SPRUCE CREEK WATERSHED

KITTERY, MAINE

2015 WATER QUALITY MONITORING REPORT

PREPARED FOR

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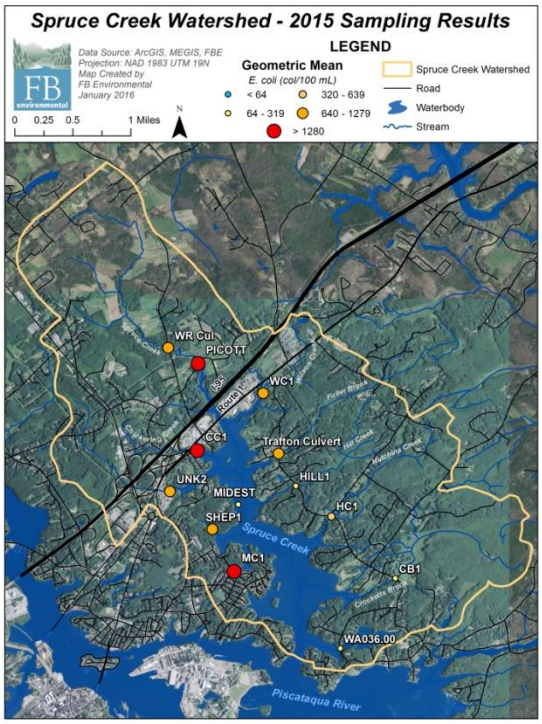
2015 REPORT SUMMARY

SPRUCE CREEK WATERSHED WATER QUALITY MONITORING REPORT

PROJECT OVERVIEW



Due to poor water quality, the estuarine portion of Spruce Creek is listed in Maine's 2012 Integrated Report as impaired under Category 4-A: Estuarine & Marine Water Impaired by Bacteria (TMDL completed) for elevated fecal bacteria. Spruce Creek is also identified by the Maine Department of Environmental Protection (Maine DEP) on the Threatened Stream and Marine Watersheds Priority List due to negative water quality indicators and its status as an MS4 priority water. Finally, the Spruce Creek watershed is listed by the Maine DEP as one of seven coastal watersheds in the State being "most at risk from development." Shellfish beds (DMR Closed Area 1-B) within Spruce Creek have been closed since July 2005.

Prior to 2009, there had been little data collected to determine areas of bacterial contamination in the watershed. To augment the available data, the Spruce Creek Association (SCA), the Town of Kittery, and FB Environmental Associates (FBE) began conducting studies of stormwater outfalls to the creek in 2009, with follow-up projects in subsequent years. These studies identified bacteria hotspots in the creek, allowing project partners to better focus future investigations and implementation efforts. In 2015, monitoring continued by sampling the tributaries to Spruce Creek and analyzing new and existing data from these locations. DNA analyses were performed on tributary samples to identify the primary bacteria source (human vs. animal). Data sondes were also deployed at the upper and middle estuaries along the main stem of Spruce Creek. Surface grab samples were collected for chemical analyses. This project also included the development and implementation of an USEPA-approved Quality Assurance Project Plan (QAPP) for water quality monitoring in the Spruce Creek watershed for 2015-2016.

FINDINGS

- Overall, wet weather produced high bacteria counts at sampling locations throughout the watershed in 2015. Many of these locations experienced their highest recorded bacteria counts when compared to historical data. 2015 was a very dry summer, so wet weather events likely produced a large "flushing" of bacteria that had accumulated on the landscape during the dry periods.
- **CC1** (Chickering Creek outlet), **PICOTT** (upper Spruce Creek estuary), and **MC1** (Mill Pond Road/Manson Avenue drainage) exceeded the State criteria for both single sample and geometric mean for all samples in 2015. These three sites also had consistently-high bacteria in both wet and dry weather.
- High bacteria counts during dry weather at **MC1** may be a result of human waste from an unknown source. Smoke tests from 2014 indicated a potential problem with the condition of the sewer line upstream of this area. Inspection of a nearby manhole by Kittery Sewer Department in January 2016 did not indicate any leaks or other issues.

- **PICOTT** bacteria counts may be related to a nearby unnamed tributary with surrounding agricultural land use and wildlife. DNA analysis indicated Canada geese as a potential source, with no human source genetic markers. However, malfunctioning septic systems in the nearby residential neighborhoods may also be contributing to high bacteria counts during dry weather.
- Among the Spruce Creek main stem sites (**WR Cul** (Wilson Road culvert across Spruce Creek), **PICOTT**, and **MIDEST** (middle estuary)), **PICOTT** had the highest geometric mean for fecal coliform and *E. coli*. Though **MIDEST** exceeded the geometric mean criteria, only one sample exceeded the single sample criteria.
- Bacteria at **UNK2** (unnamed tributary behind Kittery Estates)**, WA036.00** (Barter's Creek), **Trafton Culvert** (Fuller Brook), and other sites along Haley Road **(HILL1, HC1, CB1)** were likely linked to stormwater runoff during wet weather in 2015, though malfunctioning septic systems may be an underlying contributor at **Trafton Culvert**. DNA analysis indicated canine sources of bacteria for **UNK2, Trafton Culvert**, and **WA036.00**, which may come from pet waste in these residential neighborhoods.
- Analysis of all historical data highlighted areas of concern in the watershed, several of which were apparent in the 2015 data. The Mill Pond Road/Manson Avenue (**MC1**) area, Chickering Creek drainage (**CC1**), and the upper Spruce Creek estuary (**PICOTT** and nearby sites) areas stood out as high priority sites with consistently-high bacteria counts across many years of sampling.
- Continuous *in situ* monitoring at **PICOTT** (upper estuary) and **MIDEST** (middle estuary) show that low dissolved oxygen is a consistent issue for both sites throughout the late summer and early fall. **PICOTT** also continues to show high nutrients (both nitrogen and phosphorus) and high biological oxygen demand (BOD) at concentrations indicative of human-derived pollution.

NEXT STEPS

1. **Investigate sources of bacteria in the Mill Pond Road/Manson Avenue area (MC1), including:**
    a. Conduct door-to-door septic surveys for any remaining septic systems in the Mill Pond Road/Chickadee Lane area (MC1). Most of this neighborhood is served by town sewer.
    b. Continue follow-up dye tests of residential properties in the Manson Avenue neighborhood from 2014 smoke tests. Additionally, conduct dye testing in areas of potential cross-connections (where sewer and stormwater pipes physically cross underground).
    c. Monitor any further investigative work related to the elevated manhole (connected to the force main) immediately upstream of MC1; investigations by the Kittery Sewer Department in January 2016 found no evidence of fecal contamination or leaks from this infrastructure, but additional follow-up work may be forthcoming.
2. **Assess potential sources of bacteria to PICOTT and the unnamed tributary along Picott Road. This should include consideration of agricultural, wildlife, and human sources of bacteria.**
    a. Use microbial source tracking to further pinpoint the source of bacteria to the unnamed tributary by also testing for bovine (cow) DNA.
    b. Work with local farmers to install agricultural BMPs, including increasing the width of vegetative stream buffer and minimizing use of manure, if currently used. The Town of Kittery has indicated that one of the farms may become land trust property in the near future (J. Kellogg, Kittery Shoreland Resource Office, pers. comm.), which may change the land use in this area.
    c. Investigate locations along Picott Road near the culvert to install stormwater BMPs that treat road runoff.

d. Consult the septic system database (currently in development) for septic age and pump out history for residential properties in the area. Conduct follow-up door to door surveys, if other sources cannot be linked to bacteria in the Picott Road area (this neighborhood is a lower priority for septic surveys than other neighborhoods).

3. **Monitor any potential changes to bacteria loads at CC1, as many of the residences in the Chickering Creek drainage are set to discontinue private septic or overboard discharges and will be connected to Town sewer beginning in spring 2016.**

4. **Address stormwater runoff throughout the watershed, possibly using a grant from Maine DEP that was awarded to the Town to continue Phase IV implementation. Recommendations include:**

   a. Target neighborhoods around Trafton Culvert (Trafton Lane/Parsonage Way/Cedar Drive/Ash Lane) for "residential socials" on proper pet waste disposal and septic system maintenance.
   b. Install proper pet waste disposal signage near WA036.00; residents frequently walk pets along Crockett's Neck Road, which separates Barter's Creek from Spruce Creek at this site.
   c. Install stormwater BMPs to treat bacteria near Chickering Creek (CC1) and Wilson Creek (WC1).

5. **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.**

   a. Redeploy data sondes at the upper and middle estuary sites in 2016 for at least August and September.
   b. Continue to collect at least three sets of surface grab samples for key water quality parameters at the upper and middle estuaries.
   c. Continue to collect bacteria samples at major tributary sites, particularly those sites with consistently-high bacteria counts and/or with near-future changes to land use. This could be aided by the reactivation and expansion of the Spruce Creek Association Volunteer Monitoring Program.

Kittery Harbormaster, Derek Jacobs, boating up Spruce Creek to the middle estuary site (left). A sunny sampling day at the upper estuary site along Picott Road (right).

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PROJECT OVERVIEW

The Spruce Creek watershed covers 9.6 square miles in the Towns of Kittery (8.6 square miles) and Eliot (1 square mile), Maine. Spruce Creek is fed by seven freshwater streams (Wilson Creek, Fuller Brook, Hill Creek, Hutchins Creek, Chickering Creek, Barter's Creek, and Crockett's Brook) before it empties into the Piscataqua River just 1.5 miles north of where the Piscataqua River meets the Gulf of Maine. About 3 square miles of the downstream portion of Spruce Creek is estuarine (tidally-influenced) and consists of high salt marsh, ledge, and mud flats. The freshwater portion of Spruce Creek is classified as Class B and the estuary portion is classified as Class SB by the State of Maine, as mandated under the Federal Clean Water Act. Class SB marine waters are required to meet water quality standards to support the designated uses of recreation, such as swimming, boating, fishing, and the harvesting of shellfish.

