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

PRE-PROJECT WATER QUALITY MONITORING FOR SOUTH CREEK AT CAMPBELL AVENUE AND KANSAS EXPRESSWAY, SPRINGFIELD, MISSOURI April 1, 2014 – March 31, 2015

FINAL REPORT

Prepared by:

Marc R. Owen, M.S., Assistant Director, OEWRI
Robert T. Pavlowsky, Ph.D., Director, OEWRI
Adam Mulling, Graduate Assistant, OEWRI

Completed for:

Carrie Lamb, Water Quality Coordinator
Department of Environmental Services
City of Springfield, Missouri
840 Boonville Ave.
Springfield, Missouri 65802

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SCOPE AND OBJECTIVES

The City of Springfield has 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 Creek located in south Springfield. This project involves the removal of the concrete low flow channel between Campbell Ave. and Kansas Expressway and replacing it with natural substrate and reintroducing meanders to the channel design with the goal of improving aquatic habitat and water quality. South Creek is a sub-watershed of Wilson Creek, which has 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). Projects that attempt to reintroduce natural channel form and function to an urbanized stream have shown improvement in both water quality and biological conditions compared to the typical altered urban stream (Purcell et al. 2002).

To better understand how the new channel design impacts the water quality of the stream, pre-construction water quality monitoring is necessary to quantify the existing load. The Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University has been contracted to perform the water quality monitoring component of this project. The purpose of this study is to determine nonpoint source loads under present channel conditions for which to compare with post-project sampling to assess load reduction along South Creek at Kansas Expressway (KAN) and Campbell Avenue (CAM) (Table 1, Photos 1 and 2). A water quality monitoring station was installed along South Creek at CAM for the Springfield-Greene County Urban Watershed Stewardship Project, a Section 319 Nonpoint Source Implementation Grant, and will be used to compare with the load downstream at KAN. The specific objectives of this project are; 1) establish a water quality monitoring station at KAN that includes continuous stage recorder, 2) collect and analyze base and storm flow water quality samples over a 12 month monitoring period for nutrients, sediment, and chloride, and 3) quantify the nutrient, sediment and chloride loads upstream and downstream of the project site. This report contains the results of pre-project water quality and discharge monitoring at sites upstream and downstream of the project reach. This project 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) is a 2^{nd} order tributary 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). 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).

The stream's flow begins just downstream of National Avenue and flows west to the confluence with Wilson Creek located near the Southwest Clean Water Plant. An artificial (concrete) stream channel extends upstream of National for a total stream length of nearly 12,000 m.
The project reach is approximately 1,800 m long located between CAM and KAN. The stream between National Ave. and Campbell Ave. has been channelized, but trees and other riparian vegetation has been allowed to grow along the banks and floodplain (Owen and Pavlowsky 2014, Photo 3). Between Campbell Avenue and Kansas Expressway the stream is channelized, relatively straight, trapezoidal, and grass-lined with a narrow concrete trickle channel (Photos 4). The low flow channel widens when it passes under a series of 5 box culverts at CAM, a private drive going to the First Home Savings Bank, Grant Avenue, Fort Avenue, and KAN. A small pond just downstream of KAN backs water upstream under the bridge year round. The upstream drainage area at CAM is 4.8 km^2 and the upstream drainage area at KAN is 8.6 km^2 (Table 2). South Creek is a highly urbanized watershed, with greater than 90% urban land use in the drainage areas upstream of both sites (Figure 2 and Table 2).

METHODS

Sample Collection

In-stream surface water quality monitoring was conducted at KAN from March 16, 2014 to March 31, 2015 and at CAM from January 2012 to March 2015 (Table 1). For this study, only samples collected between March 16, 2014 and March 31, 2015 at CAM will be used to compare with KAN samples. 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 and were collect 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. At base flow, samples were collected by hand 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 2006a). 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 (OEWRI 2006b, OEWRI 2007c). Total suspended solids (TSS) were determined by filtering samples through a 1.5 µm filter (OEWRI 2007d). 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 (OEWRI 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 both sites were surveyed to calibrate each levelogger. 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 flow measurements were collected using a SonTek FlowTracker Acoustic Doppler velocity meter in the field to verify and calibrate rating curves (OEWRI 2007e, Photo 6). The highest calibration flows were provided by the City of Springfield Storm Water Division. Flow frequency curves 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 for calculating a more realistic annual load. 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 yields for TP and TN will be 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

Nearly 35,000 stage readings were collected at 15 minute intervals during the monitoring period. were recorded during a period of rainfall that was drier than normal. Between March 2014-March 2015 rainfall totals were about 17 cm below the 30-year average (Figure 3).

Consequently, stream base flow was low and even dry during the summer of 2014 at CAM where no water went under the bridge for a period of time (Figure 4). It appears that South Creek loses at Campbell Avenue bridge where during dry periods there is water flowing to the pool located just upstream of the bridge, but no water goes under the bridge. Over this monitoring period this occurred about 6-7% of the time (Figure 6). The peak flow (0% of flows exceed) at site CAM was around 30 m^3/s and around 100 m^3/s at KAN with drainage areas of 4.8 km^2 and 8.6 km^2 respectively.

A shift in the stage-discharge rating curve occurred in the middle of the monitoring period at KAN making it necessary to adjust the rating curve over that period. In November of 2014, the pond downstream of KAN started holding back less water, lowering the base flow level over 30 cm in 40-days (Figure 5). After that 40-day period, the base flow stage was fairly consistent. An additional discharge measurement was collected to shift the lower portion of the rating curve to better reflect the new condition. The 40-day period during the active lowering of stage, discharge was estimated using a straight line between the two stable base flow periods representing the average flows over that period. Consequently, the discharge estimates over those 40 days are not as accurate and represent the average flow conditions over that time.

Samples Collected

There were a total of 51 water quality samples collected at both sites over the sampling period. A total of 28 samples were collected over the 12-month sampling period at KAN. Of those, 14 were storm samples and 14 were base flow samples. At CAM, a total of 23 samples were collected for the Springfield-Greene County Urban Watershed Stewardship Project. Of those, 9 were storm flows and 14 were base flow.

Base Flow Water Quality

Samples collected at base flow represent the typical conditions of the stream when not influenced by storm events and forms the basis of the ecological flows to a stream. Therefore, comparing base flow water quality before and after the restoration project is essential for assessing improvements to aquatic habitat in the stream. Base flow water quality at each site will be compared two ways. First, base flow water quality data from each will be summarized and compared using descriptive statistics. Second, selected parameters will also be compared using time-series plots to look at seasonal variability between sites.

<u>Physical Water Parameters</u>

In-situ SC and pH variability was lower than T, DO and TB and overall water chemistry parameter variability was higher at KAN compared to CAM. Average base flow T was 15.1°C at CAM compared to 17.5°C at KAN over the sampling period with a coefficient of variation (cv% = standard deviation/mean x 100) that varied 33% at CAM compared to 50% at KAN (Table 4). Similarly, DO and TB had higher average values at KAN (11.7 mg/L and 6.2 NTU) compared to CAM (9.5 mg/L and 3.9 NTU) and also had higher variability. Mean SC was slightly higher at CAM (528 µS/cm) than at KAN (480 µS/cm) and average pH was lower at CAM (7.5) than KAN (8.3). Variability of SC and pH was slightly higher at KAN compared to CAM, but cv% was <20% for SC and <10% for pH at both sites.

Nutrients, Sediment and Chloride

Average base flow TP concentrations at CAM are slightly lower compared to KAN, but mean concentrations of TN, TSS and Cl were higher at CAM. The mean base flow TP concentration at CAM is 0.015 mg/L compared to 0.021 mg/L at KAN (Table 4). Mean base flow TN is 2.16 mg/L at CAM compared to 1.52 mg/L at KAN. Mean base flow TSS was slightly higher at CAM compared to KAN, but was very low at both sites. The average base flow Cl concentration at CAM was 60.9 mg/L compared to 57.1 mg/L at KAN. Nutrient variability among the sites was higher at KAN compared to CAM, but TSS and Cl variability was higher at CAM.

Time-Series Base Flow Analysis

Analysis of paired base flow values of T, DO and SC over the monitoring period shows the largest variations in water chemistry parameters occur in the summer and winter. The channel conditions at each site appear to make the most impact on T over the monitoring period. The T at KAN varied from 0-30°C over the monitoring period, while it only varied from 5-20°C at CAM (Figure 7). The channel above Campbell is natural, more narrow and shaded by trees in contrast to the channel below Campbell which is a flat concrete channel without shade. This is especially true in the summer where the biggest variation occurs when T at KAN can be 5-10°C higher than at CAM. Similarly, DO is 5-6 mg/L higher at KAN compared to CAM suggesting the increase in DO is due to photosynthesis occurring in the water standing under the bridge from the pond downstream and is mixing with the water flowing down from CAM. Base flow SC is similar at both sites throughout much of the monitoring period.

Paired sample time-series analysis of base flow nutrients shows seasonal shifts between sites while Cl concentrations remain relatively consistent over the monitoring period. Concentrations of TP are higher at KAN for most of the year, except for in the winter when they are actually lower than at CAM (Figure 8). However, TP concentrations at both sites remain well below the TMDL eutrophic threshold of 0.075 mg/L at base flow throughout the year. Concentrations of TN are higher at CAM during the warmer months of the monitoring period and are similar to KAN during the colder months. Over the entire monitoring period concentrations of TN at CAM were above the TMDL eutrophic threshold of 1.5 mg/L and above that limit from October-March at KAN. Concentrations of Cl remain consistently similar at both sites throughout the year.

