Ozarks Environmental and Water Resources Institute (OEWRI)
Missouri State University (MSU)

SOUTH CREEK AND FASSNIGHT CREEK WATER QUALITY ASSESSMENT SPRINGFIELD, MISSOURI

January 2012-March 2015

FINAL REPORT

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SCOPE AND OBJECTIVES

The Watershed Committee of the Ozarks in cooperation with the James River Basin Partnership and the City of Springfield, Missouri implemented a Section 319 Grant from the Missouri Department of Natural Resources and the Environmental Protection Agency Region VII designed to reduce nonpoint source pollution in South and Fassnight Creeks located in south/central Springfield. This project involved the implementation of several storm water BMPs with the goal of improving water quality. South and Fassnight Creeks are sub-watersheds of Wilson Creek, which have a long history of water quality degradation from a variety of point and nonpoint pollution sources associated with urban development (Richards and Johnson 2002; Miller 2006; Hutchinson 2010).

To better understand the present water quality conditions for both streams, water quality monitoring was necessary to quantify the existing loads. The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University was contracted to perform the water quality monitoring component of this project. The purpose of this study is to determine nonpoint source loads of nutrients, sediment and chloride along South Creek and Fassnight Creek in Springfield, Missouri. The specific objectives of this project are: 1) establish four water quality monitoring stations along South and Fassnight Creeks that include continuous stage recorders; 2) collect and analyze base and storm flow water quality samples over a 38 month monitoring period for nutrients, sediment, and chloride; and 3) quantify the nutrient, sediment and chloride loads at each site. This report contains the results of water quality and discharge monitoring at each site. This study will support meeting the requirements of the approved James River Total Maximum Daily Load (TMDL) and the future Wilson Creek TMDL.

WATERSHED CHARACTERISTICS

South Creek (drainage area = 27.9 km^2) and Fassnight Creek (14.3 km^2) are tributaries of Wilson Creek within the 12-digit Hydrologic Unit Code (HUC) 110100020303 (Headwaters Wilson Creek) located in southern Greene County in southwest Missouri and is a tributary of the James River (Figure 1). Both streams begin near Glenstone Avenue and flow west until they enter Wilson Creek on the west side of the City of Springfield. The underlying geology is Mississippian age cherty-limestone in which a karst landscape has formed where springs, losing streams, and sinkholes are common (Thompson 1986). Upland soils typically have a thin layer of loess over highly weathered cherty subsoil (Hughes 1982).

There are a total of four sites monitored for this study. Sites for this project include South Creek at National Avenue (NAT), South Creek at Campbell Avenue (CAM), South Creek at Highway FF (HFF) and Fassnight Creek at Fort Avenue (FOR) (Table 1, Figure 1 and Photos 1-4). Upstream drainage areas range from 2.2 km^2 at NAT to 27.8 km^2 at HFF (Table 2). Both watersheds are highly urbanized with NAT, CAM and FOR having greater than 90% urban land use upstream and HFF with >75% urban land use upstream (Figure 2).

METHODS

Sample Collection

In-stream surface water quality monitoring was conducted over about a 38 month sampling period. The first sample collected January 25, 2012 and the last sample collected March 25, 2015. In-situ pH, temperature (T), specific conductivity (SC), dissolved oxygen (DO) and turbidity (TB) were measured during sample collection using a Eureka Amphibian with Manta multiprobe (OEWRI 2007a). Water samples were collected in two, 500 mL plastic bottles that were rinsed three times in ambient water and were collected differently depending on if it was during a storm event, or at base flow (OEWRI, 2007b). During storm events, a depth-integrated sampler was used to collect water samples to be sure that water was collected throughout the water column that would be representative of the entire flow. At base flow, samples were hand-collected by placing the bottle approximately three to six inches below the water surface. Upon collection, samples were transported on ice and delivered to the laboratory using chain of custody procedures (OEWRI 2006). At the laboratory, one of 500 mL bottles collected during sampling was preserved by adding 2 mL of sulfuric acid (H_2SO_4) to lower the pH to <2 for nutrient analysis. The second 500 mL bottle was not preserved and used for total suspended solids and chloride analysis. Both samples were stored in the laboratory refrigerator.

Laboratory Analysis

Samples were analyzed at the OEWRI Water Quality Laboratory at Missouri State University. Samples were analyzed for total nitrogen (TN) and total phosphorus (TP) using a Genesys 10S UV-Vis Spectrophotometer using EPA standard method 365.2 and methods outlined by Crumpton et al., 1992 (OEWRI 2010a, OEWRI 2010b). Total suspended solids (TSS) were determined by filtering samples through a 1.5 µm filter (OEWRI 2007c). Chloride (Cl) was measured in the lab using an Accumet Excel XL25 Dual Channel pH/Ion Meter (OEWRI 2009). Acceptable detection limits for these procedures are ≤0.1 mg/L TN, ≤0.005 mg/L TP, 0.5 mg/L TSS and 0.1 mg/L Cl with all accuracy and precision checks within the range of + or – 20%.

Hydrological Monitoring

Stage was recorded at both sites every 15-minutes over the monitoring period using Solinst Levelogger and Baralogger leveloggers (Photos 5-8) (OEWRI 2012). Leveloggers were installed at NAT, CAM and FOR between January 24th-30th, 2012. The leveloggers were installed inside a PVC pipe assembly and secured (Photo 5). As water rises in the pipe the levelogger uses the change in pressure to record changes in the water level. The barologger was used to compensate for barometric pressure changes. Raw data was downloaded from the levelloggers onto a laptop periodically over the monitoring period to create a continuous stage record for each site.

Stage gages were installed at each site and the channel at each site was surveyed to calibrate each levelogger to the specific channel conditions. Channel survey data were then used to create discharge rating curves at each site to estimate flows at different stream levels over the monitoring period (Figures 4 and 5, Appendix A). Additional low flow measurements were collected using a SonTek FlowTracker Acoustic Doppler velocity meter in the field to verify and calibrate rating curves (OEWRI 2007d, Photo 6). The highest calibration flows were provided by the City of Springfield Storm Water Division. Site HFF is just downstream of USGS gaging station South Creek near Springfield, Missouri (#07052120) which was used for discharge data for that particular site and has been in operation since 1998 (Table 3). Flow frequency curves for the monitoring period at all sites were created using the levelogger readings in 1% increments over the monitoring period using discharge rating curve equations.

Load Calculations

Flow-weighted loads over the monitoring period were calculated using the load duration method (USEPA 2007). This method combines the flow frequency curves from the hydrologic monitoring with load rating curves from the water quality monitoring portion of the project (Appendix B). Load rating curves are based on log-log linear regression equations between discharge and load. When the regression line over predicted load at the highest flows sampled, the average of the actual loads were used to better fit the trend line to the field data. Modeled daily load error was calculated by adding and subtracting the standard error from the regression line. Load at a given flow is then multiplied by the frequency of that flow during the study period in 1% intervals to create a load duration curve. Finally, duration curves for TP and TN were compared to the James River TMDL eutrophic threshold (ET) values of 0.075 mg/L TP and 1.5 mg/L TN (MDNR 2001).

RESULTS AND DISCUSSION

Hydrology

Continuous stage records were collected at all sites during the monitoring period that was overall drier than normal. Over 100,000 stage readings were collected at 15 minute intervals at NAT, CAM and FOR during the monitoring period. Between January 2012-March 2015 rainfall totals were nearly 46 cm below the 30-year average (Figure 3). Relatively dry conditions occurred from January 2012 through February 2013 where rainfall totals were 36.5 cm below normal. This was followed by a relatively wet period from March 2013 through October 2013 where rainfall was 21 cm above normal. Then, another dry period occurred from November 2013 to March 2015 where rainfall was 31 cm below normal. While the overall pattern is drier than it has been over the last 30 years, rainfall seems to be cyclic with alternating periods of wet and dry. However, the dry periods were much longer in duration than the wet periods over the monitoring period.

Sites NAT and HFF are ephemeral while FOR and CAM are perennial. Stage records show that NAT flows approximately 6% of the time while HFF flows about 13% of the time (Figure 4). Due to hot and dry conditions during the summer months stream base flow was low and was even dry at CAM where no flow occurred under the bridge 5-6% of time. It appears that South Creek water loses into the bed at the Campbell Avenue bridge from the pool located just upstream of the bridge, and no water flows through the culvert. Site FOR had continuous flow throughout the year, even during the very dry conditions, but did get extremely low at times. Annual mean discharge at all sites ranged from 0.04 m^3/s at NAT to 0.26 m^3/s at HFF (Table 4). The peak flow (0% of flows exceeds) ranged from 12.4 m^3/s at NAT to 43.0 m^3/s at HFF.

Hydrology Corrections

Due to bedrock along the channel edge, the initial location of the levelogger at FOR (location 1) was too high to record low flow stage. Consequently, an average base flow discharge of 0.005 m^3/s was used over the first 447 days of monitoring period to estimate base flows. On June 22, 2013 hydrology data was lost at all stations due to the theft of the levelogger and barologger at FOR. Data was lost over a 79 day period at CAM and NAT and over a 138 day period at FOR while new equipment was being purchased and installed at FOR (Figure 5). A new location (Location 2) for the levelogger on a set of concrete blocks was located upstream of FOR where low flow stage could be recorded for the remaining 577 days of the monitoring period. The two locations were combined by applying the appropriate % of time to each flow duration interval calculated and summing the values from the two locations, which was 43.65% at location 1 and 56.35% at location 2. Levelogger stage at location 2 was calibrated to the Fort street bridge stage gage in the field and a relationship between levelogger stage and thalweg depth was created to calculate discharge from that location.

Samples Collected

A total of 151 water quality samples were collected from all sites over the monitoring period spread out over all four seasons to best represent variable stream conditions found throughout the year. There were 30 base flow samples and 121 storm samples collected for this study. All base flow samples came from CAM and FOR with 15 collected at each site (Table 5). Of the 30 total base flow samples collected, 8 were collected in the winter, 8 in the spring, 6 in the summer and 8 in the fall. Of the 121 total storm samples, 30 each were collected at NAT, FOR and HFF and 31 collected at CAM (Table 6). Of these, 22 (18%) were collected over the winter, 45 (37%) during the spring, 34 (28%) over the summer, and 20 (17%) in the fall.

Base Flow Water Quality

Physical Water Parameters

Average in-situ base flow T was similar between the two sites while mean base flow SC, pH and DO was higher at FOR compared to CAM suggesting shallow ground water systems can be variable even in streams with similar land use located in similar geologic settings. Average base flow T was 14.8°C at both CAM and FOR over the sampling period (Table 7). Mean SC was 650 µS/cm at FOR compared to 532 µS/cm at CAM. The range of SC values at both sites was similar, but FOR SC values were higher than at CAM. Average base flow pH was 8.1 at FOR and 7.5 at CAM. Average DO was 10.7 at FOR and 9.7 at CAM. Average TB was 3.7 NTU at FOR and 4.5 NTU at CAM. These data reflect the variability in urban streams in Springfield and may reflect elevated contamination in the shallow ground water system flowing to Fassnight Creek.

Nutrients, Sediment and Chloride

Similar to the results of the in-situ physical water parameter measurement, average base flow TP, TN and Cl concentrations at FOR are higher compared to CAM suggesting low levels of shallow ground water contamination in Fassnight Creek. The mean base flow TP concentration at CAM is 0.015 mg/L compared to 0.027 mg/L at FOR (Table 7). At CAM, 73% of the samples collected at base flow exceeded the regional ambient nutrient criteria (ANC) of 0.01 mg/L TP and 93% exceeded the ANC at FOR (USEPA 2000). However, all samples collected fell below the James River TMDL ET criteria of 0.075 mg/L TP at base flow. Mean base flow TN is 2.15 mg/L at CAM compared to 2.48 mg/L at FOR. All samples exceeded the ANC for TN at base flow from both sites. Additionally, 93% of the base flow samples collected at FOR and 100% at CAM exceeded the TMDL ET over the sample period. The average base flow Cl concentration at CAM was 61.1 mg/L compared to 69.9 mg/L at FOR. Mean base flow TSS was similar at CAM and FOR, but was very low at both sites. These data suggest the shallow ground water system feeding Fassnight Creek may have low levels of contamination that could be from a variety of sources such as leaky wastewater infrastructure or other point source located upstream. The nutrient and Cl loads from each of these sites demonstrate how variable water quality can be in karst systems even in streams within close proximity of one another.

Storm Flow Water Quality

Physical Water Parameters

In-situ storm flow physical water parameters were fairly consistent throughout the sampling period within sites for all parameters accept SC and TB. Average storm flow T ranged from 14.7°C at NAT to 18.9°C at HFF over the sampling period with cv% between 38.4% at HFF and 50.5% at CAM (Table 8). Mean storm flow SC ranged from 77.9 µS/cm at NAT to 258.5 µS/cm at HFF with cv% between 47.1% at HFF and 103.9% at FOR. Storm flow pH was very consistent among sites with average values between 7.4 at CAM and 7.6 at NAT, FOR and HFF with a cv% <10% at all sites. Mean DO was also fairly similar among sites ranging from 9.3 at HFF to 11.0 at NAT with cv% from 23.0% at NAT to 31.4% at CAM. Average TB ranged from 87.8 NTU at HFF to 352.3 NTU at NAT and had relatively high variability with cv% ranging from 82.4% at HFF to 226.3% at FOR.

Nutrients, Sediment and Chloride

Nutrient concentrations at storm flow have less variability than TSS and Cl. Average storm flow TP ranged from 0.150 mg/L at NAT to 0.201 mg/L at FOR with cv% from 51.6% at FOR to 83.9% at NAT. Mean storm flow TN ranged from 1.0 mg/L at NAT to 1.27 mg/L at FOR with cv% between 37.3% at HFF and 62.6% at NAT. The largest difference in average storm flow concentrations among sites was with TSS which ranged from 34.2 mg/L at NAT to 102.6 mg/L at FOR with cv% from 126.8% at HFF to 145.6% at CAM. The range in mean concentration of Cl was relatively low from 20.5 mg/L at HFF to 30.5 mg/L at CAM but had relatively high variability with cv% between 93.3% at HFF and 217.6% at FOR. The high variability in Cl is likely due to seasonal road salt distribution in the winter. While TP concentrations do not vary as much as TSS, the highest mean TP and TSS concentration both come from FOR suggesting the importance of sediment bound phosphorus in that system. However, average TP concentrations are not much different at the other sites which suggest the importance of dissolved nutrient loads in these watersheds that may be independent of sediment pulses through the system. This is an important to understand because the type of water quality BMP considered to reduce nonpoint nutrient loads is dependent on whether the dominant form of phosphorus is dissolved or sediment bound. A more detailed sampling scheme that looks at how nutrients and sediment change over the hydrograph would be necessary to confirm this trend.

In general, the majority of storm samples are higher than the ANC and TMDL ET for TP and the majority of the samples are between the ANC and TMDL ET for TN. Over the sampling period, 100% of the samples collected at storm flow exceeded the ANC for TP at all sites. For TN, all storm samples collected at FOR and HFF exceeded the ANC, with 93% exceeding at NAT and 97% exceeding at CAM. The percentage of samples exceeding the TMDL ET for TP ranged from 81% at CAM to 93% at FOR over the sampling period. For TN, between 17% and 29% of the storm samples collected exceeded the TMDL ET recommendation. These results suggest watershed management efforts should focus on reducing TP contributions during storm flows and TN contributions from the shallow ground water are diluted.

Annual Loads

The annual TP load exceeds the eutrophic threshold at all sites, even though the daily load is < than the ET >95% of the monitoring period. The average flow weighted TP concentrations ranged from 0.130 mg/L at NAT to 0.427 mg/L at HFF (Table 9). The annual TP load at NAT is 0.17 Mg/yr and increases downstream to 0.96 Mg/yr at CAM and 3.5 Mg/yr at HFF. The annual TP load at FOR is 1.3 Mg/yr. The annual TP yield ranged from 0.08 Mg/km^2/yr at NAT to 0.20

Mg/km^2/yr at CAM. This shows the contributing area between NAT and CAM is contributing relatively high amounts of TP compared to the other sites. Annual loads are 74-469% higher than the load would be using the TMDL suggested eutrophic limit concentration of 0.075 mg/L (Table 10). However, all sites are well below the eutrophic threshold daily load for the majority of the monitoring period, but exceed the eutrophic threshold at only the highest flows (Figure 6). Site NAT exceeded the eutrophic threshold 7% of the monitoring period, CAM 2%, FOR 4%, and HFF 3%. These data suggest nonpoint source TP associated with urban development delivered during the largest flood events overwhelmingly controls the TP load in these highly urbanized watersheds.

