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

Wastewater Exfiltration Sources in Pearson Creek, Springfield, Missouri

FINAL REPORT

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SCOPE AND OBJECTIVES

Pearson Creek is located in east Springfield, Missouri and is on the state's 303(d) list of impaired waters for *E. Coli* bacteria contamination. Pearson Creek consistently exceeds Missouri Department of Natural Resources (MDNR) water quality standards for Whole Body Contact Recreation (WBCR) Class-A designation of 126 MPN/100 mL from both urban and rural nonpoint pollution sources (Richards and Johnson 2002, Owen and Pavlowsky 2014, MDNR 2014, MDNR 2016). It is known that leaking sanitary sewer infrastructure can release wastewater including bacteria, phosphorus, and nitrogen to surface waters and water quality surveys have been used successfully to pinpoint the locations of exfiltrating wastewater to streams during base flow conditions (Dove et al. 2013, Owen et al. 2017). To better understand the influence of exfiltrating wastewater on water quality trends in Pearson Creek and to identify areas within the sewer system that may need maintenance, the City of Springfield, Missouri contracted with the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University to use a water quality survey to locate potential points of exfiltration of sewage from leaking sewer lines. The purpose of this study is to quantify variations in wastewater-specific indicators at base flow along a 9.7 km segment of Pearson Creek beginning at the confluence with the James River going upstream to State Highway YY (Division St.).

The specific objectives of this assessment are to:

1. Perform a source risk assessment using GIS analysis of the segment to locate sewer line crossings, inflowing tributaries, local springs, faults and other geologic features, and permitted point discharges;
2. Collect field-based temperature (T), dissolved oxygen (DO), pH, and specific conductivity (SC) and water quality samples to be analyzed in the laboratory for total phosphorus (TP), total nitrogen (TN), chloride (CL), and *E. Coli* concentrations at equally spaced stream locations throughout the study reach; and
3. Make specific recommendations to the City of Springfield and its engineers regarding site prioritization based on results from this exfiltration risk assessment.

STUDY AREA

The Pearson Creek watershed (HUC-12 #110100020106) drains approximately 59.2 km^2 of the eastern portions of the City of Springfield and unincorporated Greene County flowing south to its confluence with the James River above Lake Springfield (Figure 1). The underlying geology of the watershed is Mississippian age limestone within which a karst landscape has formed where sinkholes, losing streams, and springs are common (Bullard et al. 2001). The study segment is 9.7 km long beginning at the confluence with the James River (river kilometer (R-km) 0.0) upstream to State Highway YY (Division St.) at R-km 9.7 (Figure 2). Land use of the watershed ranges from high-low density urban in the western half of watershed to residential, livestock grazing, and forage crop production outside the city limits to the east (Hutchison 2010). There is a United States Geological Survey (USGS) gaging station, Pearson Creek near Springfield (07050690), located at R-km 1.95 that has been in constituent operation since July 1999 and is used to account for hydrological variability during the study (Table 1).

METHODS

Source Risk Assessment & Infrastructure Identification

Prior to sampling, a source risk assessment was conducted to identify factors likely to contribute to exfiltration in this watershed such as: locations of sewer line crossings, tributaries, faults, and land use practices. This was accomplished by using geospatial data from online sources such as the USGS and Missouri Spatial Data Information Service (MSDIS). The City of Springfield provided the sewer infrastructure data required for this assessment.

Field Sampling

All sampling occurred during fair-weather, base flow conditions since *E.coli* transport and storm water derived *E. Coli* sources are more variable during higher flows. Field sampling protocols followed previously tested procedures used for source risk assessment sampling in the area (Owen et al. 2017). Field sampling occurred during Fall 2017. The primary sampling event was conducted on October 26th at 41 sites over intervals of 200 m along the 9.7 km long study segment. A follow-up sampling event was conducted on November 9th at 15 sites at 100-200 m intervals within selected reaches to verify and refine primary sampling results. Field workers walked upstream from site to site to ensure that sampling occurred in the undisturbed water column in the middle of the channel. Care was taken to insure that bottom sediment was not disturbed during measurement collection or sampling.

Field Measurements

In-stream field measurements of specific conductivity (SC), pH, dissolved oxygen (DO), and temperature (T) were collected using a YSI multiprobe environmental meter (Pro Plus Model; YSI, Inc. Yellow Springs, OH, USA) (OEWRI 2015). Instrument accuracy was maintained by using the auto-calibration procedure before each sampling day and by re-conditioning and manually calibrating each sensor prior to each sampling day. Two YSI meters were used for this project and side-by-side comparison before each sample collection day showed the difference between values was less than 7% for all parameters.

Water Sample Collection

Surface water grab samples were collected laboratory analysis of total phosphorus (TP), total nitrogen (TN), and chloride (Cl) using 500 mL polypropylene (Nalgene™) open-mouth bottles (OEWRI 2007). Additional surface water grab samples were collected in pre-sterilized 100 mL bottles and analyzed for *E.coli* bacteria (OEWRI 2013). Sample bottles were triple rinsed with ambient water prior to sampling and water was collected in the deepest part of the channel. Samples were collected by inverting the bottle to approximately 0.6 of the water depth from the surface and then turning up the opening to allow water to enter. Upon collection, samples were transported on ice and delivered to the laboratory using chain of custody procedures (OEWRI 2006). At the laboratory each 500 mL sample was split into two 250 mL samples. One 250 mL sample was preserved for nutrient analysis by adding 1 ml of concentrated sulfuric acid (H_2SO_4) to lower the pH below 2 standard units to stop all biological processes and preserve nutrient concentrations. The remaining 250 mL was used for Cl analysis and was not preserved. All samples were stored at ~ 4°C prior to further analysis.

