2018 WATER QUALITY MONITORING REPORT FOR

SPRUCE CREEK

FOR THE TOWN OF KITTERY, ME

[April 2019]

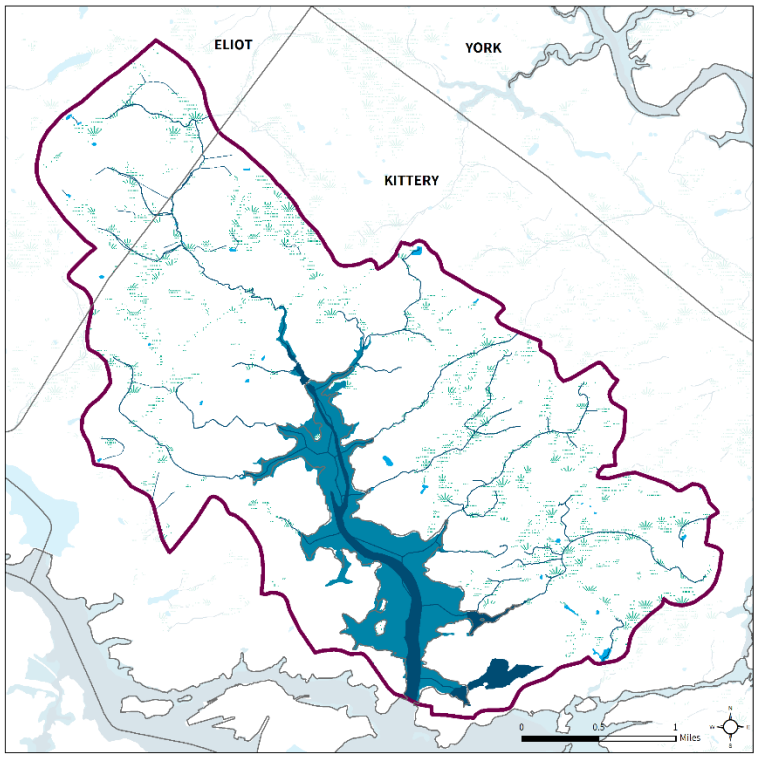
FB ENVIRONMENTAL ASSOCIATES
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com

TABLE OF CONTENTS

Flock of birds spotted near the outlet to Spruce Creek. Photo credit: FBE.

BACKGROUND

The Spruce Creek watershed covers 9.5 square miles in the Towns of Kittery (90%) and Eliot (10%), Maine. Drained by seven major freshwater streams (Barters Creek, Wilson Brook, Fuller Brook, Hill Brook, Hutchins Creek, Chickering Creek, and Crocketts Brook), the watershed feeds the Spruce Creek estuary, which in turn empties into the Piscataqua River, 1.5 miles north of the Piscataqua River's mouth to the Gulf of Maine. Approximately 3-square miles of the watershed's area are tidal, comprised of high salt marsh, ledge, and mud flats within the estuary. Watershed land cover is characterized by a mix of residential neighborhoods, commercial business corridors, conserved forest and shoreland, and agricultural areas, serviced by both municipal sewer and private septic systems. Many parks, boat launches, and residential homes provide both public and private access to the Creek, which also provides an iconic vista for travelers along Route 1 and Interstate 95 (or direct recreational enjoyment through boating, kayaking, and fishing) and is an integral part of Kittery's identity and local quality of life.



Fecal contamination (as evidenced through elevated fecal indicator bacteria or FIB) comprise the primary pollutant of concern in the Spruce Creek watershed. The estuarine portion of Spruce Creek is listed in the Maine DEP's 2016 Integrated Water Quality Monitoring and Assessment Report as impaired under Category 5-B-1: Estuarine and Marine Waters Impaired for Bacteria Only (fecal pollutants) – TMDL Required (refer to Waterbody ID 812-1 for Kittery). Spruce Creek is also identified by Maine DEP on the Threatened Stream and Marine Watersheds Priority List due to negative water quality indicators and its status as an MS4 (Municipal Separate Stormwater Sewer Systems) priority water. Shellfish beds (Department of Marine Resources (DMR) Closed Area 1-B) within Spruce Creek have been closed since July 2005 because the beds reside within the Prohibited/Safety Zone defined as high risk for sewage contamination following possible disinfection failure at the Pierce Island Wastewater Treatment Facility. Per a Consent Decree, the City of Portsmouth is required to upgrade its facility from primary to secondary treatment by December 2019. The upgrade is expected to greatly reduce the number of bacterial and viral pathogens in effluent. This will likely allow reopening of administratively-closed shellfish beds. Lowering that contamination risk could result in a complete reclassification of the Spruce Creek area following reinstatement of sanitary surveys and monitoring by the Maine DMR.

Monitoring conducted by the Town of Kittery, Spruce Creek Association (SCA), Maine DMR, and Maine Healthy Beaches program has shown elevated FIB levels exceeding USEPA's recommendations and Maine state criteria. Dry and wet weather sampling since 2008 have shown multiple "hotspots" of fecal contamination to Spruce Creek. Many of these "hotspots" have been addressed through the implementation of Phases I – IV and are continuing to be addressed in the current Phase V of the USEPA-funded (Maine DEP-administered) Spruce Creek Watershed Restoration Project (SCWRP), along with other important town-funded remediation efforts. Since the SCWRP began in 2008, more than 60 best management practices (BMPs) have been implemented throughout the watershed. As these remediation efforts are now underway, monitoring data becomes essential to assess the trajectory of any changes in the water quality of Spruce Creek.

In 2018, FB Environmental Associates (FBE) was hired by the Town of Kittery to complete water quality monitoring per the Spruce Creek Watershed-Scale Water Quality Monitoring QAPP for the Spruce Creek Watershed Restoration Project, Phase V (dated July 26, 2018). The following report summarizes 2018 results and details next step recommendations.

WATER QUALITY RESULTS

In 2018, FBE completed the first of two years collecting water quality data per the Spruce Creek Watershed-Scale Water Quality Monitoring QAPP for the Spruce Creek Watershed Restoration Project, Phase V (dated July 26, 2018) (refer to Appendix A for quality assurance-quality control review). FBE deployed and maintained town-owned data loggers at the upper and middle estuary of Spruce Creek. The town, in coordination with volunteers, sampled from nine sites that bracket a buffer planting project scheduled for installation in spring 2019 in the upper portion of the Creek.

CONTINUOUS MONITORING (DATA LOGGERS)

Data loggers were first deployed in Spruce Creek in 2012. The loggers collect water quality data at 15-minute intervals, providing a picture of in-estuary conditions over the course of multiple days and tidal cycles during the peak growing season (August-September). The use of loggers ensures continuity of data and maintains a baseline from which to compare future conditions as restoration work progresses in the watershed.

In 2018, continuous Onset HOBO® data loggers (owned by the town) were deployed at two locations in the main channel of Spruce Creek (upper and middle estuary) from 8/1/18-9/27/18 (58 days). The middle estuary loggers were secured inside a metal eel trap using cable ties. The eel trap was tied with thick rope to a bright orange buoy that floated on the surface of the water for retrieval. Two bricks were placed inside the eel trap to help anchor the trap in place and prevent any drift. The upper estuary loggers were secured to a PVC pipe using cable ties and tied with rope to a metal handle that was attached to the inside of the concrete culvert under Picott Road. Rocks were placed around and on top of the PVC pipe to secure the loggers and hide them from public view. Loggers recorded depth (i.e., relative tidal stage), conductivity, temperature, and dissolved oxygen (mg/L) at 15-minute intervals. FBE computed the percent saturation through the HOBOware® Pro Dissolved Oxygen Data Assistant by using local barometric pressure data retrieved from the nearest quality-controlled weather station. Maintenance performed every two weeks consisted of taking calibrated field meter readings near the deployed logger sensors, cleaning the loggers, and downloading data recorded by the loggers using a portable HOBO® Waterproof Shuttle. FBE coordinated with the Kittery Harbormaster (John Brosnihan) and a local resident (Don Craig) for transport to the middle estuary site. Quality assurance and quality control of the data followed the USGS Guidelines and Standard Procedures for Continuous Water-Quality Monitors, as well as the HOBO® logger user manuals and best professional judgement.

