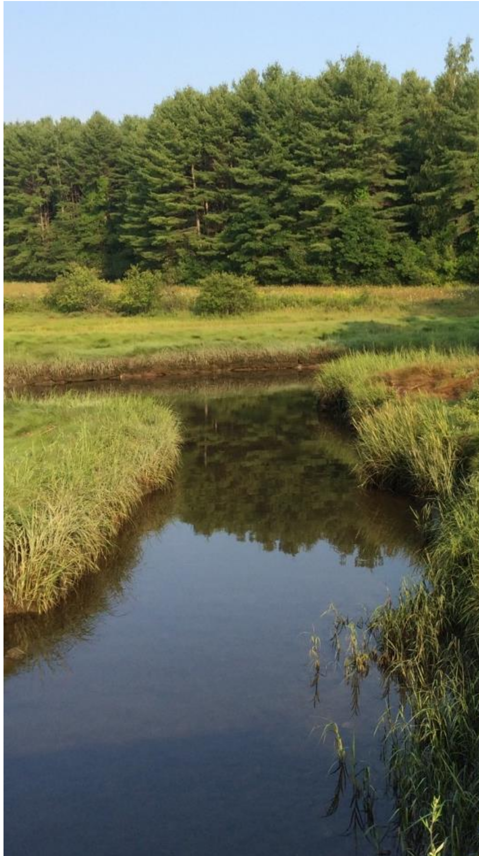
2014 WATER QUALITY REPORT

SPRUCE CREEK WATERSHED



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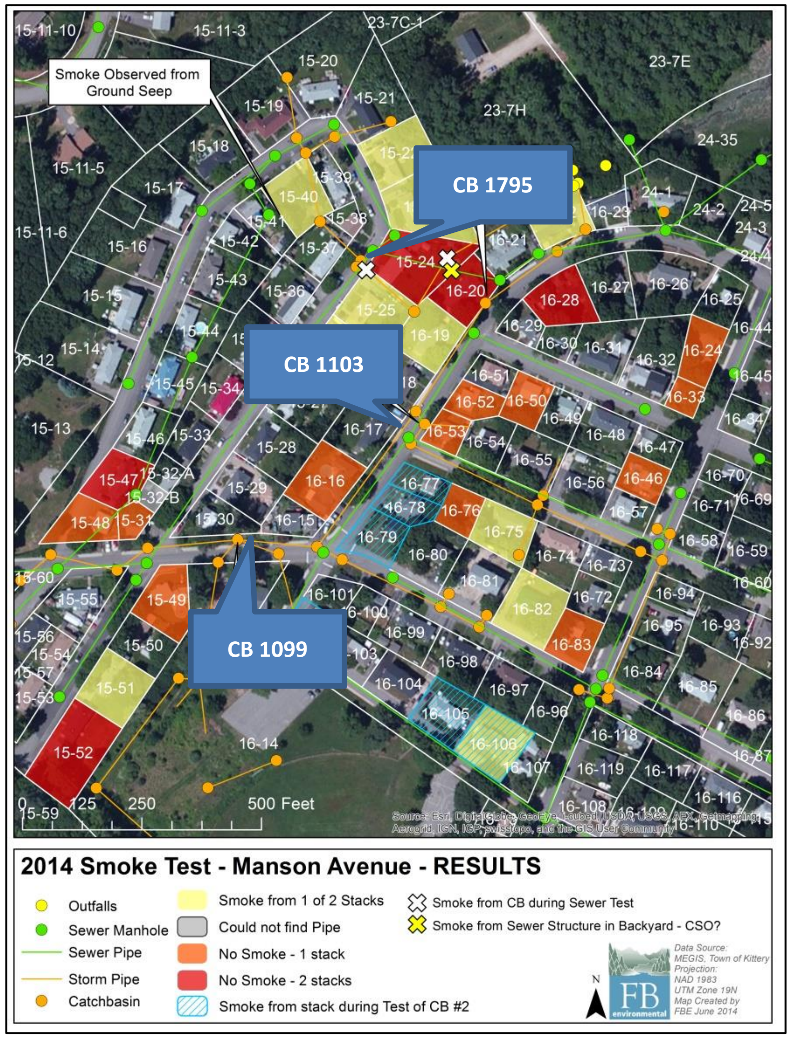
SUMMARY OF 2014 MANSON AVENUE STORM DRAIN SYSTEM BACTERIA SOURCE TRACKING

Based on the 2012 and 2013 sampling projects conducted by FBE, two outfalls on Manson Avenue were identified as hotspots of bacterial contamination to Spruce Creek. The storm drain system flowing to these outfalls was found to have continuous flow throughout the system even in dry weather. This flow is likely from an illicit discharge to the storm drain system and needs to be identified and remediated. To address this concern, FBE completed the following tasks in 2014:

- Identified and conducted bracket sampling of specific locations in catch basins upstream of the outfalls.
- Utilized canine detection of the storm drain system on Manson Avenue to identify human-specific types of pollution in conjunction with water analyses for *E. coli* bacteria. This helped rule out wildlife or agriculture as possible sources of bacterial contamination at these locations.
- Conducted a smoke test of the storm and sewer systems in this neighborhood.



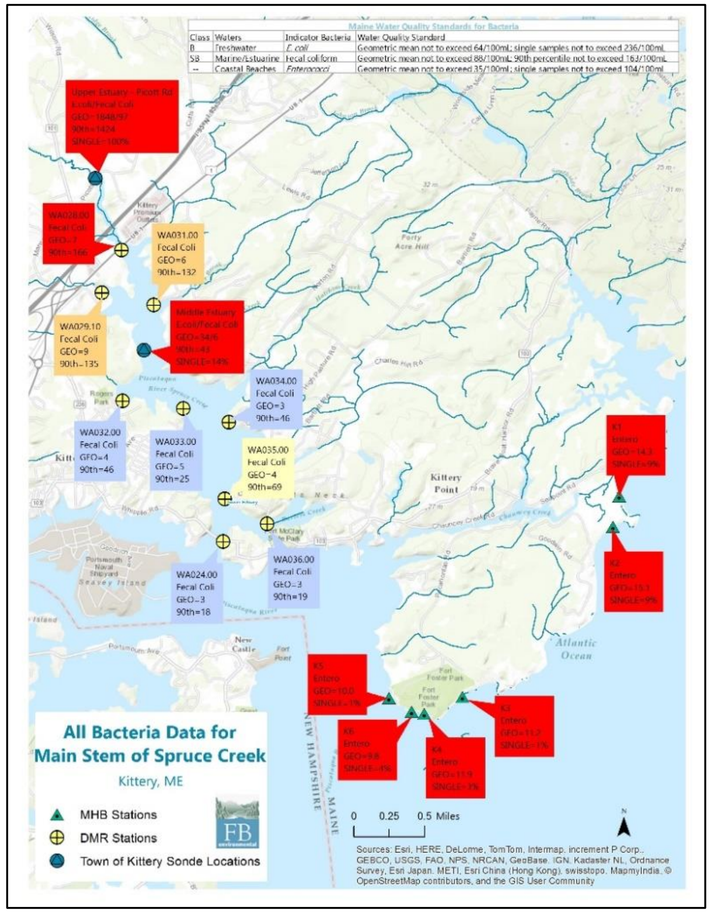
Results

- Both outfalls exceeded the State limit of 236 col/100mL for single samples and were above the lab detection limit under dry weather conditions.
- Three catch basins were identified as areas of concern (**1099, 1103, and 1795**). Flow from many of their inflow pipes exceeded the State limit of 236 col/100mL for single samples and some were above the lab detection limit. Bacteria in these catch basins were found to be of human origin.
- Results of the smoke test conducted in August 2014 indicated possible cross-contamination of the sewer and storm drain lines at CB 1795.

Next Steps

- Continue to monitor bacteria in the storm drain system of Admiralty Village.
- Further investigate the source of human bacteria in catch basin 1099, specifically from inlets 1099-A, -D, and -C.
- Conduct a camera investigation of the storm and sewer lines near catch basin 1795 to determine the source and ensure no cross-connections.