Storm Flow Water Quality

Storm flow water quality samples represent the typical conditions of the stream during runoff events and these events make up the majority of the annual load in watersheds. Storm flow water quality data collected at each site is summarized below and compared between sites using descriptive statistics.

Physical Water Parameters

Storm flow average T, SC, pH and DO are very similar between sites while mean TB is much higher at CAM compared to KAN. Average T and DO were the same at both sites, 17.9°C and 8.3 mg/L (Table 5). Mean SC was 0.103 mS/cm at CAM and 0.126 mS/cm at KAN. Average storm flow pH values were 7.6 at CAM and 7.8 at KAN. However, mean TB values at CAM (596 NTU) was >7x higher than at KAN (77 NTU). While relative variability in TB was similar at both sites (cv% ≈ 154), the range in TB values was also much higher at CAM compared to KAN.

Nutrients, TSS and Chloride

Mean storm flow concentrations of nutrients, TSS and Cl were higher at CAM compared to KAN. For example, the average storm flow TP concentration was 0.201 mg/L at CAM compared to 0.162 mg/L at KAN (Table 5). Similarly, mean storm flow TN, TSS and Cl concentrations were higher at CAM compared to KAN. The range in concentrations of TP, TN and Cl were also higher at CAM compared to KAN. However, there was a wider range of TSS concentrations at KAN compared to CAM even though the average concentration of TSS was higher at CAM.

Annual Loads

The annual TP load for both sites exceeds the eutrophic threshold, even though the daily load is < than the ET >95% of the monitoring period. The annual TP load at CAM is 0.80 Mg/yr with an average flow weighted concentration of 0.206 mg/L TP (Table 6). The annual TP load at KAN is 3.78 Mg/yr with an average flow weighted concentration of 0.256 mg/L TP. The annual TP yield for CAM is 0.17 $Mg/km^2/yr$ and at KAN is 0.44 $Mg/km^2/yr$. Both sites are well below the eutrophic threshold daily load for the majority of the monitoring period, but exceed the eutrophic threshold by almost an order of magnitude at the highest flows (Figure 9). These data suggest nonpoint source TP associated with urban development delivered during the largest flood events overwhelmingly controls the TP load in South Creek.

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 over most of the monitoring period. The annual TN load at CAM is 4.7 Mg/yr with an average flow weighted concentration of 1.21 mg/L TN (Table 6). The annual TN load at KAN is 10.4 Mg/yr with an average flow weighted concentration of 0.70 mg/L TN. The annual TP yield for CAM is 0.98 $Mg/km^2/yr$ and at KAN is 1.21 $Mg/km^2/yr$. Daily TN load at CAM is at or slightly above the eutrophic threshold daily load for the majority of the monitoring period and at or slightly below the eutrophic threshold at KAN (Figure 10).

The annual TSS load at CAM is 198.4 Mg/yr with an average flow weighted concentration of 51.0 mg/L TSS (Table 6). The annual TSS load at KAN is 639.7 Mg/yr with an average flow weighted concentration of 43.3 mg/L TSS. The annual TSS yield for CAM is 41.3 $Mg/km^2/yr$ and at KAN is 74.4 $Mg/km^2/yr$. The yield duration curve shows TSS is higher at CAM for most of the year (Figure 11).

The annual Cl load at CAM is 54.0 Mg/yr with an average flow weighted concentration of 13.9 mg/L Cl (Table 6). The annual Cl load at KAN is 66.8 Mg/yr with an average flow weighted concentration of 4.52 mg/L. The annual Cl yield for CAM is 11.3 $Mg/km^2/yr$ and at KAN is 7.77 $Mg/km^2/yr$. The yield duration curve shows Cl is higher at CAM most of the year (Figure 12).

CONCLUSIONS

There are 7 main conclusions from this study:

1. **A water quality/hydrology monitoring station was established at Kansas Expressway and monitored for 12 months.** A hydrologic monitoring station was installed at KAN and operated between April 1, 2014 and March 31, 2014 and compared to the existing station located upstream at CAM. A total of 14 base flow samples and 13 storm flow samples were collected over the monitoring period at KAN. At CAM, 14 base flow samples and 9 storm flow samples were collected. Water quality data collection included in-situ T, pH, DO, SC and TB and laboratory analysis included TP, TN, TSS and Cl.

2. **In-situ physical water parameters at base flow appear to be influenced by channel conditions at each site.** For example, T at KAN varied from 0-30°C over the monitoring period, while it only varied from 5-20°C at CAM. The biggest variation occurs in the summer when T at KAN was 5-10°C higher than at CAM. This suggests the shallow depth of concrete low flow channel and lack of shading along riparian corridor between CAM and KAN can have a significant impact on water conditions at base flow.

3. **Average base flow TP concentrations at CAM are slightly lower compared to KAN, but mean concentrations of TN and Cl were higher at CAM**. The mean base flow TP concentration at CAM is 0.015 mg/L compared to 0.021 mg/L at KAN. Mean base flow TN is 2.16 mg/L at CAM compared to 1.52 mg/L at KAN. The average base flow Cl concentration at CAM was 60.9 mg/L compared to 57.1 mg/L at KAN.

4. **Paired sample time-series analysis of base flow nutrients shows seasonal shifts while Cl concentrations remain relatively consistent over the monitoring period.** Concentrations of TP are higher at KAN for most of the year, except for in the winter when they are actually lower than at CAM. Concentrations of TN are higher at CAM during the warmer months of the monitoring period and are similar to KAN during the colder months.

5. **Mean storm flow concentrations of nutrients, TSS and Cl were higher at CAM compared to KAN.** For example, the average storm flow TP concentration was 0.201 mg/L at CAM compared to 0.162 mg/L at KAN. Similarly, mean storm flow TN, TSS and Cl concentrations were higher at CAM compared to KAN.

6. **The annual TP load for both sites exceeds the eutrophic threshold, even though the daily load is < than the eutrophic threshold >95% of the monitoring period.** The annual TP load at CAM is 0.80 Mg/yr and 3.78 Mg/yr at KAN. Both sites are well below the eutrophic threshold daily load for the majority of the monitoring period, but exceed the eutrophic threshold by almost an order of magnitude at the highest flows.

7. **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 over most of the monitoring period.** The annual TN load at CAM is 4.72 Mg/yr and 10.4 Mg/yr at KAN. Daily TN load at CAM is at or slightly above the eutrophic threshold daily load for the majority of the monitoring period and at or slightly below the eutrophic threshold at KAN.

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TABLES

Table 1. Sample site locations in the South Creek Watershed

Site	Location	UTM Zone 15N (m)	
		Easting	Northing
CAM	Campbell Avenue Bridge	473,773.315	4,113,406.568
KAN	Kansas Expressway Bridge	471,937.260	4,113,493.436

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
CAM	4.8	27.5	63.8	0.0	7.6	1.2	0.0
KAN	8.6	30.6	60.6	0.1	7.5	1.1	0.0

Table 3. Seasonal sample collection over the monitoring period.

Samples	Base flow		Storm flow		Total
	CAM	KAN	CAM	KAN	
Winter 2014	0	0	1	1	2
Spring 2014	4	4	4	4	16
Summer 2014	3	3	2	4	12
Fall 2014	4	4	1	4	13
Winter 14-15	3	3	0	0	6
Spring 2015	0	0	1	1	2
Total	14	14	9	14	**51**

Table 4. Base flow water quality summary statistics for CAM and KAN

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	14	14	14	14	14	14	14	14	14
Mean	0.015	2.16	2.0	60.9	15.1	528	7.5	9.5	3.9
Median	0.015	2.23	1.8	51.7	15.9	525	7.4	8.9	1.5
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	0.32	2.5	37.3	5.0	56.0	0.3	2.7	5.1
CV%	52.9	14.7	124.9	61.3	33.2	10.6	4.1	28.5	131.3
Base Flow KAN	**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	14	14	14	14	14	14	14	14	14
Mean	0.021	1.52	1.3	57.1	17.5	480	8.3	11.7	6.2
Median	0.019	1.49	0.8	51.4	18.5	494	8.1	11.5	1.5
Min	0.001	0.85	0.1	40.5	0.2	271	7.4	4.2	0.0
Max	0.048	2.16	5.3	137.4	29.3	630	9.6	22.3	44.8
SD	0.015	0.40	1.5	23.9	8.7	82.0	0.7	4.9	11.6
CV%	70	27	121	42	50	17	8	42	188

Table 5. Storm flow water quality summary statistics for CAM and KAN.

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	9	9	9	9	9	9	9	9	9
Mean	0.201	1.35	83.9	21.3	17.9	103	7.6	8.3	596.4
Median	0.200	1.50	47.7	8.4	20.0	44.0	7.6	8.1	193.3
Min	0.060	0.27	9.0	2.72	4.4	18.0	7.1	6.2	35.1
Max	0.371	2.09	327.3	67.5	25.0	480	8.3	12.4	2,217
SD	0.116	0.65	102.4	25.9	5.9	147	0.3	2.0	916.7
CV%	57.9	47.8	122.1	121.8	32.7	142.0	4.1	24.2	153.7
Storm Flow KAN	**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	14	14	14	14	14	14	14	14	13
Mean	0.169	0.98	77.2	14.1	17.5	134	7.8	8.3	81.3
Median	0.172	0.88	29.0	7.3	18.8	126	7.7	8.1	49.0
Min	0.036	0.13	0.13	1.1	4.7	42.0	7.5	5.9	13.0
Max	0.323	2.04	378.0	50.0	25.0	276	8.5	12.2	448.2
SD	0.076	0.55	118.8	16.0	5.4	74.0	0.2	1.7	114.4
CV%	44.8	56.0	153.9	113.1	30.7	55.3	3.1	20.7	140.8

Table 6. Flow-Weighted Concentrations, Loads, and Yield for Nutrients, Sediment and Chloride.