Laboratory Analysis

Sample processing and analysis was performed at OEWRI's Water Quality Laboratory located on the campus of Missouri State University. Surface water grab samples were analyzed for TN and TP using a Genesys 10S UV-Vis Spectrophotometer using EPA standard method 365.2 and methods outlined by Crumpton et al. (1992) (OEWRI 2010a, OEWRI 2010b). Laboratory Cl was measured using an Accumet Excel XL25 Dual Channel pH/Ion Meter (OEWRI 2009). As determined by in-house QA/QC procedures, acceptable detection limits for these procedures are ≤ 0.1 mg/L TN, ≤ 0.005 mg/L TP, and 0.1 mg/L Cl^- with all accuracy and precision checks within the range of + or – 20%. Samples were analyzed for the presence of *E. Coli* using the IDEXX Colilert® and Quanti-Tray® method for detection and enumeration (OEWRI 2013). The detection limit of this method is 1 MPN/100 mL with accuracy of + or – 20%. IDEXX MPN Generator 3.2 software was used for confirming MPN of sample results, as well as calculation of 95% confidence intervals.

RESULTS AND DISCUSSION

Potential Source Assessment

The source assessment identified multiple potential exfiltration source locations along the Pearson Creek study segment including 9 sewer crossings, 12 tributaries, and a major fault system (Table 2, Figure 1). Mapped fault lines cross the stream at four locations between stations 1,200 m and 2,000 m. Sewer lines cross Pearson Creek at multiple points along the study segment but the main line is adjacent to the stream nearly the entire length of the study reach. The 12 tributaries entering the main channel are significant because sewers cross these streams upstream of the confluence with Pearson Creek. Additionally, the largest tributary (Jones Branch) enters the study segment at station 3,200 m. There are no permitted point source discharge locations in the watershed above the study segment.

Field Sampling Results

A total of 56 probe measurements and water samples were collected along the Pearson Creek study segment over two periods during this study. Discharge at the gage during both sampling periods did not vary over the day (Figures 5 and 6). Discharge on October 26th was about 7.0 ft^3/s and 4.5 ft^3/s on November 10th and are between the 50% and 90% flow exceedance discharge reported at the USGS gage. Also, during field sampling on October 26th Pearson Creek was dry between stations 3,600-5,400 m. Results and summary statistics for each sampling period can be seen in Tables 6 and 7 and downstream plots of the sampling results can be viewed in Figures 4 and 5. Complete records for each sample site and date, including location and water quality parameters and concentrations of nutrients are included in the Appendix.

Potential Source Locations

There were a total of nine potential source locations identified in the Pearson Creek study reach that are ranked into three priority classes based on pollution magnitude and type. Priority #1 represents the most critical areas to investigate due to the high magnitude *E. Coli* peaks identified at these locations. Priority #2 represent lower magnitude peaks of *E. Coli* that are elevated, but not to the magnitude of the Priority #1 locations. Finally, Priority #3 locations have elevated concentration of parameters other than *E. Coli*, but are contributing to nonpoint source pollution. A summary of locations identified in this study are outlined in Table 5.

Priority # 1

1. The highest and most significant peak detected during this study was at station 2,000 m at FR 148 (USGS gage). There are several potential sources of *E. Coli* contamination at FR 148 including multiple sewer line junctions, a fault line, and livestock access to the stream (Figure 1). Sample results suggest the highest *E. Coli* concentrations are from sewer exfiltration and more moderate sources from cattle access. The peak *E. Coli* concentration occurs near station 2,000 m at a known sewer crossing (Figure 5). However, downstream plots do show *E. Coli* concentrations start to increase upstream of station 2,000 m where cattle do have access to the stream suggesting there may be some influence from nonpoint agriculture sources. Follow-up sampling on Nov. 9th verified this trend.
2. The second highest peak detected during this study occurred at station 9,600 m, but there is no sewer mapped at that location (Figure 1 and 5). However, field workers noted what seemed to be something in the channel made of concrete at that location. Follow-up sampling on Nov. 9th that included further sampling upstream of State Highway YY showed that concentrations of *E. Coli* decreased upstream. These results suggests high concentrations are not due to the cattle operation upstream of State Highway YY. The karst connections at this location are unknown, but this spot may be linked to sewer exfiltration via an underground conduit originating from some other location.

Priority #2

3. There is a lower magnitude *E. Coli* peak associated with a sewer crossing at station 3,400 m located upstream of Catalpa Street. *E. Coli* concentrations increase from less than 20 MPN/100 mL at station 3,600 m to nearly 100 MPN/100 mL at station 3,400 m (Figures 1 and 5). This indicates possible sewer line exfiltration, but the bacteria concentration does not exceed the water quality criteria of 126 MPN/100 mL.
4. A lower magnitude *E. Coli* peak was found near the sewer crossing located at station 6,800 m upstream of Chestnut Street. *E. Coli* concentrations increase from less than 20 MPN/100 mL at station 7,000 m to nearly 100 MPN/100 mL at station 6,800 m (Figure 1 and 5). This may be caused by sewer line exfiltration, but *E. Coli* concentrations do not exceed the water quality criteria of 126 MPN/100 mL at this location.
5. A lower magnitude *E. Coli* peak was identified at the sewer crossing located at station 5,400 m at Cherry Street. *E. Coli* concentrations are about 100 MPN/100 mL at station 5,400 m (Figures 1 and 5). However, the peak gets progressively higher starting at station 6,000 m suggesting other sources of *E. Coli* may be contributing to the increase at this location too. Again, this indicates possible sewer line exfiltration, but the bacteria concentration does not exceed the water quality criteria of 126 MPN/100 mL.

Priority #3

6. The water chemistry of the water entering the main channel from Jones Branch at station 3,200 m is very different than the water from the upstream portion of the study. There are elevated levels of TN and CL, and lower levels of TP coming out of Jones Branch compared to the upstream sections (Figure 5). While *E. Coli* concentrations are low coming from Jones Spring Branch, the elevated levels of TN are at or above the James River total maximum daily load (TMDL) target of 1.5 mg/L (MDNR 2001).
7. Field sampling results downstream of the gaining section at station 3,600 m shows that the chemistry of the water coming back to the surface is different than the water upstream of the losing section at station 5,400 m. Both DO and pH are relatively lower below station 3,600 m than above station 5,400 m, and SC and TN are relatively higher (Figures 4 and 5). While it is likely the water moving underground in the upstream section is resurfacing below, there is definitely a change occurring either by chemical reactions within the karst system or mixing from other sources. Again, karst connections in this area are complicated and poorly understood.
8. There is a site with an elevated TP concentration located at station 7,200 m suggesting a potential nonpoint source pollution risk that is not associated with a sewer crossing (Figure 5).
9. There is another site with a peak TP concentration located at station 5,600 m that is not associated with a sewer crossing (Figure 5). Again, this nutrient increase may be an indication other nonpoint sources are influencing this location.