The upper estuary (PICOTT) of Spruce Creek experienced large swings in daily dissolved oxygen, specific conductivity, and temperature compared to the middle estuary (MIDEST) (Figures 1-2). The upper estuary site is located further upstream where the Creek narrows considerably above Picott Road and becomes more directly connected to freshwater influences from the landscape (e.g., surface runoff and groundwater). The middle estuary site is located where the Creek is much wider and more influenced by marine waters. As observed in previous years, large precipitation events caused a drop in specific conductivity as freshwater runoff from the watershed flowed to the Creek. Specific conductivity and dissolved oxygen were higher at high tide and lower at low tide in the upper estuary (Appendix B). Temperature was generally cooler at high tide and warmer at low tide in the middle estuary.

Dissolved oxygen saturation exceeded the state criterion of 85% for tidal waters for 58 of 58 days (100%) or 76% of all readings in the upper estuary and 31 of 37 days (84%) or 11% of all readings in the middle estuary. Low dissolved oxygen may indicate high concentrations of nutrients and/or organic matter entering the Creek. Excess nutrients can stimulate rapid growth of algae and other aquatic plants; excess organic matter has a high potential biological oxygen demand as decomposition can deplete oxygen in the water column, causing stressful conditions for aquatic organisms, such as fish and shellfish.

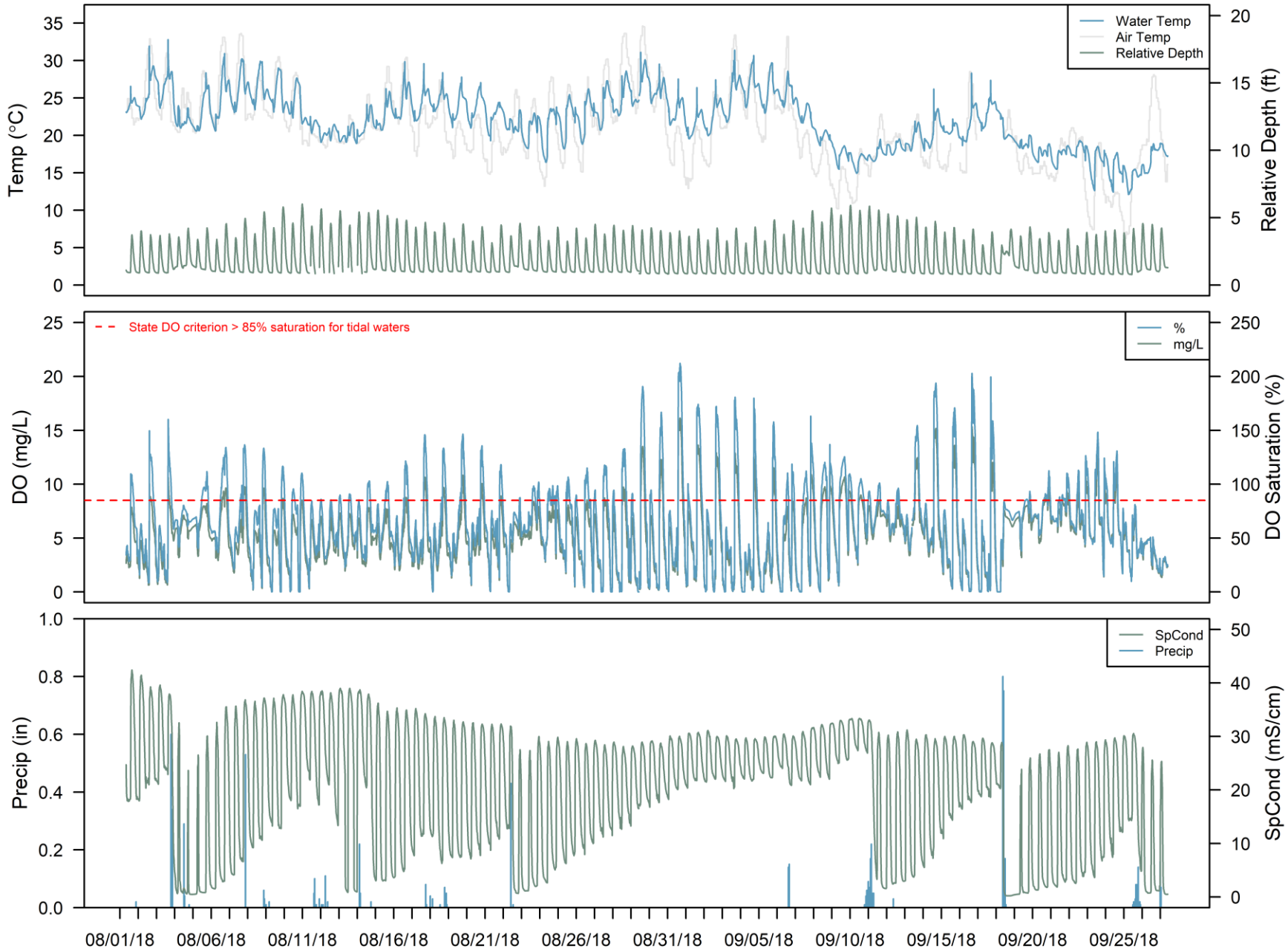


FIGURE 1. Continuous data collected in the upper estuary of Spruce Creek (PICOTT).

