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

ASHER CREEK WATERSHED 319 PROJECT

ASHER CREEK WATER QUALITY ASSESSMENT, GREENE AND POLK COUNTIES, MISSOURI

FINAL REPORT

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SCOPE AND OBJECTIVES

The Greene County Soil and Water Conservation District 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 the Asher Creek Watershed in northern Greene and southern Polk Counties. In 1998, the Little Sac River was placed on the 303d list for bacterial contamination, for which a TMDL for Total Coliform was approved in 2006 (Baffaut 2006). Various studies have indicated Asher Creek has the highest level of E. Coli bacteria in the entire Little Sac River Watershed and the Upper Little Sac Watershed Plan has identified Asher Creek as a priority area for BMP implementation and restoration (WCO 2010). However, these recommendations are based on limited spatial and temporal data availability within the watershed and an evaluation of bacteria sources has not been done. Furthermore, little is known of nutrient loadings in this watershed.

To better understand the variability in the water quality of Asher Creek, the monitoring portion of this project was designed to address three questions. First, how does E. Coli and total Coliform bacteria vary throughout the watershed and between seasons to better focus remediation efforts in the watershed? Second, how do bacteria concentrations compare to optical brightener (OB) concentrations that would indicate a potential municipal waste water source? Finally, what are the nutrient loads from this watershed to the Little Sac River that may be contributing to water quality degradation?

The purpose of this project is to identify the bacteria levels and to quantify the nutrient loads within the Asher Creek Watershed. The specific objectives of this project are; 1) establish 6 water quality monitoring stations throughout the watershed with two of those sites hydrologic monitoring stations, 2) collect and analyze regular time-interval grab samples from each station over an 18 month monitoring period for nutrients, bacteria, and OB, 3) describe the spatial and temporal variability in bacteria concentrations at these 6 stations, 4) compare OB and E. Coli results that may indicate municipal waste sources, and 5) quantify the nutrient loads at the two hydrologic monitoring stations.

WATERSHED CHARACTERISTICS

The Asher Creek watershed is located in the 12-digit Hydrologic Unit Code (HUC) 102901060406 Asher Creek-Little Sac River and is located in northwest Greene and southwest Polk Counties in southwest Missouri and is a tributary of the Little Sac River (Figure 1). The underlying geology of Asher Creek is Mississippian age cherty-limestone in which 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). Small tributary valleys contain alluvial deposits composed of stratified layers of

chert gravel and silty alluvium. Larger main valleys have relatively deep accumulations of silty alluvium over coarse gravel. Land use within the watershed is mostly grass and forest. The urban area is relatively small occurring mostly in the southern part of the watershed near the town of Willard and along Highway 123 between Willard and Walnut Grove.

METHODS

Site Selection and Sampling

In-stream surface water quality monitoring was conducted at five sample sites along Asher Creek and from one site along the Walnut Grove tributary for 18 months from May 1, 2012 to October 31, 2013 (Figure 2, Table 1, and Photos 1-6). These locations were spaced throughout the watershed in an effort to gather data from above and below future potential BMP sites. Because livestock and forage production related BMPs are the primary focus of the restoration efforts in this watershed, an attempt was made to not locate the sampling points near large areas of timber to reduce variability and increase the number of representative samples to meet the water quality monitoring goals and objectives of the project (Figure 3, Table 2).

Surface water grab samples were collected weekly from April 1st until October 31st by the Watershed Committee of the Ozarks (WCO) staff. Monthly samples were collected the rest of the year. Total nitrogen (TN) and total phosphorus (TP) samples were only collected at sites Asher Creek Site 03 (AC03) and AC06. Optical brighteners, E. Coli and total coliform samples were collected at all six sites. If sample collection could not be conducted due to dry conditions it was noted in the field notebook and resampling was not conducted. Water quality samples were collected approximately three to six inches below the water surface. Nutrient samples were collected in 500 ml plastic bottles. Bacteria samples were collected in sterile 100 ml Thio-Test bags. Optical Brightener samples were collected in brown 500ml plastic bottles. Duplicate samples were collected during each sampling event pre-selected sites. Upon collection, samples were transported on ice and delivered to the laboratory and preserved.

Laboratory Analysis

Samples were analyzed the OEWRI Laboratory at Missouri State University. Samples were analyzed for TN and TP using a Genesys 10S UV-Vis Spectrophotometer. Average detection limits were 0.2 mg/L TN and 0.003 mg/L TP with accuracy within the range of + or – 20%. The IDEXX Quanti-Tray/2000 system is used to analyze water samples for the presence of total coliform and E. coli. The detection limit of this machine is 1 MPN/100mL with accuracy of + or – 20%. Analysis of OB was competed using a Hitachi FL-2500 fluorometer with a detection limit of ≤0.5 mg/L with an accuracy of + or – 20%.

Hydrological Monitoring

Stage was recorded at sites AC03 and AC06 every 15 minutes over the 20 month monitoring period using Solinst Levelogger Gold and Baralogger Gold leveloggers. The level loggers were installed inside a PVC pipe assembly and secured to the bridge (Photo 7). As water rises in the pipe the levelogger uses the change in pressure to record changes in water level. The barologger was used to compensate for barometric pressure changes. Raw data was downloaded from the levelloggers onto a laptop during each sampling event.

Flow conditions will also be recorded at the time of sampling with a Marsh McBirney Flow-Mate 2000 portable flow-meter. These data were used to create discharge rating curves at each site to estimate flows at different stream levels over the monitoring period (Figures 4 and 5). Additional flow measurements were collected using a SonTek FlowTracker Acoustic Doppler velocity meter to verify and calibrate rating curves (Photo 8). The highest calibration flows were estimated for both sites using Manning's equation in Hydraflow Express software (Intelisolve 2006). Two regression lines were used to best represent the data split at the 0.3 m stage. Flow frequency curves were created using the levelogger readings over the monitoring period and the discharge rating curves.

Load Calculations

Flow-weighted loads over the monitoring period were calculated using the load duration method. This method combines the flow frequency curves from the hydrologic monitoring and nutrient rating curves from the water quality monitoring portion of the project. Nutrient concentrations are allocated to specific flows representing 1% increments is based on the percentage of time that flow occurred over the monitoring period. Then by multiply the concentrations and the flow a load representing each increment of time is calculated and the sum represents the load from the entire monitoring period. Nutrient loads will be compared to published eutrophic thresholds (ET) used in the Ozarks of 0.75 mg/L TP and 1.5 mg/L TN and Environmental Protection Agency (EPA) ambient water quality recommendations of 0.0066 mg/L TP and 0.379 mg/L TN (Dodds et al. 1998, USEPA 2000, MDNR 2001).

RESULTS AND DISCUSSION

Hydrology

Hydrologic monitoring over the 18 month study period of the two main channel sites show water levels in Asher Creek varied from being completely dry in 2012 to a 2-yr flood in 2013. Over 52,000, 15-minute stage readings during nearly a 550 day period covered two distinct rainfall cycles during the monitoring period that impacted sample collection at sites AC03 and AC06. The 8 month sampling period in 2012 was extremely dry. The period of May-July 2012 rainfall totals were about 21 cm below the 30-year average (Figure 6). Consequently, stream flows were very low in the first 250 days of the study with no high water events and very low base flows (Figures 7 and 8). In fact, the stream went completely dry in June and July of 2012 representing

about 10% of flow record during the monitoring period at both sites (Figures 9 and 10). Starting in January of 2013, rainfall begins to pick up and the 10 month 2013 sampling period was wet having around 20 cm of rainfall above the 30-year average. As a result, stream flows were much higher in the last 300 days of the monitoring period with several high flow events and a higher base flow. The peak stage (0% of flows exceed) at site AC03 was 1.15 m (29.6 m^3/s) and 1.67 m (67.4 m^3/s) at AC06. Using the rural regression flood frequency equation for Missouri, these events are about the 2-yr flood recurrence interval (Alexander and Wilson 1995). The 18 month water quality sampling period included two different hydrologic periods, one being a relatively long droughty period with a few small storms and the other more frequent small storms including a significant flood event. In general, storm samples were usually collected after the peak discharge and don't fully include rising limb conditions of larger flood events. Thus, annual loading calculations provided in this report may under-represent water quality trends during larger storm flows. However, the weekly sampling interval used in this study does provide valuable data for the lower flows that occurred during the sampling period and these flows are those most frequently observed in Asher Creek.

Samples

A total of 343 samples were collected over the 18 month sampling period. Due to the extremely dry conditions in 2012, a full set of samples were not collected at all sites (Table 3). Particularly in the summer of 2012 where several sites were dry for a couple of months and no samples were collected. Of all the sites sampled, AC04 appears to be impacted the most by the dry weather with only 48 samples being collected. Sites AC02, 03, and 06 were less impacted by drought with ≥60 samples at each over the monitoring period.

Optical Brighteners

Optical brighteners (OBs) are fluorescent white dyes added to laundry soaps and detergents that are discharged into sanitary sewers or on-site wastewater systems for disposal (Aley and Thompson, 2002). Therefore the presence of OBs in natural waters is an indicator of a waste water pollution source. Concentrations of OBs were relatively low at all sites with generally higher concentrations in the winter months. Site AC01, with the highest urban land use upstream, had the highest average concentration of OBs among sites (Table 4). The average concentration of 10.4 mg/L was 10-50% higher than the average concentration at the other sites studied. Site AC02 has the lowest average concentration of 4.7 mg/L, but the highest variability among sites with a CV% of nearly 100%. Seasonally, OB concentrations tend to be higher in the cooler months compared to the warmer months (Figure 11). This makes sense if onsite wastewater systems are the source of OB in this watershed since evapotranspiration in the lateral field is less effective in the winter. Further evidence for dilution can be seen in the spikes in OB concentrations from the summer of 2012, which was very dry.

E. Coli

E. Coli levels exceeded the State of Missouri water quality standard at four of the six sites sampled for this study. Asher Creek is designated for Whole Body Contact (WBC) level B, which is 206 colony-forming units (CFU)/100 mL for the geometric mean (geomean) of samples collected from April 1st-October 31st (Kander, 2014). The method used for this study produces most probable number (MPN) E. Coli counts that are similar to the membrane filtration techniques that provide a CFU designation (Buckalew et al., 2006). Site AC01 had the highest E. Coli concentrations among sites with a geomean of 1,475 MPN/100 mL (Table 5). Other sites that exceeded the WBC criteria are AC02 (267 MPN), AC03 (444 MPN), and Site AC05 (601 MPN). Sites AC04 and AC06 had the lowest concentration among sites with a geomeans of 191 and 69 MPN/100 mL respectively. These are actually low numbers because maximum reporting level for an undiluted 100 mL sample for this method is 2,420 MPN/100 mL, which was obtained in at least one sample at all 6 sites. A dilution of 1:10 was performed for samples collected on August 6, 2013 and shows E. Coli concentrations can be as high as 7,000-14,000 MPN/100 mL (Appendix C).

Seasonal trends in E. Coli concentrations show that sources of bacteria can be varied throughout the year at different locations in the watershed. Site AC01, has the highest average OB and E. Coli concentrations of any site. However, bacteria concentrations are higher in the summer months and OB concentrations are higher in the winter months (Figure 12). This "inverse" trend can also be seen in AC02 and suggests E. Coli and OB are not originating from the same source. Comparatively, the seasonal trends in bacteria at site AC06, with the lowest average E. Coli concentration, tend to mirror OB concentrations. This suggests E. Coli and OB are originating from the same source at this site. Sites 03, 04, and 05 are more variable which could indicate multiple sources at these sites. These are observations from this one study and should be investigated further. For instance, microbial source tracking may be able to verify these assumptions.

Total Coliform

Total coliform bacteria concentrations were very high throughout the watershed over the sampling period. Average concentrations at all sites were >2,000 MPN/100 mL (Table 6). These are actually low averages because the detection limit for this method is 2,420 MPN/100 mL, which was obtained in over half of the samples collected at all 6 sites. A dilution of 1:10 was performed for samples collected on August 6, 2013 and shows total coliform concentrations can be >24,196 MPN/100 mL (Appendix C).

Total Phosphorus

Average TP concentrations in Asher Creek are lower than the eutrophic threshold of 0.075 mg/L over the study period. Site AC03 had an average TP concentration of 0.074 mg/L and site AC06 had an average TP concentration of 0.048 mg/L (Table 7). AC03 was more variable than AC06

with a coefficient of variation percentage (CV%) of 149.2% compared to 70.6%. The high average concentrations and variability in AC03 is mostly due to the very high concentrations sampled during extremely low flow events <0.02 m^3/s (Figure 13). Even after removing the low flow samples, the trend over discharges ranging from 0.02-2 m^3/s increases very little due to the high variability at AC03. Site AC06 is less variable but TP concentrations increase at a higher rate at discharges between 0.01-5 m^3/s (Figure 14). For the purpose of creating a load duration curve, the low flow outliers were removed from the TP rating curve for both sites.