CONCLUSIONS

The purpose of this study was to monitor a 9.7 km reach of Pearson Creek and use water quality trends to locate points of potential exfiltration of sewage from leaking sewer lines so they could be repaired and ultimately improve water quality. A total of 56 probe measurements and water samples were collected and analyzed over two sampling dates in October-November 2017 for this study. The source assessment identified a total of 21 potential source locations along the Pearson Creek study segment including sewer crossings, a major fault, and several tributary confluences. A total of nine locations were identified for further action and were classified into three priority categories. Priority #1 and Priority #2 sites are potential sewer exfiltration sources while Priority #3 sites are likely from other nonpoint sources. Specific locations identified by this study are summarized here by priority class:

1. Priority #1 sites are located at stations 2,000 m and 9,600 m and have the highest *E. Coli* concentrations identified during the study and should be the first locations to be addressed. At station 2,000 m, there are several potential sources of *E. Coli* including multiple sewer crossings, a major fault system, and nonpoint agriculture. This site is particularly important since it is located near the USGS gaging station and has a history of very high bacteria concentrations that exceed water quality standards. However, results show that the problem is concentrated locally around station 2,000 m and is not widespread throughout the watershed at base flow. Therefore, addressing bacteria pollution at this site is critical for water quality improvement in the lower Pearson Creek watershed before it enters the James River immediately downstream. At site 9,600, there is a high concentration of *E. Coli,* but does not appear to be directly related to a sewer line. However, it may be connected sewer line exfiltration via an unknown karst conduit.

2. Priority #2 sites are located at 6,800 m, 3,400 m, and 5,400 m have lower magnitude peaks of *E. Coli* that are associated with sewer crossings. These sites are at sewer line crossing locations where *E. Coli* concentrations increased compared to samples collected upstream, but were below the 126 MPN/100 mL limit. These areas are places exfiltration may be occurring, but not to the magnitude of the Priority #1 areas.

3. Priority #3 sites located at 3,200 m, 7,200 m, and 5,600 m have peaks in nutrients and are not necessarily associated with sewer crossings. Jones Branch in particular changes the water quality of Pearson Creek dramatically by increasing the base flow TN concentrations to, or above, the TMDL target. While this is likely not due to sewer exfiltration, Jones Branch and the Jones Spring recharge area may need to be targeted for urban nonpoint source reduction implementation efforts in the future.

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TABLES

Table 1. Drainage area and discharge at USGS gaging station (R-km 1.95).

USGS Gage ID #	Description	Period of Record	Drainage Area	Annual Mean Discharge	10% Exceeds	50% Exceeds	90% Exceeds
07050690	Pearson Creek near Springfield, MO	July 21, 1999 to present	21 mi^2 (54.4 km^2)	27.7 ft^3/s (0.78 m^3/s)	58.3 ft^3/s (1.65 m^3/s)	12.1 ft^3/s (0.34 m^3/s)	3.6 ft^3/s (0.10 m^3/s)

Table 2. Locations of crossings and tributaries along the study reach.

Number	Station (m)	Source Type
	0	Confluence with James River
1	725	Sewer
2	1,200	Tributary
3	1,850	Sewer
4	1,950	Tributary
5	2,050	Sewer
6	2,760	Sewer
7	3,175	Jones Branch
8	3,250	Sewer
9	4,000	Tributary
10	4,600	Sewer
11	4,600	Tributary
12	5,280	Tributary
13	5,500	Tributary
14	6,150	Tributary
15	6,700	Sewer
16	6,800	Sewer
17	7,500	Tributary
18	8,120	Sewer
19	8,200	Tributary
20	9,000	Tributary
21	9,200	Tributary

Table 3. Summary statistics for October 26, 2017 sampling.

	Temp (°C)	**pH (std.)**	**SC (µS/cm)**	**DO (mg/L)**	**Cl (mg/L)**	**TN (mg/L)**	**TP (mg/L)**	***E. Coli* (MPN/100 mL)**
n	41	41	41	41	41	41	41	41
Min	11.1	7.3	457	2.8	19.1	0.88	0.019	14.6
Mean	12.9	7.7	485	9.3	21.5	1.49	0.031	144.1
Median	12.8	7.8	467	9.6	21.5	1.40	0.035	73.3
Max	15.6	8.0	524	10.9	24.4	2.00	0.054	686.7
Stdev	0.9	0.2	25.2	1.4	1.5	0.37	0.008	186.8
CV%	7.4	2.4	5.2	14.9	7.2	24.6	25.8	129.7

Table 4. Summary statistics for November 9, 2017 sampling

	Temp (°C)	**pH (std.)**	**SC (µS/cm)**	**DO (mg/L)**	**Cl (mg/L)**	**TN (mg/L)**	**TP (mg/L)**	***E. Coli* (MPN/100 mL)**
n	15	15	15	15	15	15	15	15
Min	7.0	7.0	469	8.4	24.5	1.24	0.020	17.5
Mean	9.4	7.5	499	10.3	29.2	1.44	0.023	159.6
Median	9.7	7.5	512	10.4	29.8	1.49	0.022	160.7
Max	11.2	7.7	533	11.5	35.2	1.65	0.034	435.2
Stdev	1.3	0.2	22.2	0.9	3.6	0.13	0.004	118.3
CV%	14.3	2.9	4.5	8.5	12.5	9.2	15.7	74.1

Table 5. Summary of potential exfiltration source points.