Site	Ad km^2	TP Avg. Con. mg/L	TP Annual Load (Range) Mg	TP Annual Yield Mg/km^2	TN Avg. Con. mg/L	TN Annual Load (Range) Mg	TN Annual Yield Mg/km^2	TSS Avg. Con. mg/L	TSS Annual Load (Range) Mg	TSS Annual Yield Mg/km^2	Cl Avg. Con. mg/L	Cl Annual Load (Range) Mg	Cl Annual Yield Mg/km^2
CAM	4.8	0.206	0.80 (0.51-1.25)*	0.17	1.21	4.72 (3.01-7.33)*	0.98	51.0	198.4 (26.9-1,465)*	41.3	13.9	54.0 (29.3-99.6)*	11.3
KAN	8.6	0.256	3.78 (1.08-13.3)*	0.44	0.70	10.4 (5.62-19.3)	1.21	43.3	639.7 (98.4-4,159)*	74.4	4.52	66.8 (33.5-133.1)*	7.77
Diff**	3.8		2.98	0.78		5.7	1.50		441.3	116.1		12.8	3.37

* +/- the standard error

** Diff refers to the difference in drainage area between the two sites

FIGURES

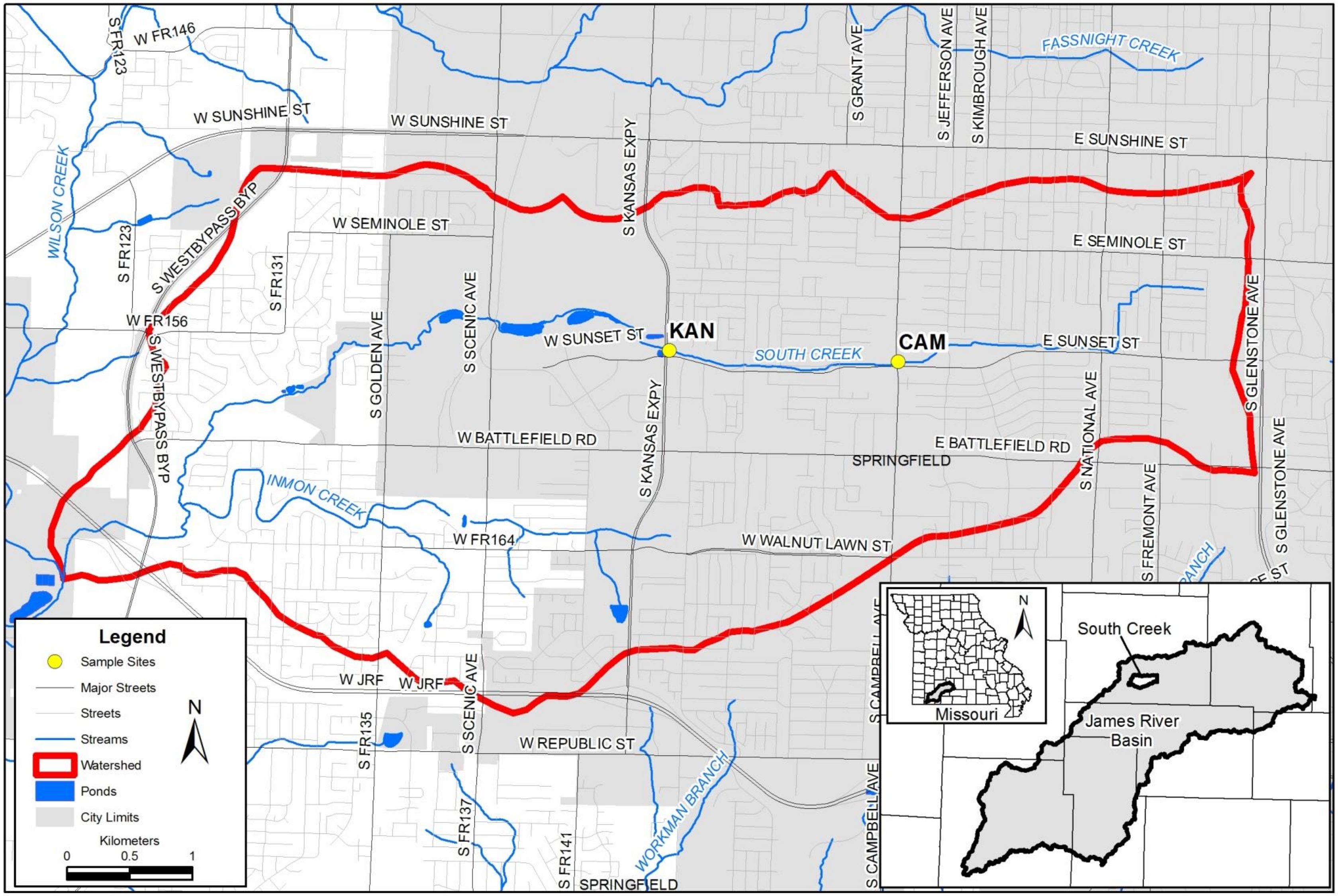

Figure 1. South Creek Watershed and sample site locations.

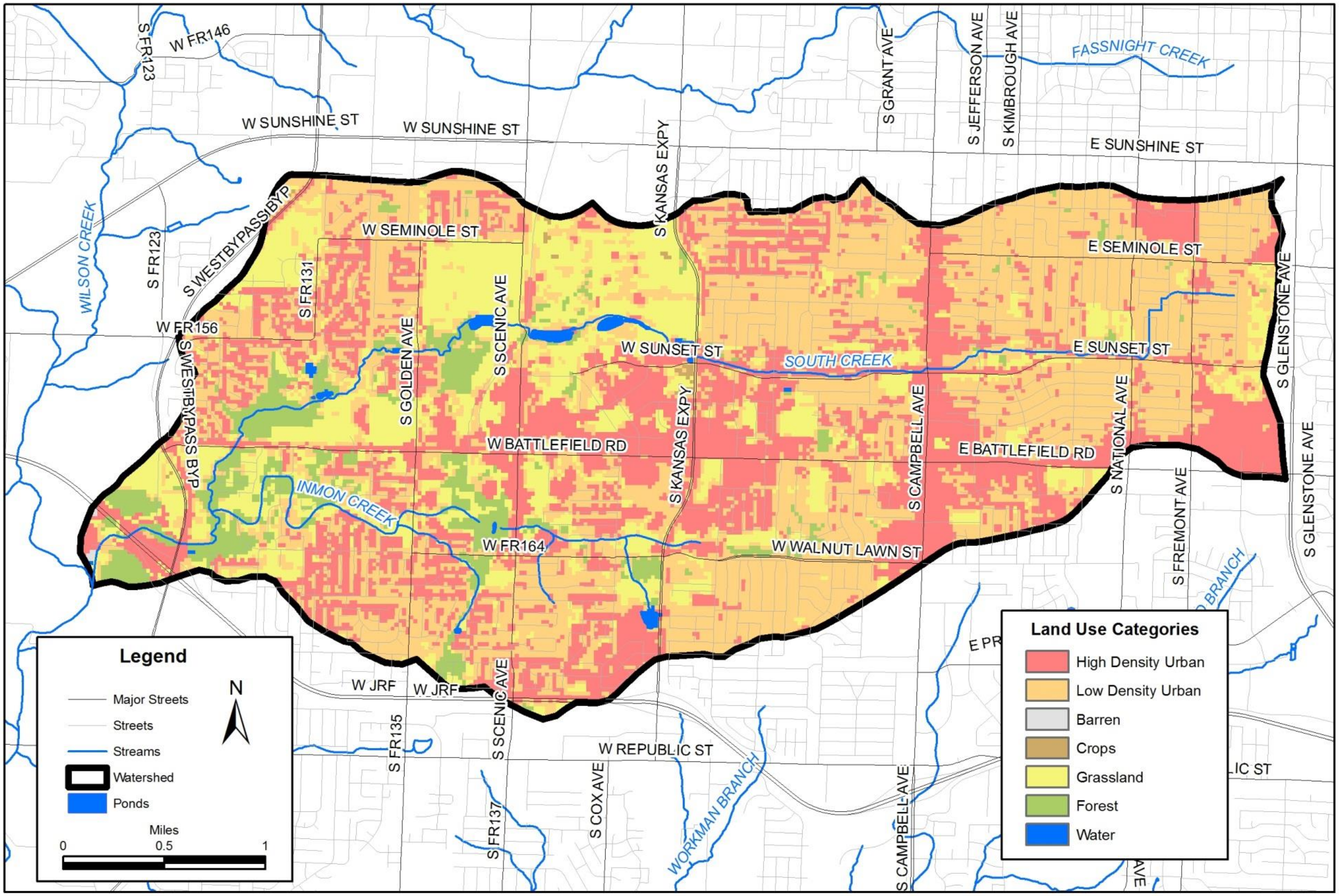

Figure 2. South Creek Watershed land use map.