Total Nitrogen

Average TN concentrations in Asher Creek are at or lower than the eutrophic threshold of 1.5 mg/L over the study period. As with TP, TN concentrations are higher at site AC03 compared to AC06. The average TN concentration at AC03 is 1.53 mg/L compared to 0.89 mg/L at AC06 (Table 8). However, TN concentrations have higher variability at AC06 with a CV% of 72.9% compared to 55.9% at AC03. Again, the high variability distorts the overall trend over several flow events as lower flow events influence the raw numbers. With outliers removed, the trend is for TN concentrations to rise above eutrophic threshold at about 0.1 m^3/s at AC03 (Figure 15). However at AC06, TN concentrations do not rise above the eutrophic threshold of 1.5 mg/L until discharge is >1 m^3/s (Figure 16). For the purpose of creating a load duration curve, outliers were removed from the TN rating curve for both sites.

Annual Loads

The annual TP loads for sites AC03 and AC06 from this study shows that TP is well below the eutrophic threshold. The annual TP load at AC03 is 0.81 Mg/yr with an average flow weighted concentration of 0.042 mg/L (Table 9). The annual TP load at AC06 is 2.0 Mg/yr with an average flow weighted concentration of 0.048 mg/L. Both sites are well below the ET of 0.075 mg/L. The TP load does exceed the ET at very low flows (>85% flows exceed) at site AC03, but the flows are so low it makes little difference in the overall annual load (Figures 17 and 18). The annual TP yield for both AC03 and AC06 is 0.02 $Mg/km^2/yr$. Daily loads do exceed the EPA recommended limit for ambient water quality for the region, which is set at 0.0066 mg/L TP and is near the analytical detection limit of 0.003 mg/L.

The TN loads at AC03 and AC06 exceeds the ET for portions of the monitoring period. The annual TN load at AC03 is 50.7 Mg/yr with an average flow weighted concentration of 2.63 mg/L (Table 9). The annual TN load at AC06 is 154 Mg/yr with an average flow weighted concentration of 3.73 mg/L. While the average concentration at AC06 is higher, the TN load at AC03 begins to exceed the ET near the 50% flow, while the load at AC06 begins to exceed the ET at 15% even with the higher average concentration (Figures 19 and 20). This suggests nitrogen pollution is tied to the highest flows at AC06, but TN exceeds the ET for a longer period of time at AC03 at more intermediate flows. However, daily loads are below the EPA recommended limit for ambient water quality for the region of 0.379 mg/L TN at low flows.

Daily load is below 0.379 mg/L at AC03 10% of the sample period and 40% of the sample period at AC06. The annual TN yields are similar at both sites, AC03 is 1.3 $Mg/km^2/yr$ and AC06 is 1.7 $Mg/km^2/yr$. These results show that TN at base flow meets both published criteria but exceeds both criteria during storm events. While TP is considered the limiting nutrient for eutrophication, these results suggest nitrogen sources in the upper watershed may need to be considered for management to reduce future risk of eutrophic conditions.

The TP yields from this study are within the range of those found in other studies, but the TN yields are high compared to other studies. The TP yield from this study is low compared to national data published by the EPA that range from 0.01 $Mg/km^2/yr$ to 0.2 $Mg/km^2/yr$ (Table 10). Similarly, local data shows that yields from this study are in the lower range of those found in the James River at sites that are not impacted by wastewater treatment plants between 0.02 to 0.04 $Mg/km^2/yr$ (Hutchison, 2010). The TN yields from this study are high compared to EPA published yields from around the nation that range from 1.11 $Mg/km^2/yr$ to 0.18 $Mg/km^2/yr$. Yields from this study are more similar to those found in the James River at sites that are not impacted by wastewater treatment plants which range from 0.54 to 1.47 $Mg/km^2/yr$.

CONCLUSIONS

There are 6 main conclusions from this study:

1. **Six water quality monitoring stations were established in the Asher Creek watershed and monitored for 18 months.** A total of 5 stations were placed along the main channel of Asher Creek and 1 station was placed in the tributary draining the town of Walnut Grove. Between May 1, 2012 and October 31, 2013, 343 optical brightener and bacteria samples were collected and 120 nutrient samples were collected at these sites.

2. **Two hydrologic monitoring stations were established in the Asher Creek watershed and monitored for 18 months.** Over 52,000, 15-minute stage readings over nearly 550 days covered two distinct rainfall cycles during the monitoring period that impacted sample collection at sites AC03 and AC06. The 8 months in 2012 were extremely dry causing the creek to run dry for a few months. That changed in 2013 when rainfall exceeded the 30-year average. So, over the sampling period flow ranged from no flow to the highest stage recorded that corresponds to the 2-5yr recurrence interval.

3. **Optical brighteners were relatively low, but were higher closer to the urban area.** Concentrations of OBs were relatively low at all sites with generally higher concentrations in the winter months. Site AC01, with the highest urban land use upstream, had the highest average concentration of OB among sites. Seasonally, OB concentrations tend to be higher

in the cooler months compared to the warmer months likely due to lower evapotranspiration in onsite wastewater system's lateral fields in the winter.

4. **E. Coli bacteria exceeded the State of Missouri water quality standard for whole body contact at all sites.** E. Coli levels exceeded the State of Missouri water quality standard of 206 CFU/ 100 mL at four of the six sites sampled for this study. These are actually low numbers because maximum reporting level for an undiluted 100 mL sample for this method is 2,420 MPN/100 mL, which was obtained in at least one sample at all 6 sites. Seasonal trends in E. Coli concentrations show that sources of bacteria can be varied throughout the year at different locations in the watershed but these observations are from this one study and should be investigated further. For instance, microbial source tracking may be able to verify these assumptions.

5. **Annual TP loads are lower than the eutrophic thresholds but exceeded EPA recommended criteria.** The annual TP load at AC03 is 0.81 Mg/yr with an average flow weighted concentration of 0.042 mg/L. The annual TP load at AC06 is 2.0 Mg/yr with an average flow weighted concentration of 0.048 mg/L. Both sites are well below the eutrophic threshold of 0.075 mg/L. Daily loads exceed the EPA recommended criteria of 0.0066 mg/L TP over the sampling period.

6. **TN loads were near or below EPA recommended criteria at lower flows but exceed the eutrophic threshold at higher flows suggesting nitrogen inputs during storms**. The TN load at AC03 is 50.7 Mg/yr with an average flow weighted concentration of 2.63 mg/L. The annual TN load at AC03 is 154 Mg/yr with an average flow weighted concentration of 3.73 mg/L. These are both above the eutrophic threshold of 1.5 mg/L and yields are similar to other watersheds in the region. Daily loads are below the EPA recommended criteria of 0.379 mg/L TN at lower flows, particularly at AC06. These results suggest nitrogen sources in the upper watershed may need to be considered for management to reduce future risk of eutrophic conditions.

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TABLES

Table 1. Sample site locations in the Asher Creek Watershed

Site	Location	UTM Zone 15N	
		Easting	Northing
AC01	Asher Creek at Z Highway	461,708.951	4,131,274.063
AC02	Asher Creek west of Farm Road 52	458,850.347	4,133,928.853
AC03	Asher Creek N Farm Road 81	458,372.432	4,137,431.609
AC04	Asher Creek State Highway BB	459,065.613	4,140,208.780
WG05	Tributary from Walnut Grove on Farm Road 4	457,692.475	4,141,598.555
AC06	Asher Creek / Little Sac River confluence	458,859.676	4,143,475.676

Table 2. Upstream land use and drainage area for sample sites

Site	Drainage Area (km^2)	Land Use (%)				
		Urban	Cropland	Grassland	Forest	Water
AC01	7.5	3.5	14.8	72.3	8.9	0.4
AC02	23.2	2.2	12.6	69.1	15.8	0.3
AC03	38.7	1.8	9.5	67.3	20.9	0.4
AC04	55.7	1.6	7.2	64.0	26.9	0.4
WG05	25.3	1.5	3.2	72.4	22.6	0.2
AC06	91.9	1.5	5.5	64.6	28.2	0.3

Table 3. Seasonal sample collection over the monitoring period.

Samples	AC01	AC02	AC03	AC04	WG05	AC06	Total
Spring 2012	8	8	8	8	8	7	47
Summer 2012	6	13	11	2	9	12	53
Fall 2012	7	7	7	4	7	7	39
Winter 12-13	2	2	2	2	2	2	12
Spring 2013	13	13	13	13	13	13	78
Summer 2013	13	13	13	13	13	13	78
Fall 2013	6	6	6	6	6	6	36
Total	55	62	60	48	58	60	**343**

Table 4. Optical brightener summary statistics by site.

OB (mg/L)							
Site	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
AC01	55	10.4	10.2	2.2	32.5	6.0	57.7
AC02	62	4.7	3.8	0.1	25.6	4.6	97.8
AC03	60	8.7	7.9	2.0	25.1	4.6	53.0
AC04	48	8.5	7.4	2.3	34.7	5.8	67.9
WG05	58	9.0	7.9	2.3	20.4	4.6	51.3
AC06	60	6.7	5.9	0.1	21.8	4.3	63.9

Table 5. E. Coli summary statistics by site.

E. Coli (MPN)								
Site	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**	**Geomean***
AC01	55	1,755	***2,420***	32	***2,420***	900	51.3	1,475
AC02	62	535	244	7.3	***2,420***	676	126.3	267
AC03	60	850	435	7.1	***2,420***	797	93.8	444
AC04	48	458	156	7.5	***2,420***	765	166.8	191
WG05	58	1,084	649	7.0	***2,420***	942	87.0	601
AC06	60	417	66	0.5	***2,420***	767	183.7	69

*Only samples collected from April 1 – October 31

Table 6. Total coliform summary statistics by site

Total Coliform (MPN)							
Site	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
AC01	55	2,298	***2,420***	1,203	***2,420***	313	13.6
AC02	62	2,084	***2,420***	326	***2,420***	625	30.0
AC03	60	2,257	***2,420***	866	***2,420***	409	18.1
AC04	48	2,161	***2,420***	365	***2,420***	594	27.5
WG05	58	2,273	***2,420***	687	***2,420***	429	18.9
AC06	60	2,195	***2,420***	435	***2,420***	537	24.5

Table 7. Total phosphorus summary statistics by site.

TP (mg/L)							
Site	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
AC03	60	0.074	0.039	0.005	0.780	0.111	149.2
AC06	60	0.048	0.036	0.003	0.151	0.034	70.6

Table 8. Total nitrogen summary statistics by site.

TN (mg/L)							
Site	**n**	**mean**	**median**	**min**	**max**	**sd**	**cv%**
AC03	60	1.53	1.49	0.08	4.15	0.86	55.9
AC06	60	0.89	0.93	0.04	2.26	0.64	72.6

Table 9. Annual nutrient loads by site.

Site	Ad km^2	TP Avg. Con. mg/L	TP Load Mg/yr	TP Yield $Mg/km^2/yr$	TN Avg. Con. mg/L	TN Load Mg/yr	TN Yield $Mg/km^2/yr$
AC03	38.7	0.042	0.81	0.02	2.63	50.7	1.3
AC06	91.9	0.048	2.0	0.02	3.73	154	1.7

Table 10. EPA reported TP and TN yields.

Land Use	TP Yield $Mg/km^2/yr$	TN Yield $Mg/km^2/yr$
Corn	0.20	1.11
Residential	0.12	0.75
Pasture	0.01	0.31
Forest	0.01	0.18

Source: USEPA, 2008

FIGURES

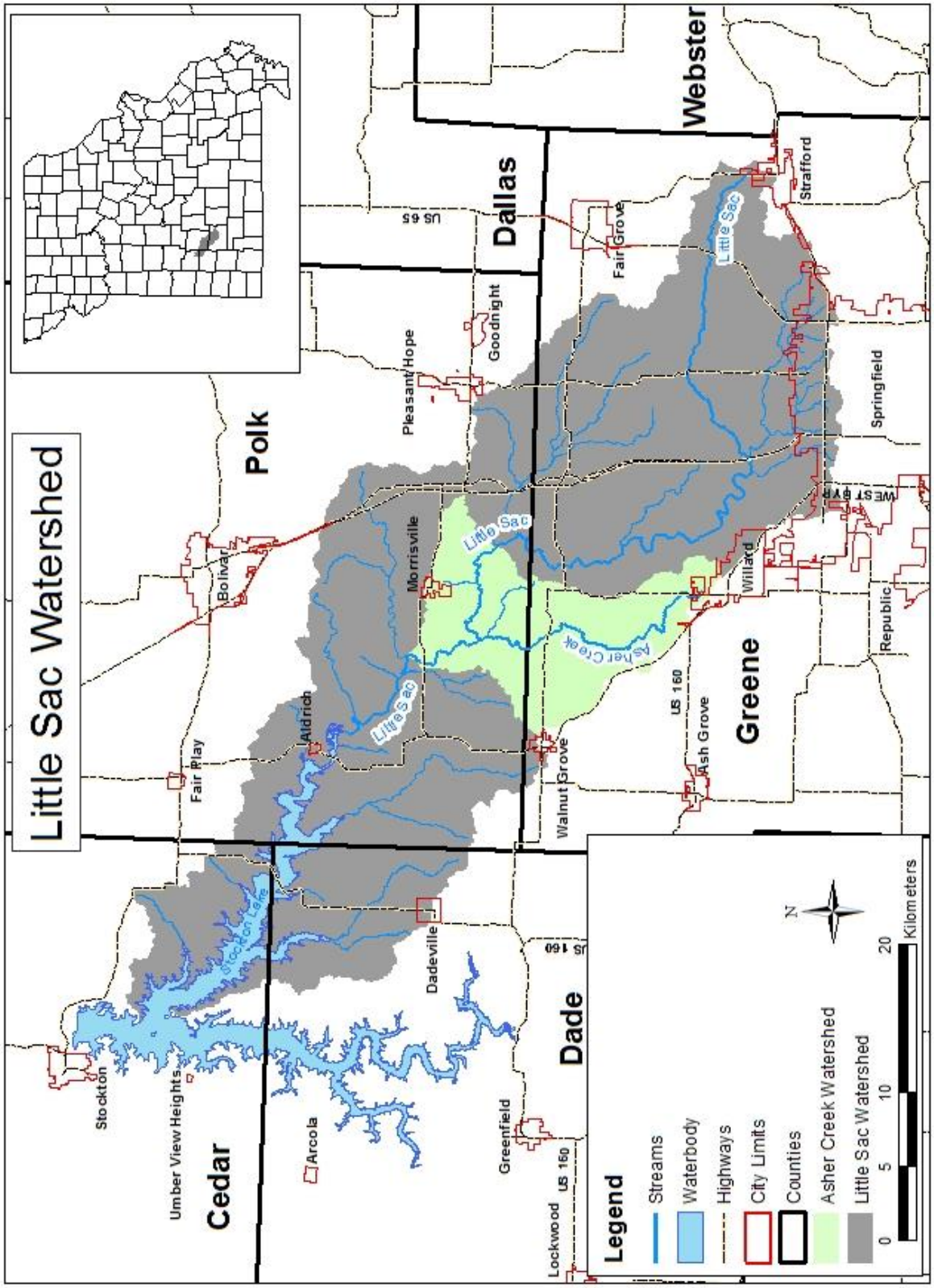

Figure 1. Location of Asher Creek in the Little Sac Watershed.