Source Rank	**Potential Sources**	**Location**	**Station (m)**	**Pollutants**
<u>Priority #1</u>				
1	sewer/nonpoint ag	@ FR 148 (old Sunshine St.)	2,000	*E. Coli*
2	unknown	below State Highway YY	9,600	*E. Coli*
<u>Priority #2</u>				
3	sewer	upstream of FR 132 (Chestnut St.)	6,800	*E. Coli*
4	sewer	@ FR 144 (Catalpa St.)	3,400	*E. Coli*
5	sewer	@ FR 136 (Cherry St.)	5,400	*E. Coli*
<u>Priority #3</u>				
6	nonpoint urban	@ Jones Branch confluence	3,200	Chloride and Nitrogen
7	unknown	upstream of FR 132 (Chestnut St.)	7,200	Phosphorus
8	unknown	upstream of FR 136 (Cherry St.)	5,600	Phosphorus

FIGURES

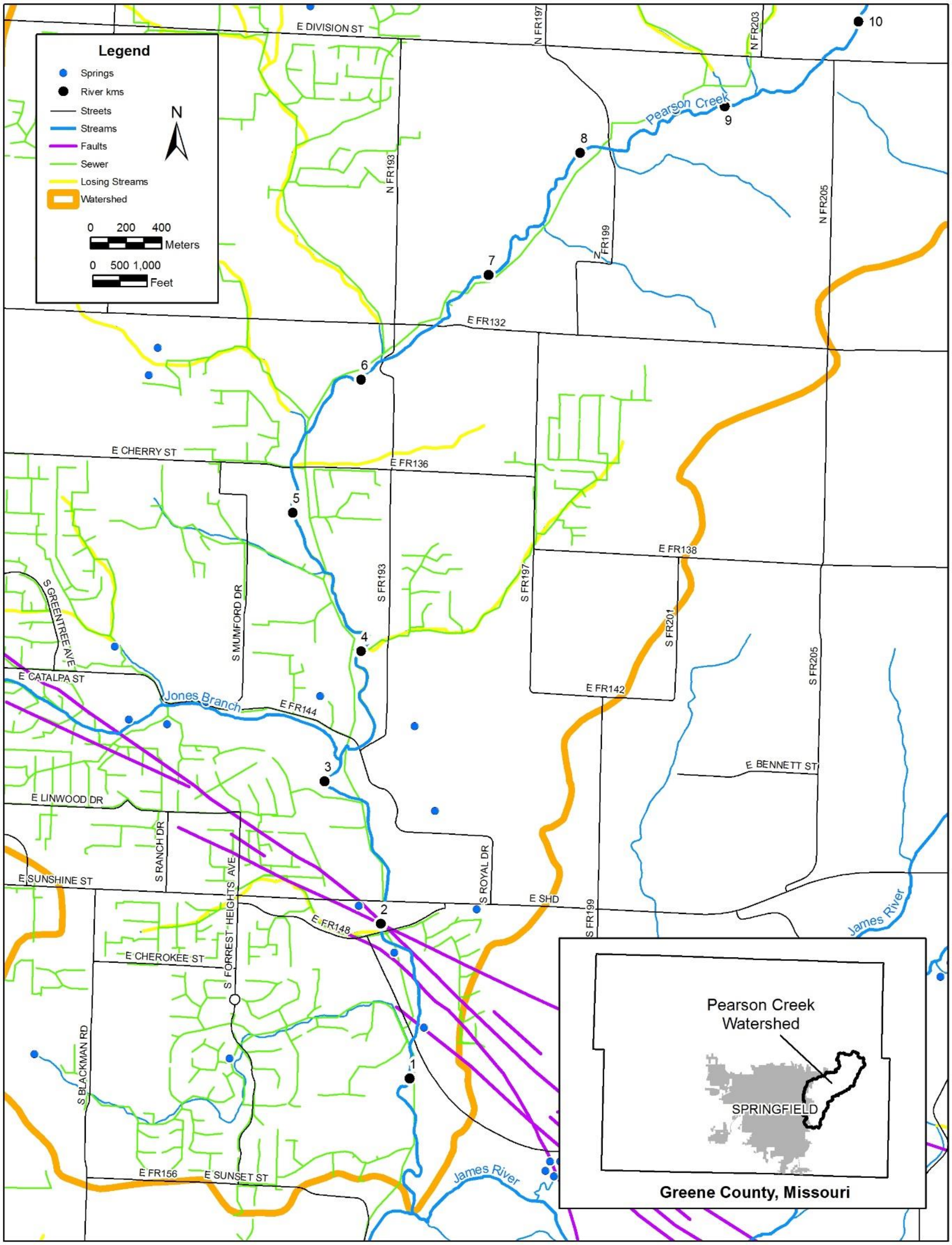

Figure 1. Wilson Creek location within the James River Basin.

