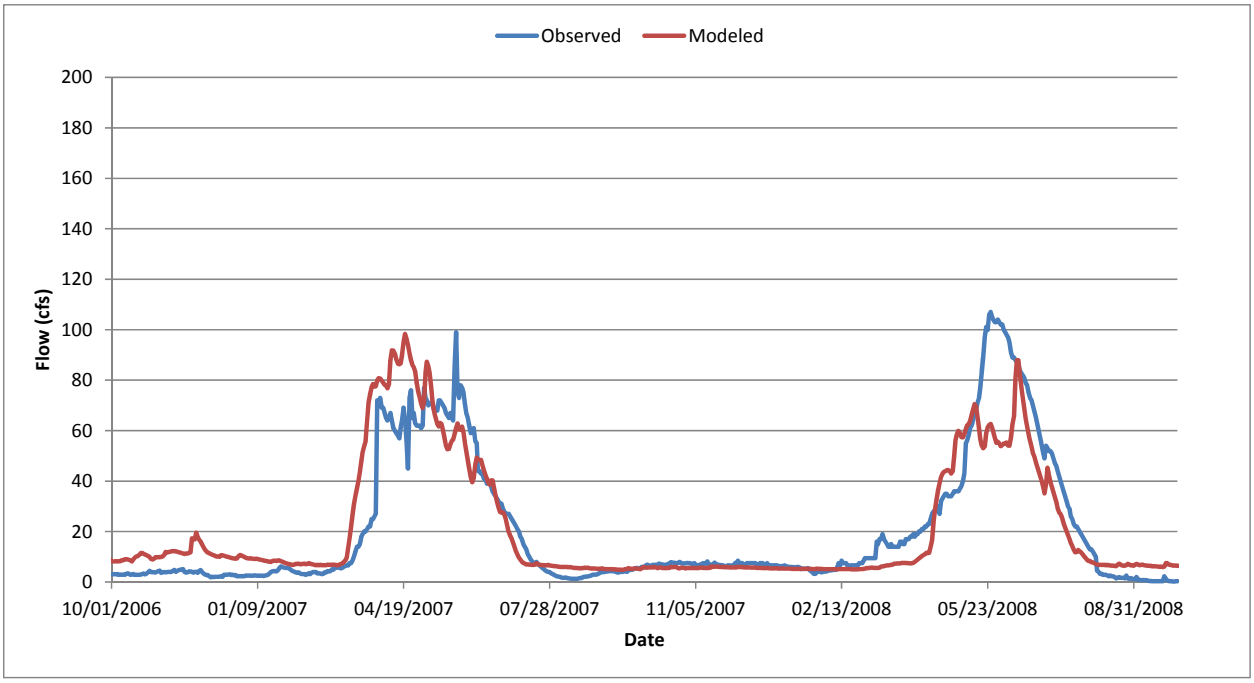


Figure A-9. Calibration DEQ Observed and Modeled Daily Average Flow below Smith Lake.

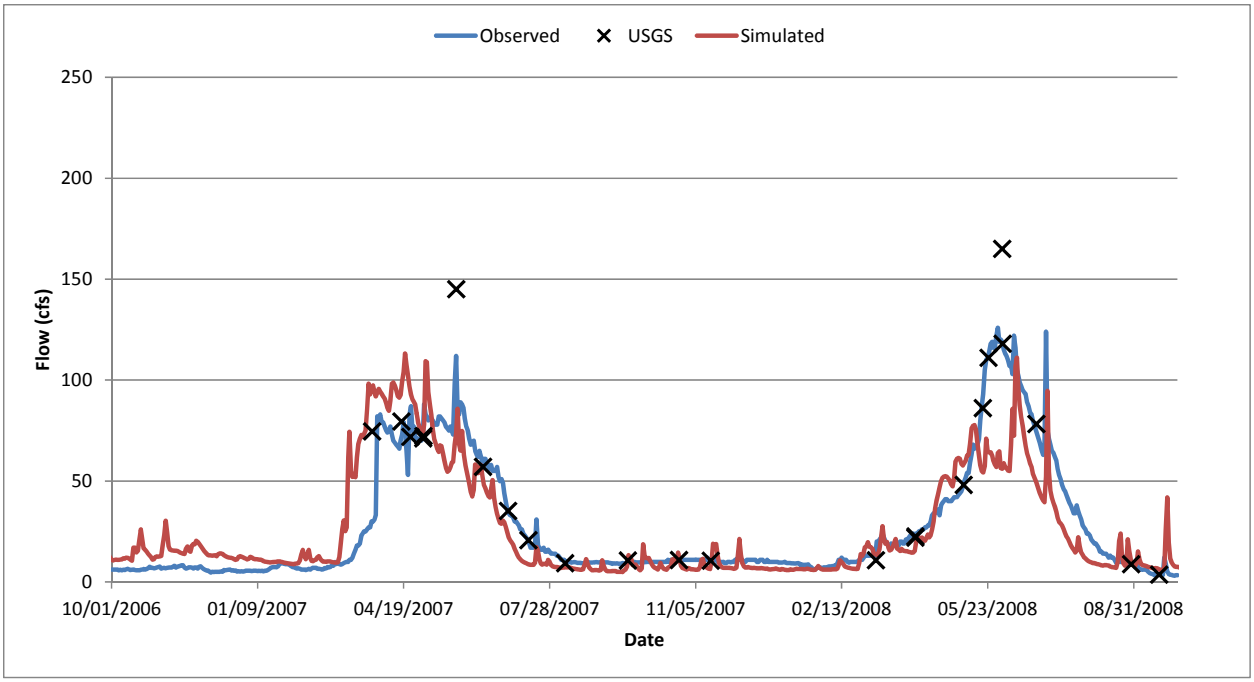


Figure A- 10. Calibration and Modeled Daily Average Flow at USGS 12367800 at Kalispell, MT.

Synoptic Data

Synoptic flow measurements are compared to modeled daily flow in **Figure A-11** through **Figure A-17** for a number of the other stations in the watershed without continuous data, but with a handful of instantaneous flow measurements. The fit is somewhat poor at AC-1 (**Figure A-11**), likely reflecting the influence of outflow and stage management of Ashley Lake. The comparison is better at AC-3 (**Figure A-12**), though there remains some discrepancy as flow from Ashley Lake is still dominant at this station. The fit improves moving downstream through the stations, confirming the overall quality of the calibration across the three year range.

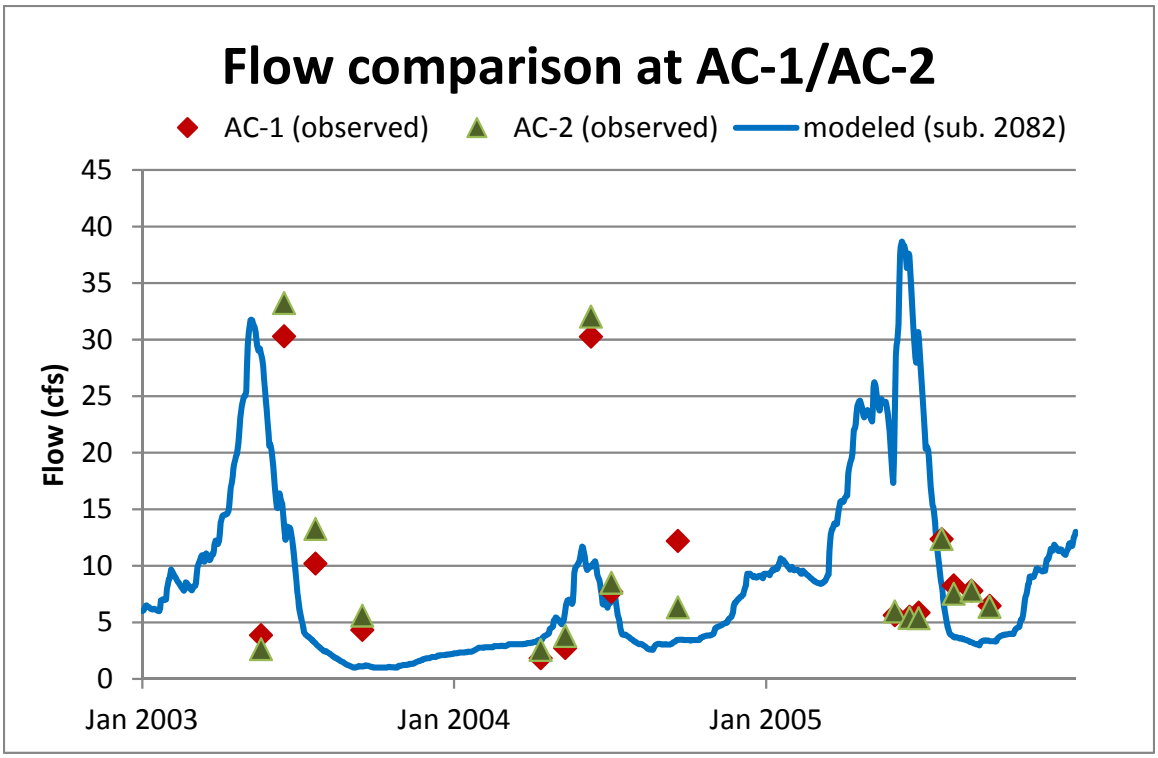


Figure A-11. Calibration DEQ Observed and Modeled Daily Average Flow at AC-1 and AC-2.

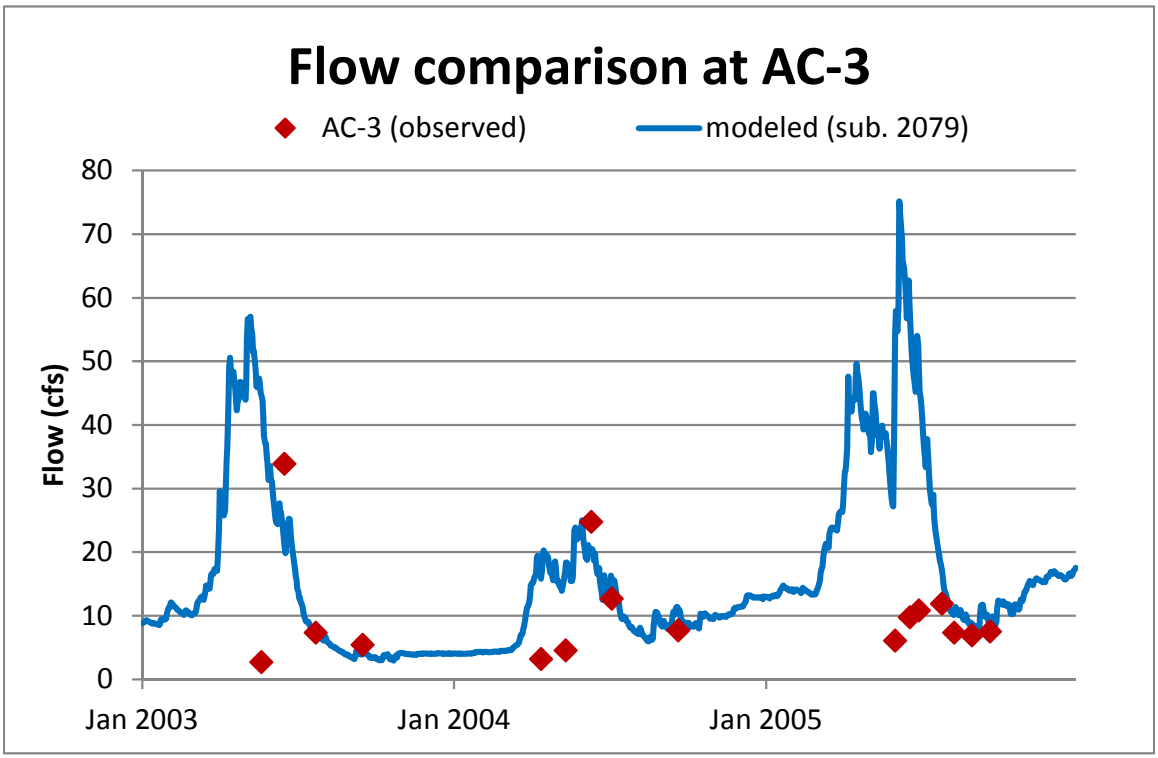


Figure A-12. Calibration DEQ Observed and Modeled Daily Average Flow at AC-3.

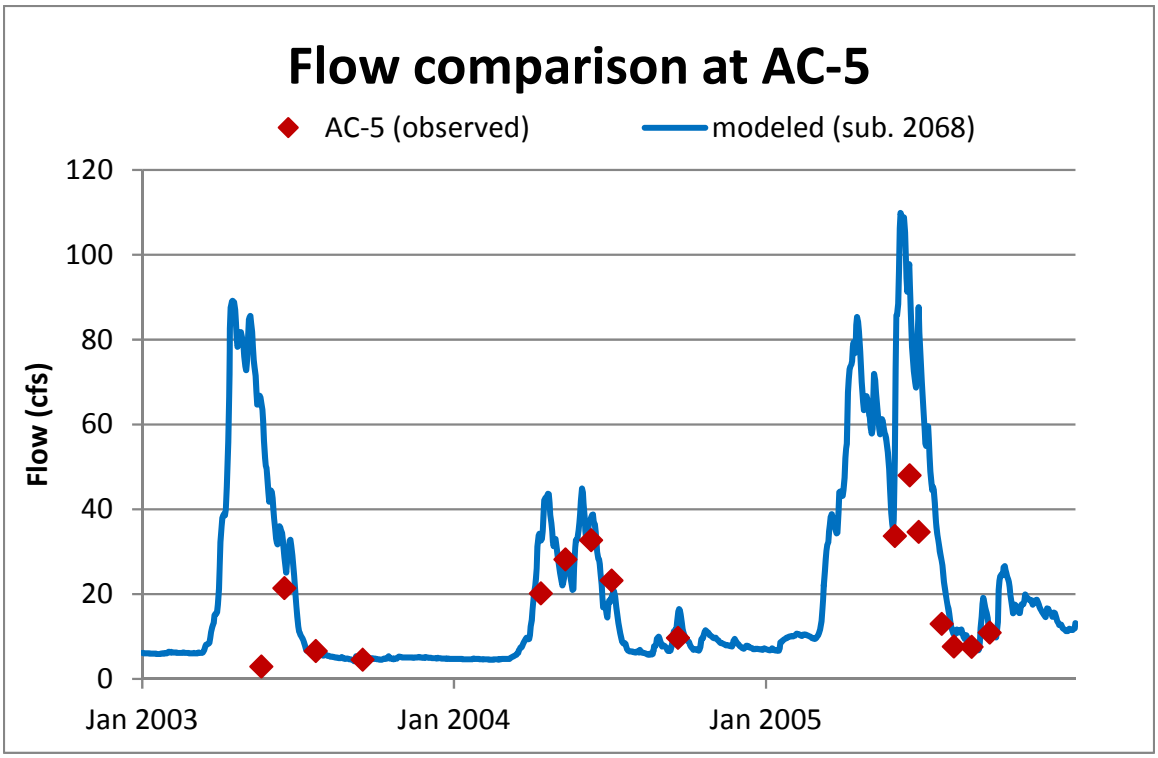


Figure A-13. Calibration DEQ Observed and Modeled Daily Average Flow at AC-5.

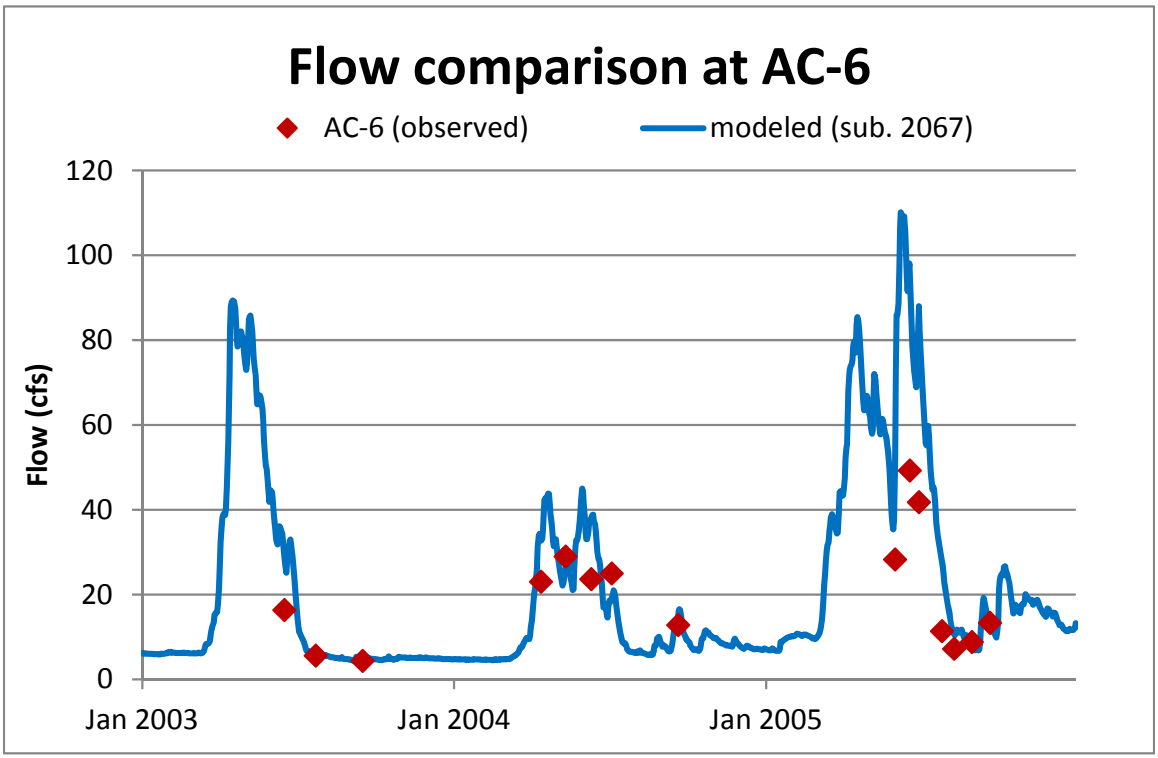


Figure A-14. Calibration DEQ Observed and Modeled Daily Average Flow at AC-6.

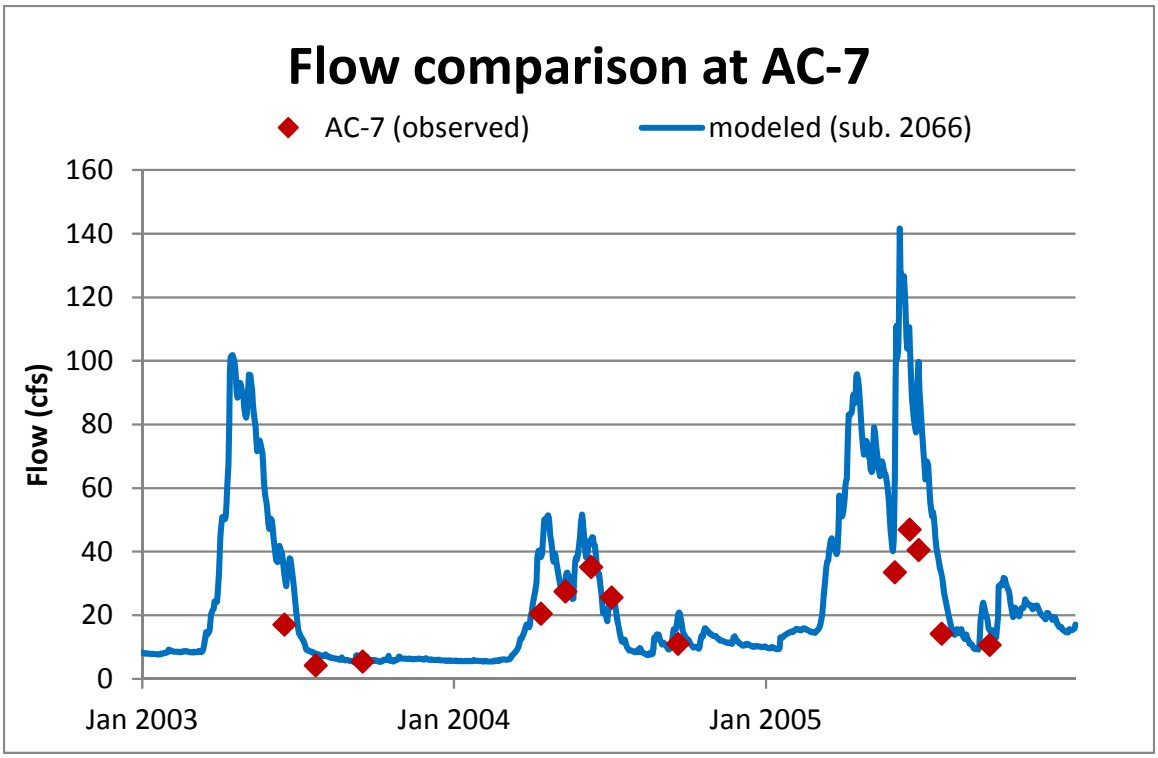


Figure A-15. Calibration DEQ Observed and Modeled Daily Average Flow at AC-7.

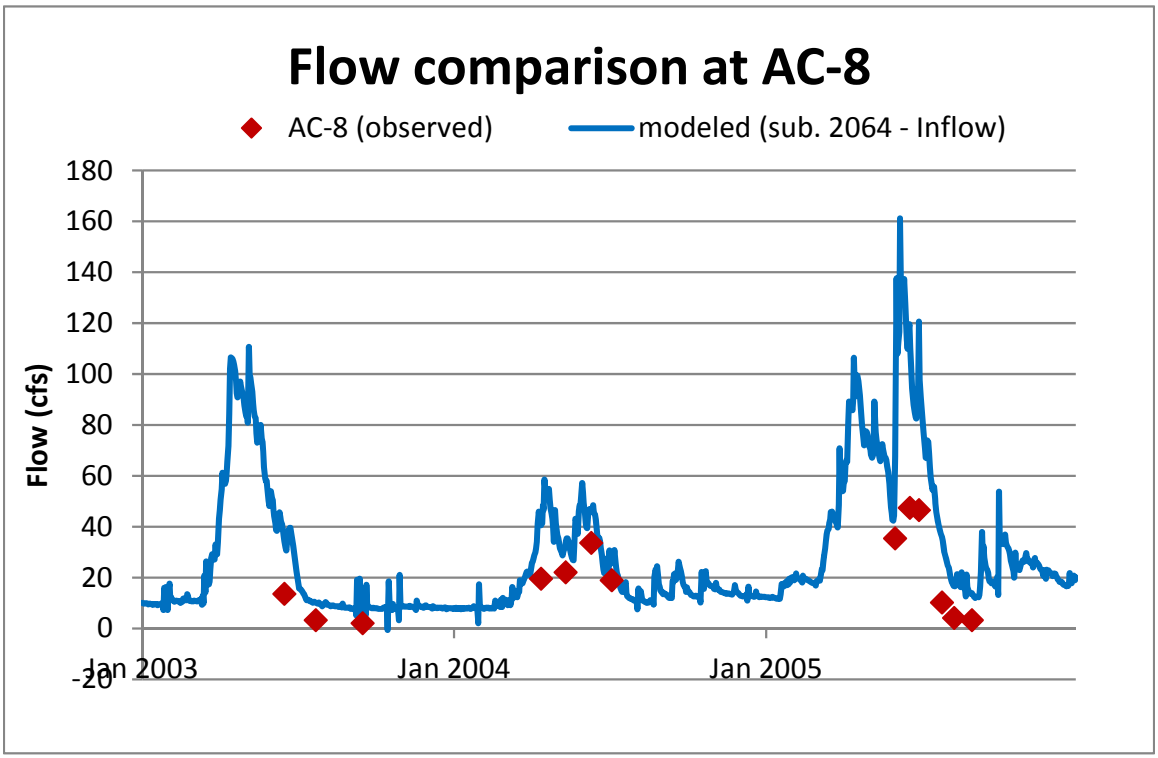


Figure A-16. Calibration DEQ Observed and Modeled Daily Average Flow at AC-8.

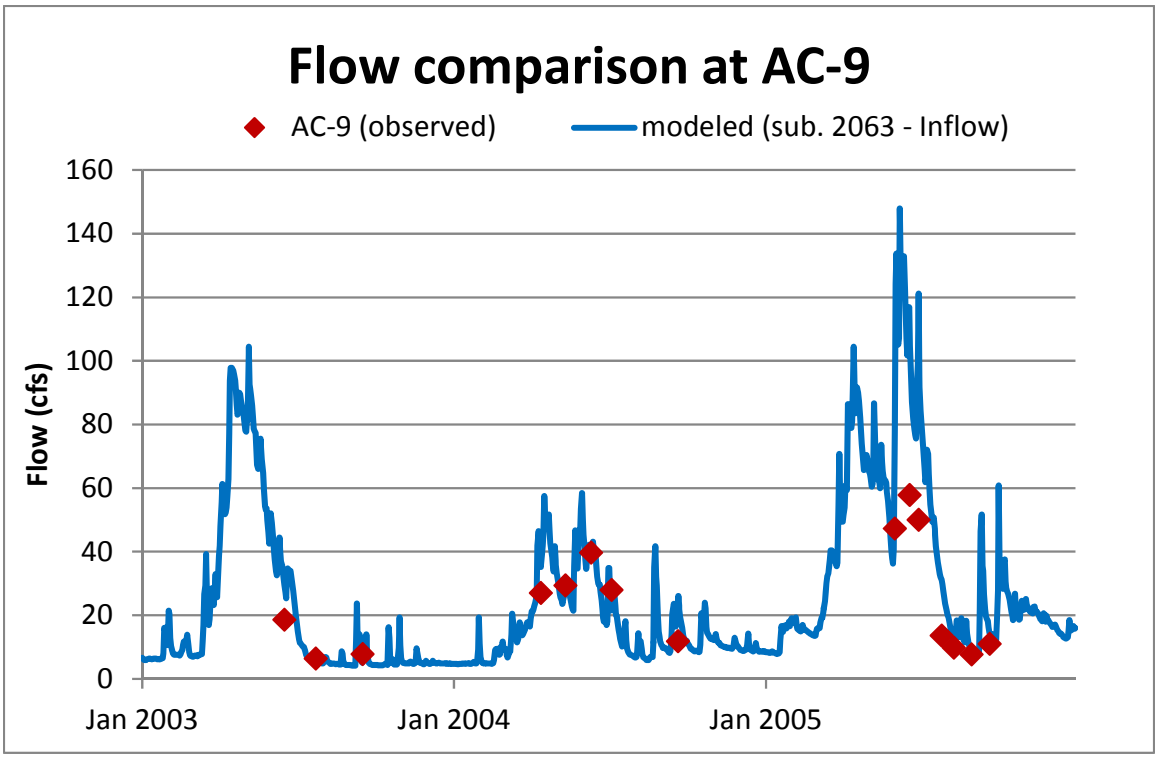


Figure A-17. Calibration DEQ Observed and Modeled Daily Average Flow at AC-9.

A-3. WATER QUALITY CALIBRATION RESULTS

Calibration and corroboration results are reviewed for each of the model pollutants. First a table of statistical measures for the paired observed and simulated data is presented. General performance targets for water quality simulation are provided by Donigian (2000) and are shown in **Table A-4**. These are calculated from observed and simulated daily values, and are typically only applied in cases where there are a minimum of 20 observations. However, there were a number of stations with data counts less than 20, so the minimum number of observations for this calibration was reduced to 15. To aid in the presentation of the model performance results, a table cell color code scheme has been used (**Table A-4**). Both average and median relative errors are calculated for concentrations and load. The median is an important measure since an average may be overly influenced by outlier observations.

Table A-4. Performance Targets for Water Quality Simulation

Model Component	Very Good	Good	Fair	Poor
1. Suspended Sediment	≤ 20%	20 - 30%	30 - 45%	> 45%
2. Nutrients	≤ 15%	15 - 25%	25 - 35%	> 35%

The calibration table is followed by graphs showing various relationships of simulated and observed data to each other and/or to flow. Results are shown for each parameter and station. In the results discussion, general trends and items of interest are noted, but not every graph is discussed. The graphs shown for each station and parameter are as follows:

- **Time Series.** Continuous modeled concentration is compared to point-in-time observations over the simulation. No model can perfectly replicate observed conditions, but a good fit is indicated by the model being relatively close to most observations.
- **Concentration versus Flow.** The distribution of concentration versus flow is plotted simultaneously for daily model output and observations. The distributions should overlap for a good fit.
- **Paired Simulated versus Observed Concentration.** Daily average concentrations are compared to observations for each unique date on which monitoring occurs. A good fit is obtained when the paired points are close to the 1:1 line.
- **Paired Concentration Error versus Flow.** The difference between daily average concentration and observed concentration for each unique date on which monitoring occurs is plotted against flow. This plot reveals bias in the simulation as a function of flow. A good fit is indicated by error being close to zero across a range of flows, and by a lack of bias towards consistently over-predicting or under-predicting observed concentrations.
- **Load versus Flow.** The distribution of load versus flow is plotted simultaneously for daily model output and observed load. Load is calculated as the product of daily average flow and concentration. If flow monitoring data aren't available, then simulated flow is used to calculate observed concentration. The distributions should overlap for a good fit.
- **Paired Simulated versus Observed Load.** Daily average loads are compared to observed loads for each unique date on which monitoring occurs. Load is calculated as the product of daily average flow and concentration. If flow monitoring data aren't available, then simulated flow is

used to calculate observed concentration. A good fit is obtained when the paired points are close to the diagonal 1:1 line.

SEDIMENT

Sediment is important for its role in transporting sorbed phosphorus, and phosphorus sorption to sediment is included in the LSPC simulation. Calibrations statistics for total suspended solids (TSS) are shown in **Table A-5**. Sufficient monitoring data were not available at all stations for calculation of statistics. Most of the relative error measures rated *Very Good*. Two of the measures rated *Fair*. When considering the adequacy of sediment calibration, load for TMDL purposes is more important than concentration, and annual load tends to be driven by a handful of large storm events.

Table A-5. Performance for the TSS Water Quality Calibration for the Ashley Creek model

Water Quality Calibration Site	TSS			
	Concentration		Load	
	Average	Median	Average	Median
Ashley Creek at AC-1 (SWS 2082)	N/A	N/A	N/A	N/A
Ashley Creek at AC-3 (SWS 2079)	N/A	N/A	N/A	N/A
Ashley Creek near AC-5 (SWS 2068)	-28%	-37%	-5%	-16%
Ashley Creek at AC-6 (SWS 2067)	N/A	N/A	N/A	N/A
Ashley Creek at AC-7 (SWS 2066)	N/A	N/A	N/A	N/A
Ashley Creek near 12367800 (SWS 2064) – above Kalispell WWTP	-8%	-6%	-7%	-5%
Ashley Creek near FBC05003 (SWS 2063) – below Kalispell WWTP	-13%	13%	42%	14%

Calibration plots for TSS near AC-5 are shown in **Figure A-18** through **Figure A-23**. TSS concentrations are low at this station, with observed values never exceeding 5 mg/L, reflecting the role of Smith Lake for attenuating TSS. Without the benefit of a separate lake model, this presented a challenge for representing TSS at this location; stochastic processes tend to drive observed variations in concentrations that cannot be captured by the model. The time series graph (**Figure A-18**) shows a reasonable agreement between simulated and observed TSS, though concentrations are over-predicted for some days during periods of seasonal high flow. Observed and modeled TSS concentration versus flow (**Figure A-19**) shows that the observed distribution shows no apparent correlation to flow (based on visual observation), whereas the model predicts an increase in TSS concentration as flow increases.. Paired simulated versus observed TSS concentrations show a poor fit (**Figure A-20**), but it is important to note that the magnitude of both simulated and observed concentrations are very low. Paired data concentration error versus flow (**Positive values** indicate model over-prediction, negative values indicate model under-prediction.
Figure A-21) shows a tendency to under-predict TSS at low flows, consistent with **Figure A-19**. Observed and modeled TSS load versus flow (**Figure A-22**) echo trends seen in previous graphs, with load under-predicted at low flows. Paired simulated versus observed TSS loads (**Figure A-23**) are similar to the paired concentration data).

Model performance improves at Ashley Creek near 12367800 in the lower watershed (**Figure A-24** through **Figure A-29**). The timing (**Figure A-24**) and distribution (**Figure A-25** and **Figure A-26**) of TSS are well represented, and paired error versus flow is not biased (**Positive values** indicate model over-prediction, negative values indicate model under-prediction.

Figure A-27). Loads are well replicated (**Figure A-28** and **Figure A-29**).

Monitored TSS at Ashley Creek near FBC05003 show a similar trend as seen near AC-5 – concentrations are low, never exceeding 25 mg/L. Plots are shown in **Figure A-30** through **Figure A-35.** The time series plot suggests a good fit (**Figure A-30**), but remaining plots show TSS is under-predicted at low flows and somewhat over-predicted at high flows. **Figure A- 31** shows the highest TSS concentrations occurring at low flows, perhaps due to peak TSS concentrations in the Kalispell WWTP effluent that are not well represented in the composite-based sampling reported on the discharge monitoring reports (DMR) and used for the model input.

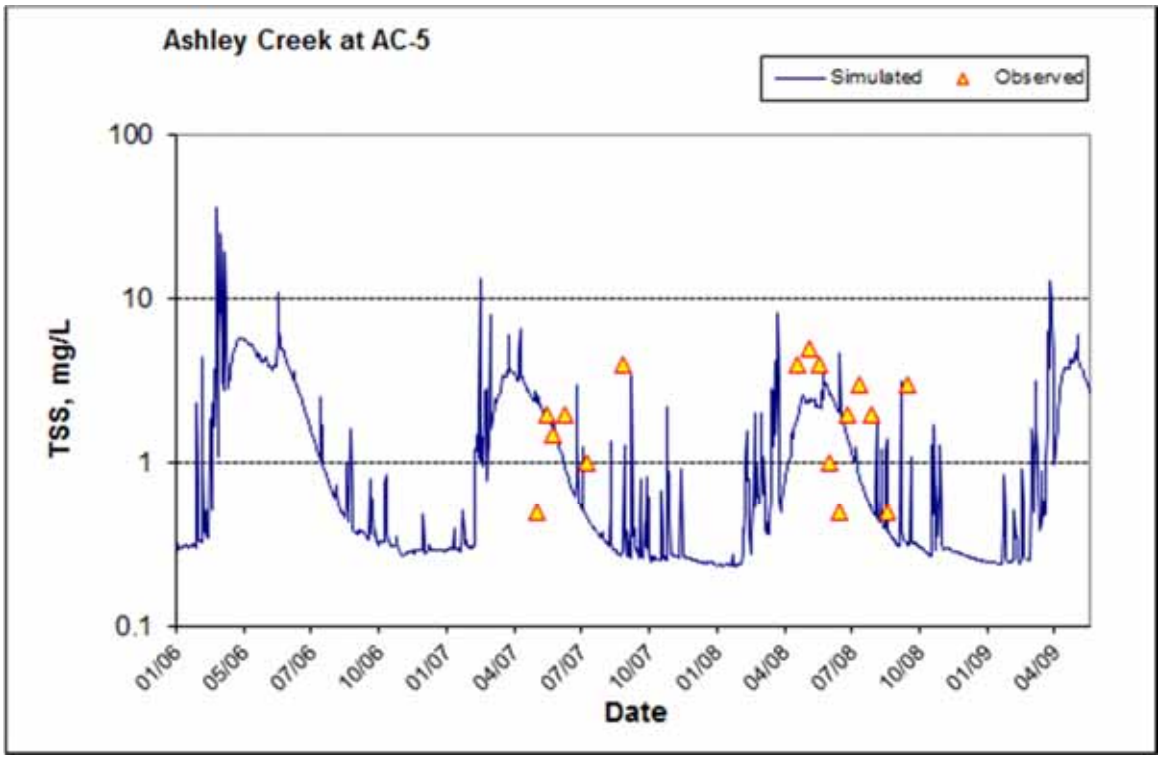


Figure A-18. Observed and Modeled TSS Time series January 2006 through May 2009, Ashley Creek near AC-5.

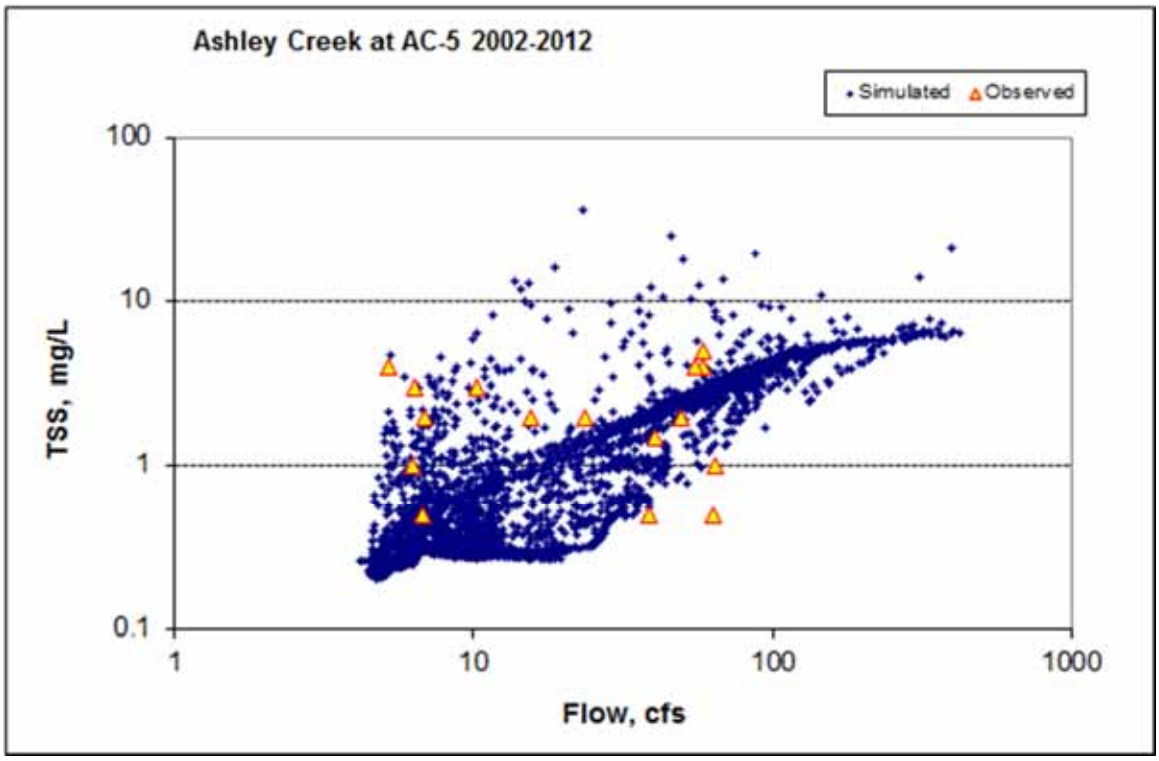


Figure A-19. Observed and Modeled TSS Concentration vs. Flow, Ashley Creek near AC-5.

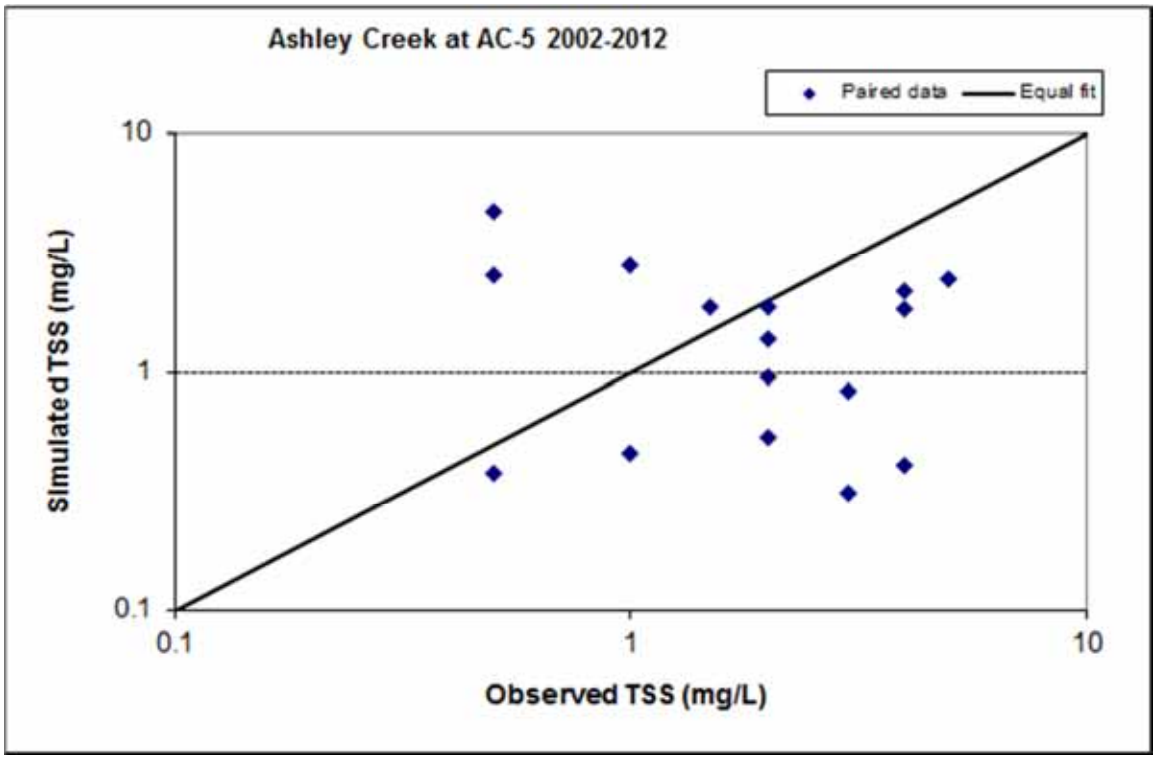
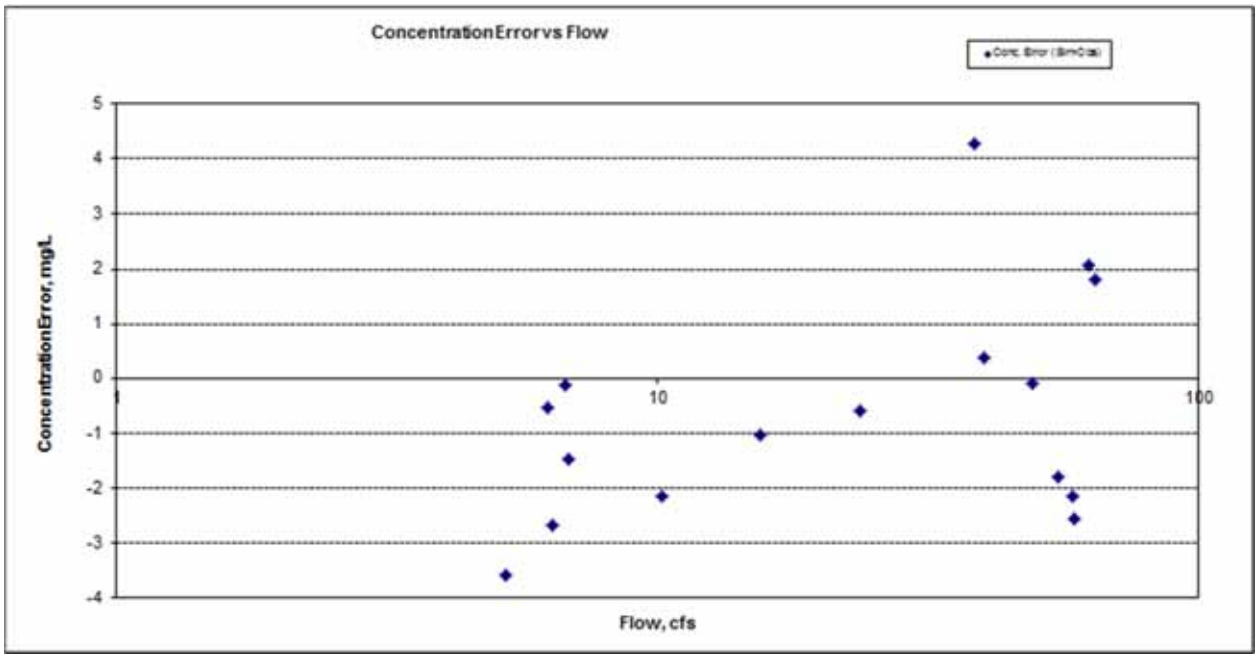


Figure A-20. Observed and Modeled TSS Daily Paired Concentration, Ashley Creek near AC-5.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-21. Observed and Modeled TSS Daily Paired Concentration Error vs. Flow, Ashley Creek near AC-5.