The annual TN load for the sites with base flow are lower than eutrophic threshold, even though the daily load is at or slightly above the eutrophic threshold over most of the monitoring period. The average flow weighted TN concentrations ranged from 0.79 mg/L at NAT to 1.09 mg/L at HFF (Table 9). The annual TN load at NAT is 1.0 Mg/yr and increases downstream to 3.4 Mg/yr at CAM and 8.9 Mg/yr at HFF. The annual TN load at FOR is 5.5 Mg/yr. The annual TN yield ranged from 0.33 Mg/km^2/yr at HFF to 0.70 Mg/km^2/yr at CAM. Again the contributing area between NAT and CAM is contributing relatively high amounts of TN compared to the other sites. Annual loads are 28-47% lower than the load would be using the TMDL suggested eutrophic limit concentration of 1.5 mg/L (Table 10) The sites without base flow, NAT and HFF, are at or just below the eutrophic threshold daily load when there is water in the channel (Figure 7). Ephemeral sites NAT and HFF never exceeded the eutrophic threshold over the monitoring period while CAM exceeded the limit 83% of the monitoring period and FOR 96% during moderate, low and very low flows. Again, relatively low concentrations of TN during the largest flood events overwhelmingly controls the TN load in these watersheds.

The annual TSS load at FOR along Fassnight Creek was relatively high and TSS yield at CAM was also high compared to the other sites along South Creek (Table 6). The average flow weighted TSS concentrations ranged from 52.9 mg/L at NAT to 185.9 mg/L at FOR (Table 9). The annual TSS load at NAT is 68.9 Mg/yr and increases downstream to 237.2 Mg/yr at CAM and 747.2 Mg/yr at HFF. The annual TSS load at FOR is very high at 1,221 Mg/yr. The annual TSS yield ranged from 27.2 Mg/km^2/yr at HFF to 100 Mg/km^2/yr at FOR. As with TP and TN the contributing area between NAT and CAM is contributing relatively high amounts of TSS compared to the other sites along South Creek. Additionally, TSS loads are very high at FOR that could be the result of in-channel construction and/or bank erosion along Fassnight Creek upstream of the monitoring station. Further investigation of upstream channel conditions would be necessary to confirm this trend. Figure 8 shows the TSS load duration curves for this study.

The average flow weighted Cl concentrations ranged from 4.4 mg/L at NAT to 9.8 mg/L at HFF (Table 9). The annual Cl load at NAT is 5.8 Mg/yr and increases downstream to 24.1 Mg/yr at CAM and 80.6 Mg/yr at HFF. The annual Cl load at FOR is 39.3 Mg/yr. The annual Cl yield ranged from 2.6 Mg/km^2/yr at NAT to 5.0 Mg/km^2/yr at CAM. Again, the contributing area between NAT and CAM is delivering relatively high amounts of Cl compared to the other sites along South Creek. Figure 9 shows the Cl load duration curves for this study.

CONCLUSIONS

There are 6 main conclusions from this study:

1. **Three water quality/hydrology monitoring station were established along South Creek and one station was established at Fassnight Creek. A total of 151 samples were collected over a 38 month monitoring period.** Two hydrologic monitoring stations were installed at Campbell and National Avenues along South Creek. The third station was near the USGS gaging station near Highway FF. A forth station was installed at Fassnight Creek near Fort Avenue. All stations were in operated between January 2012 and March 2015. A total of 30 base flow samples and 121 storm flow samples were collected over the monitoring period. Water quality data collection included in-situ T, pH, DO, SC and TB and laboratory analysis included TP, TN, TSS and Cl.

2. **Base flow nutrient and Cl concentrations are higher at FOR than at CAM suggesting the shallow ground water system feeding Fassnight Creek has consistent low levels of contamination independent of storm events.** The mean base flow TP concentration at CAM is 0.015 mg/L compared to 0.027 mg/L at FOR. Mean base flow TN is 2.15 mg/L at CAM and 2.48 mg/L at FOR. The average base flow Cl concentration at CAM was 61.1 mg/L compared to 69.9 mg/L at FOR. These data suggest the shallow ground water system feeding Fassnight Creek may have low levels of contamination that could be from a variety of sources. The nutrient and Cl loads from each of these sites demonstrate how variable water quality can be in karst systems even in streams within close proximity of one another.

3. **Nutrient, TSS and Cl yields are significantly higher at CAM compared to NAT just upstream.** Annual yield of TP, TN, TSS and Cl are significantly higher at CAM compared to NAT immediately upstream suggesting the contributing area between the two sites is delivering relatively high amounts of contaminates during storms compared to the other locations sampled for this project. This area should be considered a potential target for storm water BMPs.

4. **The TSS load at FOR is very high relative to the other sites.** The annual TSS load at FOR is 1,221 Mg/yr for an annual yield of 100 Mg/km^2/yr which is more than double the next highest yield measured for this study. The high TSS load at FOR that could be the result of in-channel construction and/or bank erosion along Fassnight Creek upstream of the

monitoring station. Further investigation of upstream channel conditions would be necessary to confirm this trend.

5. **Annual TP load at all site exceeds the load using the TMDL eutrophic threshold limit at all sites even though daily loads are below the threshold over 95% of the time.** Annual loads are 74-469% higher than the load would be using the TMDL suggested eutrophic limit concentration of 0.075 mg/L. However, all sites are well below the eutrophic threshold daily load for the majority of the monitoring period, but exceed the eutrophic threshold at only the highest flows. These data suggest nonpoint source TP associated with urban development delivered during the largest flood events overwhelmingly controls the TP load in these highly urbanized watersheds.

6. **The annual TN load for both sites is lower than eutrophic threshold, even though the daily load is at or slightly above the eutrophic threshold most of the time.** Annual loads are 28-47% lower than the load would be using the TMDL suggested eutrophic limit concentration of 1.5 mg/L. The sites without base flow, NAT and HFF, are at or just below the eutrophic threshold daily load when there is water in the channel. The two sites with base flow are at or above the eutrophic threshold daily load for the majority of the year. Again, relatively low concentrations of TN during the largest flood events overwhelmingly controls the TN load in these watersheds.

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TABLES

Table 1. Sample site locations in the South Creek and Fassnight Creek watersheds.

Site	Location	UTM Zone 15N (m)	
		Easting	Northing
NAT	National Avenue Bridge	475,412.640	4,113,508.441
CAM	Campbell Avenue Bridge	473,773.315	4,113,406.568
FOR	Fort Avenue Bridge	472,622.868	4,115,710.857
HFF	Downstream of Highway FF	467,598.622	4,112,080.080

Table 2. Upstream land use and drainage area for each sample site.

Site	Drainage Area (km^2)	Land Use (%)					
		High Density Urban	Low Density Urban	Cropland	Grassland	Forest	Water
NAT	2.2	35.0	57.3	0.0	7.4	0.2	0.0
CAM	4.8	27.5	63.8	0.0	7.6	1.2	0.0
FOR	12.2	31.9	61.5	0.0	3.6	2.9	0.0
HFF	27.5	31.4	45.1	0.1	17.6	5.5	0.2

Table 3. USGS gaging station summary.

Station #:	07052120
Station Name:	South Creek near Springfield, MO.
UTM Zone 15N Easting (m):	467,786.5
UTM Zone 15N Northing (m):	4,111,977.8
Period of Record:	May 29, 1998 – Current year
Peak Discharge (m^3/s)	81.3
Annual Mean Discharge (m^3/s):	0.13
10% Flow (m^3/s):	0.17
50% Flow (m^3/s):	0.00
90%Flow (m^3/s):	0.00

Table 4. Discharge record for monitoring period (January 2012-March 2015).

Site	Period of Record	Drainage area (km^2)	Peak Q (m^3/s)	Mean Q (m^3/s)	10% Q (m^3/s)	50% Q (m^3/s)	90% Q (m^3/s)
NAT	1/30/2012-3/31/2015	2.2	12.4	0.04	0.0	0.0	0.0
CAM	1/27/2012-3/31/2015	4.8	18.0	0.11	0.05	0.01	0.001
FOR	1/24/2012-3/31/2015	12.2	41.6	0.21	0.05	0.006	0.004
HFF	1/1/2012-3/31/2015	27.5	43.0	0.26	1.33	0.0	0.0

Table 5. Base flow sample summary by season.

Samples	Base Flow Samples		Total
	CAM	FOR	
Winter 2014	1	1	2
Spring 2014	4	4	8
Summer 2014	3	3	6
Fall 2014	4	4	8
Winter 14-15	3	3	6
Total	15	15	**30**

Table 6. Storm flow sample summary by season.

Samples	Storm Flow Samples				Total
	NAT	CAM	FOR	HFF	
Winter 2012	1	1	1	1	4
Spring 2012	1	1	1	1	4
Summer 2012	3	3	3	1	10
Fall 2012	1	1	1	1	4
Winter 2013	2	2	2	1	7
Spring 2013	5	6	5	8	24
Summer 2013	3	3	2	3	11
Fall 2013	2	2	2	3	9
Winter 2014	3	4	3	1	11
Spring 2014	4	4	4	2	14
Summer 2014	3	2	2	6	13
Fall 2014	1	1	3	2	7
Winter 2015	0	0	0	0	0
Spring 2015	1	1	1	0	3
Total	30	31	30	30	**121**

Table 7. Base flow water quality summary statistics for CAM and FOR

Base Flow CAM	**TP mg/L**	**TN mg/L**	**TSS mg/L**	**Cl mg/L**	**Temp °C**	**SC μS/cm**	**pH std.**	**DO mg/L**	**Turb NTU**
n	15	15	15	15	15	15	15	15	15
Mean	0.015	2.15	2.2	61.1	14.8	532	7.5	9.7	4.5
Median	0.015	2.21	2.0	51.8	15.1	525	7.4	9.0	1.6
Min	0.003	1.54	0.0	39.0	5.3	456	7.1	5.7	0.0
Max	0.030	2.62	10.0	187.4	21.1	701	8.3	15.7	17.1
SD	0.008	0.31	2.5	36.0	5.0	55.9	0.3	2.7	5.4
CV%	54.9	14.4	116	58.9	33.8	10.5	4.2	28.1	121
% >ANC*	73%	100%							
% >TMDL**	0%	100%							

Base Flow FOR	**TP mg/L**	**TN mg/L**	**TSS mg/L**	**Cl mg/L**	**Temp °C**	**SC μS/cm**	**pH std.**	**DO mg/L**	**Turb NTU**
n	15	15	15	15	15	15	15	15	15
Mean	0.027	2.48	2.0	69.0	14.8	650	8.1	10.7	3.7
Median	0.025	2.74	1.0	66.9	17.1	650	8.2	8.6	1.6
Min	0.006	0.85	0.05	53.7	0.96	537	6.2	5.7	0.0
Max	0.050	3.53	18.0	117.9	23.9	766	8.7	19.1	10.1
SD	0.011	0.75	4.5	16.0	7.5	49.3	0.6	4.0	3.6
CV%	40.5	30.4	221	23.2	50.7	7.6	6.9	37.3	99.1
% >ANC*	93%	100%							
% >TMDL**	0%	93%							

* ANC = Ambient nutrient criteria for Ecoregion XI, TP = 0.01 mg/L, TN = 0.31 mg/L

** TMDL = Total maximum daily load recommendations for James River, TP = 0.075 mg/L, TN = 1.5 mg/L

Table 8. Storm flow water quality summary statistics for all sites

Storm Flow NAT	**TP mg/L**	**TN mg/L**	**TSS mg/L**	**Cl mg/L**	**Temp °C**	**SC µS/cm**	**pH std.**	**DO mg/L**	**Turb NTU**
n	30	30	30	30	29	29	29	29	22
Mean	0.150	1.00	34.2	28.2	14.7	77.9	7.6	11.0	352.3
Median	0.116	0.79	19.0	5.4	14.1	55.0	7.6	10.8	54.5
Min	0.025	0.05	1.0	0.01	1.5	18.0	6.3	7.5	0.0
Max	0.662	3.32	201.3	141.4	25.8	268.0	8.9	16.3	3,122
SD	0.126	0.62	47.0	42.2	6.5	56.1	0.7	2.5	736.1
CV%	83.9	62.2	137.6	149.9	44.1	72.0	8.6	23.0	209.0
% >ANC*	100%	93%							
% >TMDL**	87%	17%							
Storm Flow CAM	**TP mg/L**	**TN mg/L**	**TSS mg/L**	**Cl mg/L**	**Temp °C**	**SC µS/cm**	**pH std.**	**DO mg/L**	**Turb NTU**
n	31	30	31	31	30	31	31	30	21
Mean	0.169	1.09	57.2	30.5	15.2	99.6	7.4	10.2	351.6
Median	0.134	0.93	20.3	5.7	15.6	78.0	7.5	9.7	128.4
Min	0.036	0.27	2.0	0.02	0.5	18.0	6.0	3.6	0.1
Max	0.497	2.09	327.3	264.6	36.7	480.0	8.3	16.0	2,217
SD	0.119	0.51	83.2	66.3	7.7	89.2	0.6	3.2	642.7
CV%	70.3	46.9	145.6	217.5	50.5	89.5	7.5	31.4	182.8
% >ANC*	100%	97%							
% >TMDL**	81%	29%							
Storm Flow FOR	**TP mg/L**	**TN mg/L**	**TSS mg/L**	**Cl mg/L**	**Temp °C**	**SC µS/cm**	**pH std.**	**DO mg/L**	**Turb NTU**
n	30	30	30	29	30	30	30	30	23
Mean	0.201	1.27	102.6	28.9	15.2	115.4	7.6	9.9	227.7
Median	0.187	1.03	59.3	6.7	14.9	96.0	7.8	10.0	87.0
Min	0.035	0.35	5.0	1.1	2.5	18.0	5.8	4.5	0.08
Max	0.474	3.28	545.3	316.1	34.6	700.0	8.8	15.7	2,499
SD	0.104	0.72	132.4	63.0	6.7	119.8	0.7	2.9	515.2
CV%	51.6	57.0	129.0	217.6	44.3	103.9	9.3	28.8	226.3
% >ANC*	100%	100%							
% >TMDL**	93%	23%							
Storm Flow HFF	**TP mg/L**	**TN mg/L**	**TSS mg/L**	**Cl mg/L**	**Temp °C**	**SC µS/cm**	**pH std.**	**DO mg/L**	**Turb NTU**
n	30	30	30	30	26	26	29	26	20
Mean	0.199	1.11	87.0	20.5	18.9	258.5	7.6	9.3	87.8
Median	0.156	1.08	56.9	17.2	19.1	257.0	7.7	8.8	66.3
Min	0.025	0.45	7.3	3.8	6.3	87.0	6.3	2.8	0.0
Max	0.592	1.93	538.0	102.8	42.8	553.0	8.7	13.8	264.0
SD	0.138	0.41	110.3	19.1	7.3	121.8	0.5	2.4	72.4
CV%	69.5	37.3	126.8	93.3	38.4	47.1	6.9	26.2	82.4
% >ANC*	100%	100%							
% >TMDL**	83%	17%							

* ANC = Ambient nutrient criteria for Ecoregion XI, TP = 0.01 mg/L, TN = 0.31 mg/L

** TMDL = Total maximum daily load recommendations for James River, TP = 0.075 mg/L, TN = 1.5 mg/L

Table 9. Flow-weighted concentrations, loads, and yield for nutrients, sediment and chloride