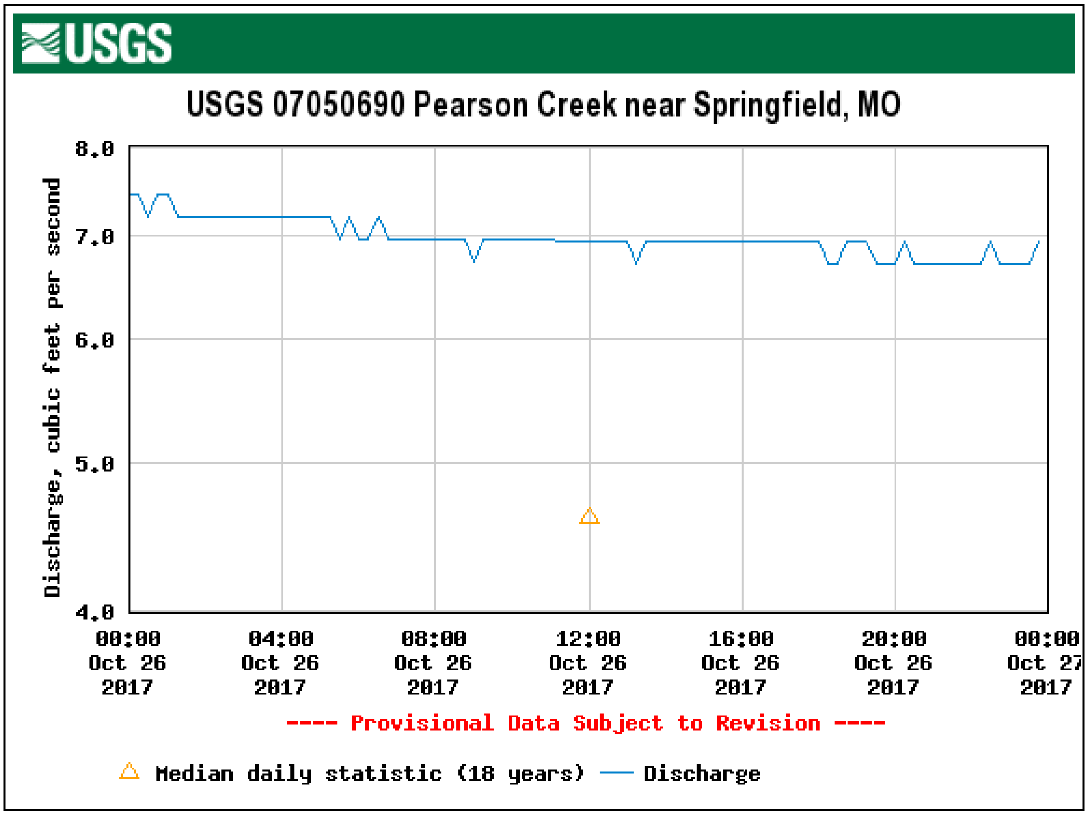

Figure 2. Discharge and gage height on October 26, 2017.

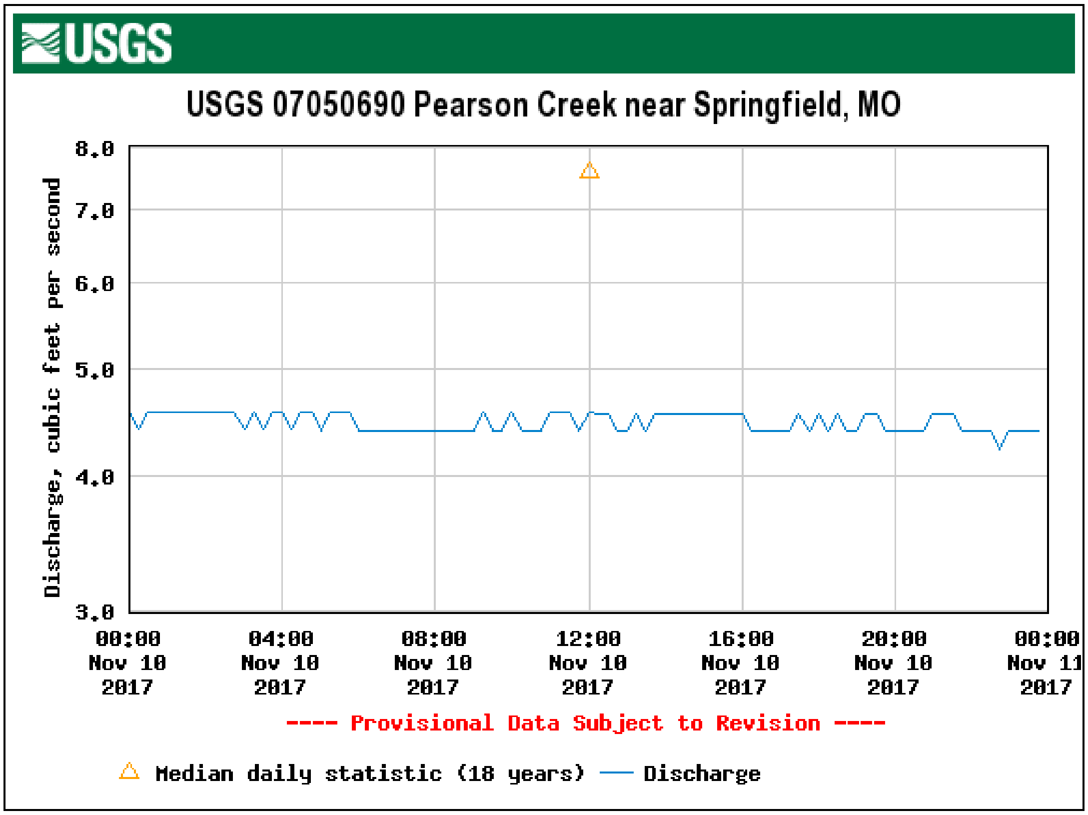

Figure 3. Discharge and gage height for November 10, 2017.