Land cover near the shoreline of Spruce Creek is characterized by a mix of residential and commercial development. Spruce Creek crosses under Interstate 95 and Route 1, which serves as a transportation corridor to the Kittery Premium Retail Outlets. The western portion of the Spruce Creek watershed is largely high-density residential serviced by Town sewer. The eastern and northern portion of the watershed is mostly rural residential serviced by private septic systems often on marginal soils, with some high-density commercial areas (i.e., Kittery outlets). These developed areas may harbor unbuffered impervious surfaces, fertilized lawns, potentially-faulty sewer lines or septic systems, and unmanaged pet or farm animal waste that contribute pollutants in stormwater runoff to Spruce Creek.

Due to poor water quality, the estuarine portion of Spruce Creek is listed in Maine's 2012 Integrated Report as impaired under Category 4-A: Estuarine & Marine Water Impaired by Bacteria (TMDL completed) for elevated fecal bacteria. Spruce Creek is also identified by the Maine Department of Environmental Protection (Maine DEP) on the Threatened Stream and Marine Watersheds Priority List due to negative water quality indicators and its status as an MS4 priority water. Finally, the Spruce Creek watershed is listed by the Maine DEP as one of seven coastal watersheds in the State being "most at risk from development." Shellfish beds (DMR Closed Area 1-B) within Spruce Creek have been closed since July 2005.

In conjunction with FBE, the Maine DEP, and the USEPA, the Town of Kittery funded the development of a USEPA-approved Quality Assurance Project Plan (QAPP) for their bacteria monitoring program in the Spruce Creek watershed. With this approved QAPP, the Town was able to receive matching Section 319 funds from the USEPA and the Maine DEP. This QAPP was approved for 2015-2016 monitoring.

Watershed-scale bacteria monitoring has been in place since 2009 in the Spruce Creek watershed. This monitoring is designed to identify suspected illicit discharges and sources of fecal contamination and prioritize hotspots for remediation. The results will be used to assist future monitoring efforts and continue to locate target areas for bacterial-source mitigation. The Spruce Creek Restoration Project in currently in Phase IV of Section 319 funding, and many management practices have been implemented throughout the watershed. As these remediation efforts are now underway, these data may be used to assess the trajectory of any changes in bacterial counts. Further work may be needed to track the source of bacteria in additional hotspot areas. These efforts will provide important economic and public health benefits for the communities within the Spruce Creek watershed.

METHODOLOGY

FBE staff, with occasional assistance from local volunteer Kristina and Rich DeMarco, conducted *E.coli* bacteria sampling during three wet weather and three dry weather sampling events at 12 monitoring locations throughout the Spruce Creek watershed within an hour of low tide between July and November 2015 (Figures 1 and 2). These locations were selected based on their status as tributaries to Spruce Creek and from priority "hotspot" sites identified during previous bacteria sampling and canine detection efforts (2009-2014). The middle estuary was also sampled for *E.coli* six times during in-field maintenance of sondes by FBE staff or with the help of local volunteer,

Rich DeMarco. A new location was added in 2015 at an unnamed stream that passes through Roger's Park and empties into Shepherd's Cove. Residents often walk their dogs in the park. Dissolved oxygen (DO), temperature, and salinity data were also collected during sampling events at each location using an YSI ProODO meter and a refractometer. Bacteria collection was conducted in accordance with methods outlined in the QAPP. A more detailed discussion of QAPP deviations is provided in Appendix A.

Additional samples were collected for DNA analysis during one wet (8/11/2015) and one dry (8/31/2015) weather event. DNA analysis can identify the primary bacteria source based on genetic markers in the bacterial DNA. This analysis was conducted by Dr. John Bucci at the University of New Hampshire. Samples were tested for the presence of human, canine, and avian (Canada goose) bacterial DNA markers.

Bacteria samples were analyzed for *E. coli* at Nelson Analytical Water Testing Laboratory in Kennebunk, Maine. Though Enterococci is typically used as an indicator of the presence of fecal material in brackish/marine waters (such as the main channel of Spruce Creek), all monitoring sites throughout the Spruce Creek watershed are tested for *E. coli* (typically used for freshwater environments) to allow comparison with historical data. In Maine, the State water quality criteria for *E. coli* is 236 col/100 mL for a single grab sample and 64 col/100 mL for the geometric mean of multiple samples.

FBE also conducted baseline continuous and discrete water quality monitoring of the estuarine portion of Spruce Creek at the upper and middle estuaries in 2015. Two data sondes (YSI 6920), along with DIVER water level loggers, were deployed in Spruce Creek at the middle and upper estuary stations for 95 days from 8/7/15 to 11/10/15. The sondes monitored for dissolved oxygen (saturation and mg/L), temperature, relative water depth, pH, turbidity, and specific conductivity at 15 minute intervals.

The middle estuary sonde was secured to a metal eel trap using cable ties, with the sensor end sticking slightly outside of the trap; 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 significant drift. The upper estuary sonde was 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 crate to secure the sonde and hide it from public view.

Each sonde was replaced with a freshly-calibrated sonde on 9/10/15 and 10/8/15, so that the retrieved sondes could be taken back to the safety of the office for proper post-calibration checks. The sonde at the middle estuary was found highly biofouled and covered in marine tunicates on both the sonde casing and sensors on 9/10/15, but was found with only minor algae and silt coating on the sensors on 10/8/15 and 11/10/15. The sonde at the upper estuary was found with minor to moderate algae and silt coating on the sensors on 9/10/15, 10/8/15, and 11/10/15. Overall, the sondes functioned well with minimal data interferences from biofouling. The DIVER water level logger at the middle estuary malfunctioned after 10/7/15; the DIVER water level logger at the upper estuary malfunctioned during the entire deployment period.

Three sets of grab samples were also collected (8/7/15, 9/10/15, 10/8/15) at the middle and upper estuaries and sent to Katahdin Analytical Services in Scarborough, ME for various analyses (nitrate-nitrite, total phosphorus, total suspended solids, biological oxygen demand, total Kjeldahl nitrogen, and total organic carbon). Six sets of grab samples were also collected for fecal coliform on 8/7/15, 9/10/15, 10/8/15, 10/26/15, 11/6/15, and 11/10/15 at both sites. All samples were collected within 2 hours of dead low tide. It is important to note that grab samples are a very limited "snapshot" of the water quality of Spruce Creek. Developing a more comprehensive sampling program in Spruce Creek for multiple parameters is recommended to determine the variation in water quality over time.

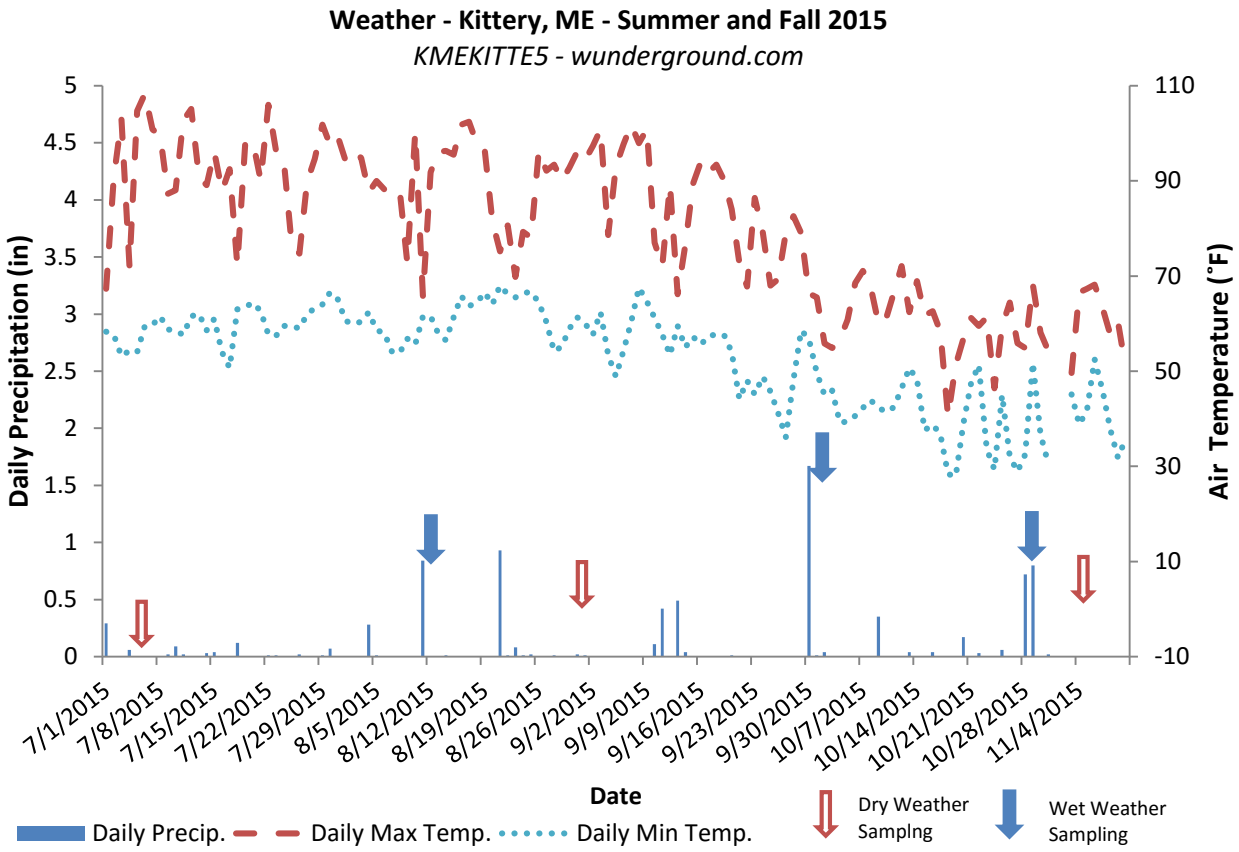

FIGURE 1. Daily high and low air temperature and precipitation data from July – November 2015 with tributary sampling dates indicated by arrows. PICOTT was sampled for *E. coli* on 7/6/15, 8/7/15, 8/11/15, 8/31/15, 9/10/15, 9/30/15, and 10/8/15. MIDEST was sampled for *E. coli* on 8/7/15, 9/10/15, 10/8/15, 10/26/15, 11/6/15, and 11/10/15. Data were retrieved from Weather Underground for Kittery, ME (KMEKITTE5).