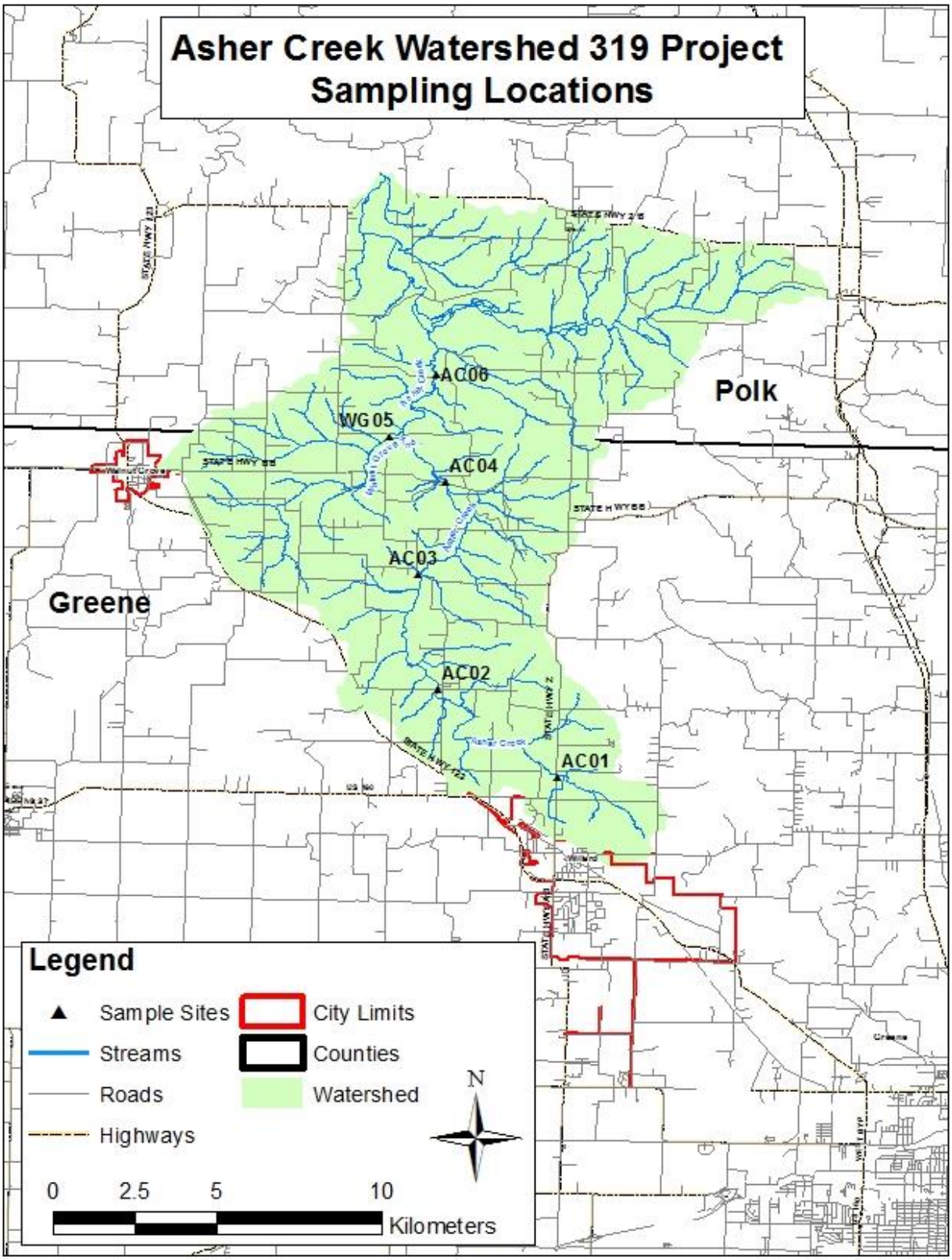

Figure 2. Sample site locations in the Asher Creek Watershed.

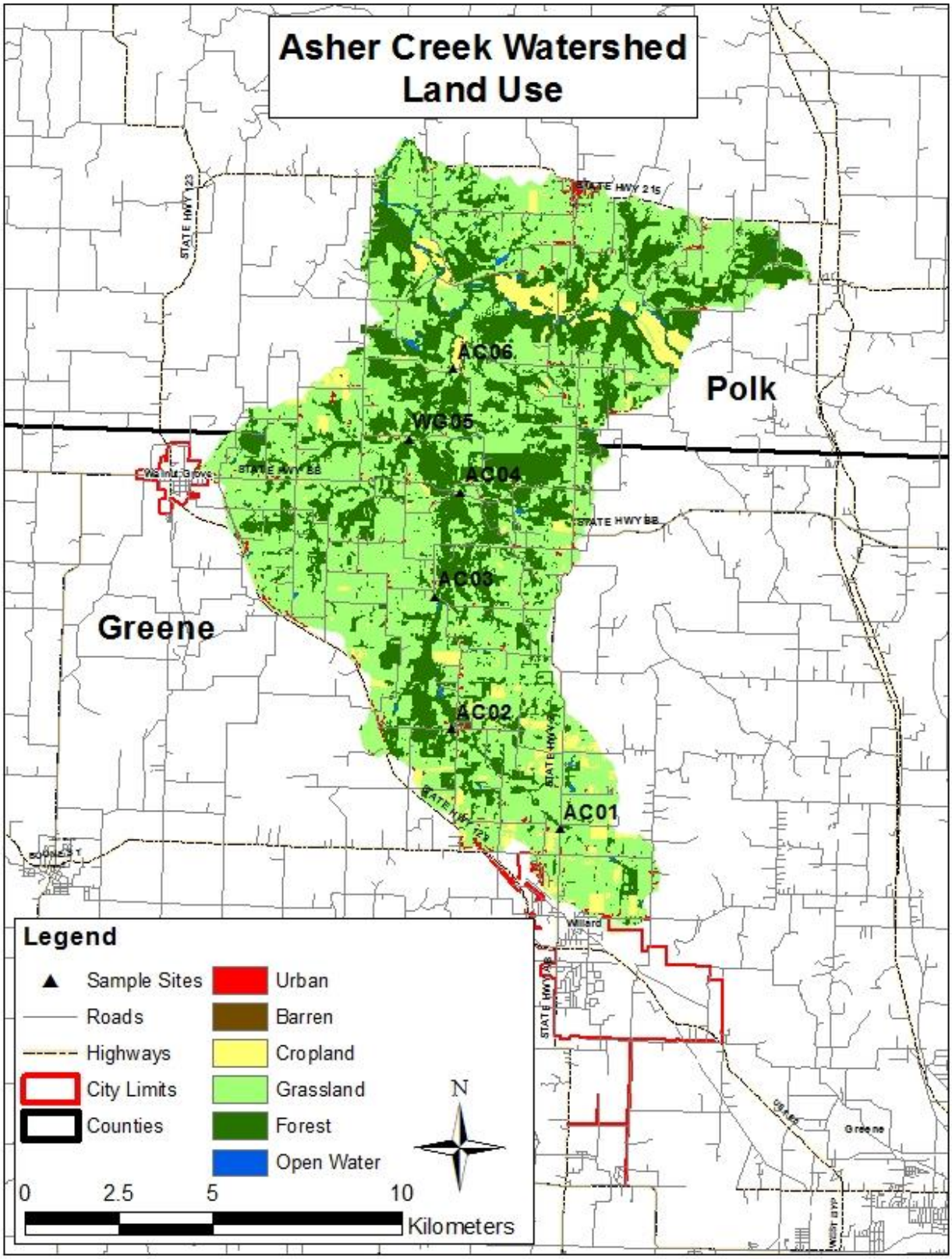

Figure 3. Asher Creek land use map.

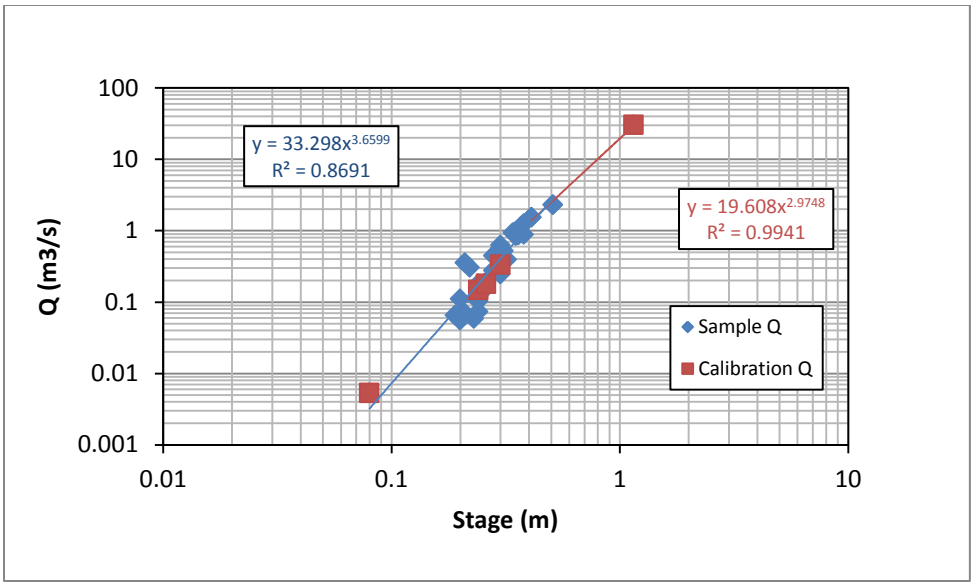

Figure 4. Discharge rating curve for site AC03.

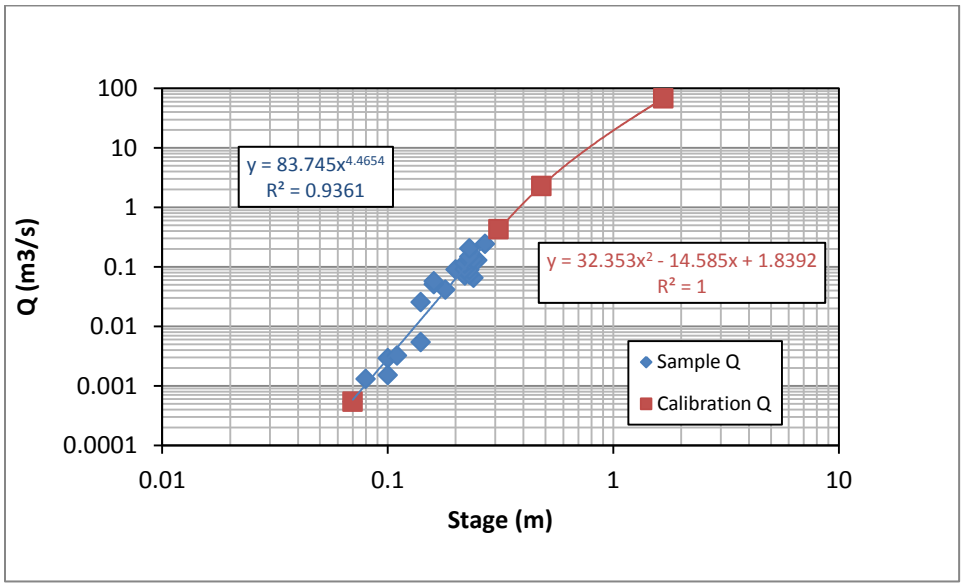

Figure 5. Discharge rating curve for site AC06.