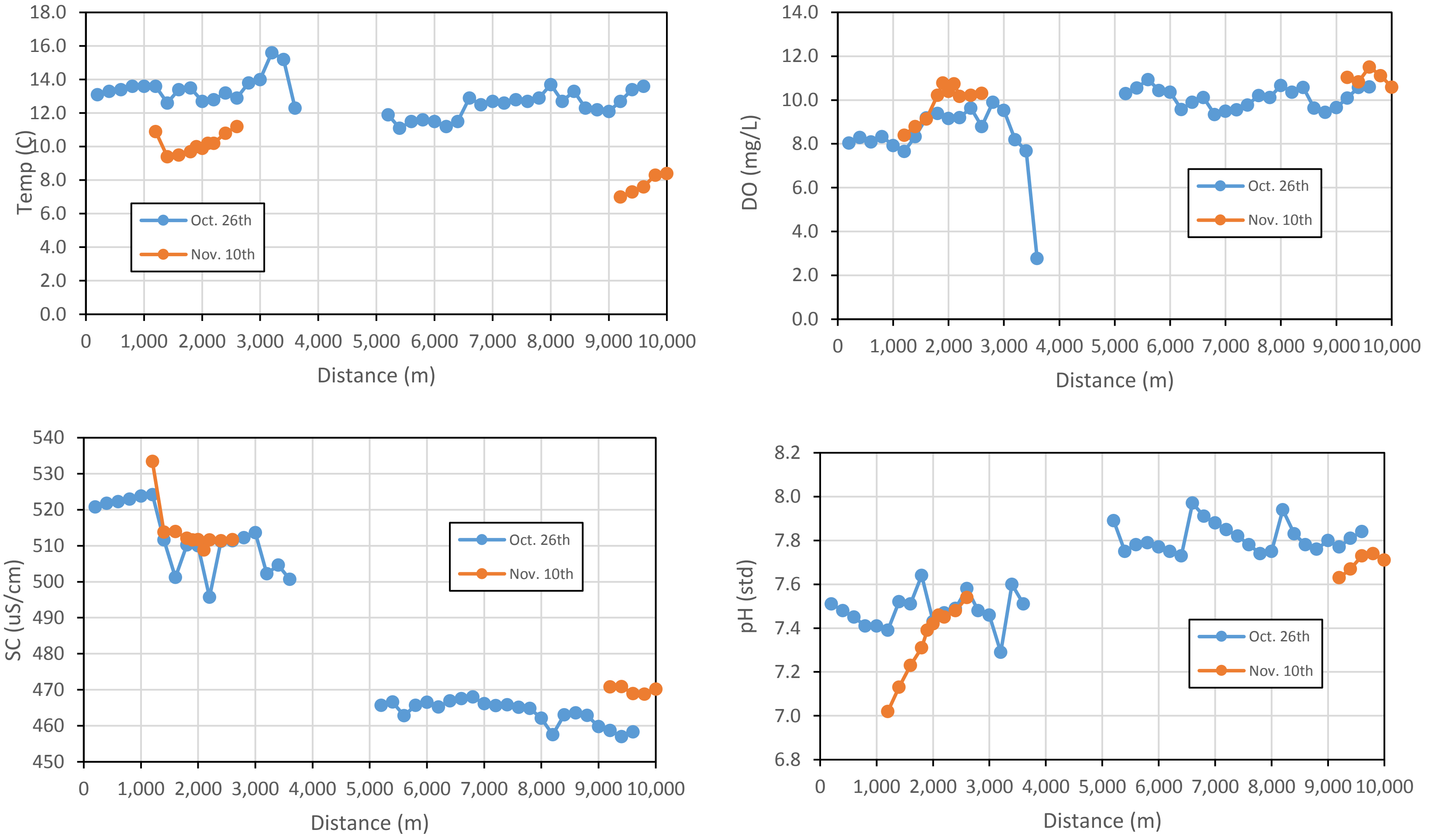

Figure 4. Downstream water parameter trends.