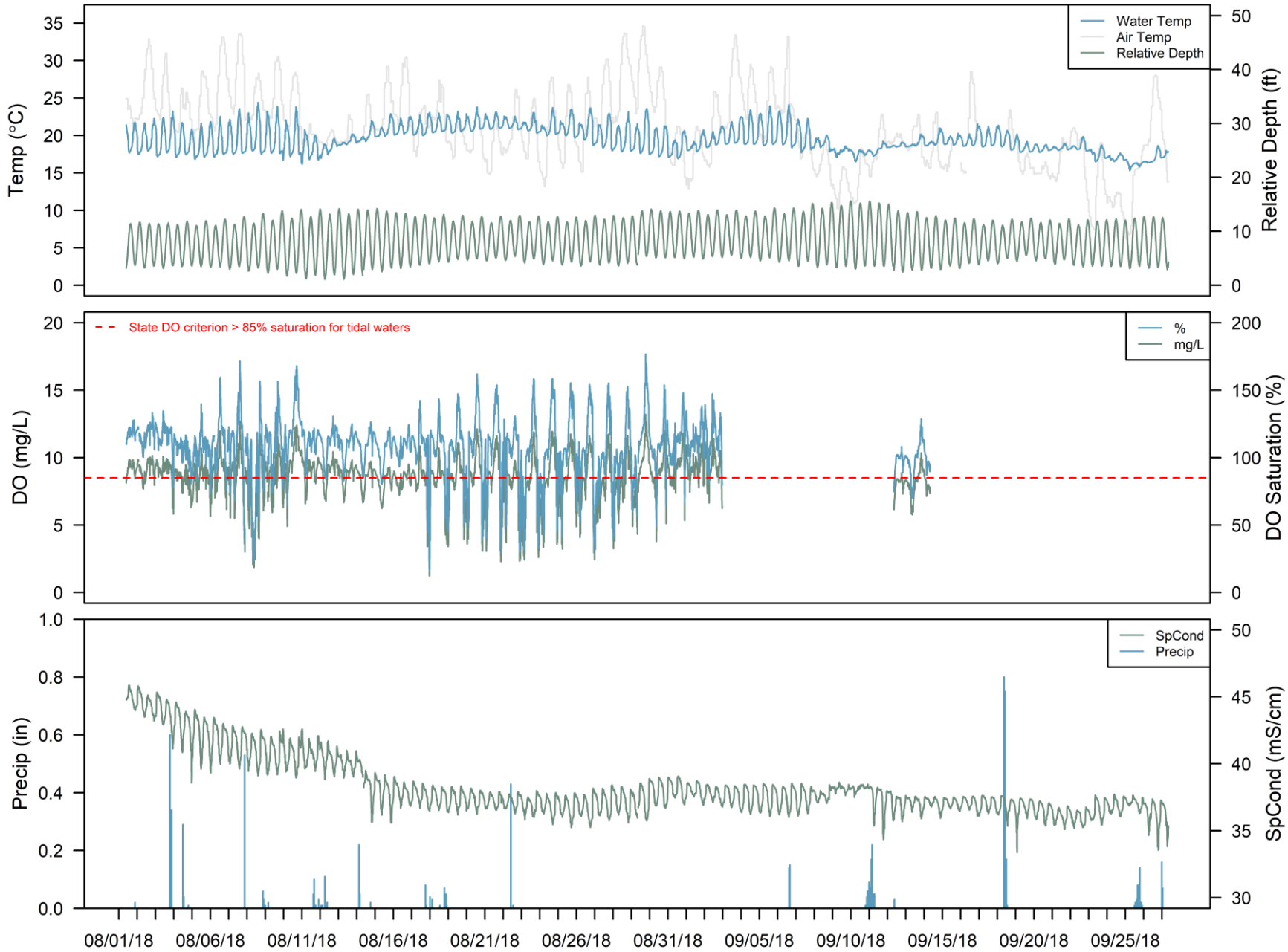


FIGURE 2. Continuous data collected in the middle estuary of Spruce Creek (MIDEST).

TARGETED SAMPLING (GRAB SAMPLES)

The Town of Kittery and volunteers collected water quality samples at nine sites in the upper portion of Spruce Creek to better track possible fecal sources upstream of the known "hotspot" site at Picott Road (PICOTT) and to assess water quality improvements following implementation of the proposed stream buffer planting (Figure 3). Six sets of samples were collected at low tide (±2 hours) during both wet and dry weather from July to September 2018. Samples were delivered on ice to Absolute Resource Associates and were analyzed for Enterococci, nitrate, nitrite, ortho-phosphate, total Kjeldahl nitrogen, and total phosphorus. Water temperature, dissolved oxygen, salinity, conductivity, total dissolved solids (TDS), ammonia, and pH field readings were taken at each site. Three sets of samples were also collected by FBE at PICOTT and MIDEST during logger deployment (8/1/18), maintenance (8/29/18), and retrieval (9/27/18) and analyzed for Enterococci at Absolute Resource Associates and for nitrate-nitrite, total Kjeldahl nitrogen, total phosphorus, total suspended solids, biological oxygen demand, and total organic carbon at Alpha Analytical Services.

PICOTT has been a consistently-elevated fecal "hotspot" in the upper portion of Spruce Creek, draining a large area upstream of Interstate 95 and Route 1. Land use is more rural in the PICOTT drainage than in other areas of the watershed and includes agricultural fields such as Rustlewood Farm and several hobby farms. Historic nonpoint source watershed surveys in 2008 and 2013 identified agricultural stormwater runoff as a potential contributor of fecal contamination to the Creek. Historic water quality monitoring and analysis (including 2018 results) concluded that the upper estuary at PICOTT showed evidence of nutrient and organic enrichment during both wet and dry weather events. The upper estuary experienced large swings in daily dissolved oxygen, daily minimum dissolved oxygen that regularly exceeded the state criterion of 85% saturation, and elevated total nitrogen concentrations (~0.8-1.0 ppm) and biological oxygen demand. These results are consistent year to year and suggest that a possible source of pollution from upstream agricultural, residential, or wetland areas is impacting the upper estuary (with excess nutrients driving recurrent algae blooms). Phase V of the current 319 implementation grant aims to re-establish a buffer along 400 feet of Spruce Creek that flows through Rustlewood Farm, whose owners apply manure on adjacent hayfields according to a USDA-approved Comprehensive Nutrient Management Plan. The goal of the buffer planting is to reduce possible untreated surface runoff from the manured hayfields to the Creek. To assess whether the buffer planting and any other efforts help to improve water quality in the Creek over time, nine sites (including PICOTT) were selected for the 2019-20 sampling effort.

Refer to Tables 1-2 and Figure 3 for a summary of grab sample results. Additional figures can be found in Appendix C. The following summarizes general observations from 2018 grab sample results:

- **OLFARMLN** was only sampled during wet weather (no flow during dry weather) but exceeded the state criteria for both single sample and geomean for Enterococci and had elevated nutrients (both nitrogen and phosphorus), along with elevated temperature and low dissolved oxygen, likely due to concentrated pollutants in pulsed runoff from paved surfaces and groundwater.
- **RUSWOODFARM-3**, **RUSWOODFARM-2**, **RUSWOODFARM-1**, **UPSC-PRDRIVE**, and **WR Cul** met the state criteria for both single sample and geomean for Enterococci during dry weather but not during wet weather, suggesting that fecal sources were activated during storm events that carried fecal sources to the Creek in surface runoff or in groundwater through saturated soils. **PICOTT** and **PICOTT CULVERT** showed similar differences between dry and wet weather but with exceedances for single sample and/or geomean for Enterococci for both dry and wet weather. **PICOTT DS** exceeded the state criteria for both single sample and geomean for Enterococci during both dry and wet weather, suggesting a possible direct source of fecal input. Numerous Canada geese have been observed at or near PICOTT DS and are likely the most significant source of fecal indicator bacteria and nutrients to this site, as well as PICOTT CULVERT and possibly PICOTT due to tidal inundation.
- Total Kjeldahl nitrogen was elevated above natural background conditions for the ecoregion, with **OLFARMLN** and **RUSWOODFARM-2** especially high; total phosphorus was below natural background conditions for the ecoregion except at OLFARMLN and RUSWOODFARM-2. Elevated nitrogen and phosphorus concentrations at OLFARMLN and RUSWOODFARM-2 are possibly due to runoff from the adjacent manured hayfields. Concentrations of total Kjeldahl nitrogen decreased downstream of RUSWOODFARM-2 until **PICOTT** where concentrations increased during wet weather, suggesting a surface runoff source between WR Cul and PICOTT.
- Total phosphorus was higher during wet weather than dry weather except at **RUSWOODFARM-3** and **RUSWOODFARM-2**, both of which had total phosphorus concentrations higher and more variable during dry weather compared to wet weather.

These baseflow sources of nutrients became less significant downstream of UPSC-PRDRIVE compared to the RUSWOODFARM sites.

- **MIDEST** exceeded the state criterion for single sample during wet weather and had elevated nutrients (nitrogen), likely from upstream contributing sources to PICOTT.
- Biological oxygen demand at **PICOTT** had non-detects at significantly elevated reporting limits (up to a maximum of 40 mg/L); discussions with lab personnel indicated that negative (non-detect) results at elevated reporting limits suggest that the samples were toxic and inhibited the growth of microbes (salinity may have also been a contributing factor). **MIDEST** experienced similar issues with biological oxygen demand. We recommend discontinuing biological oxygen demand analyses at these sites.

TABLE 1. Average 2018 field measurements for Spruce Creek. Bold, italicized red or orange text indicates results exceeding state criteria and natural background or suggested levels, respectively. DO = dissolved oxygen. Cond = conductivity. TDS = total dissolved solids.