SUMMARY OF 2014 SPRUCE CREEK CHANNEL INVESTIGATION



Two data sondes were deployed in Spruce Creek at the middle and upper estuary stations for two deployments (in August and from mid-September to mid-October) and monitored for dissolved oxygen (saturation and mg/L), temperature, relative water depth, pH, and specific conductivity at 15 minute intervals. A total of five sets of grab samples were collected during these deployments and sent to Katahdin Analytical in Scarborough, ME for various analyses.

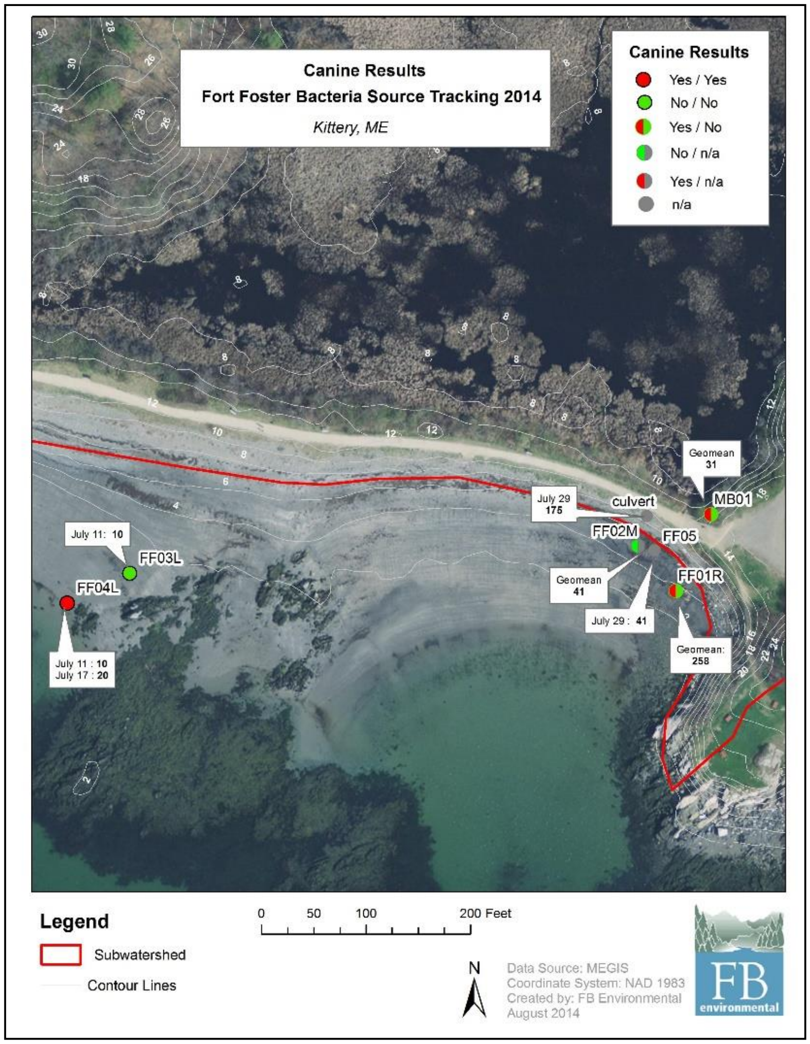
Results

- The <u>upper estuary</u> showed degraded water quality with elevated biological oxygen demand (3-5 mg/L), high *E. coli* (geomean of 1,848 col/100mL) and fecal coliform (geomean of 97 col/100mL) that exceeded the State standard, elevated nutrients (nitrogen and phosphorus forms) that corresponded with precipitation events (0.79 in), wide range in total organic carbon (2.9-9.2 mg C/L) and total suspended solids (9-29 mg/L), and large swings in daily dissolved oxygen that fell below the State standard of 85% saturation on all monitored days.
- The <u>middle estuary</u> showed better and more stable water quality with low biological oxygen demand (<2 mg/L), low fecal coliform (geomean of 6 col/100mL), low levels of inorganic nutrients (nitrogen and phosphorus forms) that typically fell below the laboratory's detection limit of 0.05 mg/L, stable total organic carbon (1.4-2.1 mg C/L), and less variable range in total suspended solids (6-17 mg/L). However, the middle estuary did exceed the State standard for E. coli (geomean of 109 col/100mL) in 2014 and the NH standard for TN (>0.45 mg/L) on all occasions; and also experienced large swings in daily DO that fell below the State standard of 85% saturation on all except 9 monitored days.
- In an effort to highlight portions of the channel impacted by bacteria, all historical bacteria results for the main stem of Spruce Creek were compiled from the Town of Kittery, the Department of Marine Resources (DMR), and Maine Healthy Beaches (MHB). The majority of exceedances occurred in the upper to middle estuary of the main stem of Spruce Creek. Lower bacteria counts observed in the lower estuary are likely a result of dilution and mixing with marine waters. Coastal beaches also show multiple single sample exceedances.

Next Steps

- Continue sampling of the main stem of Spruce Creek at the upper and middle estuaries using continuous sonde and grab sampling techniques, and consider adding a third sonde at the lower estuary.
- Consider conducting a grab sampling effort of the seven major tributaries to Spruce Creek in conjunction with the sonde grab sampling to better understand and evaluate the fate and transport of bacteria sources to Spruce Creek and target priority tributaries.
- Consider conducting multiple (dry and wet weather) sampling upstream of the upper estuary to determine hotspots of bacterial contamination since bacteria counts were consistently high in 2014.

SUMMARY OF 2014 FORT FOSTER BEACH FOLLOW-UP INVESTIGATION



In 2012 and 2013, FB Environmental worked with Environmental Canine Services to identify sources of bacteria to Fort Foster Beach. Though some of these sources have been successfully remediated, other sources may still present and have been shown to contribute large amounts of bacteria to the beach. To address this concern, FBE conducted a watershed investigation to identify potential bacteria sources to the beach. This investigation included mapping, water quality sampling, and the use of canine detection to identify bacteria sources.

Results

- Although lower than previous years, some samples taken on the beach at Fort Foster exceeded the State water quality standard for *Enterococci* in dry weather (>104 colonies/100mL).
- The canines alerted to the presence of human-sourced bacteria at multiple locations on the beach and throughout the sub-watershed.
- Higher bacteria levels are concentrated on the east side of the beach.

Major Findings

- The majority of bacteria sources to Fort Foster Beach are found to be natural.
- There is no known infrastructure near the east side of the beach that is contributing to the high bacteria levels.
- There are very few possible sources of human-sourced bacteria within the Fort Foster beach sub-watershed, all of which appear to be functioning correctly, well-maintained, and not posing a problem.

Next Steps

- Continue to monitor bacteria levels on the beach to ensure levels do not increase.
- Continue to pump/maintain septic tanks on the property regularly.
- Educate park visitors of proper pet waste disposal.

ACKNOWLEDGMENTS

A special **thanks** to those who made the deployment, maintenance, and retrieval of the Spruce Creek sondes possible:

Dan and Phyllis Ford
Paul Bourque (Kittery Interim Harbormaster)

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INTRODUCTION

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 Brook, Fuller Brook, Hill Brook, 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.

Photo of Spruce Creek taken from the 2014 middle estuary sonde location.

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 nonpoint pollutant sources. Spruce Creek is also identified by the Maine Department of Environmental Protection (Maine DEP) as a "nonpoint source pollution priority watershed" due to bacterial contamination, low dissolved oxygen, toxic contamination, and a compromised ability to support commercial marine fisheries. 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 and are listed under Category 5-B-1: Estuarine & Marine Water Impaired by Bacteria (TMDL required).

In 2014, three projects were conducted in Kittery, Maine to assess the water quality of Spruce Creek and nearby Fort Foster. These projects serve as follow-up work to issues identified in projects in 2012 and 2013. The following projects were conducted:

1. Manson Avenue Storm Drain System Bacteria Source Tracking
2. Spruce Creek Channel Investigation
3. Fort Foster Beach Follow-up Investigation

Summaries of these projects are provided above and detailed descriptions of the work completed and can be found below.