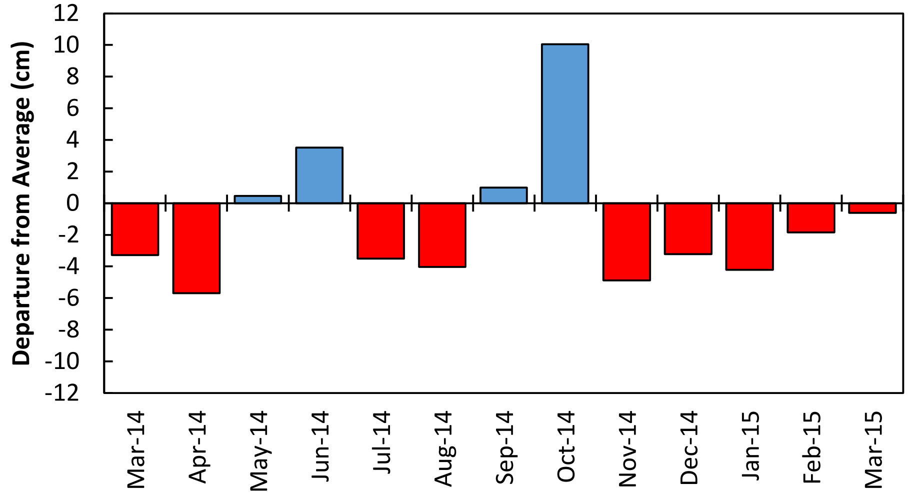

Figure 3. Departure from average monthly rainfall totals over the sampling period.

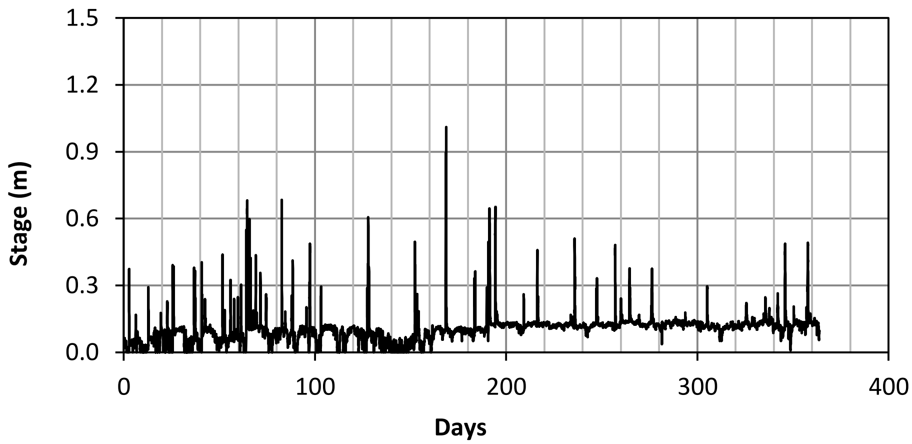

Figure 4. Monitoring period stage readings for CAM.

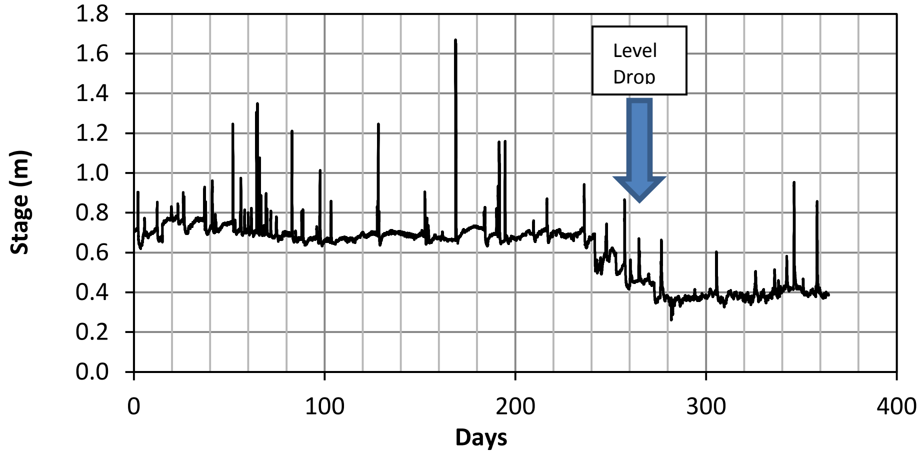

Figure 5. Monitoring period stage readings for KAN.

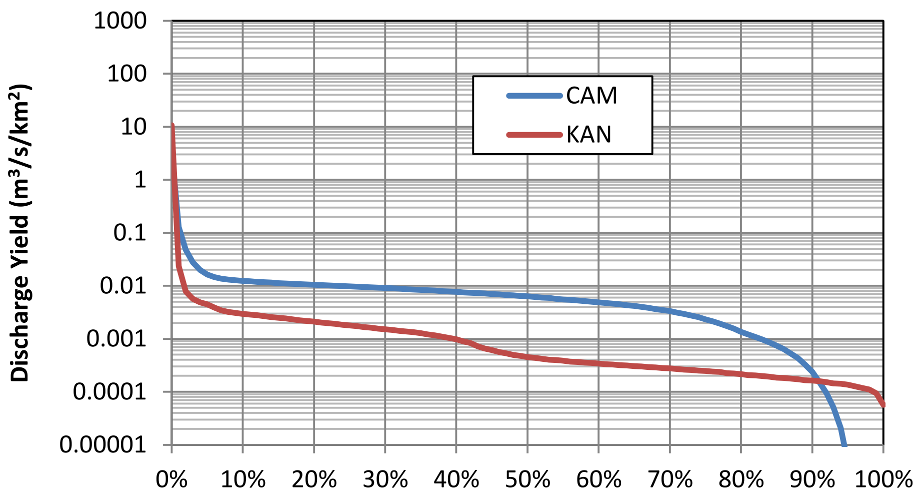

Figure 6. Flow frequency curve for CAM and KAN.

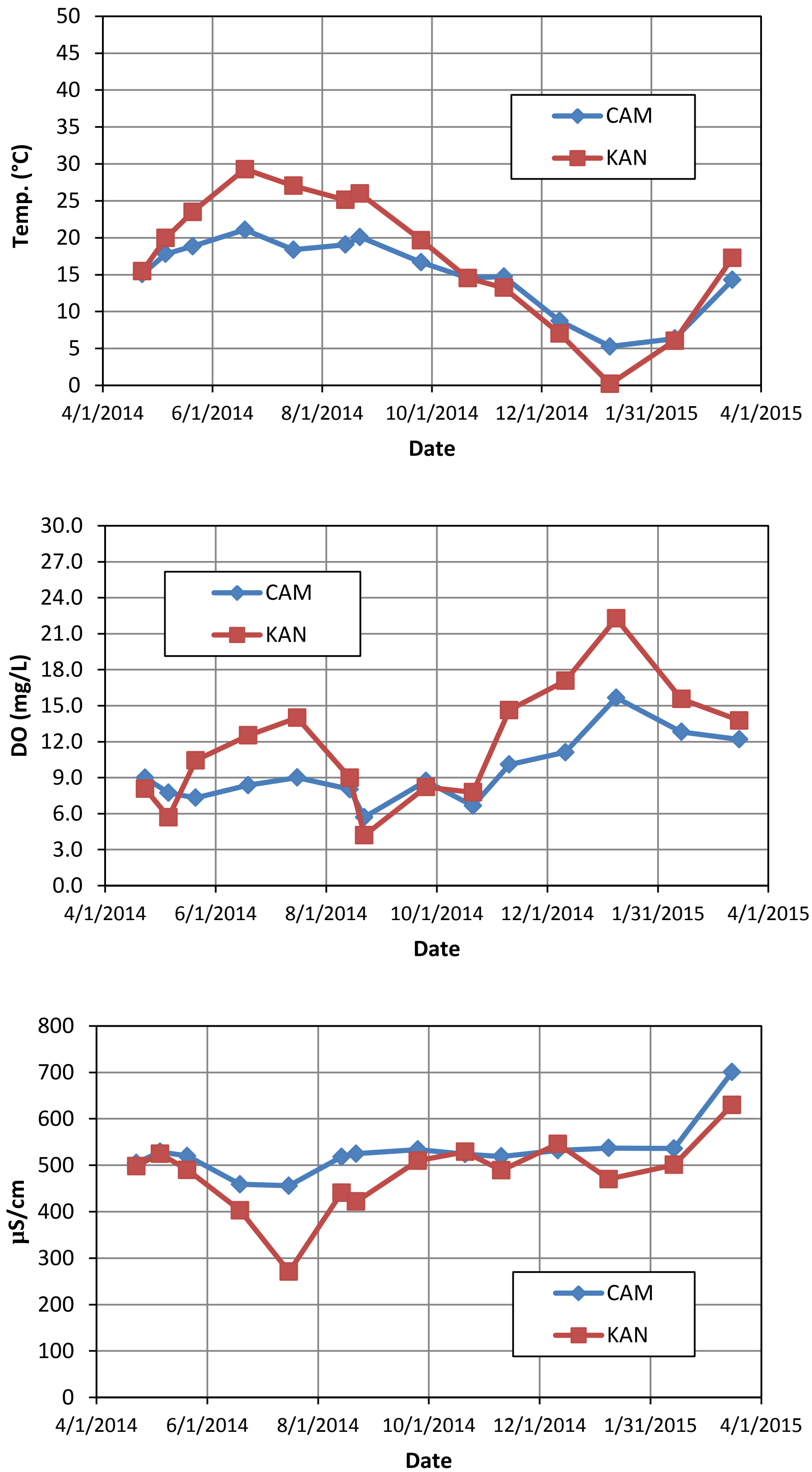

Figure 7. Water chemistry parameter comparison between CAM and KAN at base flow.