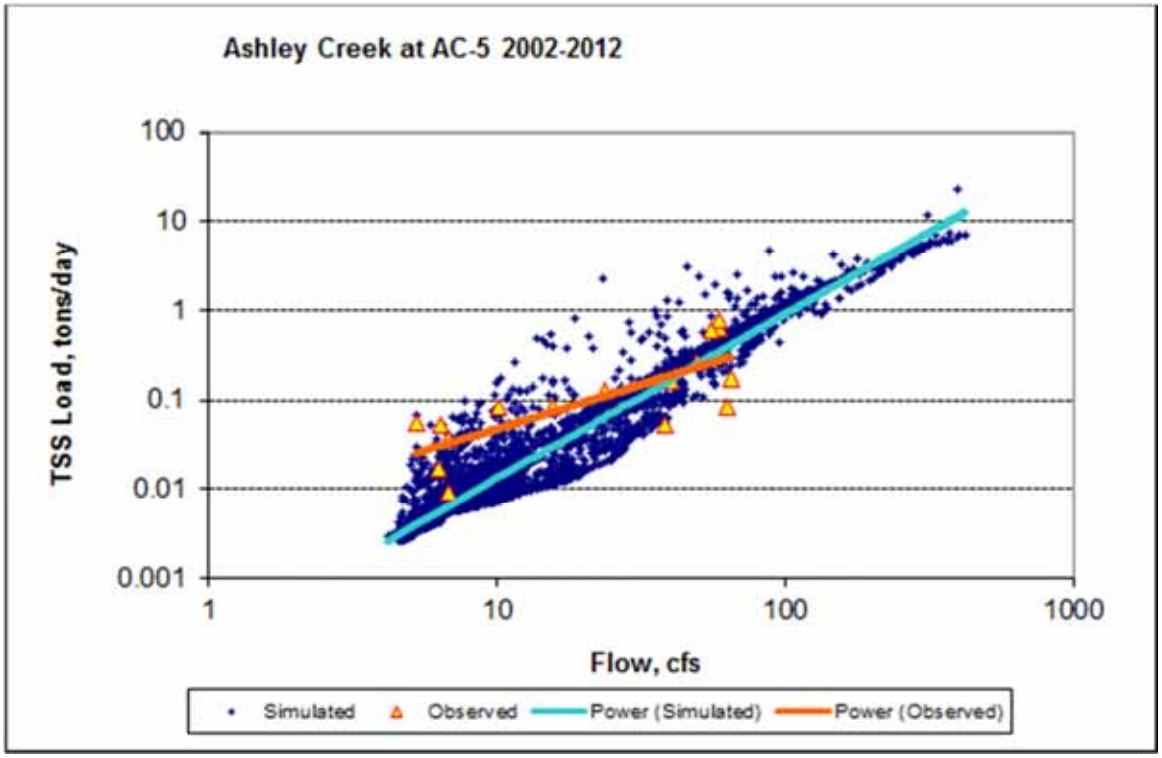


Figure A-22. Observed and Modeled TSS Load vs. Flow, Ashley Creek near AC-5.

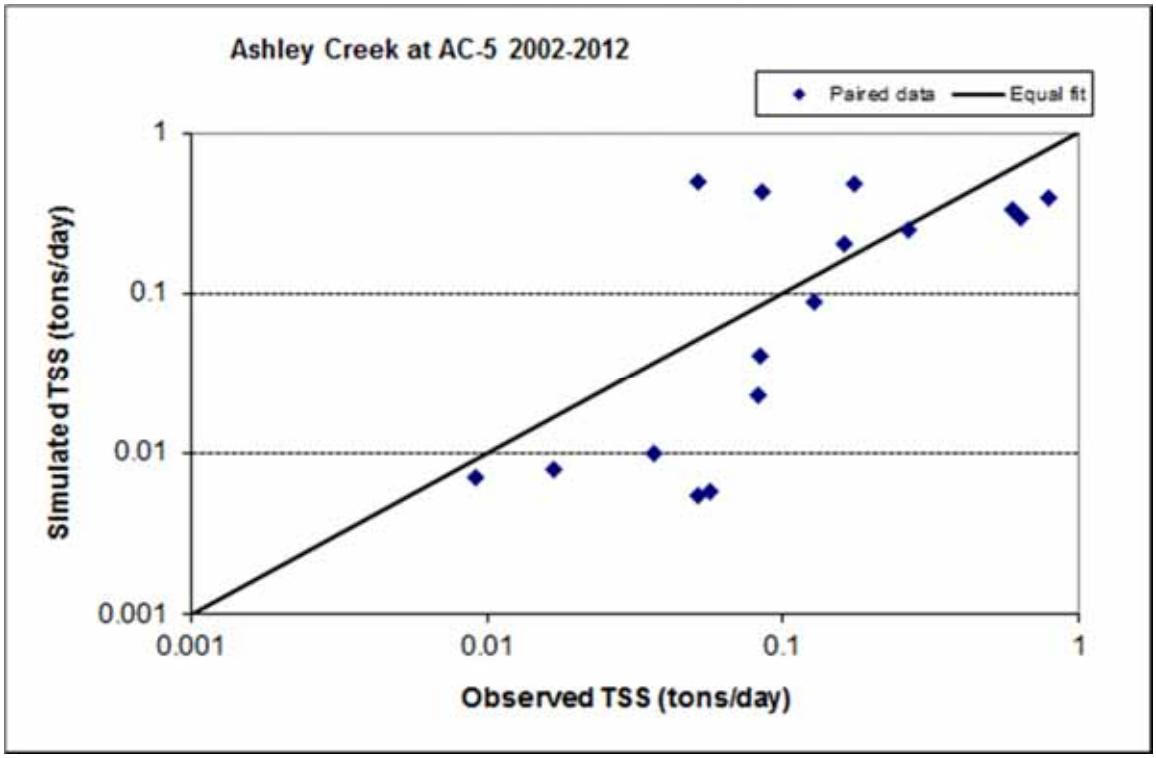


Figure A-23. Observed and Modeled TSS Daily Paired Load, Ashley Creek near AC-5.

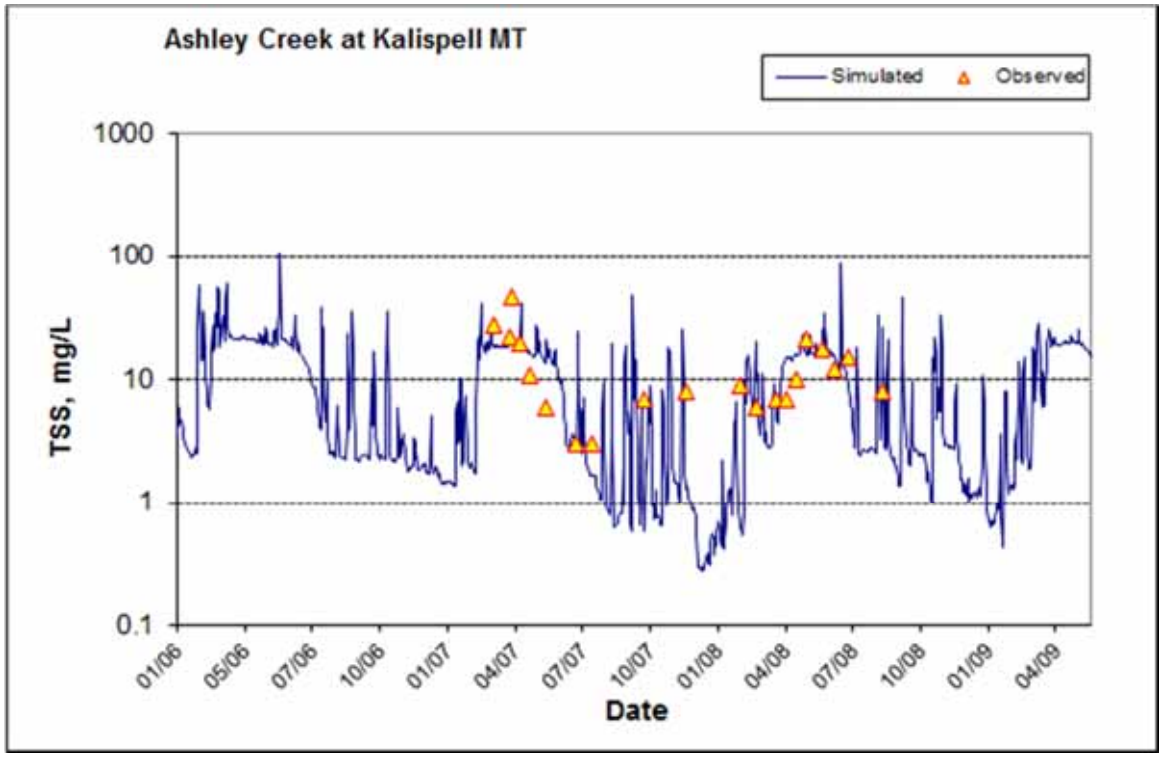


Figure A-24. Observed and Modeled TSS Time series Feb. 2006 through May 2009, Ashley Creek near 12367800.

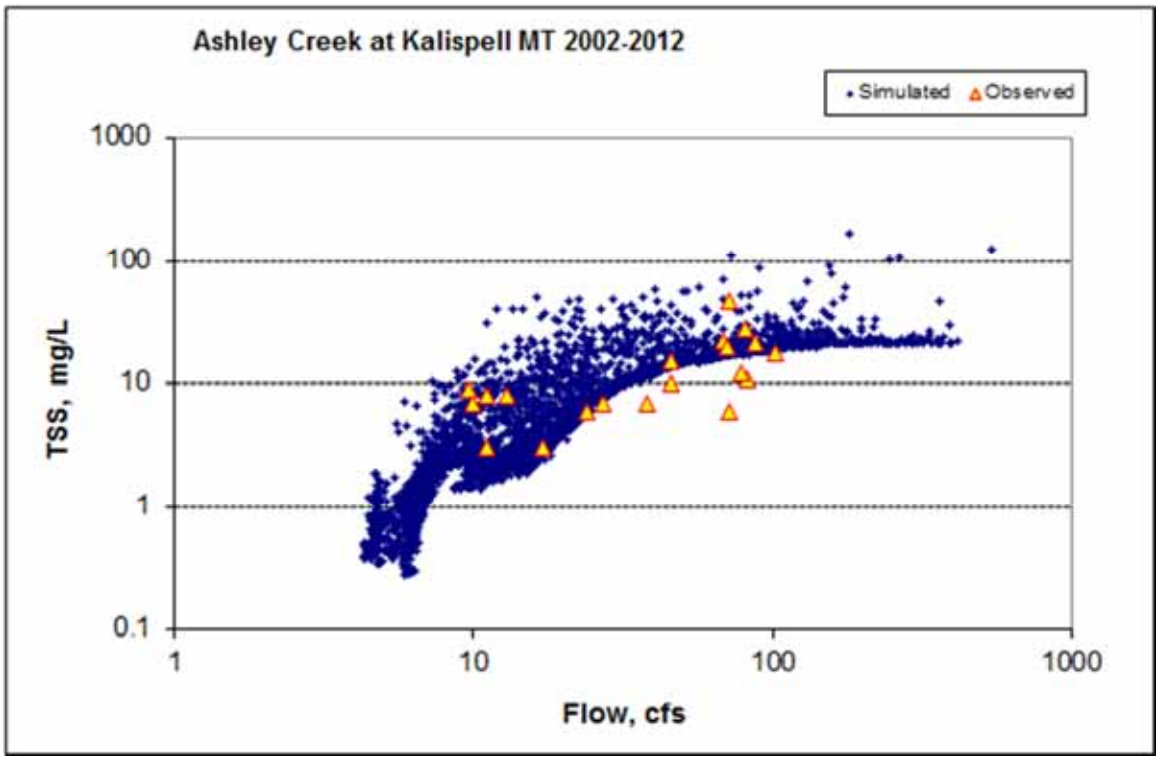


Figure A-25. Observed and Modeled TSS Concentration vs. Flow, Ashley Creek near 12367800.

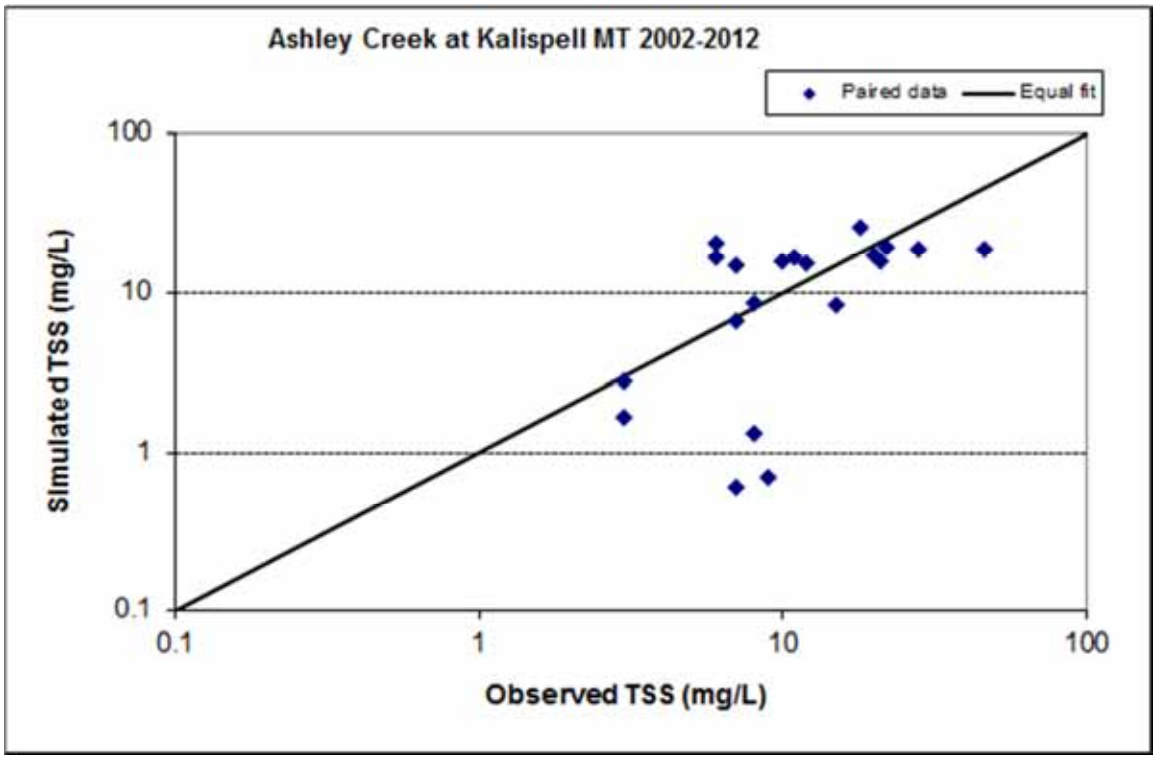
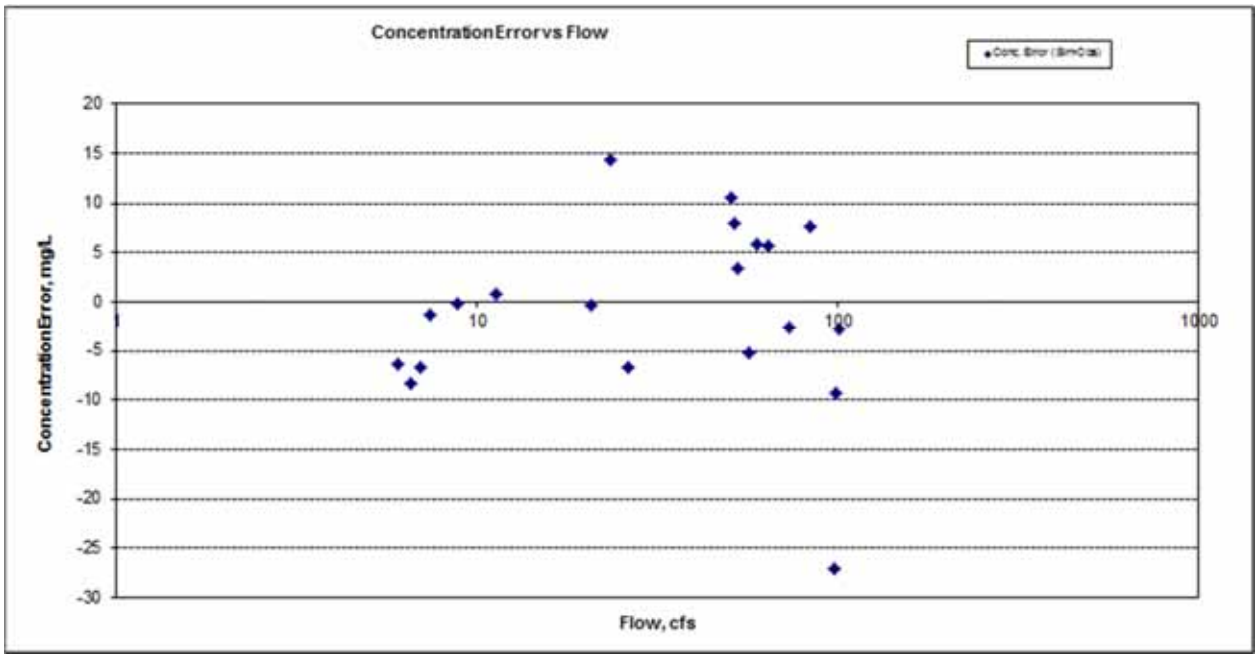


Figure A-26. Observed and Modeled TSS Daily Paired Concentration, Ashley Creek near 12367800.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-27. Observed and Modeled TSS Daily Paired Concentration Error vs. Flow, Ashley Creek near 12367800.

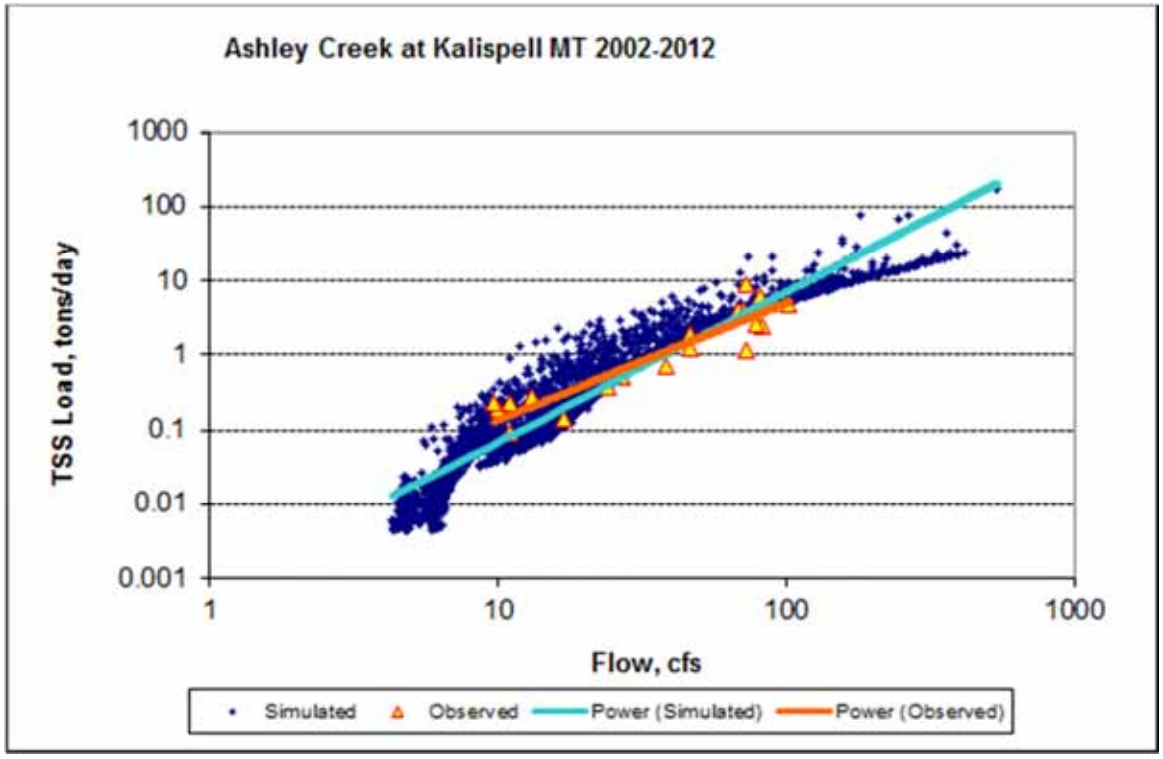


Figure A-28. Observed and Modeled TSS Load vs. Flow, Ashley Creek near 12367800.

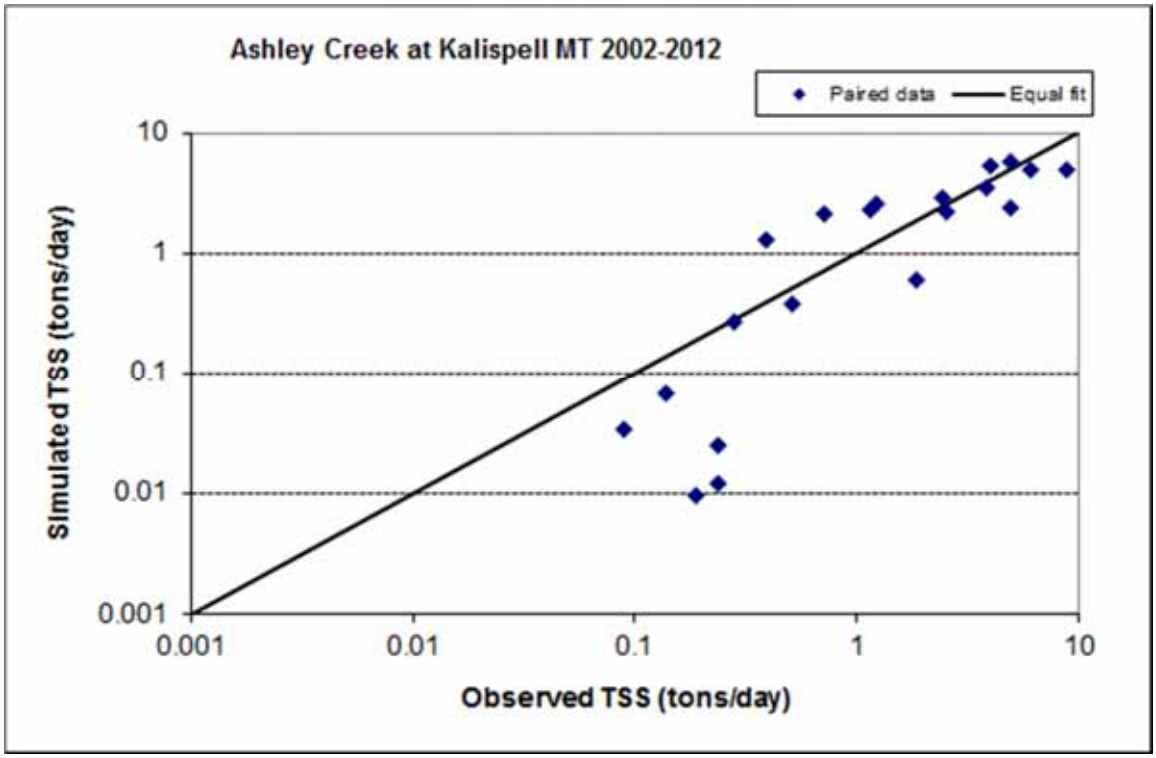


Figure A-29. Observed and Modeled TSS Daily Paired Load, Ashley Creek near 12367800.

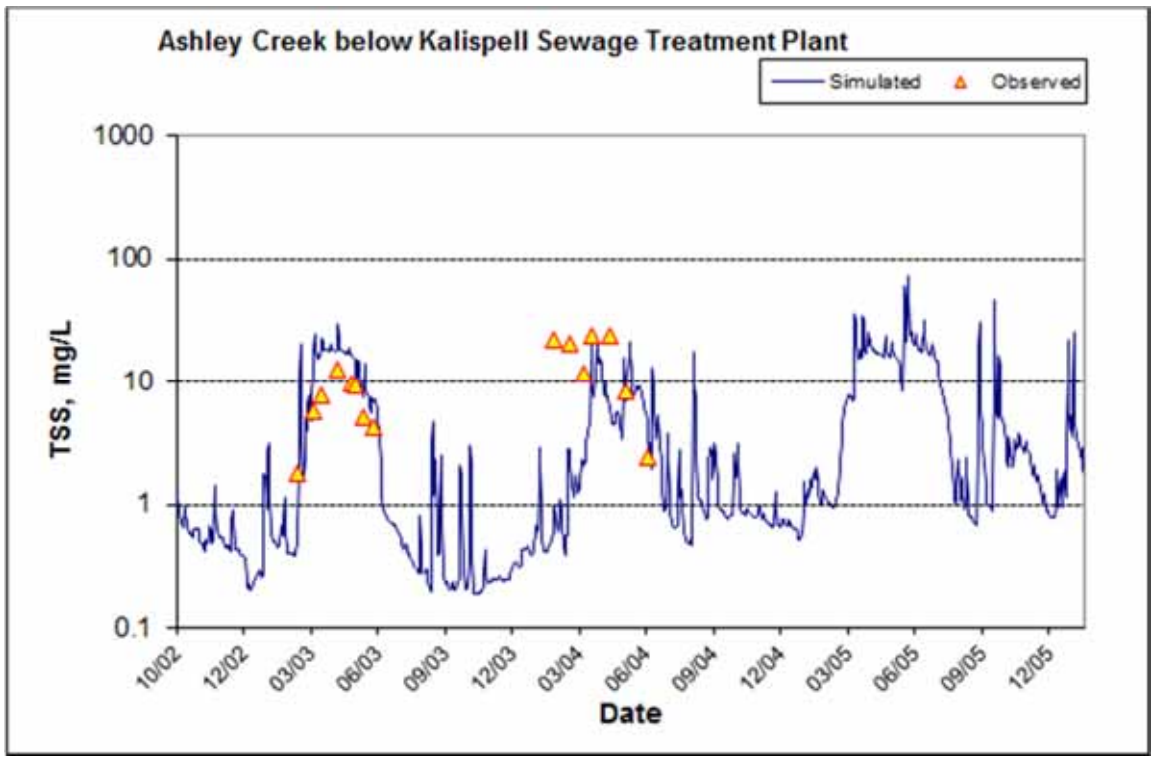


Figure A-30. Observed and Modeled TSS Time series Oct. 2002 through Jan. 2006, Ashley Creek near FBC05003.

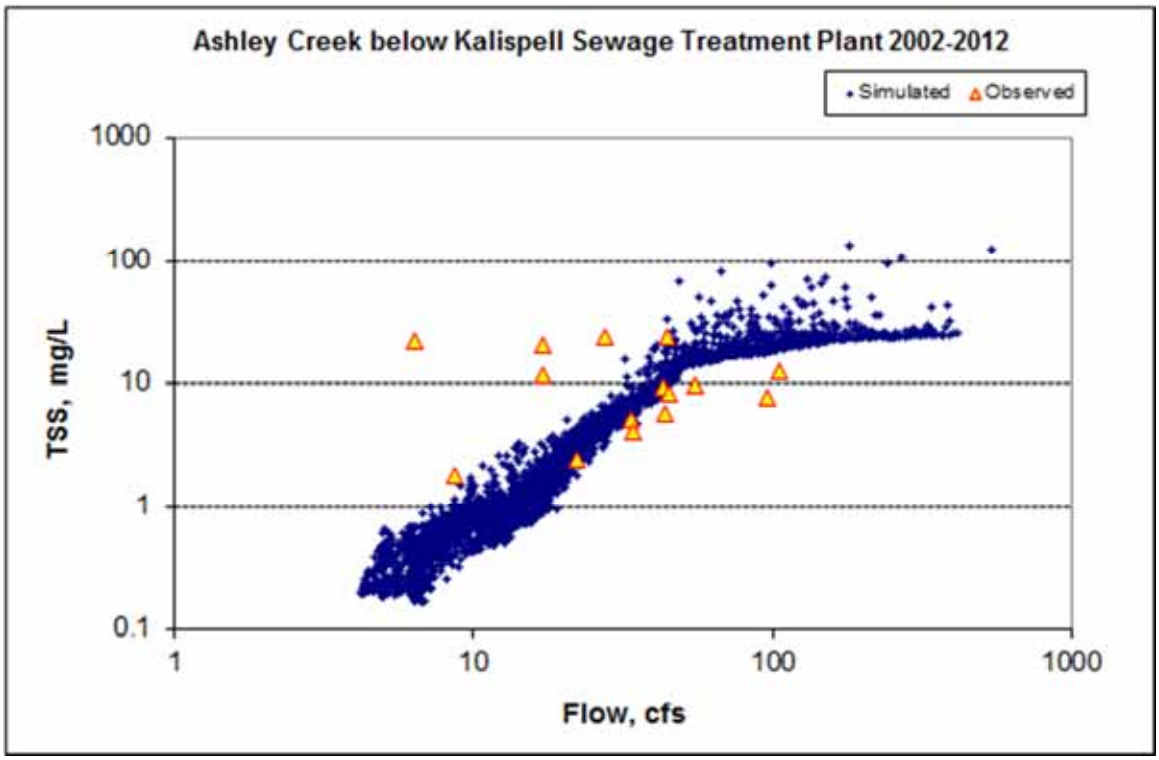


Figure A- 31. Observed and Modeled TSS Concentration vs. Flow, Ashley Creek near FBC05003.

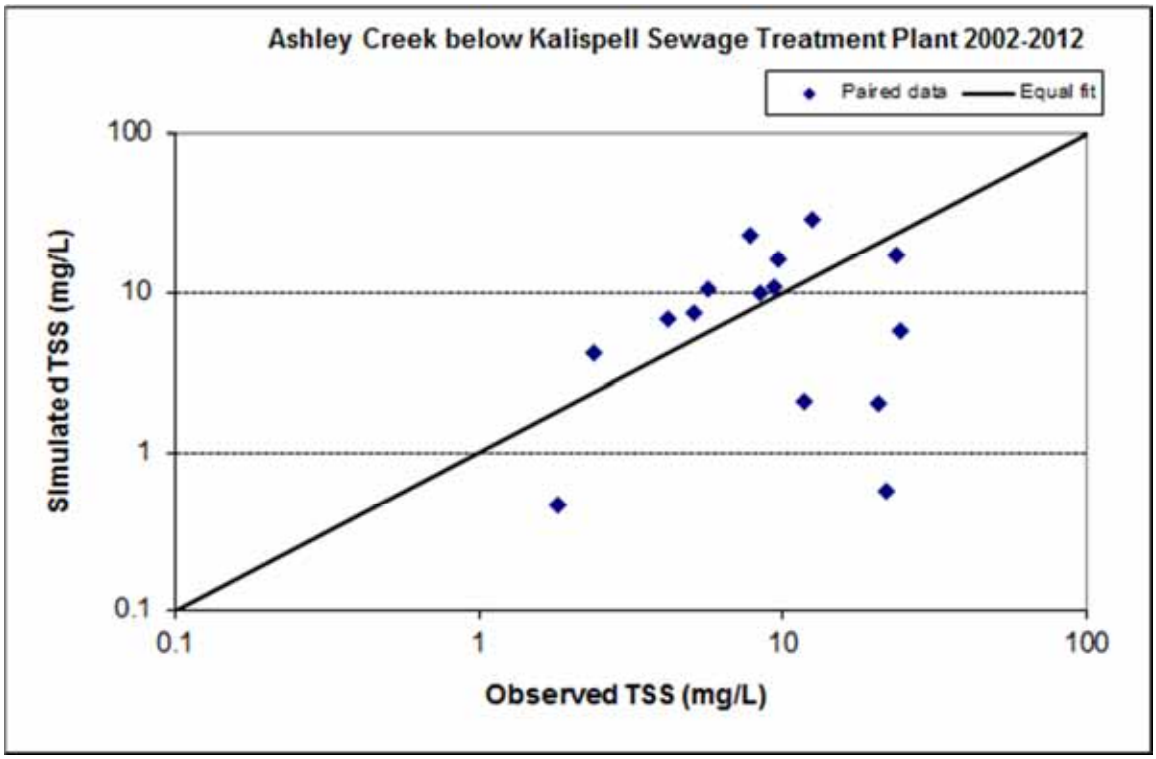
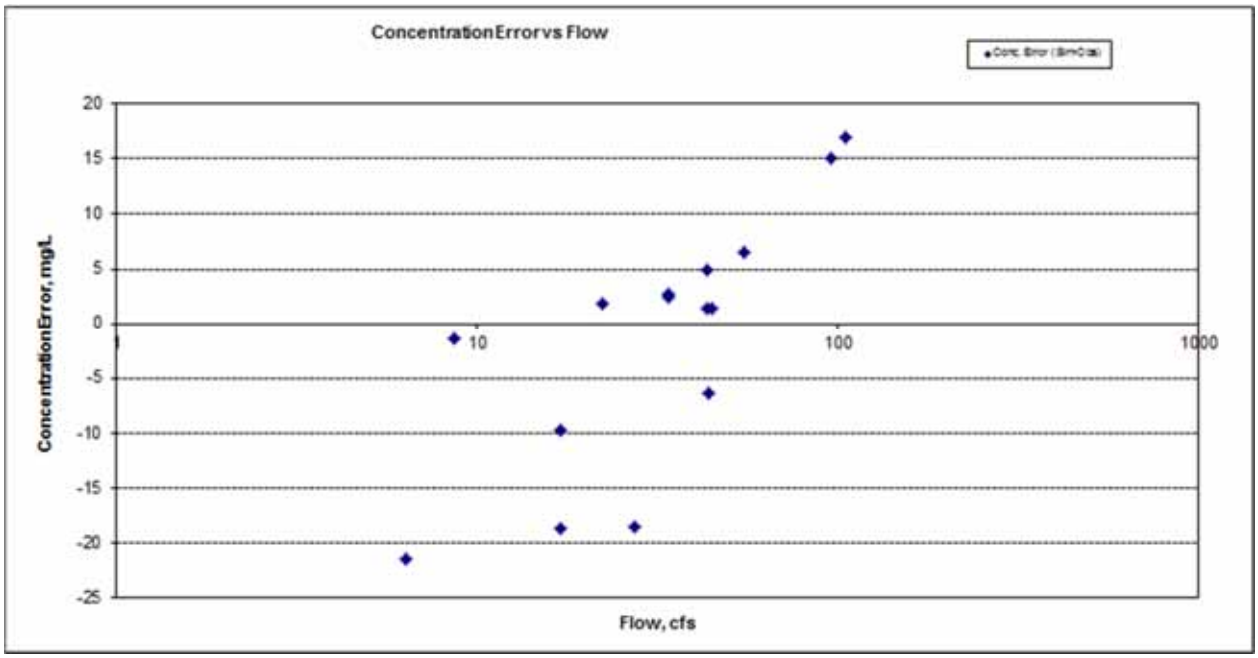


Figure A-32. Observed and Modeled TSS Daily Paired Concentration, Ashley Creek near FBC05003.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-33. Observed and Modeled TSS Daily Paired Concentration Error vs. Flow, Ashley Creek near FBC05003.

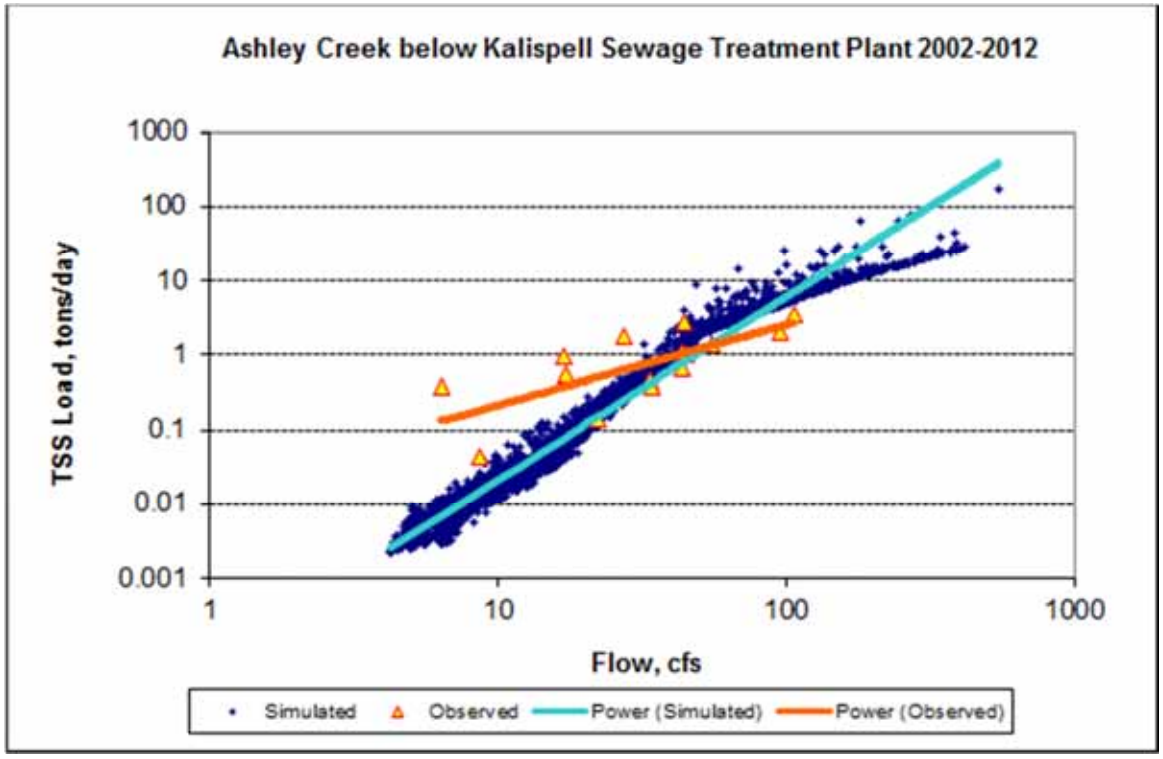


Figure A-34. Observed and Modeled TSS Load vs. Flow, Ashley Creek near FBC05003.

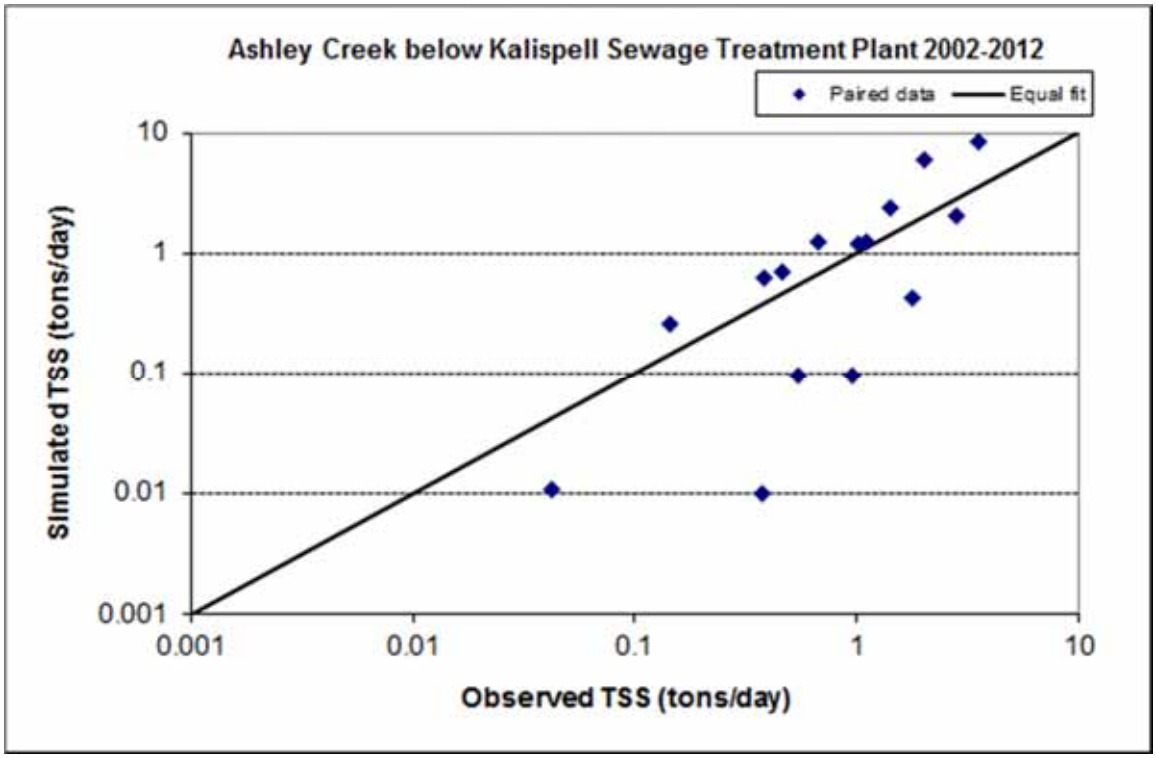


Figure A-35. Observed and Modeled TSS Daily Paired Load, Ashley Creek near FBC05003.