MANSON AVENUE STORM DRAIN SYSTEM BACTERIA SOURCE TRACKING

In 2012, two outfalls on Manson Avenue were identified as "hotspots" of bacterial contamination to Spruce Creek. The storm drain system flowing to these outfalls were found to have continuous flow throughout the system even in dry weather. This flow is likely from an illicit discharge to the storm drain system and needs to be identified and remediated.

To address this concern, FBE completed the following tasks:

1. Identified specific locations in the catch basins upstream of the outfalls and conducted bracket sampling in dry weather.
2. Utilized canine detection throughout the storm drain system on Manson Avenue to identify human-specific types of pollution in conjunction with water analyses for *E. coli* bacteria. This was performed to help rule out wildlife or agriculture as possible sources of bacterial contamination at these locations.
3. Conducted a smoke test of the storm drain and sewer system.

All bacteria samples were analyzed for *E. coli* bacteria at Nelson Analytical Water Testing Laboratory in Kennebunk, Maine. *E.coli* bacteria are commonly used as an indicator of the presence of fecal material in freshwater. In Maine, the State water quality standard for *E. coli* is 236 colonies/100mL for a single grab sample and 64 colonies/100mL for the geometric mean of multiple samples.

1.1 CANINE AND BACTERIA RESULTS

Three catch basins upstream of the outfalls were identified to conduct dry weather bracket sampling based:

1. Catch basin 1099 on Manson Ave;
2. Catch basin 1797 on Cromwell Street; and
3. Catch basin 1103 on Manson Ave.

All inlet pipes with flow, as well as basin flow were sampled on two occasions during dry weather for bacteria concentrations. In August, catch basin 1099 resulted in three of the four inlet pipes in exceedance of the State standard of 236 colonies/100mL (Figure 1). Two of the inlet pipes (1099-C and 1099-A) had bacteria concentrations that exceeded the laboratory's detection limit of 2,419.6 colonies/100mL (Table 1). Inlet pipe 1099D had high levels (866 colonies/100mL) in August and low levels in September (3 colonies/100mL), while 1099-B resulted in low levels (18 colonies/100mL) in August and not enough flow in September to sample (Table 1).

The basin flow from 1099 had lower concentrations of bacteria than three of the four inlets; however, this site was still above the State standard. Flow from basin 1975 on August 18, 2014 had bacteria concentrations that were above the State standard, as well as the laboratory's detection limit (2,419.6 colonies/100mL; Figure 2). Inlet 1795- B had low levels of bacteria on both August 18 and September 12, 2014, while the other inlet did not have enough flow to sample (Figure 2). Catch basin 1103 had bacteria levels in August that were above the standard, but much lower than the other two catch basins sampled (Table 1, Figure 3). Both the outlets (Manson out-L and Manson out-R) were above the State standard for *E. coli* and also above the laboratory's detection limit (Table 1).

Table 1. 2014 *E. coli* (colonies/100mL) results in Manson Avenue Storm drain system in Kittery, Maine. Red text indicates exceedance of State standard for single sample.

Sample	Description	*E. coli* Results		Canine Results	
		18-Aug	12-Sept	Logan	Sable
1099-A	6" clay pipe-flow	>2,420	Not enough flow	Yes	Yes
1099-B	12" tran-flow	18	No sample	n/a	n/a
1099-C	24" steel-flow	>2,420	Not enough flow	Yes	No
1099-D	10" tran-flow	866	3	Yes	Yes
1009	flow from catch basin	461	No sample	Yes	Yes
1795 B	10" clay from unknown	29	2	Yes	Yes
1795	catch basin flow	>2,420	No sample	Yes	Yes
1103-A	15" clay-flow	152	No sample	n/a	n/a
1103	bottom of basin	236	No sample	Yes	Yes
Manson out-L	outlet on left (when facing)	>2,420	No sample	n/a	n/a
Manson out-R	outlet on right (when facing)	>2,420	No sample	n/a	n/a
Maine Standard for *E. coli* = 236 col/100mL (single sample)					

Figure 1. ***E. coli*** **(colonies/100mL) and canine results from Manson Ave storm drain investigation of catch basin 1099.**

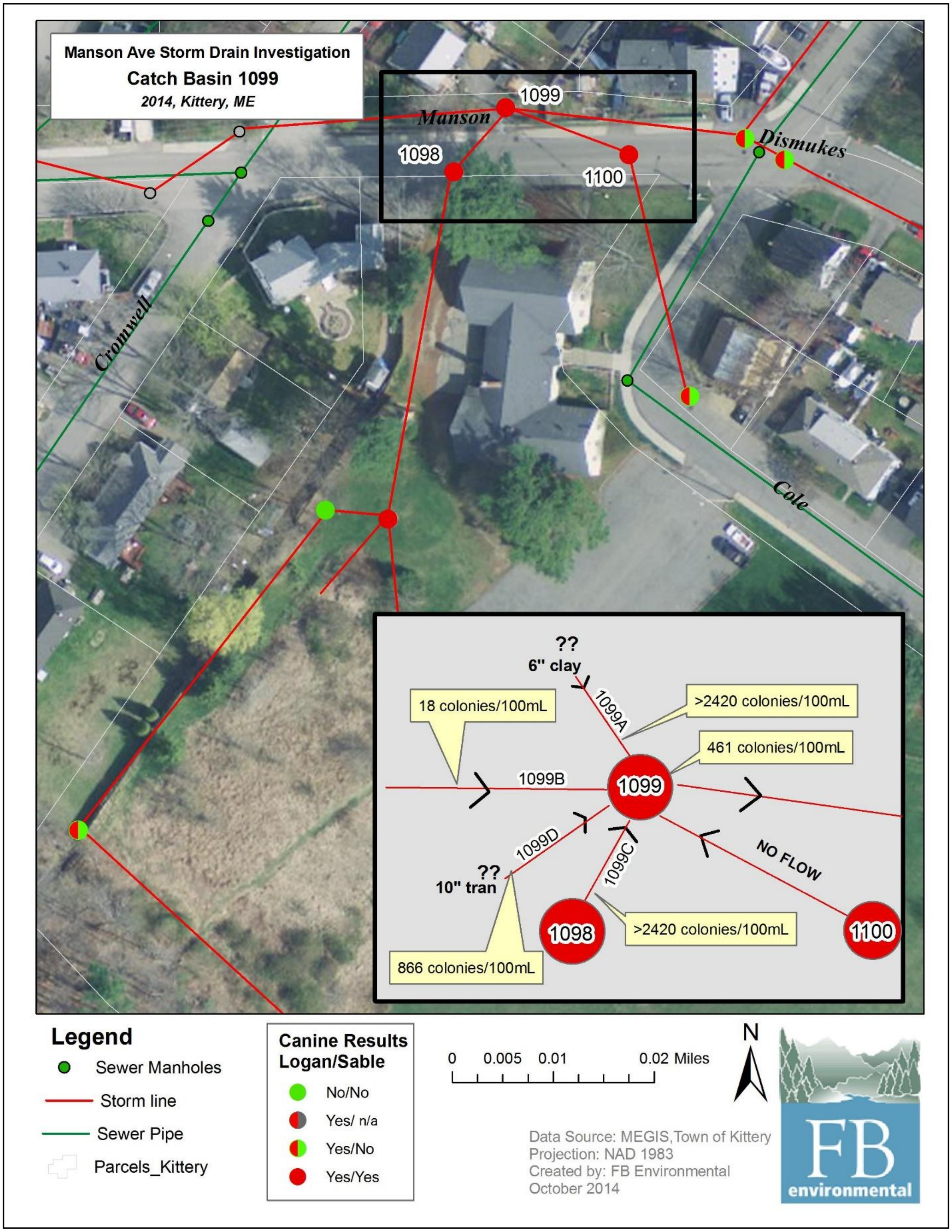


Figure 2. *E. coli* (colonies/100mL) and canine results from Manson Ave storm drain investigation of catch basin 1795