Site ID	Temp (°C)	DO (%)	DO (mg/L)	pH	Salinity (PSU)	Cond (µS/cm)	TDS (ppt)	Ammonia (mg/L)
Freshwater	24-28	75	7.0	6.5-8.0	NA	854	NA	0.5
OLFARMLN	18.7	***28***	***2.6***	6.9	1.2	266	1.9	0
RUSWOODFARM-3	17.9	***34***	***3.3***	7.0	2.2	473	3.4	0
RUSWOODFARM-2	18.0	***32***	***3.1***	6.9	2.2	464	3.3	0
RUSWOODFARM-1	17.0	***51***	***5.1***	7.1	3.2	680	3.0	0
UPSC-PRDRIVE	17.4	***64***	***6.3***	7.2	1.8	384	2.7	0
Tidal	24-28	85	NA	NA	NA	NA	NA	0.5
WR Cul	18.6	96	9.1	7.6	3.3	685	4.9	0
PICOTT	20.4	***67***	6.2	7.1	4.4	5,203	5.9	0
PICOTT CULVERT	17.8	***68***	6.8	6.6	3.1	645	4.6	0
PICOTT DS	19.3	***73***	6.9	6.6	3.2	615	4.4	0
MIDEST	20.4	88	7.6	--	--	42,383	--	--

TABLE 2. Average 2018 laboratory analysis results for Spruce Creek. Bold, italicized red or orange text indicates results exceeding state criteria and natural background or suggested levels, respectively. TKN = total Kjeldahl nitrogen. TP = total phosphorus. TOC = total organic carbon. TSS = total suspended solids. BOD = biological oxygen demand. Most samples for nitrate, nitrite, and phosphate fell below the reporting limit on one or more occasions; maximum values for nitrate, nitrite, and phosphate are shown.

Site ID	Entero (mpn/ 100mL)	TKN (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Phosphate (mg/L)	TP (mg/L)	TOC (mg/L)	TSS (mg/L)	BOD (mg/L)
Freshwater	35	0.20	0.20	0.20	0.24	0.24	NA	30	2
OLFARMLN	***258***	***1.95***	<0.10	<0.10	<0.10	***0.36***			
RUSWOODFARM-3	***67***	***1.05***	<0.10	<0.10	<0.10	0.15			
RUSWOODFARM-2	***90***	***1.49***	***0.30***	<0.10	<0.10	***0.34***			
RUSWOODFARM-1	***135***	***0.79***	***0.30***	<0.10	<0.10	0.07			
UPSC-PRDRIVE	***216***	***0.89***	0.10	<0.10	<0.10	0.08			
Tidal	35	0.57	0.31	0.31	0.24	0.24	NA	30	2
WR Cul	***201***	***0.93***	***0.50***	<0.10	0.10	0.09			
PICOTT	***268***	***1.20***	0.30	<0.20	0.20	0.10	16.1	24	***<40***
PICOTT CULVERT	***325***	***1.28***	0.20	<0.20	<0.10	0.08			
PICOTT DS	***660***	***1.20***	0.10	<0.20	0.10	0.09			
MIDEST	27	***0.85***	0.10	--	--	0.07	6.0	19	***<40***

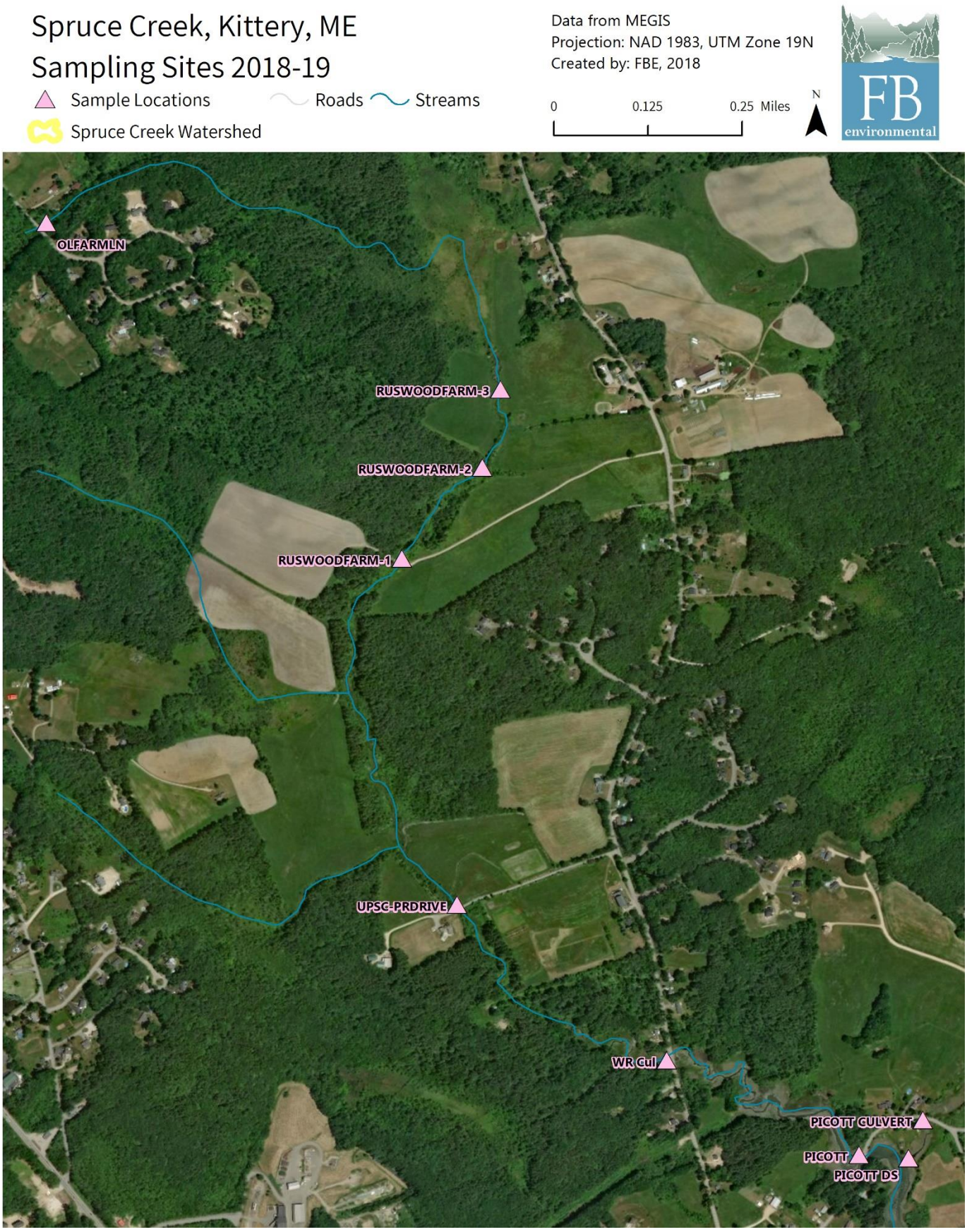


FIGURE 3. Location of 2018 sampling sites in the Spruce Creek watershed. MIDEST not shown.

CONCLUSIONS AND NEXT STEPS

The water quality monitoring dataset for Spruce Creek becomes more robust for every year that monitoring is continued. As the data record expands, water quality analysis will provide better insights to long-term trends and allow better understanding of interannual changes in water quality that may be related to specific conditions within a given year (e.g., weather patterns, land use changes, remediation efforts, etc.).