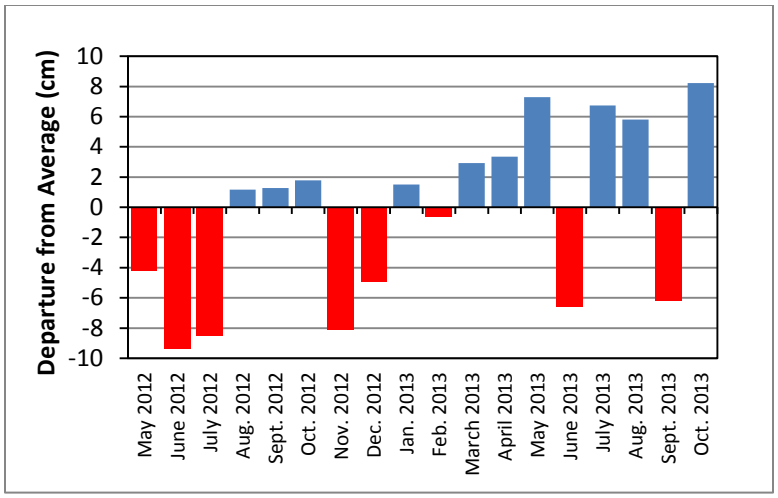

Figure 6. Departure from average monthly rainfall totals over the sampling period.

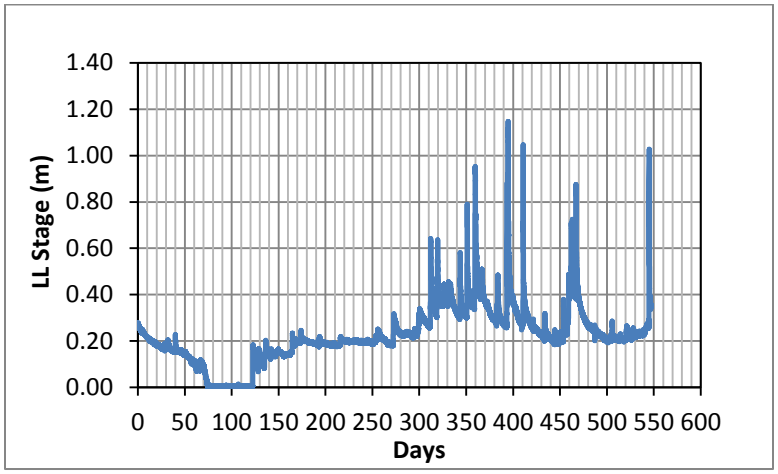

Figure 7. Monitoring period stage readings for site AC03.

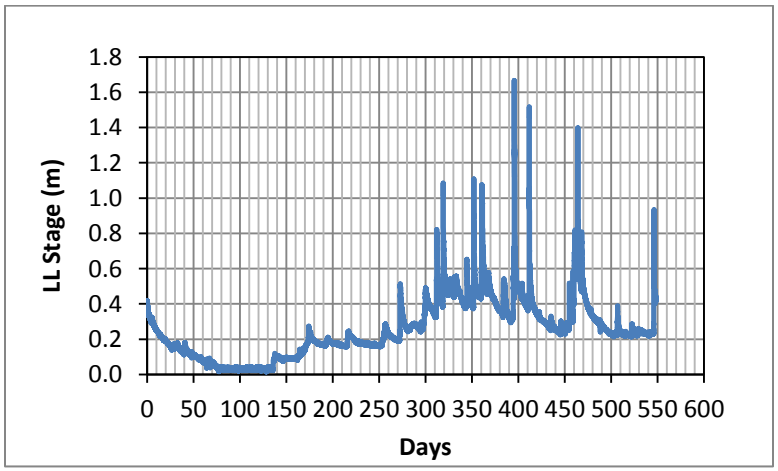

Figure 8. Monitoring period stage readings for site AC06.

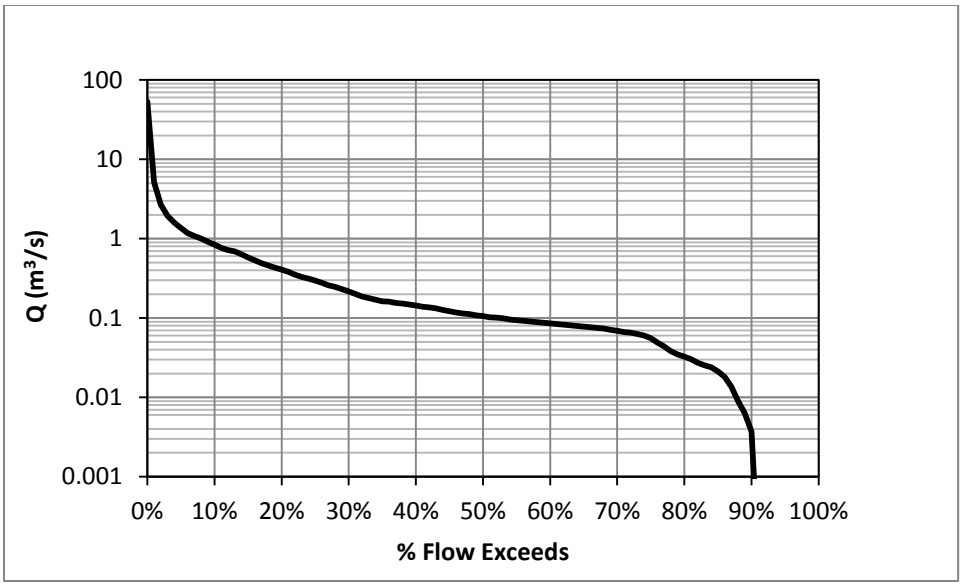

Figure 9. Flow frequency curve for site AC03.

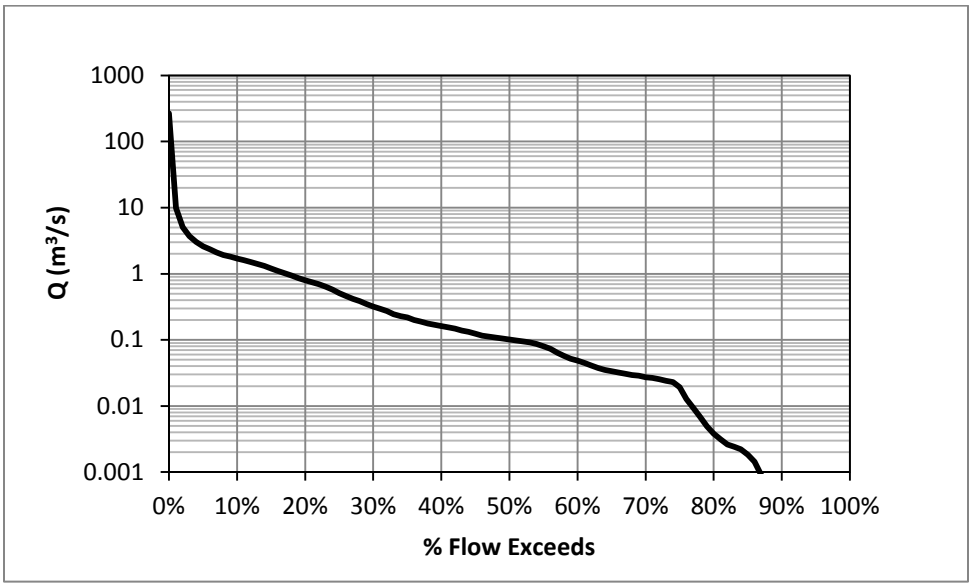

Figure 10. Flow frequency curve for site AC06.

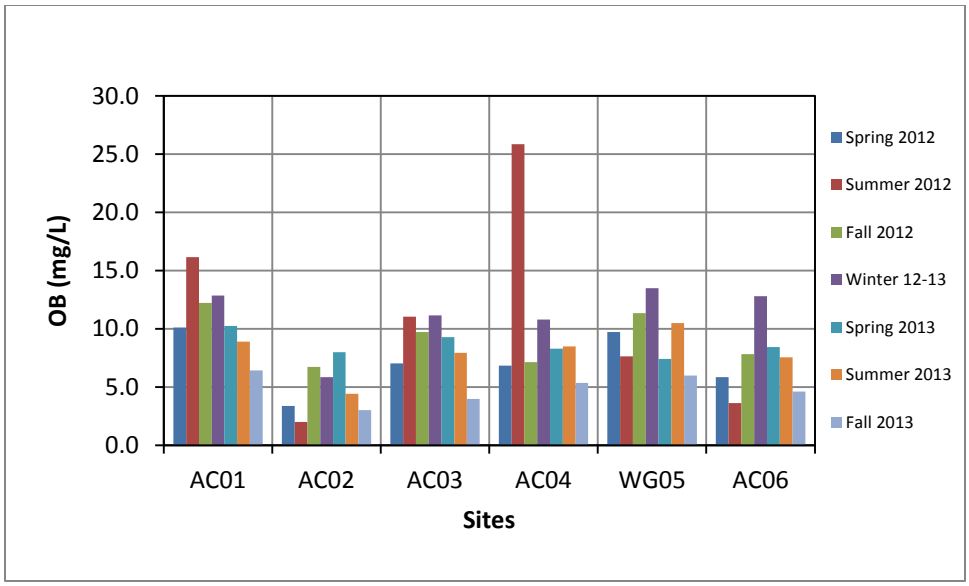

Figure 11. Seasonal variability in OB concentrations by site.

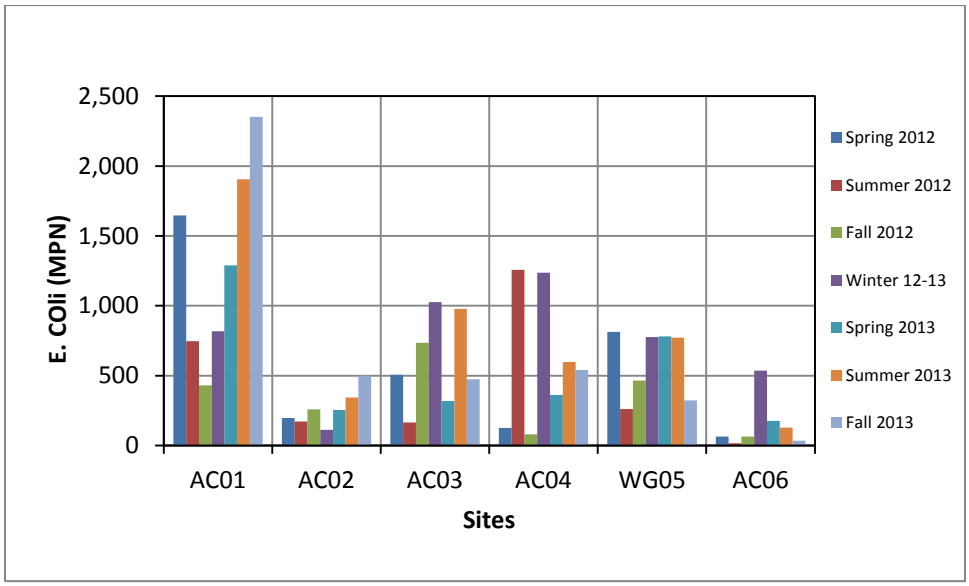

Figure 12. Seasonal variability in E. Coli concentrations by site.

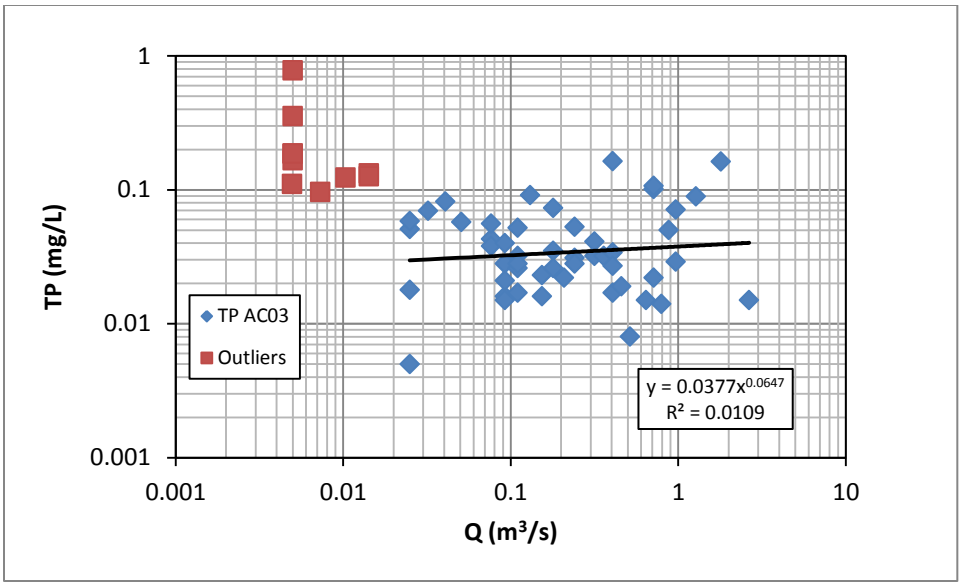

Figure 13. TP rating curve for AC03.