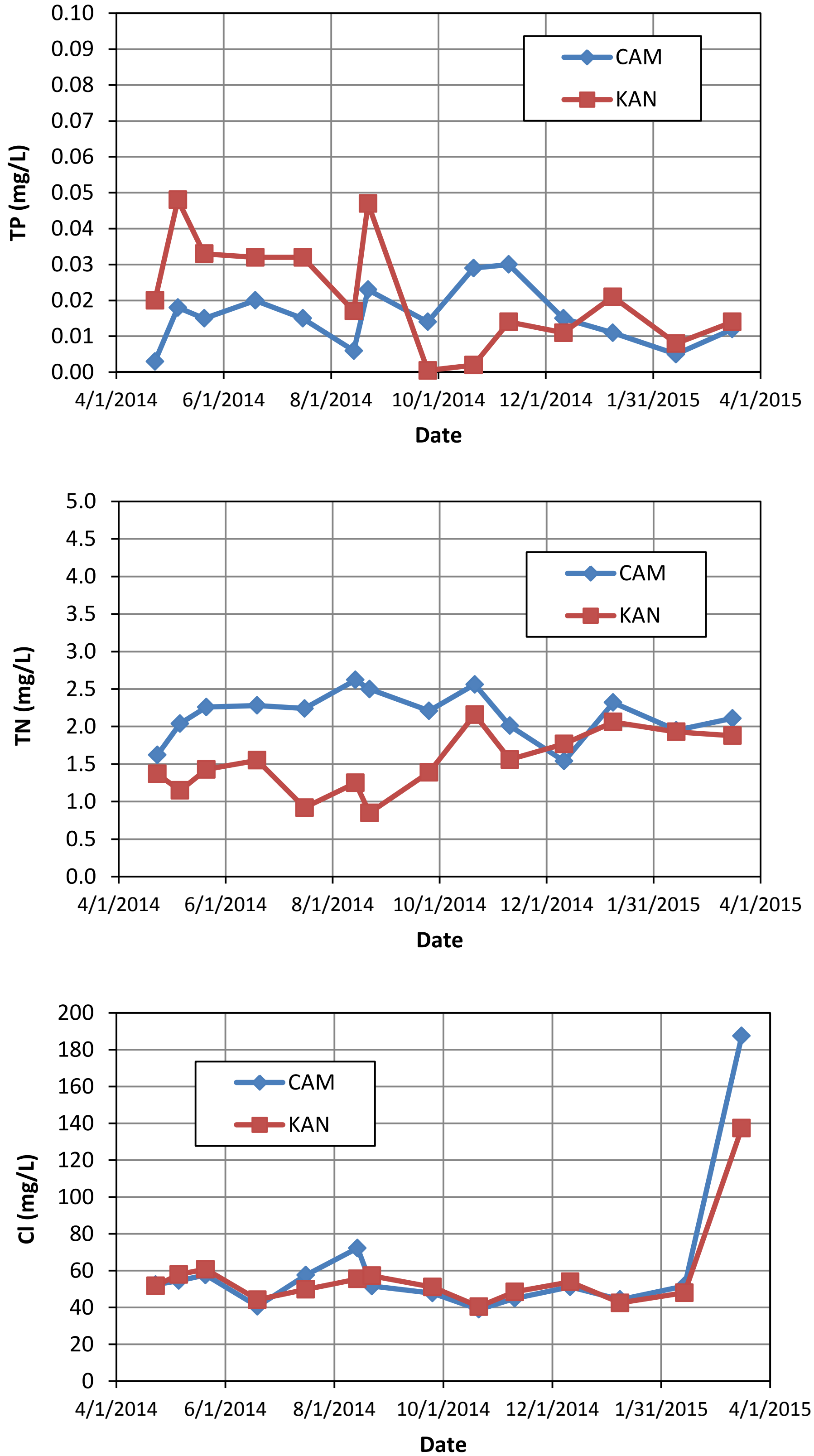

Figure 8. Nutrient and chloride comparison between CAM and KAN at base flow.

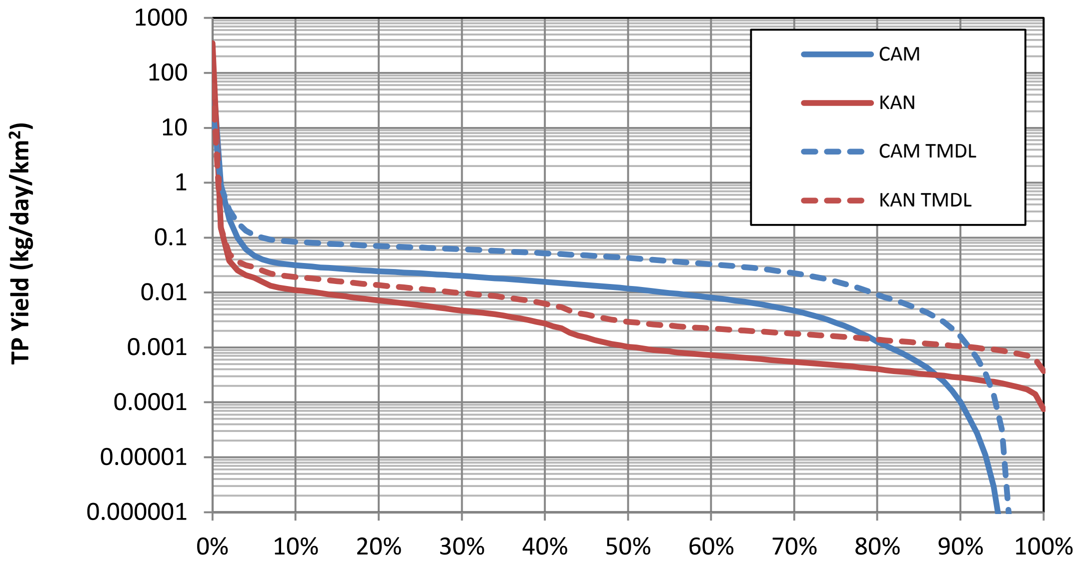

Figure 9. TP yield duration curve for CAM and KAN.

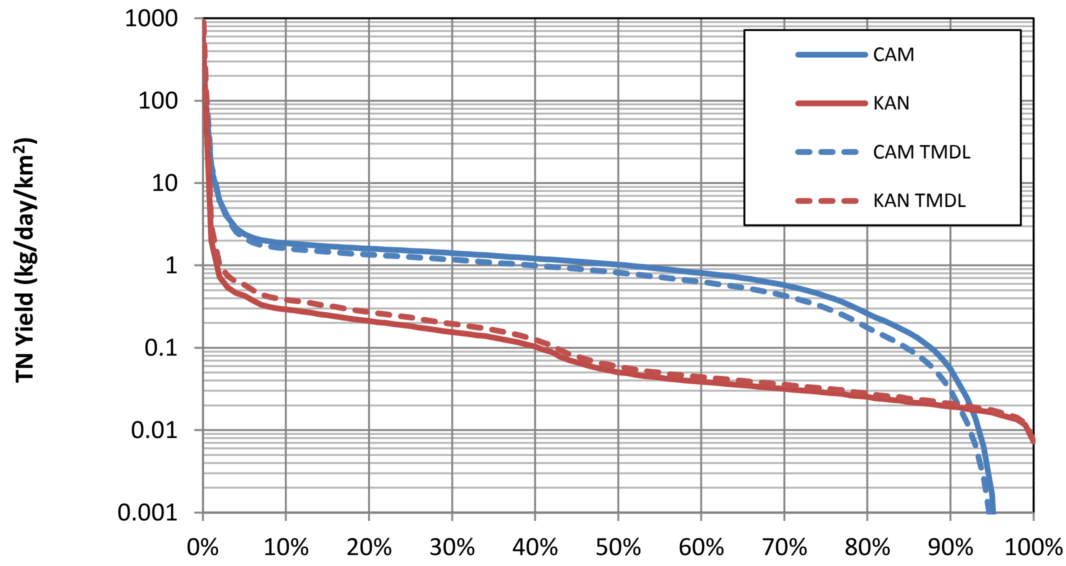

Figure 10. TN yield duration curve for CAM and KAN.

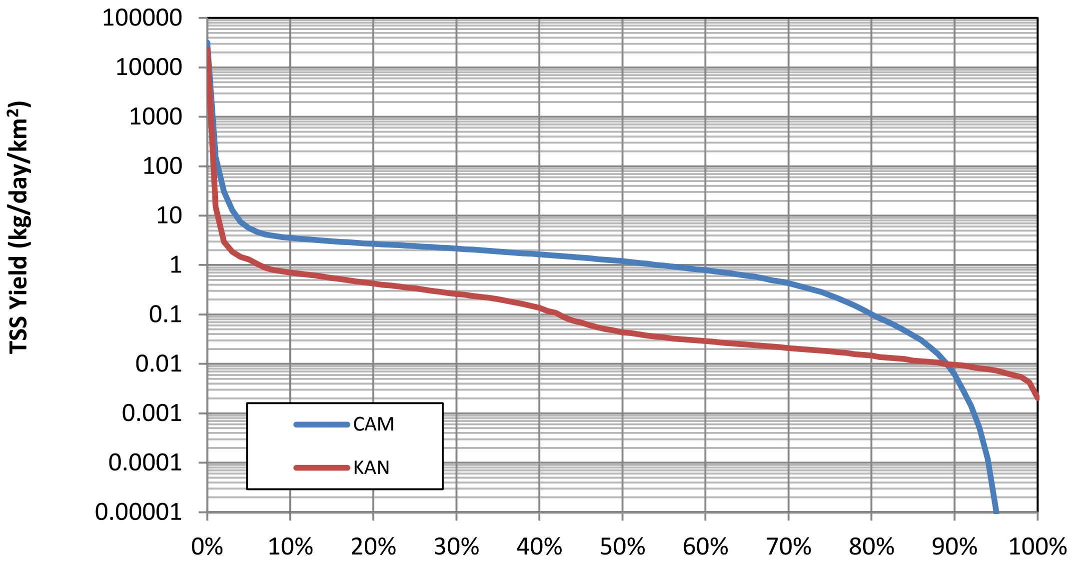

Figure 11. TSS yield duration curve for CAM and KAN.