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Calibration statistics are shown in **Table A-6** for TN. Performance is *Poor* to *Fair* at AC-1 and AC-2, *Fair* to *Good* near AC-5 and AC-6, and *Good* to *Very Good* at AC-7, Ashley Creek near FBC05003, and Ashley Creek near 12367800. The model systematically under-predicts TN in Ashley Lake and its outflow, and underprediction error is carried through the model until loads from other sources dominate the nitrogen representation. LSPC includes simplified algorithms for representing nutrient dynamics in lakes and reservoirs. However, Ashley Lake is deep and the residence time is on the order of ten years. A robust lake/reservoir model would be needed to more accurately model conditions in Ashley Lake. While the model representation of nitrogen loading from Ashley Lake is biased low, the lake is not a major source of nitrogen in the watershed overall, and the model does a good job of predicting loads at the outlet of Ashley Creek. It is also important to note that while the magnitude of error from Ashley Lake is high, the absolute error is low (around 0.2 mg/L) since observed nitrogen concentrations in the lake outflow are low.

Table A-6. Performance for the TN Water Quality for the Ashley Creek model

Water Quality Calibration Site	TN			
	Concentration		Load	
	Average	Median	Average	Median
Ashley Creek at AC-1 (SWS 2082)	-84%	-60%	-73%	-54%
Ashley Creek at AC-3 (SWS 2079)	-74%	-36%	-60%	-32%
Ashley Creek near AC-5 (SWS 2068)	-28%	-26%	-31%	-18%
Ashley Creek at AC-6 (SWS 2067)	-30%	-29%	-30%	-18%
Ashley Creek at AC-7 (SWS 2066)	-16%	-5%	-23%	-7%
Ashley Creek near 12367800 (SWS 2064) – above Kalispell WWTP	4%	3%	-24%	-5%
Ashley Creek near FBC05003 (SWS 2063) – below Kalispell WWTP	12%	9%	-4%	7%

Calibration plots for TN at AC-1 are shown in **Figure A-36** through **Figure A- 41.** The model predicts TN at a more or less constant value of 0.05 mg/L, whereas monitoring data have a median of 0.26 mg/L and an average of about 0.34 mg/L. The model bias is evident in all of the graphs.

The trend towards under-prediction is carried through to AC-3 (**Figure A-42** through **Figure A-47**), but the magnitude of the error is less and the model shows more variability in its TN predictions. Observed and modeled concentrations versus flow show that the distributions overlap (**Figure A-43**).

At AC-5 (**Figure A-48** through **Figure A-53**), there is some under-prediction of TN in all of the plots, but the magnitude of the error is less than AC-3, indicating that model prediction is getting closer to observed values moving downstream through the watershed. In the observed and modeled concentration (**Figure A-49**) and load (**Figure A-52**) graphs, nearly all of the observed values fall within the modeled distribution. The trends are similar at AC-6 (**Figure A-54** through **Figure A-59**).

Model performance improves at AC-7 (**Figure A-60** through **Figure A- 65**). Modeled concentrations follow the trend towards decreasing concentration with increasing flow seen in the observed data

(**Figure A-61**). There is a slight tendency for the model to under-predict loads at higher flows, as seen in **Figure A-64** and **Figure A- 65**.

Results for Ashley Creek near 12367800 are shown in **Figure A-66** through **Figure A-71**. Performance at this station is very good. As seen at AC-7, observed and modeled concentrations decrease with increasing flow (**Figure A-67**), though there are two elevated observed values at high flow. Paired concentrations and loads fit well (**Figure A- 68** and Figure **A-71**), and loads are well replicated across the range of flows (**Figure A-70**).

Below the Kalispell WWTP, model performance is also very good (**Figure A-72** through **Figure A-77**). Time series of simulated and observed TN track well (**Figure A-72**). Concentration and load versus flow distributions are well replicated (**Figure A-73** and **Figure A-76**). Paired daily modeled and observed concentrations are clustered towards the 1:1 line (**Figure A-74** and **Figure A-77**).

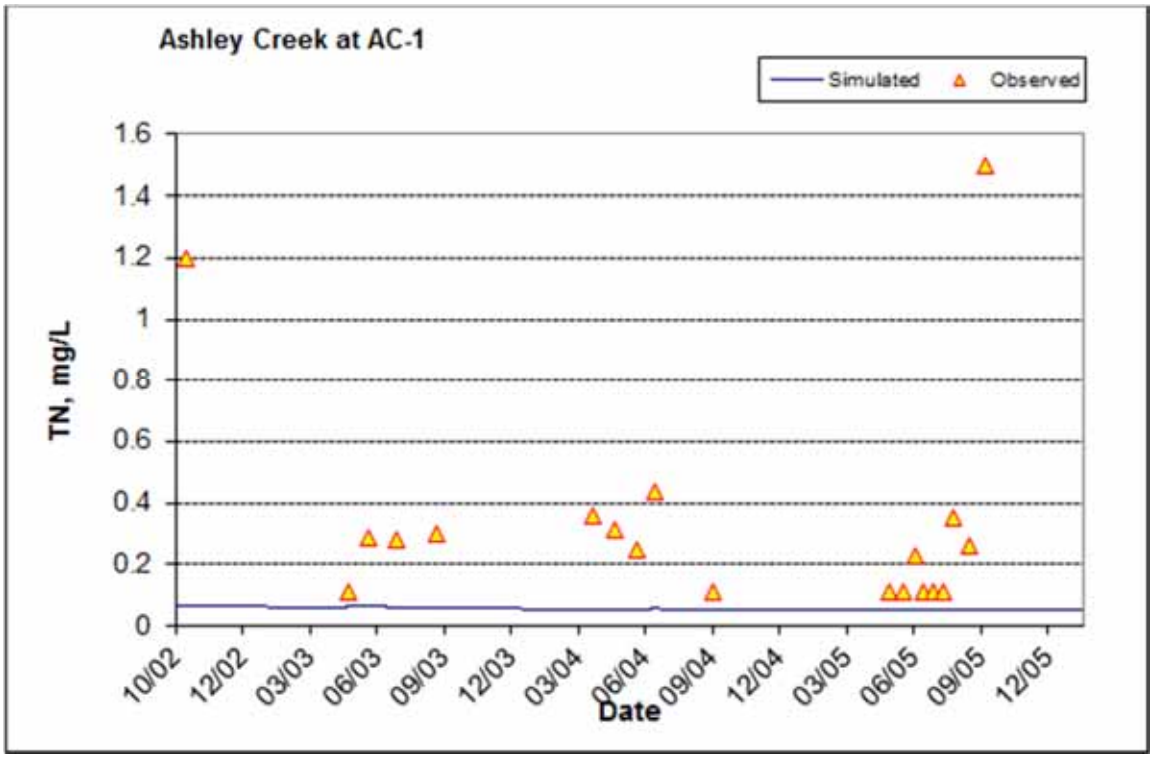


Figure A-36. Observed and Modeled TN Time Series Oct. 2002 through Jan. 2006, Ashley Creek at AC-1.

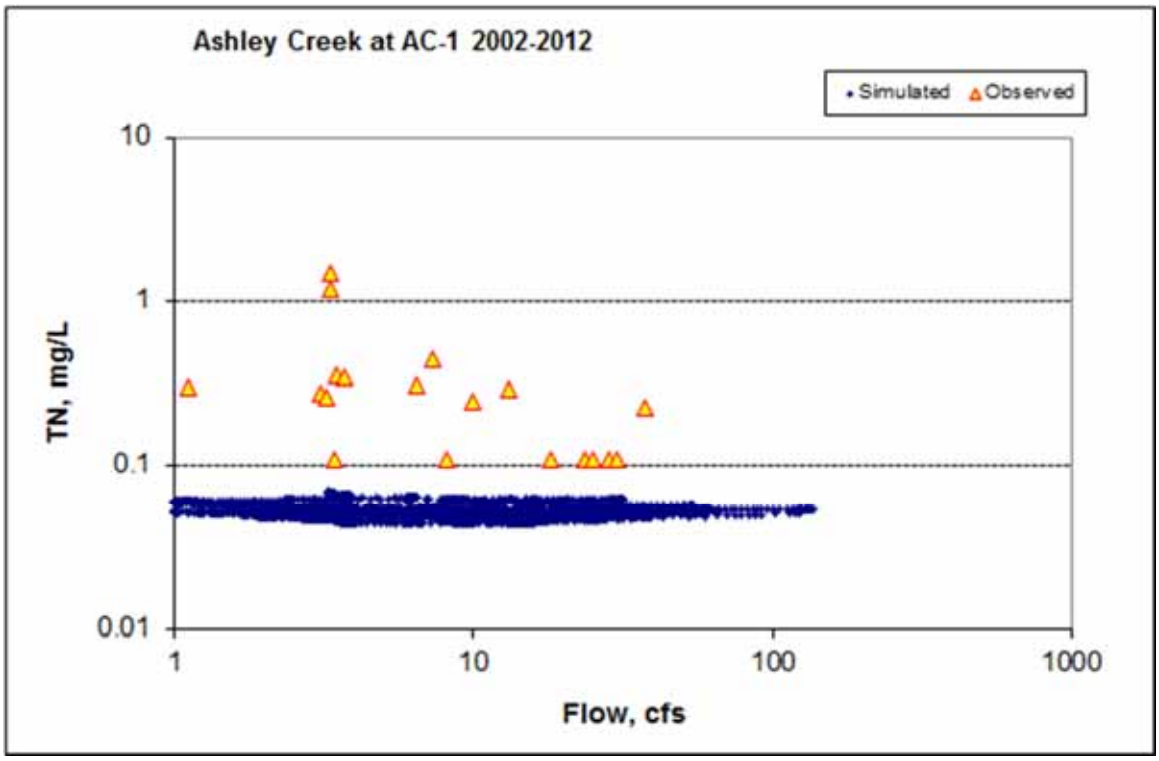


Figure A-37. Observed and Modeled TN Concentration vs. Flow, Ashley Creek at AC-1.

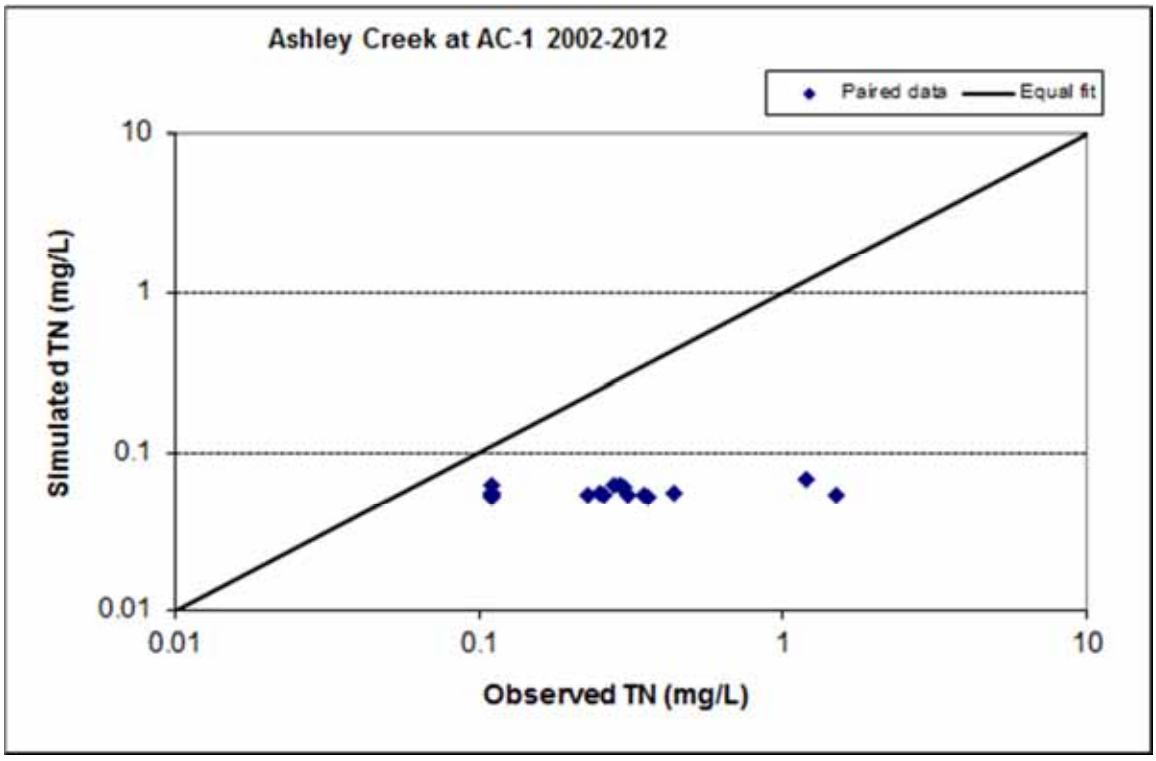
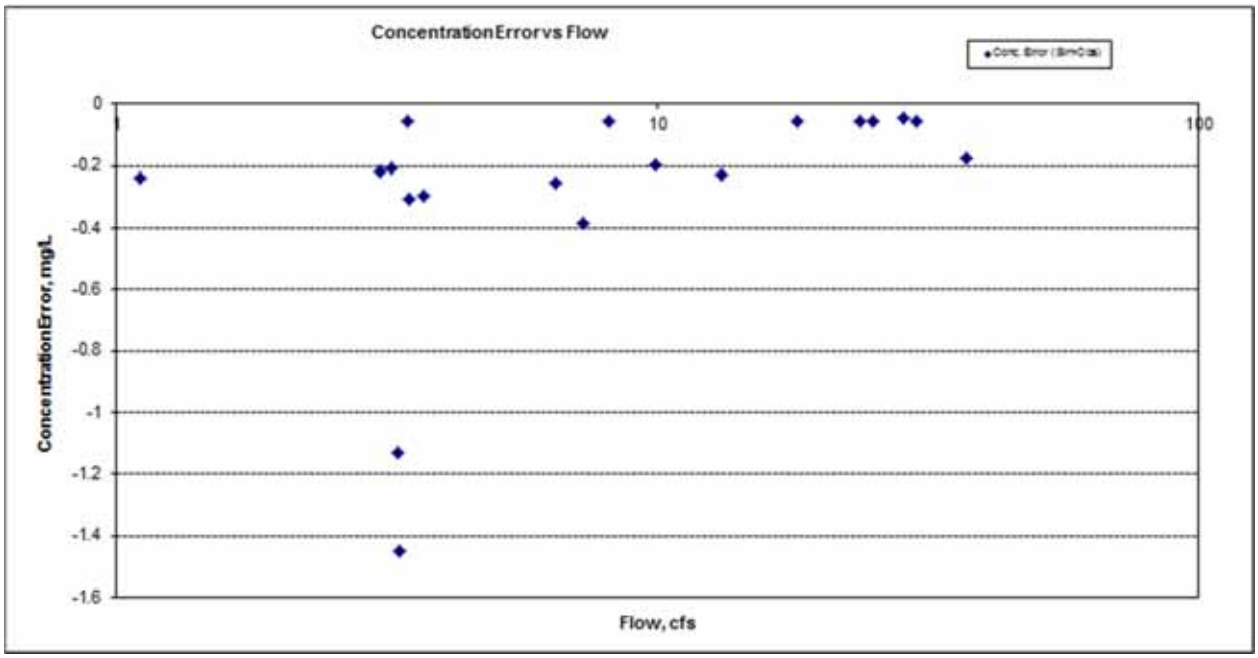


Figure A-38. Observed and Modeled TN Daily Paired Concentration, Ashley Creek at AC-1.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-39. Observed and Modeled TN Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-1.

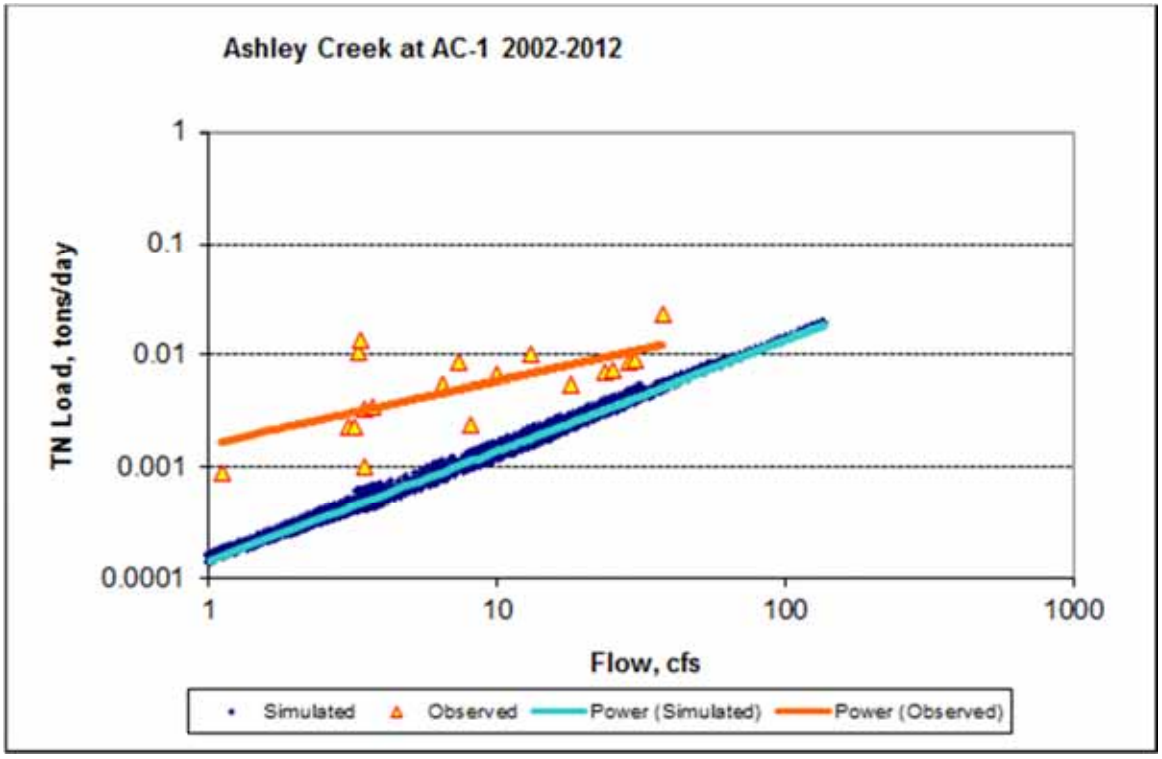


Figure A-40. Observed and Modeled TN Load vs. Flow, Ashley Creek at AC-1.

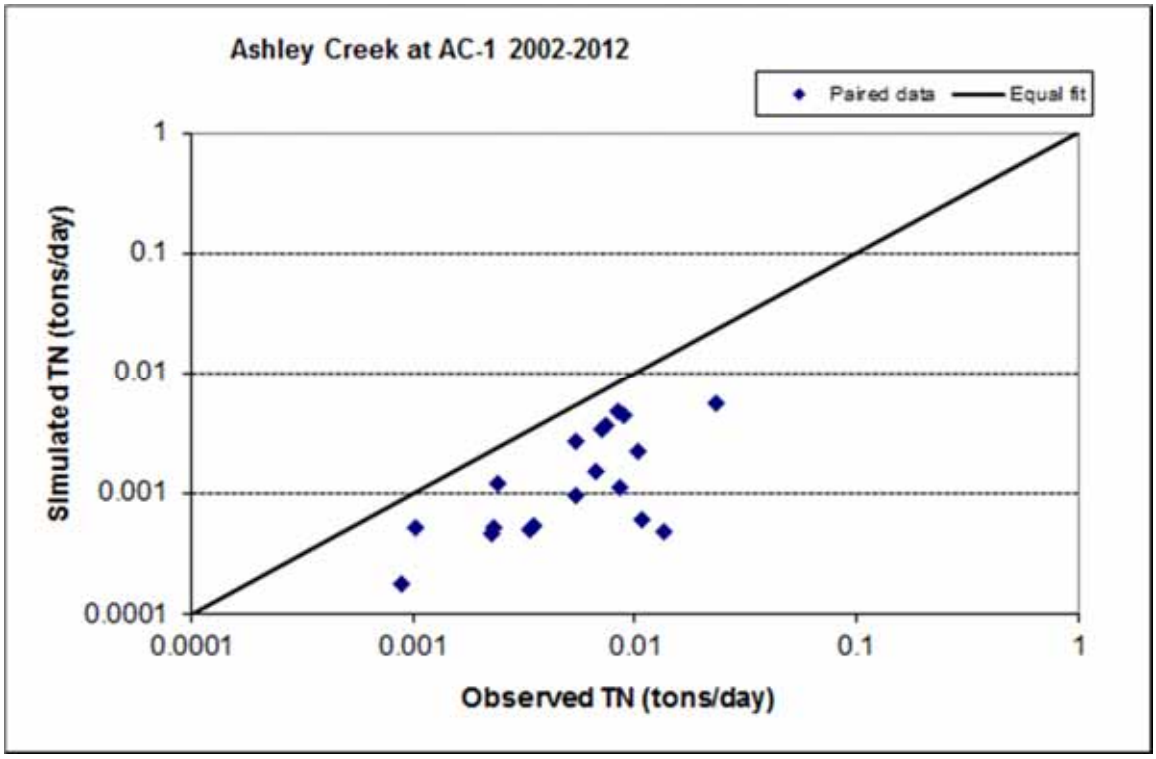


Figure A- 41. Observed and Modeled TN Daily Paired Load, Ashley Creek at AC-1.

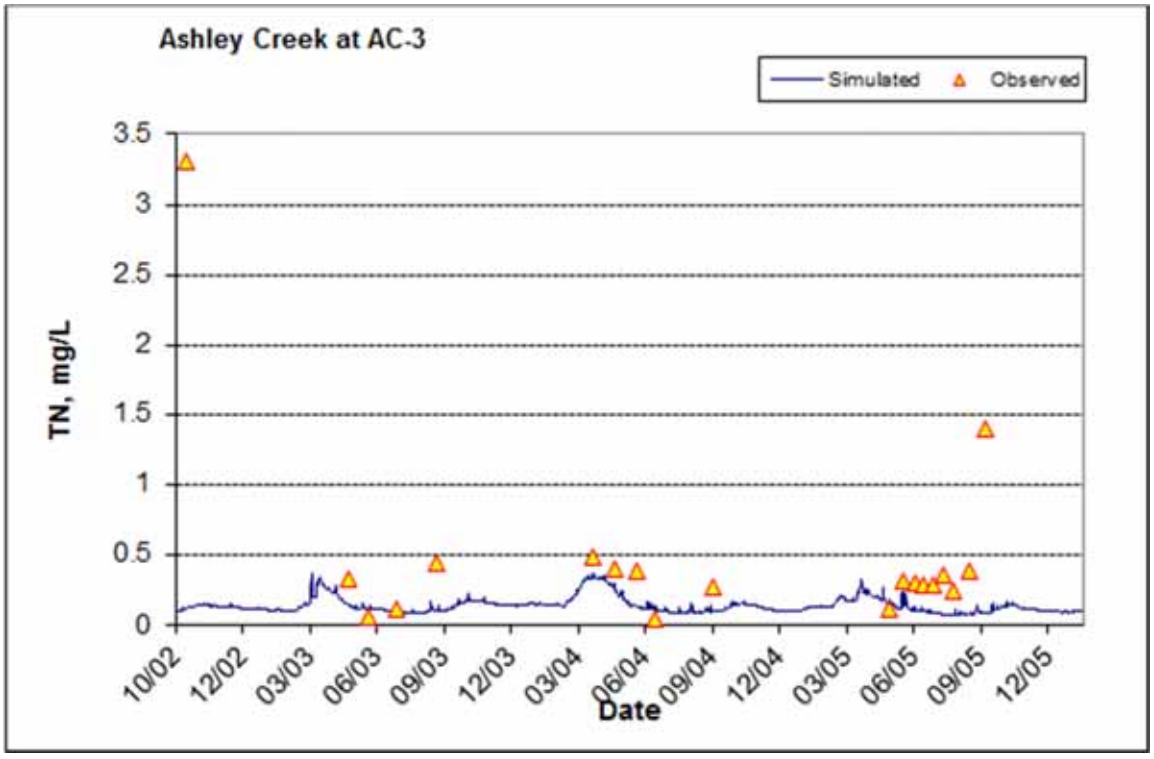


Figure A-42. Observed and Modeled TN Time series Oct. 2002 through Jan. 2006, Ashley Creek at AC-3.

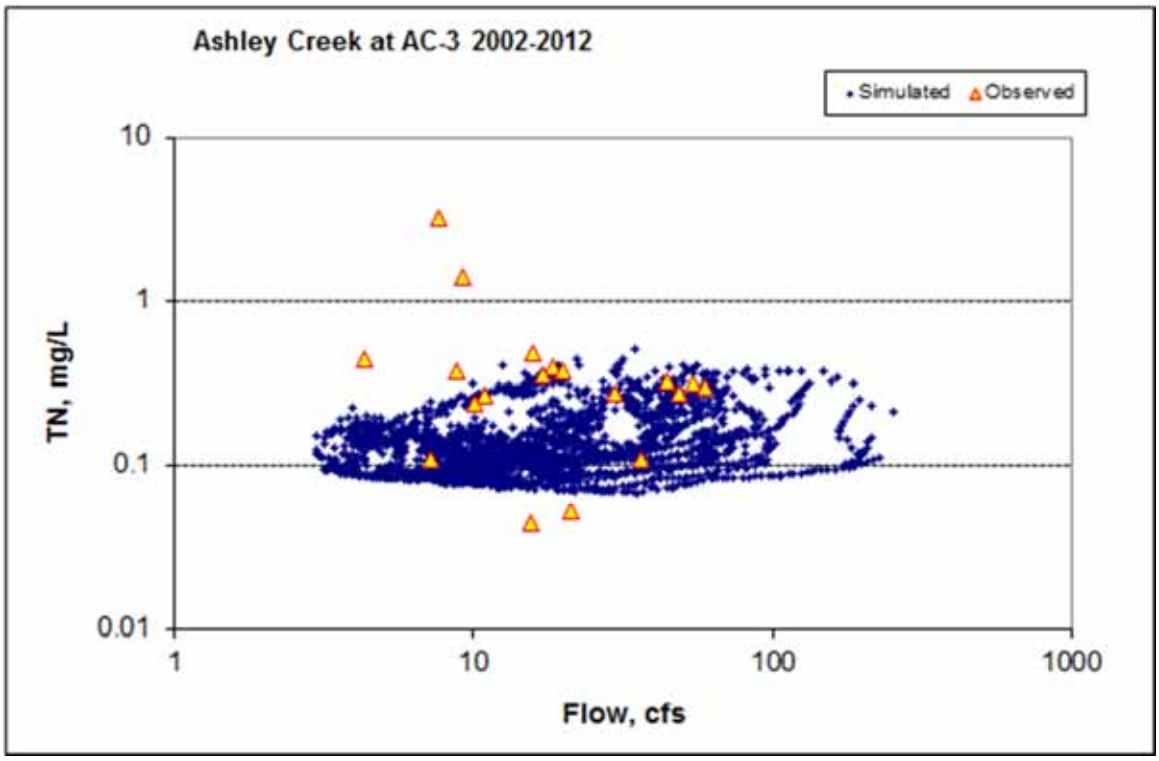


Figure A-43. Observed and Modeled TN Concentration vs. Flow, Ashley Creek at AC-3.

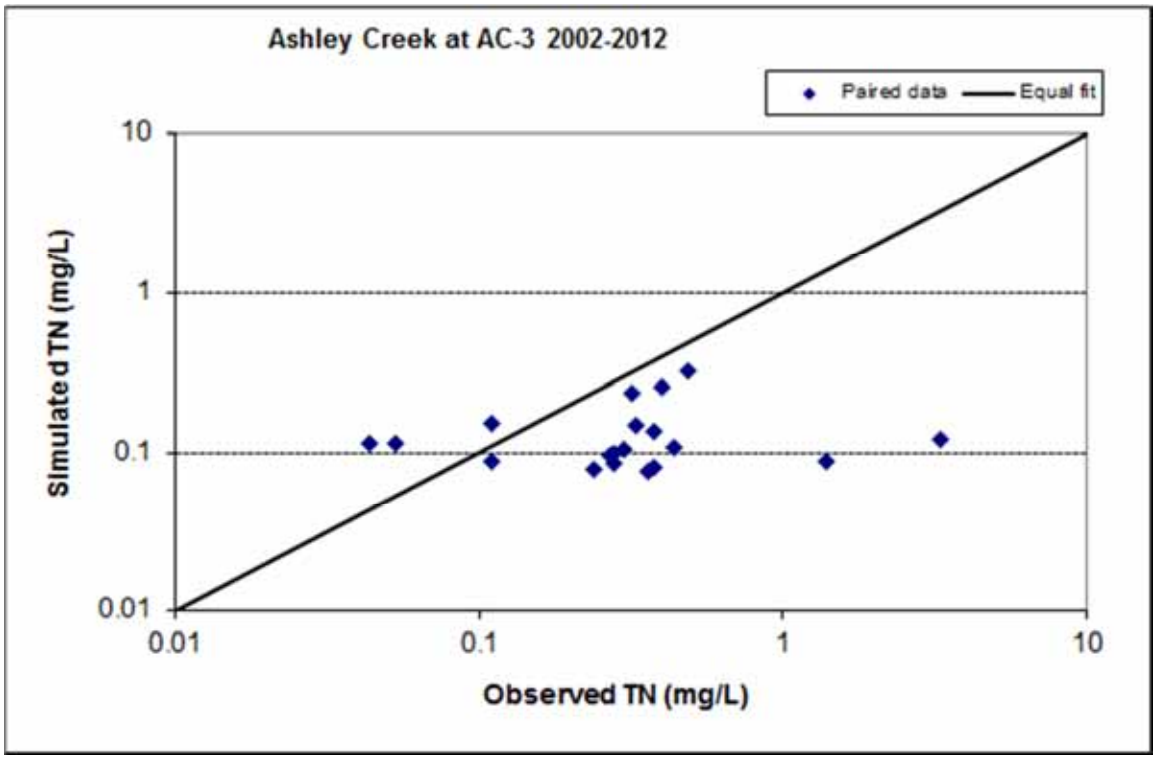
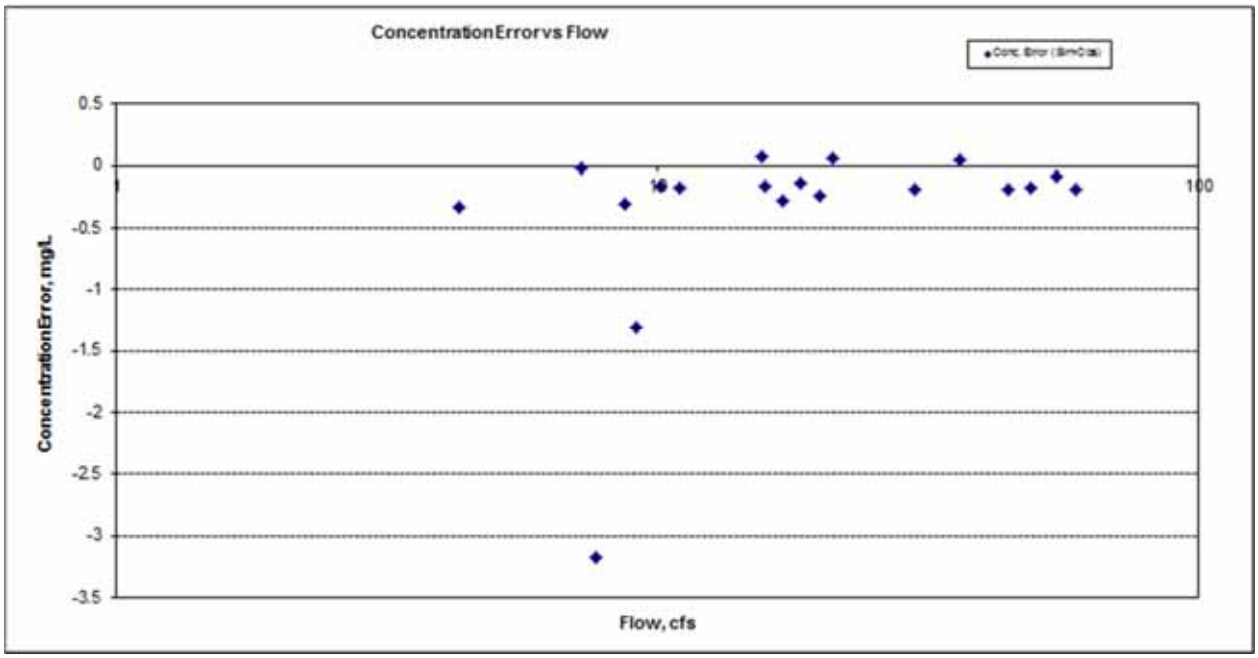


Figure A-44. Observed and Modeled TN Daily Paired Concentration, Ashley Creek at AC-3.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-45. Observed and Modeled TN Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-3.

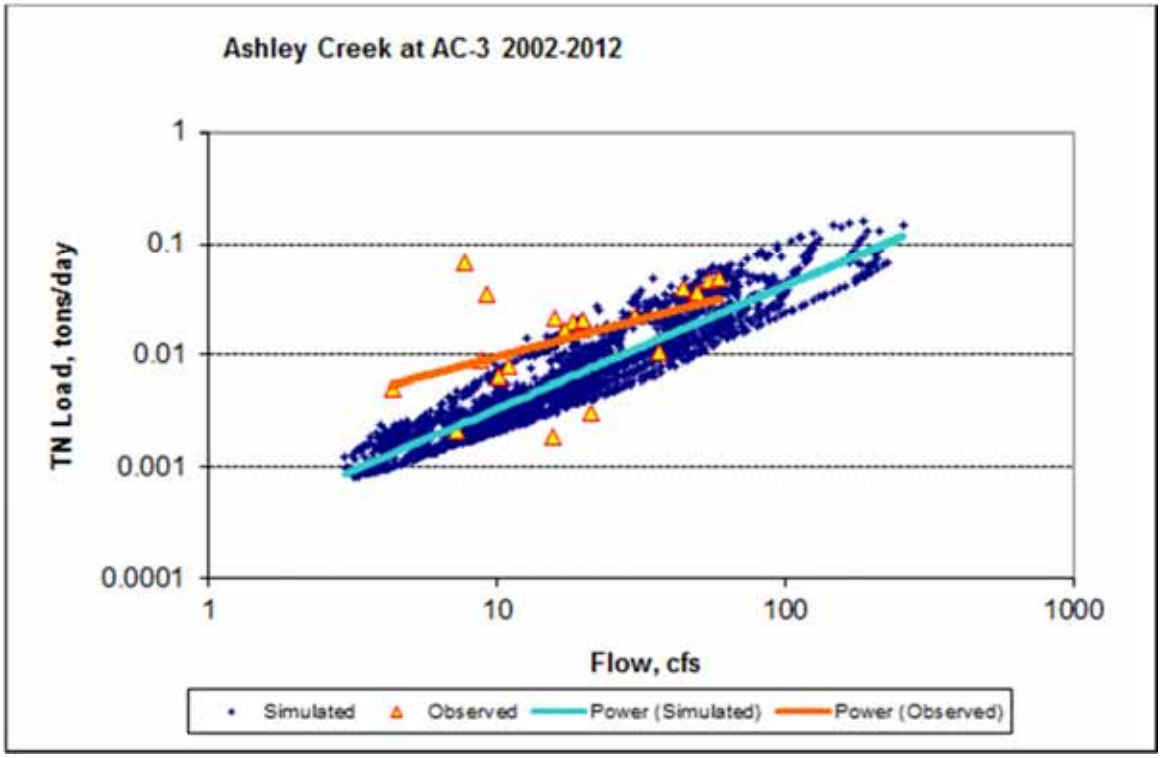


Figure A-46. Observed and Modeled TN Load vs. Flow, Ashley Creek at AC-3.

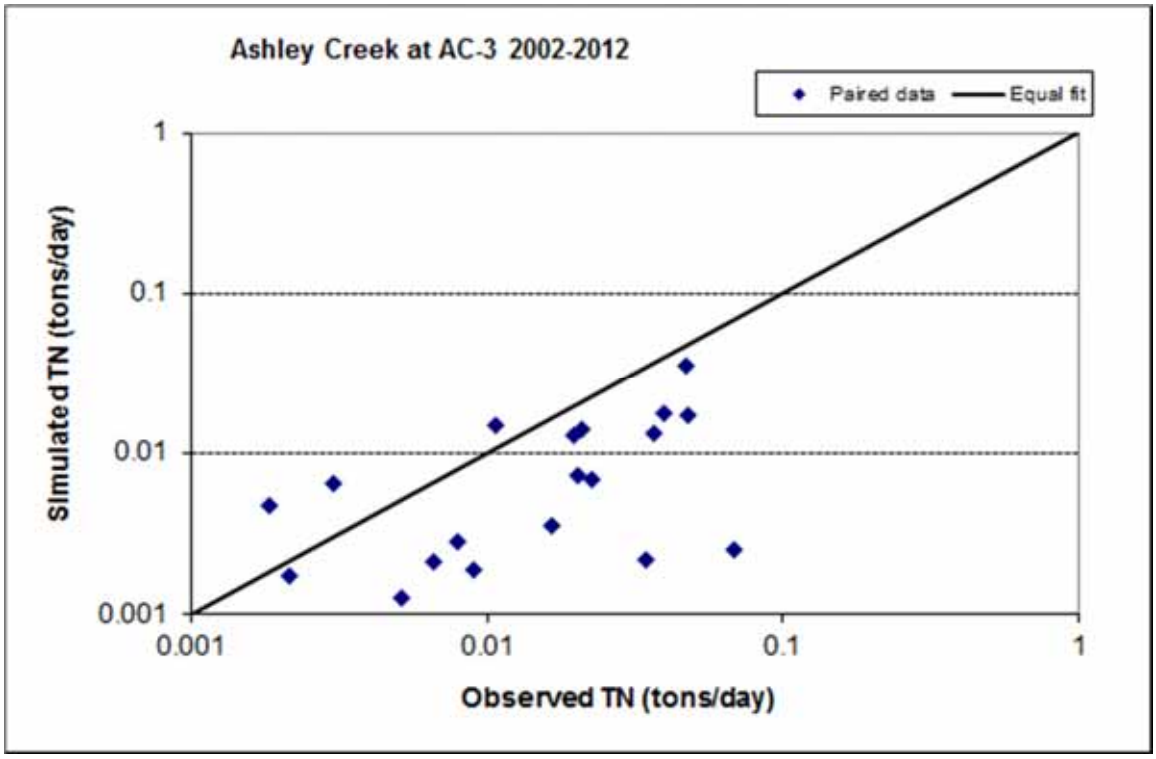


Figure A-47. Observed and Modeled TN Daily Paired Load, Ashley Creek at AC-3.

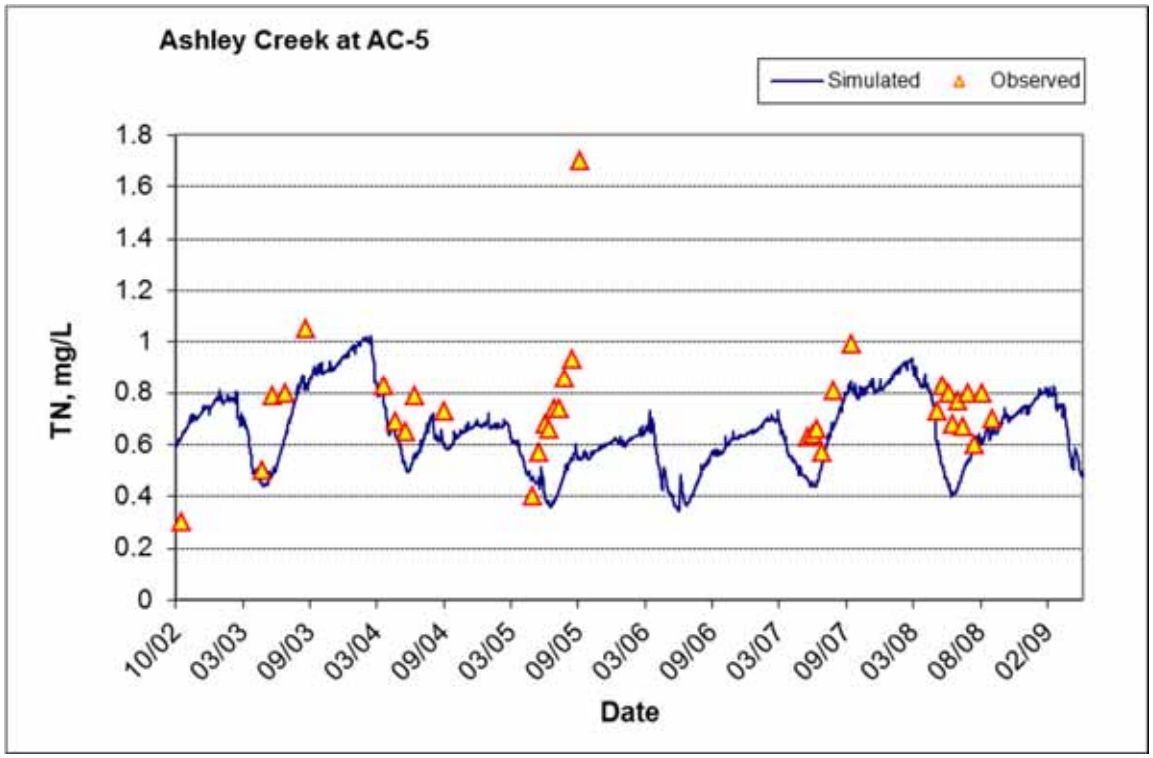


Figure A-48. Observed and Modeled TN Time series Oct. 2002 through May 2009, Ashley Creek near AC-5.