RESULTS

2015 TRIBUTARY SAMPLING

For 2015 bacteria sampling in the Spruce Creek watershed, *E. coli* concentrations ranged from <1 to >24,196 col/100mL, which spans the range of the laboratory's detection limits for both high and low counts (Table 1). For most sampling events, the maximum detection limit was 2,420 col/100mL, but samples on 9/30/15 were diluted in the lab to expand the detection range to 24,196 col/100mL. Bacteria exceeded the State water quality criterion of 236 col/100mL for single samples in the majority of samples, particularly during wet weather. Geometric means ranged from 100 to 3,437 col/100mL, exceeding the State water quality criterion of 64 col/100mL in all cases. Refer to Tables 1 and 2 and Figure 2 for the following results:

- CC1, PICOTT, and MC1 exceeded the State criteria for both single sample for all samples and geometric mean in 2015.
- Of the 12 sites, MC1 had the highest geometric mean at 3,437 col/100mL, followed by PICOTT and CC1 at 1,886 col/100mL and 1,501 col/100mL, respectively. These three sites had consistently-high bacteria counts in both wet and dry weather. UNK2 and WR Cul also had notably-high geometric means at 1,201 col/100mL and 1,170 col/100mL, respectively.
- Two of 12 sites (CB1 and HILL1) had elevated bacteria levels above the State criterion for single samples on wet sampling events only.

- Ten of 12 total sites had elevated bacteria levels above the State criterion for single samples on both wet and dry sampling events.
- Among the Spruce Creek main stem sites (WR Cul, PICOTT, and MIDEST), PICOTT and WR Cul had the highest geometric means for both fecal coliform (Table 2) and *E. coli*. Though MIDEST exceeded the geometric mean criterion, only one sample exceeded the single sample criterion.

TABLE 1. *E. coli* (col/100mL) results and geometric means for all sampling locations within the Spruce Creek watershed from July - November 2015.

		E. coli (col/100mL)						
Sample ID	Waterbody	7/6/15 DRY	8/11/15 WET	8/31/15 DRY	9/30/15[§] WET	10/29/15 WET	11/4/15 DRY	2015 Geometric Mean
CB1	Crockett's Brook	150	>2,420	118	9,804	>2,420	<1	282
CC1	Chickering Creek	261	>2,420	1,986	4,352	>2,420	866	1,501
HC1	Hutchins Creek	548	>2,420	78	285	>2,420	36	370
HILL1	Hill Creek	32	>2,420	23	1,396	1,553	3	150
MC1	Mill Cove Drainage	1,986	>2,420	>2,420	>24,196	>2,420	>2,420	3,437
PICOTT	Spruce Creek	411	>2,420	>2,420	2,489	--	--	1,886*
SHEP1	Rogers Park Drainage	118	>2,420	n.f.	n.f.	1,553	>2,420	1,018^
Trafton Culvert	Fuller Brook	93	>2,420	>2,420	9,208	>2,420	59	946
UNK2	Unnamed stream	78	>2,420	1,414	>24,196	>2,420	192	1,201
WA036.00	Barter's Creek	45	>2,420	452	41	19	26	100
WC1	Wilson Creek	219	>2,420	>2,420	9,208	>2,420	19	903
WR Cul	Spruce Creek	179	>2,420	>2,420	5,475	>2,420	185	1,170
Sample ID	Waterbody	8/7/15 DRY	9/10/15 DRY	10/8/15 DRY	10/26/15 DRY	11/6/15 DRY	11/10/15 DRY	
MIDEST	Spruce Creek	153	1,986	106	39	14	21	88

Gray cells indicate an exceedance of Maine DEP water quality standard for E. coli*; 236 colonies/100mL for single samples and 64 colonies/100mL for geometric means. "n.f." = no flow. "--" = not visited on date. Samples <1 were calculated using 0.5 col/100mL.*

[§]Based on previous wet weather sampling, samples collected on this date were diluted in the lab to expand the detection range.

*PICOTT geomean also includes samples taken during dry weather on 8/7/2015, 9/10/2015, 10/8/2015 (all >2420).

^ SHEP1 geomean only includes four sampling events due to low flow (Maine DEP recommends six sampling events).

TABLE 2. Fecal coliform results, geometric means, and 90th percentile for main stem sampling locations within Spruce Creek from August - November 2015.

		Fecal coliform (col/100mL)							
Sample ID	Waterbody	8/7/15 DRY	9/10/15 DRY	10/8/15 DRY	10/26/15 DRY	11/6/15 DRY	11/10/15 DRY	2015 Geometric Mean	2015 90th percentile
MIDEST	Spruce Creek	<10	30	<10	20	<10	10	10	25
PICOTT	Spruce Creek	78	230	40	270	40	100	96	250

Gray cells indicate an exceedance of Maine DEP water quality criteria for fecal coliform; 88 col/100mL for geometric mean, 163 col100mL for 90th percentile. Samples <10 col/100mL were calculated using 5 col/100mL.

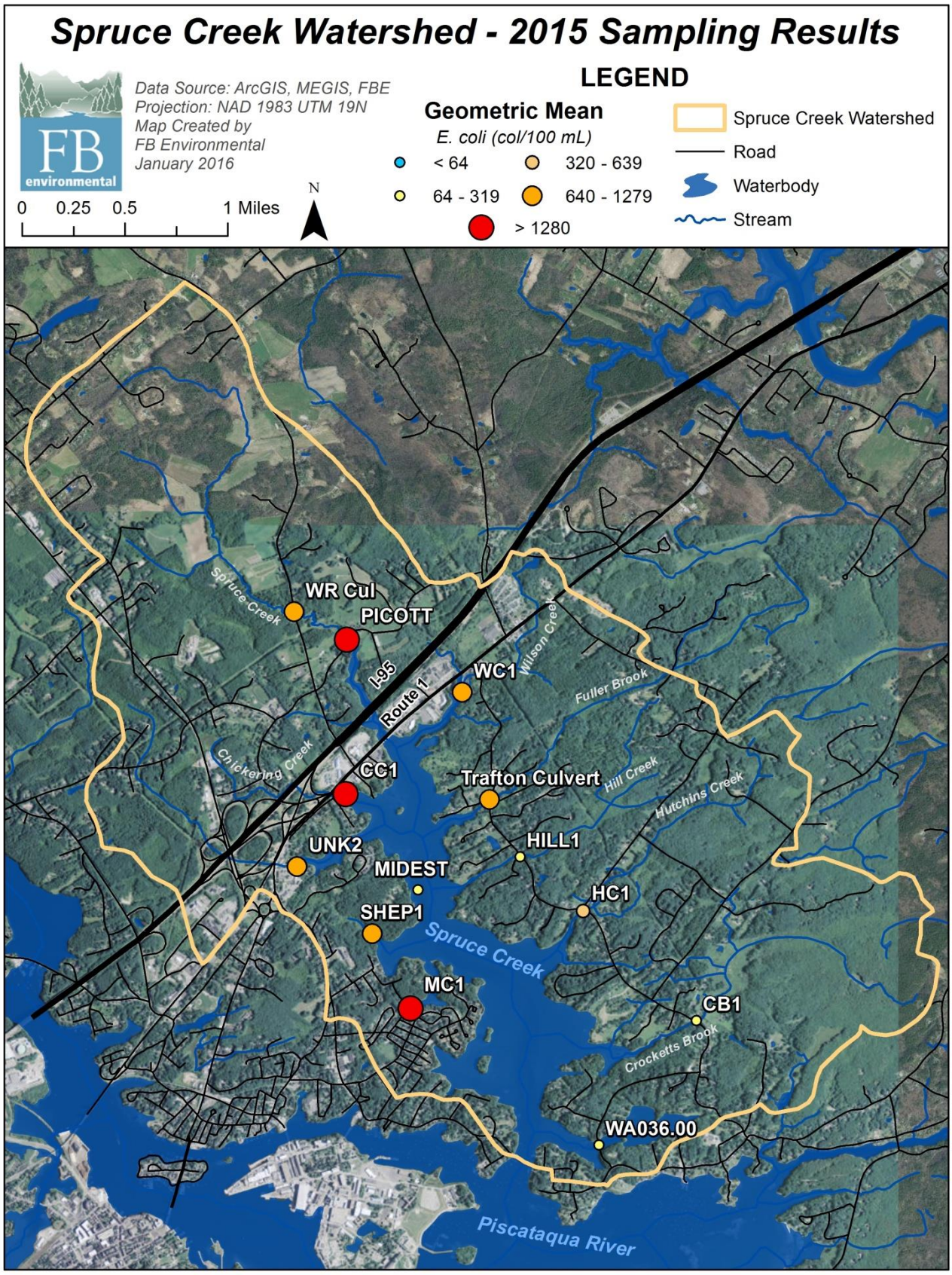

FIGURE 2. Sampling locations and bacteria concentrations (geometric means in col/100mL) for bacteria sampling in the Spruce Creek watershed from July – November 2015. SHEP1 geometric mean only includes four sampling events due to low flow (Maine DEP recommends six sampling events for geometric mean calculation).

DNA analysis from both wet and dry weather sampling generally supported patterns observed in bacteria monitoring, with more samples positive for bacterial DNA during wet weather and at sites with higher bacteria counts (Table 3). MC1 and CC1, with high bacteria counts during both wet and dry weather, were positive for human bacteria sources in both types of weather. Similarly, the Trafton Culvert site (Fuller Brook) was positive for canine bacteria sources in wet and dry weather. Canine and goose bacteria sources were more frequently detected during wet weather, when overland flow is likely to pick up bacteria from feces left on the landscape. Additionally, human bacteria sources were detected at several sites only during wet weather (WR Cul, WC1, CB1).

TABLE 3. *E. coli* (col/100mL) and DNA analyses results for sampling locations within the Spruce Creek Watershed in 2015.

		2015 Geometric Mean			2015 DNA Analysis	
Site ID	Waterbody	Overall	Wet	Dry	8/11/15 WET	8/31/15 DRY
CB1	Crockett's Brook	282	3,858	21	Human, Goose	
CC1	Chickering Creek	1,501	2,943	766	Human	Human
HC1	Hutchins Creek	370	1,186	115		
HILL1	Hill Creek	150	1,738	13		
MC1	Mill Cove Drainage	3,437	5,213	2,266	Human, Canine	Human
PICOTT*	Spruce Creek	1,886	2,454	1,698	Goose	
SHEP1^	Rogers Park Drainage	1,018	1,939	534		n.f.
Trafton Culvert	Fuller Brook	946	3,778	237	Canine	Canine
UNK2	Unnamed stream	1,201	5,213	277	Canine	
WA036.00	Barter's Creek	100	124	81	Canine	
WC1	Wilson Creek	903	3,778	216	Human	
WR Cul	Spruce Creek	1,170	3,177	431	Human	

Gray cells indicate an exceedance of Maine DEP water quality criterion for E. coli*; 64 colonies/100mL for geometric means. "n.f." = no flow.*
^ SHEP1 geomean only includes two wet and two dry events due to low flow (Maine DEP recommends six sampling events for geometric mean calculation).