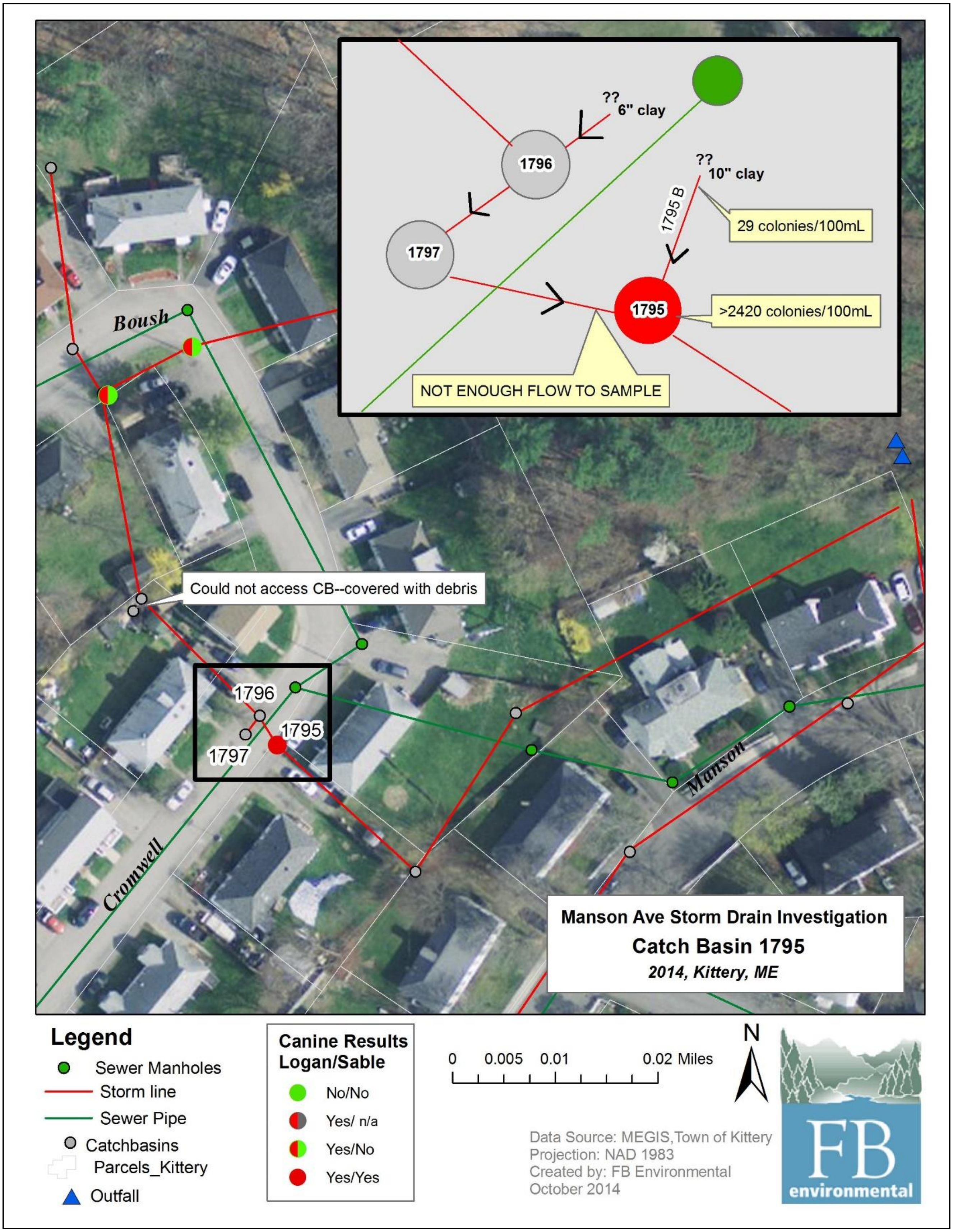
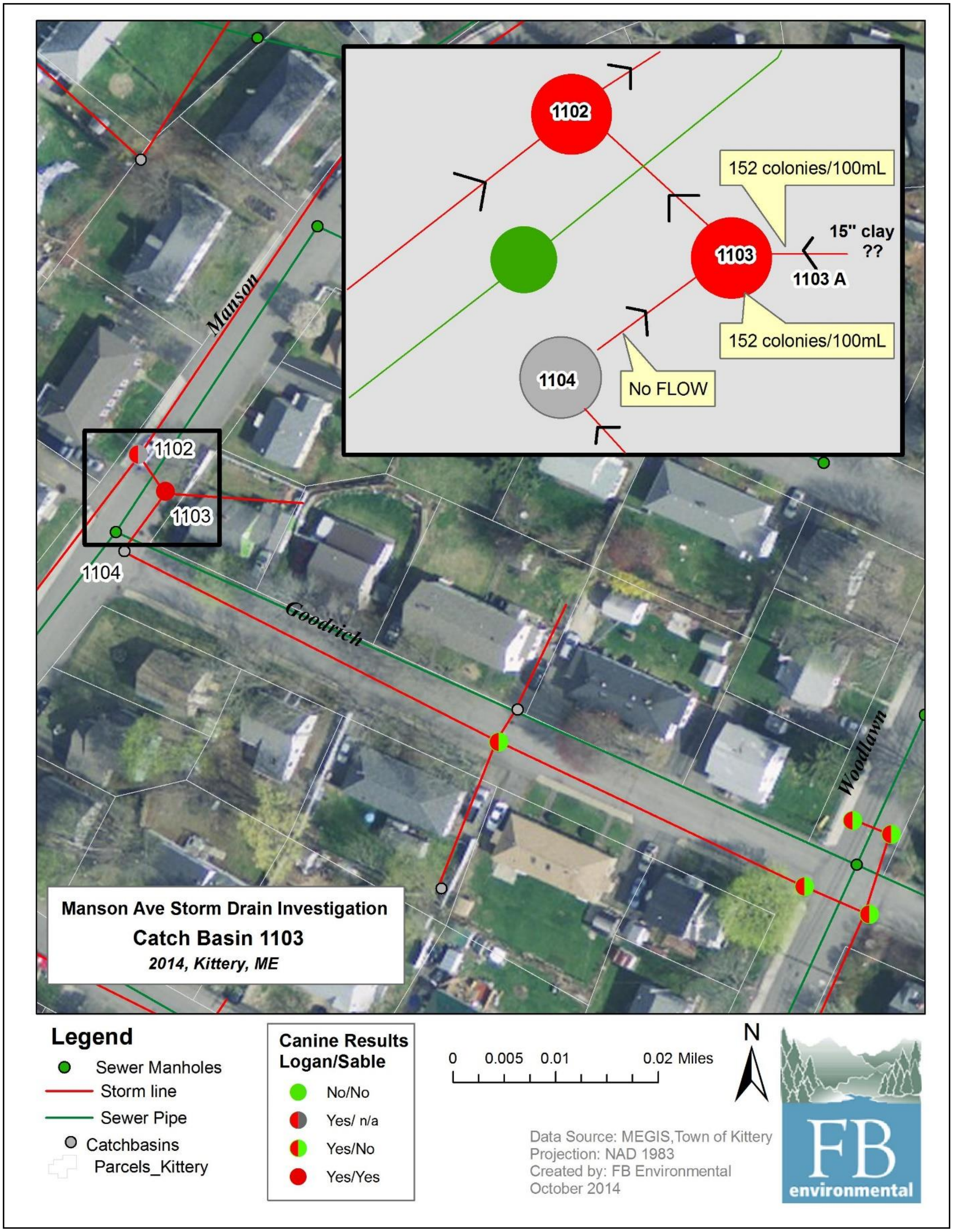


Figure 3. ***E. coli*** **(colonies/100mL) and canine results from Manson Ave storm drain investigation of catch basin 1103.**



On September 12, 2014, Karen and Scott of Environmental Canine Services, along with canines Sable and Logan came to investigate the three catch basins of interest and surrounding areas. Both canines alerted to the presence of human-sourced bacteria in catch basin 1099 (Figure 1). Samples from 1099-A and 1099-D also resulted in alerts from both canines. Inlet 1099-C resulted in an alert from canine Logan, while canine Sable did not alert (Table 1).

Both canines alerted to the two catch basins directly linked to 1099 on either side. From there, the other catch basins down the line resulted in an alert from Logan, but no alert from Sable with the exception of a catch basin located in the field next to the old community center, which had a positive alert from both canines (Figure 1).