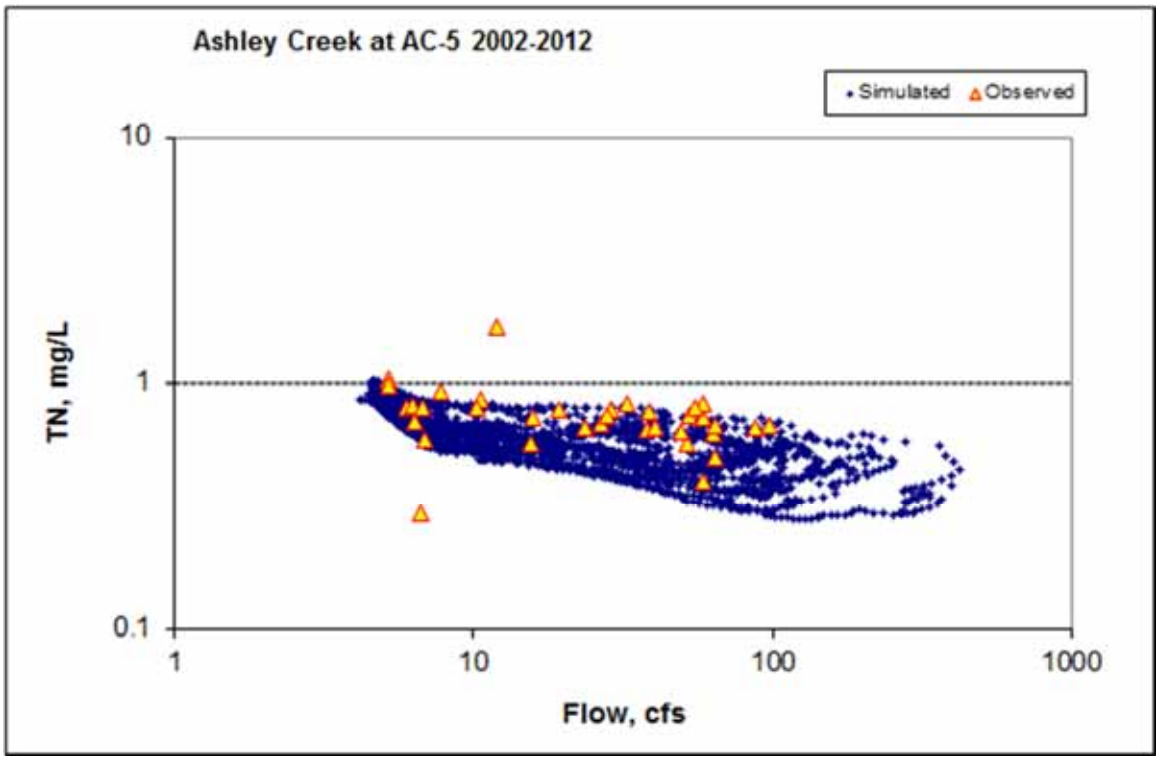


Figure A-49. Observed and Modeled TN Concentration vs. Flow, Ashley Creek near AC-5.

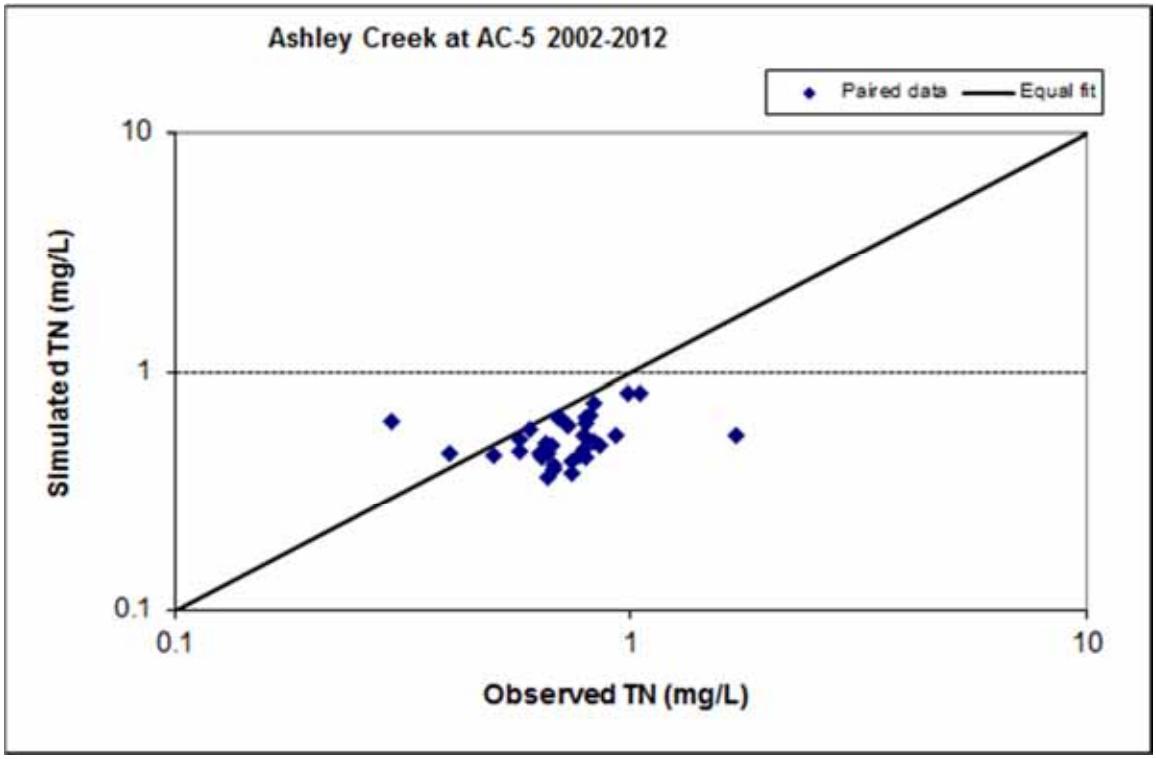
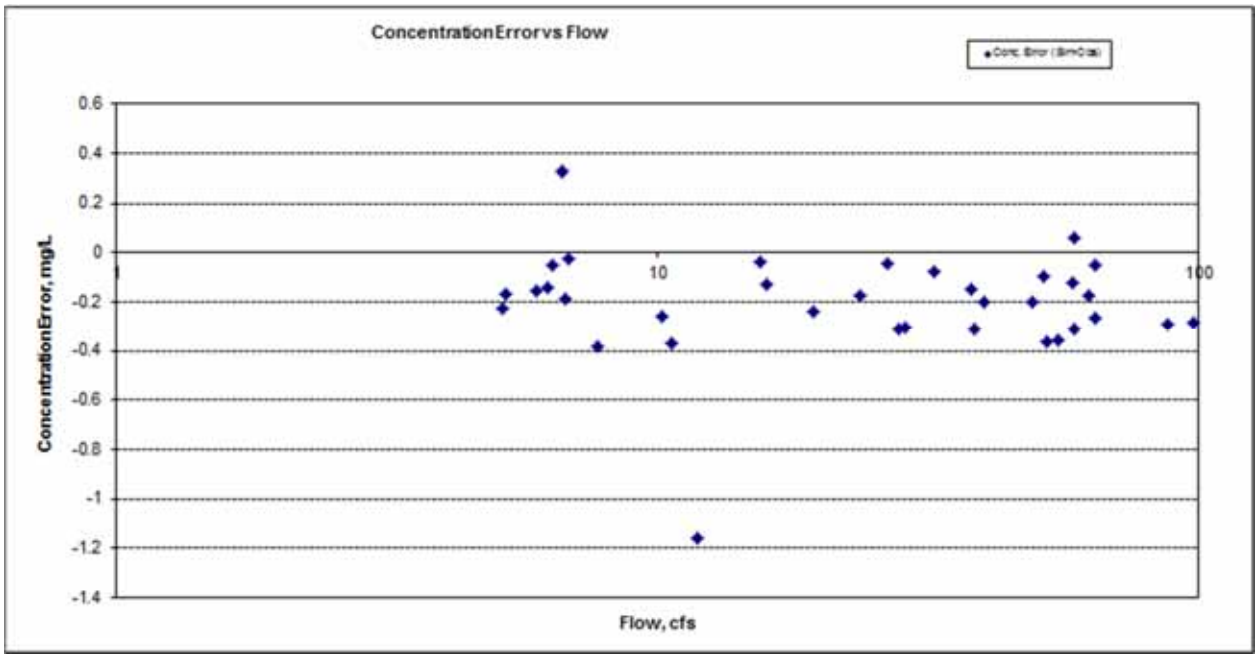


Figure A-50. Observed and Modeled TN Daily Paired Concentration, Ashley Creek near AC-5.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-51. Observed and Modeled TN Daily Paired Concentration Error vs. Flow, Ashley Creek near AC-5.

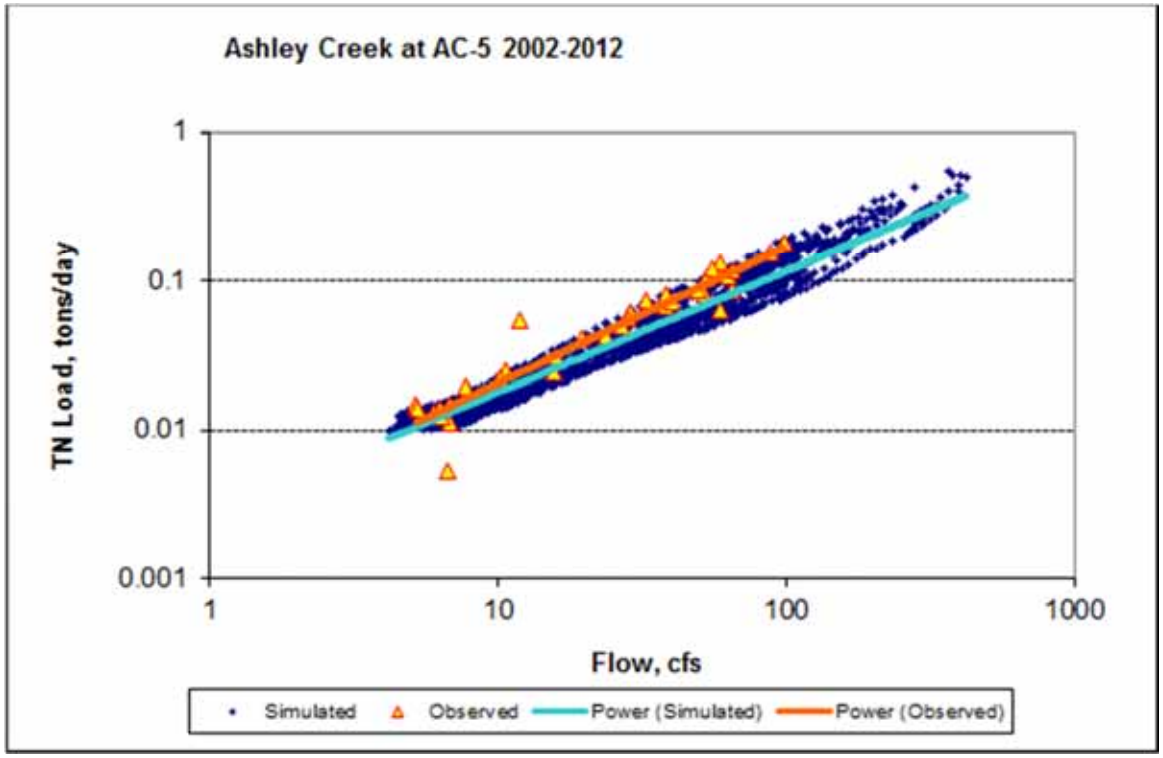


Figure A-52. Observed and Modeled TN Load vs. Flow, Ashley Creek near AC-5.

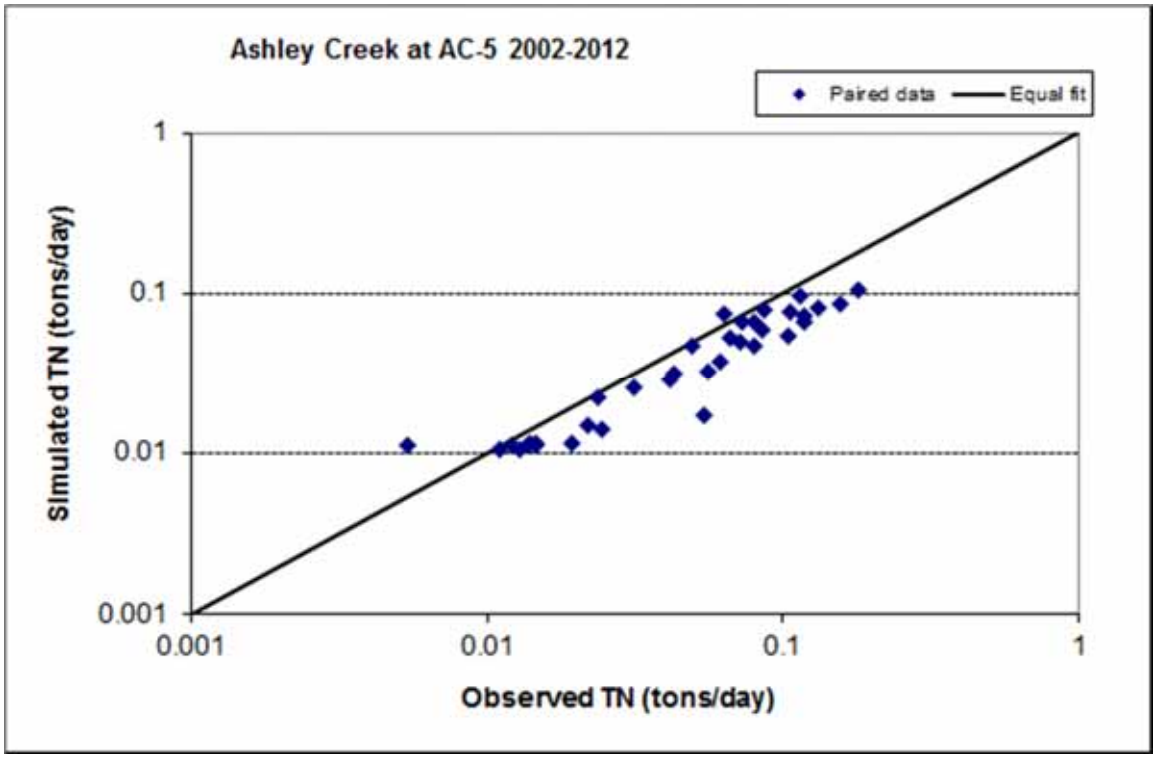


Figure A-53. Observed and Modeled TN Daily Paired Load, Ashley Creek near AC-5.

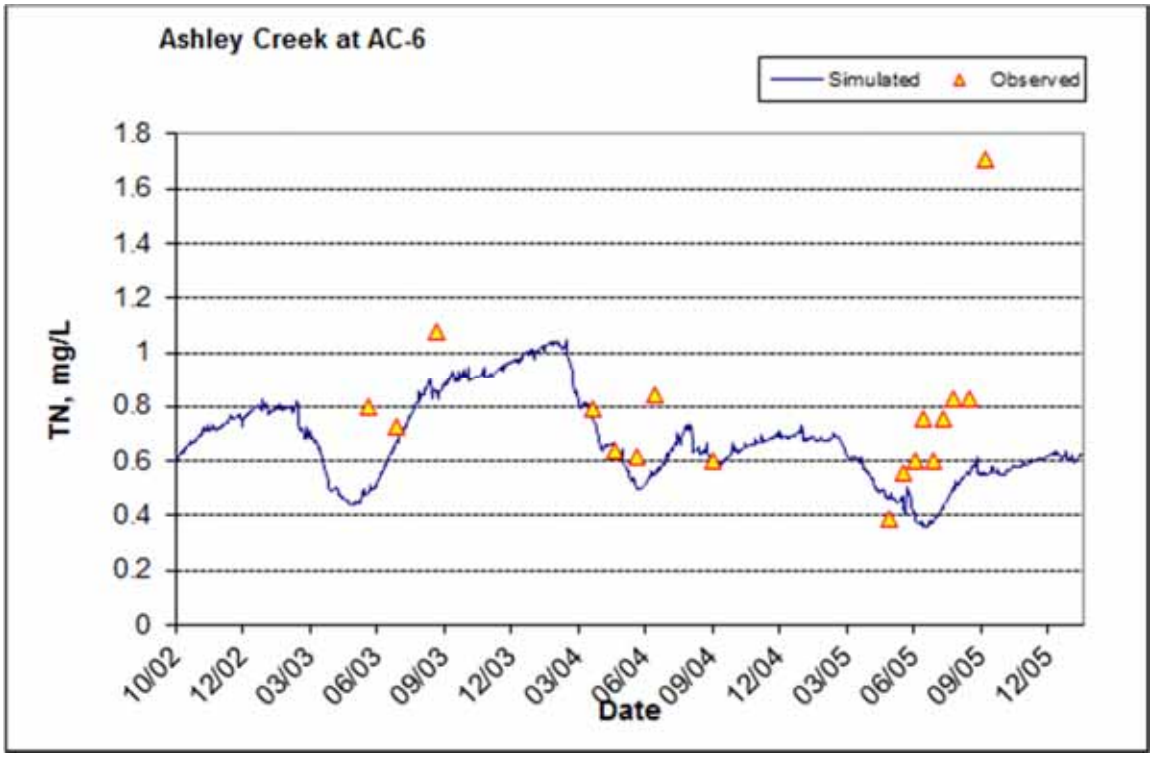


Figure A-54. Observed and Modeled TN Time series Oct. 2002 through Feb. 2006, Ashley Creek at AC-6.

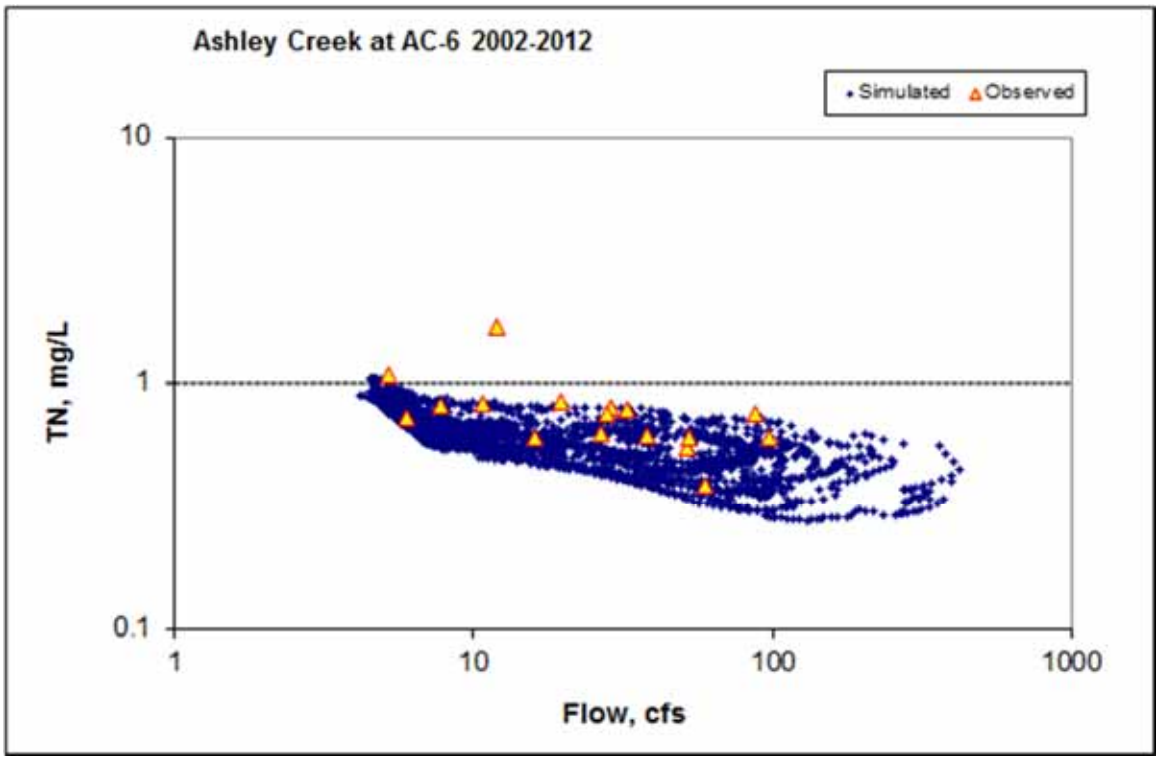


Figure A-55. Observed and Modeled TN Concentration vs. Flow, Ashley Creek at AC-6.

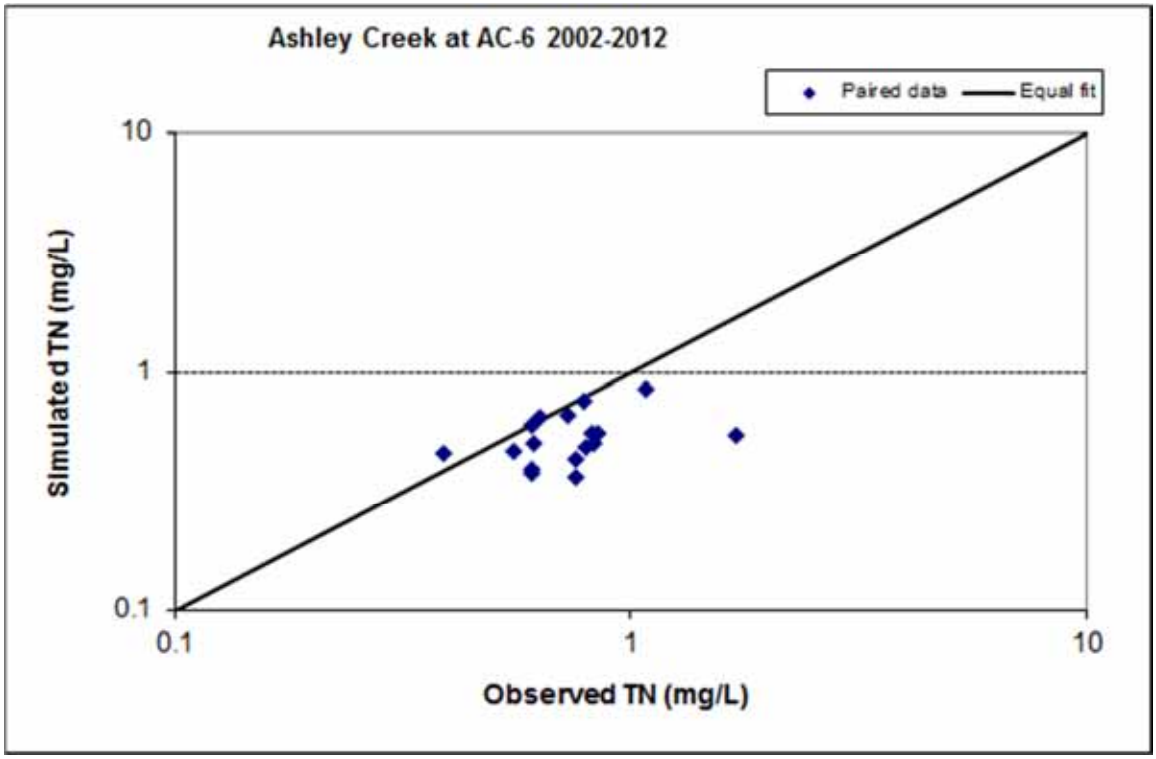
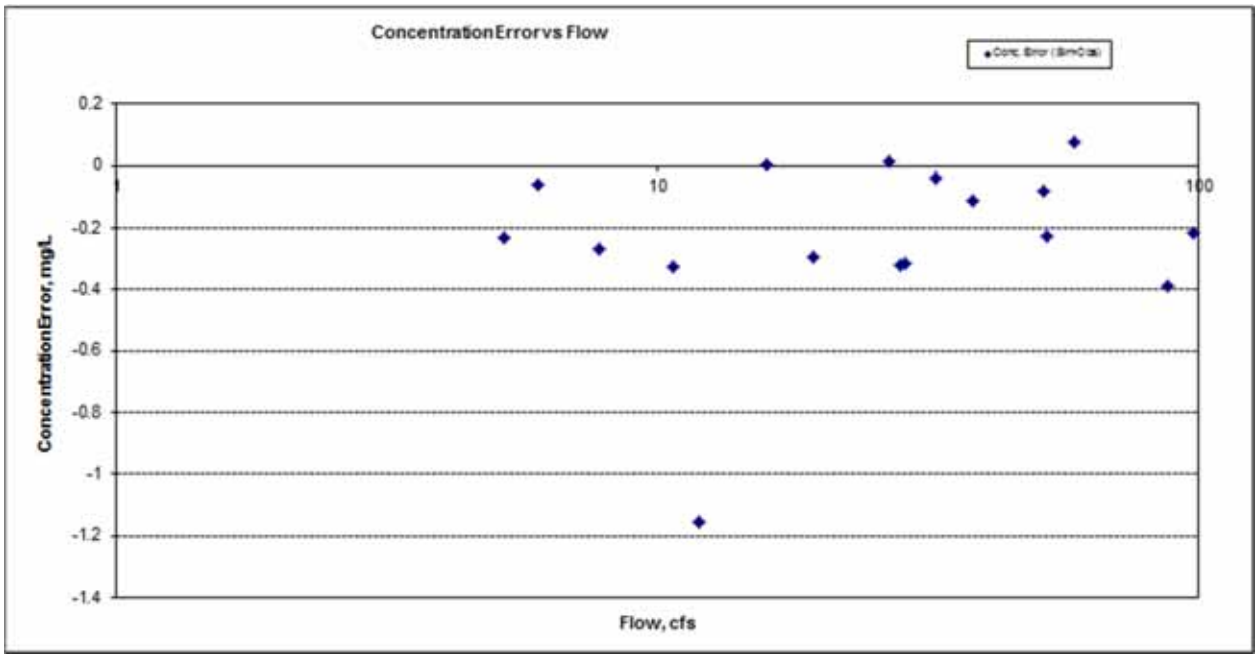


Figure A-56. Observed and Modeled TN Daily Paired Concentration, Ashley Creek at AC-6.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-57. Observed and Modeled TN Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-6.

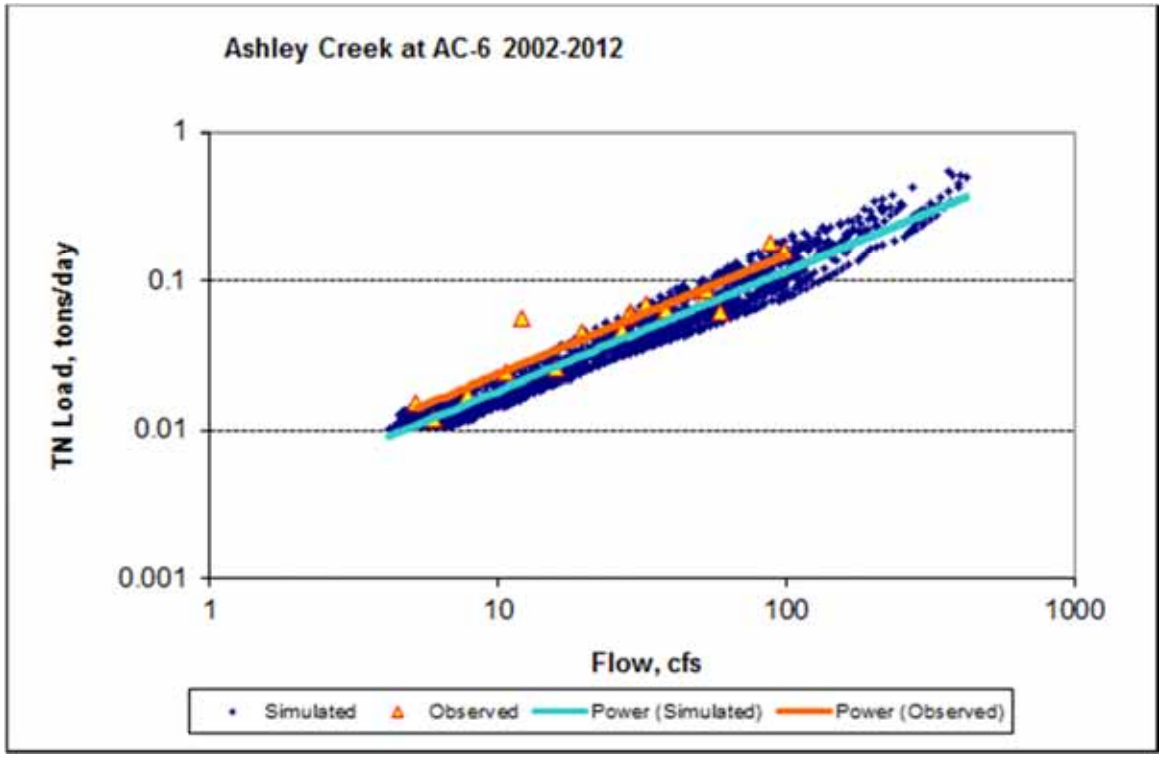


Figure A-58. Observed and Modeled TN Load vs. Flow, Ashley Creek at AC-6.

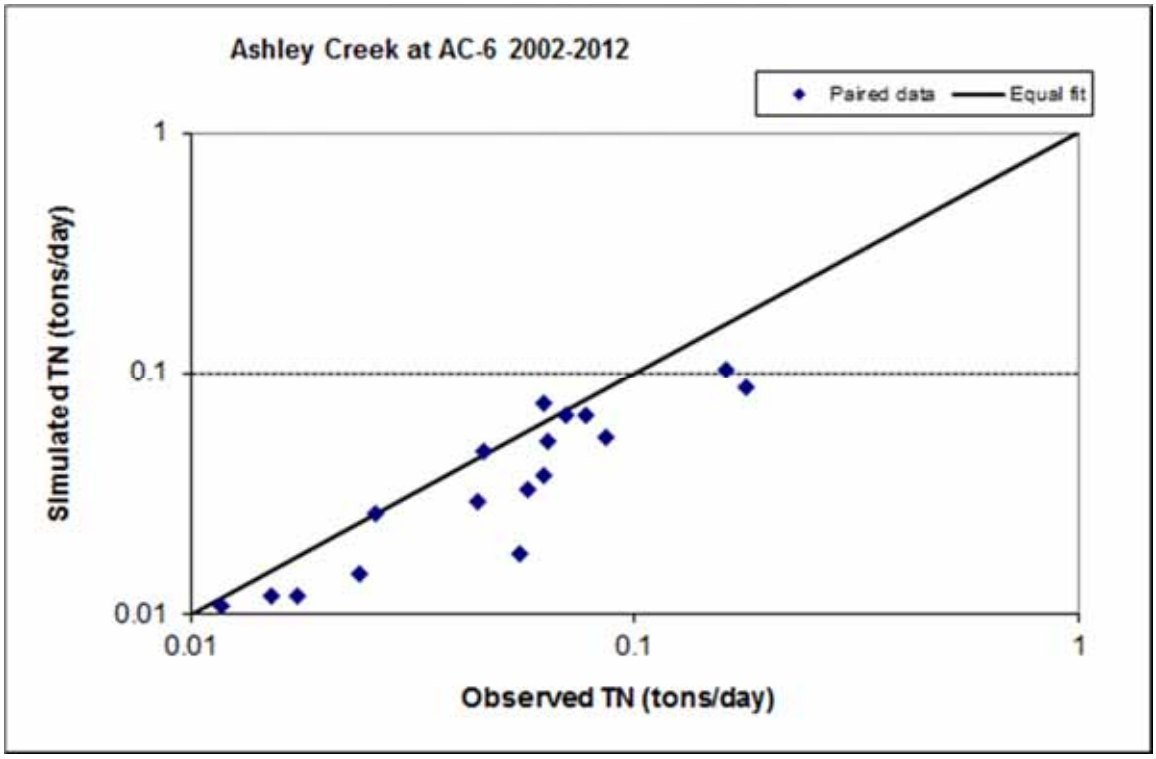


Figure A-59. Observed and Modeled TN Daily Paired Load, Ashley Creek at AC-6.

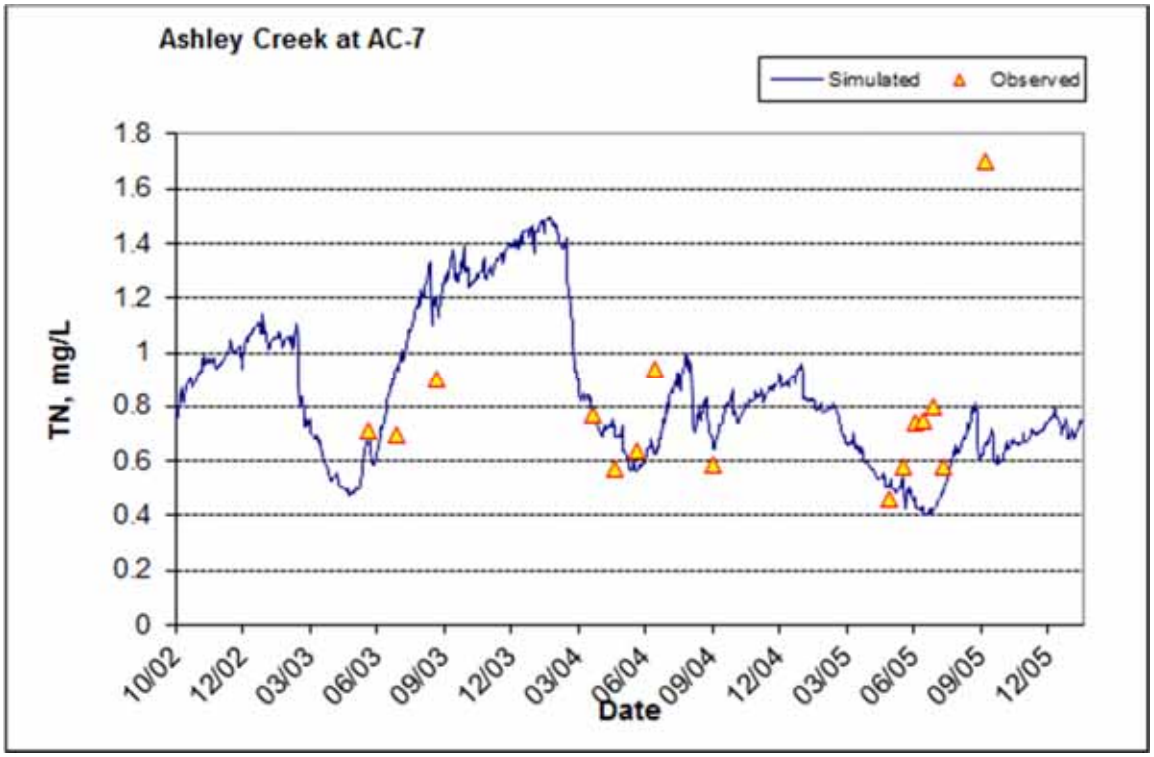


Figure A-60. Observed and Modeled TN Time series Oct. 2002 through Feb. 2006, Ashley Creek at AC-7.

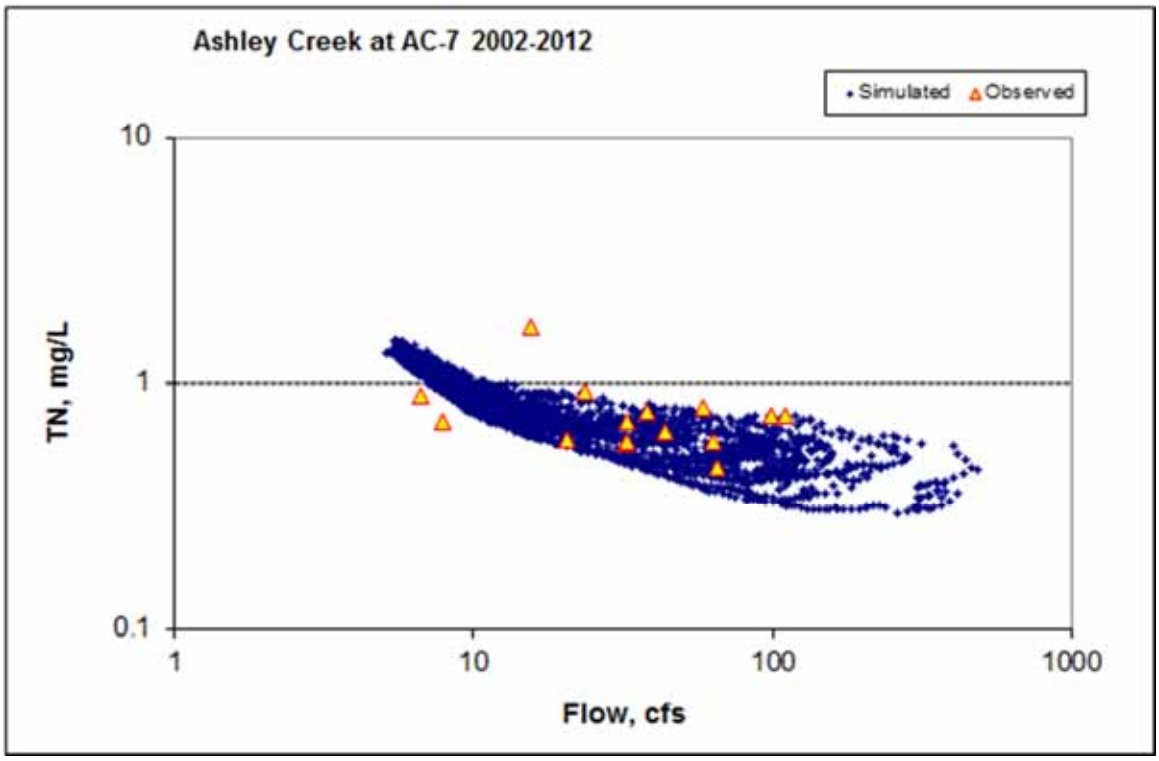


Figure A-61. Observed and Modeled TN Concentration vs. Flow, Ashley Creek at AC-7.

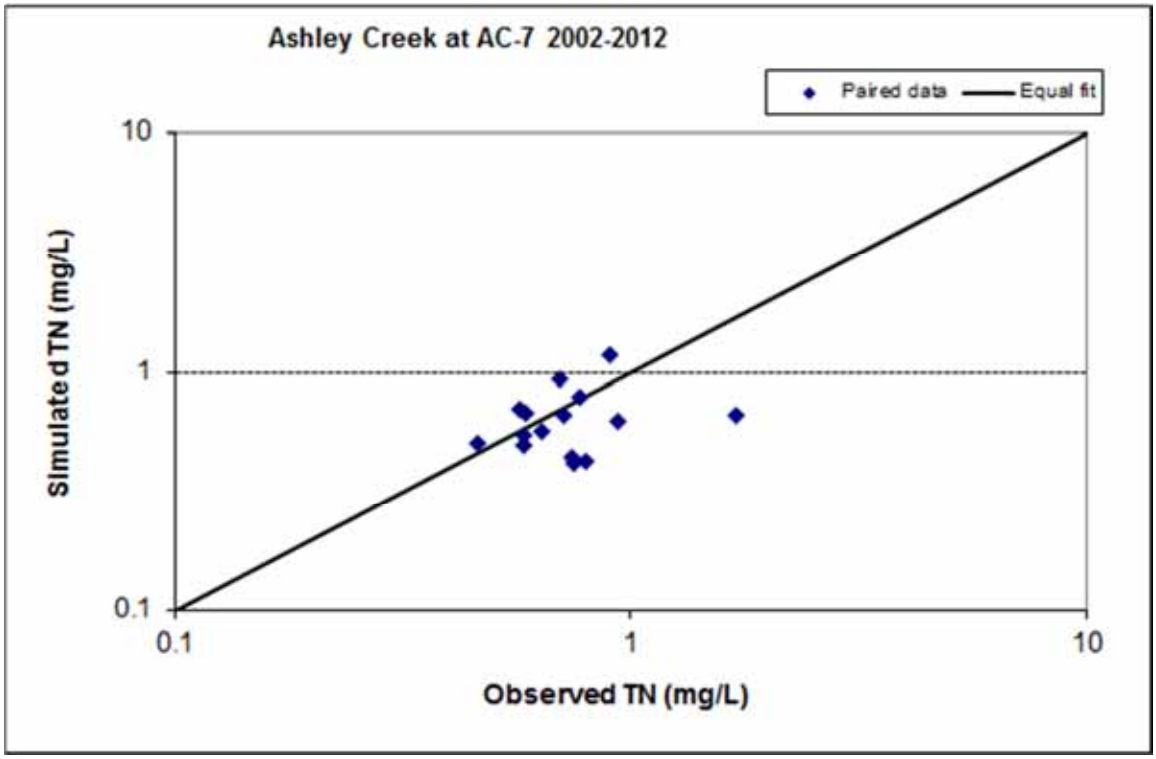
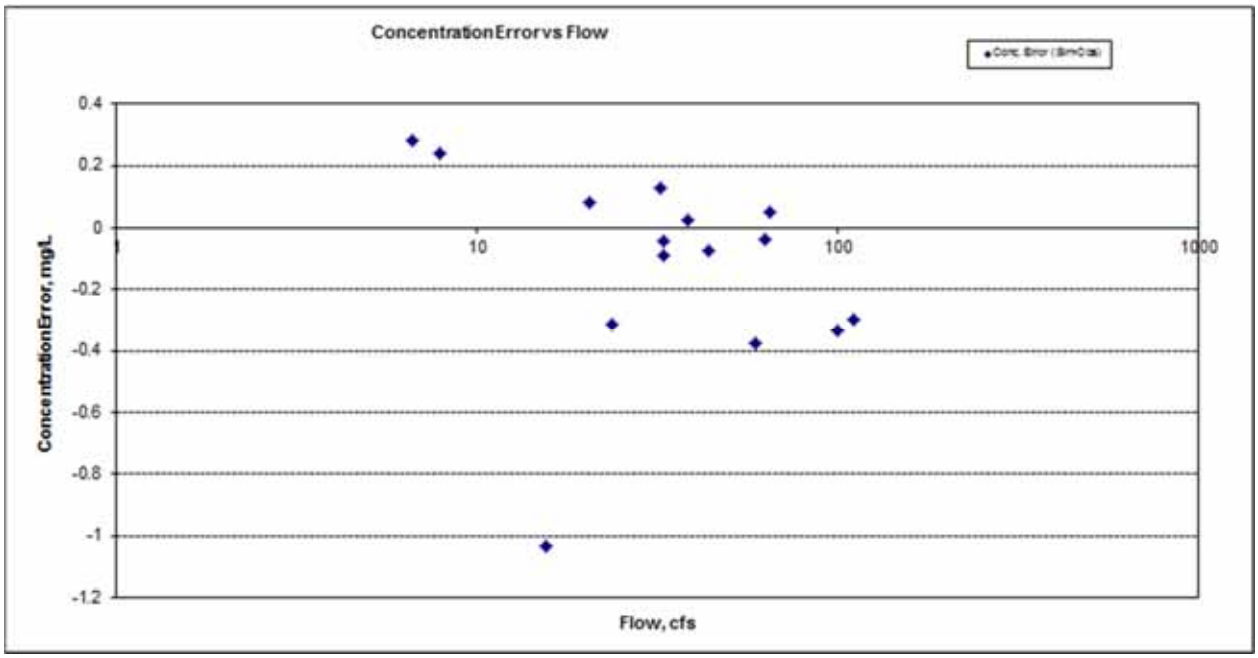


Figure A-62. Observed and Modeled TN Daily Paired Concentration, Ashley Creek at AC-7.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-63. Observed and Modeled TN Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-7.