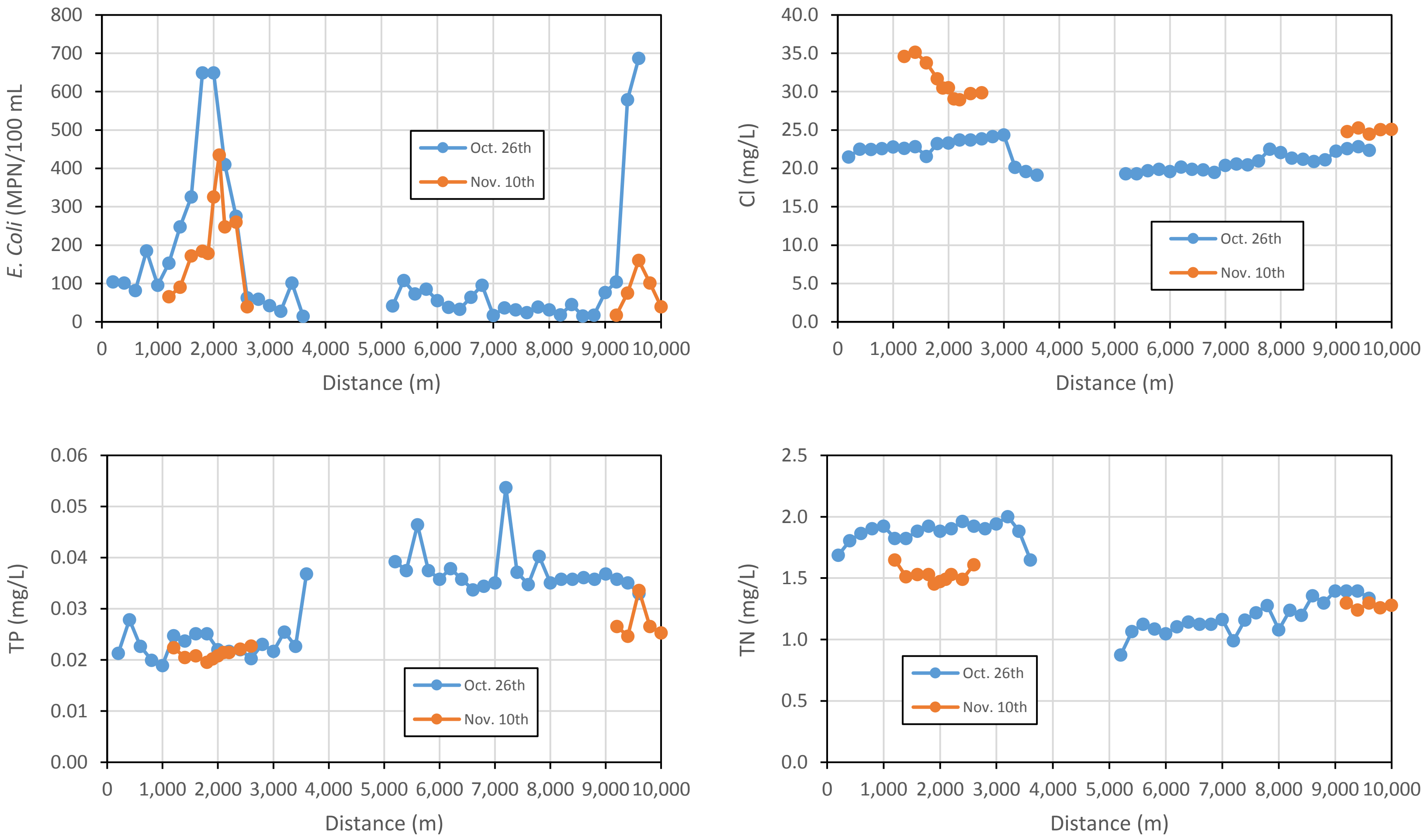

Figure 5. Downstream bacteria, chloride, and nutrient trends

APPENDIX All Water Quality Results

Sample ID	Site ID	UTM Zone 15N Northing m	UTM Zone 15N East m	Date	Time	Temp C	DO mg/L	SPC uS/cm	pH	Total Coliform MPN/100mL	Ecoli MPN/100mL	Cl mg/L	TP mg/L	TN mg/L
1	200	4,113,216.930	482,515.138	10/26/2017	9:53	13.1	8.0	521	7.5	>2419.6	104.3	21.5	0.021	1.69
2	400	4,113,295.358	482,612.465	10/26/2017	10:09	13.3	8.3	522	7.5	>2419.6	101.4	22.5	0.028	1.81
3	600	4,113,487.896	482,576.320	10/26/2017	10:22	13.4	8.1	522	7.5	>2419.6	82.0	22.5	0.023	1.86
4	800	4,113,670.701	482,528.539	10/26/2017	10:35	13.6	8.3	523	7.4	>2419.6	185.0	22.6	0.020	1.90
5	1,000	4,113,808.574	482,544.052	10/26/2017	10:42	13.6	7.9	524	7.4	>2419.6	95.9	22.8	0.019	1.92
6	1,200	4,114,003.342	482,546.964	10/26/2017	10:50	13.6	7.7	524	7.4	>2419.6	152.9	22.6	0.025	1.82
7	1,400	4,114,190.569	482,600.040	10/26/2017	10:59	12.6	8.3	512	7.5	>2419.6	248.1	22.8	0.024	1.82
8	1,600	4,114,385.237	482,568.336	10/26/2017	11:09	12.9	8.8	511	7.6	1,986.3	325.5	21.6	0.025	1.88
9	1,800	4,114,546.143	482,493.232	10/26/2017	11:20	13.5	9.4	510	7.6	>2419.6	648.8	23.3	0.025	1.92
10	2,000	4,114,679.540	482,377.016	10/26/2017	9:41	12.7	9.2	510	7.4	>2419.6	648.8	23.3	0.022	1.88
11	2,200	4,114,875.810	482,411.339	10/26/2017	9:54	12.8	9.2	496	7.5	>2419.6	410.6	23.7	0.022	1.90
12	2,400	4,115,056.967	482,364.232	10/26/2017	10:06	13.2	9.6	511	7.5	>2419.6	275.5	23.7	0.022	1.96
13	2,600	4,115,239.469	482,302.883	10/26/2017	10:18	13.4	9.2	501	7.5	1,986.3	62.7	23.9	0.020	1.92
14	2,800	4,115,386.826	482,222.010	10/26/2017	10:32	13.8	9.9	512	7.5	1,987.3	59.1	24.1	0.023	1.90
15	3,000	4,115,479.418	482,054.726	10/26/2017	10:42	14.0	9.5	514	7.5	>2419.6	42.6	24.4	0.022	1.94
16	3,200	4,115,634.514	482,150.627	10/26/2017	10:55	15.6	8.2	502	7.3	1,732.9	27.9	20.1	0.025	2.00
17	3,400	4,115,707.401	482,300.884	10/26/2017	11:56	15.2	7.7	505	7.6	1,986.3	101.4	19.6	0.023	1.88
18	3,600	4,115,887.571	482,293.929	10/26/2017	12:03	12.3	2.8	501	7.5	1,553.1	14.6	19.1	0.037	1.65
19	5,200	4,117,182.503	481,876.238	10/26/2017	12:44	11.9	10.3	466	7.9	228.2	41.4	19.3	0.039	0.88
20	5,400	4,117,365.822	481,903.819	10/26/2017	11:19	11.1	10.6	467	7.8	517.2	108.1	19.3	0.038	1.07
21	5,600	4,117,533.298	482,001.475	10/26/2017	11:29	11.5	10.9	463	7.8	686.7	73.3	19.7	0.046	1.12
22	5,800	4,117,706.971	482,092.619	10/26/2017	11:47	11.6	10.4	466	7.8	579.4	85.5	19.9	0.038	1.09
23	6,000	4,117,745.876	482,249.741	10/26/2017	11:58	11.5	10.4	467	7.8	579.4	55.6	19.6	0.036	1.05
24	6,200	4,117,864.970	482,402.635	10/26/2017	12:09	11.2	9.6	465	7.8	547.5	37.9	20.2	0.038	1.11
25	6,400	4,117,984.097	482,558.687	10/26/2017	12:18	11.5	9.9	467	7.7	648.8	33.1	19.9	0.036	1.14
26	6,600	4,118,093.389	482,722.656	10/26/2017	13:30	12.9	10.1	468	8.0	613.1	64.4	19.8	0.034	1.12
27	6,800	4,118,231.173	482,816.363	10/26/2017	13:39	12.5	9.4	468	7.9	547.5	95.9	19.5	0.034	1.12