Catch basin 1795 was positive for human bacteria from both canines (Figure 2). Inlet 1795-B also tested positive for human sourced bacteria from both canines, while there was not enough flow to test the other inlet (Table 1). There was no access to the next catch basin towards Boush Street due to debris on the basin cover in a residential yard; however, the next two catch basins upstream towards Boush Street resulted in an alert from canine Logan and no alert from canine Sable. The catch basin on the other side of 1795 leads directly to the outlets that have consistently high levels of bacteria (Figure 2). It was also observed that the sewer and storm system appear to cross over each other at this location and that the sewer is much more shallow than the catch basins; suggesting that the sewer line sits above the catch basin lines in that particular area. Catch basin 1103 resulted in a positive alert for the presence of human-sourced bacteria from both canines (Figure 3). There was a positive alert on the catch basin leading towards the outlets by canine Logan. Canine results from Goodrich Street yielded positive alerts from Logan and no alert from Sable (Figure 3).

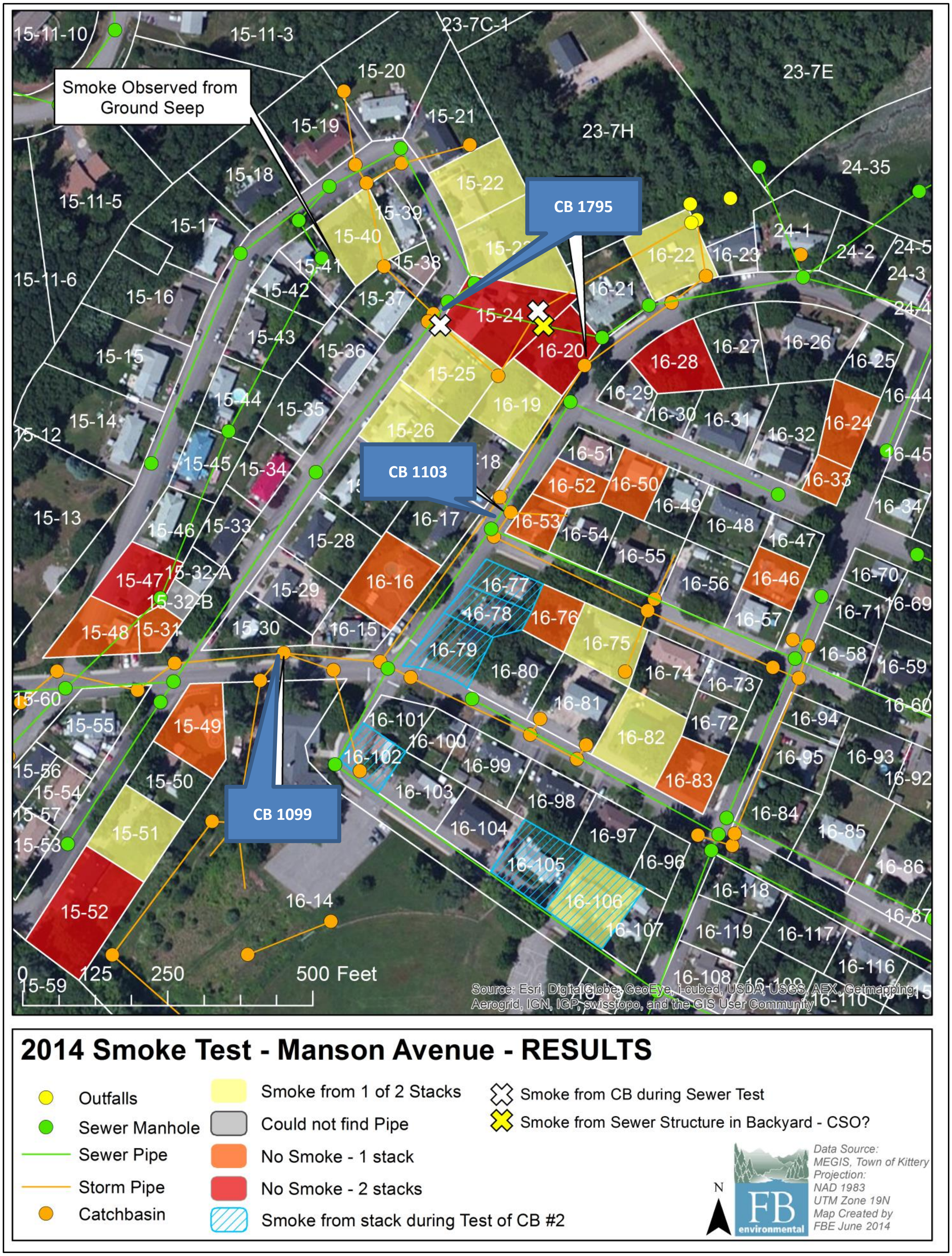
In August 2014, a smoke test of the storm and sewer system was conducted (Figure 4). A full list of properties identified through this smoke test was provided to the Shoreland Resource Officer. Major findings include:

1. Multiple properties did not have smoke from smokestacks during smoking of the sewer line.
2. In two locations near CB 1795, smoke was identified in the storm drain system during the smoke test of the sewer line and at one location near CB 1795, smoke was identified in the sewer line during the smoke test of the storm drain system.

1.2 NEXT STEPS

1. Continue to monitor bacteria levels in the storm drain system of Admiralty Village and at the outfalls.
2. Further investigate the sources of human bacteria in catch basin 1099, specifically from inlets 1099-A, 1099-D, as well as 1099-C.
3. Conduct a camera investigation of the storm and sewer lines near catch basin 1795 to determine the source and ensure there are no cross-connections or problems with the condition of the lines that could allow for leaching of the sewer into the storm drain.

Figure 4: **Smoke test results from smoke test conducted in August 2014.**



SPRUCE CREEK CHANNEL INVESTIGATION

Minimal water quality data were available prior to 2012 for the main stem of Spruce Creek. Given the water quality restoration efforts in the Spruce Creek watershed by the Town of Kittery, it was recommended that a more complete analysis of water quality within the main channel of Spruce Creek be completed. FB Environmental (FBE) conducted baseline continuous and discrete water quality sampling of the estuarine portion of Spruce Creek at the lower, middle, and upper estuaries in 2012, the middle estuary in 2013, and now the middle and upper estuaries in 2014 (Figure 5).

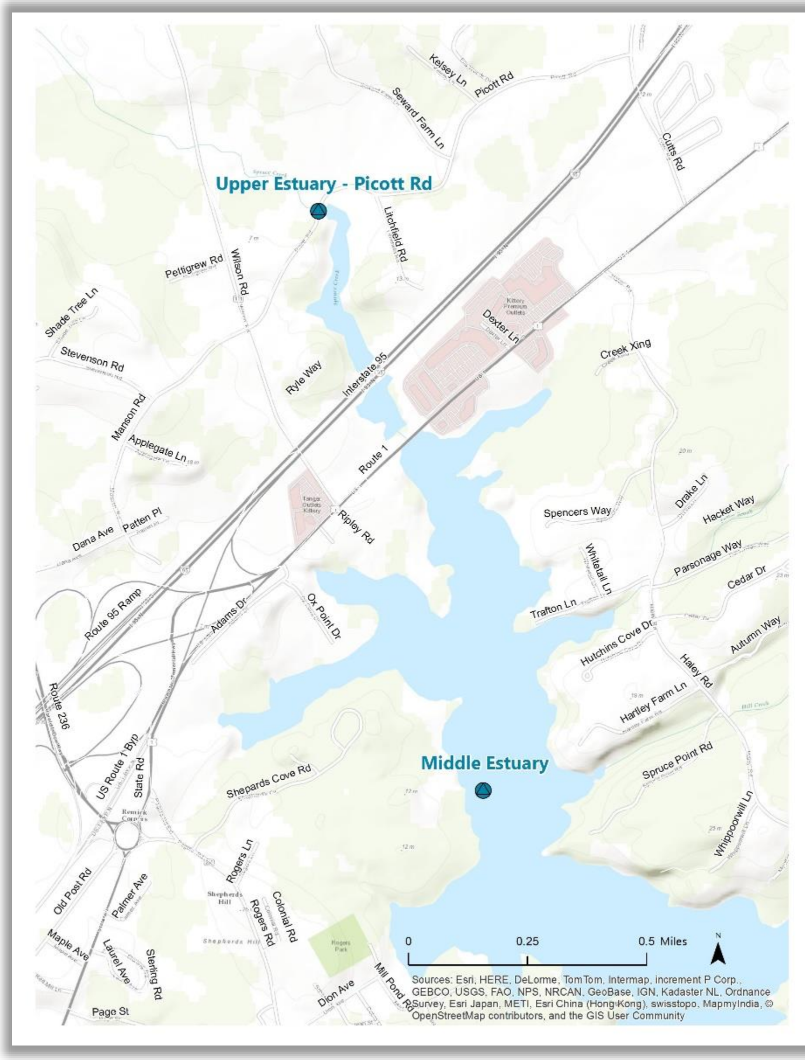


Figure 5. 2014 Spruce Creek sonde locations.