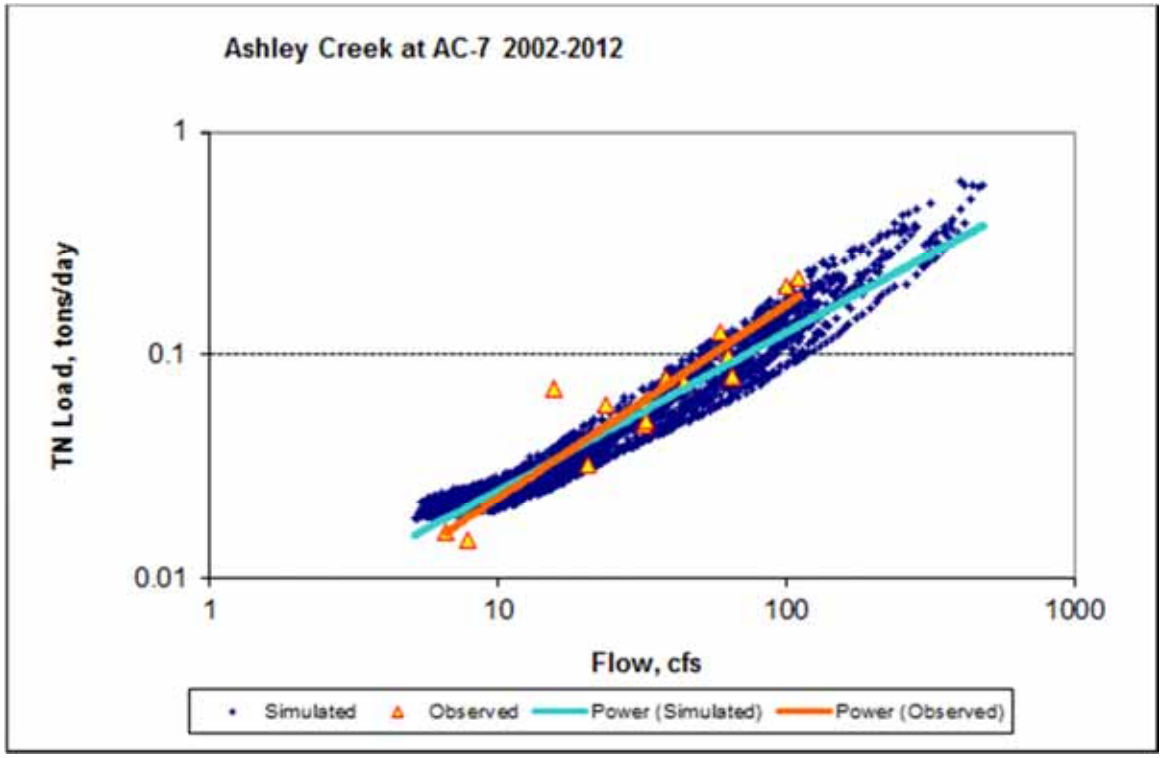


Figure A-64. Observed and Modeled TN Load vs. Flow, Ashley Creek at AC-7.

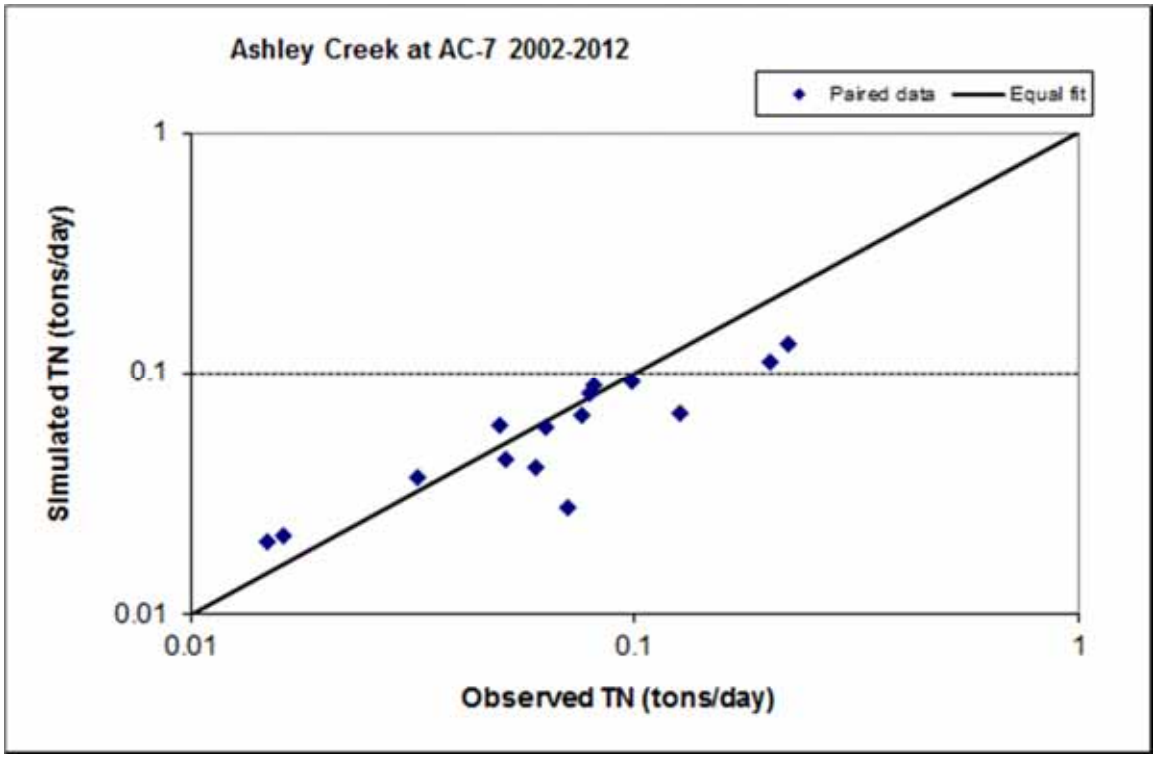


Figure A- 65. Observed and Modeled TN Daily Paired Load, Ashley Creek at AC-7.

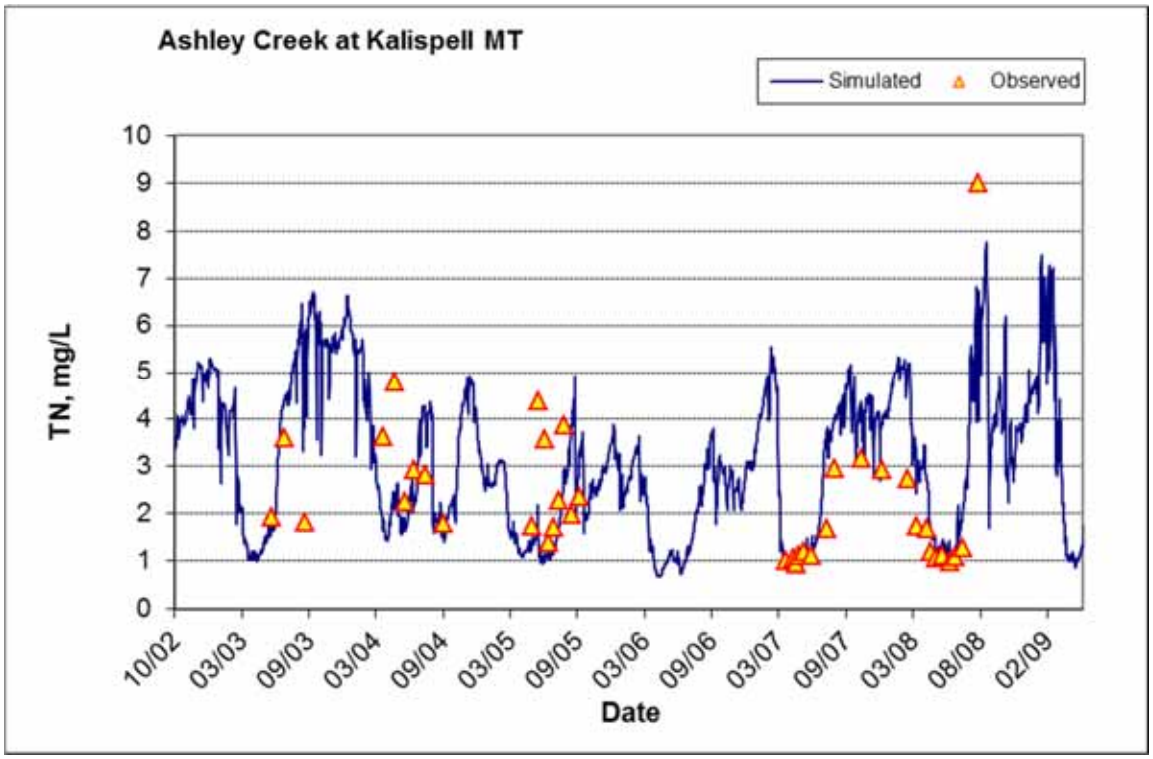


Figure A-66. Observed and Modeled TN Time series Oct. 2002 through May 2009, Ashley Creek near 12367800.

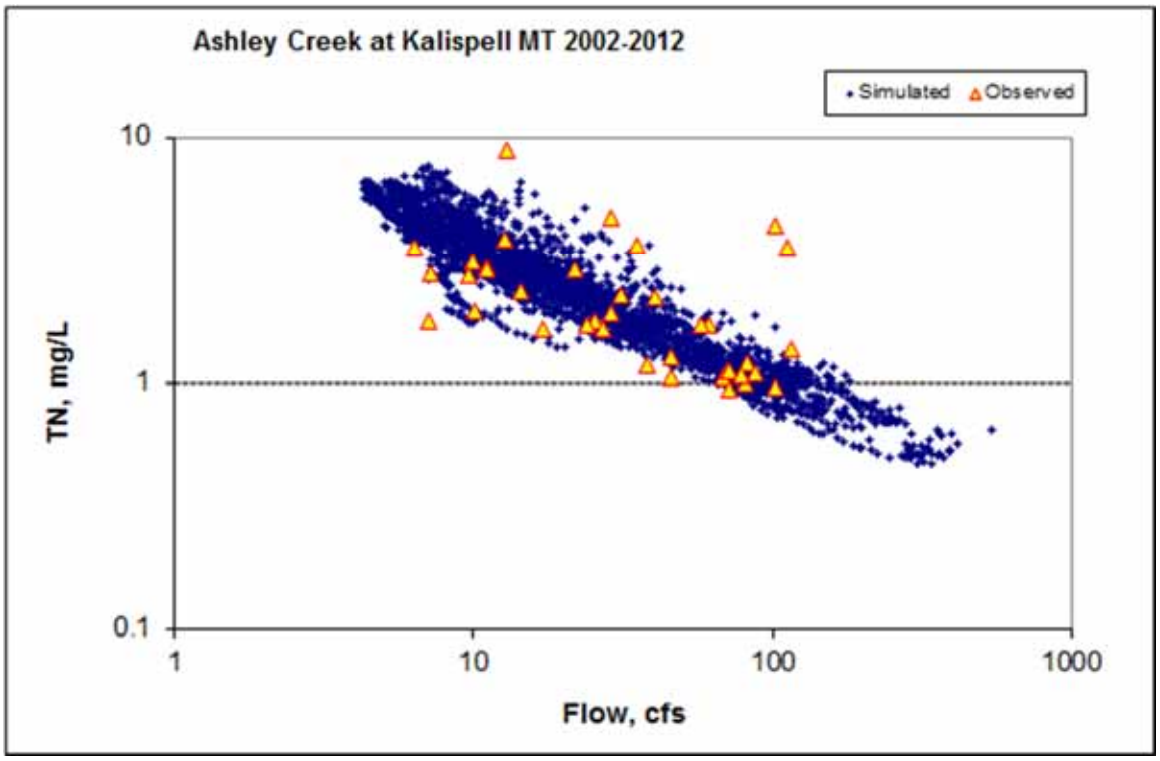


Figure A-67. Observed and Modeled TN Concentration vs. Flow, Ashley Creek near 12367800.

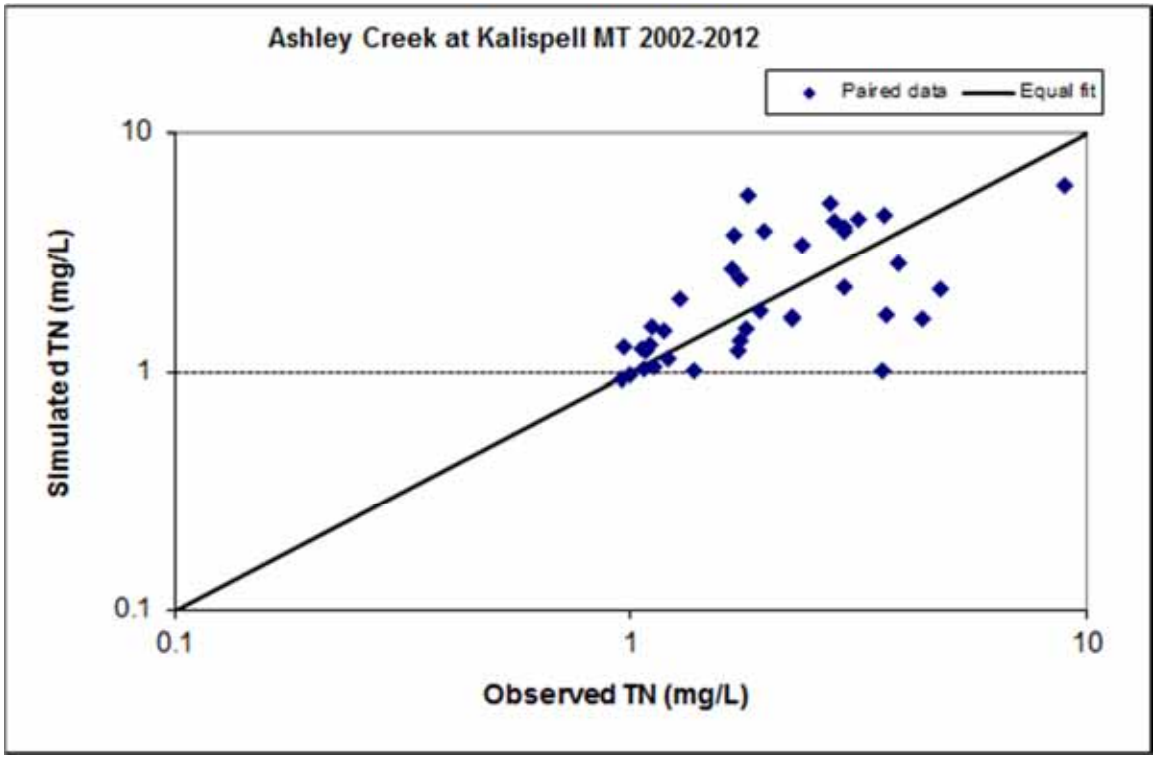
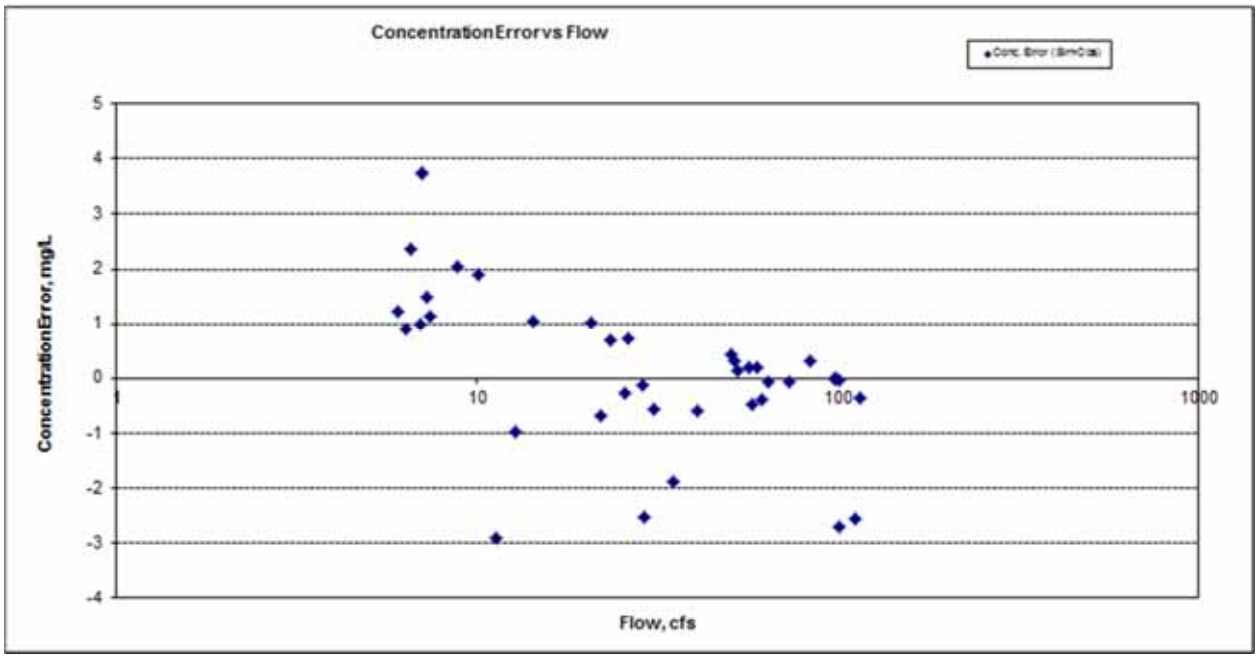


Figure A- 68. Observed and Modeled TN Daily Paired Concentration, Ashley Creek near 12367800.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A- 69. Observed and Modeled TN Daily Paired Concentration Error vs. Flow, Ashley Creek near 12367800.

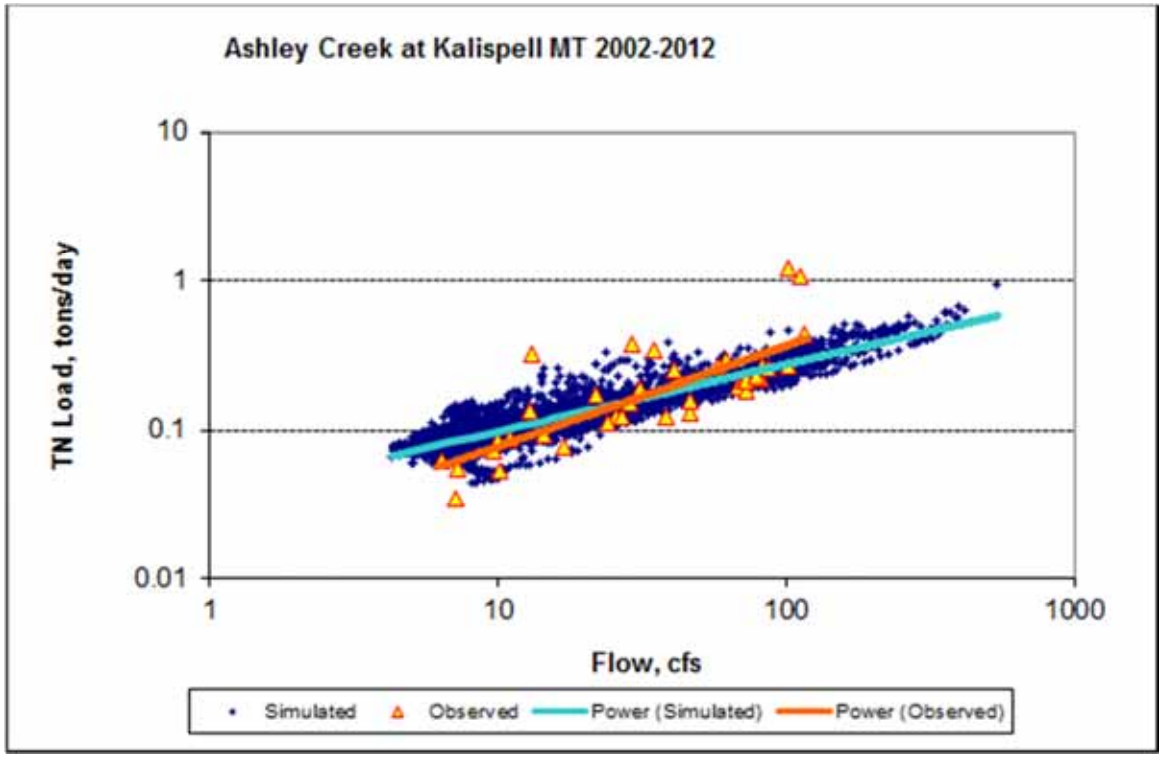


Figure A-70. Observed and Modeled TN Load vs. Flow, Ashley Creek near 12367800.

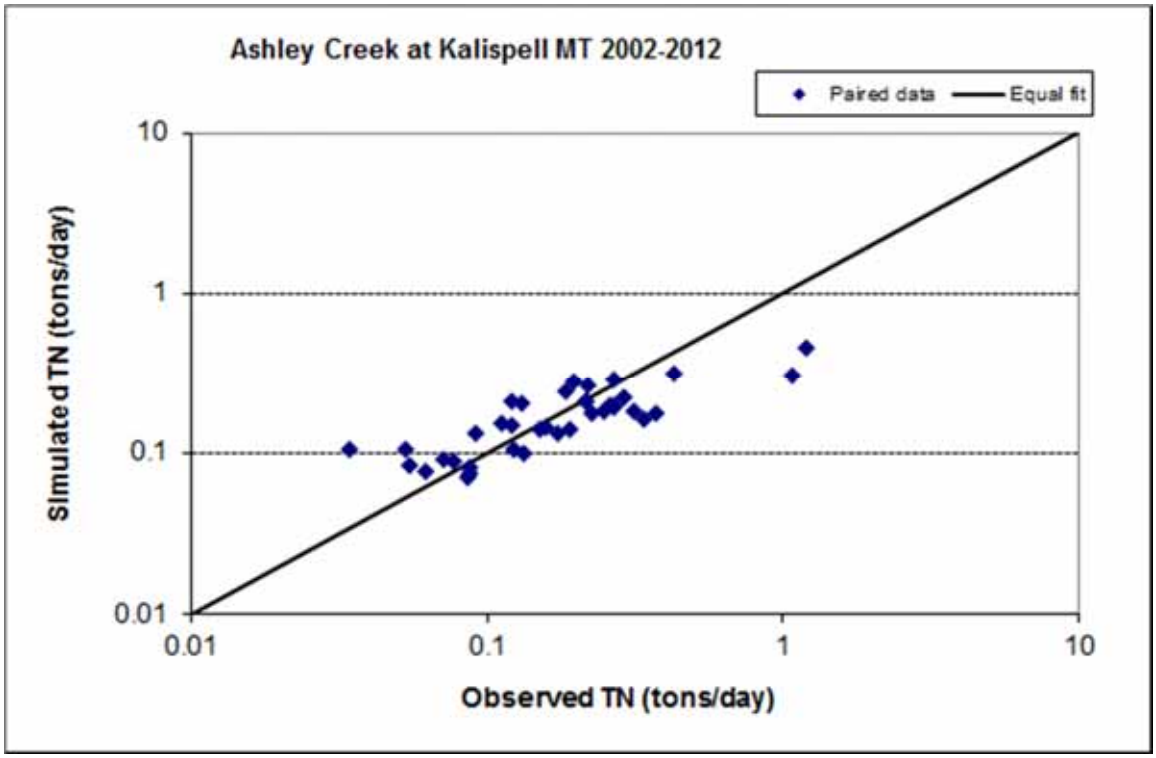


Figure A-71. Observed and Modeled TN Daily Paired Load, Ashley Creek near 12367800.

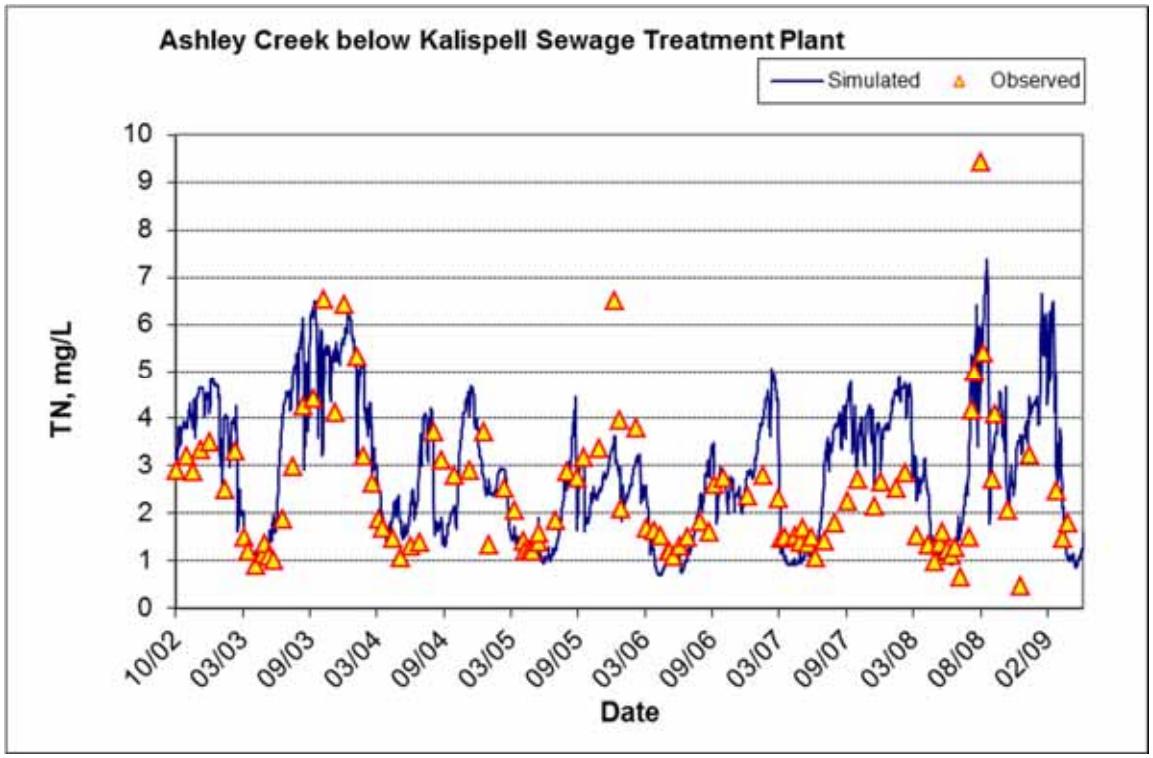


Figure A-72. Observed and Modeled TN Time series Oct. 2002 through May 2009, Ashley Creek near FBC05003.

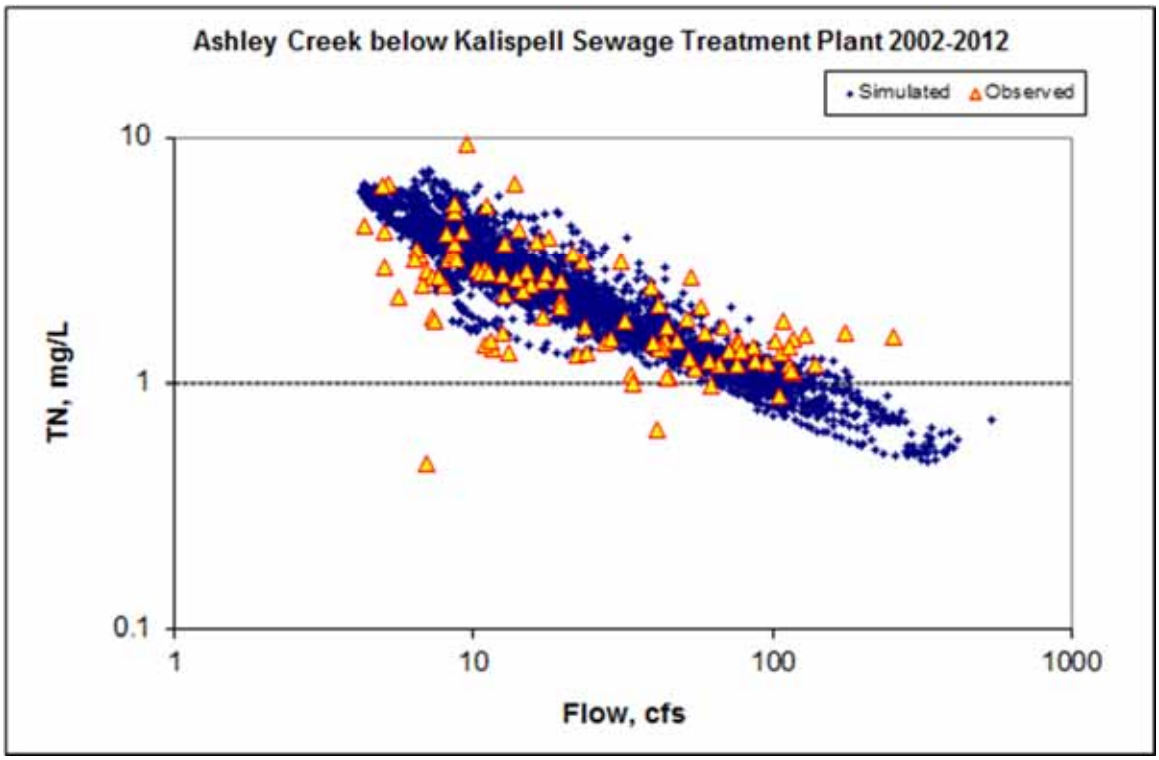


Figure A-73. Observed and Modeled TN Concentration vs. Flow, Ashley Creek near FBC05003.

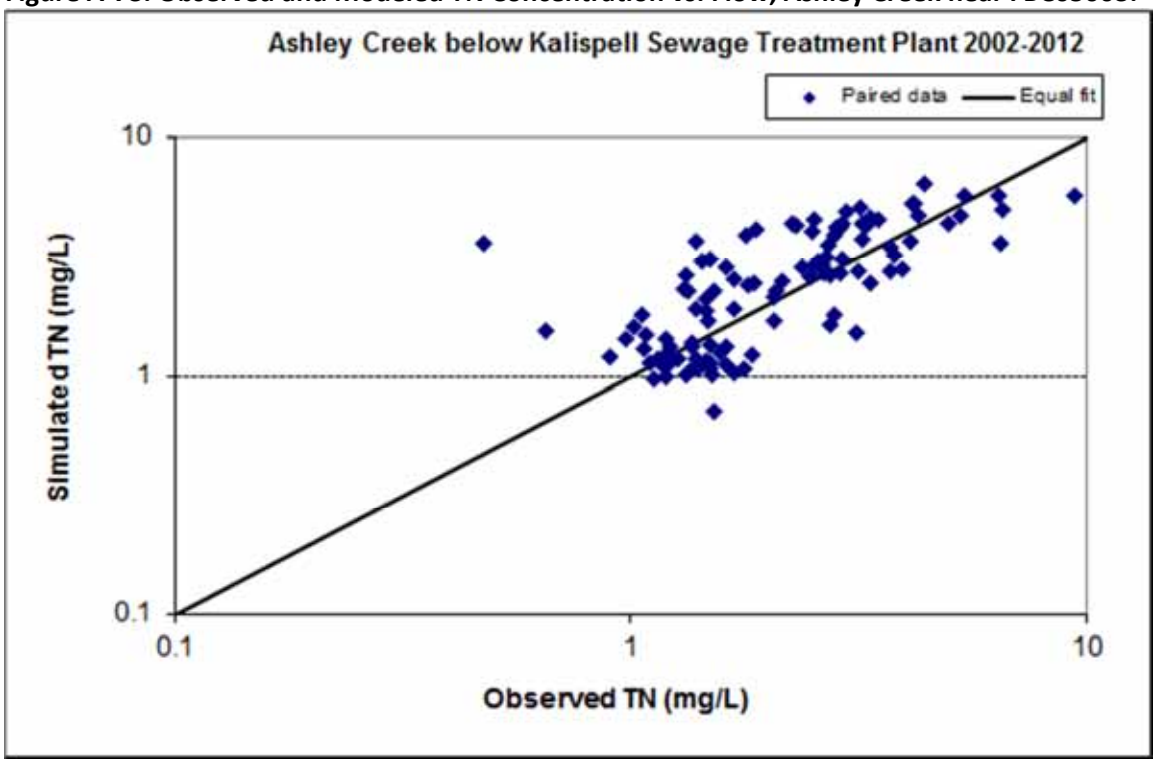


Figure A-74. Observed and Modeled TN Daily Paired Concentration, Ashley Creek near FBC05003.

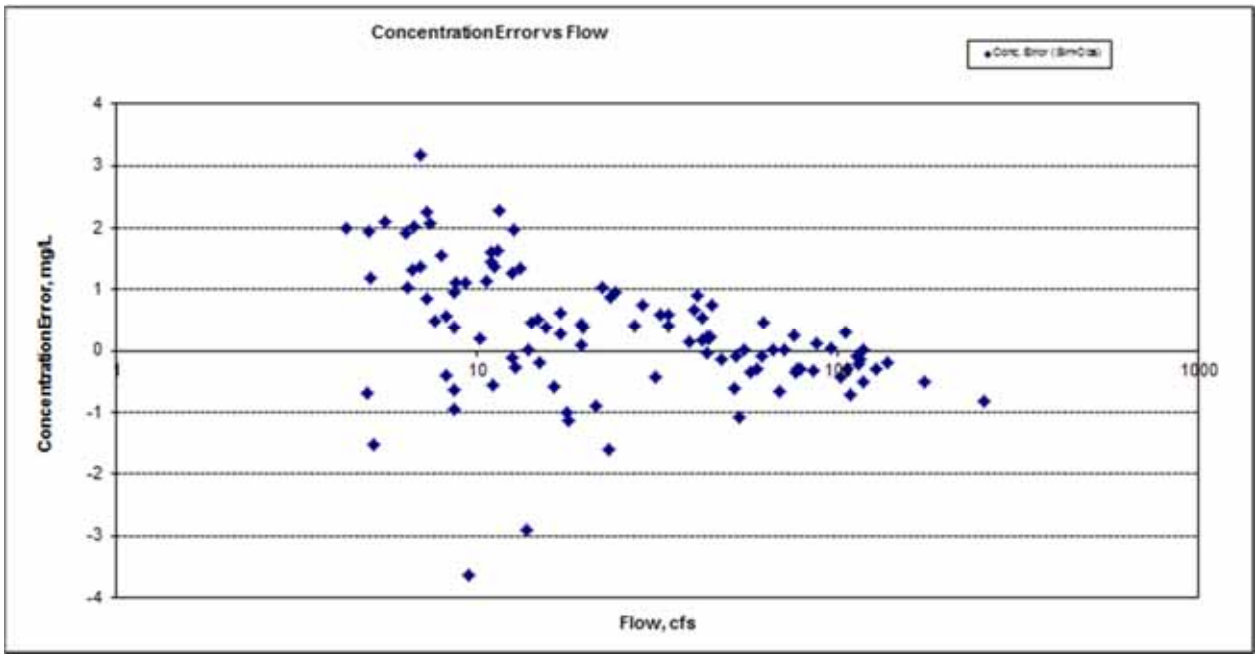


Figure A-75. Observed and Modeled TN Daily Paired Concentration Error vs. Flow, Ashley Creek near FBC05003.

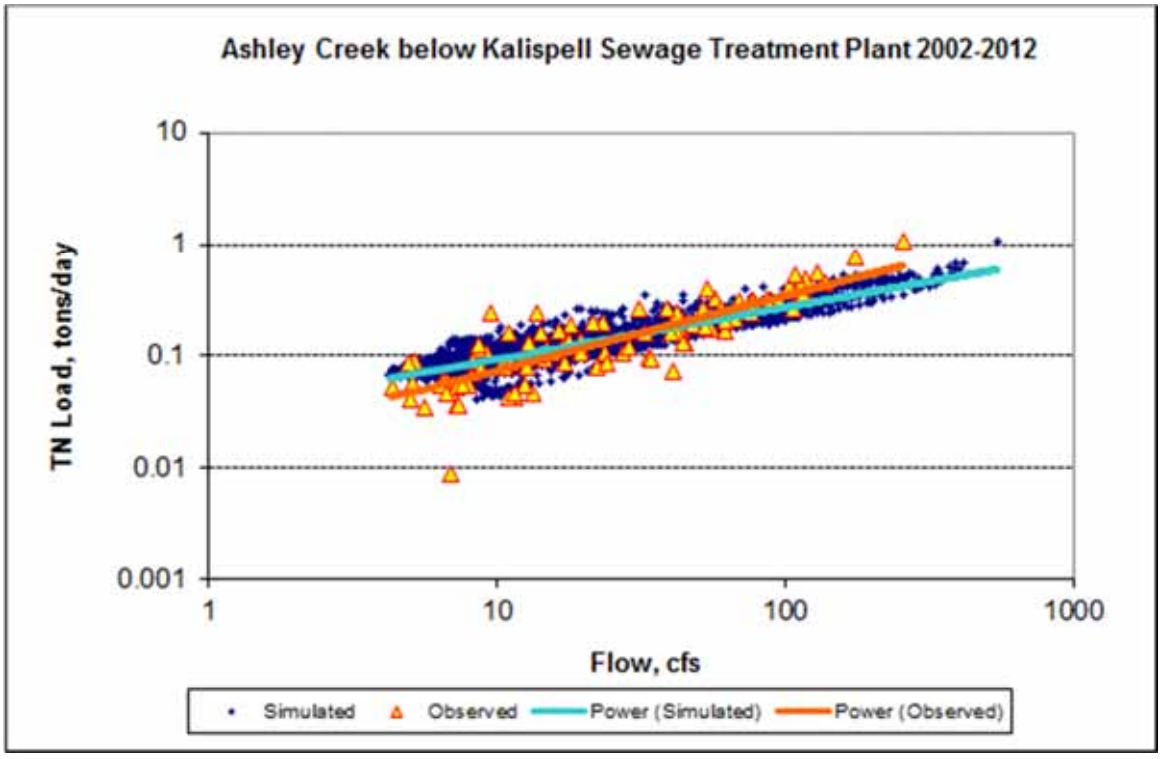


Figure A-76. Observed and Modeled TN Load vs. Flow, Ashley Creek near FBC05003.

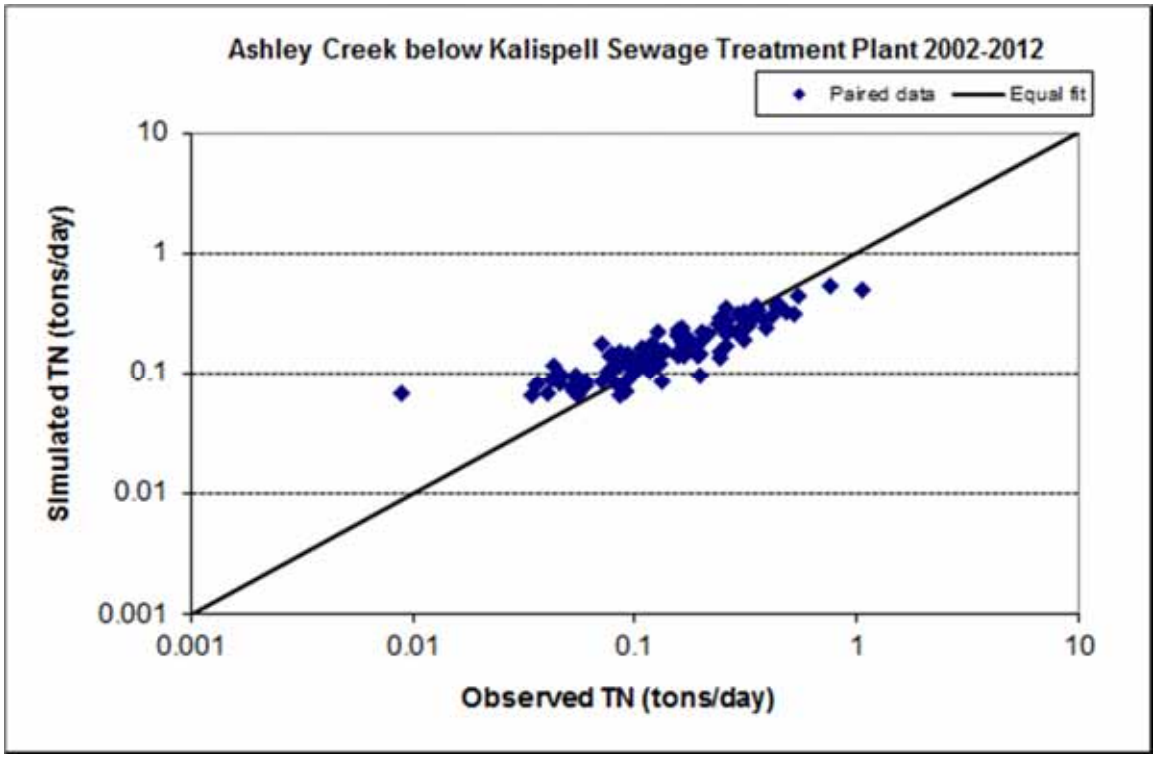


Figure A-77. Observed and Modeled TN Daily Paired Load, Ashley Creek near FBC05003.

PHOSPHORUS

Table A-7 provides calibration statistics for TP. In most cases, performance is either *Good* or *Very Good*. Predictions are biased low at AC3 and AC-6 resulting in some *Poor* and *Fair* ratings, and are biased high at Ashley Creek near 12367800 resulting in two *Fair* ratings. Median Load was especially well represented, with nearly all of the ratings *Very Good*.

Table A-7. Performance for the TP Water Quality for the Ashley Creek Model

Water Quality Calibration Site	TP			
	Concentration		Load	
	Average	Median	Average	Median
Ashley Creek at AC-1 (SWS 2082)	8%	18%	6%	7%
Ashley Creek at AC-3 (SWS 2079)	-50%	-42%	-28%	-24%
Ashley Creek near AC-5 (SWS 2068)	-6%	3%	-15%	1%
Ashley Creek at AC-6 (SWS 2067)	-26%	-19%	-32%	-8%
Ashley Creek at AC-7 (SWS 2066)	-7%	-10%	-11%	-11%
Ashley Creek near 12367800 (SWS 2064)	35%	27%	22%	3%
Ashley Creek near FBC05003 (SWS 2063)	7%	15%	-20%	4%

At AC-1 (**Figure A-78** through **Figure A-83**), the model predicts a nearly constant concentration of 0.014 mg/L from the Ashley Lake outflow. In contrast to TN, simulated values are comparable to observations, which range from 0.008 to 0.026 mg/L (**Figure A-78** and **Figure A-79**). Loads are well represented (**Figure A-82** and **Figure A-83**).