Site	Ad km^2	TP			TN			TSS			Cl		
		Avg. Con. mg/L	**Annual Load (Range) Mg**	**Annual Yield Mg/km^2**	**Avg. Con. mg/L**	**Annual Load (Range) Mg**	**Annual Yield Mg/km^2**	**Avg. Con. mg/L**	**Annual Load (Range) Mg**	**Annual Yield Mg/km^2**	**Avg. Con. mg/L**	**Annual Load (Range) Mg**	**Annual Yield Mg/km^2**
NAT	2.2	0.130	0.17 (0.09-0.33)*	0.08	0.79	1.0 (0.62-1.62)*	0.47	52.9	68.9 (23.6-200.8)*	31.3	4.4	5.8 (1.6-21.3)*	2.6
CAM	4.8	0.269	0.96 (0.42-2.2)*	0.20	0.94	3.4 (2.1-5.6)*	0.70	66.5	237.2 (45.5-1,237)*	49.4	6.8	24.1 (4.6-127.5)*	5.0
FOR	12.2	0.200	1.3 (0.65-2.6)*	0.11	0.83	5.5 (3.3-9.1)*	0.45	185.9	1,221 (245.4-6,074)*	100.0	6.0	39.3 (13.7-112.5)*	3.2
HFF	27.5	0.427	3.5 (1.9-6.4)*	0.13	1.09	8.9 (6.1-13.1)*	0.33	90.7	747.2 (361.5-1,545)*	27.2	9.8	80.6 (38.5-168.9)*	2.9

* +/- the standard error of the regression model

Table 10. Comparison of TP and TN loads with TMDL eutrophic threshold

Site	Ad km^2	% of samples >TMDL 0.075 mg/L Limit	TMDL TP Annual Load (Mg)	Study TP Annual Load (Mg)	%Diff	% of samples >TMDL 1.5 mg/L Limit	TMDL TN Annual Load (Mg)	Study TN Annual Load (Mg)	%Diff
NAT	2.2	86.7%	0.10	0.17	+74%	46.7%	1.96	1.0	-47%
CAM	4.8	54.3%	0.27	0.96	+259%	16.7%	5.4	3.4	-37%
FOR	12.2	62.2%	0.49	1.3	+166%	50.0%	9.9	5.5	-45%
HFF	27.5	83.3%	0.62	3.5	+469%	16.7%	12.4	8.9	-28%

FIGURES

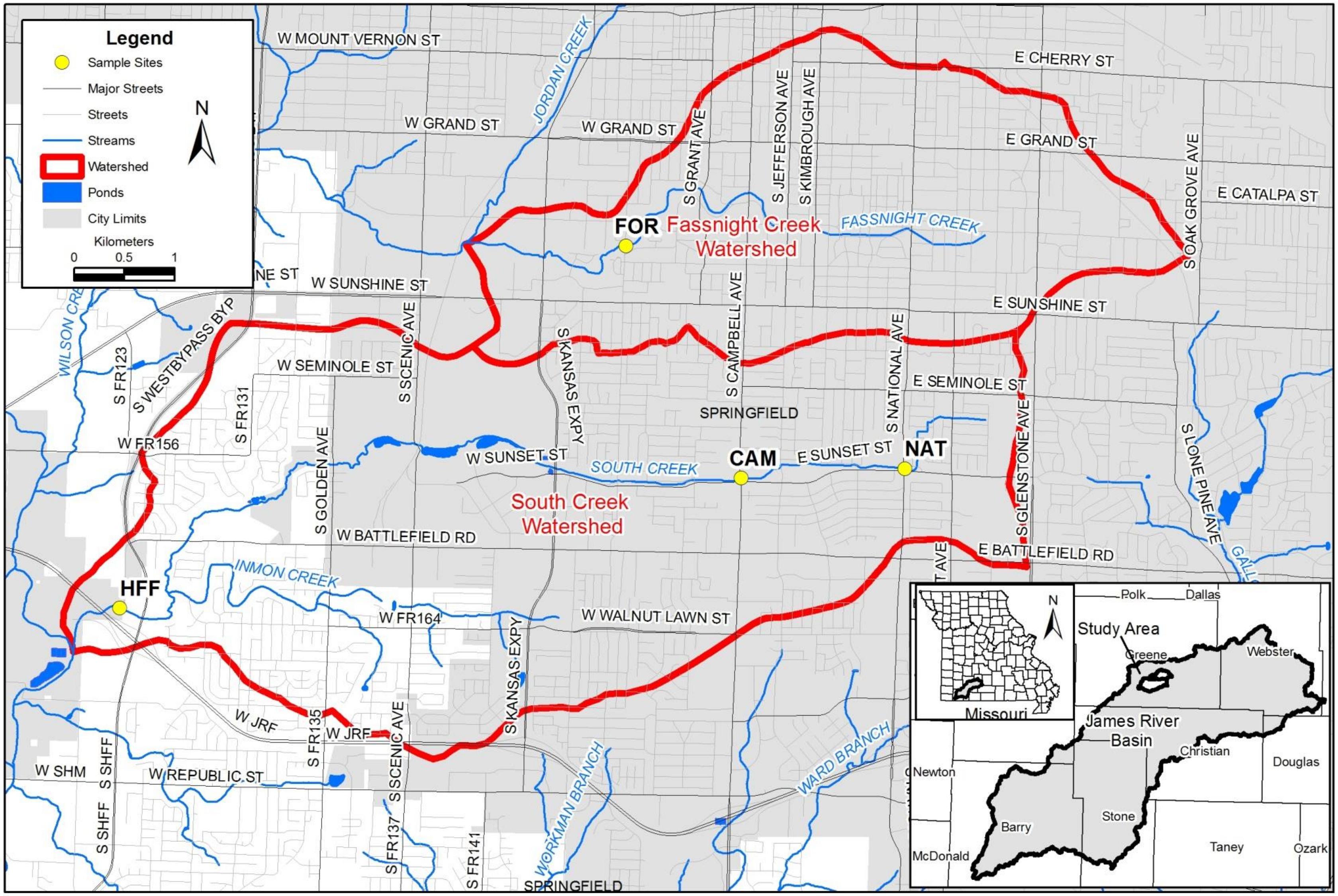


Figure 1. South Creek and Fassnight Creek watersheds and monitoring locations.

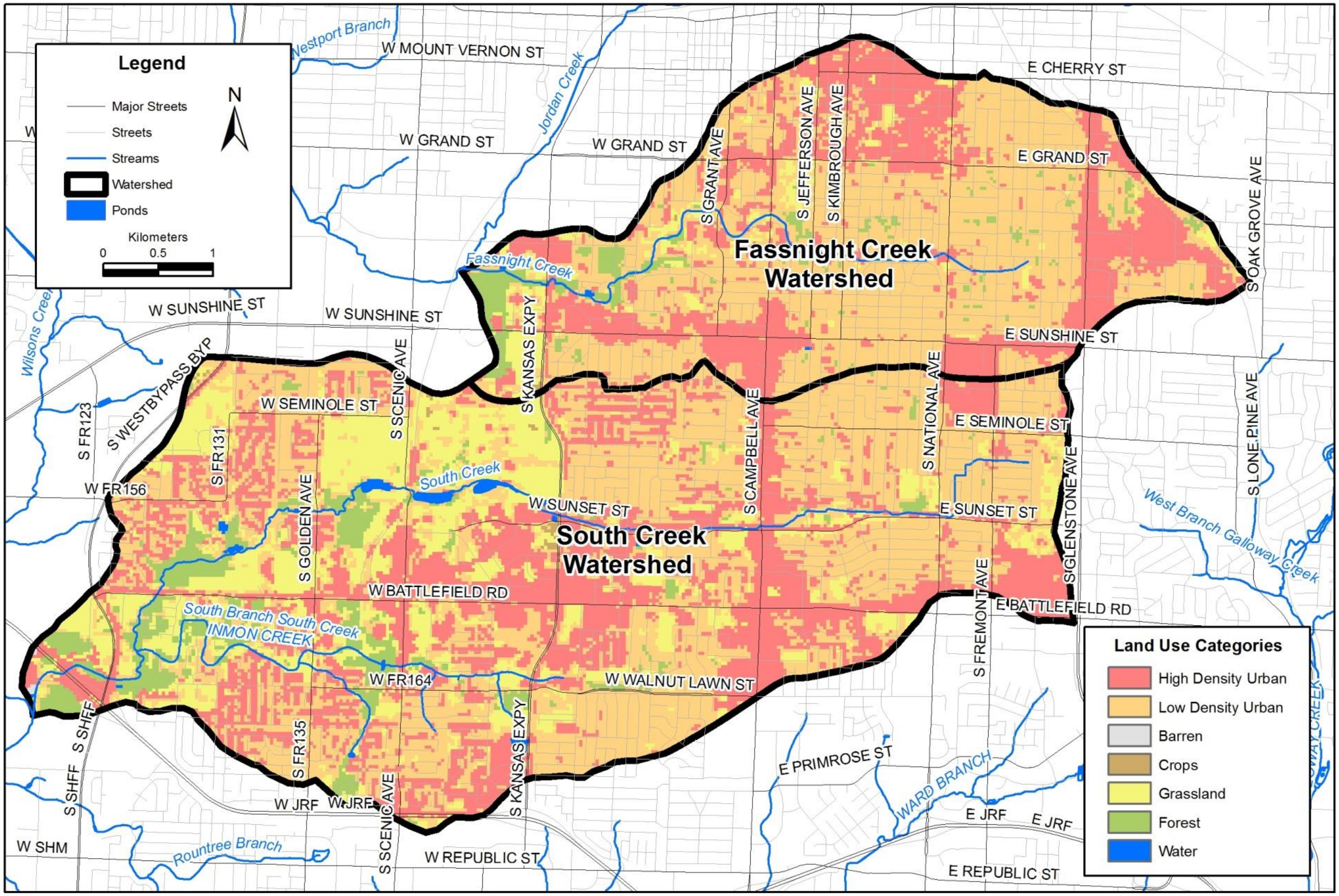
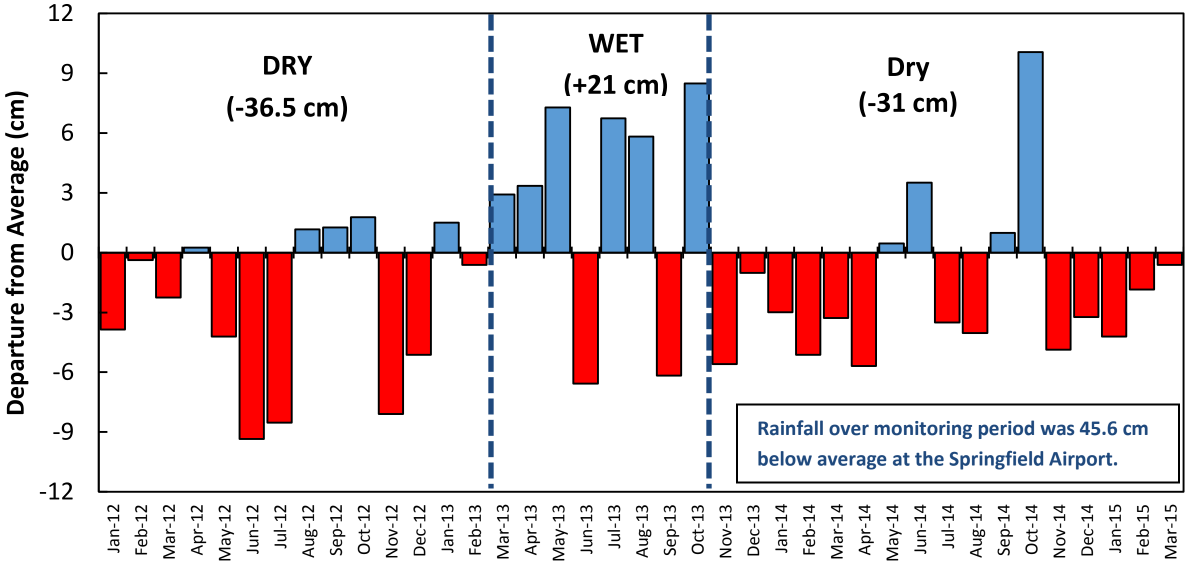


Figure 2. Land use in the South and Fassnight Creek watersheds.



Rainfall over monitoring period was 45.6 cm below average at the Springfield Airport.

Figure 3. Rainfall departure from normal over the study period.

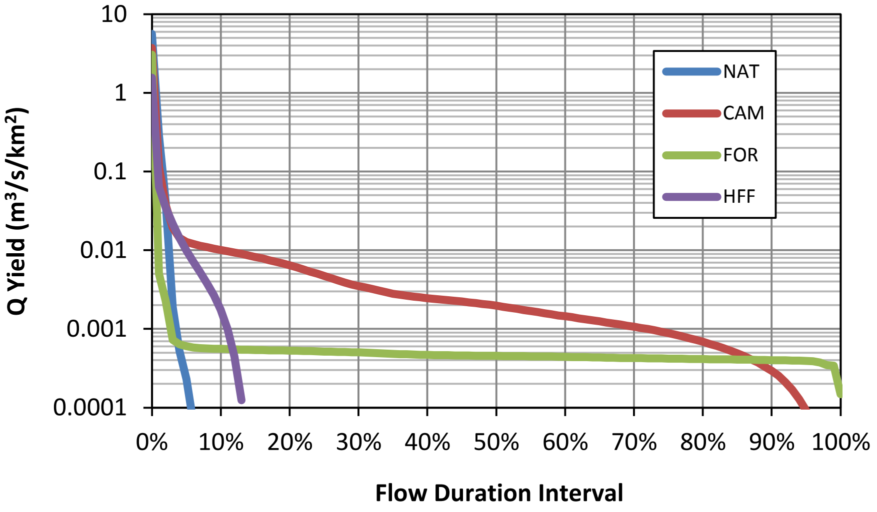


Figure 4. Flow duration curve showing discharge yield at each monitoring station.

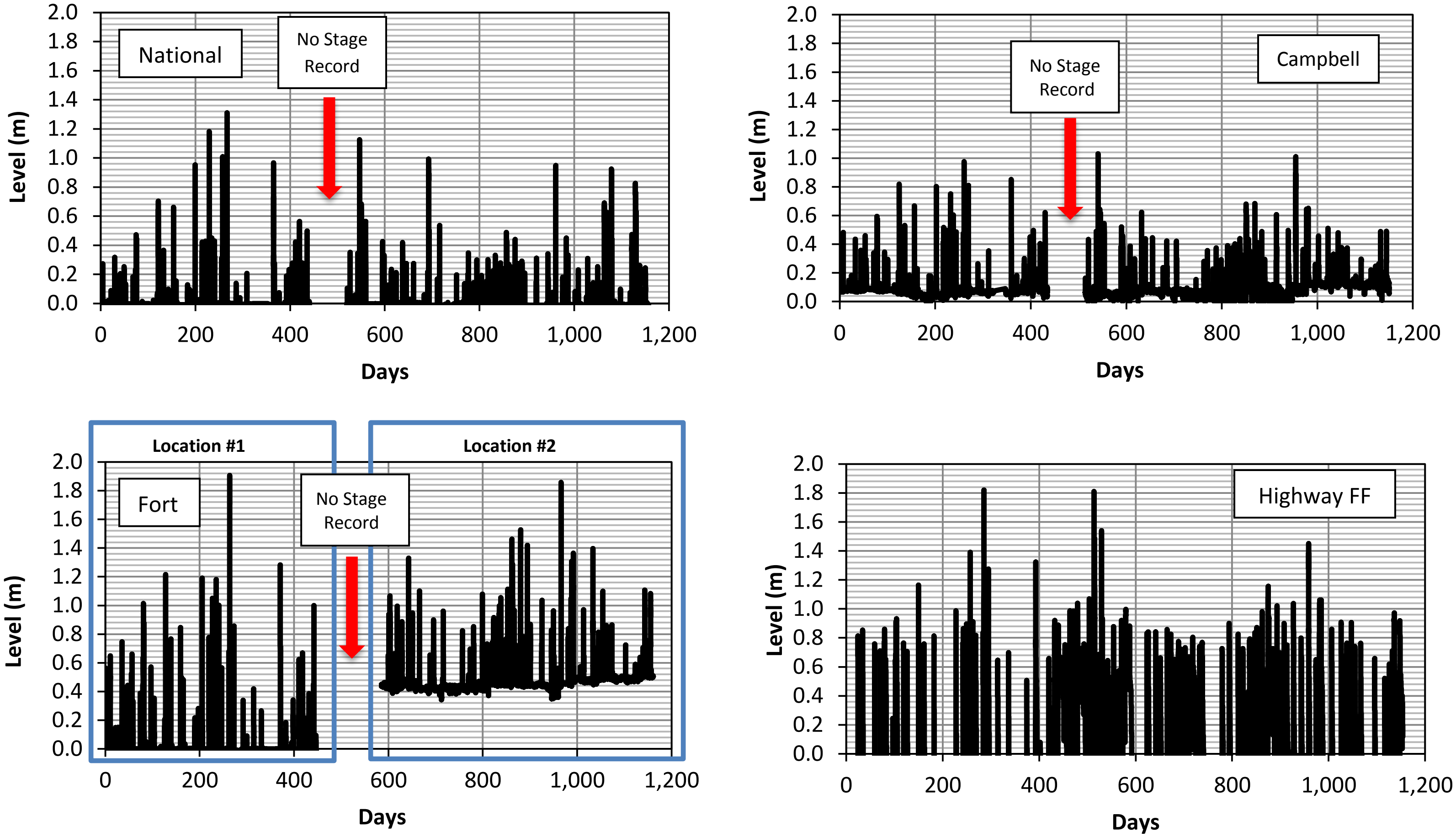


Figure 5. Stage vs. time for each monitoring station.