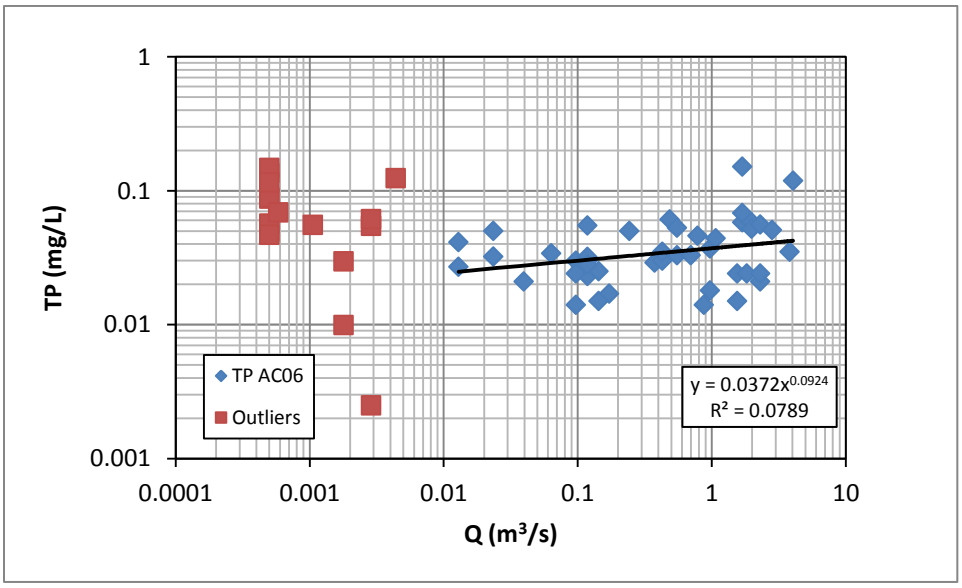

Figure 14. TP rating curve for AC06.

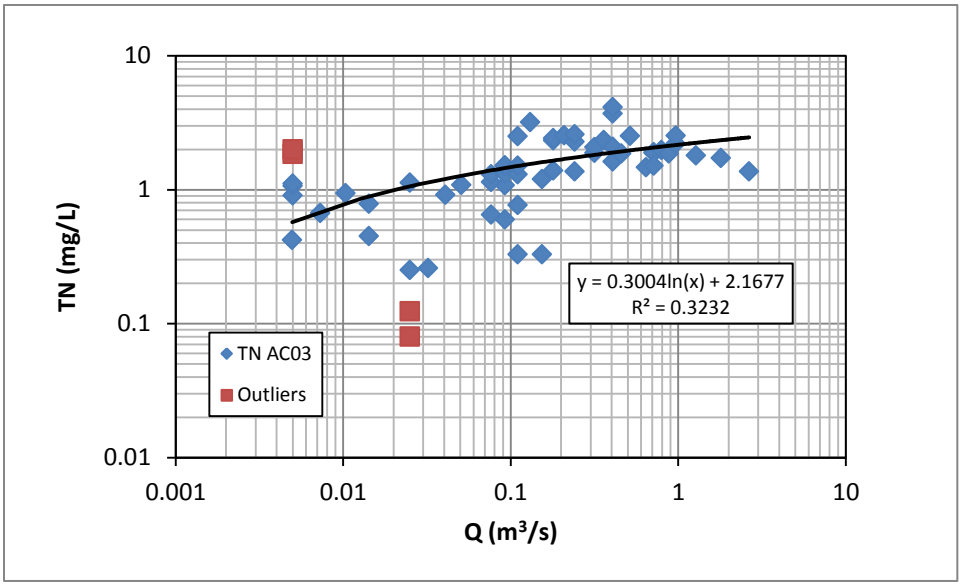

Figure 15. TN rating curve for AC03.

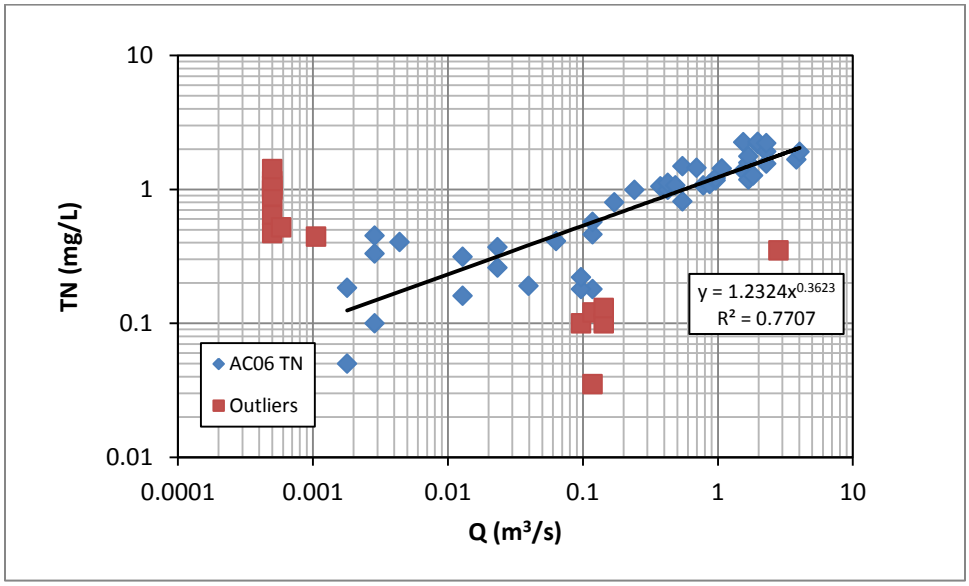

Figure 16. TN rating curve for AC06.

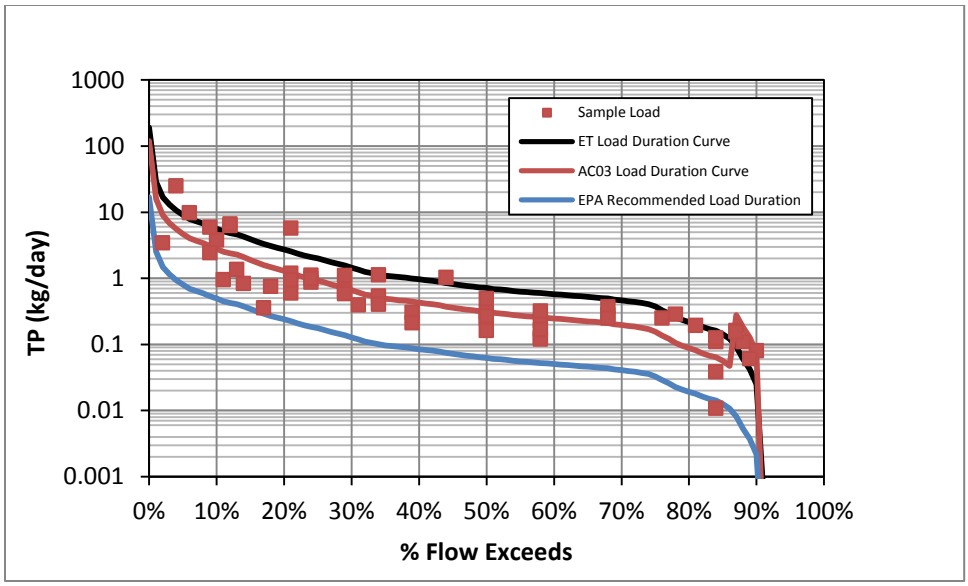

Figure 17. TP load duration curve for AC03.

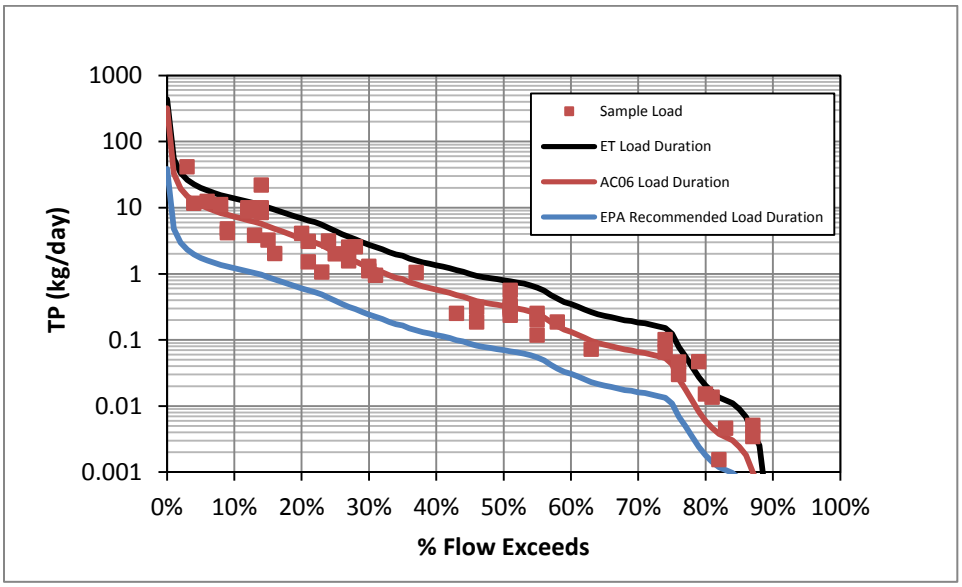

Figure 18. TP load duration curve for AC06.

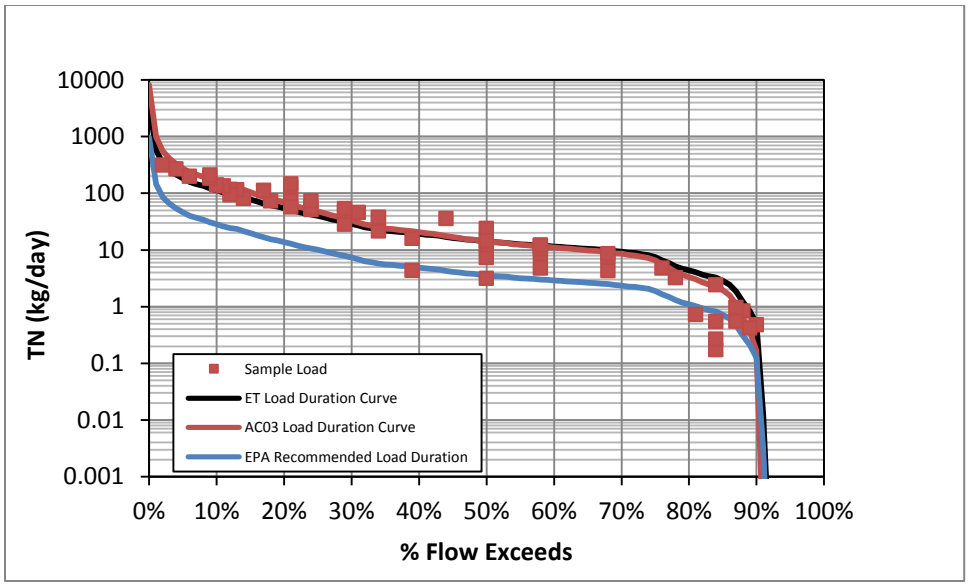

Figure 19. TN load duration curve for AC03

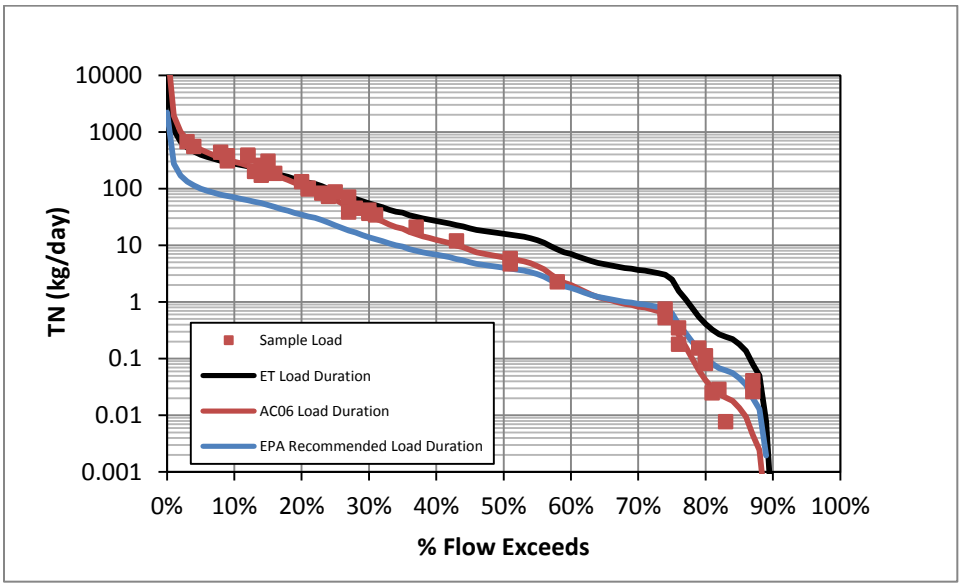

Figure 20. TN load duration curve for AC06.

PHOTOS

Photo 1. Site AC01 (10/31/13).