Model predictions at AC-3 show more variability, but observations are consistently under-predicted (**Figure A-84** through **Figure A-89**). Concentration is nearly constant across the range of flows for both the observations and modeled values (**Figure A-85**). It is important to note that observed concentrations are low at this location, averaging about 0.016 mg/L. While the relative error is large, the average absolute error is about 0.008 mg/L (**Figure A-87**).

TP near AC-5 (**Figure A-90** through **Figure A-95**) is strongly influenced by Smith Lake, so as a result both simulated and observed values show relatively little variation (**Figure A-90**). The distribution of concentration across the range of flows is well replicated (**Figure A-91**). Loads are well represented (**Figure A-94** and **Figure A-95**).

As noted previously, some of the performance measures at AC-6 (**Figure A-96** through **Figure A-101**) rated Fair with a tendency for the model to under-predict average values. This trend is more difficult to discern in the plots; for instance, the time series (**Figure A-96**) and concentration/load versus flow plots (**Figure A-97** and **Figure A-100**, respectively) suggest a good agreement between modeled and observed values. However, the bias can be seen in the paired simulated versus observed plots (**Figure A-98** and **Figure A-101**). As was the case at AC-3, the absolute error is low at an average of 0.008 mg/L.

AC-7 shows good agreement between modeled and observed values (**Figure A-102** through **Figure A-107**). Concentration distributions are well replicated (**Figure A-102**, **Figure A-103**, and **Figure A-104**), and loads show a tight fit (**Figure A-106** and **Figure A-107**).

At Ashley Creek near 12367800 (**Figure A-108** through **Figure A-113**), concentrations are over-predicted with an average error of 0.011 mg/L. Higher simulated values are apparent in the time series plot (**Figure A-115**), the concentration versus flow plot (**Figure A-109**), and the paired simulated versus observed plot (**Figure A-110**). However, the load error is less (**Figure A-112** and **Figure A-113**).

Performance measures at Ashley Creek below Kalispell WWTP (**Figure A-114** through **Figure A-120**) rate *Good* or *Very Good*. There is some scatter between simulated and observed values when comparing the time series plots (**Figure A-114** and **Figure A-115**), but that is not surprising since the model representation of the WWTP does not capture daily variation in effluent concentrations. However, the remaining plots suggest that the model over-predicts TP at lower flows and under-predicts at higher flows. This can be seen most clearly in the concentration versus flow plot (**Figure A-116**) and the paired error versus flow plot (**Figure A-118**). The discrepancies appear to balance each other, resulting in the *Good* and *Very Good* performance measures.

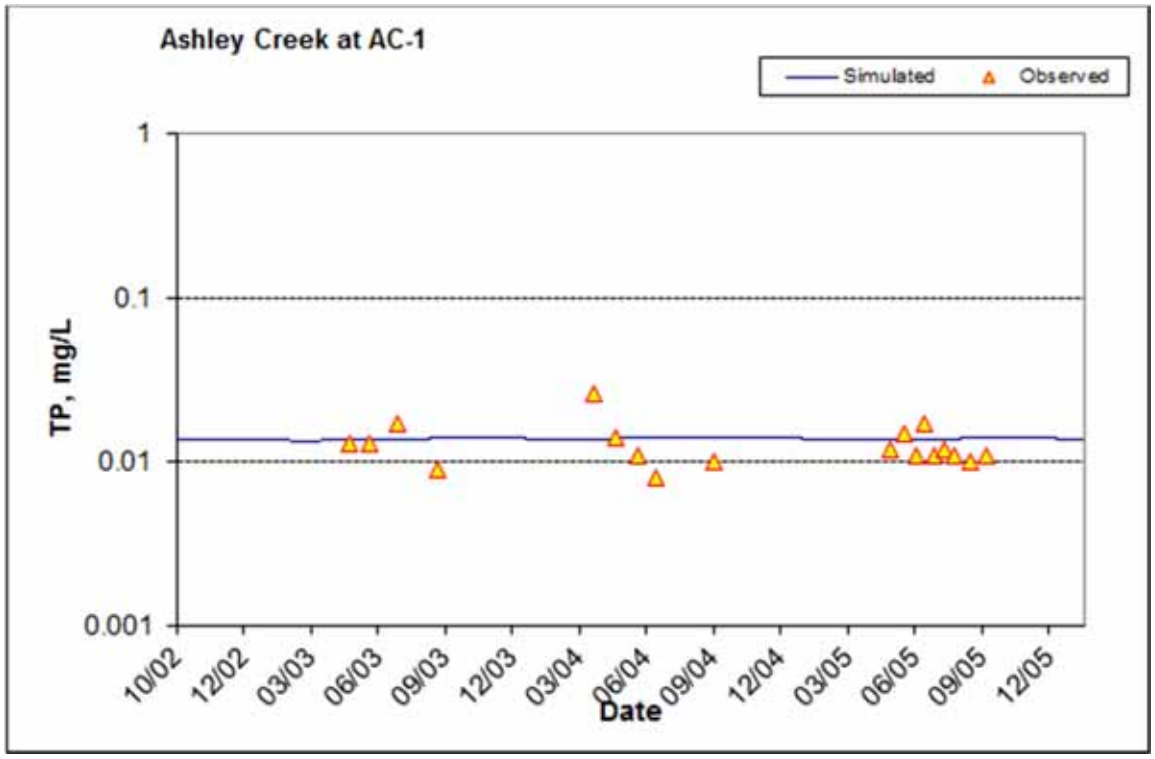


Figure A-78. Observed and Modeled TP Time series Oct. 2002 through Jan. 2006, Ashley Creek at AC-1.

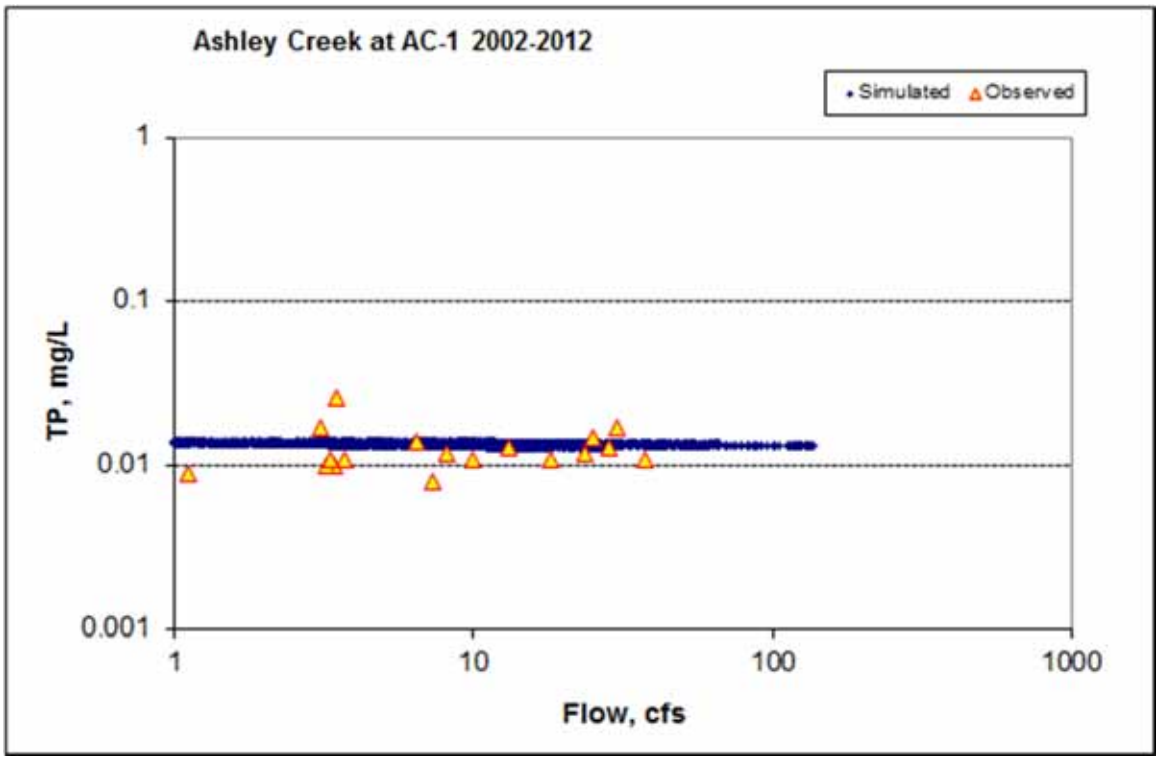


Figure A-79. Observed and Modeled TP Concentration vs. Flow, Ashley Creek at AC-1.

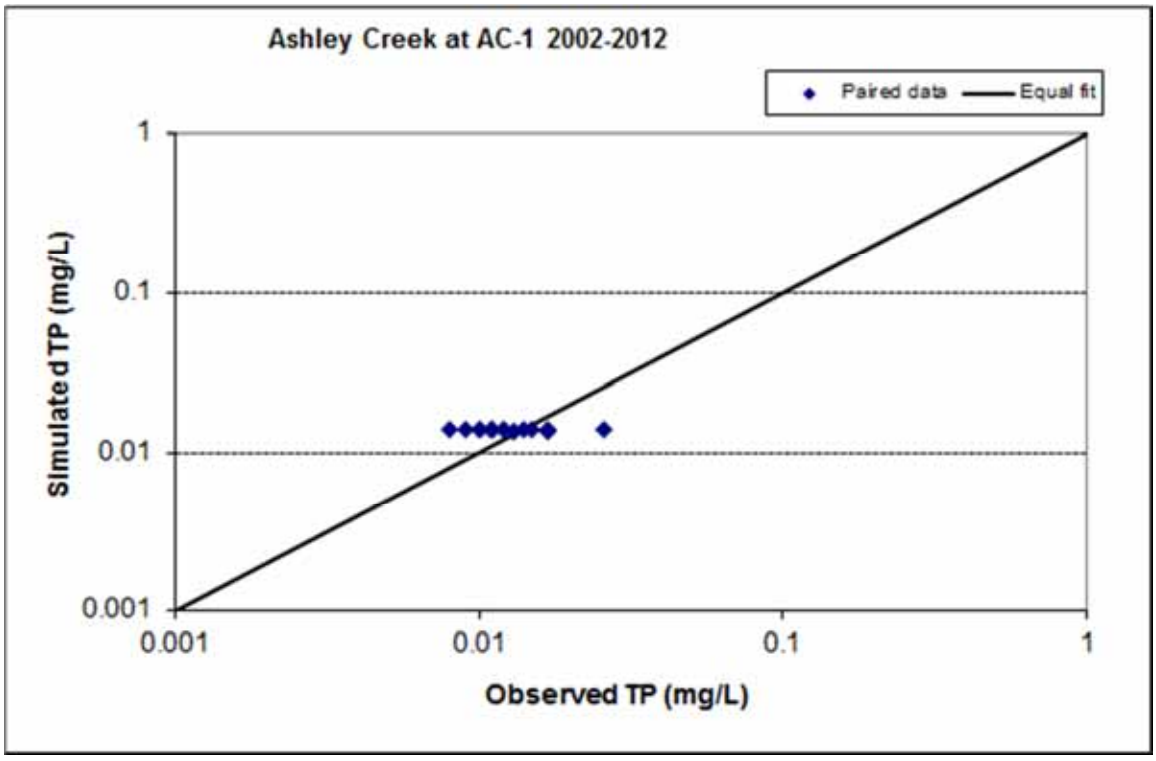
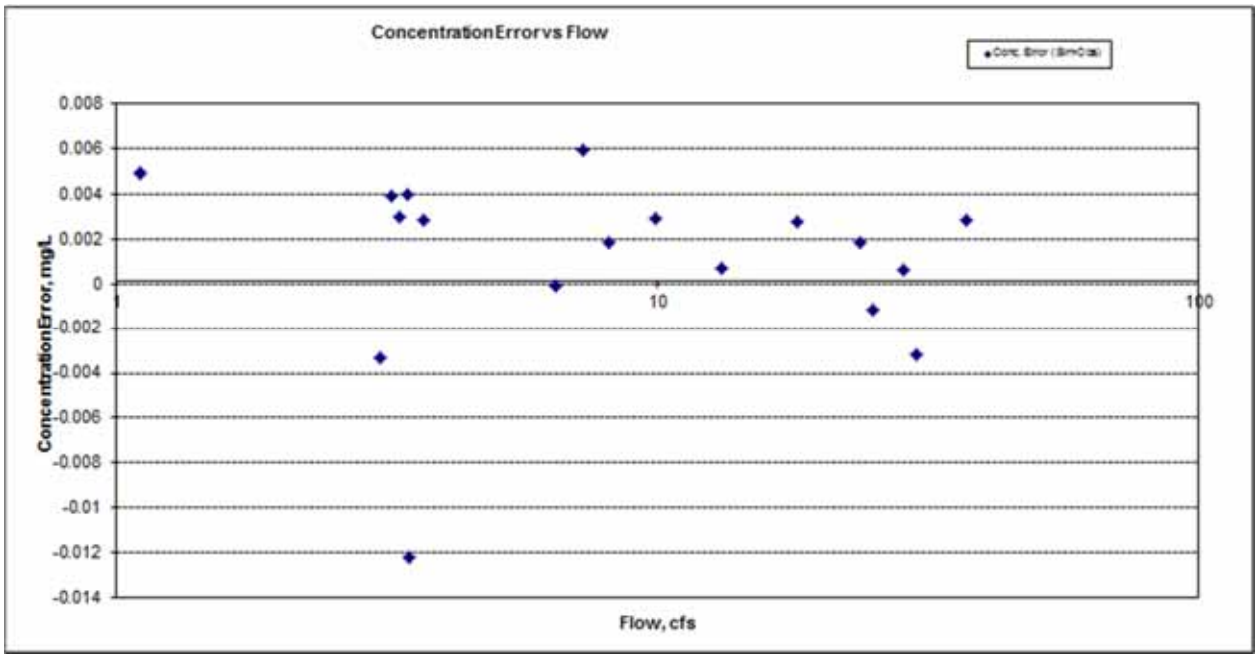


Figure A-80. Observed and Modeled TP Daily Paired Concentration, Ashley Creek at AC-1.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A- 81. Observed and Modeled TP Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-1.

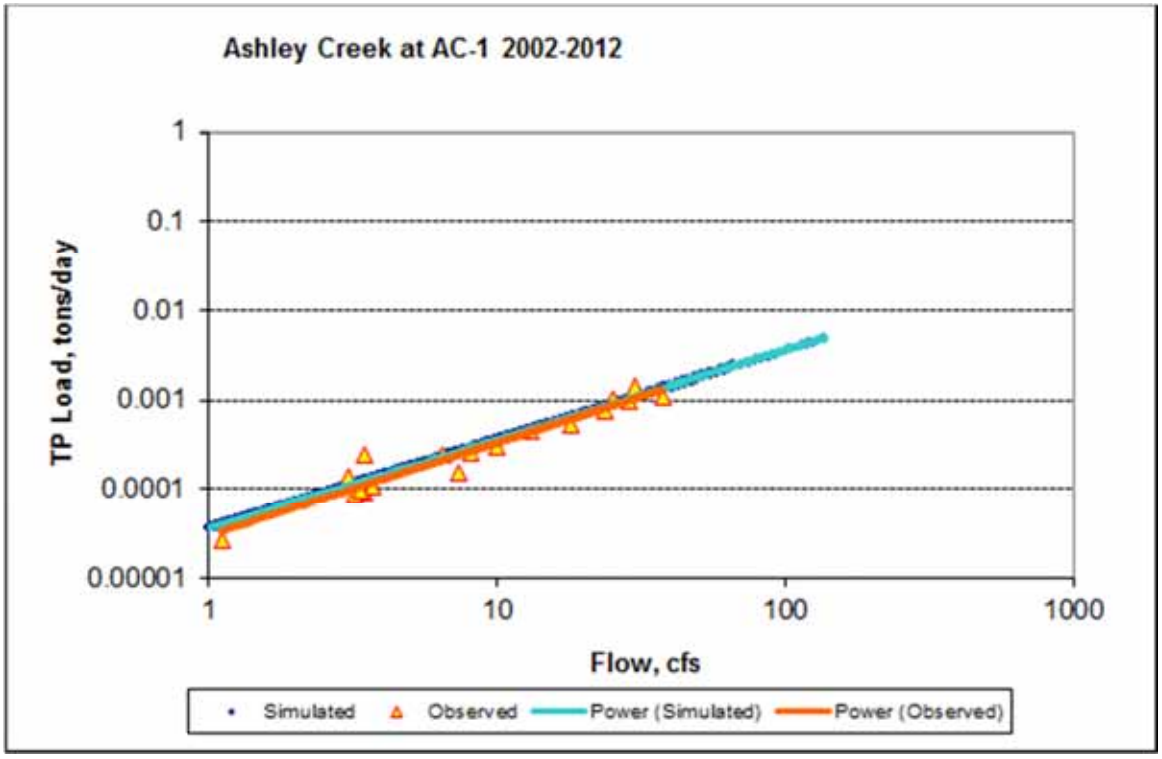


Figure A-82. Observed and Modeled TP Load vs. Flow, Ashley Creek at AC-1.

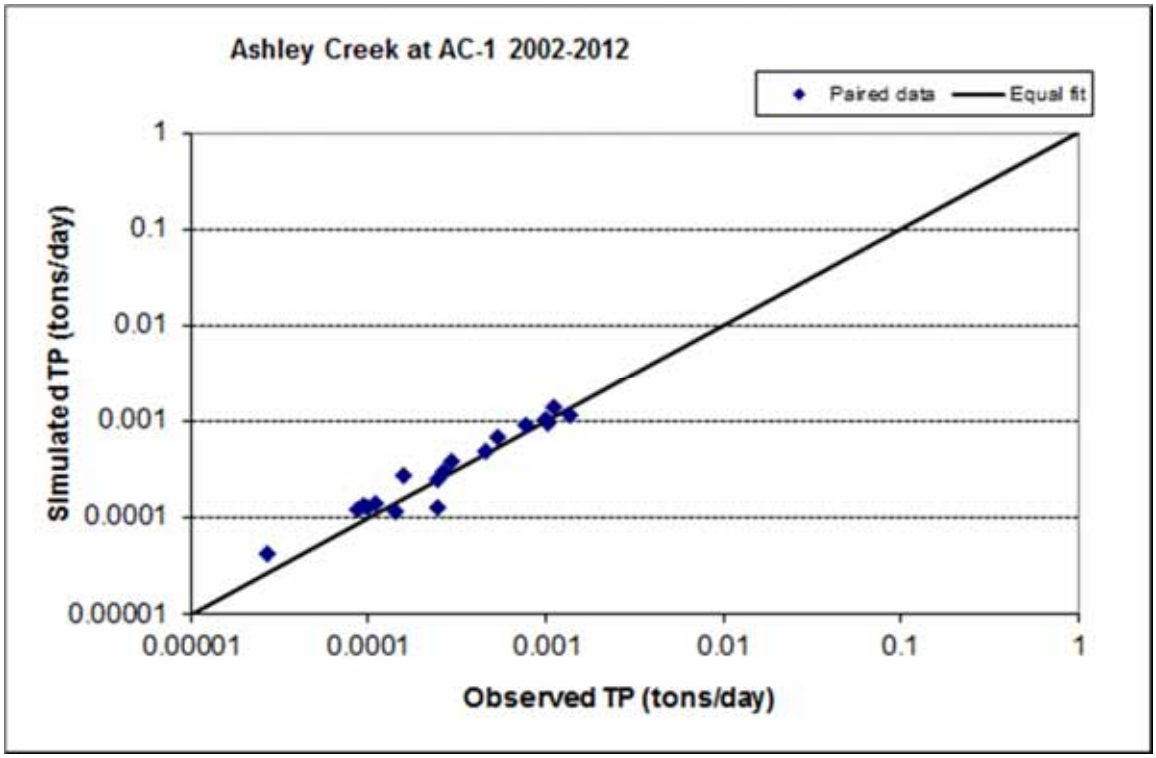


Figure A-83. Observed and Modeled TP Daily Paired Load, Ashley Creek at AC-1.

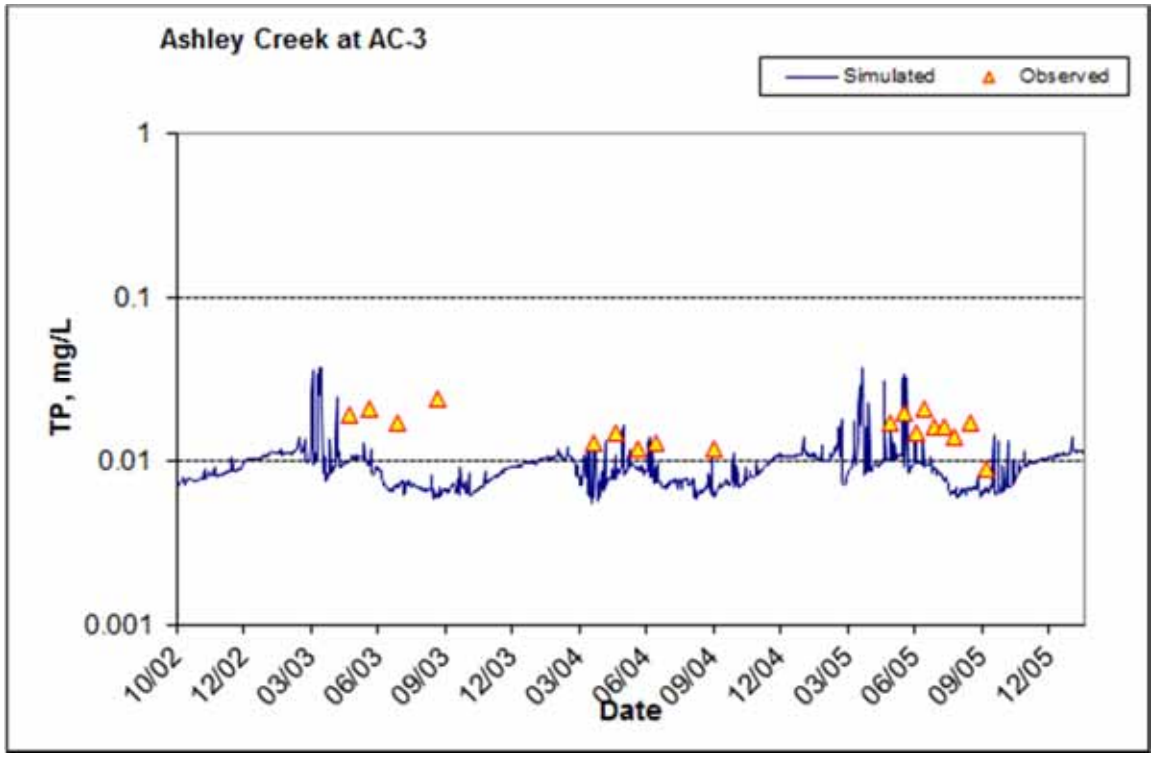


Figure A-84. Observed and Modeled TP Time series Oct. 2002 through Jan. 2006, Ashley Creek at AC-3.

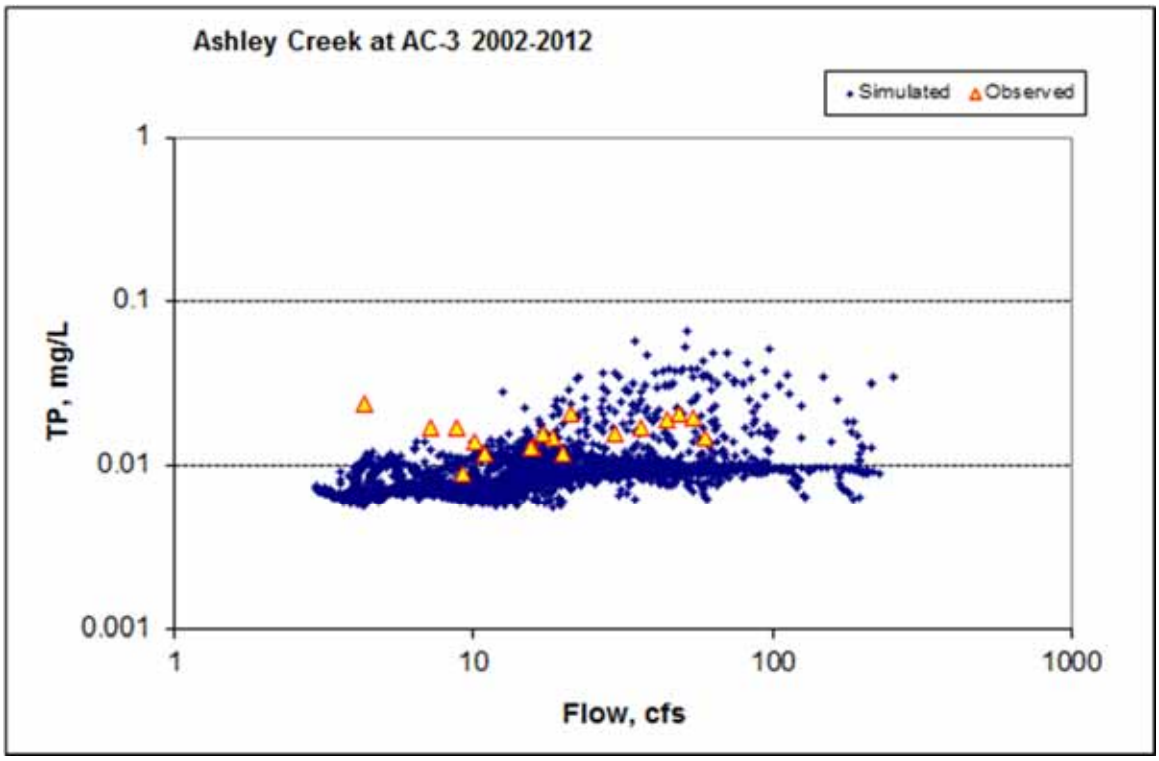


Figure A-85. Observed and Modeled TP Concentration vs. Flow, Ashley Creek at AC-3.

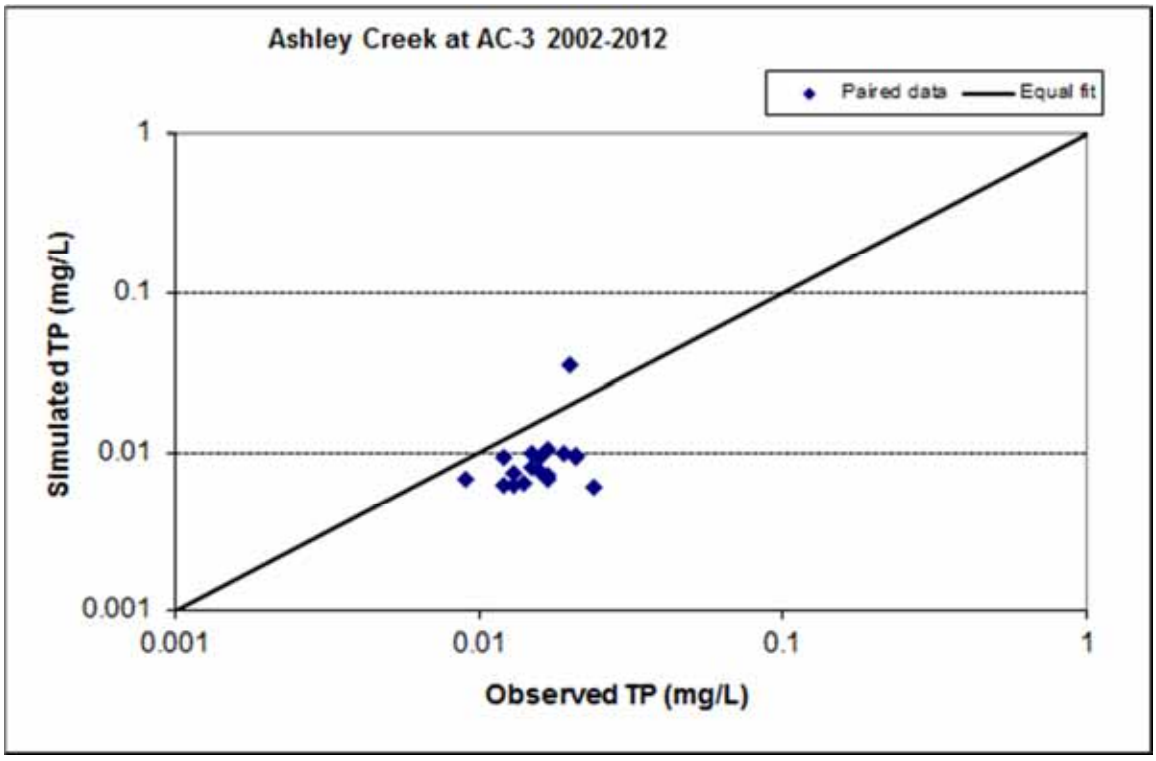
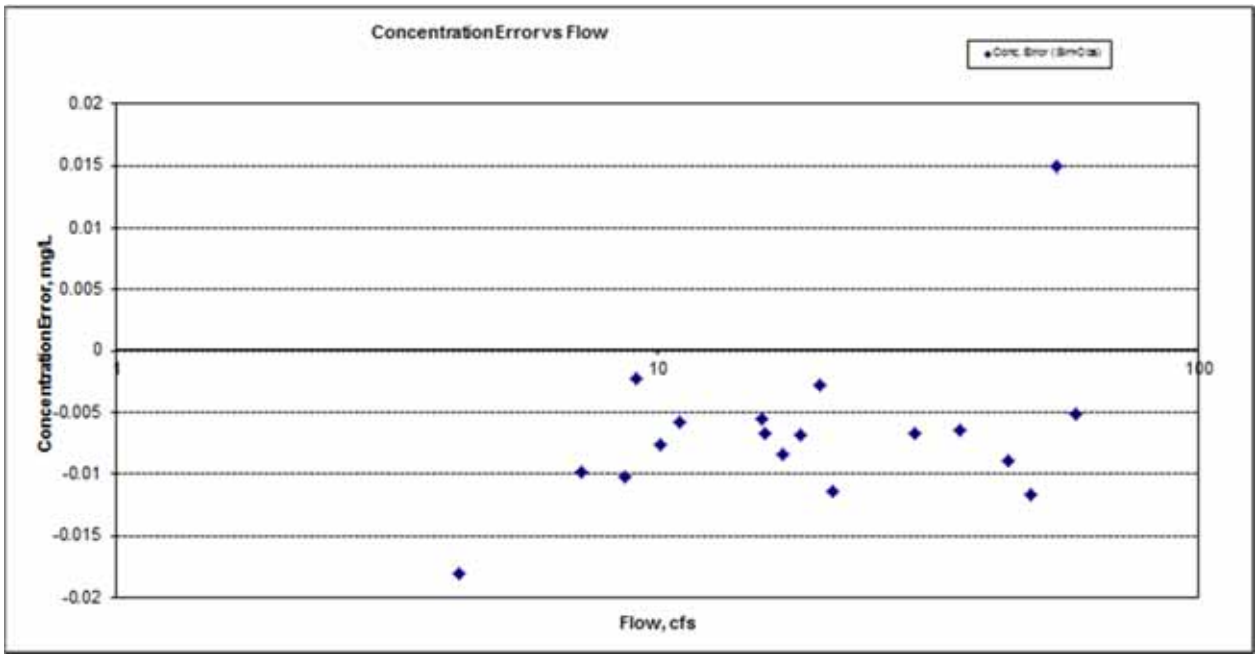


Figure A-86. Observed and Modeled TP Daily Paired Concentration, Ashley Creek at AC-3.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-87. Observed and Modeled TP Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-3.

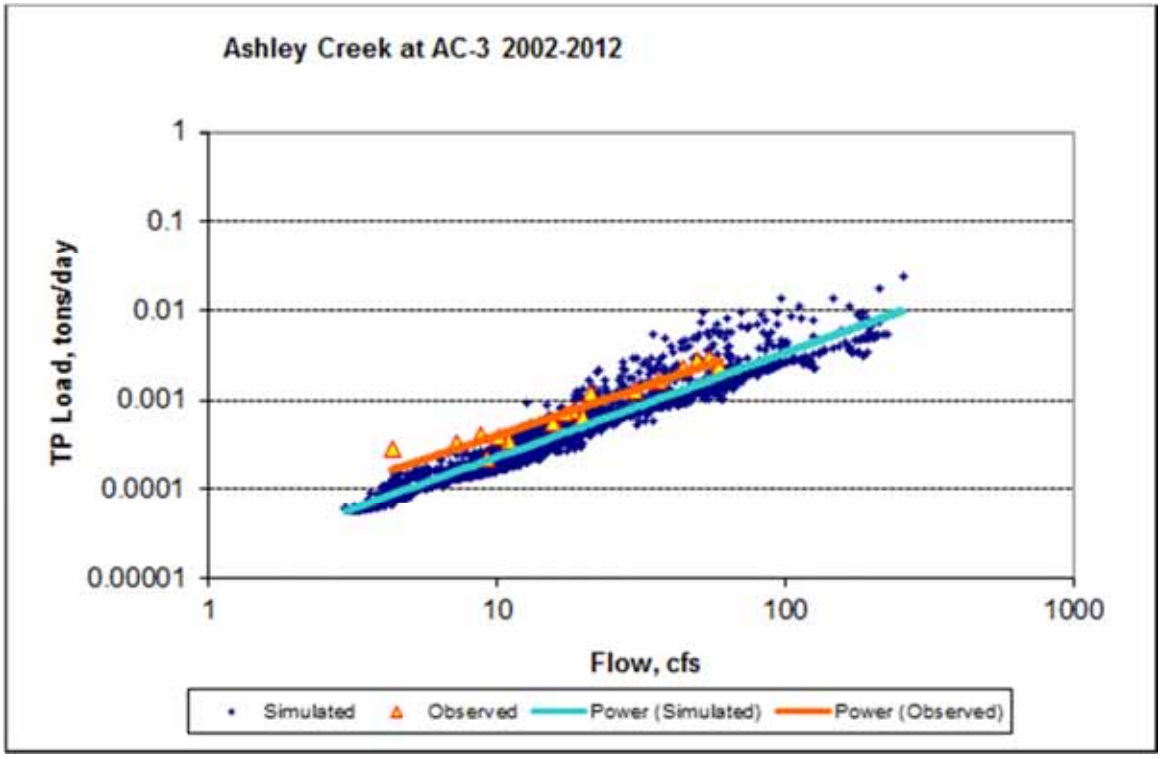


Figure A-88. Observed and Modeled TP Load vs. Flow, Ashley Creek at AC-3.

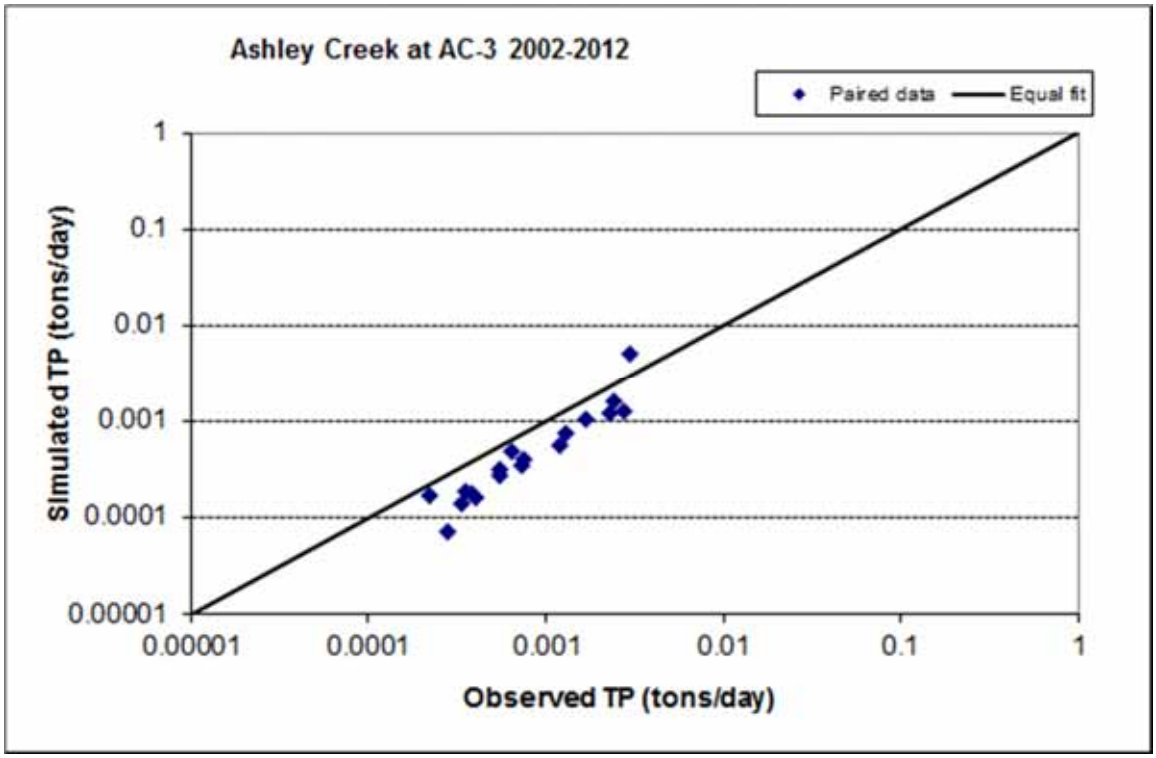


Figure A-89. Observed and Modeled TP Daily Paired Load, Ashley Creek at AC-3.

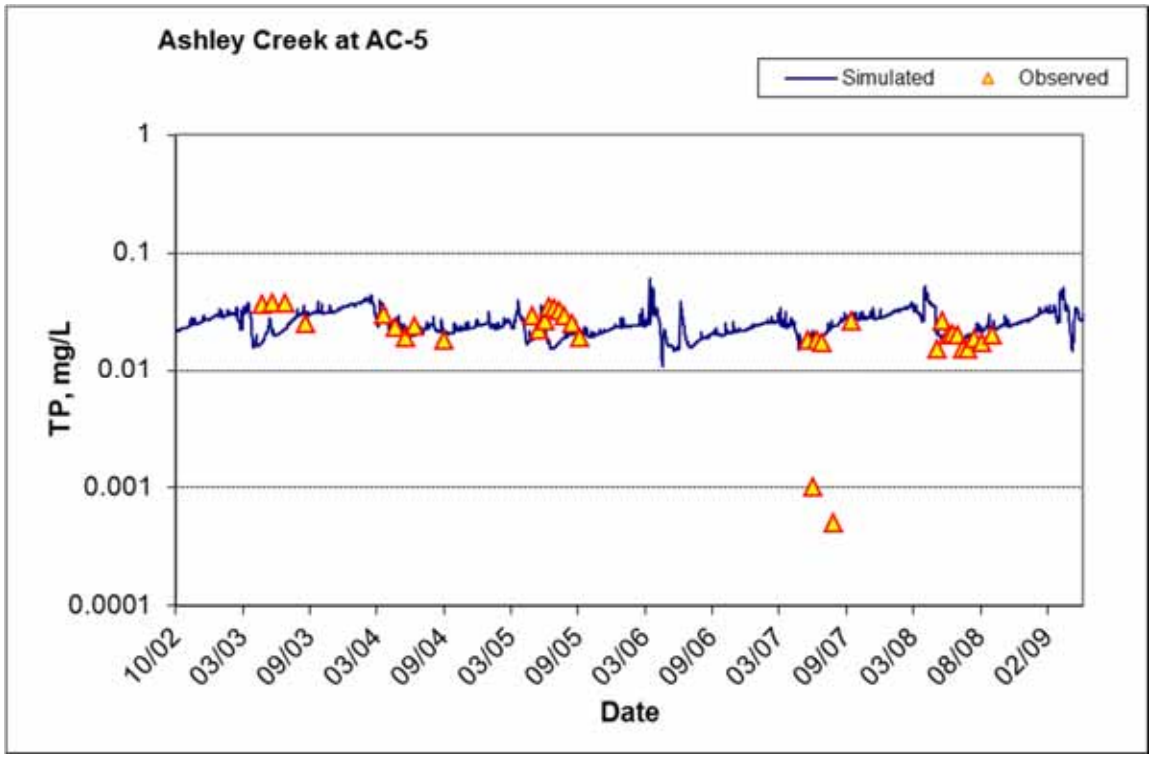


Figure A-90. Observed and Modeled TP Time series Oct. 2002 through May 2009, Ashley Creek near AC-5.

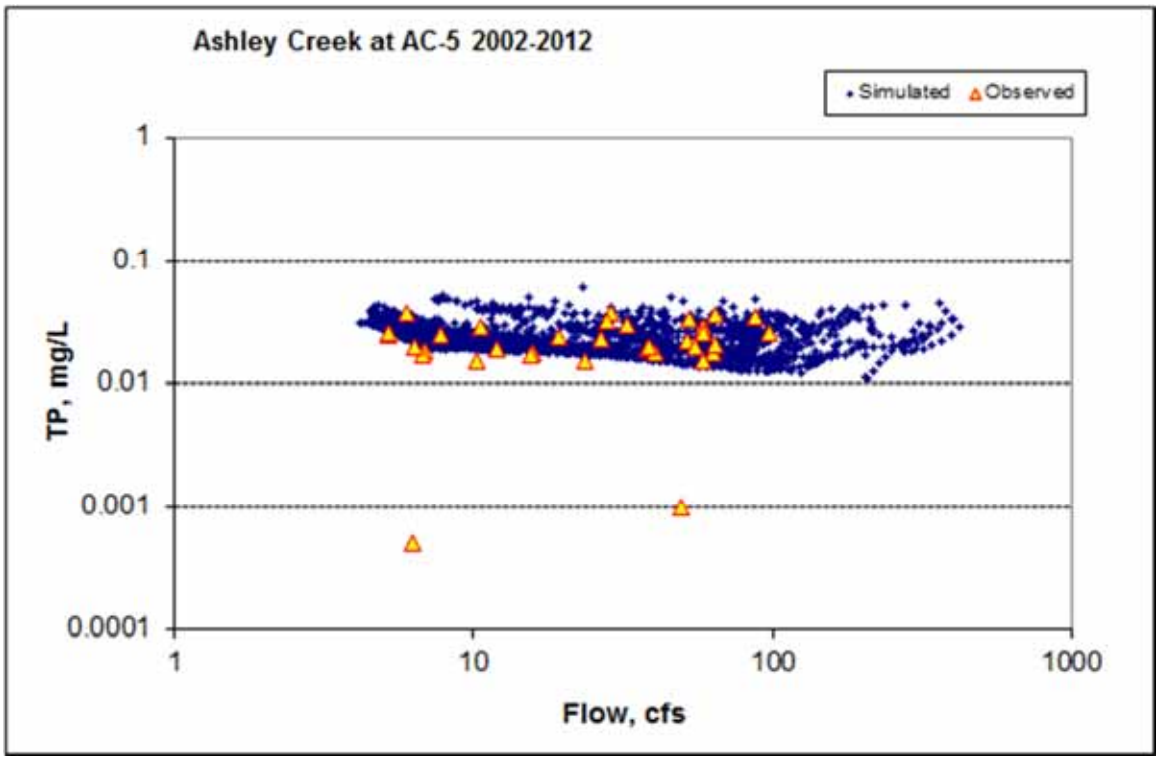


Figure A-91. Observed and Modeled TP Concentration vs. Flow, Ashley Creek near AC-5.