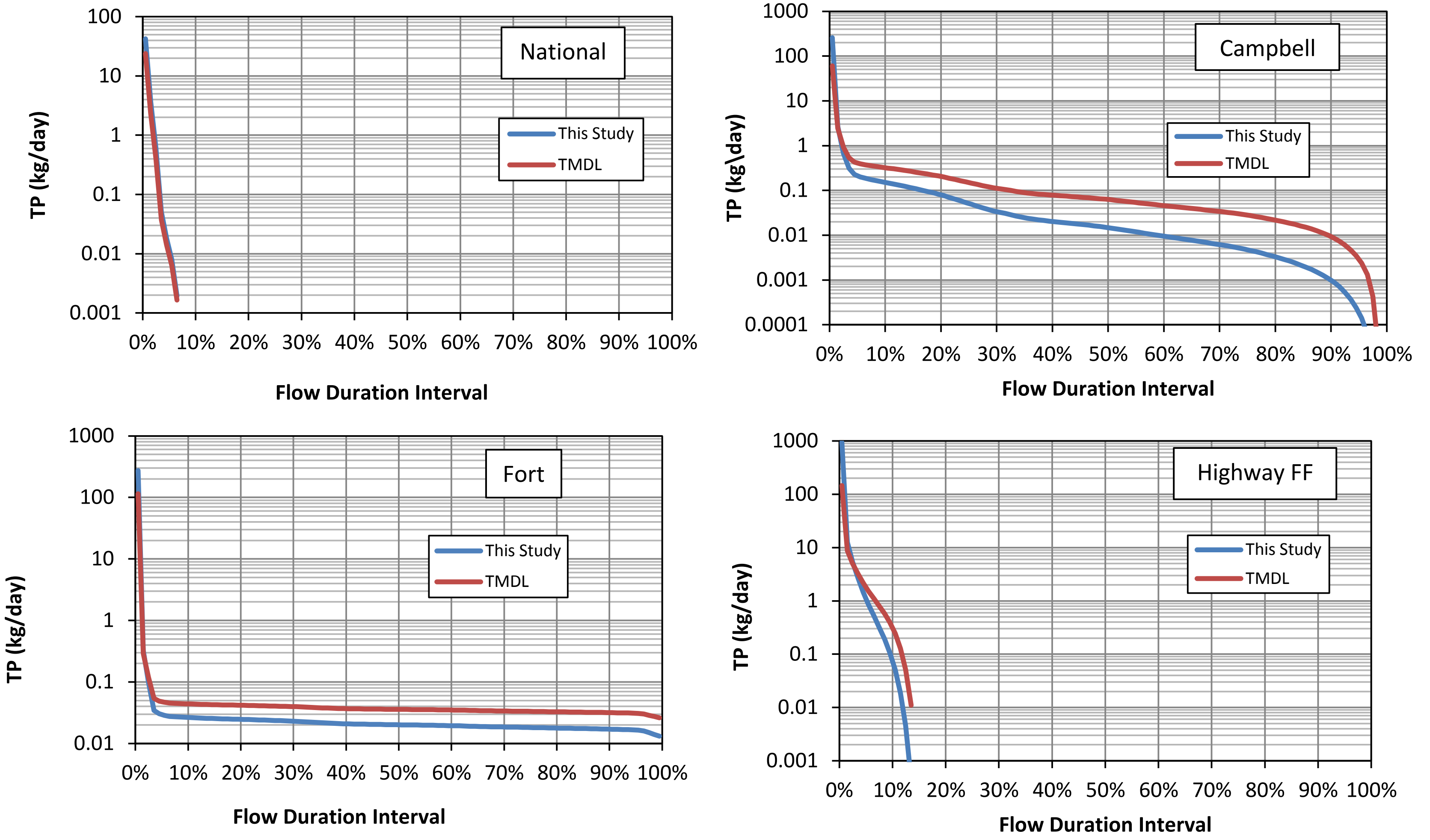


Figure 6. TP load duration curves for each site.

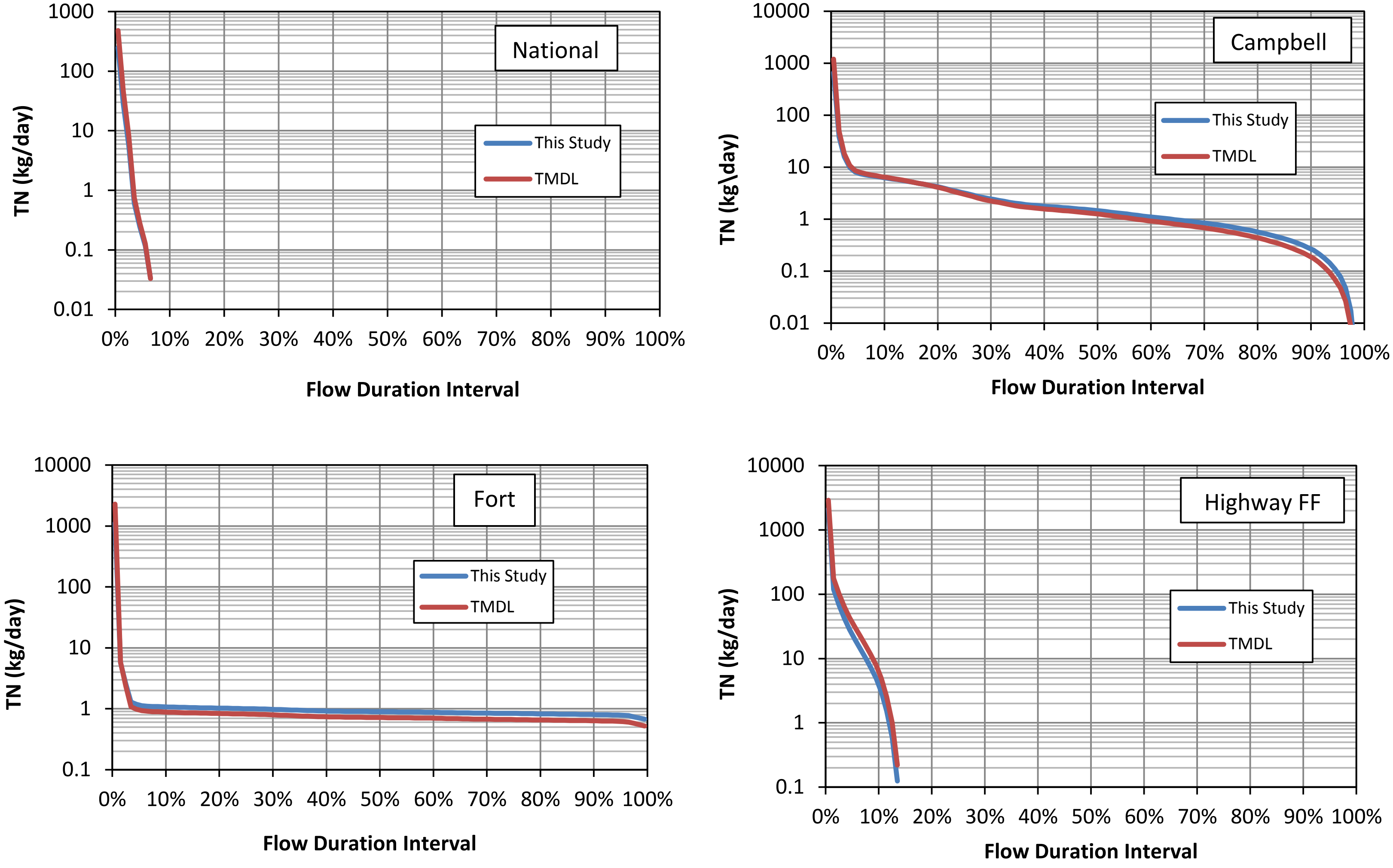


Figure 7. TN load duration curves for each site.

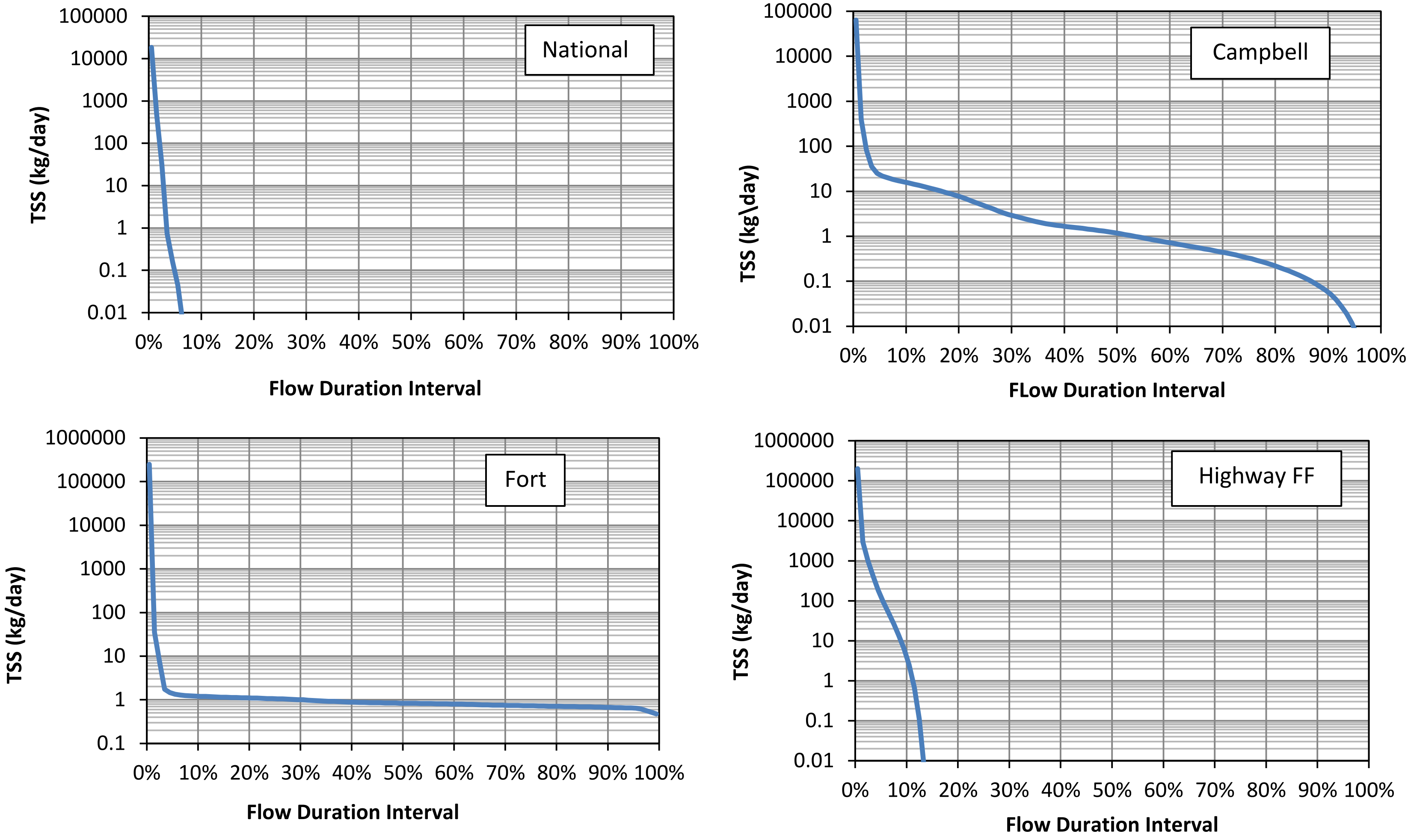


Figure 8. TSS load duration curves for each site.

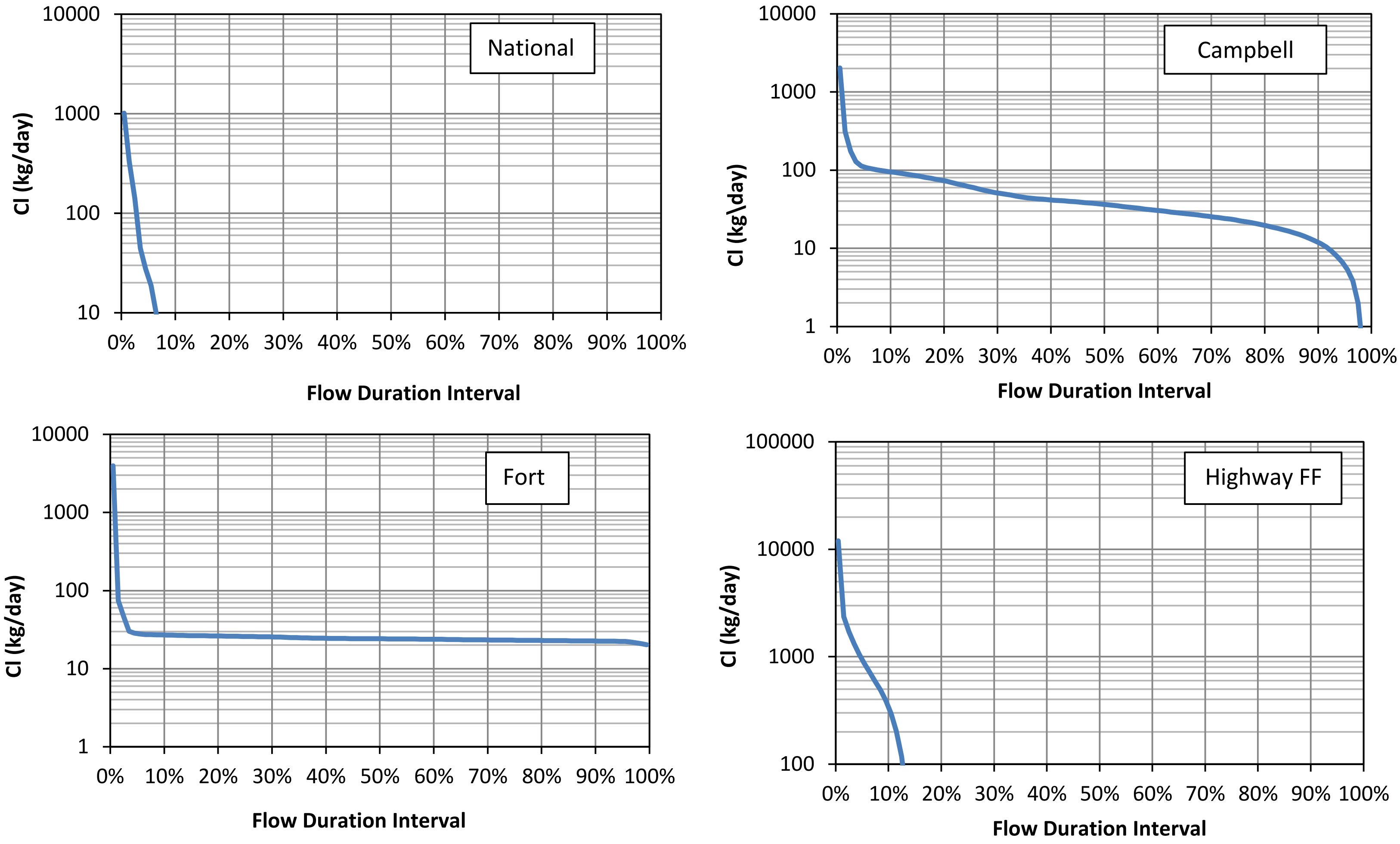


Figure 9. Cl load duration curves for each site.

PHOTOS

Photo 1. Site NAT upstream of National Avenue.