Sample ID	Site ID	UTM Zone 15N Northing m	UTM Zone 15N East m	Date	Time	Temp C	DO mg/L	SPC uS/cm	pH	Total Coliform MPN/100mL	Ecoli MPN/100mL	Cl mg/L	TP mg/L	TN mg/L
28	7,000	4,118,339.629	482,965.347	10/26/2017	13:49	12.7	9.5	466	7.9	721.5	17.1	20.4	0.035	1.16
29	7,200	4,118,479.035	483,086.593	10/26/2017	13:58	12.6	9.6	466	7.9	1,119.9	36.8	20.6	0.054	0.99
30	7,400	4,118,585.941	483,182.380	10/26/2017	14:06	12.8	9.8	466	7.8	1,732.9	31.3	20.5	0.037	1.16
31	7,600	4,118,716.038	483,299.338	10/26/2017	14:15	12.7	10.2	465	7.8	1,299.7	24.3	21.0	0.035	1.22
32	7,800	4,118,884.973	483,361.661	10/26/2017	14:24	12.9	10.1	465	7.7	1,299.7	38.4	22.5	0.040	1.28
33	8,000	4,119,032.203	483,479.353	10/26/2017	14:33	13.7	10.7	462	7.8	1,732.9	31.5	22.1	0.035	1.08
34	8,200	4,119,048.339	483,669.085	10/26/2017	13:09	12.7	10.4	458	7.9	1,119.9	18.7	21.4	0.036	1.24
35	8,400	4,119,147.347	483,800.844	10/26/2017	13:34	13.3	10.6	463	7.8	1,553.1	45.0	21.2	0.036	1.20
36	8,600	4,119,214.848	483,941.932	10/26/2017	13:46	12.3	9.6	464	7.8	727.0	15.8	20.9	0.036	1.36
37	8,800	4,119,254.033	484,108.892	10/26/2017	13:54	12.2	9.4	463	7.8	2,419.6	17.5	21.1	0.036	1.30
38	9,000	4,119,299.109	484,292.259	10/26/2017	14:01	12.1	9.7	460	7.8	1,046.2	76.7	22.3	0.037	1.40
39	9,200	4,119,360.978	484,468.212	10/26/2017	14:08	12.7	10.1	459	7.8	1,553.1	104.6	22.6	0.036	1.40
40	9,400	4,119,380.492	484,649.839	10/26/2017	14:16	13.4	10.6	457	7.8	>2419.6	579.4	22.9	0.035	1.40
41	9,600	4,119,511.555	484,792.379	10/26/2017	14:22	13.6	10.6	458	7.8	>2419.6	686.7	22.4	0.033	1.34
42	400 DUP	4,119,625.016	484,943.300	10/26/2017	10:12	13.3	8.3	522	7.5	>2419.6	107.1	22.7	0.022	1.84
43	2,200 DUP	4,114,875.810	482,411.339	10/26/2017	9:54	12.8	9.2	496	7.5	>2419.6	410.6	23.6	0.022	2.04
44	3,600 DUP	4,115,887.571	482,293.929	10/26/2017	12:03	12.6	3.1	499	7.5	>2419.6	25.0	19.1	0.042	1.65
45	5,600 DUP	4,117,533.298	482,001.475	10/26/2017	11:29	11.5	10.9	463	7.8	1,203.3	72.3	19.5	0.041	1.12
46	6,800 DUP	4,118,231.173	482,816.363	10/26/2017	13:41	12.5	9.1	468	7.9	980.2	90.6	20.2	0.036	1.11
47	8,400 DUP	4,119,147.347	483,800.844	10/26/2017	13:34	13.3	10.6	463	7.8	1,413.6	45.0	20.8	0.035	1.26
48	Blank 1	NA	NA	10/26/2017	14:30	NA	NA	NA	NA	<1.0	<1.0	0.3	0.000	0.06
49	1,200	4,114,003.342	482,546.964	11/10/2017	9:12	10.9	8.4	533.4	7.0	1299.7	65.7	34.6	0.022	1.65
50	1,400	4,114,190.569	482,600.040	11/10/2017	9:23	9.4	8.8	513.8	7.1	2419.6	90.6	35.2	0.021	1.51
51	1,600	4,114,385.237	482,568.336	11/10/2017	9:33	9.5	9.1	513.9	7.2	>2419.6	172.3	33.8	0.021	1.53
52	1,800	4,114,546.143	482,493.232	11/10/2017	9:42	9.7	10.2	512.1	7.3	2419.6	184.2	31.7	0.020	1.53
53	1,900	4,114,586.137	482,402.066	11/10/2017	9:46	10	10.8	511.6	7.4	1986.3	178.9	30.5	0.020	1.45
54	2,000	4,114,679.540	482,377.016	11/10/2017	9:52	9.9	10.4	511.7	7.4	>2419.6	325.5	30.5	0.021	1.47
55	2,100	4,114,777.697	482,393.465	11/10/2017	9:59	10.2	10.8	508.8	7.5	>2419.6	435.2	29.1	0.021	1.49

Sample ID	Site ID	UTM Zone 15N Northing m	UTM Zone 15N East m	Date	Time	Temp C	DO mg/L	SPC uS/cm	pH	Total Coliform MPN/100mL	Ecoli MPN/100mL	Cl mg/L	TP mg/L	TN mg/L
56	2,200	4,114,875.810	482,411.339	11/10/2017	10:05	10.2	10.2	511.6	7.5	>2419.6	248.1	29.0	0.021	1.53
57	2,400	4,115,056.967	482,364.232	11/10/2017	10:11	10.8	10.2	511.4	7.5	>2419.6	260.3	29.8	0.022	1.49
58	2,600	4,115,239.469	482,302.883	11/10/2017	10:22	11.2	10.3	511.7	7.5	2419.6	39.3	29.9	0.023	1.61
59	9,200	4,119,360.978	484,468.212	11/10/2017	10:03	7	11.0	470.8	7.6	866.4	17.5	24.8	0.027	1.30
60	9,400	4,119,380.492	484,649.839	11/10/2017	10:19	7.3	10.8	470.9	7.7	2419.6	74.9	25.3	0.025	1.24
61	9,600	4,119,511.555	484,792.379	11/10/2017	10:27	7.6	11.5	468.9	7.7	1732.9	160.7	24.5	0.034	1.30
62	9,800	4,119,625.016	484,943.300	11/10/2017	10:41	8.3	11.1	468.8	7.7	>2419.6	101.4	25.0	0.027	1.26
63	10,000	4,119,780.178	485,044.887	11/10/2017	10:53	8.4	10.6	470.2	7.7	>2419.6	39.3	25.1	0.025	1.28
64	1,400 DUP	4,114,190.569	482,600.040	11/10/2017	9:24	9.4	8.8	513.8	7.2	1986.3	129.6	33.8	0.021	1.43
65	9,400 DUP	4,119,380.492	484,649.839	11/10/2017	10:20	7.3	10.9	470.9	7.7	2419.6	91.1	25.2	0.027	1.24
66	Blank 2	NA	NA	11/10/2017	11:30	NA	NA	NA	NA	<1.0	<1.0	0.1	0.001	0.11