CONCLUSIONS

- The upper and middle estuary showed evidence of nutrient and organic enrichment as a persistent source of nonpoint source pollution, possibly from agricultural, residential, or wetland areas upstream.
- OLFARMLN had elevated fecal indicator bacteria, nutrients, and temperature, along with low dissolved oxygen, likely due to concentrated pollutants in pulsed runoff from paved surfaces and groundwater.
- Areas upstream of PICOTT showed consistent exceedances of fecal indicator bacteria during wet weather only, suggesting that fecal sources were activated during storm events that carried fecal sources to the Creek in surface runoff or in groundwater through saturated soils.
- Numerous Canada geese have been observed at or near PICOTT DS and are likely the most significant source of fecal indicator bacteria and nutrients to this site, as well as PICOTT CULVERT and possibly PICOTT due to tidal inundation.
- Elevated nutrient concentrations at OLFARMLN and RUSWOODFARM-2 are possibly due to runoff from the adjacent manured hayfields. Concentrations of nitrogen decreased downstream of RUSWOODFARM-2 until PICOTT where nitrogen concentrations increased during wet weather, suggesting a surface runoff source between WR Cul and PICOTT.

NEXT STEPS

- Continue to monitor sites for changes in water quality in Spruce Creek. This will provide valuable information and allow the Town of Kittery to track progress toward improving water quality in Spruce Creek. Consistency and continuity of monitoring efforts is essential to detecting long term trends in water quality.
    - → Redeploy data loggers at the upper and middle estuary annually in August-September.
    - → Re-start collection of samples at major tributary sites, particularly those sites with consistently-high fecal indicator bacteria counts and/or with future changes to land use. This could be aided by the reactivation and expansion of the SCA Volunteer Monitoring Program.
    - → Re-sample sites bracketing the buffer planting in the upper portion of Spruce Creek to assess the success of the buffer planting project once the buffer has established.
- Assess and remediate potential sources of nonpoint source pollution to Spruce Creek.
    - → Investigate locations along Picott Road and Old Farm Lane to install stormwater BMPs that treat road runoff.
    - → Work with property owners adjacent to Spruce Creek to enhance buffers and/or install other practices that help treat runoff before entering the Creek.
    - → Install geese deterrents at or near PICOTT DS.
    - → Investigate possible sources of excess nitrogen between WR Cul and PICOTT.

REFERENCES

FBE. (2018). Spruce Creek Watershed-Scale Water Quality Monitoring: Spruce Creek Watershed Restoration Project, Phase V Quality Assurance Project Plan (QAPP). Prepared by FB Environmental Associates on behalf of the Town of Kittery for the Maine Department of Environmental Protection, July 26, 2018.

Maine DEP. (2018). 2016 Integrated Water Quality Monitoring and Assessment Report and Appendices: 305(b) report and 303(d) list of impaired surface waters. Maine Department of Environmental Protection, final approved February 28, 2018. https://www.maine.gov/dep/water/monitoring/305b/2016/28-Feb-2018_2016-ME-IntegratedREPORT.pdf

Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J., and Smith, B.A. (2006). Guidelines and standard procedures for continuous water-quality monitors-Station operation, record computation, and data reporting: U.S. Geological Survey Techniques and Methods 1–D3, 51 p. + 8 attachments; accessed at http://pubs.water.usgs.gov/tm1d3.

APPENDIX A: Quality Assurance-Quality Control Review

Sampling conducted in 2018 followed protocols detailed in the Spruce Creek Watershed-Scale Water Quality Monitoring QAPP for the Spruce Creek Watershed Restoration Project, Phase V (dated July 26, 2018). A summary of those protocols and any deviations are described below.

1) A mix of weather conditions (3 dry and 3 wet weather events) from July through September were sampled.

2) Any field measurements for dissolved oxygen (mg/L and % saturation) with salinities greater than 9 PSU were corrected.

3) Samples from tidal sites on 8/15/19, 8/29/18, and 9/25/18 were collected up to 57 minutes past the 2-hour window surrounding the head of tide (thus heading into slack tide and data were acceptable). All fecal indicator bacteria samples were delivered to Absolute Resource Associates within the 6-hour holding time limit. All samples were delivered to the labs at or below 10°C. Refer to Table A1.

4) All COC forms and field forms were complete. One possible entry error for OLFARMLN for salinity was found and corrected from 8.84 PSU to 0.84 PSU in the database to match the correlation between specific conductivity and salinity for all other field measurements collected in 2018.

5) Dissolved oxygen measurements were not collected on 8/15/18 due to a malfunctioning YSI 55 meter. Total Kjeldahl nitrogen and total phosphorus samples were not collected on 7/18/18 due to a miscommunication between the project manager and field sampler. Overall, 95% of the discrete grab sampling and field measurements were successfully collected and analyzed.

6) Field duplicates for fecal indicator bacteria should attempt to yield a relative percent difference (RPD) <30%, but two out of six duplicate samples resulted in RPDs >30% (Table A2). RPDs >30% can be deemed acceptable given the inherent variability of collecting and measuring biological communities. Typically, higher bacteria counts will be less variable than lower bacteria counts of <200 mpn/100mL. As such, 2018 RPDs ranging from 0-69% were acceptable and reflected a consistent field sampling procedure by personnel.

7) Field duplicates for all other laboratory parameters should attempt to yield an RPD <20% (Table A2). RPD values greater than that limit were flagged, including total phosphorus on 8/21/18 at PICOTT DS and nitrate on 9/25/18 at RUSWOODFARM-1. Because all other parameters measured in the same sample water had acceptable duplicate RPDs, it is likely that these elevated duplicate RPDs were due to natural differences found in the water. Data were deemed acceptable and reflected a consistent field sampling procedure by personnel.

8) Matrix interference was a significant issue for samples collected at PICOTT. Ortho-phosphate for PICOTT on 8/28/18 received a "J" or estimate qualifier; nitrate-nitrite and total phosphorus for PICOTT on 8/1/18 received a "J" or estimate qualifier; nitrate-nitrite for PICOTT on 9/27/18 received a "J" or estimate qualifier; ortho-phosphate for PICOTT on 7/18/18 was flagged for an internal quality control lab duplicate RPD outside the 10% acceptable range; ortho-phosphate for PICOTT on 9/25/18 had an elevated reporting limit (from 0.1 to 0.5 mg/L) – all due to matrix interference. Nitrate for PICOTT, PICOTT DS, and/or PICOTT CULVERT on 7/18/18, 8/15/18, 8/21/18, 8/28/18, and 9/25/18 had elevated reporting limits (from 0.1 to 0.2 or 0.5 mg/L) due to matrix interference. Biological oxygen demand (BOD) at PICOTT on the three dates sampled (8/1/18, 8/29/18, and 9/27/18) had non-detects at significantly elevated reporting limits (up to a maximum of 40 mg/L); discussions with lab personnel indicated that negative (non-detect) results at elevated reporting limits suggest that the samples were toxic and inhibited the growth of microbes (salinity may have also been a contributing factor). MIDEST experienced similar issues with BOD and received a few "J" or estimate qualifiers for total organic carbon and total phosphorus due to matrix interference. We recommend discontinuing BOD analyses at all sites.

TABLE A1. Summary of adherence to quality assurance and quality control protocols. Deviations are highlighted.