A summary of water quality results taken during bacteria sampling is provided in Table 4. Water temperatures were slightly warmer within the main channel of Spruce Creek (PICOTT and WR Cul). Dissolved oxygen (DO) levels below water quality criteria at Crockett's Brook (CB1) may be a result of stagnation in the upstream segment feeding this culvert; this may also be the case at SHEP1 and WR Cul. Similarly, the plunge pool at the Hutchins Creek outfall (HC1) where DO was measured did not always have good flow. Low DO levels may threaten aquatic life within these tributaries.

TABLE 4. Summary of 2015 water quality data for sampling locations within the Spruce Creek watershed. Red text indicates values exceeding water quality criteria.

Sample ID	Waterbody	Temp(°C)	DO (%)	DO (mg/L)[1]	Salinity (ppt)
			Criteria		
		NA	*75 for freshwater, 85 for estuarine*	*7.0 for freshwater*	*NA*
CB1	Crockett's Brook	18.2	49	4.6	0
CC1	Chickering Creek[2]	18.6	79	7.4	3
HC1	Hutchins Creek	17.0	59	5.5	1
HILL1	Hill Creek	17.6	74	7.1	1
MC1	Mill Cove Drainage[2]	18.1	88	8.4	2
PICOTT	Spruce Creek[2]	20.7	60	7.9	16
SHEP1	Roger's Park Drainage	17.4	67	6.5	0
Trafton Culvert	Fuller Brook	17.7	71	6.9	1
UNK2	Unnamed stream[2]	18.3	80	7.5	1
WA036.00	Barter's Creek[2]	19.1	103	7.9	25
WC1	Wilson Creek[2]	19.3	85	7.8	9
WR Cul	Spruce Creek[2]	20.2	69	8.3	9

[1] Individual DO measurements corrected for the effects of salinity for salinity ≥ 10 ppt. (http://water.usgs.gov/software/DOTABLES/)
[2] Estuarine sites

HISTORICAL ANALYSIS OF TRIBUTARY DATA

2015 watershed monitoring focused on the tributaries to Spruce Creek and the main stem, many of which have been previously sampled or investigated. For all of the 2015 sites plus an additional site for a small tributary along Picott Road, all available data (2009 – 2015) were combined and the total geometric means for all data, wet weather, and dry weather were calculated (Table 5). Geometric means for each year are also presented.

- Overall geometric means ranged from 76 to 3,437 col/100mL.
- Geometric means for wet weather were generally higher than dry weather. A notable exception is Spruce Creek at the Picott Road crossing (PICOTT), where dry weather had higher bacteria counts than wet weather (though both were exceptionally high).
- For most sites, 2015 had the highest geometric mean of all years from 2009-2015. 2015 weather was characterized by long spells of dry weather followed by infrequent, but intense rain storms. When the rains came, exceptionally-high bacteria counts were recorded at most sites in the watershed, likely from stormwater flushing out an accumulation of waste and other pollutants from the landscape. It should also be noted that during one wet weather sampling event in 2015, samples were diluted in the lab to allow for a higher detection limit. This may be a confounding factor associated with the higher geometric means observed in 2015.
- All sites showed exceedances of the State criterion for the geometric mean of all data (2009-2015) and during all wet weather sampling events with the exception of the mid-estuary site (MIDEST), which was below the State criterion of 64 col/100mL.
- Among sites with more than one year of sampling data, PICOTT, Trafton Culvert, Picott Culvert, CC1, and WR Cul had the highest overall geometric means.

TABLE 5. *E. coli* (col/100mL) geometric mean results for sampling locations within the Spruce Creek watershed from 2009-2015. 2012 results are based on only two sampling dates.

Sample ID	Waterbody	2009	2011	2012	2013	2014	2015	2009-2015 Overall	2009-2015 Dry	2009-2015 Wet
CB1	Crockett Brook	99		34			282	133	38	1,221
CC1	Chickering Creek		282	136	402		1,501	490	252	1,330
HC1	Hutchins Creek	96		37			370	166	66	623
HILL1	Hill Creek			211			150	175	21	1,042
MC1	Mill Cove						3,437	3,437	2,266	5,213
MIDEST	Spruce Creek				11	109	88	69	70	58
PICOTT	Spruce Creek					1,848	1,886	1,870	1,987	1,559
Picott Culvert	Unknown Tributary		1,093	856				958	893	1,073
SHEP1	Shepard's Hill Cove						1,018	1,018	534	1,939
Trafton Culvert	Fuller Brook		574	642			946	701	506	1,095
UNK2	Unknown Tributary						1,201	1,201	277	5,213
WA036.00	Barter's Creek			318			100	187	171	207
WC1	Wilson Creek						903	903	216	3,778
WR Cul	Spruce Creek			477			1,170	722	401	1,434

Gray cells indicate an exceedance of Maine DEP water quality criterion for E. coli*; 64 colonies/100mL for geometric means.*

To gather a spatial, watershed-scale perspective from the last six years of data, geometric means of all available data from 2009-2015 for outfalls and tributary sampling sites (seeps and catch basins excluded) were calculated and mapped (Figure 3). 2015 sampling sites are labeled for reference.

Some areas of concern from the 2009-2015 data are similar to those evident from the 2015 data alone: the Mill Creek/Manson Avenue drainage (near MC1) and upper estuary portion of Spruce Creek (PICOTT). The outlet of Chickering Creek (CC1) is still high, but the overall geometric mean from 2009-2015 is not as high as 2015 data alone. However, an upstream site had very high bacteria counts (from a 2013 drainage investigation) and should not be discounted.

The map also serves as a reminder of other previously-identified areas of high bacteria concentrations. In particular, outfalls in the Admiralty Village area (AV2 and AV3, south of MC1) and an unnamed tributary that drains to Spruce Creek just downstream from the PICOTT site. These areas were investigated and sampled in 2012-2013, though some actions have been taken in the Admiralty Village area to address catch basins draining to the AV2 and AV3 outfalls. Follow-up sampling in future monitoring seasons would provide an updated picture of the bacteria inputs in these areas.

Canine detection data from 2012-2014 were also mapped (Figure 4). Canine services were used in these years to detect the presence of human fecal contamination. While human fecal contamination seems to be a factor throughout the Manson Avenue/Admiralty Village area, high bacteria counts in the other survey areas are not as clear as to their source.

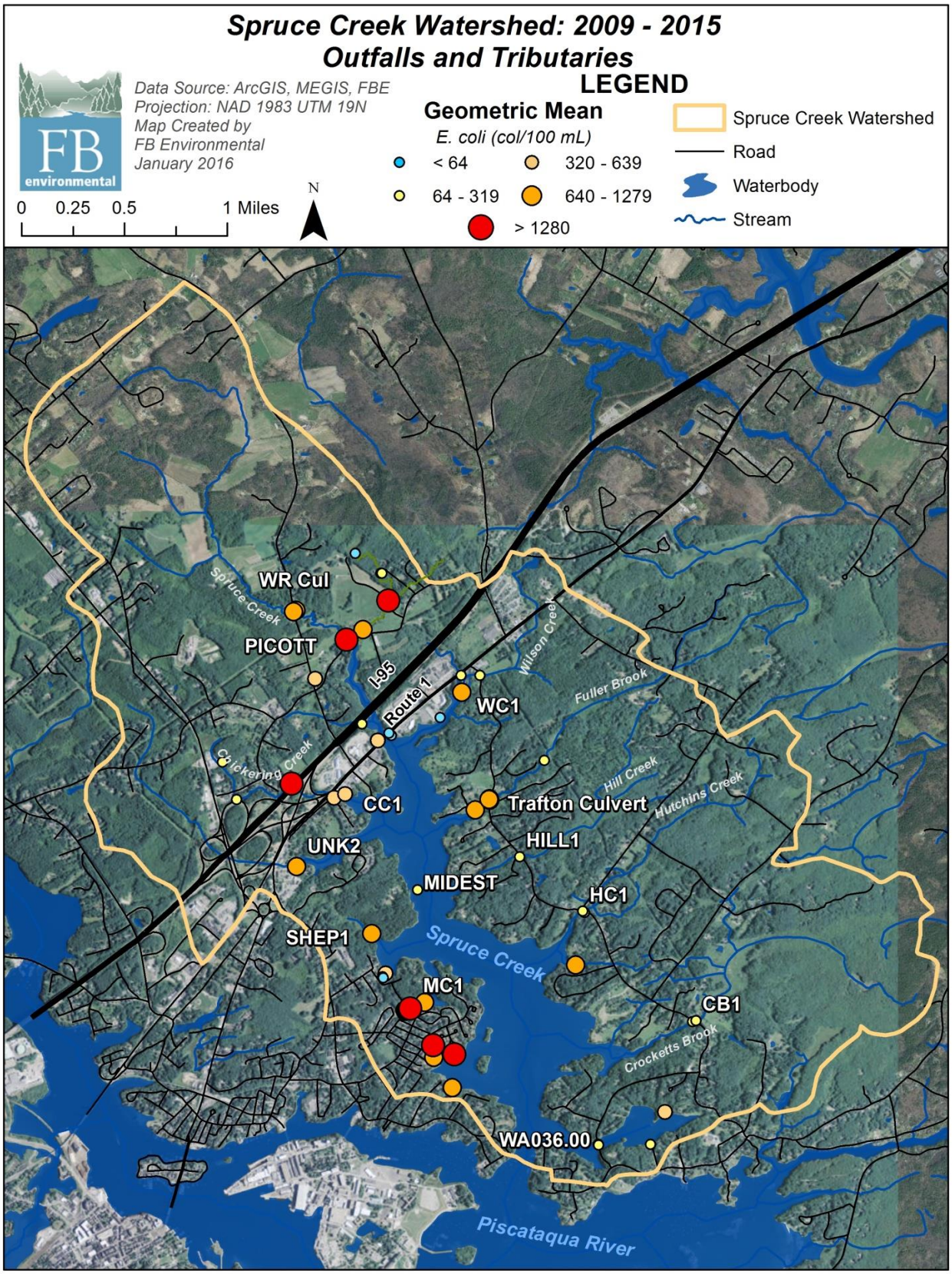

FIGURE 3. Sampling locations and bacteria concentrations (geometric means in col/100mL) for bacteria sampling of outfalls and tributaries in the Spruce Creek watershed from 2009 - 2015. The map does not include outfalls which were investigated but never sampled (typically due to lack of flow), catchbasins, or seeps. 2015 sampling sites are labeled for reference.