Photo 2. Site AC02 (10/31/13).

Photo 3. Site AC03 (10/31/13).

Photo 4. Site AC04 (10/31/13).

Photo 5. Site AC05 (10/31/13).

Photo 6. Site AC06 (10/31/13).

Photo 7. Levelogger installation at site AC03.

Photo 8. Discharge measurement at site AC06 using the FlowTracker

APPENDIX A – All Water Quality

Site	Date	Time	OB (mg/L)	Ecoli (MPN)	Total Coliform (MPN)
AC01	5/3/2012	1:14:00 PM	8.3	1,733	2,420
AC01	5/7/2012	12:55:00 PM	12.1	2,420	2,420
AC01	5/16/2012	12:54:00 PM	9.4	1,414	1,553
AC01	5/21/2012	11:20:00 AM	11.4	2,420	2,420
AC01	5/31/2012	9:10:00 AM	10.7	2,420	2,420
AC01	6/5/2012	10:32:00 AM	10.4	372	2,420
AC01	6/14/2012	9:56:00 AM	11.9	2,420	2,420
AC01	6/19/2012	10:20:00 AM	6.6	1,733	2,420
AC01	6/29/2012	8:50:00 AM	15.1	2,420	2,420
AC01	7/5/2012	11:05:00 AM	13.1	816	2,420
AC01	7/9/2012	7:47:00 AM	15.4	365	2,420
AC01	7/19/2012	9:14:00 AM	15.8	501	2,420
AC01	7/26/2012	11:15:00 AM	24.9	2,420	2,420
AC01	9/18/2012	11:45:00 AM	12.7	197	1,733
AC01	9/26/2012	10:45:00 AM	16.6	2,420	2,420
AC01	10/4/2012	12:30:00 PM	14.3	461	2,420
AC01	10/11/2012	1:00:00 PM	12.3	179	2,420
AC01	10/18/2012	2:10:00 PM	7.2	488	1,300
AC01	10/25/2012	10:20:00 AM	10.3	2,420	2,420
AC01	11/1/2012	12:15:00 PM	7.0	160	1,733
AC01	12/5/2012	10:50:00 AM	17.8		
AC01	12/20/2012			71.7	1,414
AC01	1/30/2013	11:00:00 AM	15.2	2,420	2,420
AC01	2/28/2013	11:15:00 AM	10.5	275.5	1,733
AC01	3/26/2013	11:45:00 AM	16.8	201.4	1,986
AC01	4/3/2013	12:50:00 PM	14.5	32.3	1,203
AC01	4/11/2013	12:45:00 PM	32.5	2,420	2,420
AC01	4/17/2013	12:15:00 PM	6.8	2,420	2,420
AC01	4/25/2013	12:00:00 PM	12.8	1,414	2,420
AC01	4/29/2013	11:00:00 AM	12.0	2,420	2,420
AC01	5/9/2013	1:25:00 PM	5.7	2,420	2,420
AC01	5/16/2013	11:05:00 AM	3.9	1,986	2,420
AC01	5/23/2013	10:50:00 AM	8.5	1,553	2,420
AC01	5/28/2013	1:55:00 PM	3.8	2,420	2,420
AC01	6/6/2013	2:00:00 PM	6.7	2,420	2,420
AC01	6/13/2013	12:35:00 PM	3.7	1,987	2,420
AC01	6/19/2013	1:30:00 PM	5.5	2,420	2,420
AC01	6/28/2013	8:50:00 AM	5.7	2,420	2,420
AC01	7/2/2013	12:45:00 PM	4.3	2,420	2,420
AC01	7/10/2013	12:41:00 PM	10.0	2,420	2,420
AC01	7/17/2013	12:20:00 PM	3.7	299	2,420
AC01	7/25/2013	12:10:00 PM	4.2	1,733	2,420
AC01	7/30/2013	2:10:00 PM	9.7	2,420	2,420
AC01	8/6/2013	1:20:00 PM	26.8	2,420	2,420
AC01	8/15/2013	12:00:00 PM	7.1	2,420	2,420
AC01	8/22/2013	1:21:00 PM	7.3	2,420	2,420
AC01	8/28/2013	1:10:00 PM	6.9	2,420	2,420
AC01	9/4/2013	12:45:00 PM	7.8	1,553	2,420
AC01	9/12/2013	11:05:00 AM	13.5	2,420	2,420
AC01	9/18/2013	1:10:00 PM	13.9	2,420	2,420
AC01	9/25/2013	12:15:00 PM	10.4	2,420	2,420
AC01	10/2/2013	12:50:00 PM	2.7	2,420	2,420
AC01	10/10/2013	1:35:00 PM	2.2	1,986	2,420
AC01	10/16/2013	1:00:00 PM	2.2	2,420	2,420
AC01	10/24/2013	12:40:00 PM	3.5	2,420	2,420
AC01	10/31/2013	12:40:00 PM	10.2	2,420	2,420

Site	Date	Time	OB (mg/L)	Ecoli (MPN)	Total Coliform (MPN)
AC02	5/3/2012	1:32:00 PM	6.5	291	2,420
AC02	5/7/2012	1:07:00 PM	4.5	82	548
AC02	5/16/2012	1:12:00 PM	3.7	99	2,420
AC02	5/21/2012	11:36:00 AM	3.1	40	1,300
AC02	5/31/2012	9:28:00 AM	2.0	2,420	2,420
AC02	6/5/2012	10:45:00 AM	3.3	75	2,420
AC02	6/14/2012	10:08:00 AM	3.5	613	2,420
AC02	6/19/2012	10:40:00 AM	0.3	210	2,420
AC02	6/29/2012	9:10:00 AM	0.3	649	2,420
AC02	7/5/2012	11:20:00 AM	0.3	128	2,420
AC02	7/9/2012	7:58:00 AM	0.3	155	2,420
AC02	7/19/2012	9:28:00 AM	0.1	139	2,420
AC02	7/26/2012	11:30:00 AM	0.1	770	2,420
AC02	8/2/2012	9:00:00 AM	0.3	29	517
AC02	8/8/2012	10:00:00 AM	0.3	7.3	326
AC02	8/17/2012	8:25:00 AM	15.0	240	2,420
AC02	8/23/2012	1:02:00 PM	0.1	27	770
AC02	8/27/2012	11:30:00 AM	0.1	1,046	2,420
AC02	9/7/2012	8:40:00 AM	0.1	87	1,414
AC02	9/14/2012	12:10:00 PM	5.3	649	2,420
AC02	9/18/2012	12:05:00 PM	3.9	980	2,420
AC02	9/26/2012	11:05:00 AM	10.5	1,413	2,420
AC02	10/4/2012	12:40:00 PM	9.6	214	2,420
AC02	10/11/2012	1:20:00 PM	8.8	1,046	2,420
AC02	10/18/2012	2:20:00 PM	2.7	387	1,414
AC02	10/25/2012	10:35:00 AM	4.4	64	2,420
AC02	11/1/2012	12:30:00 PM	3.5	37	2,420
AC02	12/5/2012	11:05:00 AM	7.6		
AC02	12/20/2012			88	1,414
AC02	1/30/2013	11:20:00 AM	4.5	124.6	2,420
AC02	2/28/2013	11:35:00 AM	7.2	101.9	1,733
AC02	3/26/2013	12:05:00 AM	13.3	238.2	1,203
AC02	4/3/2013	1:10:00 PM	11.2	38.9	517
AC02	4/11/2013	1:05:00 PM	25.6	2,420	2,420
AC02	4/17/2013	12:30:00 PM	4.6	65.0	1,120
AC02	4/25/2013	12:20:00 PM	7.7	150	2,419
AC02	4/29/2013	11:20:00 AM	14.0	921	2,420
AC02	5/9/2013	1:40:00 PM	4.1	517	2,420
AC02	5/16/2013	11:25:00 AM	3.2	192	727
AC02	5/23/2013	11:05:00 AM	4.8	39.3	1,733
AC02	5/28/2013	2:10:00 PM	2.5	326	2,420
AC02	6/6/2013	2:10:00 PM	4.4	649	2,420
AC02	6/13/2013	12:50:00 PM	2.8	109	2,420
AC02	6/19/2013	1:45:00 PM	5.5	1,046	2,420
AC02	6/28/2013	9:10:00 AM	3.0	157	2,420
AC02	7/2/2013	1:00:00 PM	2.4	2,420	2,420
AC02	7/10/2013	1:02:00 PM	1.4	727	2,420
AC02	7/17/2013	12:40:00 PM	1.4	299	2,420
AC02	7/25/2013	12:25:00 PM	1.3	1,733	2,420
AC02	7/30/2013	2:20:00 PM	2.7	461	2,420
AC02	8/6/2013	1:40:00 PM	13.0	2,420	2,420
AC02	8/15/2013	12:15:00 PM	6.5	546	2,420
AC02	8/22/2013	1:35:00 PM	6.1	88.4	1,203
AC02	8/28/2013	1:25:00 PM	5.1	29.2	1,986
AC02	9/4/2013	1:00:00 PM	4.3	40.2	2,420
AC02	9/12/2013	11:32:00 AM	5.0	410.6	2,420
AC02	9/18/2013	1:20:00 PM	5.2	248.9	2,420
AC02	9/25/2013	12:25:00 PM	5.8	365.4	2,420
AC02	10/2/2013	1:05:00 PM	0.8	275.5	2,420
AC02	10/10/2013	1:45:00 PM	1.2	1,120	2,420
AC02	10/16/2013	1:20:00 PM	1.0	194	2,420
AC02	10/24/2013	1:05:00 PM	1.9	291	2,420
AC02	10/31/2013	1:00:00 PM	7.6	2,420	2,420