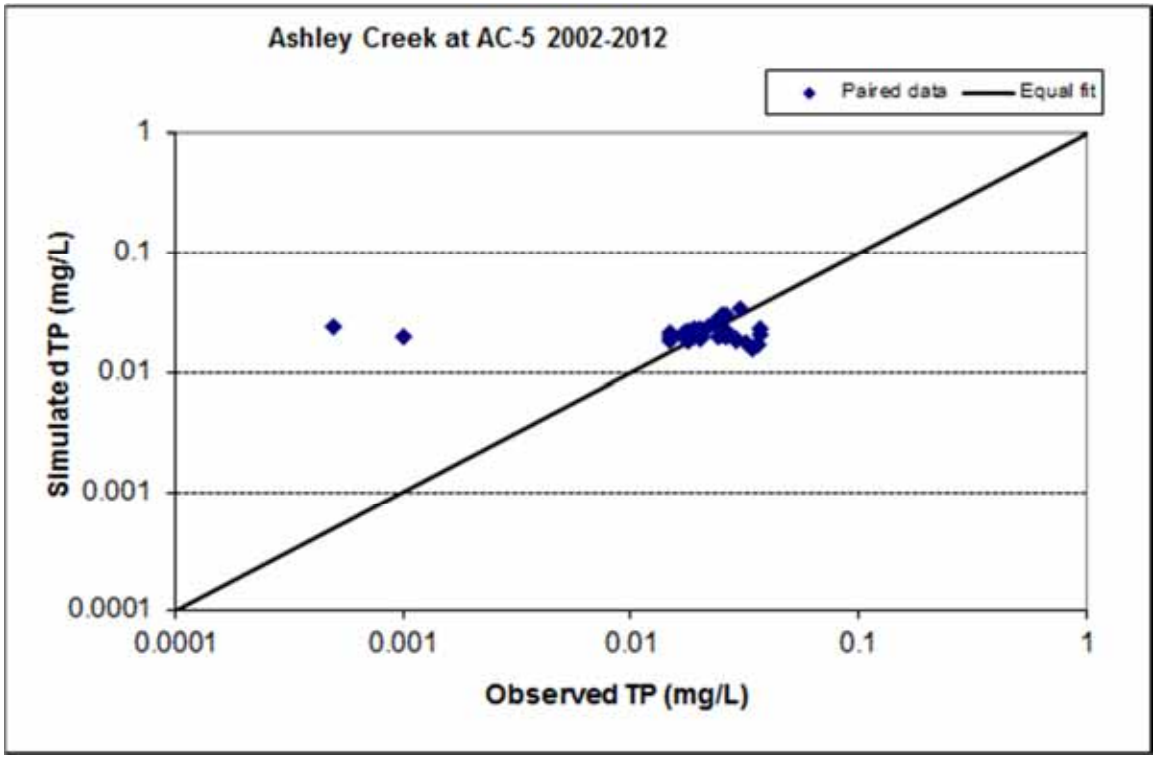
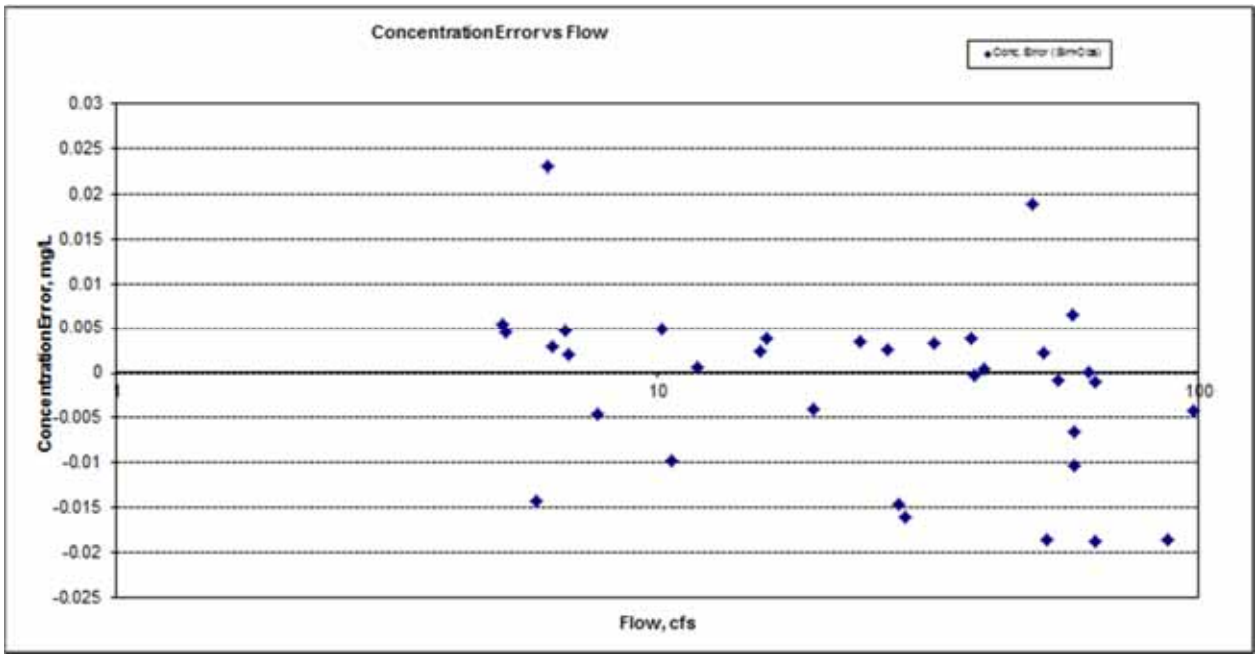


Figure A-92. Observed and Modeled TP Daily Paired Concentration, Ashley Creek near AC-5.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-93. Observed and Modeled TP Daily Paired Concentration Error vs. Flow, Ashley Creek near AC-5.

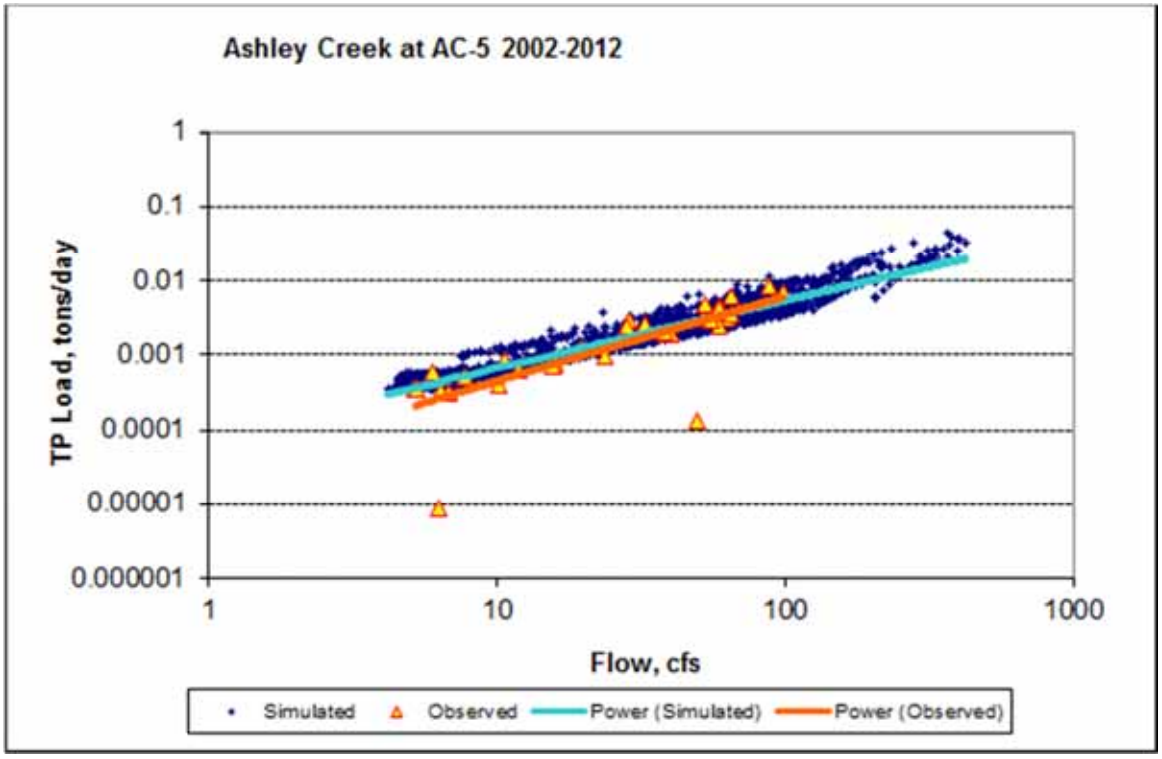


Figure A-94. Observed and Modeled TP Load vs. Flow, Ashley Creek near AC-5.

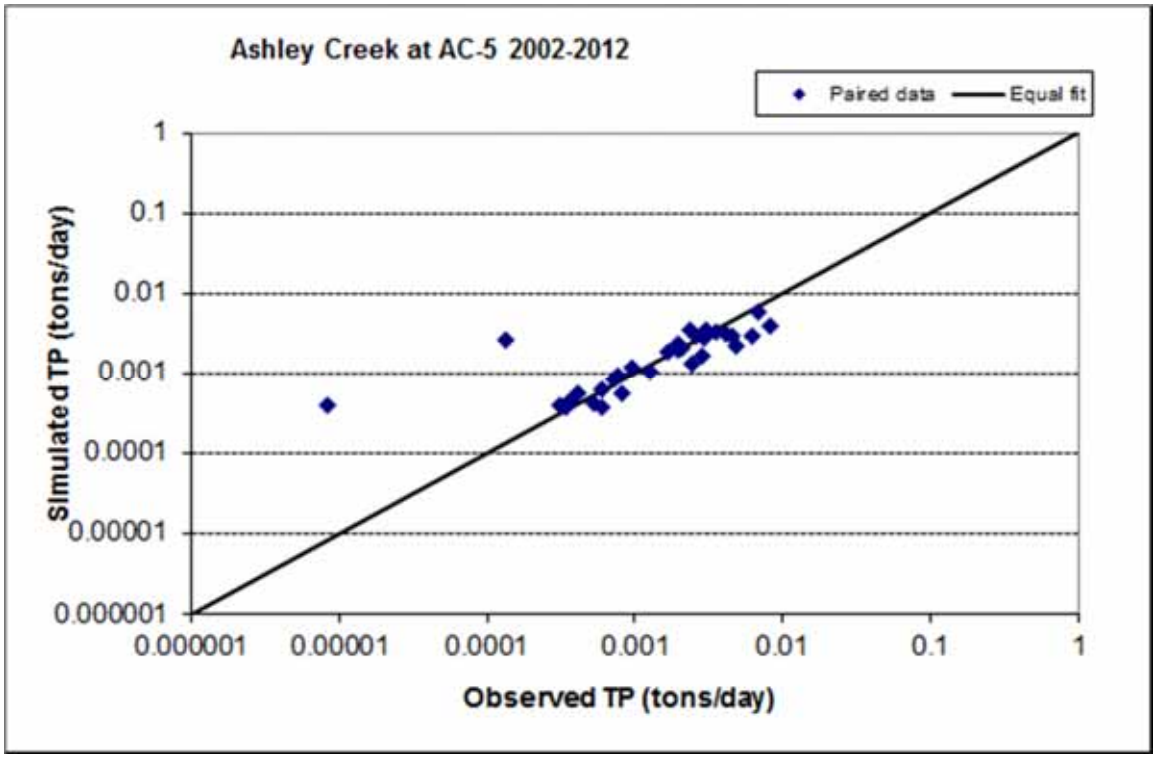


Figure A-95. Observed and Modeled TP Daily Paired Load, Ashley Creek near AC-5.

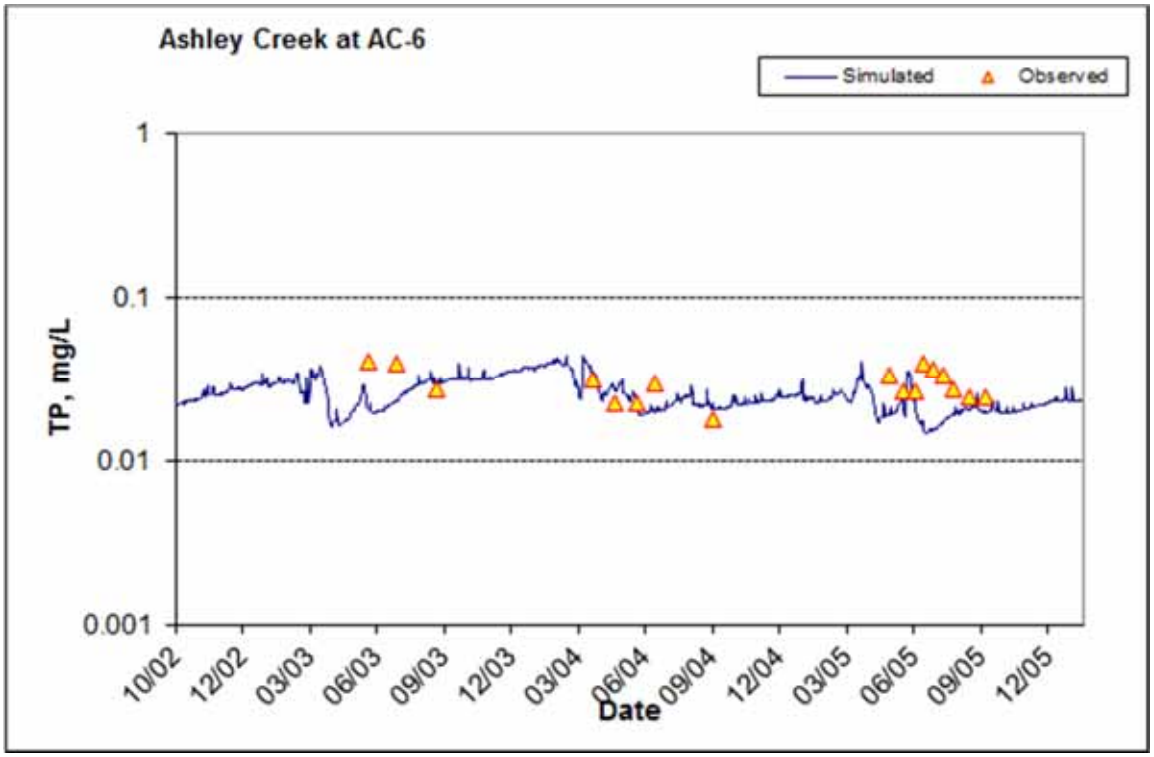


Figure A-96. Observed and Modeled TP Time series Oct. 2002 through Jan. 2006, Ashley Creek at AC-6.

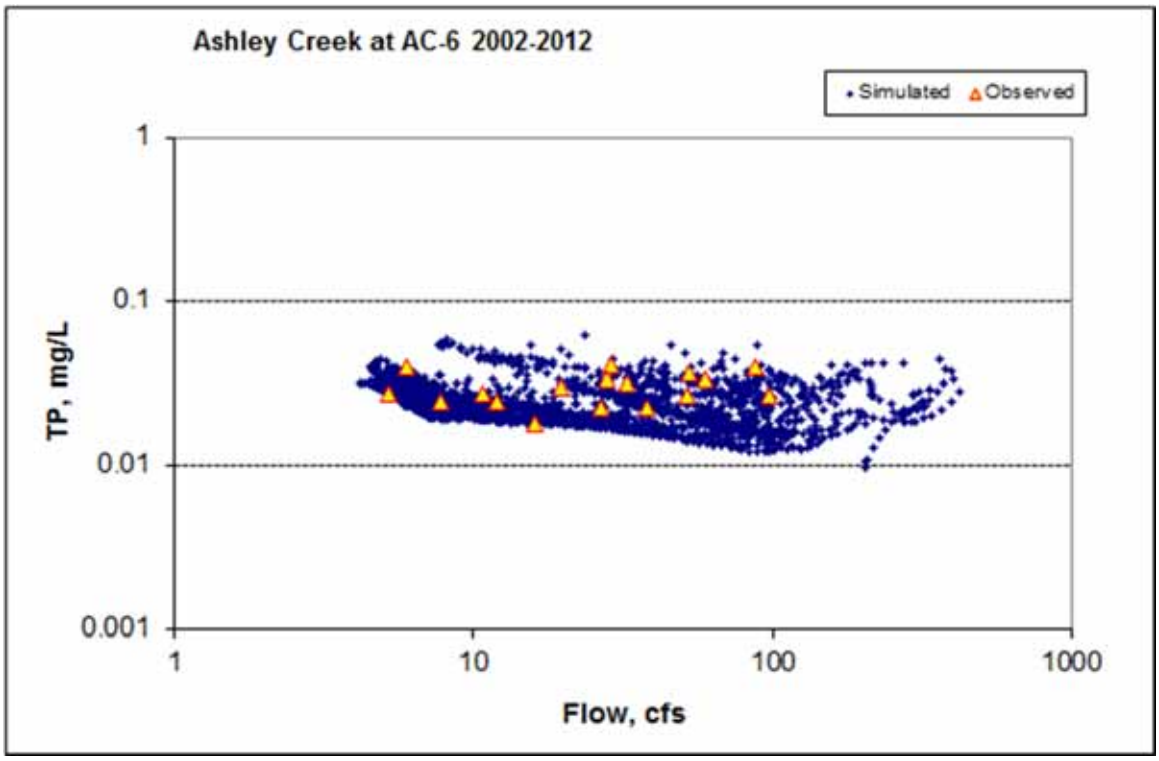


Figure A-97. Observed and Modeled TP Concentration vs. Flow, Ashley Creek at AC-6.

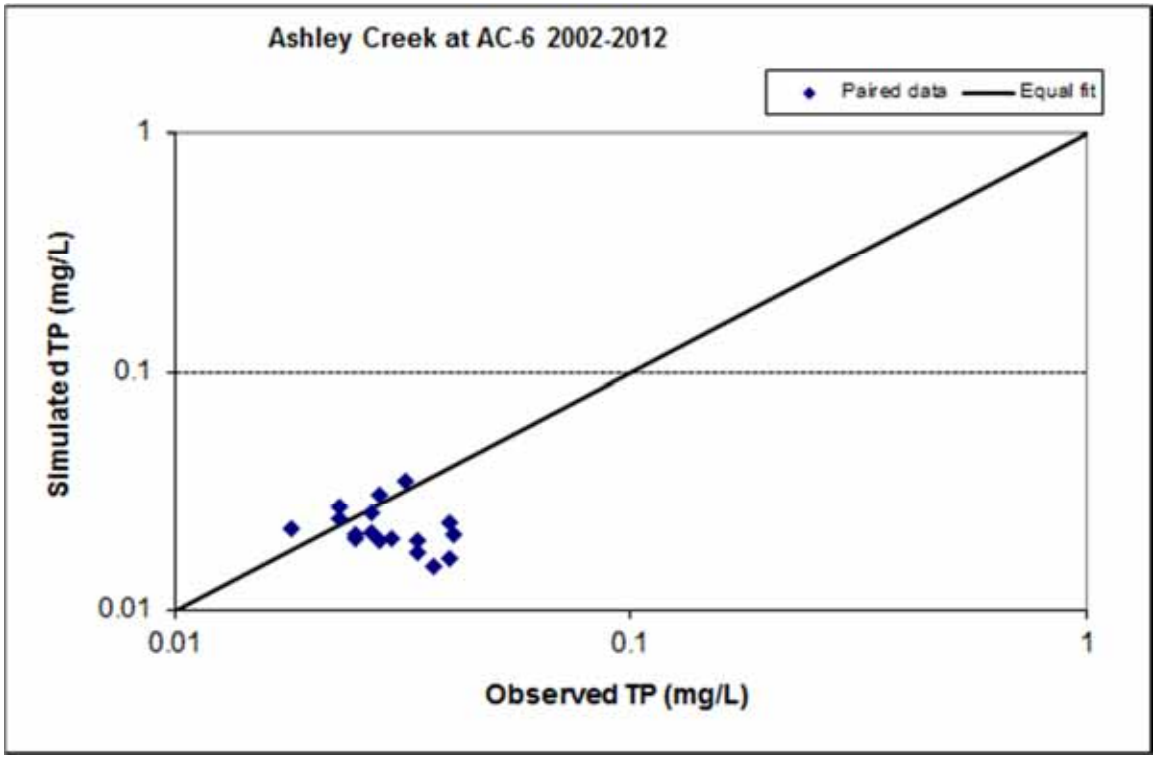
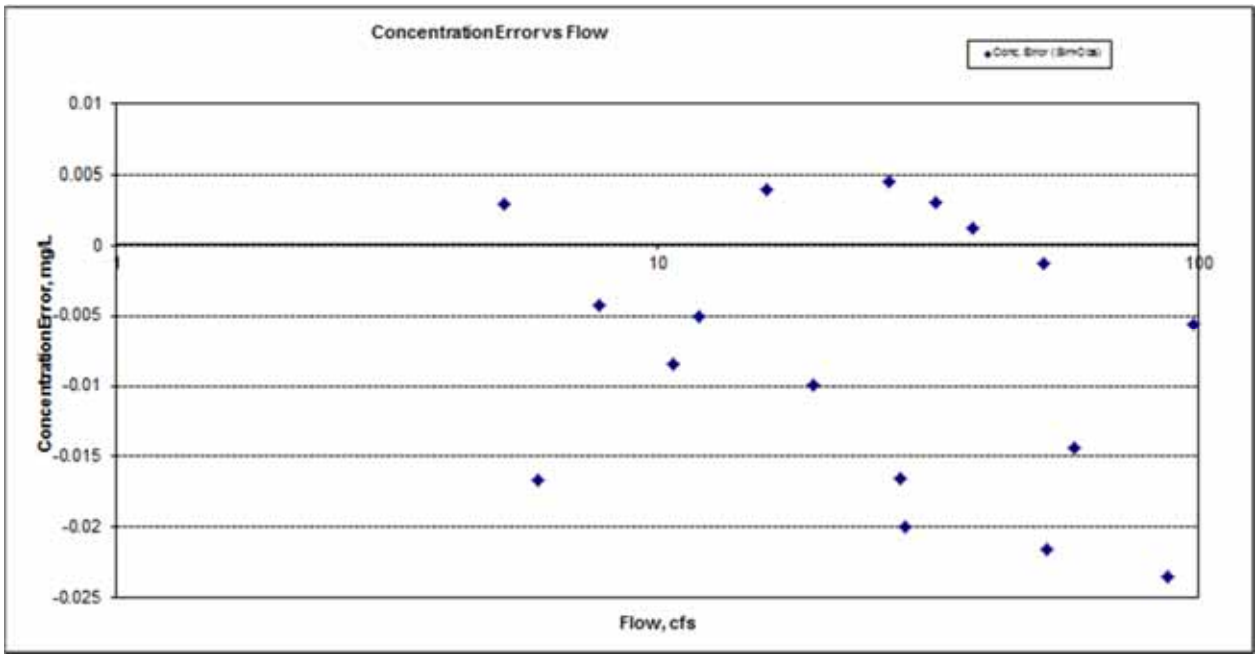


Figure A-98. Observed and Modeled TP Daily Paired Concentration, Ashley Creek at AC-6.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-99. Observed and Modeled TP Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-6.

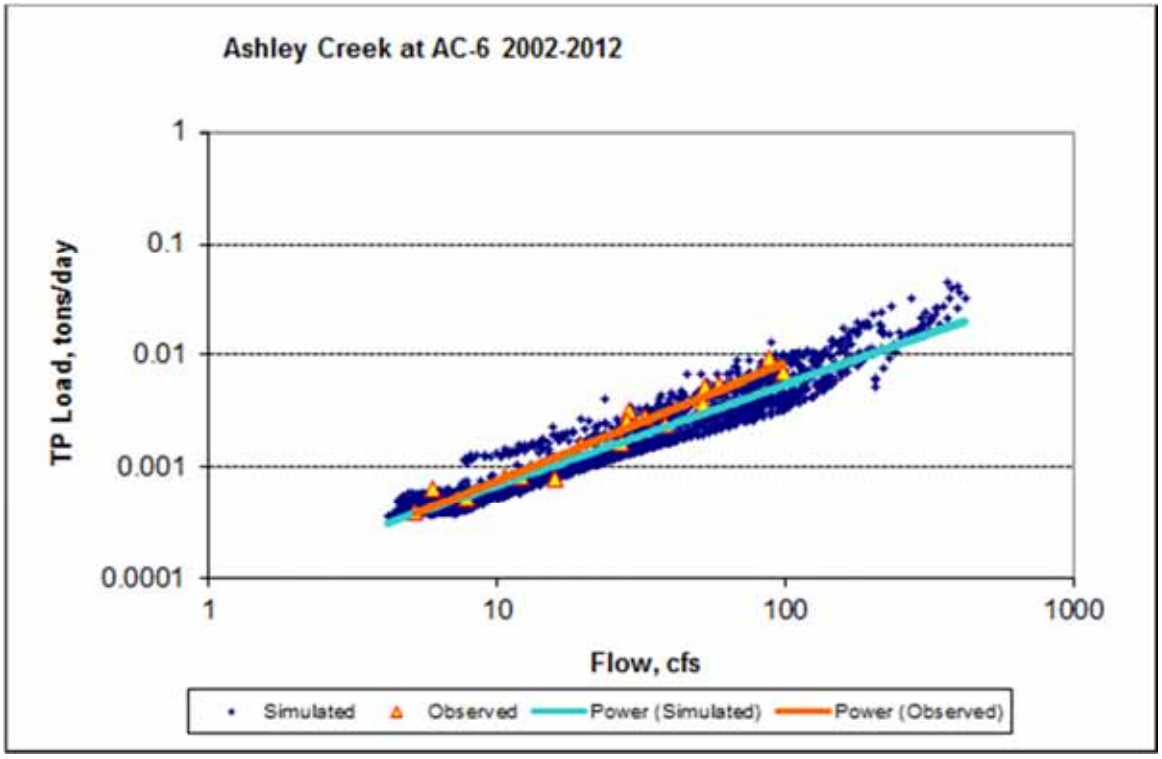


Figure A-100. Observed and Modeled TP Load vs. Flow, Ashley Creek at AC-6.

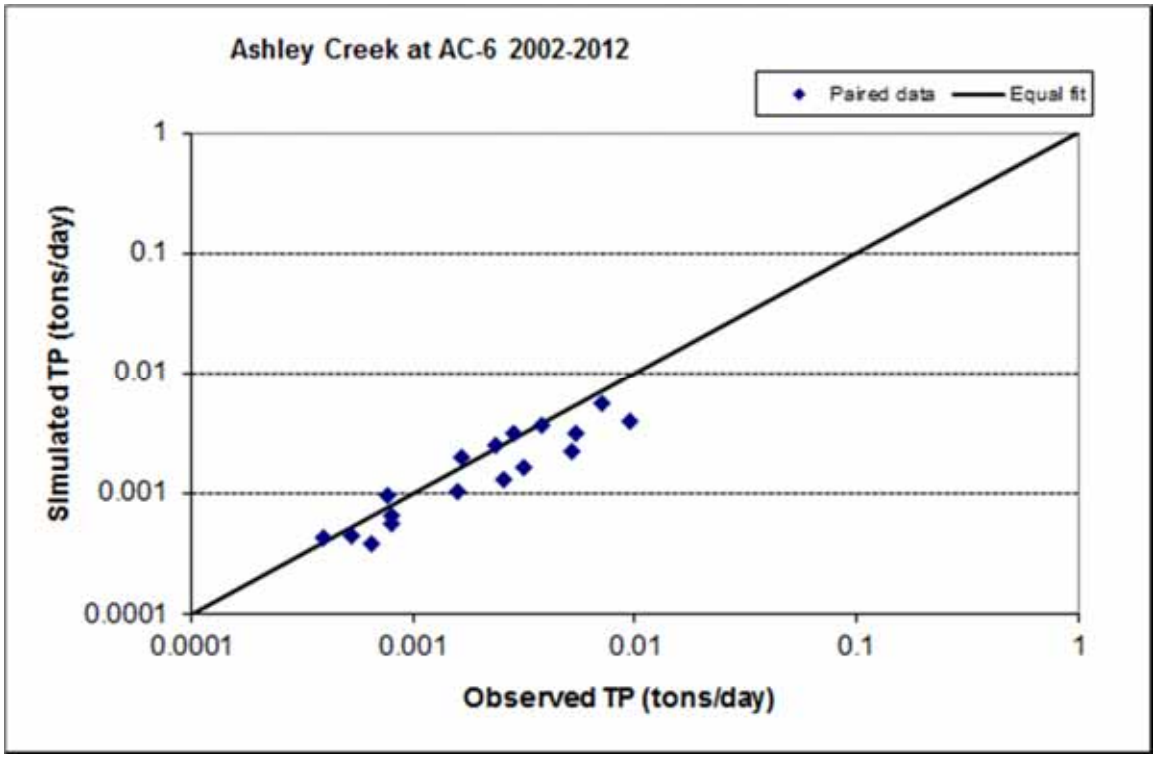


Figure A-101. Observed and Modeled TP Daily Paired Load, Ashley Creek at AC-6.

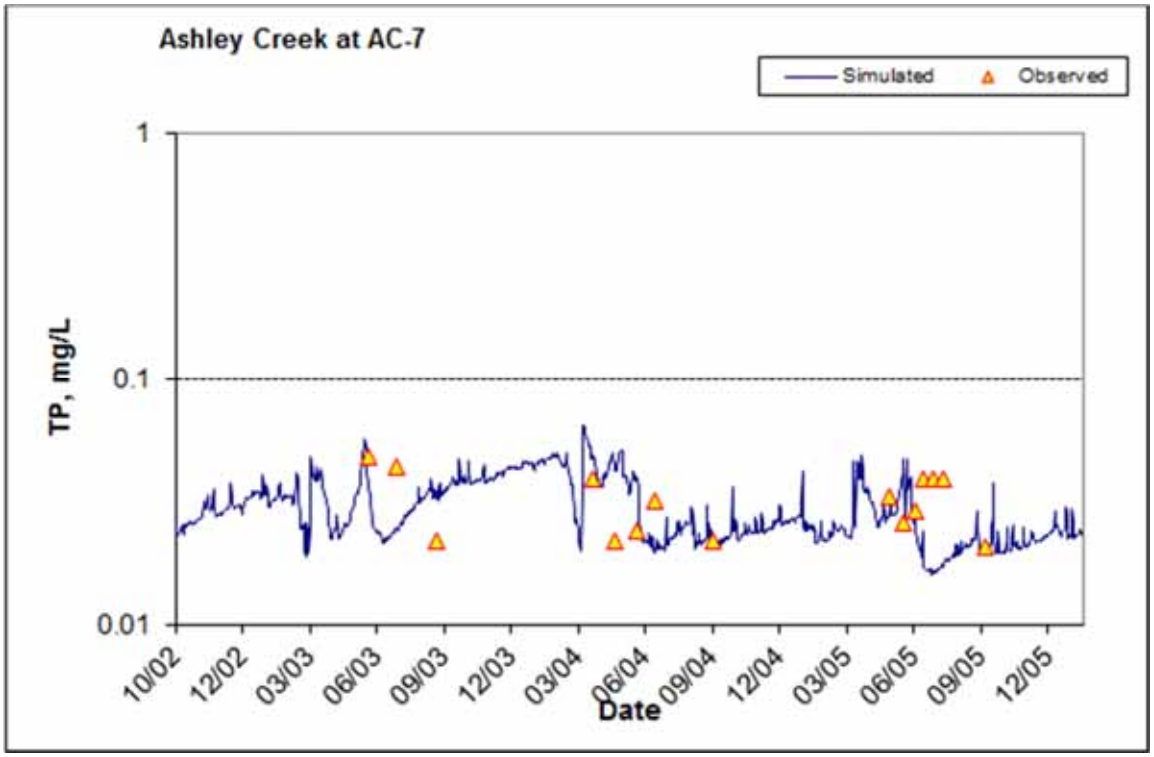


Figure A-102. Observed and Modeled TP Time series Oct. 2002 through Jan 2006, Ashley Creek at AC-7.

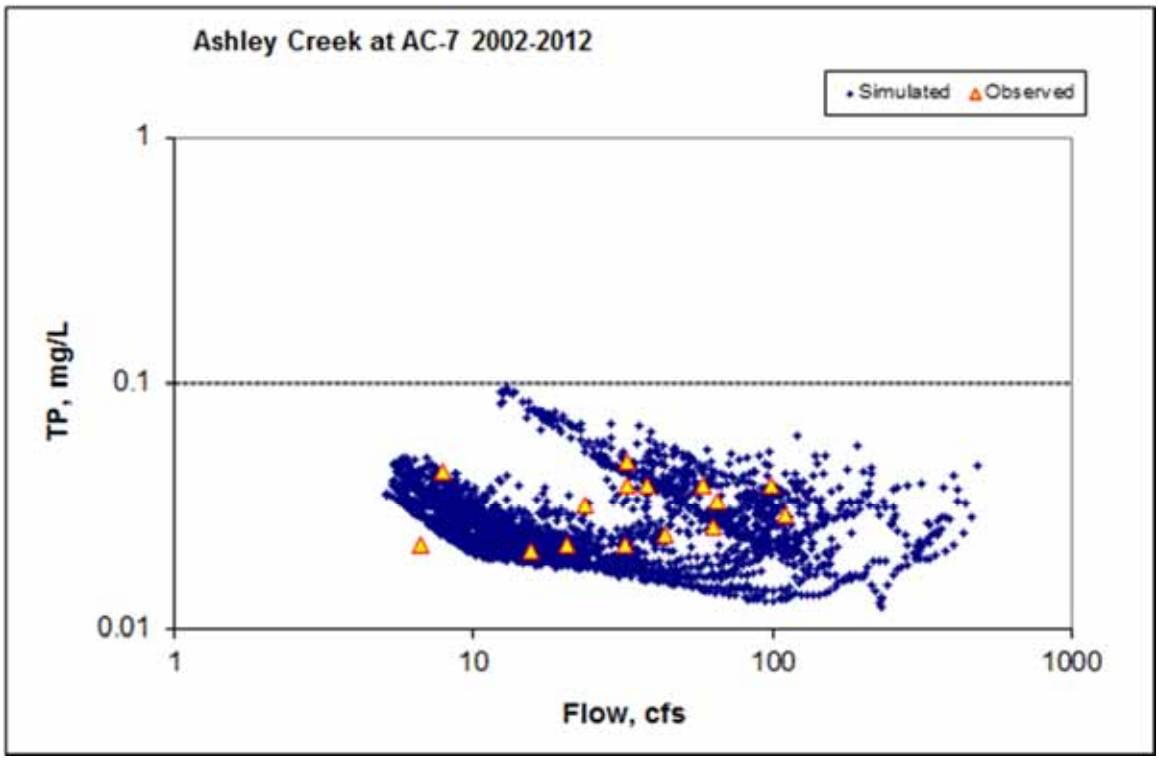


Figure A-103. Observed and Modeled TP Concentration vs. Flow, Ashley Creek at AC-7.

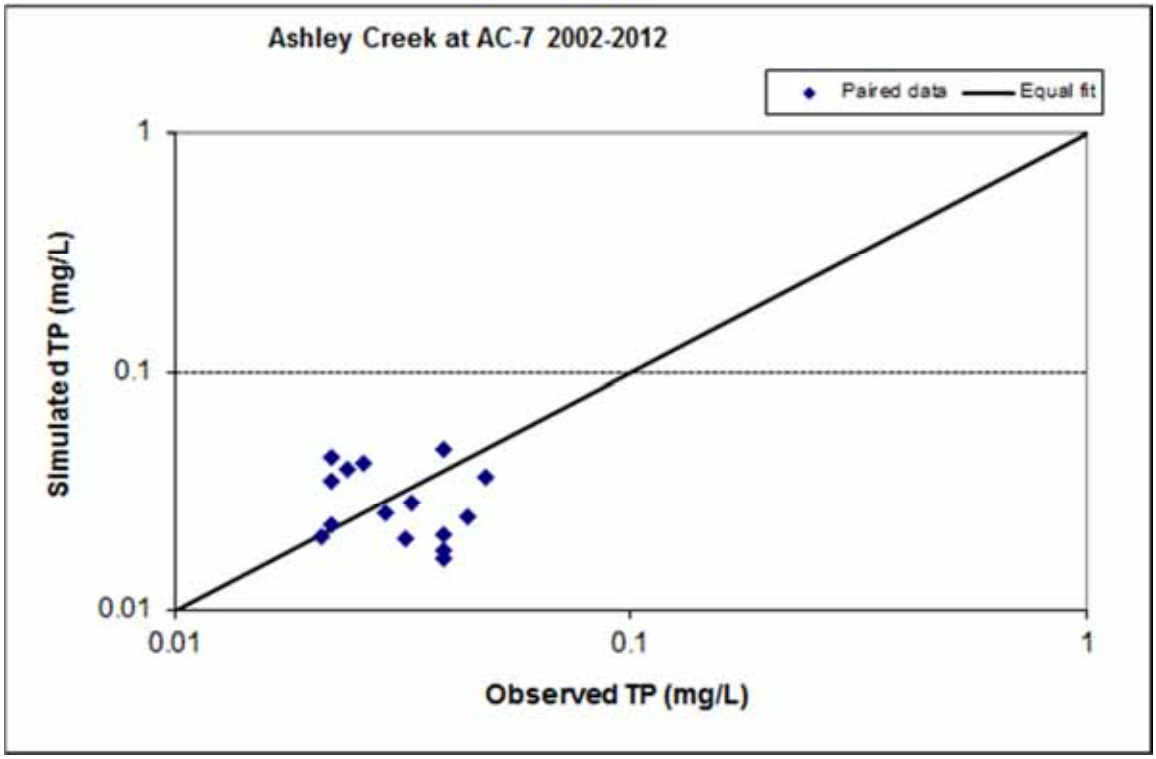
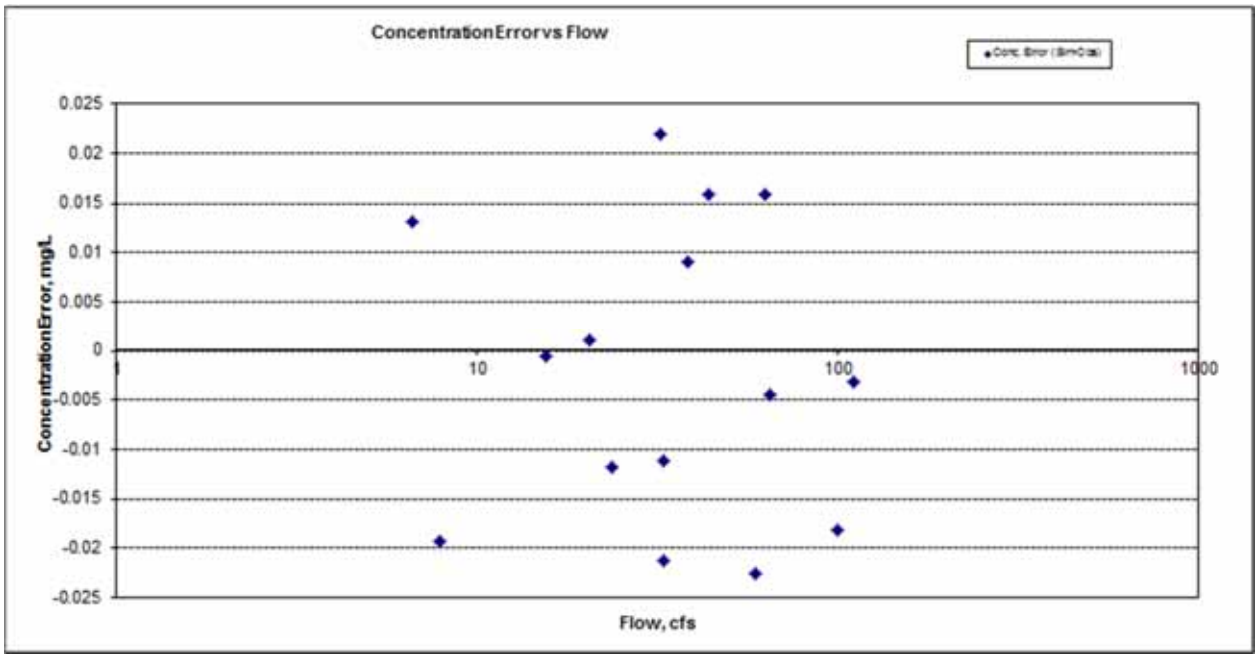


Figure A-104. Observed and Modeled TP Daily Paired Concentration, Ashley Creek at AC-7.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-105. Observed and Modeled TP Daily Paired Concentration Error vs. Flow, Ashley Creek at AC-7.