Photo 2. Site CAM upstream of Campbell Avenue.

Photo 3. Site FOR downstream of Fort Avenue.

Photo 4. Site HFF downstream of Highway FF along Greenway Trail.

Photo 5. Levelogger housing and stage gage installed at National Avenue.

Photo 6. Levelogger housing with cap.

Photo 7. Removing levelogger from housing.

Photo 8. Levelogger removed from housing.

APPENDIX A – Discharge Rating Curves

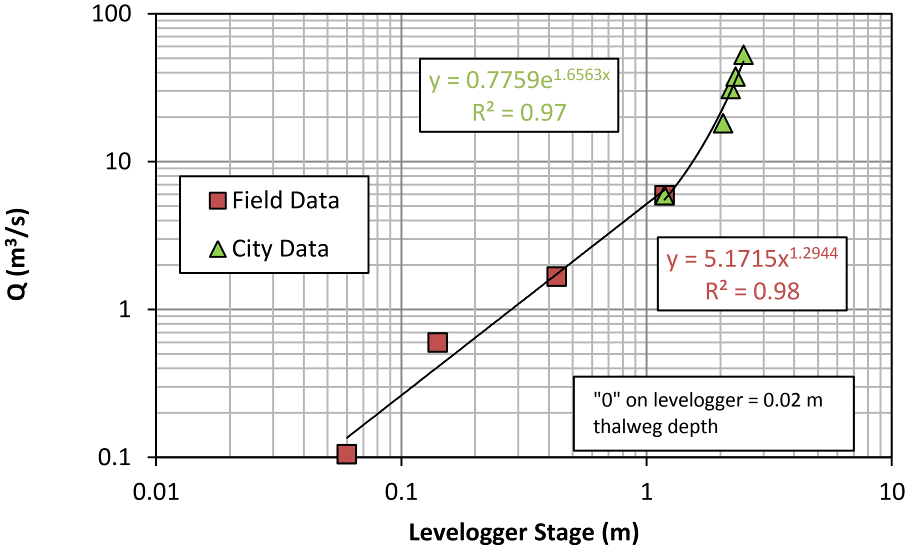


Figure 10. Discharge rating curve for NAT.

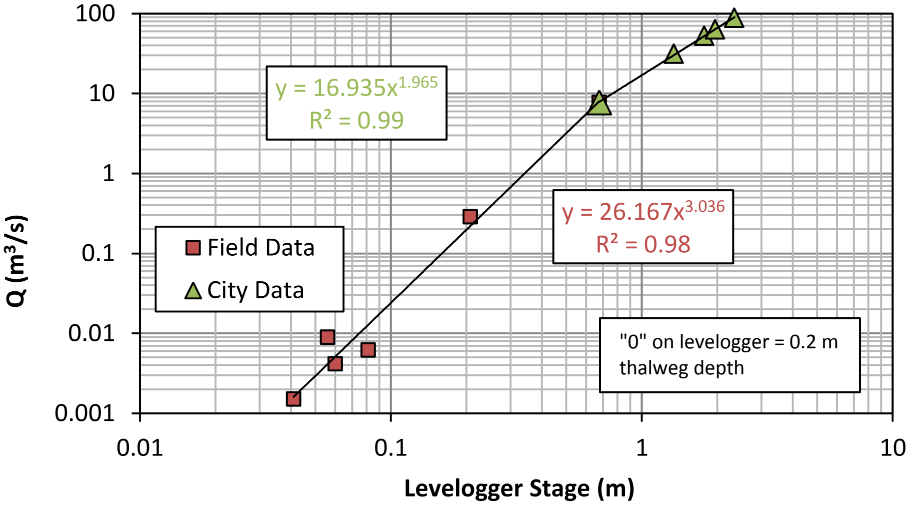


Figure 11. Discharge rating curve for CAM.

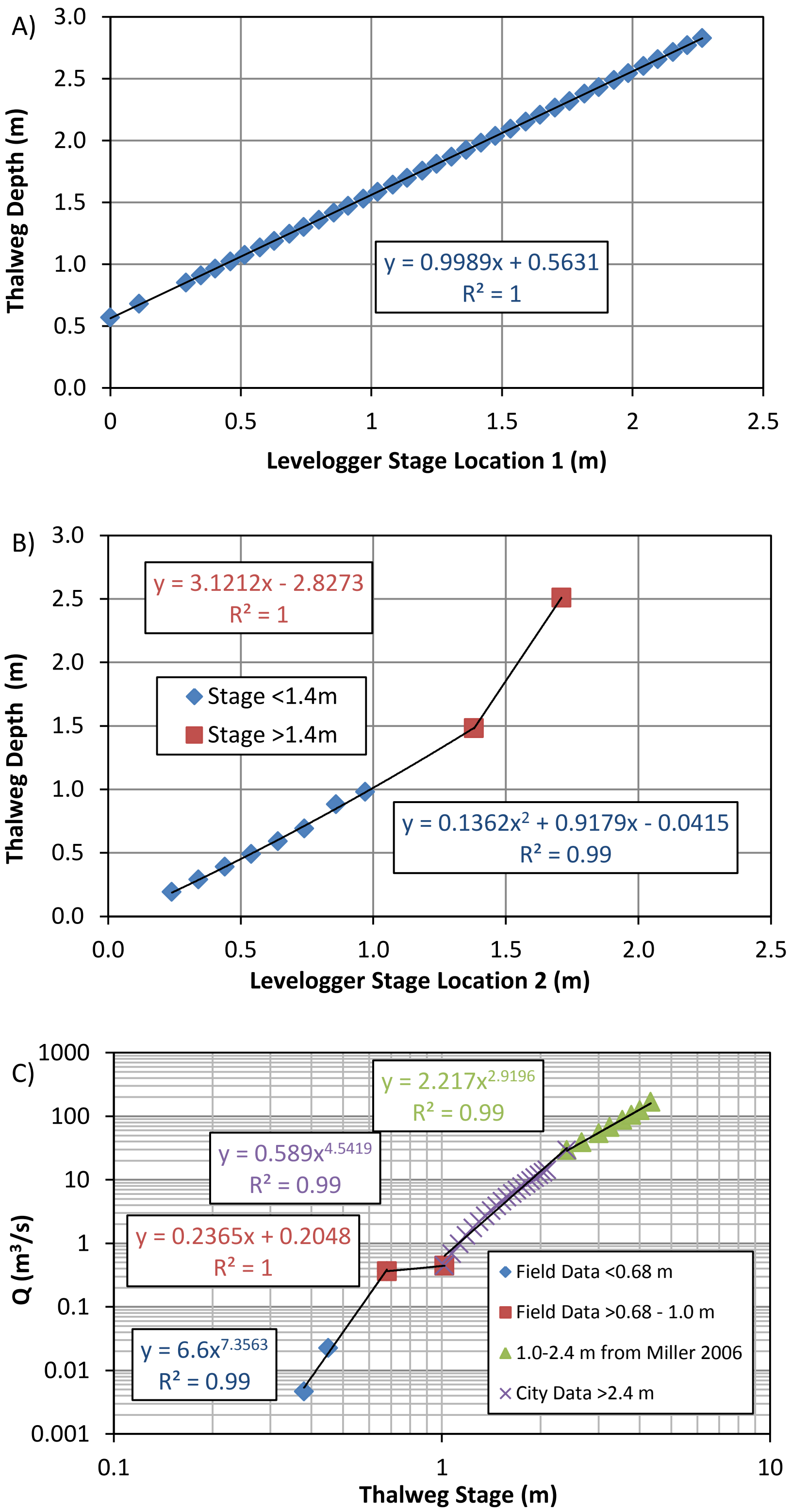


Figure 12. Levelogger stage to thalweg depth relationships at A) location 1 and B) location 2 and C) discharge rating curve at FOR.

APPENDIX B – Flow Duration Tables

Table 11. NAT Flow Duration Table

Flow Duration Interval (%)	Flow Duration Q (m^3/s)	Mean BIN Q (m^3/s)	Mid-BIN Interval
100%	0.000	0.000	
99%	0.000	0.000	99.5%
98%	0.000	0.000	98.5%
97%	0.000	0.000	97.5%
96%	0.000	0.000	96.5%
95%	0.000	0.000	95.5%
94%	0.000	0.000	94.5%
93%	0.000	0.000	93.5%
92%	0.000	0.000	92.5%
91%	0.000	0.000	91.5%
90%	0.000	0.000	90.5%
89%	0.000	0.000	89.5%
88%	0.000	0.000	88.5%
87%	0.000	0.000	87.5%
86%	0.000	0.000	86.5%
85%	0.000	0.000	85.5%
84%	0.000	0.000	84.5%
83%	0.000	0.000	83.5%
82%	0.000	0.000	82.5%
81%	0.000	0.000	81.5%
80%	0.000	0.000	80.5%
79%	0.000	0.000	79.5%
78%	0.000	0.000	78.5%
77%	0.000	0.000	77.5%
76%	0.000	0.000	76.5%
75%	0.000	0.000	75.5%
74%	0.000	0.000	74.5%
73%	0.000	0.000	73.5%
72%	0.000	0.000	72.5%
71%	0.000	0.000	71.5%
70%	0.000	0.000	70.5%
69%	0.000	0.000	69.5%
68%	0.000	0.000	68.5%
67%	0.000	0.000	67.5%
66%	0.000	0.000	66.5%
65%	0.000	0.000	65.5%
64%	0.000	0.000	64.5%
63%	0.000	0.000	63.5%
62%	0.000	0.000	62.5%
61%	0.000	0.000	61.5%
60%	0.000	0.000	60.5%
59%	0.000	0.000	59.5%
58%	0.000	0.000	58.5%
57%	0.000	0.000	57.5%
56%	0.000	0.000	56.5%
55%	0.000	0.000	55.5%
54%	0.000	0.000	54.5%
53%	0.000	0.000	53.5%
52%	0.000	0.000	52.5%
51%	0.000	0.000	51.5%
50%	0.000	0.000	50.5%

49%	0.000	0.000	49.5%
48%	0.000	0.000	48.5%
47%	0.000	0.000	47.5%
46%	0.000	0.000	46.5%
45%	0.000	0.000	45.5%
44%	0.000	0.000	44.5%
43%	0.000	0.000	43.5%
42%	0.000	0.000	42.5%
41%	0.000	0.000	41.5%
40%	0.000	0.000	40.5%
39%	0.000	0.000	39.5%
38%	0.000	0.000	38.5%
37%	0.000	0.000	37.5%
36%	0.000	0.000	36.5%
35%	0.000	0.000	35.5%
34%	0.000	0.000	34.5%
33%	0.000	0.000	33.5%
32%	0.000	0.000	32.5%
31%	0.000	0.000	31.5%
30%	0.000	0.000	30.5%
29%	0.000	0.000	29.5%
28%	0.000	0.000	28.5%
27%	0.000	0.000	27.5%
26%	0.000	0.000	26.5%
25%	0.000	0.000	25.5%
24%	0.000	0.000	24.5%
23%	0.000	0.000	23.5%
22%	0.000	0.000	22.5%
21%	0.000	0.000	21.5%
20%	0.000	0.000	20.5%
19%	0.000	0.000	19.5%
18%	0.000	0.000	18.5%
17%	0.000	0.000	17.5%
16%	0.000	0.000	16.5%
15%	0.000	0.000	15.5%
14%	0.000	0.000	14.5%
13%	0.000	0.000	13.5%
12%	0.000	0.000	12.5%
11%	0.000	0.000	11.5%
10%	0.000	0.000	10.5%
9%	0.000	0.000	9.5%
8%	0.000	0.000	8.5%
7%	0.000	0.000	7.5%
6%	0.000	0.000	6.5%
5%	0.001	0.001	5.5%
4%	0.001	0.002	4.5%
3%	0.004	0.006	3.5%
2%	0.092	0.063	2.5%
1%	0.638	0.360	1.5%
0%	12.353	3.703	0.5%

Table 12. CAM Flow Duration Table

Flow Duration Interval (%)	Flow Duration Q (m^3/s)	Mean BIN Q (m^3/s)	Mid-BIN Interval
100%	0.000		
99%	0.000	0.000	99.5%
98%	0.000	0.000	98.5%
97%	0.000	0.000	97.5%
96%	0.000	0.000	96.5%
95%	0.000	0.000	95.5%
94%	0.001	0.001	94.5%
93%	0.001	0.001	93.5%
92%	0.001	0.001	92.5%
91%	0.001	0.001	91.5%
90%	0.001	0.001	90.5%
89%	0.002	0.002	89.5%
88%	0.002	0.002	88.5%
87%	0.002	0.002	87.5%
86%	0.002	0.002	86.5%
85%	0.002	0.002	85.5%
84%	0.003	0.002	84.5%
83%	0.003	0.003	83.5%
82%	0.003	0.003	82.5%
81%	0.003	0.003	81.5%
80%	0.003	0.003	80.5%
79%	0.004	0.003	79.5%
78%	0.004	0.004	78.5%
77%	0.004	0.004	77.5%
76%	0.004	0.004	76.5%
75%	0.004	0.004	75.5%
74%	0.005	0.004	74.5%
73%	0.005	0.005	73.5%
72%	0.005	0.005	72.5%
71%	0.005	0.005	71.5%
70%	0.005	0.005	70.5%
69%	0.005	0.005	69.5%
68%	0.006	0.005	68.5%
67%	0.006	0.006	67.5%
66%	0.006	0.006	66.5%
65%	0.006	0.006	65.5%
64%	0.006	0.006	64.5%
63%	0.006	0.006	63.5%
62%	0.007	0.007	62.5%
61%	0.007	0.007	61.5%
60%	0.007	0.007	60.5%
59%	0.007	0.007	59.5%
58%	0.008	0.007	58.5%
57%	0.008	0.008	57.5%
56%	0.008	0.008	56.5%
55%	0.008	0.008	55.5%
54%	0.009	0.008	54.5%
53%	0.009	0.009	53.5%
52%	0.009	0.009	52.5%
51%	0.009	0.009	51.5%
50%	0.010	0.010	50.5%
49%	0.010	0.010	49.5%
48%	0.010	0.010	48.5%

47%	0.010	0.010	47.5%
46%	0.011	0.011	46.5%
45%	0.011	0.011	45.5%
44%	0.011	0.011	44.5%
43%	0.011	0.011	43.5%
42%	0.012	0.011	42.5%
41%	0.012	0.012	41.5%
40%	0.012	0.012	40.5%
39%	0.012	0.012	39.5%
38%	0.013	0.012	38.5%
37%	0.013	0.013	37.5%
36%	0.013	0.013	36.5%
35%	0.014	0.014	35.5%
34%	0.014	0.014	34.5%
33%	0.015	0.015	33.5%
32%	0.016	0.015	32.5%
31%	0.016	0.016	31.5%
30%	0.017	0.017	30.5%
29%	0.018	0.018	29.5%
28%	0.019	0.019	28.5%
27%	0.020	0.020	27.5%
26%	0.022	0.021	26.5%
25%	0.023	0.022	25.5%
24%	0.025	0.024	24.5%
23%	0.026	0.025	23.5%
22%	0.028	0.027	22.5%
21%	0.030	0.029	21.5%
20%	0.032	0.031	20.5%
19%	0.033	0.032	19.5%
18%	0.035	0.034	18.5%
17%	0.037	0.036	17.5%
16%	0.039	0.038	16.5%
15%	0.040	0.039	15.5%
14%	0.042	0.041	14.5%
13%	0.044	0.043	13.5%
12%	0.046	0.045	12.5%
11%	0.048	0.047	11.5%
10%	0.050	0.049	10.5%
9%	0.051	0.050	9.5%
8%	0.053	0.052	8.5%
7%	0.056	0.055	7.5%
6%	0.059	0.057	6.5%
5%	0.062	0.061	5.5%
4%	0.070	0.066	4.5%
3%	0.095	0.083	3.5%
2%	0.185	0.140	2.5%
1%	0.568	0.377	1.5%
0%	17.958	9.263	0.5%