Date	Precip 24 hrs prior (in)	Precip 48 hrs prior (in)	Precip 96 hrs prior (in)	Time of First Sample	Time of First Tidal Sample	Time of Last Tidal Sample	Time of Low Tide	Time Delivered to Lab	Temp Received (°C)	Time to Lab (All Samples) (hh:mm)	Time to Low Tide (First Tidal Sample) (hh:mm)	Time to Low Tide (Last Tidal Sample) (hh:mm)
7/18/2018	1.72	1.72	2.39	9:10	9:10	10:10	10:19	12:10	8.0	3:00	1:09	0:09
8/1/2018	0.00	0.00	0.04	7:35	7:35	9:20	8:59	12:06	6.0	4:31	1:24	0:21
8/15/2018	0.39	0.40	0.94	8:55	11:20	11:55	8:58	12:45	7.0	3:50	2:22	2:57
8/21/2018	0.00	0.00	0.46	12:45	13:50	14:25	14:35	15:15	10.0	2:30	0:45	0:10
8/28/2018	0.00	0.00	0.00	7:40	7:40	8:15	7:14	12:40	8.0	5:00	0:26	1:01
8/29/2018	0.00	0.00	0.00	8:50	8:50	10:05	7:49	11:30	8.0	2:40	1:01	2:16
9/19/2018	2.76	2.76	2.76	12:30	13:35	14:00	14:01	14:33	0.0	2:03	0:26	0:01
9/25/2018	0.00	0.00	0.00	8:40	8:40	9:00	6:08	11:03	3.0	2:23	2:32	2:52
9/27/2018	0.58	1.19	1.19	8:40	8:40	9:50	7:17	10:55	6.0	2:15	1:23	2:33

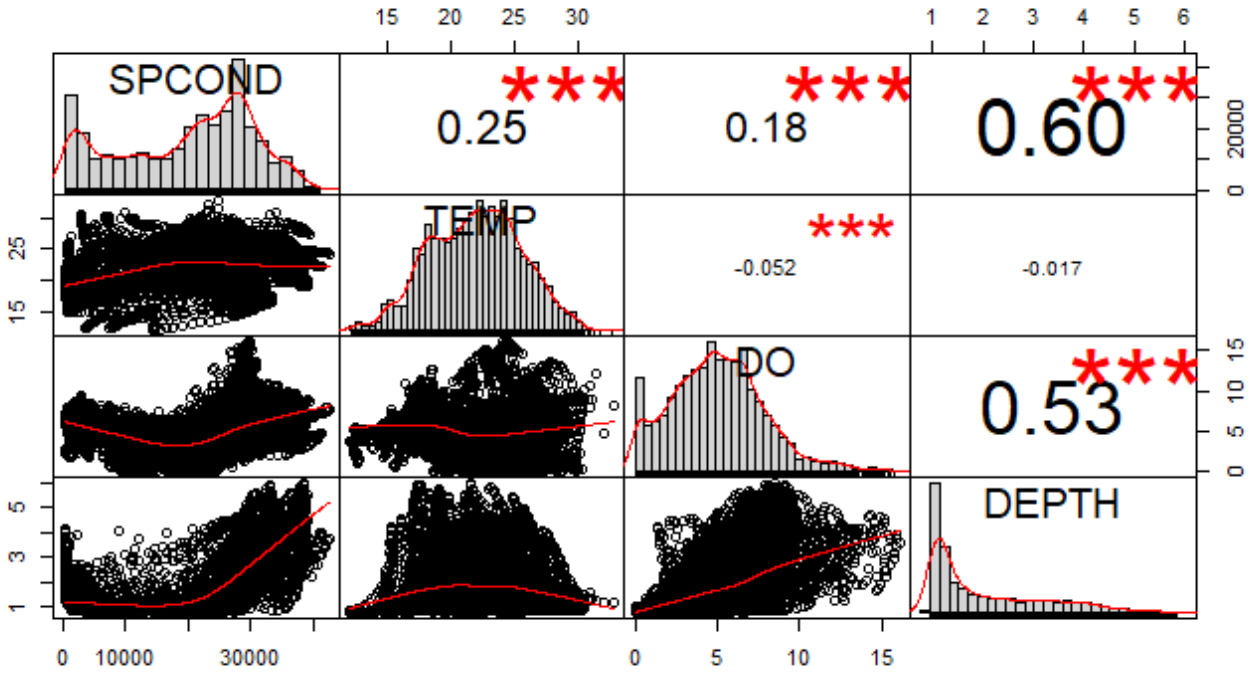
TABLE A2. Summary of relative percent difference (RPD) between duplicate field samples. OPhos = ortho-phosphate; TKN = Total Kjeldahl Nitrogen; TP = total phosphorus.

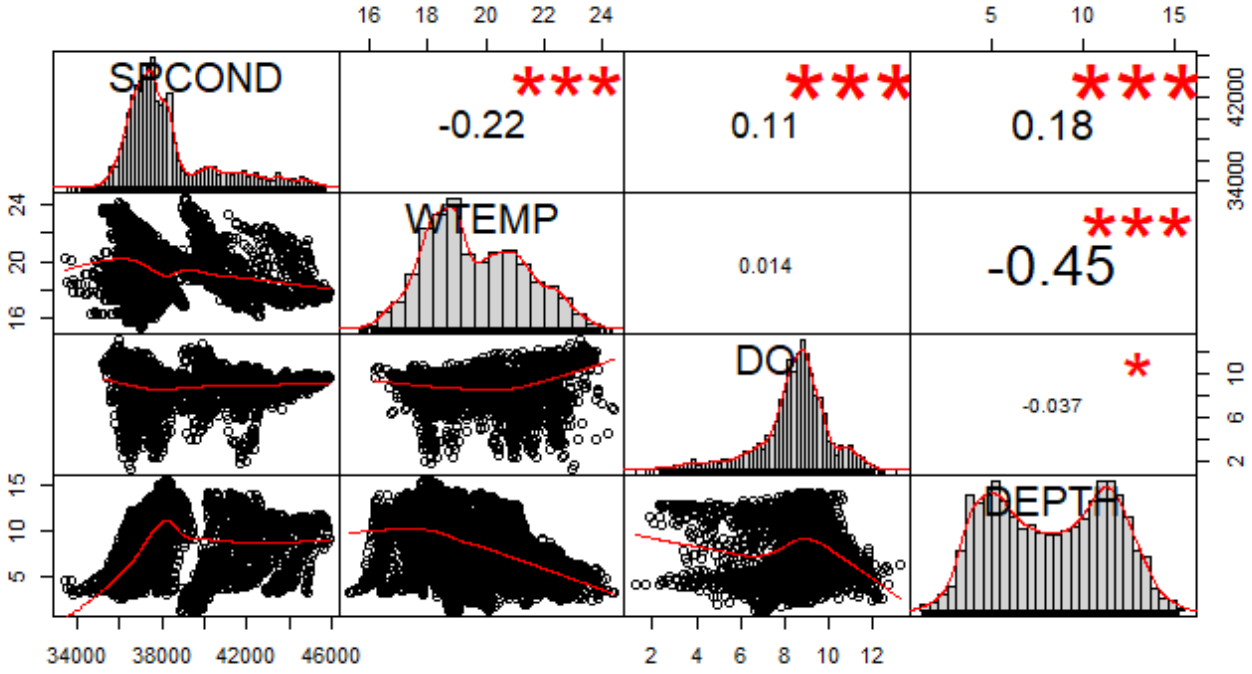
Date	Wet/ Dry	Site ID	Entero (mpn/ 100mL)	RPD	Nitrate (mg/L)	RPD	Nitrite (mg/L)	RPD	OPhos (mg/L)	RPD	TKN (mg/L)	RPD	TP (mg/L)	RPD
7/18/2018	Wet	UPSC-PRDRIVE	>2419.6	0%	<0.1	0%	<0.1	0%	<0.1	0%	NA	NA	NA	NA
7/18/2018	Wet	UPSC-PRDRIVE-DUP	>2419.6		<0.1		<0.1		<0.1		NA		NA	
8/15/2018	Wet	PICOTT	1034	30%	<0.1	0%	<0.2	0%	<0.1	0%	1.8	12%	0.14	0%
8/15/2018	Wet	PICOTT-DUP	768		<0.1		<0.2		0.1		1.6		0.14	
8/21/2018	Dry	PICOTT DS	594	7%	0.1	0%	<0.5	0%	0.1	0%	1.4	13%	0.08	156%
8/21/2018	Dry	PICOTT DS-DUP	638		0.1		<0.5		<0.1		1.6		0.01	
8/28/2018	Dry	WR Cul	63	42%	0.2	0%	<0.1	0%	0.1	0%	0.8	0%	0.06	0%
8/28/2018	Dry	WR Cul-DUP	41		0.2		<0.1		<0.1		0.8		0.06	
9/19/2018	Wet	UPSC-PRDRIVE	309	13%	<0.1	0%	<0.1	0%	<0.1	0%	0.9	0%	0.11	9%
9/19/2018	Wet	UPSC-PRDRIVE-DUP	272		<0.1		<0.1		<0.1		0.9		0.12	
9/25/2018	Dry	RUSWOODFARM-1	41	69%	0.3	100%	<0.1	0%	<0.1	0%	<0.5	0%	0.03	0%
9/25/2018	Dry	RUSWOODFARM-1-DUP	20		<0.1		<0.1		<0.1		<0.5		0.03	