Sampling included the collection of continuous dissolved oxygen (saturation and mg/L), relative water depth, temperature, and specific conductivity data using a water quality sonde at each location in the channel. In addition, surface water grab samples were collected for analysis of bacteria, nutrients, organic carbon, and total suspended solids. All data were collected in late summer and early fall. 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.

2.1 SPRUCE CREEK GRAB SAMPLE RESULTS AND SONDE DATA

Data sondes are water quality monitoring devices that stay in the water for a period of days or weeks, and record data at regular intervals to an internal memory. Two data sondes were deployed in Spruce Creek at the middle and upper estuary stations (Figure 5). The sondes (a YSI 600 XLM at the upper estuary and a YSI 600 OMS at the middle estuary) were deployed for 28 days from 8/1/2014 to 8/29/2014 (Table 2). The sondes monitored for dissolved oxygen (saturation and mg/L), temperature, relative water depth, and specific conductivity at 15 minute intervals. Three sets of grab samples were collected during this deployment period and sent to Katahdin Analytical in Scarborough, ME for various analyses discussed in Section 2.1.1. The sonde at the middle estuary malfunctioned and no data were collected.

A second round of sondes (two YSI 600 XLMs at the upper and middle estuaries) were deployed for 28 and 25 days from 9/19/2014 to 10/17/2014 and 9/22/2014 to 10/17/2014 at the middle and upper estuaries, respectively (Table 2). The sondes monitored for dissolved oxygen (saturation and mg/L), temperature, relative water depth, specific conductivity, and pH at 15 minute intervals. Two sets of grab samples were collected during this deployment period and sent to Katahdin Analytical in Scarborough, ME for various analyses discussed in Section 2.1.1. The sonde at the middle estuary malfunctioned and no water depth data were collected, but a tidal height parameter was easily generated using historic tidal information from US Harbors online.

Table 2. 2014 Spruce Creek sonde deployment and retrieval dates.

Location	Deployed	Retrieved	Total Days
Upper Estuary - Picott Rd	8/1/2014	8/29/2014	28
	9/22/2014	10/17/2014	25
Middle Estuary	8/1/2014	8/29/2014	28
	9/19/2014	10/17/2014	28

2.1.1 IN-FIELD MAINTENANCE AND GRAB SAMPLES

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 small milk crate or 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. In-field maintenance occurred only for the first deployment period on 8/19/2014 (Wagner et al., 2006). The sonde was briefly pulled out of the water and repositioned at the middle and upper estuary locations. Both sondes showed some algae on the probes that were then cleaned off. Marine tunicates or similar were found on the sonde casing, but not on the sensors and so did not impede proper function. The sondes were retrieved from the field on 8/29/2014 and data downloaded. A light coating of algae was again found on the sensors. More flounder, lobster, crabs, and small fish were found in the middle estuary eel crate. Field records indicate that the water was murky/cloudy from suspended sediment and algae at both stations.

Surface water grab samples were collected on 8/1/2014, 8/19/2014, and 8/29/2014 for the first deployment period at both stations and again on 9/19/2014 and 10/17/2014 for the second deployment period. A delay with the sonde rental company caused the middle estuary sonde to be deployed on 9/19/2014 and the upper estuary sonde on 9/22/2014. Surface water grab samples were collected on

9/19/2014 for both stations for ease of comparison. All grab samples were collected during low tide conditions within a few hours of dead low tide.

Surface water grab sample results are shown in Tables 3 and 4. Samples were brought to Katahdin Analytical Services in Scarborough, ME and analyzed for the following parameters: biological oxygen demand, chloride, *E. coli*, fecal coliform, phosphate, nitrate/nitrite-nitrogen, total kjeldahl nitrogen, total organic carbon, and total suspended solids.

The middle estuary sonde was deployed in an eel trap (top); tunicates were found only on the sonde casing (left) with some algae coatings on the sensors (right).

Table 3. 2014 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	8/1/14	8/19/14	8/29/14	9/19/14	10/17/14	PQL**	2014 Geomean	2014 90th Percentile	State WQ Standard for Class SB/B waters
Precip (Prior 24 hrs) (in)	0	0	0	0	0	--	--	--	--
Precip (Prior 48 hrs) (in)	0	0	0	0	0	--	--	--	--
Precip (Prior 96 hrs) (in)	0	0	0	0	0	--	--	--	--
Laboratory Analyses									
BOD (mg/L)	3.1	<24*	5.7	<12*	<24*	2	--	--	--
Chloride (mg/L)	12000	7600	13000	16000	3700	400	--	--	--
E.coli (col/100mL)	>2,419.6	>2419.6	>2419.6	>2419.6	629.4	1	1848	--	Geomean=64/100mL; Instantaneous=236/100mL
Fecal Coliform (cfu/100mL)	30	50	260	10	2200	1	97	1424	Geomean=88/100mL; 90th Percentile=163/100mL
PO_4-P (mg/L)	0.064	<0.05	0.067	<0.05	0.08	0.05	--	--	--
NO_3-N (mg/L)	<0.05	<0.05	<0.05	<0.05	0.16	0.05	--	--	--
NO_2-N (mg/L)	<0.05	<0.05	<0.05	<0.05	0.05	0.05	--	--	--
TKN (mg/L)	0.81	1.1	0.52	0.29	1.2	0.25	--	--	--
TOC (mg/L)	5	7	4.3	2.9	9.2	1	--	--	--
TSS (mg/L)	9.2	16	20	20	29	4	--	--	--
In-field Measurements									
Water Temp (°C)	20.9	23.7	19.6	15.9	19.8	--	--	--	--
DO (%)	37.2	102.7	41.7	83.6	81.2	--	--	--	85%
DO (mg/L)	3.33	8.71	3.82	8.27	7.42	--	--	--	--

**The laboratory's Practical Quantitation Level (PQL) could not be achieved for this parameter due to sample composition, matrix effects, sample volume, or quantity used for analysis.*

***PQL = Practical Quantification Limit for Katahdin Analytical Services in 2014; the lowest concentration that the laboratory method can accurately estimate; greater than the method detection limit (MDL).*

Table 4. 2013 and 2014 Spruce Creek middle estuary water quality results from surface grab sampling (laboratory analyses) and in-field measurements using a YSI ProODO.