Table 13. FOR Flow Duration Table

Flow Duration Interval (%)	Flow Duration Q (m^3/s)	Mean BIN Q (m^3/s)	Mid-BIN Interval
100%	0.001		
99%	0.003	0.003	99.5%
98%	0.003	0.003	98.5%
97%	0.004	0.003	97.5%
96%	0.004	0.004	96.5%
95%	0.004	0.004	95.5%
94%	0.004	0.004	94.5%
93%	0.004	0.004	93.5%
92%	0.004	0.004	92.5%
91%	0.004	0.004	91.5%
90%	0.004	0.004	90.5%
89%	0.004	0.004	89.5%
88%	0.004	0.004	88.5%
87%	0.004	0.004	87.5%
86%	0.005	0.004	86.5%
85%	0.005	0.005	85.5%
84%	0.005	0.005	84.5%
83%	0.005	0.005	83.5%
82%	0.005	0.005	82.5%
81%	0.005	0.005	81.5%
80%	0.005	0.005	80.5%
79%	0.005	0.005	79.5%
78%	0.005	0.005	78.5%
77%	0.005	0.005	77.5%
76%	0.005	0.005	76.5%
75%	0.005	0.005	75.5%
74%	0.005	0.005	74.5%
73%	0.005	0.005	73.5%
72%	0.005	0.005	72.5%
71%	0.005	0.005	71.5%
70%	0.005	0.005	70.5%
69%	0.005	0.005	69.5%
68%	0.005	0.005	68.5%
67%	0.005	0.005	67.5%
66%	0.005	0.005	66.5%
65%	0.006	0.006	65.5%
64%	0.006	0.006	64.5%
63%	0.006	0.006	63.5%
62%	0.006	0.006	62.5%
61%	0.006	0.006	61.5%
60%	0.006	0.006	60.5%
59%	0.006	0.006	59.5%
58%	0.006	0.006	58.5%
57%	0.006	0.006	57.5%
56%	0.006	0.006	56.5%
55%	0.006	0.006	55.5%
54%	0.006	0.006	54.5%
53%	0.006	0.006	53.5%
52%	0.006	0.006	52.5%
51%	0.006	0.006	51.5%
50%	0.006	0.006	50.5%
49%	0.007	0.006	49.5%
48%	0.007	0.007	48.5%

47%	0.007	0.007	47.5%
46%	0.007	0.007	46.5%
45%	0.007	0.007	45.5%
44%	0.007	0.007	44.5%
43%	0.007	0.007	43.5%
42%	0.007	0.007	42.5%
41%	0.007	0.007	41.5%
40%	0.007	0.007	40.5%
39%	0.007	0.007	39.5%
38%	0.007	0.007	38.5%
37%	0.008	0.007	37.5%
36%	0.008	0.008	36.5%
35%	0.008	0.008	35.5%
34%	0.008	0.008	34.5%
33%	0.008	0.008	33.5%
32%	0.009	0.009	32.5%
31%	0.009	0.009	31.5%
30%	0.009	0.009	30.5%
29%	0.010	0.009	29.5%
28%	0.010	0.009	28.5%
27%	0.010	0.010	27.5%
26%	0.010	0.010	26.5%
25%	0.010	0.010	25.5%
24%	0.010	0.010	24.5%
23%	0.050	0.030	23.5%
22%	0.050	0.051	22.5%
21%	0.050	0.051	21.5%
20%	0.050	0.051	20.5%
19%	0.050	0.051	19.5%
18%	0.051	0.051	18.5%
17%	0.051	0.052	17.5%
16%	0.051	0.052	16.5%
15%	0.051	0.052	15.5%
14%	0.051	0.052	14.5%
13%	0.052	0.052	13.5%
12%	0.052	0.053	12.5%
11%	0.052	0.053	11.5%
10%	0.053	0.054	10.5%
9%	0.053	0.054	9.5%
8%	0.054	0.054	8.5%
7%	0.054	0.055	7.5%
6%	0.056	0.056	6.5%
5%	0.068	0.063	5.5%
4%	0.093	0.082	4.5%
3%	0.155	0.126	3.5%
2%	0.220	0.191	2.5%
1%	0.389	0.306	1.5%
0%	41.565	18.668	0.5%

Table 14. HFF Flow Duration Table

Flow Duration Interval (%)	Flow Duration Q (m^3/s)	Mean BIN Q (m^3/s)	Mid-BIN Interval
100%	0.000		
99%	0.000	0.000	99.5%
98%	0.000	0.000	98.5%
97%	0.000	0.000	97.5%
96%	0.000	0.000	96.5%
95%	0.000	0.000	95.5%
94%	0.000	0.000	94.5%
93%	0.000	0.000	93.5%
92%	0.000	0.000	92.5%
91%	0.000	0.000	91.5%
90%	0.000	0.000	90.5%
89%	0.000	0.000	89.5%
88%	0.000	0.000	88.5%
87%	0.000	0.000	87.5%
86%	0.000	0.000	86.5%
85%	0.000	0.000	85.5%
84%	0.000	0.000	84.5%
83%	0.000	0.000	83.5%
82%	0.000	0.000	82.5%
81%	0.000	0.000	81.5%
80%	0.000	0.000	80.5%
79%	0.000	0.000	79.5%
78%	0.000	0.000	78.5%
77%	0.000	0.000	77.5%
76%	0.000	0.000	76.5%
75%	0.000	0.000	75.5%
74%	0.000	0.000	74.5%
73%	0.000	0.000	73.5%
72%	0.000	0.000	72.5%
71%	0.000	0.000	71.5%
70%	0.000	0.000	70.5%
69%	0.000	0.000	69.5%
68%	0.000	0.000	68.5%
67%	0.000	0.000	67.5%
66%	0.000	0.000	66.5%
65%	0.000	0.000	65.5%
64%	0.000	0.000	64.5%
63%	0.000	0.000	63.5%
62%	0.000	0.000	62.5%
61%	0.000	0.000	61.5%
60%	0.000	0.000	60.5%
59%	0.000	0.000	59.5%
58%	0.000	0.000	58.5%
57%	0.000	0.000	57.5%
56%	0.000	0.000	56.5%
55%	0.000	0.000	55.5%
54%	0.000	0.000	54.5%
53%	0.000	0.000	53.5%
52%	0.000	0.000	52.5%
51%	0.000	0.000	51.5%
50%	0.000	0.000	50.5%
49%	0.000	0.000	49.5%
48%	0.000	0.000	48.5%

47%	0.000	0.000	47.5%
46%	0.000	0.000	46.5%
45%	0.000	0.000	45.5%
44%	0.000	0.000	44.5%
43%	0.000	0.000	43.5%
42%	0.000	0.000	42.5%
41%	0.000	0.000	41.5%
40%	0.000	0.000	40.5%
39%	0.000	0.000	39.5%
38%	0.000	0.000	38.5%
37%	0.000	0.000	37.5%
36%	0.000	0.000	36.5%
35%	0.000	0.000	35.5%
34%	0.000	0.000	34.5%
33%	0.000	0.000	33.5%
32%	0.000	0.000	32.5%
31%	0.000	0.000	31.5%
30%	0.000	0.000	30.5%
29%	0.000	0.000	29.5%
28%	0.000	0.000	28.5%
27%	0.000	0.000	27.5%
26%	0.000	0.000	26.5%
25%	0.000	0.000	25.5%
24%	0.000	0.000	24.5%
23%	0.000	0.000	23.5%
22%	0.000	0.000	22.5%
21%	0.000	0.000	21.5%
20%	0.000	0.000	20.5%
19%	0.000	0.000	19.5%
18%	0.000	0.000	18.5%
17%	0.000	0.000	17.5%
16%	0.000	0.000	16.5%
15%	0.000	0.000	15.5%
14%	0.000	0.000	14.5%
13%	0.003	0.002	13.5%
12%	0.012	0.008	12.5%
11%	0.027	0.020	11.5%
10%	0.048	0.038	10.5%
9%	0.074	0.061	9.5%
8%	0.105	0.089	8.5%
7%	0.144	0.125	7.5%
6%	0.198	0.171	6.5%
5%	0.272	0.235	5.5%
4%	0.396	0.334	4.5%
3%	0.595	0.496	3.5%
2%	0.963	0.779	2.5%
1%	1.756	1.359	1.5%
0%	43.046	22.401	0.5%

APPENDIX C – Water Quality Datasets

Table 15. Water quality data for NAT

Site	Date	Time	LL Stage	Q	TP	TN	TSS	Cl	Temp	SC	pH	DO	Turb	Type	Season
			(m)	(m^3/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ºC)	(µS/cm)	std.	(mg/L)	(NTU)		
NAT	1/25/2012	11:25	0.03	0.055	0.085	0.99	4.7	101.8	8.1	55.0	7.5	10.8	0.4	Storm	Winter
NAT	5/7/2012	11:30	0.02	0.023	0.064	1.17	25.0	54.4	6.9	40.0	8.3	16.3	5.1	Storm	Spring
NAT	8/16/2012	20:53	0.10	0.263	0.097	1.72	6.0	5.2	10.5	99.0	6.9	14.6	282.0	Storm	Summer
NAT	8/31/2012	8:18	0.06	0.136	0.081	0.43	1.8	2.7	10.3	120.0	6.9	13.7	21.2	Storm	Summer
NAT	9/7/2012	19:36	0.28	0.995	0.025	0.53	18.3	0.0	15.9	37.0	6.3	13.0	0.0	Storm	Summer
NAT	10/12/2012	9:45	0.02	0.033	0.240	0.85	1.0	18.8	NS	NS	NS	NS	NS	Storm	Fall
NAT	1/29/2013	16:18	0.38	1.478	0.133	0.69	31.0	7.3	12.0	90.0	7.4	13.1	BP	Storm	Winter
NAT	1/29/2013	15:00	0.58	2.555	0.155	1.09	48.7	3.1	12.8	52.0	6.8	11.5	BP	Storm	Winter
NAT	4/10/2013	7:15	0.05	0.107	0.130	1.97	10.0	24.3	18.8	268.0	6.6	9.5	BP	Storm	Spring
NAT	4/10/2013	6:48	0.28	0.995	0.109	0.70	19.7	8.1	9.2	72.0	7.2	14.7	BP	Storm	Spring
NAT	4/10/2013	18:10	0.43	1.735	0.114	1.15	49.3	4.7	10.9	45.0	7.0	12.3	BP	Storm	Spring
NAT	4/18/2013	11:36	0.04	0.080	0.159	1.23	6.7	62.4	14.1	51.0	7.0	11.6	BP	Storm	Spring
NAT	4/18/2013	8:15	0.22	0.729	0.129	0.76	28.7	6.5	18.2	75.0	7.0	9.6	BP	Storm	Spring
NAT	7/26/2013	11:12	0.17	0.522	0.083	0.59	6.0	1.6	22.9	53.0	8.2	8.8	25.7	Storm	Summer
NAT	9/17/2013	8:44	0.03	0.055	0.077	1.61	2.0	4.3	20.6	144.0	7.8	8.7	19.8	Storm	Summer
NAT	9/20/2013	7:05	0.04	0.080	0.033	0.40	1.7	5.4	20.9	78.0	7.9	7.9	15.8	Storm	Summer
NAT	10/5/2013	10:20	0.18	0.562	0.069	0.59	4.7	2.0	19.5	54.0	7.6	9.1	19.8	Storm	Fall
NAT	10/29/2013	8:15	0.25	0.860	0.102	0.05	13.0	1.8	13.8	43.0	7.6	13.3	304.0	Storm	Fall
NAT	1/10/2014	13:40	0.11	0.297	0.161	0.70	35.7	113.6	2.6	47.0	8.3	13.7	140.6	Storm	Winter
NAT	1/10/2014	11:35	0.38	1.478	0.268	0.80	201.3	130.3	1.5	55.0	8.9	13.3	432.0	Storm	Winter
NAT	3/16/2014	12:30	0.06	0.136	0.079	0.62	12.3	141.4	3.6	84.0	8.5	13.2	62.3	Storm	Winter
NAT	4/27/2014	13:35	0.29	1.042	0.447	1.76	173.0	5.4	20.9	96.0	8.2	7.9	3,122	Storm	Spring
NAT	5/8/2014	16:30	0.26	0.904	0.178	1.03	44.3	2.2	21.9	57.0	8.3	7.5	53.3	Storm	Spring
NAT	6/5/2014	13:35	0.06	0.136	0.217	1.34	9.3	70.4	21.3	188.0	8.0	7.8	24.6	Storm	Spring
NAT	6/5/2014	10:29	0.61	2.727	0.141	1.00	75.7	0.0	20.2	44.0	6.9	8.4	55.7	Storm	Spring
NAT	6/23/2014	13:40	0.39	1.529	0.126	0.70	16.0	3.7	25.8	34.0	8.0	8.1	1,651	Storm	Summer
NAT	9/17/2014	9:00	0.95	4.839	0.117	0.77	32.7	2.4	18.7	25.0	7.7	9.3	265.0	Storm	Summer
NAT	9/17/2014	9:45	0.42	1.682	0.106	0.68	27.0	4.1	19.2	48.0	7.5	9.1	22.8	Storm	Summer
NAT	12/5/2014	1:30	0.12	0.332	0.111	0.62	28.5	12.5	11.3	18.0	8.3	11.3	154.0	Storm	Fall
NAT	3/25/2015	17:50	0.05	0.107	0.662	3.32	91.3	44.3	12.9	187.0	8.3	10.0	1,073	Storm	Spring

Highlighted sample concentrations = > ambient nutrient concentration (ANC), 0.01 mg/L TP and 0.31 mg/L TN.