Data flagged for elevated field duplicates

APPENDIX B: Correlation matrices for continuous data at PICOTT and MIDEST

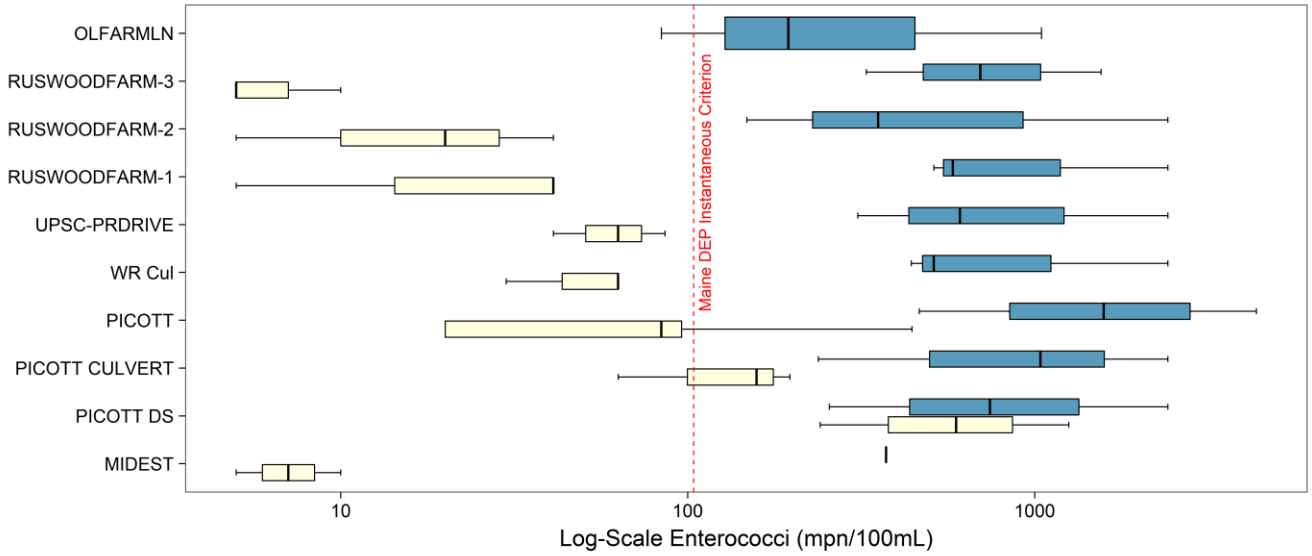
The correlation matrices shown below for PICOTT (top) and MIDEST (bottom) were generated in R statistical programming using the package *PerformanceAnalytics.* The distribution of each variable is shown on the diagonal. The bivariate scatterplots with fitted lines are shown below the diagonal. The value and significance of the correlation are shown above the diagonal. Significance levels by symbol are as follows: "***" = <0.001, "**" = 0.001, "*" = 0.01, "-" = 0.05, " " = >0.05.