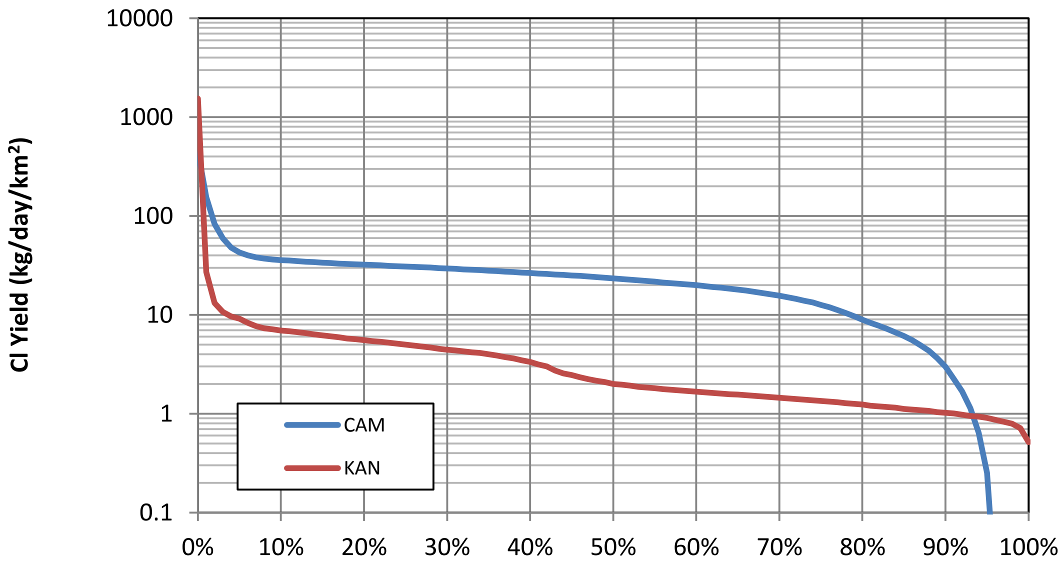

Figure 12. Cl yield duration curve for CAM and KAN.

PHOTOS

Photo 1. CAM monitoring site looking west toward Campbell Avenue.

Photo 2. KAN monitoring site looking south along Kansas Expressway.

Photo 3. Natural stream bed and vegetated riparian corridor upstream of Campbell Avenue.

Photo 4. Concrete low flow channel and mowed turf grass riparian corridor downstream of Campbell Avenue.

Photo 5. Levelogger and staff gage installed at KAN.

Photo 6. Discharge measurement using the FlowTracker ADP

APPENDIX A – DISCHARGE RATING CURVES

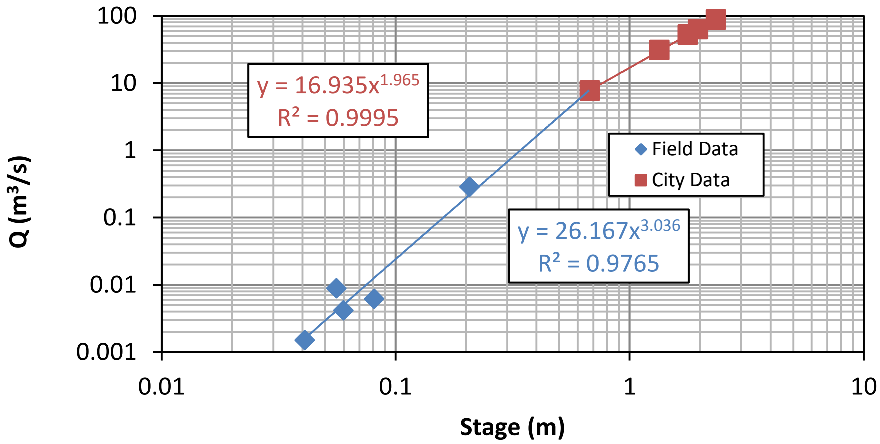

Figure 13. Discharge rating curve for CAM.

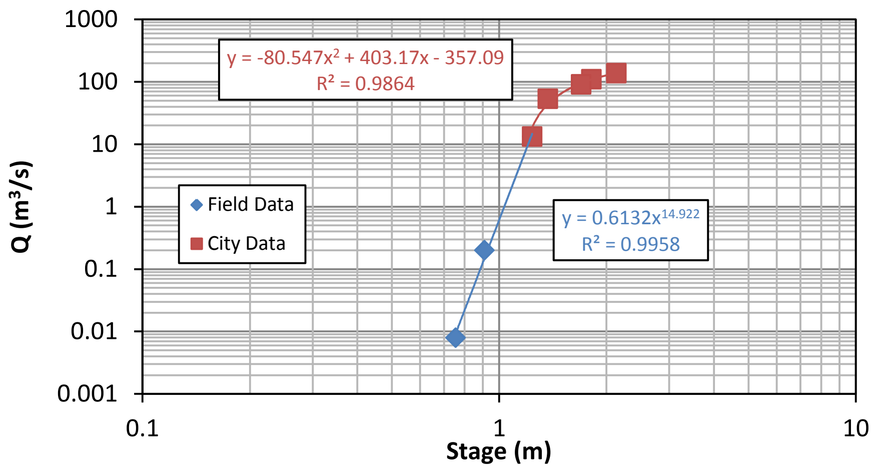

Figure 14. Discharge rating curve for KAN for the first 240 days.

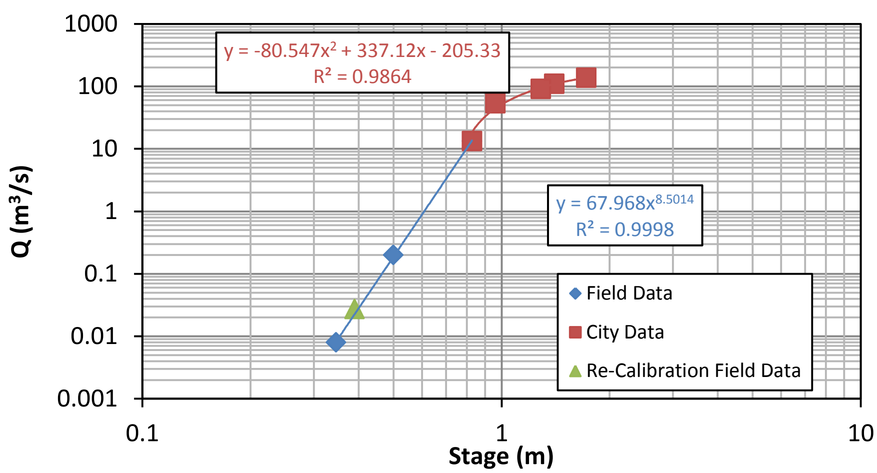

Figure 15. Discharge rating curve for KAN from 280-365 days.

APPENDIX B – DAILY LOAD RATING CURVES

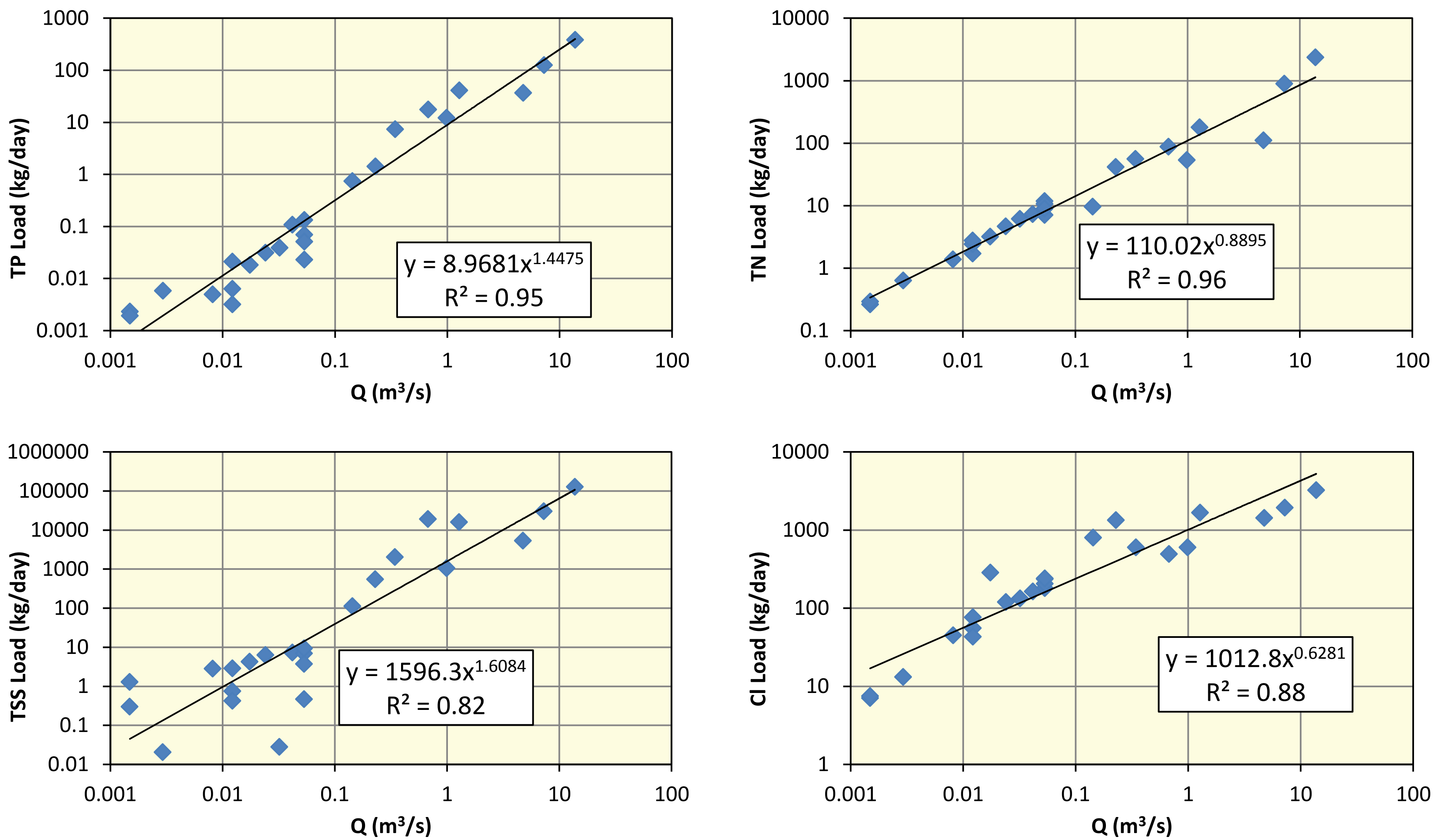

Figure 16. TP, TN, TSS and Cl load rating curves for CAM.