Site	Date	Time	LL (m)	Q (m3/s)	TP (mg/L)	TN (mg/L)	OB (mg/L)	Ecoli (MPN)	Total Coliform (MPN)
AC03	5/3/2012	2:08:00 PM	0.26	0.24	0.053	1.37	8.7	411	2,420
AC03	5/7/2012	1:30:00 PM	0.24	0.18	0.035	1.39	7.9	75	1,553
AC03	5/16/2012	1:30:00 AM	0.20	0.09	0.040	1.50	5.9	210	2,420
AC03	5/21/2012	11:57:00 AM	0.19	0.08	0.038	1.30	6.8	816	1,120
AC03	5/31/2012	10:02:00 AM	0.19	0.08	0.056	1.14	5.8	1,986	2,420
AC03	6/5/2012	11:10:00 AM	0.17	0.05	0.057	1.09	8.7	223	2,420
AC03	6/14/2012	10:52:00 AM	0.16	0.04	0.082	0.92	9.1	1,203	2,420
AC03	6/19/2012	10:55:00 AM	0.14	0.02	0.058	1.13	3.4	1,553	2,420
AC03	6/29/2012	9:35:00 AM	0.12	0.01	0.126	0.79	6.1	1,553	2,420
AC03	7/5/2012	11:40:00 AM	0.10	0.01	0.096	0.67	7.7	1,733	2,420
AC03	7/9/2012	8:34:00 AM	0.11	0.01	0.123	0.94	11.4	1,414	2,420
AC03	7/19/2012	9:45:00 AM	0.01	0.00	0.186	1.11	9.3	48	2,420
AC03	7/26/2012	11:45:00 AM	0.00	0.00	0.355	1.85	15.0	16	2,420
AC03	8/2/2012	9:25:00 AM	0.00	0.00	0.780	2.00	17.0	7.1	2,420
AC03	8/17/2012	8:45:00 AM	0.01	0.00	0.166	1.07	14.0	548	2,420
AC03	8/27/2012	11:50:00 AM	0.01	0.00	0.186	0.91	13.1	21	2,420
AC03	9/7/2012	9:15:00 AM	0.09	0.00	0.111	0.42	8.3	52	2,420
AC03	9/14/2012	12:30:00 PM	0.12	0.01	0.132	0.45	10.5	1,046	2,420
AC03	9/18/2012	12:25:00 PM	0.15	0.03	0.070	0.26	9.0	199	1,986
AC03	9/26/2012	11:40:00 AM	0.14	0.02	0.051	0.25	12.9	1,300	2,420
AC03	10/4/2012	1:05:00 PM	0.14	0.02	0.018	0.12	12.0	272	2,420
AC03	10/11/2012	1:40:00 PM	0.14	0.02	0.005	0.08	10.8	1,553	2,420
AC03	10/18/2012	2:45:00 PM	0.20	0.09	0.016	0.60	6.8	365	1,120
AC03	10/25/2012	11:05:00 AM	0.21	0.11	0.052	0.77	8.8	727	2,420
AC03	11/1/2012	1:00:00 PM	0.19	0.08	0.043	0.65	6.1	2,420	2,420
AC03	12/5/2012	11:35:00 AM	0.21	0.11	0.026	0.33	10.7		
AC03	12/20/2012	11:30:00 AM	0.20	0.09				326	2,420
AC03	1/30/2013	11:50:00 AM	0.30	0.41	0.034	3.71	14.5	2,420	2,420
AC03	2/28/2013	12:10:00 PM	0.32	0.51	0.008	2.52	7.8	435	1,553
AC03	3/26/2013	12:35:00 PM	0.38	0.96	0.029	2.21	13.0	235.9	1,300
AC03	4/3/2013	1:45:00 PM	0.36	0.79	0.014	1.98	11.2	50.4	1,120
AC03	4/11/2013	1:40:00 PM	0.41	1.27	0.089	1.80	25.1	2,420	2,420
AC03	4/17/2013	1:10:00 PM	0.31	0.46	0.019	1.86	5.3	214	1,414
AC03	4/25/2013	12:45:00 PM	0.34	0.64	0.015	1.47	7.7	178.5	2,420
AC03	4/29/2013	11:50:00 AM	0.51	2.65	0.015	1.37	9.6	770	2,420
AC03	5/9/2013	2:10:00 PM	0.35	0.71	0.022	1.88	4.4	276	2,420
AC03	5/16/2013	11:50:00 AM	0.30	0.41	0.017	2.09	4.1	276	866
AC03	5/23/2013	11:30:00 AM	0.30	0.41	0.027	1.62	6.1	150	2,420
AC03	5/28/2013	2:35:00 PM	0.28	0.32	0.032	1.88	3.7	435	2,420
AC03	6/6/2013	2:40:00 PM	0.37	0.88	0.050	1.86	19.5	411	2,420
AC03	6/13/2013	1:20:00 PM	0.28	0.32	0.041	2.08	3.6	236	2,420
AC03	6/19/2013	2:10:00 PM	0.35	0.71	0.101	1.90	7.0	816	2,420
AC03	6/28/2013	9:25:00 AM	0.26	0.24	0.031	2.29	4.7	1,414	2,420
AC03	7/2/2013	1:30:00 PM	0.25	0.21	0.022	2.55	2.4	276	2,420
AC03	7/10/2013	1:34:00 PM	0.24	0.18	0.073	2.33	4.8	2,420	2,420
AC03	7/17/2013	1:05:00 PM	0.21	0.11	0.017	1.30	3.2	1,553	2,420
AC03	7/25/2013	12:45:00 PM	0.20	0.09	0.015	1.32	3.3	435	2,420
AC03	7/30/2013	2:45:00 PM	0.30	0.41	0.163	4.15	15.6	2,420	2,420
AC03	8/6/2013	1:55:00 PM	0.45	1.79	0.162	1.73	14.9	921	2,420
AC03	8/15/2013	12:35:00 PM	0.38	0.96	0.071	2.53	7.1	411	2,420
AC03	8/22/2013	2:05:00 PM	0.29	0.36	0.032	2.35	7.2	345	2,420
AC03	8/28/2013	1:40:00 PM	0.26	0.24	0.028	2.59	6.8	1,300	2,420
AC03	9/4/2013	1:30:00 PM	0.24	0.18	0.026	2.43	6.6	2,420	2,420
AC03	9/12/2013	12:05:00 PM	0.21	0.11	0.032	2.51	9.8	1,046	2,420
AC03	9/18/2013	1:50:00 PM	0.22	0.13	0.091	3.19	14.6	2,420	2,420
AC03	9/25/2013	12:45:00 PM	0.20	0.09	0.021	1.52	10.4	461	2,420
AC03	10/2/2013	1:40:00 PM	0.20	0.09	0.028	1.08	2.3	517	2,420
AC03	10/10/2013	2:05:00 PM	0.21	0.11	0.028	1.51	2.0	249	2,420
AC03	10/16/2013	1:40:00 PM	0.23	0.15	0.023	0.33	2.6	387	2,420
AC03	10/24/2013	1:30:00 PM	0.23	0.15	0.016	1.2	3.7	196	2,420
AC03	10/31/2013	1:30:00 PM	0.35	0.71	0.107	1.51	9.3	2,420	2,420

Site	Date	Time	OB (mg/L)	Ecoli (MPN)	Total Coliform (MPN)
AC04	5/3/2012	2:22:00 PM	9.0	210	2,420
AC04	5/7/2012	2:05:00 PM	9.1	23	2,420
AC04	5/16/2012	2:00:00 PM	6.6	42	2,420
AC04	5/21/2012	12:34:00 PM	7.2	162	1,733
AC04	5/31/2012	10:37:00 AM	4.6	435	2,420
AC04	6/5/2012	11:31:00 AM	7.7	37	2,420
AC04	6/14/2012	11:00:00 AM	8.2	29	2,420
AC04	6/19/2012	11:35:00 AM	2.3	64	2,420
AC04	6/29/2012	9:50:00 AM	17.0	93	2,420
AC04	9/14/2012	1:05:00 PM	34.7	2,420	2,420
AC04	10/18/2012	3:10:00 PM	6.2	236	1,046
AC04	10/25/2012	11:20:00 AM	7.3	64	2,420
AC04	11/1/2012	1:15:00 PM	5.4	7.5	2,420
AC04	12/5/2012	11:50:00 AM	9.6		
AC04	12/20/2012			13	365.4
AC04	1/30/2013	12:00:00 PM	13.8	2,420	2,420
AC04	2/28/2013	12:30:00 PM	7.8	53	687
AC04	3/26/2013	1:00:00 PM	13.4	50	488
AC04	4/3/2013	2:00:00 PM	11.2	34	866
AC04	4/11/2013	2:00:00 PM	24.4	2,420	2,420
AC04	4/17/2013	1:45:00 PM	5.8	67	2,420
AC04	4/25/2013	12:55:00 PM	7.8	146	1,553
AC04	4/29/2013	12:10:00 PM	9.2	435	2,420
AC04	5/9/2013	2:20:00 PM	4.7	192	2,420
AC04	5/16/2013	12:10:00 PM	4.7	187	649
AC04	5/23/2013	11:45:00 AM	6.2	166	2,420
AC04	5/28/2013	2:45:00 PM	4.1	161	1,986
AC04	6/6/2013	2:50:00 PM	5.4	236	2,420
AC04	6/13/2013	1:30:00 PM	4.2	135	2,420
AC04	6/19/2013	2:25:00 PM	7.0	461	2,420
AC04	6/28/2013	9:50:00 AM	5.2	517	2,420
AC04	7/2/2013	1:50:00 PM	4.3	120	2,420
AC04	7/10/2013	2:15:00 PM	4.1	2,420	2,420
AC04	7/17/2013	1:15:00 PM	3.4	76	2,420
AC04	7/25/2013	1:20:00 PM	16.3	48	2,420
AC04	7/30/2013	3:10:00 PM	11.6	2,420	2,420
AC04	8/6/2013	2:10:00 PM	11.6	727	2,420
AC04	8/15/2013	12:50:00 PM	7.2	228	2,420
AC04	8/22/2013	2:15:00 PM	8.1	152	2,420
AC04	8/28/2013	2:05:00 PM	7.6	365	2,420
AC04	9/4/2013	1:45:00 PM	7.4	99	2,420
AC04	9/12/2013	12:35:00 PM	11.4	122	2,420
AC04	9/18/2013	2:10:00 PM	12.2	461	2,420
AC04	9/25/2013	1:00:00 PM	11.3	130	2,420
AC04	10/2/2013	1:55:00 PM	2.5	199	2,420
AC04	10/10/2013	2:25:00 PM	2.4	345	2,420
AC04	10/16/2013	1:50:00 PM	2.6	111	2,420
AC04	10/24/2013	1:40:00 PM	4.1	40	2,420
AC04	10/31/2013	1:40:00 PM	9.4	2,420	2,420

Site	Date	Time	OB (mg/L)	Ecoli (MPN)	Total Coliform (MPN)
WG5	5/3/2012	2:34:00 PM	9.4	1,553	2,420
WG5	5/7/2012	2:19:00 PM	19.1	2,420	2,420
WG5	5/16/2012	2:11:00 PM	8.2	517	2,420
WG5	5/21/2012	12:46:00 PM	9.2	579	1,733
WG5	5/31/2012	10:50:00 AM	6.6	2,420	2,420
WG5	6/5/2012	11:42:00 AM	10.1	84.9	2,420
WG5	6/14/2012	11:20:00 AM	9.5	1,120	2,420
WG5	6/19/2012	11:44:00 AM	5.6	727	2,420
WG5	6/29/2012	10:05:00 AM	3.2	190	2,420
WG5	7/5/2012	12:15:00 PM	3.8	10.8	2,420
WG5	7/9/2012	8:59:00 AM	5.2	2,420	2,420
WG5	7/19/2012	10:12:00 AM	4.9	2,420	2,420
WG5	7/26/2012	12:15:00 PM	8.3	1,553	2,420
WG5	8/2/2012	10:10:00 AM	5.8	2,420	2,420
WG5	8/8/2012	10:40:00 AM	7.5	7.1	2,420
WG5	9/14/2012	1:20:00 PM	14.8	7.0	2,420
WG5	9/18/2012	1:00:00 PM	15.2	2,420	2,420
WG5	9/26/2012	12:25:00 PM	17.4	1,414	2,420
WG5	10/4/2012	1:25:00 PM	14.9	549	2,420
WG5	10/11/2012	2:05:00 PM	12.4	1,300	2,420
WG5	10/18/2012	3:25:00 PM	7.6	816	2,420
WG5	10/25/2012	11:35:00 AM	8.2	326	2,420
WG5	11/1/2012	1:30:00 PM	5.9	125	2,420
WG5	12/5/2012	12:00:00 PM	13.0		
WG5	12/20/2012			140	1,120
WG5	1/30/2013	12:15:00 PM	17.4	2,420	2,420
WG5	2/28/2013	12:30:00 PM	9.6	248	687
WG5	3/26/2013	1:20:00 PM	11.5	228	1,046
WG5	4/3/2013	2:15:00 PM	11.0	130	866
WG5	4/11/2013	2:15:00 PM	16.7	2,420	2,420
WG5	4/17/2013	1:55:00 PM	6.0	291	2,420
WG5	4/25/2013	1:05:00 PM	6.2	517	2,420
WG5	4/29/2013	12:25:00 PM	7.3	365	2,420
WG5	5/9/2013	2:35:00 PM	4.8	1,203	2,420
WG5	5/16/2013	12:20:00 PM	5.1	1,203	2,420
WG5	5/23/2013	11:55:00 AM	5.4	770	2,420
WG5	5/28/2013	3:00:00 PM	5.0	2,420	2,420
WG5	6/6/2013	3:00:00 PM	6.1	2,420	2,420
WG5	6/13/2013	1:45:00 PM	4.8	2,420	2,420
WG5	6/19/2013	2:35:00 PM	6.6	649	2,420
WG5	6/28/2013	10:00:00 AM	7.7	2,420	2,420
WG5	7/2/2013	2:00:00 PM	5.8	411	2,420
WG5	7/10/2013	2:25:00 PM	20.4	2,420	2,420
WG5	7/17/2013	1:30:00 PM	4.6	2,420	980
WG5	7/25/2013	1:30:00 PM	5.1	172	2,420
WG5	7/30/2013	3:10:00 PM	19.6	2,420	2,420
WG5	8/6/2013	2:30:00 PM	12.0	2,420	2,420
WG5	8/15/2013	1:00:00 PM	5.8	313	2,420
WG5	8/22/2013	2:25:00 PM	9.7	548	2,420
WG5	8/28/2013	2:20:00 PM	10.2	435	2,420
WG5	9/4/2013	1:55:00 PM	9.5	345	2,420
WG5	9/12/2013	12:50:00 PM	13.1	276	2,420
WG5	9/18/2013	2:20:00 PM	13.1	830	2,420
WG5	9/25/2013	1:10:00 PM	12.7	613	2,420
WG5	10/2/2013	2:05:00 PM	2.5	649	2,420
WG5	10/10/2013	2:35:00 PM	2.3	108	2,420
WG5	10/16/2013	2:00:00 PM	2.7	365	2,420
WG5	10/24/2013	1:55:00 PM	3.9	29.2	1,986
WG5	10/31/2013	1:55:00 PM	11.8	2,420	2,420