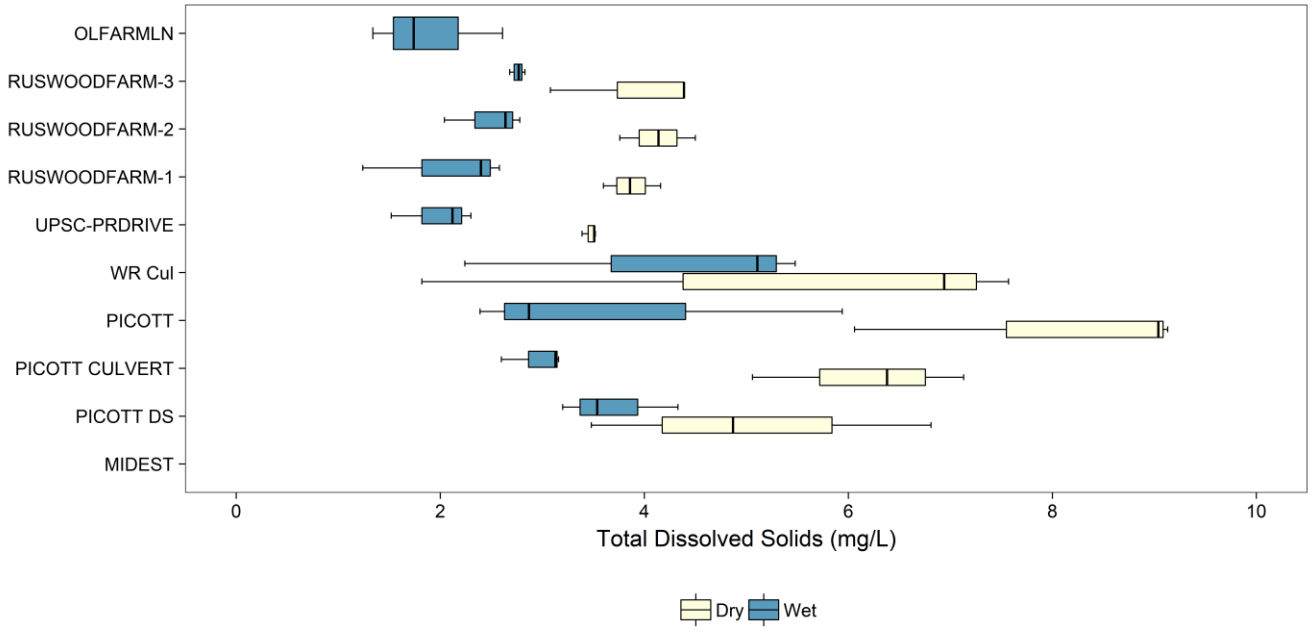


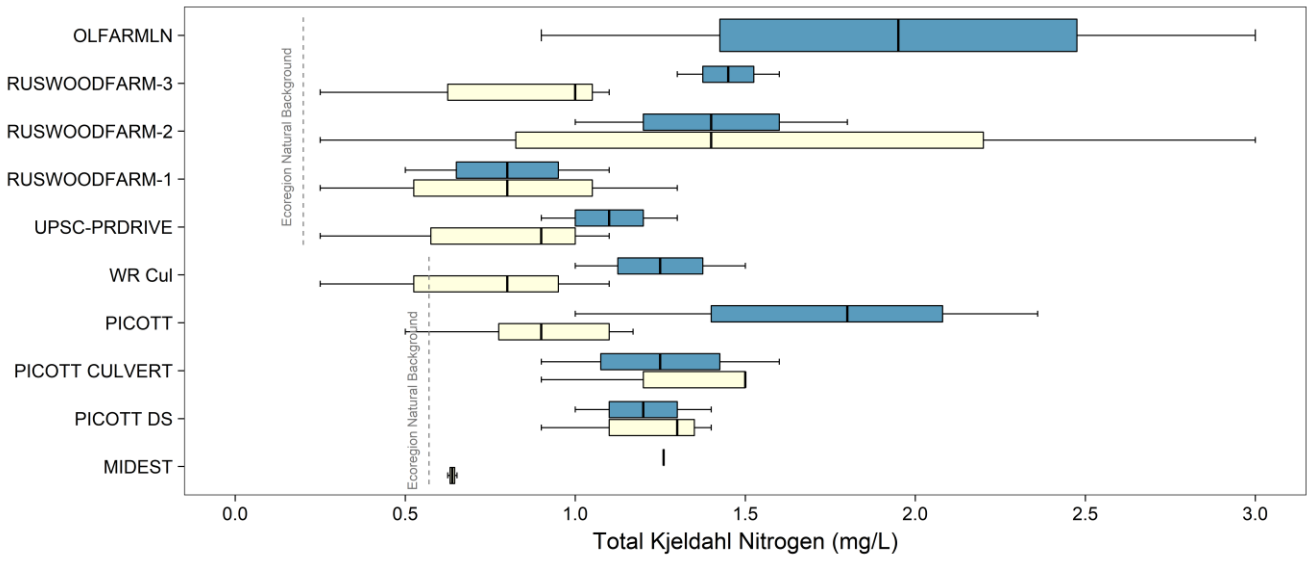


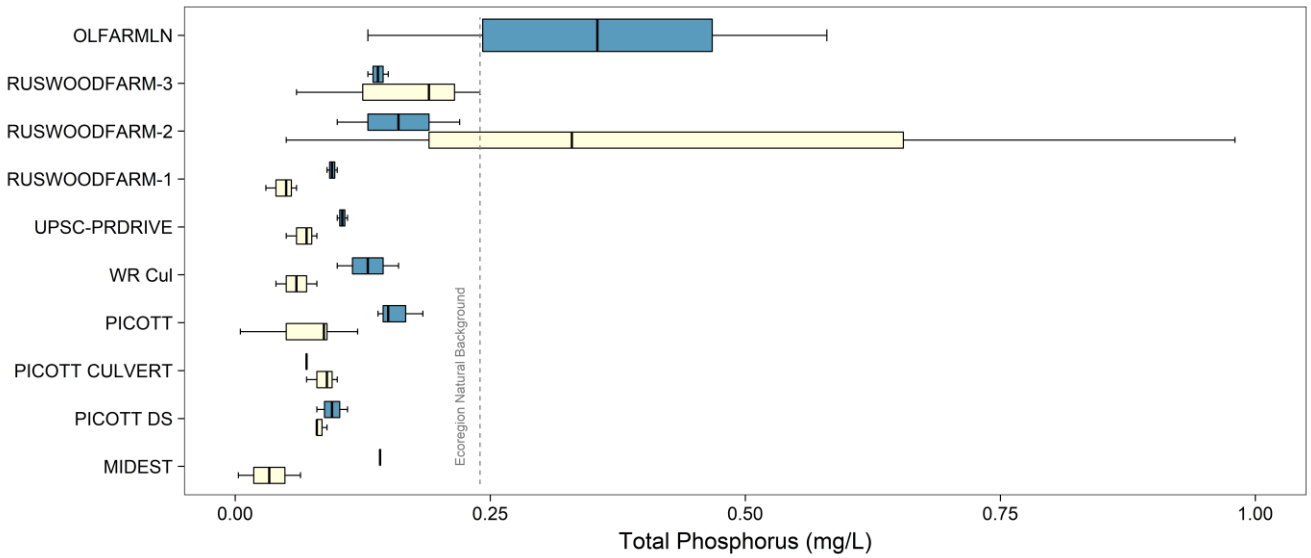
APPENDIX C: Data figures by weather for Spruce Creek sites

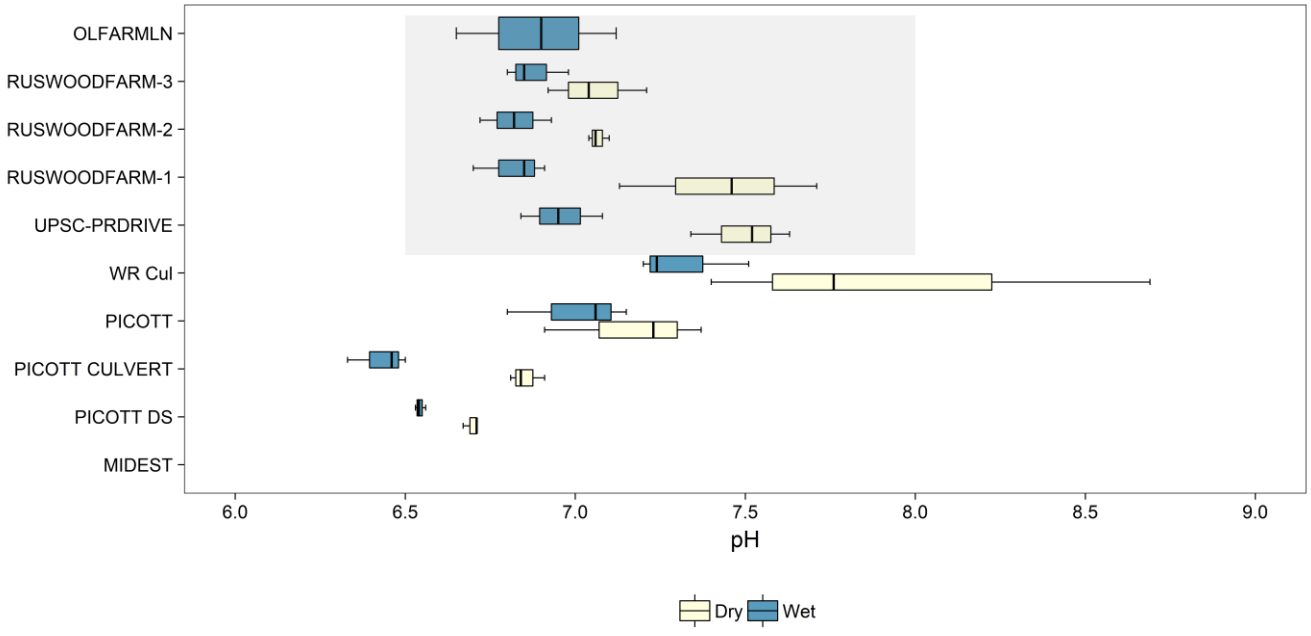
Summary of 2018 data distribution split by weather condition (dry or wet) for sites ordered from upstream (top y-axis) to downstream (bottom y-axis). The right and left of the box area in each boxplot represent the 75th and 25th percentiles of the data, respectively. The solid vertical line in each box represents the median or 50th percentile of the data. The right and left whiskers represent the maximum and minimum non-outliers of the data, respectively. Any points to the right or left of the whiskers are outliers, defined as 1.5 times the interquartile range (or the length of the box). Single vertical lines represent only a single data point. Applicable criteria or natural background conditions are shown in red or grey, respectively.






OLFARMLN
RUSWOODFARM-3
RUSWOODFARM-2
RUSWOODFARM-1
UPSC-PRDRIVE
WR Cul
PICOTT
PICOTT CULVERT
PICOTT DS
MIDEST
Ecoregion Natural Background
Ecoregion Natural Background
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Total Kjeldahl Nitrogen (mg/L)


OLFARMLN
RUSWOODFARM-3
RUSWOODFARM-2
RUSWOODFARM-1
UPSC-PRDRIVE
WR Cul
PICOTT
PICOTT CULVERT
PICOTT DS
MIDEST
Ecoregion Natural Background
0.00
0.25
0.50
0.75
1.00
Total Phosphorus (mg/L)


OLFARMLN
RUSWOODFARM-3
RUSWOODFARM-2
RUSWOODFARM-1
UPSC-PRDRIVE
WR Cul
PICOTT
PICOTT CULVERT
PICOTT DS
MIDEST
6.0
6.5
7.0
7.5
8.0
8.5
9.0
pH
Dry
Wet