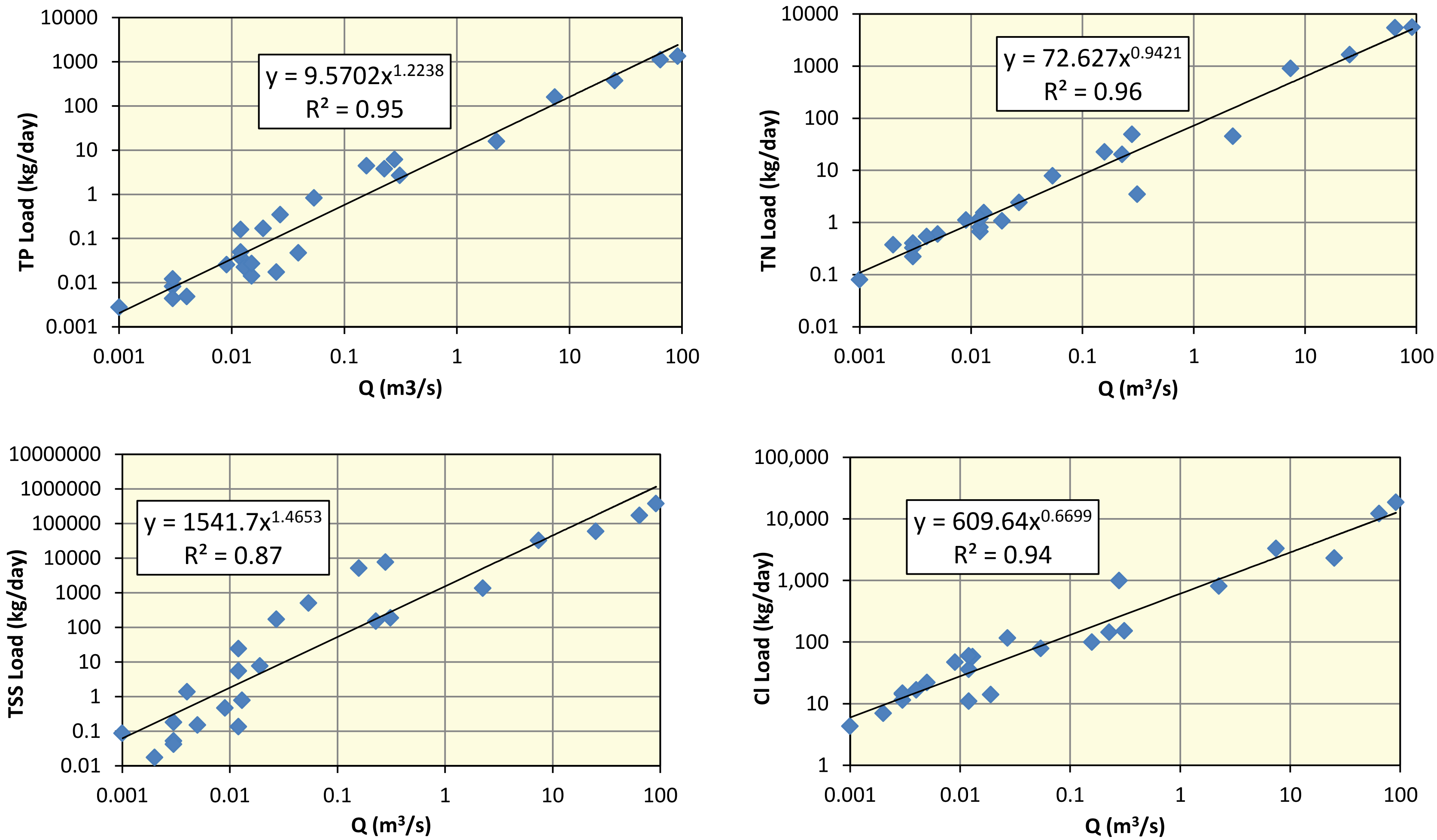

Figure 17. TP, TN, TSS and Cl load rating curves for KAN.

APPENDIX C – FLOW FREQUENCY TABLES

Table 7. Flow Frequency Table for CAM

Stage (m)	Q (m^3/s)	% of Flows Exceed
0.00	0.0000	100%
0.00	0.0000	99%
0.00	0.0000	98%
0.00	0.0000	97%
0.00	0.0000	96%
0.01	0.0000	95%
0.02	0.0001	94%
0.02	0.0002	93%
0.03	0.0005	92%
0.03	0.0007	91%
0.04	0.0011	90%
0.04	0.0016	89%
0.04	0.0021	88%
0.05	0.0025	87%
0.05	0.0031	86%
0.05	0.0035	85%
0.06	0.0041	84%
0.06	0.0046	83%
0.06	0.0052	82%
0.06	0.0058	81%
0.07	0.0065	80%
0.07	0.0074	79%
0.07	0.0083	78%
0.07	0.0093	77%
0.08	0.0103	76%
0.08	0.0112	75%
0.08	0.0123	74%
0.08	0.0132	73%
0.08	0.0141	72%
0.09	0.0150	71%
0.09	0.0159	70%
0.09	0.0167	69%
0.09	0.0175	68%
0.09	0.0184	67%
0.09	0.0192	66%
0.09	0.0199	65%
0.10	0.0206	64%
0.10	0.0213	63%
0.10	0.0220	62%
0.10	0.0226	61%
0.10	0.0234	60%
0.10	0.0239	59%
0.10	0.0246	58%
0.10	0.0253	57%
0.10	0.0260	56%
0.10	0.0266	55%
0.10	0.0273	54%
0.11	0.0282	53%

0.11	0.0288	52%
0.11	0.0296	51%
0.11	0.0302	50%
0.11	0.0310	49%
0.11	0.0316	48%
0.11	0.0323	47%
0.11	0.0330	46%
0.11	0.0336	45%
0.11	0.0342	44%
0.11	0.0348	43%
0.11	0.0355	42%
0.11	0.0361	41%
0.12	0.0368	40%
0.12	0.0375	39%
0.12	0.0381	38%
0.12	0.0388	37%
0.12	0.0394	36%
0.12	0.0401	35%
0.12	0.0408	34%
0.12	0.0415	33%
0.12	0.0422	32%
0.12	0.0428	31%
0.12	0.0436	30%
0.12	0.0443	29%
0.12	0.0449	28%
0.12	0.0456	27%
0.12	0.0463	26%
0.12	0.0470	25%
0.13	0.0475	24%
0.13	0.0481	23%
0.13	0.0488	22%
0.13	0.0494	21%
0.13	0.0500	20%
0.13	0.0507	19%
0.13	0.0514	18%
0.13	0.0523	17%
0.13	0.0532	16%
0.13	0.0540	15%
0.13	0.0550	14%
0.13	0.0559	13%
0.13	0.0571	12%
0.13	0.0583	11%
0.13	0.0595	10%
0.14	0.0610	9%
0.14	0.0629	8%
0.14	0.0656	7%
0.14	0.0704	6%
0.15	0.0787	5%
0.16	0.0945	4%
0.18	0.1324	3%
0.21	0.2275	2%
0.29	0.6175	1%
1.01	17.0661	0%

Table 8. Flow Frequency Table for KAN

Stage (m)	Q (m^3/s)	% of Flows Exceed
0.26	0.000	100%
0.35	0.001	99%
0.35	0.001	98%
0.36	0.001	97%
0.36	0.001	96%
0.37	0.001	95%
0.37	0.001	94%
0.37	0.001	93%
0.37	0.001	92%
0.38	0.001	91%
0.38	0.001	90%
0.38	0.001	89%
0.38	0.001	88%
0.38	0.002	87%
0.39	0.002	86%
0.39	0.002	85%
0.39	0.002	84%
0.40	0.002	83%
0.40	0.002	82%
0.40	0.002	81%
0.41	0.002	80%
0.42	0.002	79%
0.42	0.002	78%
0.43	0.002	77%
0.44	0.002	76%
0.45	0.002	75%
0.46	0.002	74%
0.46	0.002	73%
0.48	0.002	72%
0.50	0.002	71%
0.53	0.002	70%
0.55	0.002	69%
0.59	0.002	68%
0.61	0.003	67%
0.64	0.003	66%
0.65	0.003	65%
0.65	0.003	64%
0.65	0.003	63%
0.66	0.003	62%
0.66	0.003	61%
0.66	0.003	60%
0.66	0.003	59%
0.66	0.003	58%
0.67	0.003	57%
0.67	0.003	56%
0.67	0.003	55%
0.67	0.003	54%
0.67	0.003	53%
0.67	0.004	52%
0.67	0.004	51%
0.67	0.004	50%
0.67	0.004	49%
0.68	0.004	48%
0.68	0.005	47%
0.68	0.005	46%
0.68	0.005	45%
0.68	0.006	44%
0.68	0.006	43%
0.68	0.007	42%