Table 16. Water quality data for CAM

Site	Date	Time	LL Stage	Q	TP	TN	TSS	Cl	Temp	SC	pH	DO	Turb	Type	Season
			(m)	(m^3/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ºC)	(µS/cm)	std.	(mg/L)	(NTU)		
CAM	1/25/2012	11:35	0.12	0.042	0.067	0.72	8.0	23.9	7.3	192	7.3	10.9	0.12	Storm	Winter
CAM	5/7/2012	11:50	0.11	0.032	0.059	1.03	34.0	12.0	6.3	234	8.2	13.9	4.7	Storm	Spring
CAM	8/16/2012	21:14	0.32	0.823	0.147	2.02	7.0	3.0	11.7	97	7.0	14.2	274	Storm	Summer
CAM	8/31/2012	8:38	0.22	0.264	0.088	0.59	4.0	0.5	21.8	83	6.6	8.5	21.3	Storm	Summer
CAM	9/7/2012	19:58	0.42	1.879	0.081	1.11	12.7	0.3	14.2	65	6.4	14.9	BP	Storm	Summer
CAM	10/12/2012	10:04	0.16	0.100	0.168	0.58	2.0	0.5	36.7	132	6.0	3.6	BP	Storm	Fall
CAM	1/29/2013	16:37	0.51	3.388	0.159	0.94	38.0	5.7	12.4	93	7.6	12.6	BP	Storm	Winter
CAM	1/29/2013	15:30	0.66	7.411	0.350	1.03	103.0	2.7	12.7	62	7.5	14.3	BP	Storm	Winter
CAM	4/10/2013	7:25	0.17	0.121	0.126	1.66	16.0	14.3	17.0	177	6.4	8.3	BP	Storm	Spring
CAM	4/10/2013	18:58	0.55	4.261	0.174	0.83	70.7	3.5	9.5	65	7.2	13.9	BP	Storm	Spring
CAM	4/10/2013	18:21	0.61	5.835	0.497	1.60	316.0	9.7	11.0	102	7.0	12.7	BP	Storm	Spring
CAM	4/18/2013	11:47	0.11	0.032	0.128	1.11	6.0	14.6	14.8	194	7.1	9.9	BP	Storm	Spring
CAM	4/18/2013	9:00	0.44	2.164	0.125	0.76	20.3	5.7	16.3	94	6.7	9.5	BP	Storm	Spring
CAM	4/26/2013	14:46	0.21	0.229	0.055	0.52	5.3	6.3	NS	98	7.2	NS	NS	Storm	Spring
CAM	7/26/2013	11:24	0.42	1.879	0.134	0.90	19.0	3.4	22.6	62	7.5	7.7	29.5	Storm	Summer
CAM	9/17/2013	9:00	0.23	0.302	0.080	0.92	4.0	0.0	19.4	78	7.3	7.3	15	Storm	Summer
CAM	9/20/2013	7:15	0.13	0.053	0.036	0.52	2.7	2.8	21.7	120	7.5	7.2	12.1	Storm	Summer
CAM	10/5/2013	10:45	0.38	1.387	0.077	0.67	12.3	2.1	19.7	59	8.3	7.3	24.1	Storm	Fall
CAM	10/29/2013	8:35	0.55	4.261	0.133	0.66	29.7	1.1	13.6	26	7.5	12.9	707	Storm	Fall
CAM	1/10/2014	11:55	0.13	0.053	0.160	1.41	82.3	255.2	4.9	33	7.8	11.8	299.4	Storm	Winter
CAM	1/10/2014	14:00	0.31	0.747	0.160	0.82	43.0	122.1	1.5	53	8.1	13.7	128.4	Storm	Winter
CAM	1/10/2014	12:40	0.42	1.879	0.444	NS	181.3	264.6	0.5	40	8.0	16.0	500	Storm	Winter
CAM	2/13/2014	14:20	0.07	0.008	0.007	1.95	4.0	63.4	10.3	583	7.1	12.6	12.7	Base	Winter
CAM	3/16/2014	12:50	0.18	0.143	0.060	0.78	9.0	64.1	4.4	33	8.3	12.4	194.7	Storm	Winter
CAM	4/23/2014	11:30	0.08	0.012	0.003	1.62	0.7	52.5	15.1	505	7.5	9.0	7.5	Base	Spring
CAM	4/27/2014	14:20	0.37	1.279	0.371	1.62	143.7	15.1	20.1	18	7.7	6.8	193.3	Storm	Spring
CAM	5/6/2014	11:25	0.04	0.001	0.018	2.04	2.3	54.6	17.8	529	7.5	7.7	17.1	Base	Spring
CAM	5/8/2014	16:40	0.24	0.344	0.247	1.88	67.7	20.1	20.5	28	7.5	6.2	78	Storm	Spring
CAM	5/21/2014	12:48	0.04	0.001	0.015	2.26	10.0	57.7	18.9	520	7.4	7.3	10.6	Base	Spring
CAM	6/5/2014	13:50	0.34	0.989	0.142	0.63	12.3	7.0	20.0	103	7.6	6.5	35.1	Storm	Spring
CAM	6/5/2014	10:49	0.30	0.677	0.301	1.50	327.3	8.4	20.2	139	7.1	7.2	158.3	Storm	Spring
CAM	6/19/2014	13:30	0.08	0.012	0.020	2.28	2.7	40.6	21.1	459	7.1	8.4	4.6	Base	Summer
CAM	6/23/2014	14:00	0.65	7.076	0.200	1.42	47.7	3.1	25.0	30	7.6	8.1	2217	Storm	Summer
CAM	7/16/2014	16:55	0.10	0.024	0.015	2.24	3.0	57.5	18.4	456	7.5	9.0	6.8	Base	Summer
CAM	8/14/2014	13:15	0.08	0.012	0.006	2.62	0.4	72.3	19.1	518	7.4	8.0	4.6	Base	Summer
CAM	8/22/2014	9:15	0.05	0.003	0.023	2.50	0.1	51.6	20.1	525	7.4	5.7	0.01	Base	Summer
CAM	9/17/2014	9:30	0.90	13.768	0.322	1.99	106.7	2.7	19.0	44	7.9	9.1	242	Storm	Summer
CAM	9/25/2014	11:15	0.11	0.032	0.014	2.21	0.01	47.8	16.7	534	7.2	8.7	0.1	Base	Summer
CAM	10/10/2014	9:45	0.57	4.749	0.090	0.27	13.0	3.5	18.2	55	7.5	10.2	2200	Storm	Fall
CAM	10/21/2014	10:30	0.13	0.053	0.029	2.56	0.1	39.0	14.6	524	7.2	6.7	0.01	Base	Fall
CAM	11/10/2014	13:30	0.12	0.042	0.030	2.01	2.0	45.0	14.7	519	7.3	10.1	1.4	Base	Fall
CAM	12/11/2014	10:30	0.13	0.053	0.015	1.54	1.5	51.2	8.7	532	7.9	11.1	0.0	Base	Fall
CAM	1/8/2015	12:45	0.13	0.053	0.011	2.32	2.0	44.3	5.3	537	8.3	15.7	0.3	Base	Winter
CAM	2/13/2015	11:30	0.13	0.053	0.005	1.95	0.8	51.8	6.4	536	7.8	12.8	0.0	Base	Winter
CAM	3/17/2015	13:15	0.09	0.017	0.012	2.11	2.8	187.4	14.3	701	7.4	12.2	1.6	Base	Winter
CAM	3/25/2015	19:00	0.21	0.229	0.072	2.09	27.5	67.5	13.6	480	7.6	8.4	49.1	Storm	Spring

Highlighted sample concentrations = > ambient nutrient concentration (ANC), 0.01 mg/L TP and 0.31 mg/L TN.

Table 17. Water quality data for FOR

Site	Date	Time	LL Stage	Q	TP	TN	TSS	Cl	Temp	SC	pH	DO	Turb	Type	Season
			(m)	(m^3/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ºC)	(µS/cm)	std.	(mg/L)	(NTU)		
FOR	1/25/2012	11:05	0.11	0.358	0.128	0.72	16.3	23.2	8.0	183.0	8.1	10.1	0.1	Storm	Winter
FOR	5/7/2012	11:10	0.05	0.180	0.076	1.23	8.5	9.8	6.2	23.7	7.4	13.1	5.0	Storm	Spring
FOR	8/16/2012	20:33	0.39	0.430	0.234	1.98	66.0	4.6	14.3	120.0	7.9	9.1	336.0	Storm	Summer
FOR	8/31/2012	7:58	0.35	0.421	0.104	0.63	14.0	1.3	10.5	104.0	6.7	15.7	21.2	Storm	Summer
FOR	9/7/2012	19:15	0.53	0.880	0.277	1.70	104.5	6.3	18.8	95.0	6.2	13.0	0.1	Storm	Summer
FOR	10/12/2012	9:20	0.13	0.369	0.292	0.72	7.7	1.2	34.6	130.0	5.8	4.6	0.1	Storm	Fall
FOR	1/29/2013	15:56	0.66	1.466	0.310	1.18	124.5	7.3	12.7	97.0	7.1	13.5	BP	Storm	Winter
FOR	1/29/2013	14:34	1.28	9.434	0.326	1.05	276.0	5.6	14.3	66.0	6.8	11.5	BP	Storm	Winter
FOR	4/10/2013	7:40	0.18	0.380	0.135	1.76	69.0	16.2	16.6	167.0	6.6	10.1	BP	Storm	Spring
FOR	4/10/2013	19:10	0.67	1.521	0.186	1.04	103.3	6.7	9.4	73.0	7.2	13.9	BP	Storm	Spring
FOR	4/10/2013	18:32	0.92	3.517	0.366	0.98	250.3	4.9	9.8	65.0	7.2	4.5	BP	Storm	Spring
FOR	4/18/2013	12:12	0.08	0.259	0.104	1.07	8.0	SS	14.8	197.0	7.1	10.6	BP	Storm	Spring
FOR	4/18/2013	8:40	0.54	0.911	0.116	0.99	34.0	8.3	16.4	102.0	6.8	9.9	BP	Storm	Spring
FOR	9/17/2013	9:19	0.70	0.338	0.188	1.28	61.3	1.1	19.8	88.0	7.9	8.2	88.3	Storm	Summer
FOR	9/20/2013	7:30	0.60	0.091	0.071	0.55	5.0	5.8	21.9	131.0	7.7	7.9	19.1	Storm	Summer
FOR	10/5/2013	11:10	0.81	0.392	0.138	0.89	44.0	3.9	19.9	68.0	8.8	7.7	67.4	Storm	Fall
FOR	10/29/2013	9:10	0.83	0.397	0.219	1.02	101.0	1.1	13.8	59.0	8.3	13.1	120.0	Storm	Fall
FOR	1/10/2014	14:30	0.78	0.384	0.183	0.89	65.3	134.6	2.5	57.9	8.3	13.6	194.8	Storm	Winter
FOR	1/10/2014	12:20	0.47	0.011	0.474	2.04	363.0	316.1	4.1	87.3	7.8	12.5	424.0	Storm	Winter
FOR	2/13/2014	14:40	0.42	0.004	0.025	3.01	18.0	74.5	4.6	698.0	6.2	14.6	6.2	Base	Winter
FOR	3/16/2014	13:10	0.59	0.078	0.118	0.76	9.3	74.0	5.4	33.3	8.3	12.1	87.0	Storm	Winter
FOR	4/23/2014	12:05	0.45	0.008	0.035	1.86	1.3	69.6	17.1	627.0	8.2	9.0	8.0	Base	Spring
FOR	4/27/2014	14:05	0.71	0.382	0.264	2.78	57.3	51.3	19.4	48.6	7.9	6.7	74.2	Storm	Spring
FOR	5/6/2014	11:50	0.45	0.008	0.026	1.67	1.0	67.0	20.9	647.0	8.2	7.5	8.3	Base	Spring
FOR	5/8/2014	16:50	0.94	0.428	0.300	3.10	384.3	20.2	21.1	24.5	7.6	6.6	473.0	Storm	Spring
FOR	5/21/2014	13:29	0.45	0.008	0.027	1.97	1.0	69.2	21.4	650.0	8.0	7.7	7.8	Base	Spring
FOR	6/5/2014	14:04	0.74	0.373	0.190	0.98	42.3	6.8	20.2	152.0	7.9	7.0	125.0	Storm	Spring
FOR	6/5/2014	11:10	1.38	3.544	0.371	1.34	545.3	1.8	20.0	71.0	8.3	7.7	377.3	Storm	Spring
FOR	6/19/2014	14:10	0.46	0.009	0.021	2.98	1.7	55.5	21.6	593.0	8.0	8.5	3.6	Base	Spring
FOR	6/23/2014	15:00	0.86	0.406	0.208	1.26	69.0	6.6	24.0	105.0	7.9	7.4	46.9	Storm	Summer
FOR	7/16/2014	17:38	0.45	0.008	0.036	2.47	2.0	61.9	20.5	537.0	8.2	8.6	6.0	Base	Summer
FOR	8/14/2014	14:00	0.44	0.006	0.020	1.64	0.2	84.2	21.9	633.0	8.1	7.5	1.0	Base	Summer
FOR	8/22/2014	10:00	0.43	0.005	0.037	0.85	0.3	76.5	23.9	640.0	8.0	5.7	0.9	Base	Summer
FOR	9/17/2014	10:00	1.60	23.391	0.171	0.84	164.7	2.1	18.9	18.0	8.5	9.2	2,499	Storm	Summer
FOR	9/25/2014	12:00	0.46	0.009	0.024	2.85	0.1	65.8	17.7	651.0	7.9	8.2	10.1	Base	Fall
FOR	10/10/2014	10:30	0.97	0.436	0.096	0.35	13.0	5.7	18.0	123.0	7.6	10.9	136.0	Storm	Fall
FOR	10/21/2014	11:00	0.48	0.013	0.020	3.52	0.1	53.7	14.8	669.0	8.1	7.8	1.6	Base	Fall
FOR	11/4/2014	8:15	0.68	0.264	0.128	0.71	6.7	8.4	14.1	119.0	7.8	8.0	18.7	Storm	Fall
FOR	11/10/2014	14:00	0.48	0.013	0.038	2.36	2.0	59.3	12.5	641.0	8.4	11.6	0.4	Base	Fall
FOR	12/5/2014	2:00	0.81	0.392	0.227	0.97	52.5	21.9	10.8	153.0	8.1	10.2	112.0	Storm	Fall
FOR	12/11/2014	11:00	0.50	0.019	0.015	2.74	0.1	66.9	6.5	662.0	8.3	14.7	0.0	Base	Fall
FOR	1/8/2015	13:30	0.51	0.023	0.022	3.53	0.7	57.4	1.0	678.0	8.7	19.1	0.0	Base	Winter
FOR	2/13/2015	12:15	0.49	0.016	0.006	2.76	2.0	56.3	4.0	651.0	8.4	15.8	0.0	Base	Winter
FOR	3/17/2015	13:50	0.51	0.023	0.050	3.01	0.1	117.9	14.3	766.0	8.2	14.2	1.3	Base	Winter
FOR	3/25/2015	18:40	0.74	0.373	0.035	3.28	12.0	82.5	14.9	700.0	7.9	9.6	11.5	Storm	Spring

Highlighted sample concentrations = > ambient nutrient concentration (ANC), 0.01 mg/L TP and 0.31 mg/L TN.

Table 18. Water quality data for HFF

Site	Date	Time	Q	TP	TN	TSS	Cl	Temp	SC	pH	DO	Turb	Type	Season
			(m^3/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ºC)	(µS/cm)	std.	(mg/L)	(NTU)		
HFF	1/25/2012	11:55	1.699	0.108	0.95	58.7	15.7	7.4	380	8.1	11.0	0.2	Storm	Winter
HFF	5/7/2012	12:07	0.453	0.103	0.73	7.3	19.6	6.3	410	8.1	12.9	4.9	Storm	Spring
HFF	8/31/2012	11:06	1.076	0.154	0.61	25.7	7.3	22.8	226	6.6	8.1	23.1	Storm	Summer
HFF	10/12/2012	10:20	1.841	0.276	0.62	30.3	10.0	42.8	292	6.3	2.8	BP	Storm	Fall
HFF	1/29/2013	17:05	9.799	0.592	1.93	538.0	37.8	11.6	370	7.1	13.8	BP	Storm	Winter
HFF	4/10/2013	10:30	0.935	0.075	1.89	9.2	47.3	16.9	510	6.9	10.3	BP	Storm	Spring
HFF	4/10/2013	19:29	0.510	0.066	1.27	14.7	34.0	12.9	353	7.3	12.7	BP	Storm	Spring
HFF	4/18/2013	9:25	3.512	0.158	1.41	74.3	21.0	16.4	294	6.8	10.0	BP	Storm	Spring
HFF	4/18/2013	12:31	2.492	0.113	0.97	31.3	13.8	15.0	207	7.2	10.8	BP	Storm	Spring
HFF	4/23/2013	12:10	1.784	0.059	1.49	14.3	23.4	NS	NS	NS	NS	NS	Storm	Spring
HFF	4/26/2013	15:22	2.181	0.043	1.00	22.0	24.7	NS	NS	7.8	NS	NS	Storm	Spring
HFF	4/26/2013	14:08	1.501	0.025	1.15	7.3	21.3	NS	NS	7.8	NS	NS	Storm	Spring
HFF	6/15/2013	15:00	8.043	0.472	1.93	306.5	20.6	NS	NS	7.3	NS	NS	Storm	Spring
HFF	7/26/2013	2:58	2.549	0.212	1.33	39.3	18.7	24.3	248	7.8	7.2	52.9	Storm	Summer
HFF	9/17/2013	9:45	2.181	0.212	1.61	59.0	22.7	21.8	295	7.8	6.3	26.1	Storm	Summer
HFF	9/20/2013	6:45	2.067	0.066	1.08	24.0	6.8	22.9	181	7.8	9.6	34.6	Storm	Summer
HFF	10/5/2013	16:00	2.096	0.112	0.71	16.0	15.0	20.0	224	8.7	7.7	36.9	Storm	Fall
HFF	10/29/2013	11:30	2.124	0.273	0.60	79.3	11.3	13.5	223	7.9	12.6	105.0	Storm	Fall
HFF	10/29/2013	10:00	1.982	0.475	1.79	187.7	9.7	14.7	266	7.9	12.6	264.0	Storm	Fall
HFF	3/16/2014	13:50	1.331	0.100	1.08	44.0	102.8	10.0	553	8.4	11.0	133.6	Storm	Spring
HFF	6/5/2014	15:10	6.060	0.304	1.07	139.2	4.0	21.0	113	7.7	7.5	148.7	Storm	Spring
HFF	6/5/2014	13:20	4.984	0.390	1.23	214.0	3.8	21.9	117	7.6	7.1	186.4	Storm	Spring
HFF	6/23/2014	17:10	4.786	0.220	1.15	122.0	28.8	26.2	306	7.9	7.6	120.6	Storm	Summer
HFF	7/8/2014	11:30	3.144	0.153	0.85	62.0	31.8	25.0	282	8.0	8.5	59.6	Storm	Summer
HFF	7/8/2014	10:00	2.436	0.144	0.91	59.0	28.6	24.9	266	8.0	8.4	70.5	Storm	Summer
HFF	9/17/2014	14:00	10.847	0.251	0.83	100.7	5.3	19.1	87.0	7.5	8.6	118.0	Storm	Summer
HFF	9/17/2014	15:00	9.431	0.253	1.10	36.0	3.9	19.2	87.0	7.6	8.9	115.0	Storm	Summer
HFF	9/17/2014	13:00	12.348	0.264	0.87	169.3	8.1	19.4	114	7.2	8.4	194.0	Storm	Summer
HFF	10/10/2014	9:00	5.239	0.141	0.45	63.0	4.7	18.7	127	7.4	9.3	62.0	Storm	Fall
HFF	10/13/2014	10:00	4.305	0.162	0.69	55.0	11.9	16.9	189	7.6	8.6	NS	Storm	Fall

Highlighted sample concentrations = > ambient nutrient concentration (ANC), 0.01 mg/L TP and 0.31 mg/L TN.