Site	Date	Time	LL (m)	Q (m3/s)	TP (mg/L)	TN (mg/L)	OB (mg/L)	Ecoli (MPN)	Total Coliform (MPN)
AC06	5/3/2012	2:56:00 PM	0.36	0.78	0.046	1.07	9.4	488	2,420
AC06	5/7/2012	2:37:00 PM	0.32	0.48	0.061	1.07	8.8	8.1	2,420
AC06	5/21/2012	1:01:00 PM	0.20	0.06	0.034	0.41	6.6	66	2,420
AC06	5/31/2012	11:20:00 AM	0.16	0.02	0.050	0.37	3.5	344	2,420
AC06	6/5/2012	12:07:00 PM	0.16	0.02	0.032	0.26	6.3	16	2,420
AC06	6/14/2012	11:45:00 AM	0.14	0.01	0.041	0.31	5.9	15	2,420
AC06	6/19/2012	12:10:00 PM	0.11	0.00	0.124	0.40	0.5	219	2,420
AC06	6/29/2012	10:40:00 AM	0.10	0.00	0.055	0.33	1.8	2,420	2,420
AC06	7/5/2012	12:55:00 PM	0.08	0.00	0.056	0.44	2.8	980	2,420
AC06	7/9/2012	9:20:00 AM	0.07	0.00	0.069	0.52	5.0	130	2,420
AC06	7/19/2012	10:38:00 AM	0.03	0.00	0.136	0.98	4.3	0.5	2,420
AC06	7/26/2012	12:30:00 PM	0.04	0.00	0.115	1.16	3.3	1.0	2,420
AC06	8/2/2012	10:30:00 AM	0.04	0.00	0.057	1.42	0.6	1.0	2,420
AC06	8/8/2012	10:55:00 AM	0.03	0.00	0.087	1.00	2.9	1.0	2,420
AC06	8/17/2012	9:35:00 AM	0.03	0.00	0.148	1.07	0.1	12.5	2,420
AC06	8/27/2012	12:35:00 PM	0.04	0.00	0.047	0.47	3.2	8.4	2,420
AC06	9/7/2012	9:55:00 AM	0.03	0.00	0.089	0.89	3	0.5	2,420
AC06	9/14/2012	1:45:00 PM	0.03	0.00	0.049	0.64	9.1	2,420	2,420
AC06	9/18/2012	1:25:00 PM	0.10	0.00	0.061	0.45	7.4	6.3	1,733
AC06	9/26/2012	12:25:00 PM	0.09	0.00	0.030	0.05	11.2	87	2,420
AC06	10/4/2012	1:45:00 PM	0.09	0.00	0.010	0.18	10.8	43	2,420
AC06	10/11/2012	2:15:00 PM	0.10	0.00	0.003	0.10	9.4	12	435
AC06	10/18/2012	3:40:00 PM	0.14	0.01	0.027	0.16	5.0	866	1,733
AC06	10/25/2012	12:00:00 PM	0.22	0.10	0.024	0.22	5.6	285	2,420
AC06	11/1/2012	1:45:00 PM	0.18	0.04	0.021	0.19	4.1	16.9	1,414
AC06	12/5/2012	12:20:00 PM	0.22	0.10	0.014	0.10	8.8		
AC06	12/20/2013	12:00:00 PM	0.18	0.04				24.6	517
AC06	1/30/2013	12:30:00 PM	0.46	1.98	0.058	2.26	16.8	2,420	2,420
AC06	2/28/2013	1:05:00 PM	0.43	1.55	0.015	2.25	8.8	119	921
AC06	3/26/2013	1:40:00 PM	0.48	2.29	0.021	2.21	12.9	21.3	866
AC06	4/3/2013	2:35:00 PM	0.48	2.29	0.024	1.92	11.3	13.4	517
AC06	4/11/2013	2:35:00 PM	0.51	2.82	0.051	0.35	21.8	2,420	2,420
AC06	4/17/2013	2:20:00 PM	0.38	0.97	0.018	1.21	5.9	66.9	2,420
AC06	4/25/2013	1:30:00 PM	0.45	1.83	0.024	1.27	7.1	88.0	1,046
AC06	4/29/2013	12:40:00 PM	0.56	3.82	0.035	1.67	14.6	345	2,420
AC06	5/9/2013	2:40:00 PM	0.43	1.55	0.024	1.38	4.4	152	2,420
AC06	5/16/2013	12:35:00 PM	0.37	0.87	0.014	1.09	4.5	137	1,986
AC06	5/23/2013	12:15:00 PM	0.38	0.97	0.037	1.17	5.8	326	2,420
AC06	5/28/2013	3:15:00 PM	0.31	0.43	0.030	0.99	4.3	291	2,420
AC06	6/6/2013	3:20:00 PM	0.48	2.29	0.056	1.55	5.4	1,046	2,420
AC06	6/13/2013	2:05:00 PM	0.39	1.07	0.044	1.43	4.3	161	2,420
AC06	6/19/2013	3:00:00 PM	0.44	1.69	0.058	1.58	7.4	326	2,420
AC06	6/28/2013	10:20:00 AM	0.33	0.55	0.053	1.49	5.7	291	2,420
AC06	7/2/2013	2:25:00 PM	0.30	0.38	0.029	1.05	4.2	15.5	2,420
AC06	7/10/2013	2:45:00 PM	0.33	0.55	0.033	0.81	3.4	345	2,420
AC06	7/17/2013	1:50:00 PM	0.25	0.17	0.017	0.80	3.0	55.6	2,420
AC06	7/25/2013	2:00:00 PM	0.24	0.14	0.015	0.13	2.8	40.5	2,420
AC06	7/30/2013	3:45:00 PM	0.44	1.69	0.151	1.76	14.1	2,420	2,420
AC06	8/6/2013	2:50:00 PM	0.57	4.04	0.119	1.91	12.8	2,420	2,420
AC06	8/15/2013	1:25:00 PM	0.46	1.98	0.052	2.18	6.7	249	2,420
AC06	8/22/2013	2:50:00 PM	0.35	0.70	0.033	1.45	8.5	63.1	2,420
AC06	8/28/2013	2:30:00 PM	0.31	0.43	0.035	1.12	8.1	60.2	2,420
AC06	9/4/2013	2:20:00 PM	0.27	0.24	0.050	0.99	7.5	42.6	2,420
AC06	9/12/2013	1:10:00 PM	0.23	0.12	0.032	0.57	10.2	30.5	2,420
AC06	9/18/2013	2:40:00 PM	0.23	0.12	0.055	0.46	11.2	90.9	2,420
AC06	9/25/2013	1:30:00 PM	0.23	0.12	0.030	0.12	10.0	12.2	2,420
AC06	10/2/2013	2:30:00 PM	0.22	0.10	0.030	0.18	1.9	7.5	2,420
AC06	10/10/2013	2:55:00 PM	0.23	0.12	0.028	0.18	1.7	21.1	2,420
AC06	10/16/2013	2:20:00 PM	0.24	0.14	0.025	0.10	1.7	40.4	2,420
AC06	10/24/2013	2:25:00 PM	0.23	0.12	0.023	0.04	2.8	8.4	1,986
AC06	10/31/2013	2:20:00 PM	0.44	1.69	0.068	1.18	9.6	2,420	2,420

APPENDIX B – Flow Frequency Tables

AC03

% Exceed	Stage (m)	Q (m3/s)
100%	0.02	0.000
99%	0.03	0.000
98%	0.03	0.000
97%	0.03	0.000
96%	0.03	0.000
95%	0.03	0.000
94%	0.03	0.000
93%	0.03	0.000
92%	0.03	0.000
91%	0.04	0.000
90%	0.04	0.000
89%	0.04	0.000
88%	0.06	0.000
87%	0.07	0.001
86%	0.08	0.001
85%	0.09	0.001
84%	0.09	0.002
83%	0.09	0.002
82%	0.09	0.002
81%	0.10	0.003
80%	0.10	0.003
79%	0.11	0.004
78%	0.12	0.006
77%	0.13	0.009
76%	0.14	0.012
75%	0.15	0.019
74%	0.16	0.023
73%	0.16	0.025
72%	0.16	0.026
71%	0.17	0.028
70%	0.17	0.028
69%	0.17	0.030
68%	0.17	0.031
67%	0.17	0.032
66%	0.17	0.034
65%	0.18	0.036
64%	0.18	0.038
63%	0.18	0.041
62%	0.19	0.045
61%	0.19	0.049
60%	0.19	0.054
59%	0.20	0.058
58%	0.20	0.065
57%	0.21	0.074
56%	0.21	0.086
55%	0.22	0.095
54%	0.22	0.103
53%	0.23	0.109
52%	0.23	0.114
51%	0.23	0.118
50%	0.23	0.123
49%	0.23	0.128
48%	0.24	0.133
47%	0.24	0.138
46%	0.24	0.143
45%	0.24	0.154
44%	0.25	0.166
43%	0.25	0.175
42%	0.26	0.187
41%	0.26	0.198
40%	0.26	0.208
39%	0.26	0.219
38%	0.27	0.230
37%	0.27	0.246
36%	0.28	0.263

35%	0.28	0.289
34%	0.28	0.303
33%	0.29	0.328
32%	0.30	0.361
31%	0.30	0.390
30%	0.31	0.422
29%	0.32	0.461
28%	0.32	0.510
27%	0.33	0.556
26%	0.34	0.613
25%	0.35	0.682
24%	0.36	0.764
23%	0.37	0.853
22%	0.38	0.929
21%	0.38	0.989
20%	0.39	1.061
19%	0.40	1.137
18%	0.41	1.239
17%	0.41	1.334
16%	0.42	1.446
15%	0.43	1.563
14%	0.44	1.699
13%	0.45	1.798
12%	0.46	1.903
11%	0.46	2.022
10%	0.47	2.131
9%	0.48	2.260
8%	0.49	2.376
7%	0.50	2.564
6%	0.51	2.797
5%	0.52	3.061
4%	0.54	3.459
3%	0.57	4.060
2%	0.62	5.195
1%	0.73	8.433
0%	1.67	67.431

AC06

% Exceed	Stage (m)	Q (m3/s)
100%	0.00	0.000
99%	0.00	0.000
98%	0.00	0.000
97%	0.00	0.000
96%	0.00	0.000
95%	0.01	0.000
94%	0.01	0.000
93%	0.01	0.000
92%	0.01	0.000
91%	0.03	0.000
90%	0.08	0.004
89%	0.10	0.007
88%	0.11	0.009
87%	0.12	0.014
86%	0.13	0.019
85%	0.14	0.022
84%	0.14	0.025
83%	0.14	0.026
82%	0.15	0.028
81%	0.15	0.031
80%	0.15	0.034
79%	0.16	0.036
78%	0.16	0.040
77%	0.17	0.046
76%	0.17	0.051
75%	0.18	0.058
74%	0.18	0.063
73%	0.18	0.065
72%	0.18	0.068
71%	0.19	0.069
70%	0.19	0.072

69%	0.19	0.073
68%	0.19	0.076
67%	0.19	0.078
66%	0.19	0.079
65%	0.19	0.081
64%	0.19	0.082
63%	0.20	0.084
62%	0.20	0.086
61%	0.20	0.087
60%	0.20	0.089
59%	0.20	0.090
58%	0.20	0.092
57%	0.20	0.094
56%	0.20	0.096
55%	0.20	0.097
54%	0.20	0.099
53%	0.21	0.103
52%	0.21	0.104
51%	0.21	0.106
50%	0.21	0.110
49%	0.21	0.112
48%	0.21	0.116
47%	0.21	0.118
46%	0.22	0.122
45%	0.22	0.126
44%	0.22	0.131
43%	0.22	0.137
42%	0.23	0.142
41%	0.23	0.144
40%	0.23	0.149
39%	0.23	0.154
38%	0.23	0.158
37%	0.23	0.161
36%	0.24	0.166
35%	0.24	0.169
34%	0.24	0.177
33%	0.24	0.185
32%	0.25	0.194
31%	0.25	0.208
30%	0.26	0.224
29%	0.26	0.241
28%	0.26	0.254
27%	0.27	0.269
26%	0.27	0.288
25%	0.28	0.307
24%	0.28	0.324
23%	0.29	0.341
22%	0.29	0.363
21%	0.30	0.396
20%	0.30	0.421
19%	0.31	0.447
18%	0.31	0.474
17%	0.32	0.509
16%	0.33	0.551
15%	0.33	0.602
14%	0.34	0.656
13%	0.35	0.714
12%	0.35	0.744
11%	0.36	0.792
10%	0.37	0.867
9%	0.38	0.946
8%	0.39	1.041
7%	0.40	1.122
6%	0.41	1.218
5%	0.42	1.404
4%	0.44	1.650
3%	0.46	2.004
2%	0.51	2.594
1%	0.61	4.415
0%	1.15	29.6

APPENDIX C – Bacteria Results from August 6, 2013 Sample Event

MISSOURI STATE UNIVERSITY

Ozarks Environmental and Water Resources Institute

Tyler Smith
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To: Will Rhodes
Asher Cr

Laboratory Testing Results
***E* coli and Total Coliform (MPN/100 ml)**
Diluted [1:10]

Sample ID	Collection	Received	Analysis	Analyst	Total Coliform	*E*. coli	OEWRI SOP	QC Check	QA/QC Mng
(code)	(date)	(date)	(date)	(initials)	(MPN/100 ml)	(MPN/100 ml)	(code)	(date)	(initials)
AC01	8/6/2013	8/6/2013	8/7/2013	LLB	>24,196	14,136	4010R03 Ecoli IDEXX	8/7/2013	TS
AC02	8/6/2013	8/6/2013	8/7/2013	LLB	>24,196	4,611	4010R03 Ecoli IDEXX	8/7/2013	TS
AC03	8/6/2013	8/6/2013	8/7/2013	LLB	>24,196	1,112	4010R03 Ecoli IDEXX	8/7/2013	TS
AC04	8/6/2013	8/6/2013	8/7/2013	LLB	19,863	712	4010R03 Ecoli IDEXX	8/7/2013	TS
WG5	8/6/2013	8/6/2013	8/7/2013	LLB	19,863	2,382	4010R03 Ecoli IDEXX	8/7/2013	TS
AC06	8/6/2013	8/6/2013	8/7/2013	LLB	>24,196	7,270	4010R03 Ecoli IDEXX	8/7/2013	TS

Verification of Quality Control:

Tyler J. Smith — Signature — Date

Final check and approved for release by:

Dr. Robert T. Pavlowsky — Signature — Date