0.69	0.008	41%
0.69	0.008	40%
0.69	0.009	39%
0.69	0.009	38%
0.69	0.010	37%
0.69	0.010	36%
0.69	0.011	35%
0.69	0.011	34%
0.69	0.012	33%
0.69	0.012	32%
0.70	0.013	31%
0.70	0.013	30%
0.70	0.013	29%
0.70	0.014	28%
0.70	0.014	27%
0.70	0.015	26%
0.70	0.015	25%
0.70	0.016	24%
0.70	0.016	23%
0.70	0.017	22%
0.71	0.017	21%
0.71	0.018	20%
0.71	0.019	19%
0.71	0.019	18%
0.71	0.020	17%
0.71	0.021	16%
0.72	0.021	15%
0.72	0.022	14%
0.72	0.023	13%
0.73	0.024	12%
0.73	0.025	11%
0.73	0.025	10%
0.74	0.026	9%
0.75	0.028	8%
0.75	0.030	7%
0.76	0.033	6%
0.76	0.038	5%
0.77	0.042	4%
0.77	0.049	3%
0.79	0.067	2%
0.85	0.201	1%
1.67	91.432	0%

APPENDIX D – WATER QUALITY DATASHEETS

Table 9. Water Quality Data for CAM

Date	Time	LL (m)	Q (m^3/s)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Cl (mg/L)	Temp °C	SC (µS/cm)	pH	DO (mg/L)	Turb (NTU)	Type	Season
3/16/2014	12:50	0.18	0.14	0.060	0.78	9.0	64.1	4.4	33.0	8.3	12.4	194.7	Storm	Winter
4/23/2014	11:30	0.08	0.01	0.003	1.62	0.7	52.5	15.1	505	7.5	9.0	7.5	Base	Spring
4/27/2014	14:20	0.37	1.28	0.371	1.62	143.7	15.1	20.1	18.0	7.7	6.8	193.3	Storm	Spring
5/6/2014	11:25	0.04	0.00	0.018	2.04	2.3	54.6	17.8	529	7.5	7.7	17.1	Base	Spring
5/8/2014	16:40	0.24	0.34	0.247	1.88	67.7	20.1	20.5	28.0	7.5	6.2	78	Storm	Spring
5/21/2014	12:48	0.04	0.00	0.015	2.26	10.0	57.7	18.9	520	7.4	7.3	10.6	Base	Spring
6/5/2014	13:50	0.34	0.99	0.142	0.63	12.3	7.0	20.0	103	7.6	6.5	35.1	Storm	Spring
6/5/2014	10:49	0.30	0.68	0.301	1.50	327.3	8.4	20.2	139	7.1	7.2	158.3	Storm	Spring
6/19/2014	13:30	0.08	0.01	0.020	2.28	2.7	40.6	21.1	459	7.1	8.4	4.6	Base	Summer
6/23/2014	14:00	0.65	7.26	0.200	1.42	47.7	3.1	25.0	30.0	7.6	8.1	2217	Storm	Summer
7/16/2014	16:55	0.10	0.02	0.015	2.24	3.0	57.5	18.4	456	7.5	9.0	6.8	Base	Summer
8/14/2014	13:15	0.08	0.01	0.006	2.62	0.4	72.3	19.1	518	7.4	8.0	4.6	Base	Summer
8/22/2014	9:15	0.05	0.00	0.023	2.50	0.1	51.6	20.1	525	7.4	5.7	0.01	Base	Summer
9/17/2014	9:30	0.90	13.76	0.322	1.99	106.7	2.7	19.0	44.0	7.9	9.1	242	Storm	Summer
9/25/2014	11:15	0.11	0.03	0.014	2.21	0.01	47.8	16.7	534	7.2	8.7	0.1	Base	Summer
10/10/2014	9:45	0.57	4.75	0.090	0.27	13.0	3.5	18.2	55.0	7.5	10.2	2,200	Storm	Fall
10/21/2014	10:30	0.13	0.05	0.029	2.56	0.1	39.0	14.6	524	7.2	6.7	0.01	Base	Fall
11/10/2014	13:30	0.12	0.04	0.030	2.01	2.0	45.0	14.7	519	7.3	10.1	1.4	Base	Fall
12/11/2014	10:30	0.13	0.05	0.015	1.54	1.5	51.2	8.7	532	7.9	11.1	0.0	Base	Fall
1/8/2015	12:45	0.13	0.05	0.011	2.32	2.0	44.3	5.3	537	8.3	15.7	0.3	Base	Winter
2/13/2015	11:30	0.13	0.05	0.005	1.95	0.8	51.8	6.4	536	7.8	12.8	0.0	Base	Winter
3/17/2015	13:15	0.09	0.02	0.012	2.11	2.8	187.4	14.3	701	7.4	12.2	1.6	Base	Winter
3/25/2015	19:00	0.21	0.23	0.072	2.09	27.5	67.5	13.6	480	7.6	8.4	49.1	Storm	Spring

Table 10. Water Quality Data for KAN

Date	Time	LL (m)	Q (m^3/s)	TP (mg/L)	TN (mg/L)	TSS (mg/L)	Cl (mg/L)	Temp °C	SC (µS/cm)	pH	DO (mg/L)	Turb (NTU)	Type	Season
3/16/2014	13:30	0.82	0.03	0.149	1.03	73.3	50.0	4.7	276	8.5	12.2	38.6	Storm	Winter
4/23/2014	11:45	0.77	0.013	0.020	1.37	0.7	51.7	15.5	498	8.1	8.1	8.3	Base	Spring
4/27/2014	14:40	0.85	0.05	0.177	1.67	107	16.8	20.4	174	7.8	6.4	56.7	Storm	Spring
5/6/2014	12:10	0.77	0.012	0.048	1.15	5.3	57.9	20.0	525	7.9	5.7	8.8	Base	Spring
5/8/2014	17:10	0.91	0.16	0.323	1.64	378	7.3	21.6	119	7.7	5.9	448.2	Storm	Spring
5/21/2014	13:12	0.75	0.009	0.033	1.43	0.6	60.8	23.5	490	8.0	10.4	7.8	Base	Spring
6/5/2014	14:36	0.96	0.23	0.193	1.03	7.7	7.4	21.1	134	7.7	7.3	33.8	Storm	Spring
6/5/2014	12:51	1.29	25.2	0.173	0.76	27	1.1	20.1	68.0	7.7	7.1	39.2	Storm	Spring
6/19/2014	13:55	0.70	0.003	0.032	1.55	0.7	44.3	29.3	403	8.1	12.5	5.2	Base	Spring
6/23/2014	14:20	1.14	7.43	0.249	1.40	50.7	5.2	25.0	79.0	7.7	7.2	53.2	Storm	Summer
7/16/2014	17:17	0.66	0.001	0.032	0.92	1.0	49.9	27.0	271	9.4	14.0	6.1	Base	Summer
8/14/2014	13:45	0.71	0.003	0.017	1.25	0.2	55.5	25.1	441	7.7	9.0	1.0	Base	Summer
8/22/2014	9:30	0.69	0.003	0.047	0.85	0.2	57.3	26.0	422	7.4	4.2	2.0	Base	Summer
9/2/2014	10:30	0.77	0.01	0.036	0.64	0.1	10.6	21.9	171	7.6	7.4	16.2	Storm	Summer
9/17/2014	10:15	1.67	91.4	0.171	0.70	47.3	2.4	19.0	42.0	8.0	9.0	64	Storm	Summer
9/17/2014	14:30	1.49	64.2	0.201	0.98	31.0	2.2	18.7	47.0	7.7	8.7	35.1	Storm	Summer
9/25/2014	11:45	0.73	0.005	0.0005	*1.39*	*0.4*	51.1	19.7	510	7.7	8.2	44.8	Base	Fall
10/10/2014	10:15	1.09	2.25	*0.082*	*0.23*	*7.0*	4.2	18.2	75.0	7.5	9.6	49	Storm	Fall
10/13/2014	10:20	0.96	0.31	*0.100*	*0.13*	*7.0*	5.7	17.9	97.0	7.5	7.8	ND	Storm	Fall
10/21/2014	10:45	0.68	0.002	*0.002*	*2.16*	0.05	40.5	14.5	529	8.1	7.8	0.6	Base	Fall
11/4/2014	8:45	0.79	0.02	0.103	0.65	4.7	8.5	13.6	133	7.8	8.4	13	Storm	Fall
11/10/2014	13:50	0.71	0.004	0.014	1.56	4.0	48.5	13.2	489	8.5	14.6	1.0	Base	Fall
12/5/2014	13:45	0.75	0.01	0.154	0.78	23.5	34.9	10.5	219	7.9	11.0	75	Storm	Fall
12/11/2014	10:45	0.50	0.015	0.011	1.77	1.0	54.0	7.0	546	8.5	17.1	0.3	Base	Fall
1/8/2015	13:15	0.26	0.015	0.021	2.06	0.8	42.5	0.2	470	9.6	22.3	0.0	Base	Winter
2/13/2015	12:00	0.39	0.025	0.008	1.93	2.0	48.0	6.1	501	9.2	15.6	0.0	Base	Winter
3/17/2015	13:30	0.41	0.039	0.014	1.88	0.8	137.4	17.3	630	8.4	13.8	0.7	Base	Winter
3/25/2015	19:15	0.52	0.28	0.257	2.04	316.0	41.5	12.6	248	7.7	8.4	134.5	Storm	Spring

ND = no data