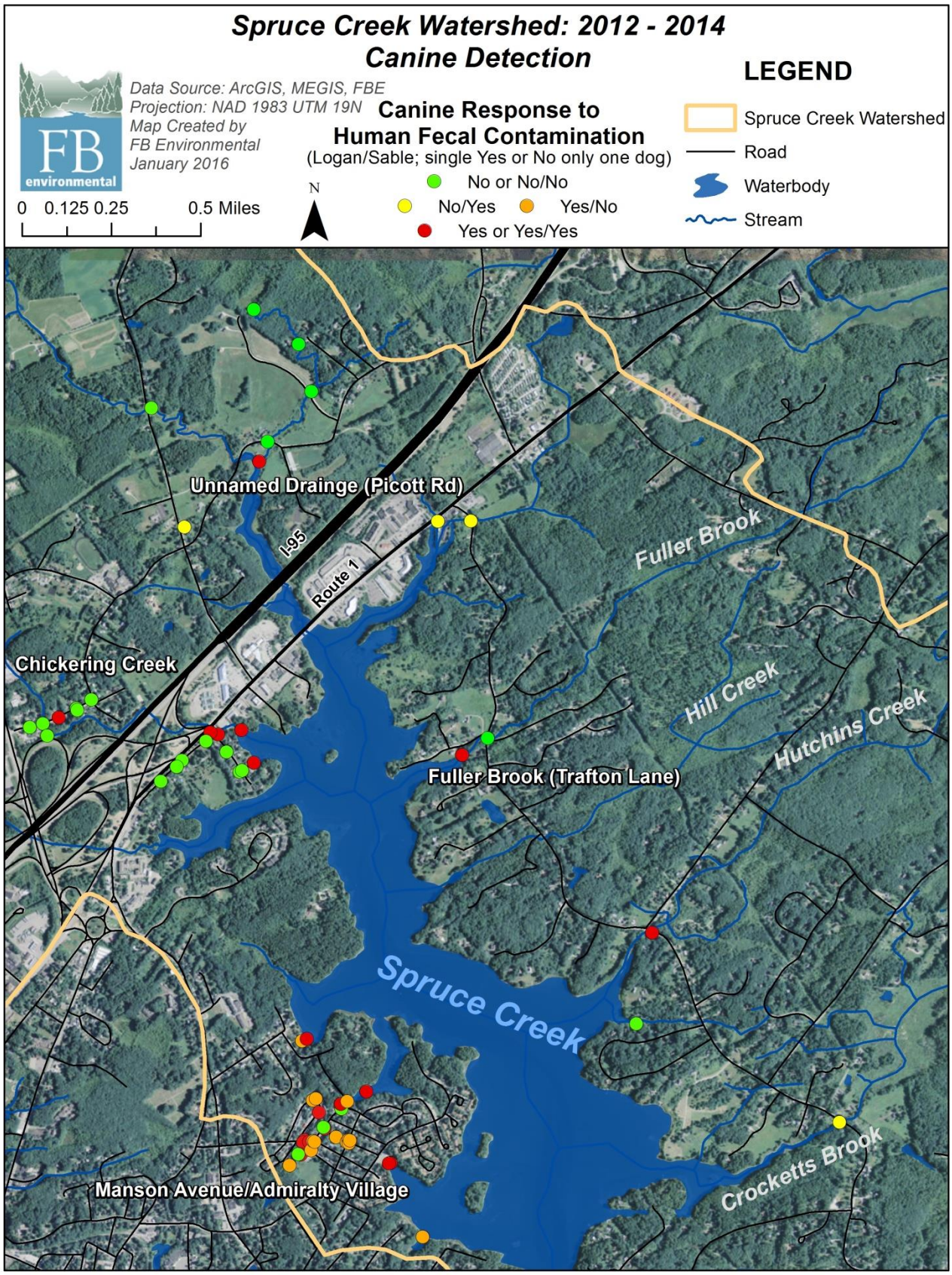

FIGURE 4. Canine detection of human fecal bacteria in the Spruce Creek watershed from 2012 – 2014.

2015 SONDE DEPLOYMENTS & WATER QUALITY SAMPLING RESULTS

The sondes measured the following parameters: water temperature (°C), dissolved oxygen (mg/L and % saturation), specific conductivity (mS/cm), relative water depth (m), turbidity, and pH (Figures 5 and 6). Relative water depth reflects a relative change in the depth of surface water and cannot be directly compared to other water depth data or considered in absolute terms. This parameter should only be used to interpret the occurrence of high and low tide. Refer to the 2014 water quality report for detailed definitions of water quality parameters. **Overall, results are consistent with monitoring results from previous years and show no trend either improving or degrading.**

The upper estuary of Spruce Creek experienced large swings in daily **DO** as DO saturation varied from 1% to 169%. Percent DO saturation fell below the State criteria of 85% for 61% of all readings at the upper estuary. The middle estuary of Spruce Creek also experienced swings in daily DO, which varied from 61% to 142%. Percent DO saturation fell below the State criteria of 85% for 31% of all readings at the middle estuary. DO should be monitored on a regular basis in Spruce Creek and, if possible, the use of sondes will provide the most comprehensive dataset. Low DO can result from many factors, including excess amounts of organic carbon and nutrients entering the Creek from freshwater sources.

Specific conductivity in the upper estuary of Spruce Creek varied from 2 to 49 mS/cm. Specific conductivity in the middle estuary of Spruce Creek varied from 40 to 49 mS/cm. Conductivity remains consistently-high at the middle estuary because it is more influenced by tides compared to the upper estuary where freshwater inputs dominate during low tide. It appears that precipitation dilutes specific conductivity at low tide at both stations when freshwater sources from the landscape are dominant.

pH at the upper estuary ranged from 6.8 to 8.1. pH at the middle estuary ranged from 7.8 to 8.2. pH generally becomes more basic at high tide when DO is high and more acidic at low tide when DO is low. This pattern is more evident at the upper estuary where low tides flush out water from adjacent marshes that carry hypoxic water (high organic content of marshes encourages rapid decomposition and consumption of oxygen). Decomposition occurs via respiration that releases CO_2 as O_2 is being consumed, which releases H^+ ions into the water as carbonic acid (H_2CO_3) dissociates in water (i.e., water becomes more acidic at low tide when DO is also low). The magnitude of change in DO and pH with each tidal cycle depends on the time of day; larger swings in DO and pH will occur when high tide peaks during the afternoon (photosynthesis active) and early morning (decomposition active).

Turbidity at the upper estuary ranged from 1-107 NTU. Turbidity at the middle estuary ranged from 0-59 NTU. Turbidity was more variable at the upper estuary likely due to the shallower deployment depth and proximity to the marsh above Picott Rd that flushes out organic content with each tidal cycle or precipitation event. Both sites showed increases in turbidity immediately following large rain events, which stir up sediment and organic matter in the water column.

Surface grab samples for chemical analyses and ProODO meter readings were also collected at the upper and middle estuary sites on three sample dates during in-field sonde maintenance (Tables 6 and 7). Refer to the 2014 water quality report for detailed definitions of water quality parameters.

Both **nitrate** and **nitrite** fell below laboratory's PQL of 0.05 mg/L, indicating natural conditions (<0.1 mg/L) at both the upper and middle estuaries. These results are better than 2014 at the upper estuary likely due to the lack of precipitation prior to each sample event. Sources of nitrogen are likely mobilized in stormwater runoff from paved areas or agricultural fields in the watershed or in rising groundwater tables that intercept septic systems during wet weather.

Total kjeldahl nitrogen (TKN) ranged from 0.49-0.82 mg/L and <0.25-0.36 mg/L at the upper and middle estuaries, respectively. All samples at the upper estuary exceeded the NHDES nutrient guidelines established for the Great Bay (<0.45 mg TN/L) to protect aquatic life.

Total phosphorus (TP) ranged from 80-130 µg/L and 40-55 µg/L at the upper and middle estuaries, respectively. TP is likely higher at the upper estuary (as also observed in previous years) because of the site's proximity to watershed sources compared to diluted sources downstream at the middle estuary.

Total suspended solids (TSS) ranged from 15-26 mg/L and 7.6-17 mg/L at the upper and middle estuaries, respectively. Field notes indicate that the upper estuary site was turbid with suspended silt and algae in late summer and early fall. These results are similar to previous years. Without any established criteria or guidelines for TSS, it is difficult to make conclusions about TSS.

Biological oxygen demand (BOD) fell below laboratory detection limit of 2.0 mg/L at both sites on all sampling dates except at the upper estuary on 9/10/15. BOD concentrations above 2.0 mg/L may indicate that pollution from industrial, residential, or agricultural wastes are impacting water quality and may cause decreases in available oxygen. These results are lower than previous sampling years.

Total organic carbon (TOC) ranged from 3.8-4.5 mg/L and 1.6-1.7 mg/L at the upper and middle estuaries, respectively. As measured in previous years, organic content is generally higher and more variable at the upper estuary compared to the middle estuary. These ranges are reasonable for New England surface waters. TOC is likely natural from wetlands, but also likely a mix of human-derived sources (e.g., detergents, fertilizers, and other chemical pollutants).

Water temperatures were generally a couple degrees warmer at the upper estuary compared to the middle estuary. DO fell below the State criteria of 85% on all sample dates at the upper estuary, while DO remained generally high or supersaturated at the middle estuary.

Upper estuary monitoring site at the Picott Road crossing.