Parameter	9/30/13	10/25/13	8/1/14	8/19/14	8/29/14	9/19/14	10/17/14	PQL **	2014 Geomean	2014 90th Percentile	State WQ Standard for Class SB/B waters
Precip (Prior 24 hrs) (in)	0	0	0	0	0	0	0	--	--	--	--
Precip (Prior 48 hrs) (in)	0	0	0	0	0	0	0	--	--	--	--
Precip (Prior 96 hrs) (in)	0	0	0	0	0	0	0	--	--	--	--
Laboratory Analyses											
BOD (mg/L)	<6	<6	<2	<24*	2.2	<2	<24*	2	--	--	--
Chloride (mg/L)	18000	22000	16000	16000	16000	18000	16000	400	--	--	--
E.coli (col/100mL)	9	13	163.8	102	721.5	22.1	58.2	1	109	--	Geomean=64/100mL; Instantaneous=236/100mL
Fecal Coliform (cfu/100mL)	--	--	<10	<10	<10	<1	67.5	1	6	43	Geomean=88/100mL; 90th Percentile=163/100mL
PO_4-P (mg/L)	--	--	0.055	<0.05	<0.05	<0.05	<0.05	0.05	--	--	--
NH_3-N (mg/L)	<0.5	<0.5	--	--	--	--	--	--	--	--	--
NO_3-N (mg/L)	<20	<20	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	--	--	--
NO_2-N (mg/L)	<0.01	<0.01	<0.05	<0.05	<0.05	<0.05	<0.05	0.05	--	--	--
TKN (mg/L)	<0.20	0.21	0.48	0.5	2.4	<0.25	0.6	0.25	--	--	--
TOC (mg/L)	3.1	2.6	1.7	2.1	1.6	1.4	2.1	1	--	--	--
TSS (mg/L)	93	54	12	12	6	11	17	4	--	--	--
In-field Measurements											
Water Temp (°C)	16.8	9.9	17.9	19.6	18.1	16.7	16.8	--	--	--	--
DO (%)	115.5	93.9	95.2	106.1	88.1	97.1	96.3	--	--	--	85%
DO (mg/L)	11.14	10.65	9.02	9.72	8.3	9.44	9.37	--	--	--	--

**The laboratory's Practical Quantitation Level (PQL) could not be achieved for this parameter due to sample composition, matrix effects, sample volume, or quantity used for analysis.*

***PQL = Practical Quantification Limit for Katahdin Analytical Services in 2014; the lowest concentration that the laboratory method can accurately estimate; greater than the method detection limit (MDL).*

Biological Oxygen Demand (BOD) is measured as the amount of dissolved oxygen needed by aerobic organisms to break down organic material and is used as an indicator of organic pollutants in water. Maine does not set a water quality standard for BOD in surface waters, but unpolluted surface waters typically have BOD concentrations below 2 mg/L (Wenner et al. 2014). BOD concentrations above 2 mg/L may indicate that pollution from industrial, residential, or agricultural wastes are impacting water quality and may cause decreases in available oxygen.

2014 BOD RESULTS: For the upper estuary at Picott Road, two of the five sampling dates showed slightly elevated BOD at 3.1 mg/L on 8/1/2014 and 5.7 on 8/29/2014. This indicates that the upper estuary is impacted by more biodegradable organic matter that may be coming from human sources. The other three sampling dates showed that the laboratory's Practical Quantitation Level (PQL) could not be achieved due to sample composition, matrix effects, sample volume, or quantity used for analysis. Two of the five sampling dates at the middle estuary showed similar PQL issues, making it difficult to draw any conclusions from the data. Three of the five sampling dates showed BOD below or around 2 mg/L, indicating natural conditions at the middle estuary.

Chloride is a large constituent of dissolved solids in water. It can also give us a basis for the amount of salt ions that are flowing into a body of water through stormwater runoff from roadways and parking areas within a watershed. Chloride in estuarine waters is influenced by incoming seawater following tidal cycles. Normal offshore seawater chloride levels are approximately 19,400 mg/L. Therefore, incoming tides carry high-chloride seawater, while outgoing tides flush out seawater and mix with freshwater sources from the watershed. For this reason, samples were collected on the outgoing tide just before dead low tide to capture the freshwater influences coming off the landscape.

2014 CHLORIDE RESULTS: The upper estuary is influenced by freshwater sources draining from the watershed with chloride concentrations around 3,700 mg/L at dead low tide. Chloride levels were high (16,000-18,000 mg/L) during all sampling events at the middle estuary despite low tide conditions in Spruce Creek; this is likely because the middle estuary is heavily influenced by tidal cycling in the Piscataqua River and is closer to the open ocean.

E. coli and **fecal coliform** are both fecal indicator bacteria, with *E. coli* being a type of fecal coliform. Bacteria concentrations in waterbodies can vary under different weather conditions, usually rising sharply after rainfall. Sources of bacteria from feces include stormwater runoff, malfunctioning septic systems, pet waste, and wildlife. High concentrations of fecal indicator bacteria in waterbodies can lead to posted advisories at swimming beaches and closure of shellfish beds. These bacteria are used to signal human health risks such as gastrointestinal, respiratory, eye, ear, nose, throat, and skin infections transmissible to humans through the consumption of contaminated fish and shellfish, skin contact, and/or ingestion of water. Though Maine uses *Enterococci* bacteria as a standard for marine waters, *E. coli* was used in the Spruce Creek channel investigation for comparison purposes. The Town of Kittery uses *E. coli* as its bacteria parameter throughout the watershed to encompass and compare both freshwater and estuarine waters. The Maine freshwater *E. coli* water quality standard for recreational use of Class B waters is 236 colonies/100mL for instantaneous samples and 64 colonies/100mL for geometric means. Fecal coliform are used to monitor shellfish harvesting. Since shellfish (e.g. clams, mussels, and oysters) are filter feeders, bacteria in the water that pass through shellfish can become concentrated in their tissue and make humans sick, if consumed. The Maine water quality standard for Class SB waters for fecal coliform is based on the National Shellfish Sanitation Program, which sets a geometric mean threshold of 88 col/100 mL and a 90th percentile threshold of 163 col/100mL for restricted growing areas (NSPP, 2009).

2014 E.COLI RESULTS: The upper estuary exceeded the single sample standard for all five sampling events and the geometric mean standard for the year. Four of the five sampling events at the upper estuary were greater than the laboratory detection limit at 2,419.6 col/100 mL. The last sampling event on 10/17/2014 showed *E. coli* lower at 629.4 col/100 mL. This was following a large rain event the day before and may be a result of dilution. Interestingly, dry weather seems to be tied to elevated *E. coli* concentrations that may be coming from septic systems or sewer pipes connected to groundwater baseflow. The middle estuary showed one single sample exceedance at 721.5 col/100 mL on 8/29/2014. This was not following any significant precipitation event. The geometric mean of the five samples taken this year for the middle estuary at 109 col/100 mL exceeded the State standard of 64 col/100 mL for geometric means.

2014 FECAL COLIFORM RESULTS: All samples fell below 10 cfu/100 mL at the middle estuary with the exception of 10/17/2014 at 67 cfu/100 mL. This may be connected to the large rain event the day before (0.79 inches). The geometric mean and 90th percentile for 2014 fecal coliform samples at the middle estuary were less than the standard for restricted shellfish growing areas. This was in contrast to the upper estuary that exceeded both standards for geometric mean and 90th percentile. The high fecal coliform concentration on 10/17/2014 at the upper estuary may also be connected to the rain event the day before.

Ortho-Phosphate (PO_4) is a form of inorganic phosphorus that promotes the growth of aquatic plants and algae. It is a primary nutrient, similar to nitrogen, and can be limiting to aquatic ecosystem productivity. Phosphate attaches to sediment particles where it can be easily transported off the landscape to nearby surface waters. Phosphate can also react with metals and low dissolved oxygen concentrations to create toxic environments and stimulate the release of more phosphate for algal growth. Historically, inorganic nitrogen was believed to be the limiting nutrient for estuarine and oceanic environments and inorganic phosphorus the limiting nutrient for freshwater. Recent studies have begun to chip away at this paradigm, revealing that these systems may actually be co-dependent and co-limited by the presence or absence of the other (Elser et al. 2007). It is recommended that future monitoring continue to include inorganic phosphorus and consider adding total phosphorus analyses.

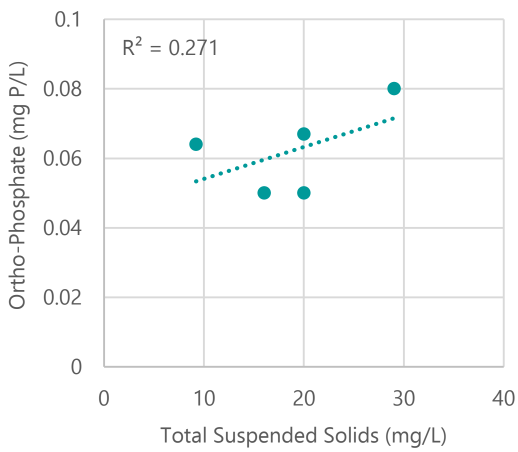


Figure 6. Ortho-phosphate increases with increasing total suspended solids (i.e. sediment) at the upper estuary where freshwater influences are more apparent.