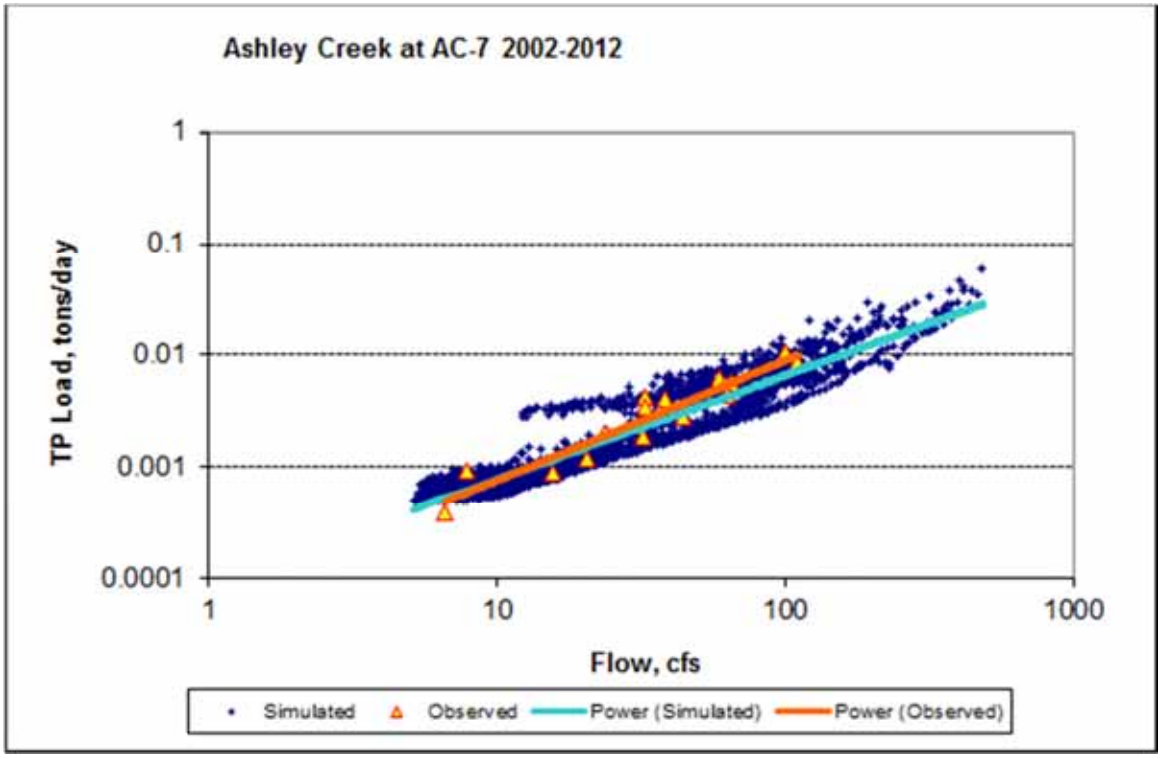


Figure A-106. Observed and Modeled TP Load vs. Flow, Ashley Creek at AC-7.

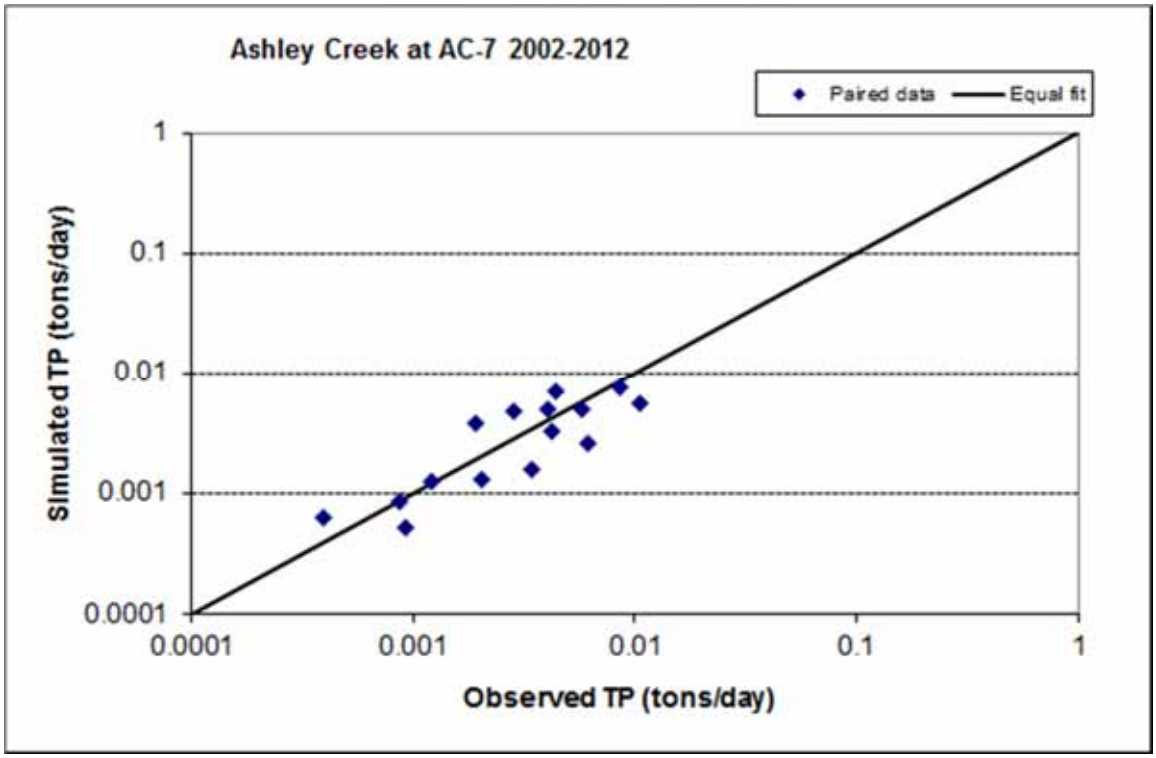


Figure A-107. Observed and Modeled TP Daily Paired Load, Ashley Creek at AC-7.

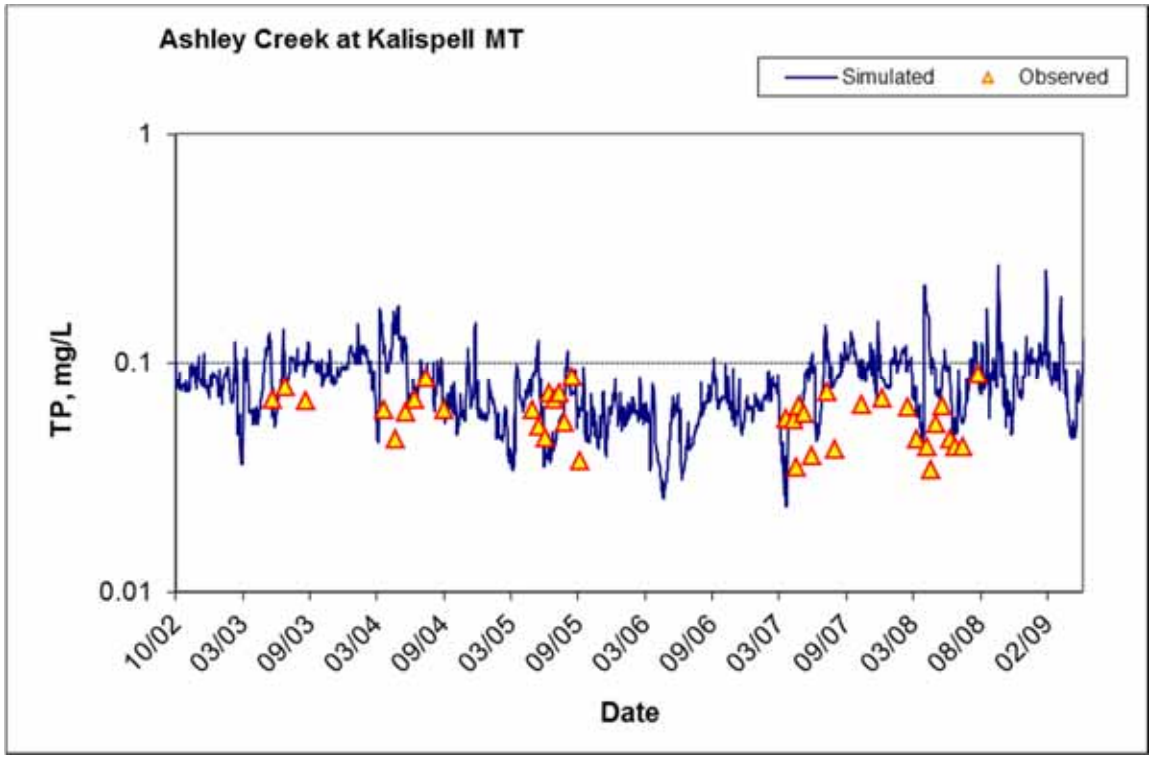


Figure A-108. Observed and Modeled TP Time series Oct. 2002 through May 2009, Ashley Creek near 12367800.

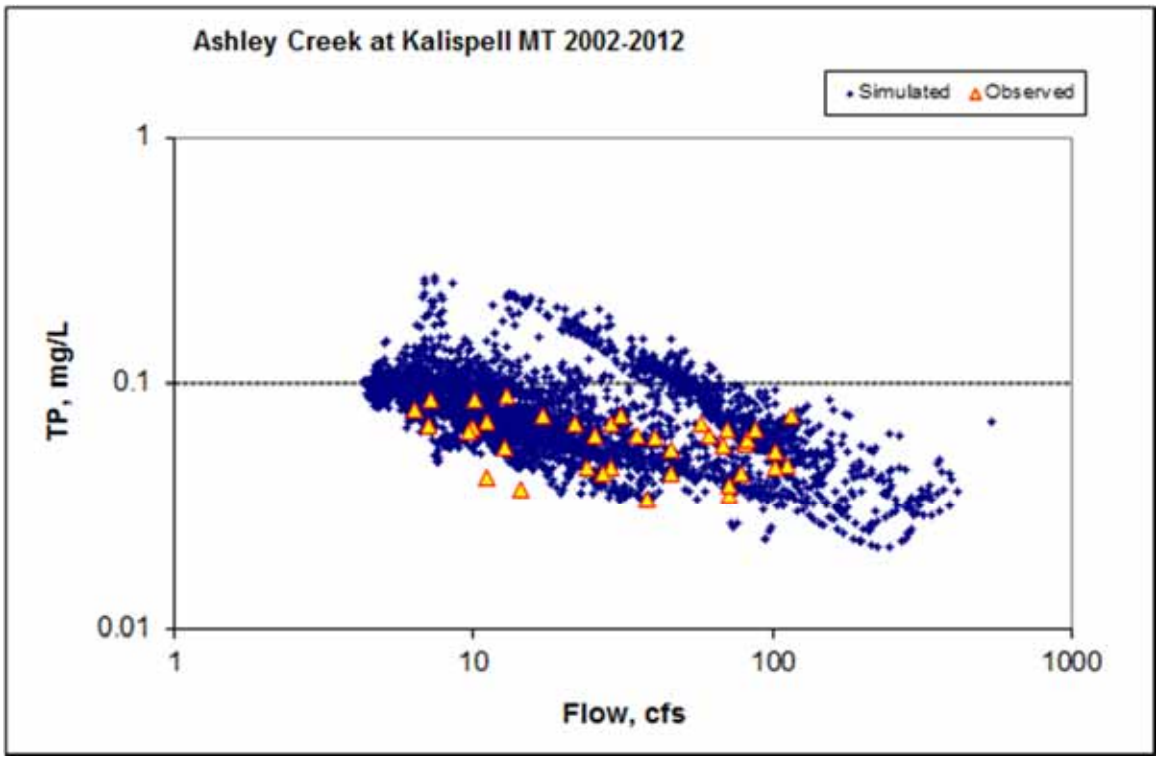


Figure A-109. Observed and Modeled TP Concentration vs. Flow, Ashley Creek near 12367800.

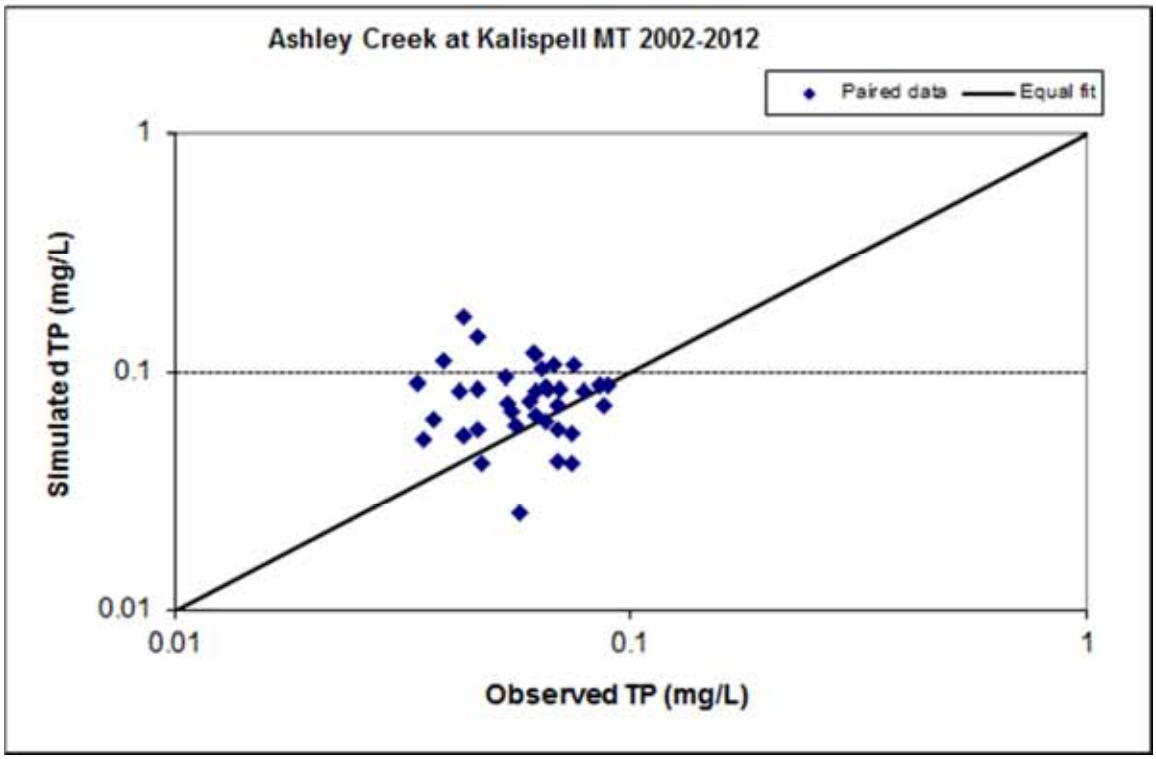
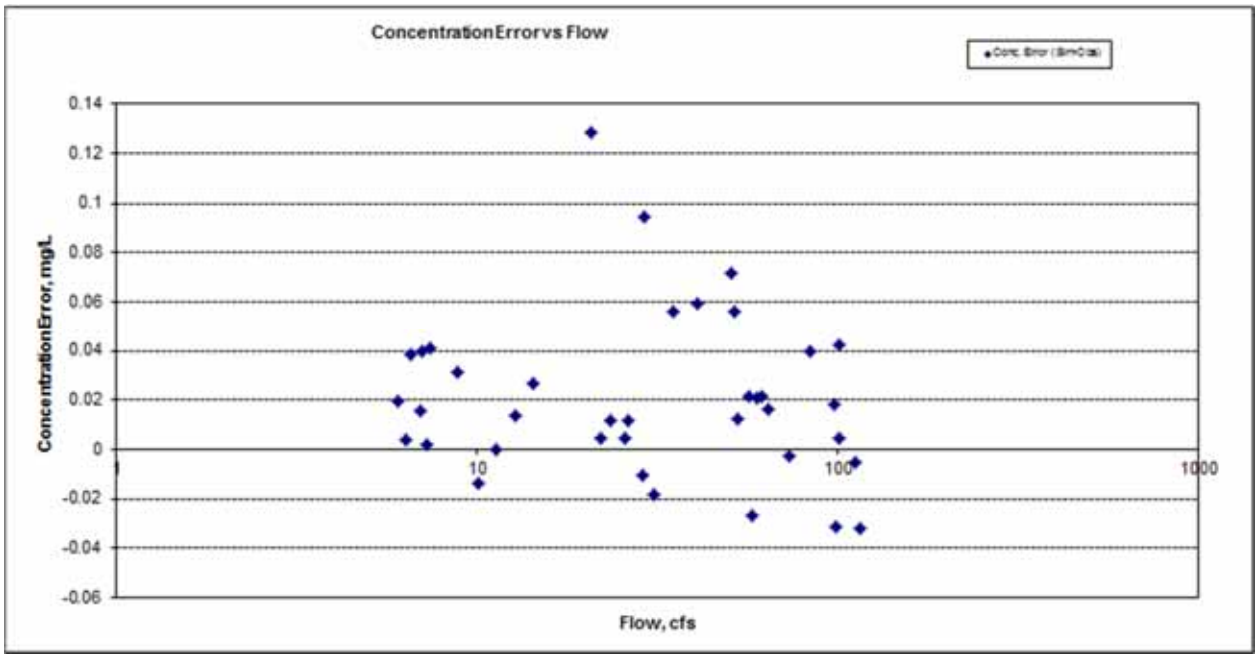


Figure A-110. Observed and Modeled TP Daily Paired Concentration, Ashley Creek near 12367800.



Positive values indicate model over-prediction, negative values indicate model under-prediction.

Figure A-111. Observed and Modeled TP Daily Paired Concentration Error vs. Flow, Ashley Creek near 12367800.

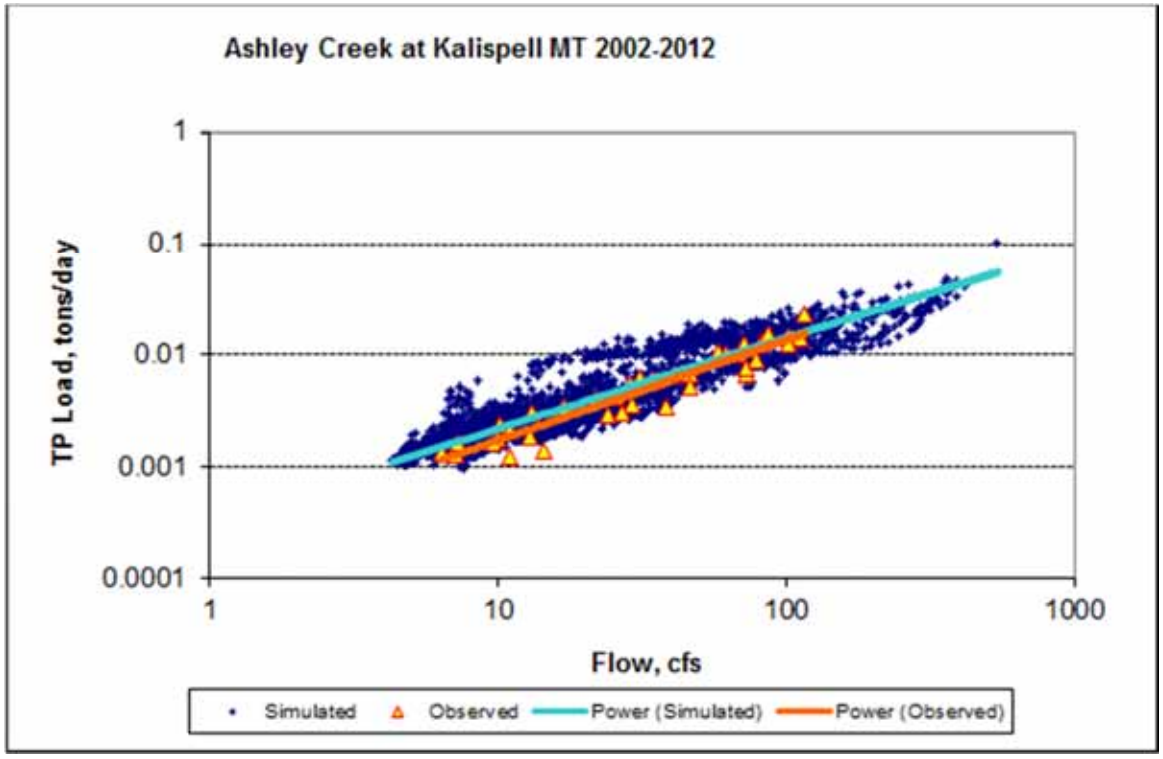


Figure A-112. Observed and Modeled TP Load vs. Flow, Ashley Creek near 12367800.

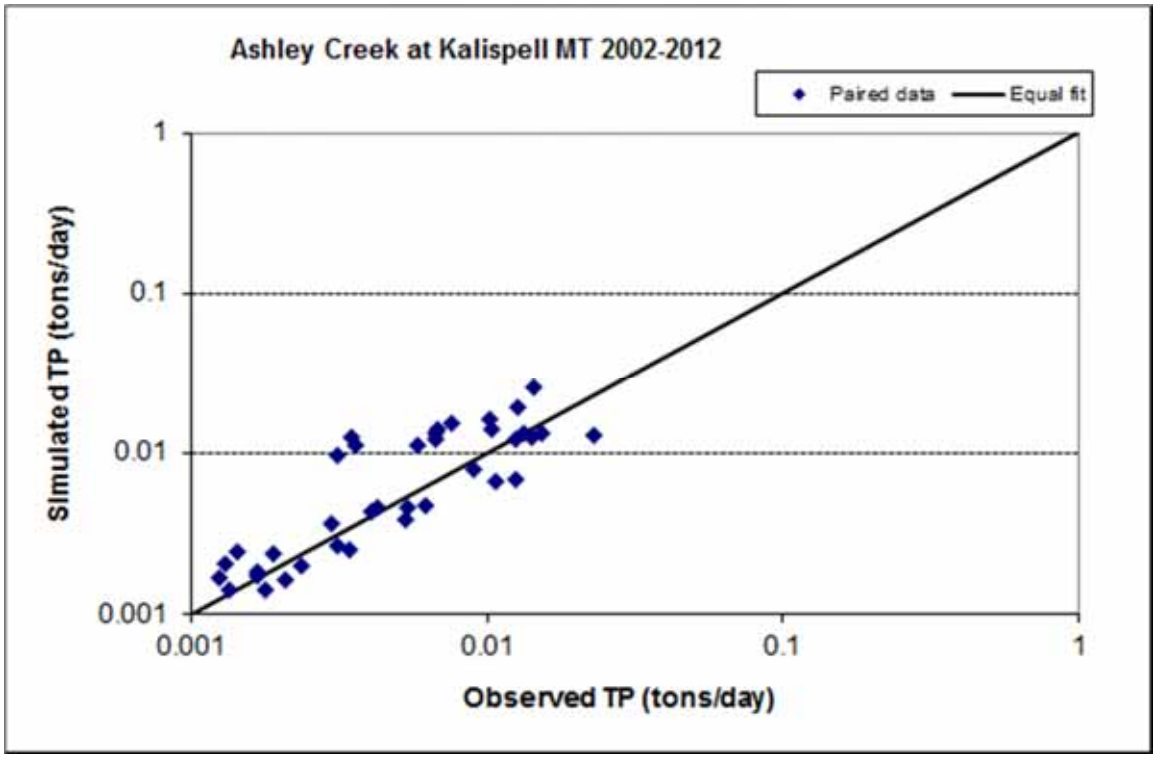


Figure A-113. Observed and Modeled TP Daily Paired Load, Ashley Creek near 12367800.

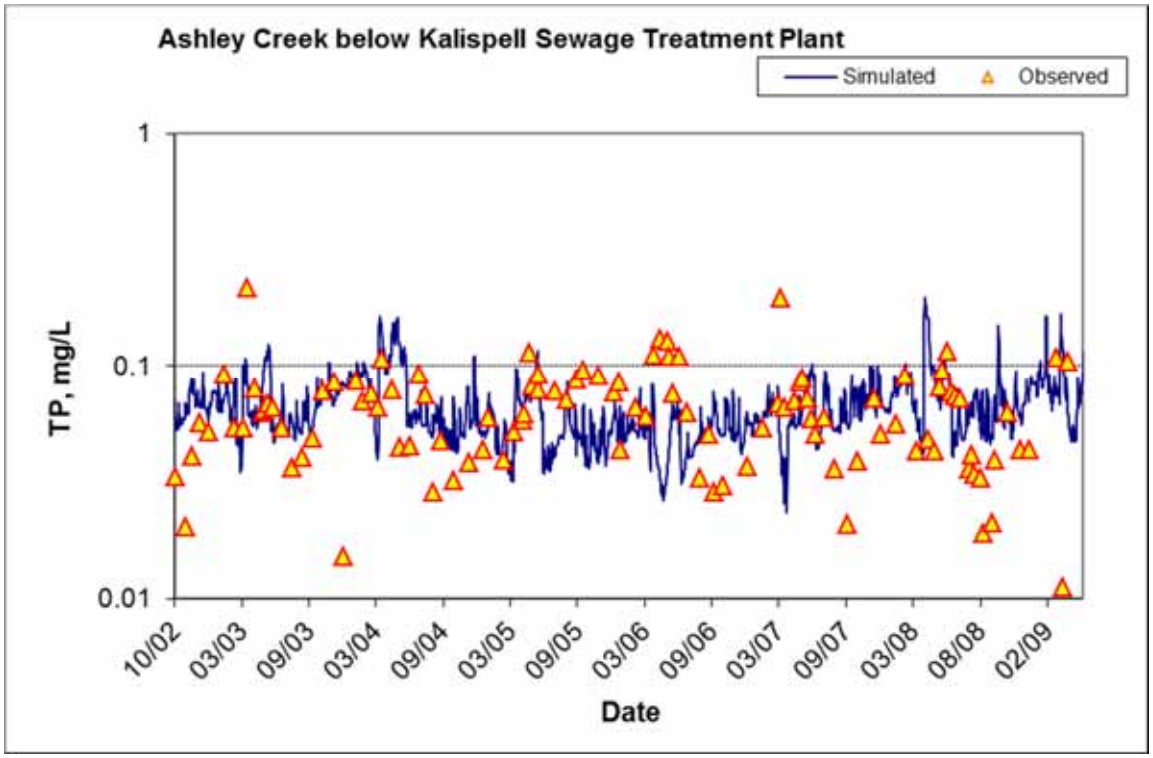


Figure A-114. Observed and Modeled TP Time series Dec. 2002 through May 2009, Ashley Creek near FBC05003.

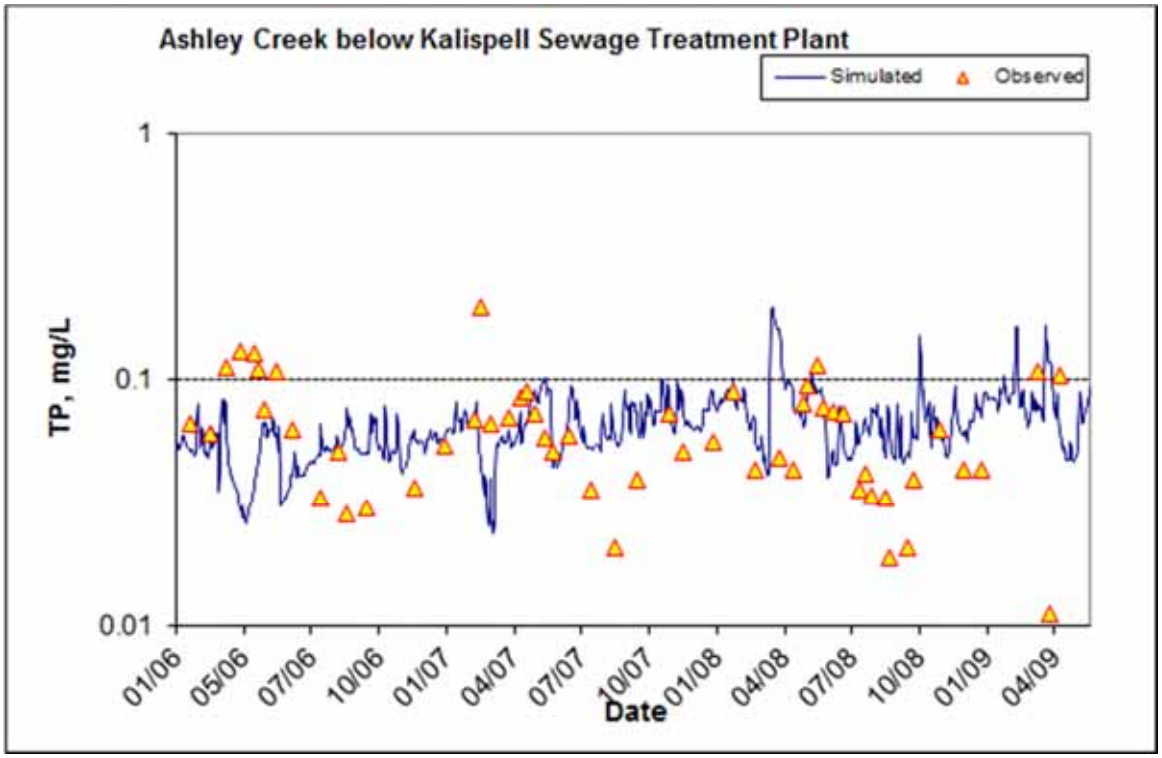


Figure A-115. Observed and Modeled TP Time series Feb. 2006 through May 2009, Ashley Creek near FBC05003.

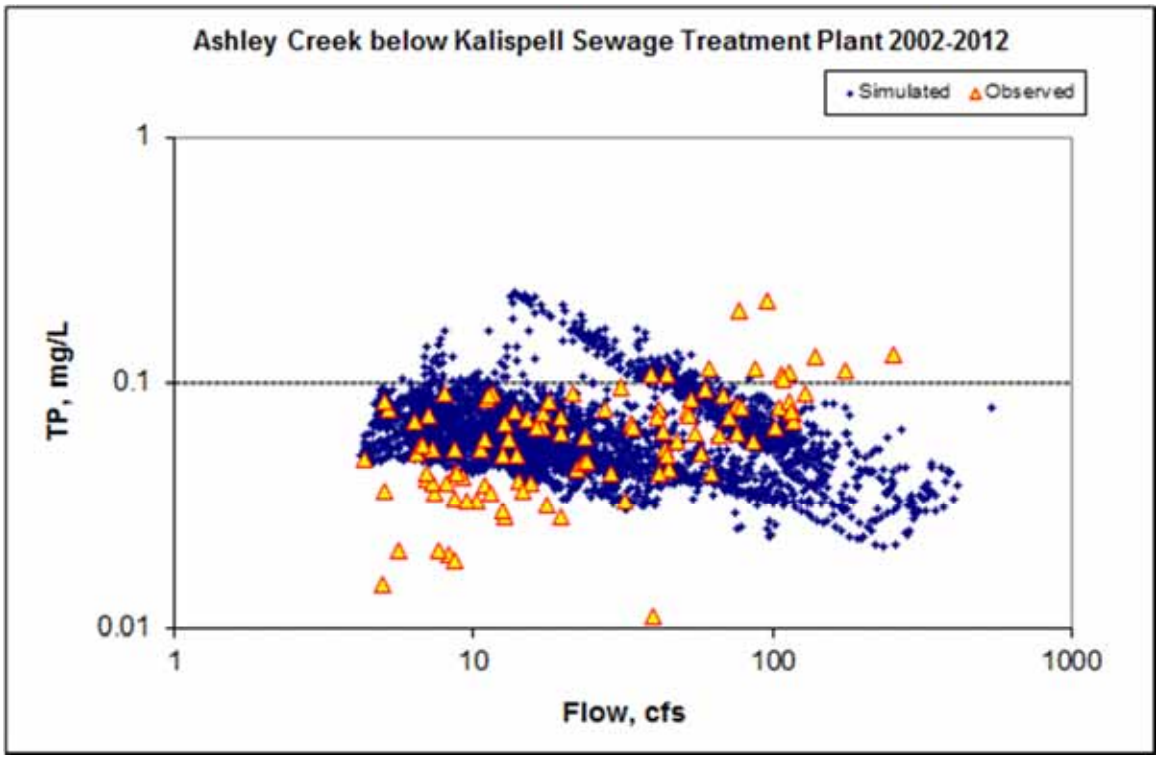


Figure A-116. Observed and Modeled TP Concentration vs. Flow, Ashley Creek near FBC05003.

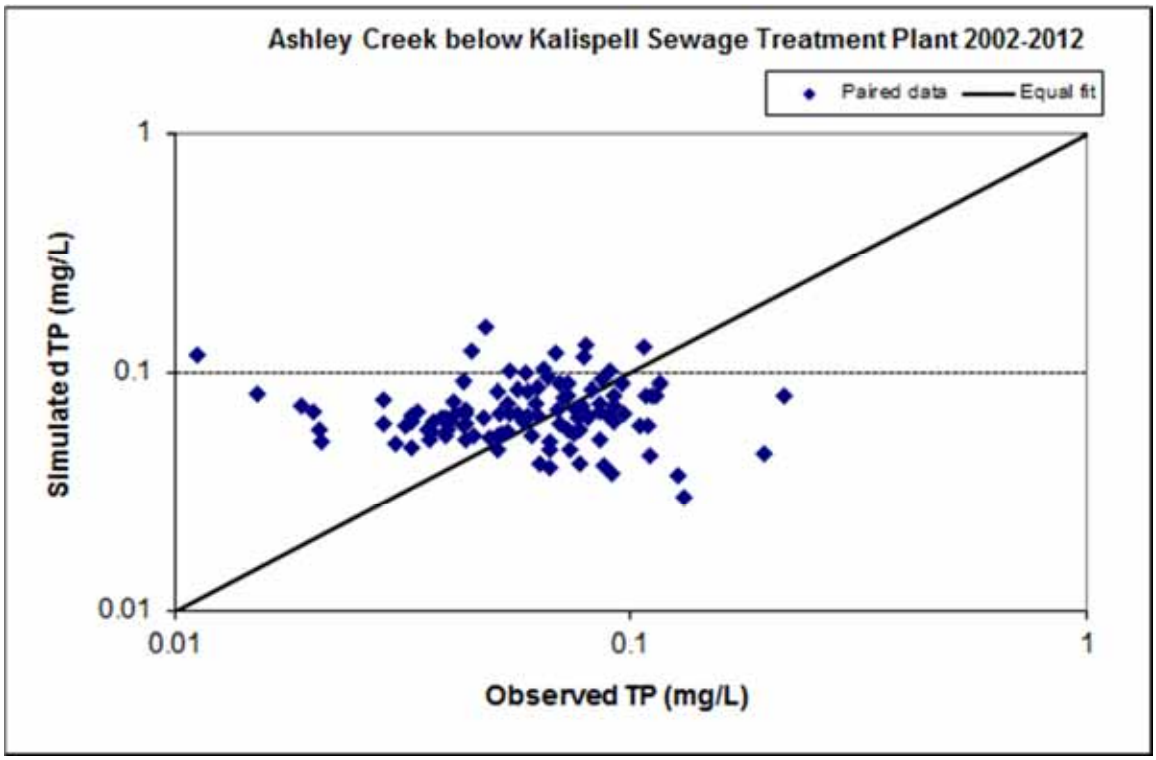


Figure A-117. Observed and Modeled TP Daily Paired Concentration, Ashley Creek near FBC05003.

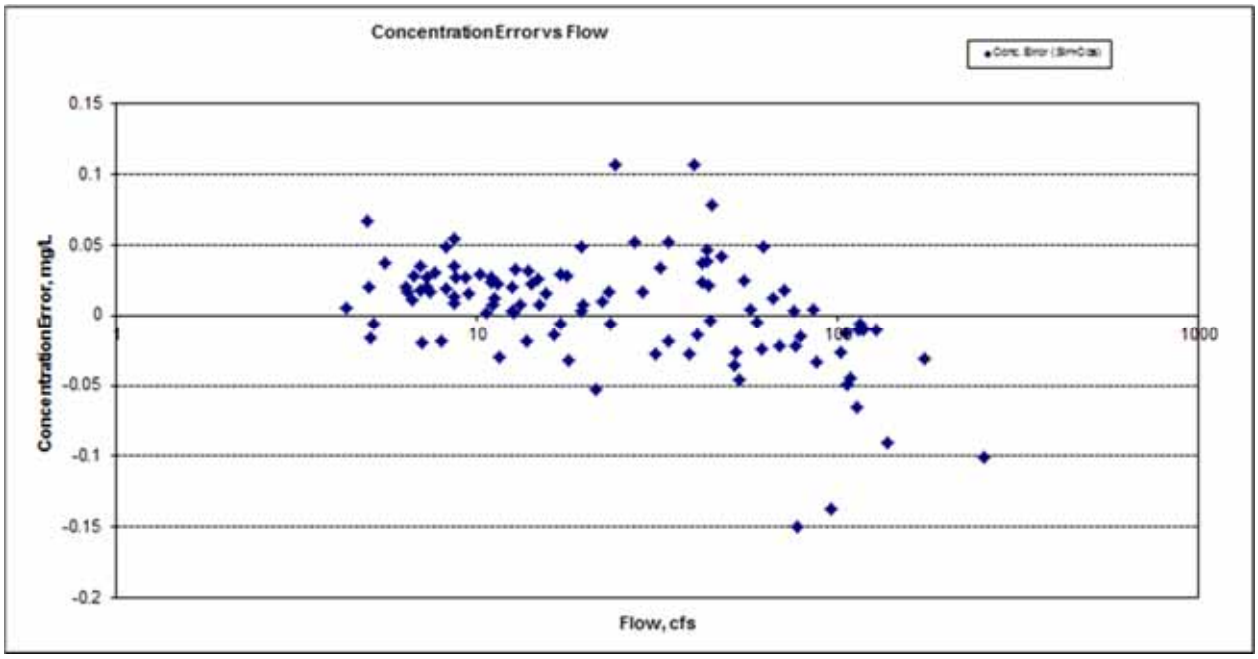


Figure A-118. Observed and Modeled TP Daily Paired Concentration Error vs. Flow, Ashley Creek near FBC05003.

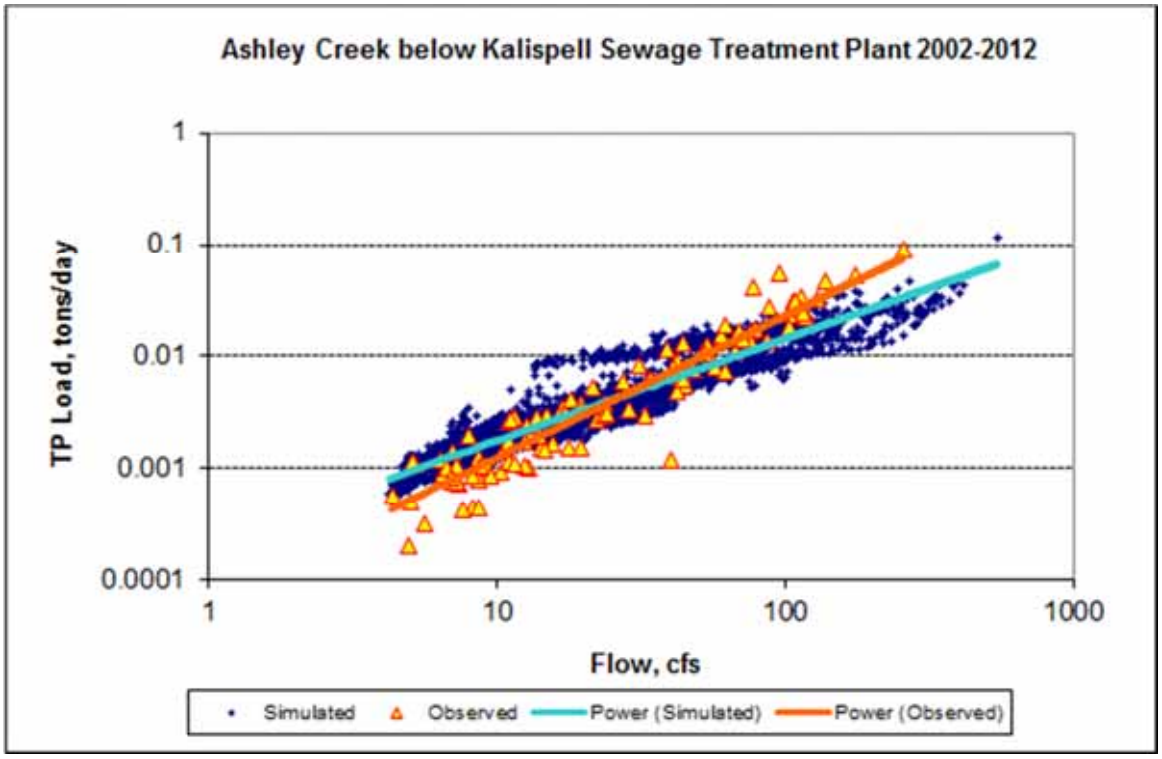


Figure A-119. Observed and Modeled TP Load vs. Flow, Ashley Creek near FBC05003.

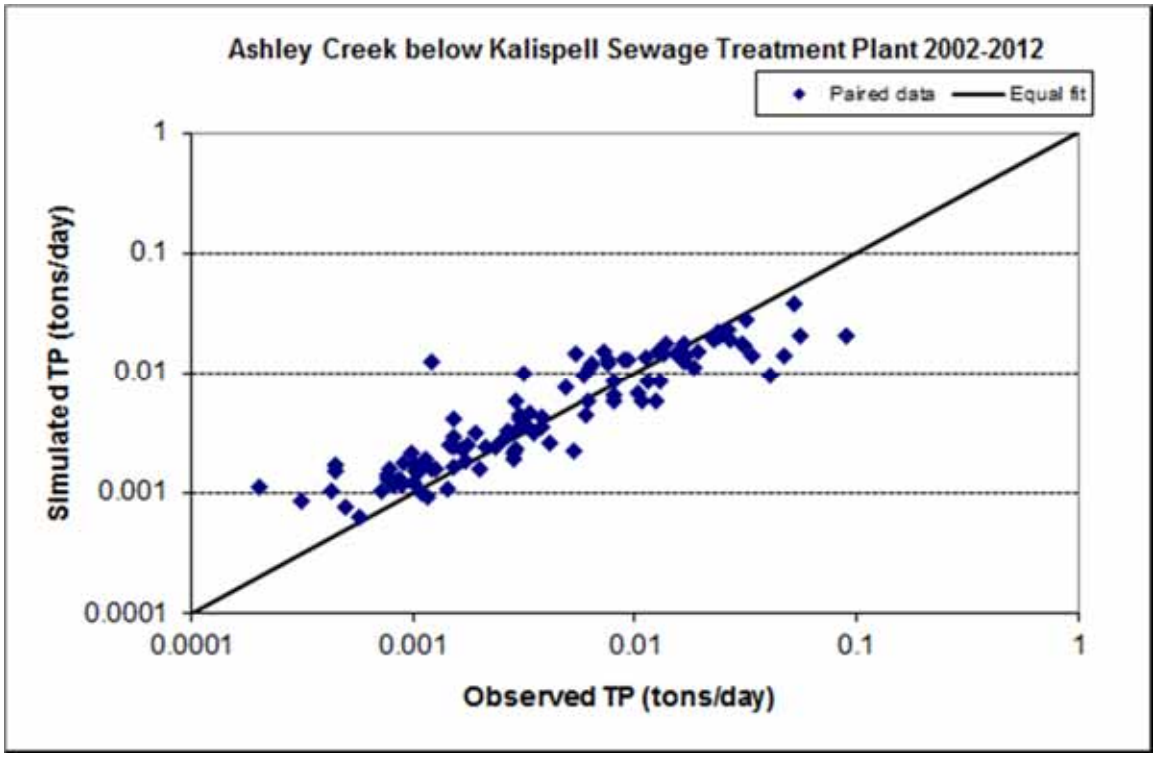


Figure A-120. Observed and Modeled TP Daily Paired Load, Ashley Creek near FBC05003.

A-4. REFERENCES

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