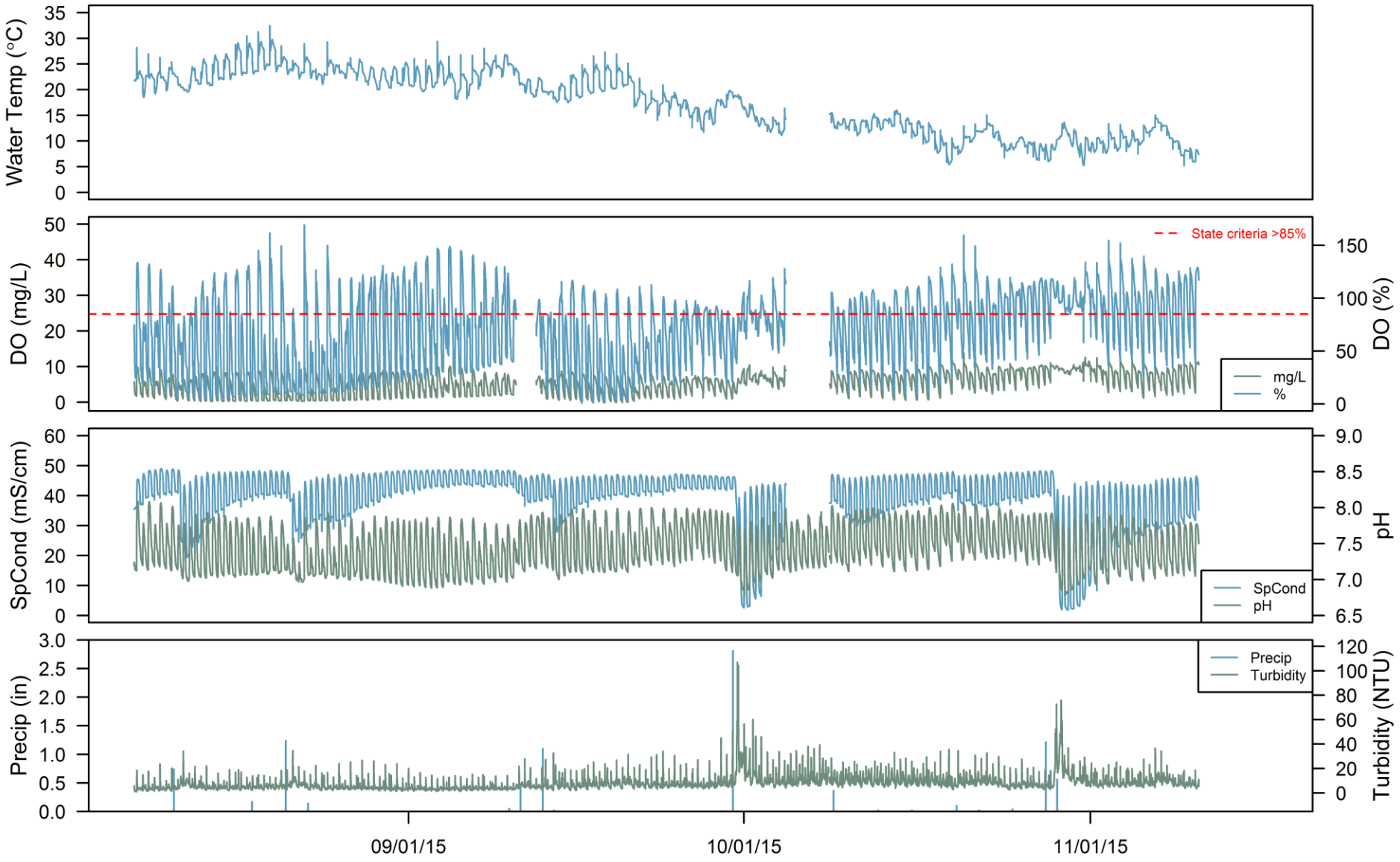

FIGURE 5. Continuous sonde data collected in the upper estuary of Spruce Creek at Picott Road.

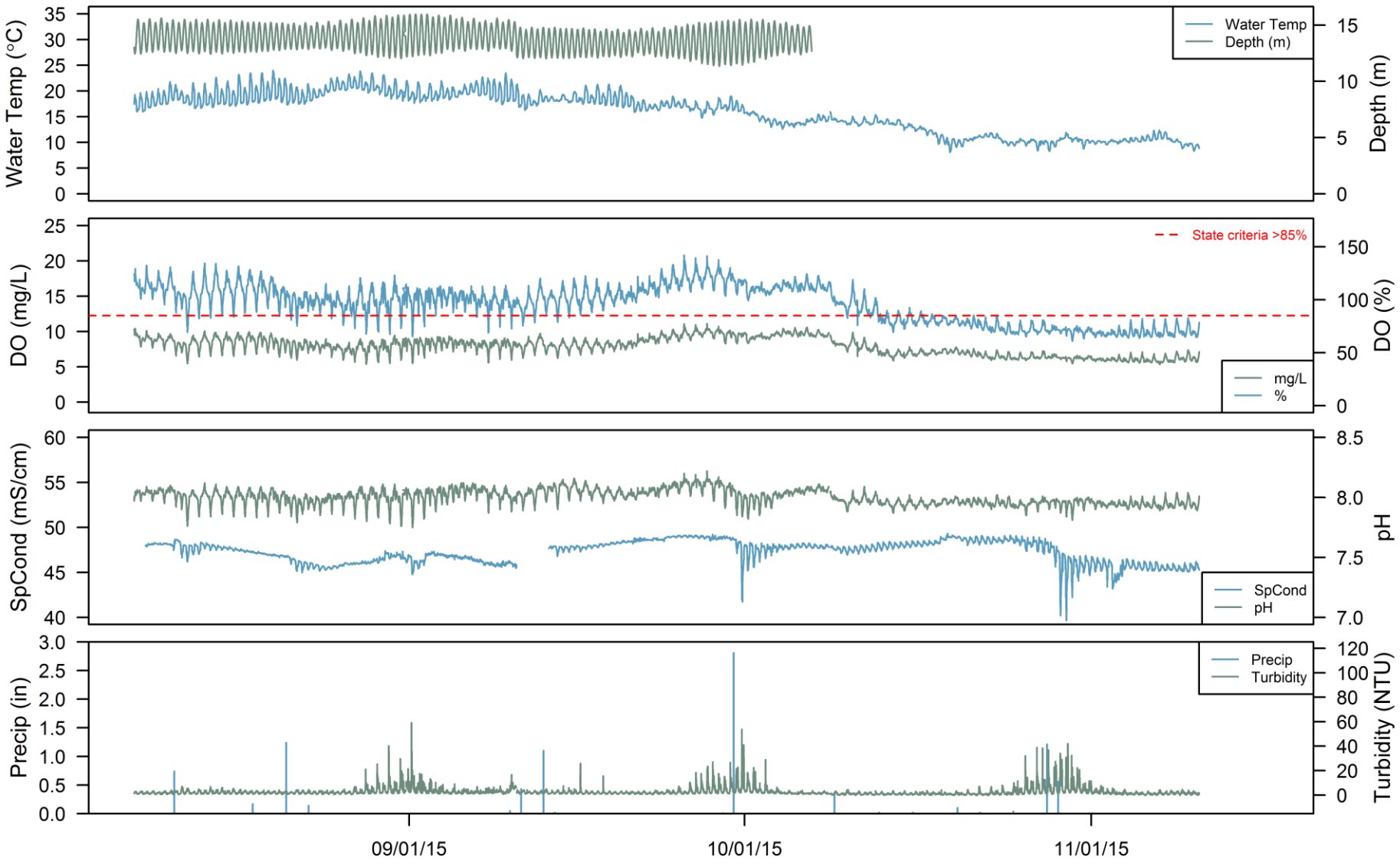

FIGURE 6. Continuous sonde data collected in the middle estuary of Spruce Creek.

TABLE 6. 2015 Spruce Creek upper estuary (at Picott Rd) water quality results from surface grab sampling (laboratory analyses) and in-field measurements using a YSI ProODO.

PARAMETER	8/7/15	9/10/15	10/8/15	PQL*
Precip (Prior 24 hrs) (in)	0.00	0.00	0.00	--
Precip (Prior 48 hrs) (in)	0.00	0.00	0.00	--
Precip (Prior 96 hrs) (in)	0.41	0.00	0.00	--
LABORATORY ANALYSES				
Nitrate-N (mg/L)	<0.05	<0.05	<0.05	0.05
Nitrite-N (mg/L)	<0.05	<0.05	<0.05	0.05
TKN (mg/L)	0.49	0.52	0.82	0.25
Total Phosphorus (mg/L)	0.080	0.130	0.080	0.005
TSS (mg/L)	15.0	20.0	26.0	4.0
BOD (mg/L)	<2.0	2.5	<2.0	2.0
TOC (mg/L)	4.5	4.4	3.8	1.0
IN FIELD MEASUREMENTS				
Water Temp (°C)	22.3	24.3	15.8	--
DO (%)	71.3	63.8	77.0	--
DO (mg/L)	6.2	5.3	7.7	--

*PQL = Practical Quantification Limit for Katahdin Analytical Services; the lowest concentration that the laboratory method can accurately estimate; greater than the method detection limit (MDL).

TABLE 7. 2015 Spruce Creek middle estuary water quality results from surface grab sampling (laboratory analyses) and in-field measurements using a YSI ProODO.

PARAMETER	8/7/15	9/10/15	10/8/15	PQL*
Precip (Prior 24 hrs) (in)	0.00	0.00	0.00	--
Precip (Prior 48 hrs) (in)	0.00	0.00	0.00	--
Precip (Prior 96 hrs) (in)	0.41	0.00	0.00	--
LABORATORY ANALYSES				
Nitrate-N (mg/L)	<0.05	<0.05	<0.05	0.05
Nitrite-N (mg/L)	<0.05	<0.05	<0.05	0.05
TKN (mg/L)	0.33	0.36	<0.25	0.25
Total Phosphorus (mg/L)	0.041	0.055	0.040	0.005
TSS (mg/L)	17.0	16.0	7.6	4.0
BOD (mg/L)	<2.0	<2.0	<2.0	2.0
TOC (mg/L)	1.6	1.7	1.6	1.0
IN FIELD MEASUREMENTS				
Water Temp (°C)	17.8	21.3	15.6	--
DO (%)	107.0	99.0	104.2	--
DO (mg/L)	10.2	8.8	10.5	--

*PQL = Practical Quantification Limit for Katahdin Analytical Services; the lowest concentration that the laboratory method can accurately estimate; greater than the method detection limit (MDL).