APPENDIX D – Load Rating Curves

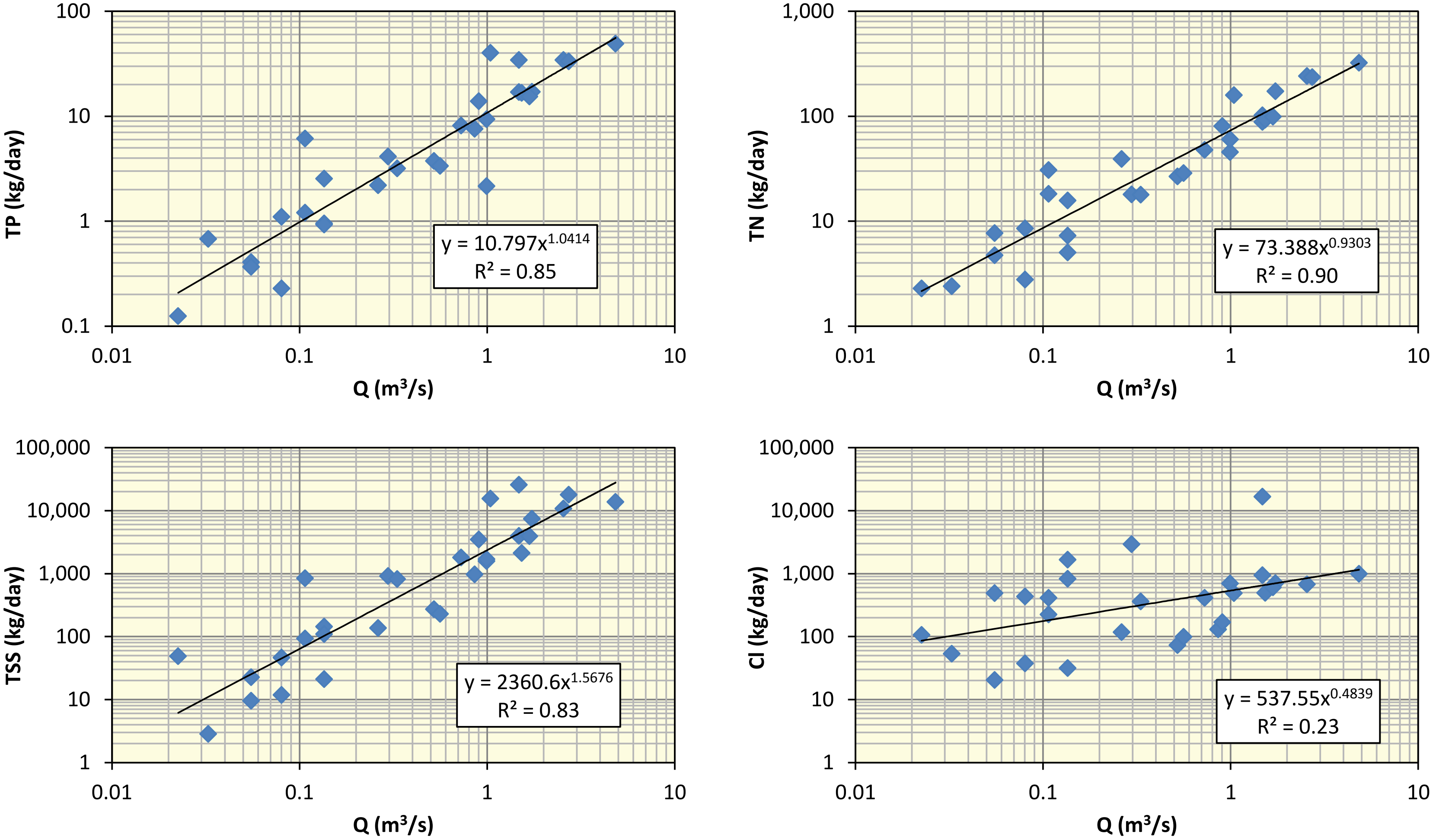


Figure 13. Load Rating Curve for NAT.

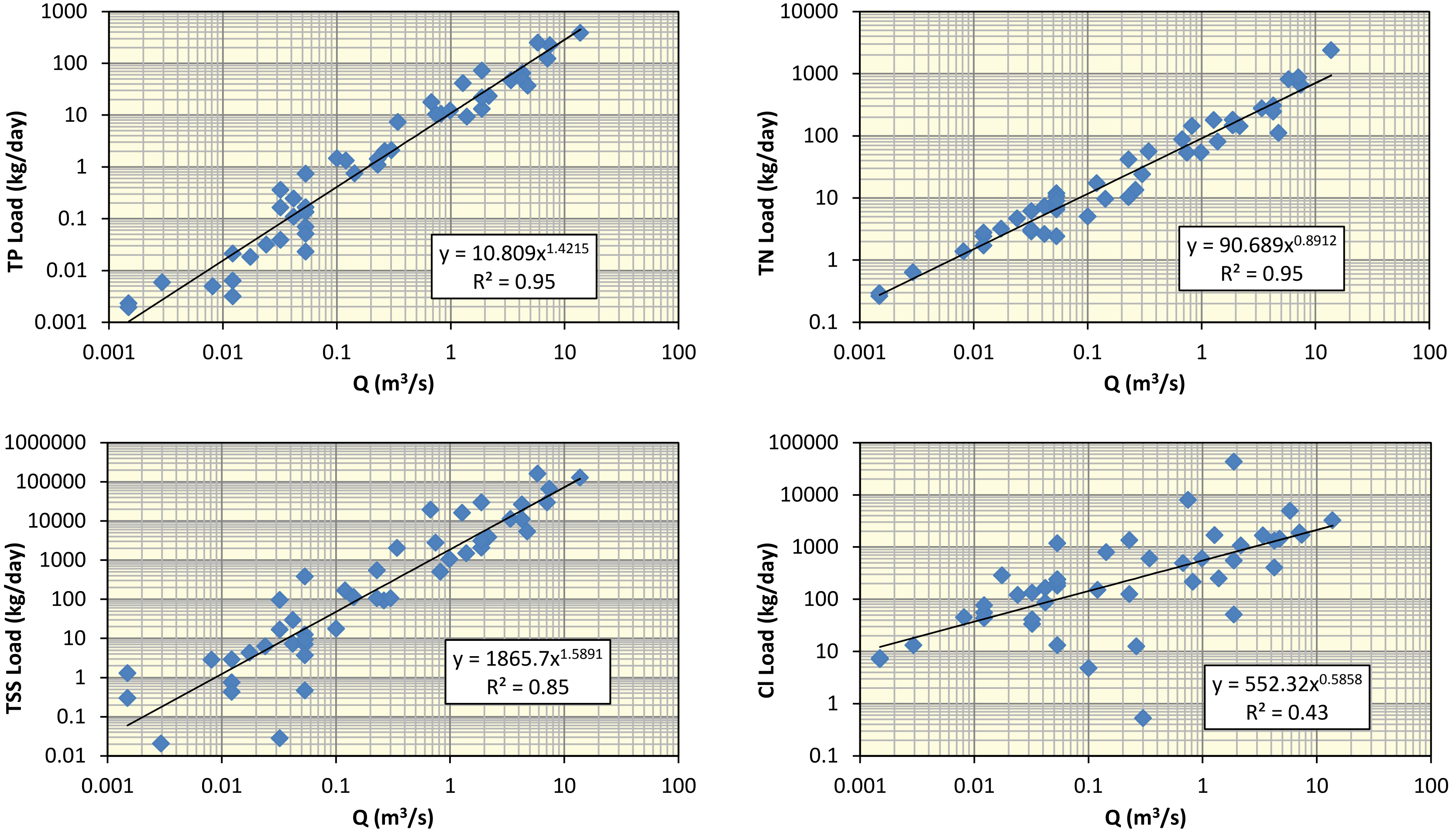


Figure 14. Load Rating Curves for CAM.

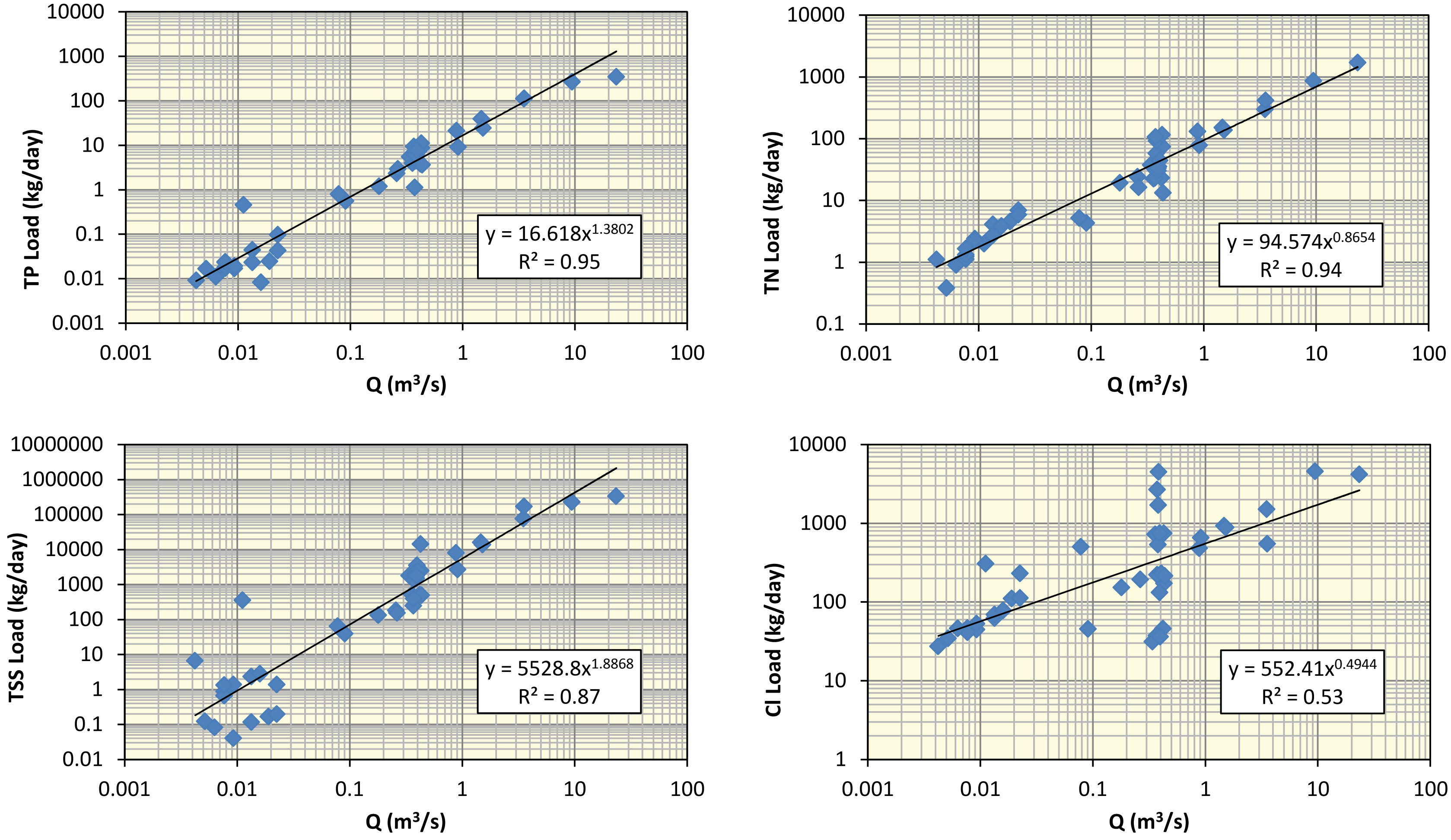


Figure 15. Load Rating Curves for FOR.

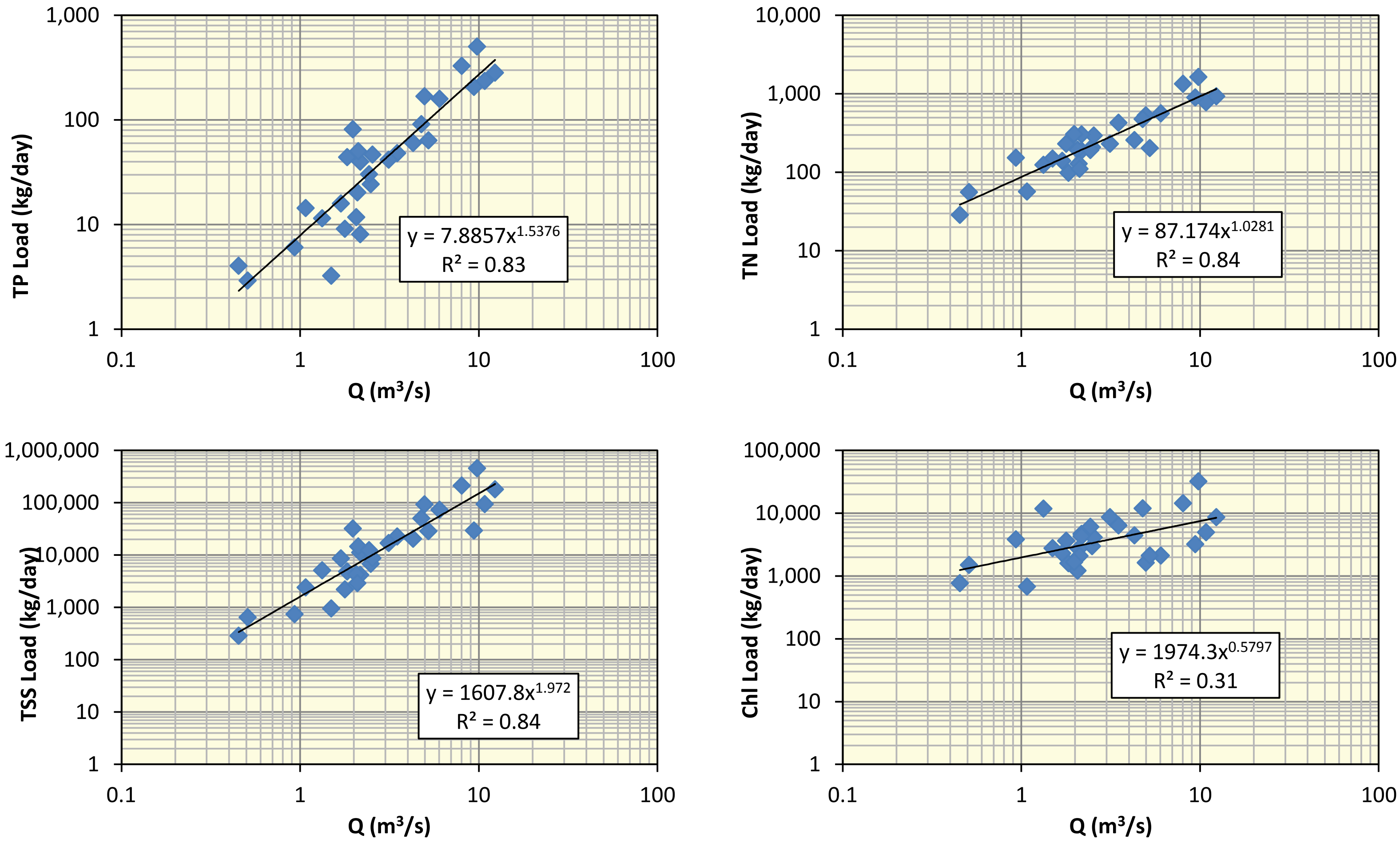


Figure 16. Load Rating Curves for HFF.