DISCUSSION

Bacteria data from 2009-2015 at most sites showed exceedances during both wet and dry weather in the Spruce Creek watershed. This indicates that bacteria are coming from a variety of sources, including stormwater runoff, malfunctioning septic systems, pet waste, and wildlife. Overall, bacteria counts were higher under wet weather conditions than under dry weather conditions, suggesting that the majority of pollution may come from stormwater runoff. As rainwater moves overland toward a waterbody, it picks up bacteria from various sources (e.g., pet waste, dumpsters, etc.) as well as other pollutants (e.g., nutrients from lawn fertilizers and sediment). This was particularly evident in 2015 when a long period of dry weather allowed accumulation of waste and other pollutants on the landscape, which were washed out during late summer and fall rains, resulting in exceptionally-high bacteria counts at most sites. Additionally, large precipitation events can raise the water table and intercept septic systems, flushing out bacteria and other pollutants to surface waters. High dry weather bacteria counts at some sites in conjunction with canine detection and DNA analyses also suggest that failing septic systems or leaky sewer lines may be significant contributors to fecal contamination. The following provides a discussion of possible bacteria sources for each sampling location and includes additional source-tracking information from historical smoke testing, DNA analysis, and canine detection.

MC1 – MILL CREEK/MANSON AVENUE/ADMIRALTY VILLAGE AREA

MC1 had the highest overall geometric mean in 2015, with alarmingly-high bacteria counts in both wet and dry weather. Other outfalls in this area (along Manson Avenue) have had high bacteria counts (see Figure 3). DNA analysis indicated human sources of bacteria in 2015, and canine detection in previous years indicated human fecal contamination as well. An aboveground sewer manhole is located on the north side of this creek, and a force main runs underneath the creek through this manhole. Kittery Sewer Department staff investigated the manhole in January 2016. A water sample from the manhole contained only 5 mpn/100mL of fecal coliform, and the force main showed no visual evidence of a leak future (J. Kellogg, Kittery Shoreland Resource Office, pers. comm.). However, smoke tests from 2014 indicated that there may be a leaky sewer connection upstream of this site as smoke was observed coming out of stormwater catch basins during a test of the sewer system (CB 1795). Additionally, nearby properties may still have private septic systems that have not been connected to the sewer line. The area around this site should be investigated further.

Sewer manhole visible to the right of MC1 sampling site. The Kittery Sewer Department found no evidence of malfunction during an investigation in January 2016.

PICOTT, WR CUL – UPPER ESTUARY AND WILSON ROAD CULVERT

This upper portion of the Spruce Creek estuary (PICOTT) had the second highest overall geometric mean in both 2015 alone and in combination with historical data (2014-15). WR Cul also had high bacteria counts, though to a lesser degree than the downstream PICOTT site. An unnamed tributary just downstream from PICOTT has also shown high bacteria counts in the past. Canine investigations of this tributary only indicated human fecal contamination in one location, and DNA analyses from PICOTT and WR Cul suggested Canada geese and humans as bacterial sources, respectively. As such, the source of these high bacteria counts may be a mix of both human and non-human (e.g., wildlife, domestic animals) sources. A large agricultural area is located in the drainage area of the unnamed tributary and upstream of WR Cul; runoff from these fields (either migratory geese or domestic animals) may be bringing bacteria to the tributary and ultimately to Spruce Creek. Spruce Creek is still tidal in the upper part of the estuary, so it is also possible that bacteria contributions from the unnamed tributary are incorporating with upstream flows (particularly at PICOTT) during high tides. Continuous data monitoring at PICOTT shows low dissolved oxygen throughout the late summer and early fall; surface grab sampling also shows elevated nutrients (both nitrogen and phosphorus) and high biological oxygen demand at concentrations indicative of human-derived or agricultural pollution.

MIDEST – MIDDLE ESTUARY

The middle estuary of Spruce Creek marginally exceeded State criteria for *E. coli* and met criteria for fecal coliform. Only a single sample collected during wet weather exceeded the single sample *E. coli* criterion. Although it is assumed that the high *E. coli* count in the middle estuary came from bacteria flushing from the upper estuary, multiple tributaries (e.g., Wilson Creek, Fuller Brook, Hill Creek, and Chickering Creek) just upstream of the middle estuary site may also be contributing to fecal contamination in the creek. Continuous data monitoring at MIDEST shows low dissolved oxygen throughout the late summer and early fall that is indicative of a productive system influenced by polluted runoff.

CC1 – CHICKERING CREEK

Chickering Creek had the third highest overall geometric mean in 2015; historical annual geometric means also exceeded the State criterion for *E. coli*, but to a lesser degree than in 2015. The creek showed high bacteria counts in both wet and dry weather, suggesting inputs from both stormwater (including outfalls near the intersection with Interstate 95) and potentially malfunctioning septic/sewer. Canine detection in 2013 also indicated human fecal contamination at scattered locations throughout the Chickering Creek drainage area, and DNA analysis in 2015 showed human-sourced bacteria in both wet and dry weather. An additional concern for this area is the large amount of filamentous green algae growing on the streambed. Though dissolved oxygen was only measured during the day, nighttime respiration by these algae may cause dissolved oxygen levels to drop at night, potentially affecting other aquatic organisms living in the creek. Most properties in the Chickering Creek drainage have private septic systems, which could be a source of both nutrients (stimulating algae growth) and fecal contamination. In 2016, most of this area will be connected to a new extension of the Town sewer line, eliminating many of the private septic systems and one of the few remaining overboard discharge sites in Kittery (B. Marchi, Kittery Code Enforcement Officer, pers. comm.).

Chickering Creek behind the Orvis Outlet. LEFT: Chickering Creek, looking towards the confluence with Spruce Creek. RIGHT: Close-up of green algae covering the creek bottom.

TRAFTON CULVERT – FULLER BROOK AND TRAFTON LANE/PARSONAGE WAY NEIGHBORHOODS

The geometric mean for the Trafton Culvert (Fuller Brook) site exceeded State criterion for *E. coli* in 2015, as well as for all historical data; these exceedances were mostly associated with wet weather. Previous canine detection indicated human fecal contamination only at a site further downstream from Trafton Culvert near the outlet, and DNA analysis from 2015 indicated canine sources of bacteria in both wet and dry weather. The upstream drainage of Fuller Brook is a residential area, which may be an ideal community for outreach on proper pet waste disposal. In the downstream portion of the brook and in the nearby Cedar Drive and Ash Lane neighborhoods (where septic records are incomplete), outreach on proper septic system maintenance or a septic survey of properties may also be appropriate.

WC1 – WILSON CREEK

Wilson Creek exceeded the State geometric mean criterion for *E. coli* in 2015; single sample exceedances were mostly associated with wet weather, which may be stormwater from nearby Route 1 and Haley Road. DNA analysis in 2015 indicated human sources of bacteria during wet weather. Canine DNA sources were not detected in this area; the nearby motel had signage reminding guests to pick up after their pets. However, pet waste was observed on several occasions in the marsh area between Wilson Creek and a drainage from Route 1.

SHEP1, UNK2 – UNNAMED TRIBUTARIES TO SPRUCE CREEK AND SHEPHERD'S HILL COVE

These two tributaries on the western shore of Spruce Creek exceeded the State geometric mean for *E. coli* during both wet and dry weather in 2015, though most individual dry weather samples fell below the single sample criterion of 236 col/100mL. DNA analysis only detected canine sources of bacteria from UNK2, while no sources (human, canine, or goose) were detected at SHEP1; fecal contamination may be coming from other wildlife waste at SHEP1.

Tributary through Rogers Park, heading towards Shepherd's Hill Cove (SHEP1).

HILL1, HC1, CB1, WA036.00 – TRIBUTARIES ALONG HALEY ROAD AND CROCKETT'S NECK ROAD

Geometric means for these sites exceeded State criterion for *E. coli* both in 2015 and historically, but high bacteria counts were found more prevalent during wet weather, likely related to stormwater runoff. Significant road runoff was observed during wet weather sampling, in some cases eroding the slope around outfalls by flowing directly off the road. Additionally, DNA analysis indicated canine sources of bacteria during wet weather at WA036.00 and human and goose sources at CB1. These tributaries are located in residential areas, which may be appropriate for signage about proper disposal of pet waste, as well as outreach on proper septic system maintenance.

NEXT STEPS

1. **Investigate sources of bacteria in the Mill Pond Road/Manson Avenue area (MC1), including:**
    a. Conduct door-to-door septic surveys for any remaining septic systems in the Mill Pond Road/Chickadee Lane area (MC1).
    b. Continue follow-up dye tests of residential properties in the Manson Avenue neighborhood from 2014 smoke tests. Additionally, conduct dye testing in areas of potential cross-connections (where sewer and stormwater pipes physically cross underground).
    c. Monitor any further investigative work related to the elevated manhole (connected to the force main) immediately upstream of MC1; investigations by the Kittery Sewer Department in January 2016 found no evidence of fecal contamination or leaks from this infrastructure, but additional follow-up work may be forthcoming.
2. **Assess potential sources of bacteria to PICOTT and the unnamed tributary along Picott Road. This should include consideration of agricultural, wildlife, and human sources of bacteria.**
    a. Use microbial source tracking to further pinpoint the source of bacteria to the unnamed tributary by also testing for bovine (cow) DNA.
    b. Work with local farmers to install agricultural BMPs, including increasing the width of vegetative stream buffer and minimizing use of manure, if currently used. The Town of Kittery has indicated that one of the farms may become land trust property in the near future (J. Kellogg, Kittery Shoreland Resource Office, pers. comm.), which may change the land use in this area.
    c. Investigate locations along Picott Road near the culvert to install stormwater BMPs that treat road runoff.
    d. Consult the septic system database (currently in development) for septic age and pump out history for residential properties in the area. Conduct follow-up door to door surveys, if other sources cannot be linked to bacteria in the Picott Road area (this neighborhood is a lower priority for septic surveys than other neighborhoods).

3. **Monitor any potential changes to bacteria loads at CC1, as many of the residences in the Chickering Creek drainage are set to discontinue private septic or overboard discharges and will be connected to Town sewer beginning in spring 2016.**

4. **Address stormwater runoff throughout the watershed, possibly using a grant from Maine DEP that was awarded to the Town to continue Phase IV implementation. Recommendations include:**

    a. Target neighborhoods around Trafton Culvert (Trafton Lane/Parsonage Way/Cedar Drive/Ash Lane) for "residential socials" on proper pet waste disposal and septic system maintenance.
    b. Install proper pet waste disposal signage near WA036.00; residents frequently walk pets along Crockett's Neck Road, which separates Barter's Creek from Spruce Creek at this site.
    c. Install stormwater BMPs to treat bacteria near Chickering Creek (CC1) and Wilson Creek (WC1).

5. **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.**

    a. Redeploy data sondes at the upper and middle estuary sites in 2016 for at least August and September.
    b. Continue to collect at least three sets of surface grab samples for key water quality parameters at the upper and middle estuaries.
    c. Continue to collect bacteria samples at major tributary sites, particularly those sites with consistently-high bacteria counts and/or with near-future changes to land use. This could be aided by the reactivation and expansion of the Spruce Creek Association Volunteer Monitoring Program.

APPENDIX A: QAPP QA/QC PROTOCOL REVIEW

In 2015, a Spruce Creek Watershed-Scale Bacteria Monitoring Quality Assurance Project Plan (QAPP) was developed by FBE in cooperation with the Town of Kittery, ME and the Maine Department of Environmental Protection (Maine DEP). Bacteria samples were collected in 2015 by FBE staff and analyzed by Nelson Analytical Laboratory and Katahdin Analytical Services in accordance with the specific Standard Operating Procedures (SOPs) outlined in the QAPP, unless mentioned below. These deviations were minor and did not impact the quality of bacteria results.

1) Outlier analysis of all data (2009-2015) for all outfall and tributary locations showed several statistically-significant outliers (defined as above or below 1.5x the interquartile range (IQR) for each site). These outliers mostly occurred during wet weather (Table A1), so are likely anomalies in the pollutants contributing to stormwater, the severity of the rain event, lab dilution to expand the maximum detection limits (9/30/15), or the duration of dry weather preceding the wet weather event.

Table A1. *E. coli* (col/100mL) outliers by sampling location within the Spruce Creek Watershed from 2009-2015.

Site	5/29/2009 WET	6/15/2009 WET	6/2/2011 DRY	7/14/2011 WET	8/9/2012 DRY	9/5/2012 WET	11/1/2013 WET	8/29/2014 DRY	7/6/2015 DRY	8/11/2015 WET	9/10/2015 DRY	9/30/2015 WET	10/29/2015 WET
AV3				4,000									
CB1												9,804	
CC-T.P.							2,420						
CC1												4,352	
Coachman Inn													
Coleman			2,100										
HC1										2,420			2,420
KTP						5,172							
MC1									1,986			24,196	
MIDEST								721			1,986		
Rt 103					2,420								
SHC1	133												
Trafton Culvert												9,208	
UNK2												24,196	
WC1												9,208	
Wilson Creek													
Wyman House						3,255							

2) Field duplicates for bacteria should attempt to yield a relative percent difference (RPD) of < 20%; 2 out of 6 duplicate samples resulted in RPD > 20% (Table A2). In most cases, RPD > 20% is acceptable given the inherent variability of collecting and measuring biological communities. Typically, higher bacteria counts will be less variable than lower bacteria counts < 200 col/100mL. As such, 2015 RPDs ranging from 0-81% were acceptable and reflect a consistent field sampling procedure by personnel.

Table A2. Summary of relative percent difference (RPD) between two duplicate field samples.

Date	Wet/Dry	Sample ID	Enterococci (col/100mL)	RPD (±%)
7/6/2015	Dry	CB1	150	3
7/6/2015	Dry	CB1-DUP	145	
8/11/2015	Wet	WA036.00	2420	0
8/11/2015	Wet	WA036.00-DUP	2420	
8/31/2015	Dry	MC1	2420	0
8/31/2015	Dry	MC1-DUP	2420	
9/30/2015	Wet	CC1	4352	12
9/30/2015	Wet	CC1-DUP	3873	
10/29/2015	Wet	WA036.00	19	81
10/29/2015	Wet	WA036.00-DUP	8	
11/4/2015	Dry	WA036.00	26	54
11/4/2015	Dry	WA036.00-DUP	15	

3) Laboratory duplicates should also attempt to yield an RPD < 20%; laboratory duplicates for 2015 bacteria sampling in Kittery yielded RPDs ranging from 0-54% (Table A3). This also reflects a consistent laboratory analysis procedure by laboratory staff with greater RPDs generally associated with lower bacteria counts and vice versa. This is to be expected when measuring biological communities, and the data are acceptable.

Table A3. Summary of relative percent difference (RPD) between field sample and laboratory duplicate results.

Date	Sample ID	Weather	Field Sample *Entero* (col/100mL)	Lab Duplicate *Entero* (col/100mL)	RPD (±%)
7/6/2015	Dry	CC1	261	192	30
7/6/2015	Dry	WilsonRd	179	192	-7
8/11/2015	Wet	CC1	2420	2420	0
8/31/2015	Dry	UNK2	1414	1300	8
9/30/2015	Wet	WA036.00	41	52	-24
10/29/2015	Wet	WA036.00	19	15	24
11/4/2015	Dry	WA036.00	26	45	-54

4) Bacteria samples were collected within a rough window of ±2 hour around dead low tide, with the exception of 9/30/2015 (Table A4). During sampling events, logistical and safety reasons (low tide before sunrise and heavy rain) prevented FBE staff from collected all samples within the low tide window. However, the last site sampled was CB1, which was previously considered a tidally-affected site. Based on the site's location upstream of a high cascade and consistent salinity ≤1 ppt, we do not believe that this site or any of the Haley Rd outfalls (CB1, HILL1, Trafton Culvert, HILL1, HC1) are tidally-influenced. Discounting these five sites, all remaining tidally-affected sites were collected within the ±2 hour window (Table A4). We recommend that the lack of tidal influence be confirmed for

these sites to improve prioritization of tidal sites during future sampling. All bacteria samples were delivered to the laboratory well within the 6-hour time limit (Table A4).

5) All samples were collected within the designated timeframe of June 1 – October 1, 2015, with the exception of samples collected on 10/8/2015, 10/26/2015, 10/29/2015, 11/4/2015, 11/6/2015, and 11/10/2015. These final sampling events were delayed due to the need for an additional wet and dry weather sampling, the persistence of dry weather throughout the sampling season, coordination with volunteers, and the need to keep sampling events of the same weather type temporally diverse.
6) Bacteria samples were delivered to the laboratory around or below the recommended 10 °C, with the exception of samples on 8/11/15 (Table A4). However, there was a high amount of road runoff due to the rain that day and samples likely did not have enough time to cool down to 10 °C between field collection and laboratory delivery. Personal communication with laboratory staff confirmed that this was not a concern for sample quality.

Table A4. Summary of QAPP protocol results for 2015 bacteria sampling.

Date	Precip 24 hrs prior (in)	Precip 48 hrs prior (in)	Precip 96 hrs prior (in)	Time of First Sample	Time of Last Sample[1]	Time of Low Tide	Time Delivered to Lab	Temp Received (°C)
7/6/2015	0	0.06	0.06	7:32	10:50	8:58	11:40	6.0
8/7/2015	0	0	0.41	9:45	10:45	11:30	12:30	0.1
8/11/2015	0.84	0.84	0.84	13:45	16:15	15:30	17:05	17.0
8/31/2015	0	0	0.01	5:19	8:15	6:57	9:25	10.0
9/10/2015	0	0	0	14:45	15:30	16:10	17:45	2.4
9/30/2015	0.4	0.4	0.4	7:10	9:45	7:01	10:45	11.0
10/8/2015	0	0	0	13:15	14:05	15:10	16:50	-0.4
10/26/2015	0.04	0.04	0.06	15:35	16:18	16:55	17:35	na
10/29/2015	1.48	1.48	1.54	5:50	6:50	6:39	9:40	11.0
11/4/2015	0	0	0.02	11:30	12:30	11:24	13:38	9.5
11/6/2015	0	0	0	12:40	13:00	13:39	14:45	10
11/10/2015	0	0	0	15:10	15:50	16:27	16:30	10.5

Date	Time Diff. First Sample (hh:mm)	Time Diff. Last Sample (hh:mm)	Time Diff. to Lab (hh:mm)
7/6/2015	1:26	1:52	4:08
8/7/2015	1:45	0:45	2:45
8/11/2015	1:45	0:45	3:20
8/31/2015	1:38	1:18	4:06
9/10/2015	1:25	0:40	3:00
9/30/2015	0:09	2:44[2]	3:35
10/8/2015	1:55	1:05	3:35
10/26/2015	1:20	0:37	1:17
10/29/2015	0:49	0:11	3:50
11/4/2015	0:06	1:06	2:08
11/6/2015	0:59	0:39	2:05
11/10/2015	1:17	0:37	1:20

[1]Last sample is typically WR CuI or CB1. [2] Last tidal sample was taken within 2 hours of low tide (WR CuI).

7) All field sheets and COC forms were complete with the exception that the COC form on 9/30/2015 was not consistent with receiving lab personnel signatures and the COC form on 10/26/2015 did not record cooler temperature. The correct protocols were followed upon sample delivery in each case, but the information was not recorded.
8) All thirteen sites were sampled six times with the exception on SHEP1, which was sampled only four times due to no flow conditions on two sampling events, and PICOTT, which was sampled seven times due to volunteer and FBE staff miscommunication.
9) Continuous data sondes functioned well throughout the deployment with the exception of relative depth. Relative depth was only recorded at MIDEST from August-October; the logger malfunctioned for the remainder of the deployment and completely malfunctioned at PICOTT, so that no data were retrievable. Some minor biofouling or other sensor interferences impacted portions of the data at PICOTT in early October for temperature, conductivity, and dissolved oxygen. A rain event in mid-September also interfered with conductivity data at MIDEST. These data were flagged as suspect and deleted from the record.