2014 ORTHO-PHOSPHATE RESULTS: All samples from the middle estuary fell below or near the laboratory's PQL of 0.05 mg P/L for phosphate. Phosphate was slightly higher at the upper estuary where only two of the five samples fell below the PQL. The highest sample at 0.08 mg P/L on 10/17/2014 corresponded to a precipitation event the day before and may be from excess sediment runoff. Approximately 27% of the variation in phosphate at the upper estuary is explained by the concentration of suspended sediments that were either resuspended during the storm or newly derived from bare soil on unbuffered development sites within the watershed (Figure 6).

Nitrite/Nitrate-Nitrogen (NO_2/NO_3) are forms of inorganic nitrogen that promote the growth of aquatic plants and algae, but can be toxic to fish in excessive amounts. Maine does not have a water quality standard for nitrate or nitrite in surface waters; however, natural levels of nitrate are most often below 0.1 mg/L. Waters that are affected by development and other human activity can have nitrate levels of up to 5 mg/L. Concentrations upward of this may indicate excessive fertilizer or illicit wastewater pollution (Wenner et al. 2014). Nitrite is an important component of soluble nitrogen in aquatic environments, but it is highly unstable and reacts easily to form nitrate in oxidizing environments.

2014 NITRATE/NITRITE-NITROGEN RESULTS: Both nitrate and nitrite fell below the laboratory's PQL of 0.05 mg/L, indicating natural conditions at the middle estuary. This was similarly the case for the upper estuary with the exception of 10/17/2014 that showed nitrate concentration at 0.16 mg N/L. This was slightly elevated above what is considered a natural level of nitrate in aquatic environments and followed a rain event the day prior. Sources of nitrogen in the Spruce Creek watershed are likely mobilized in stormwater runoff from paved areas or agricultural fields. It may also be flushed from septic systems as the groundwater table rises during wet weather.

Total Kjeldahl Nitrogen (TKN) is the sum of ammonia and organic nitrogen. Ammonia (NH_3) is a form of inorganic nitrogen that promotes aquatic plant growth and can be toxic to fish in excessive amounts. Excess ammonia can also promote algal blooms, particularly in marine waters. Organic nitrogen can also be used for aquatic plant growth, depending on its biodegradability and the availability of inorganic forms of nitrogen that tend to be preferred over organic forms. High levels of bioavailable organic nitrogen is found in fecal waste from humans, pets, farm animals, and wildlife. The New Hampshire Department of Environmental Services (NHDES) published nutrient guidelines for the Great Bay (NHDES, 2009); those recommendations indicate a limit for total nitrogen (TN) concentration of 0.45 mg/L for aquatic life. TN is the sum of TKN and nitrite/nitrate. More strict levels for TN are listed for various water column depths to protect eelgrass communities.

2014 TOTAL NITROGEN RESULTS: All sampling events at both stations exceeded the NHDES standard of 0.45 mg N/L for TN with the exception of 9/19/2014 when both stations fell below the standard. The middle estuary showed a high TN concentration of 2.4 mg N/L on 8/29/2014. The upper estuary showed high TN concentrations of 1.1 mg N/L on 8/19/2014 and 1.4 mg N/L on 10/17/2014. It is difficult to discern any specific patterns in TKN or TN from the limited data set. *Note: Nitrate, nitrite, and TKN were only summed when nitrate and/or nitrite were above the laboratory's PQL.*

Total Organic Carbon (TOC) is the amount of carbon bound in organic compounds within a sample of water. TOC can come from naturally-decaying organic matter, as well as synthetic sources such as detergents, fertilizers, and other chemical pollutants. Maine does not have a water quality standard for TOC in surface waters, but typically New England rivers and streams have TOC ranging from 1-10 mg C/L with some spikes (>10 mg C/L) in TOC during spring freshet.

2014 TOTAL ORGANIC CARBON RESULTS: The upper estuary showed a greater range (2.9 to 9.2 mg C/L) with the highest TOC concentration corresponding to the wet weather sampling on 10/17/2014. The middle estuary showed fairly unchanging TOC concentrations, ranging from 1.4 to 2.1 mg C/L. The flush of organic carbon from the landscape may be natural (e.g. wetlands) or human-derived and is likely a mixture of both, but TOC concentrations fell within a reasonable range for New England surface waters.

Total Suspended Solids (TSS) are solids present in water that will not pass through a 2 micron filter. Examples of suspended solids include sediment particles, algae, and various organic particulates. Suspended solids can carry pollutants and toxics and significantly degrade water quality in excessive amounts (USEPA, 2012). Maine has not set water quality criteria for TSS in surface waters, and it can be difficult to make general conclusions about TSS thresholds without understanding the contributing landscape.

2014 TOTAL SUSPENDED SOLIDS RESULTS: TSS in the upper estuary ranged from 9.2 to 29 mg/L , while the middle estuary ranged from 6 to 17 mg/L. Field notes indicate that the upper estuary site was extremely cloudy with suspended silt and algae in late summer and early fall sampling, and TSS steadily increased with each successive sampling event.

2.1.2 CONTINUOUS SONDE DATA

The sondes measured the following parameters: temperature (°C), dissolved oxygen (mg/L and % saturation), specific conductivity (mS/cm), relative water depth (m), and pH (Figures 6 and 7). 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.

Dissolved Oxygen (DO) is the concentration of oxygen dissolved in water, and is critical to the metabolism of many aquatic organisms. The DO standard for Class SB marine waters outlined in 38 MRSA §465-B, and used by the Maine Department of Environmental Protection, is 85% saturation or greater.

2014 DO RESULTS: The upper estuary of Spruce Creek experienced large swings in daily DO as DO saturation varied from 2% to 156% saturation with an overall average of 63% saturation (Figure 7). The minimum daily DO value fell below 85% on all days monitored at the upper estuary. The middle estuary of Spruce Creek also experienced large swings in daily DO, which varied from 62% to 137% with an average of 94% saturation (Figure 8). The minimum daily DO value fell below 85% on all except 9 days within the monitoring period at the middle estuary. The greater variability in DO at the middle estuary at the start of the second deployment (end of September) is likely a result of an eddy-effect from Shepherds Hill Cove just downstream of the station. DO values 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 is the ability of water to pass an electric current and is determined by the amount of dissolved inorganic solids ionized in water, such as chloride and other salts, standardized to a temperature of 25 °C. Specific conductivity can be used to approximate salinity and observe trends in tidal cycles.

2014 SPECIFIC CONDUCTIVITY RESULTS: Specific conductivity in the upper estuary of Spruce Creek varied from 16 to 48 mS/cm, with an average of 43 mS/cm (Figure 7). Specific conductivity in the middle estuary of Spruce Creek varied from 34 to 47 mS/cm with an average of 45 mS/cm (Figure 8). Conductivity remains consistently high at the middle estuary because it is largely 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. This dilution pattern is particularly apparent for the upper estuary at the end of the deployment period after a 0.79 in rain event on 10/16/2014.

pH is a measure of the acidity of water in terms of hydrogen ion concentration. Water contains both hydrogen (H^+) and hydroxyl (OH^-) ions. At a pH of 7.0 (neutral), the concentrations of both ions are equal; at pH < 7.0 (acidic), there are more H^+ than OH^- ions; at pH > 7.0 (alkaline or basic), there are less H^+ than OH^- ions. Everything that rivers come in contact with affect pH, including soils, organic acids (decaying leaves or other matter), and human-induced acids from acid rain. pH affects many chemical and biological processes in water, and various organisms flourish under different pH ranges, the most preferred being between 6.5 and 8.0. The ability of aquatic organisms to complete a life cycle greatly diminishes as pH falls below 5.0 or exceeds 9.0. pH is directly tied to the balance of photosynthetic and respiration processes that can change as a result of excess nutrients or organic carbon.

2014 pH RESULTS: pH at the upper estuary ranged from 7.2 to 8.1 with a log-derived averaged of 7.5 (Figure 7). pH at the middle estuary ranged from 7.9 to 8.3 with a log-derived average of 8.1 (Figure 7). 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).

Figure 7. Continuous sonde data collected in the upper estuary of Spruce Creek at Picott Road.

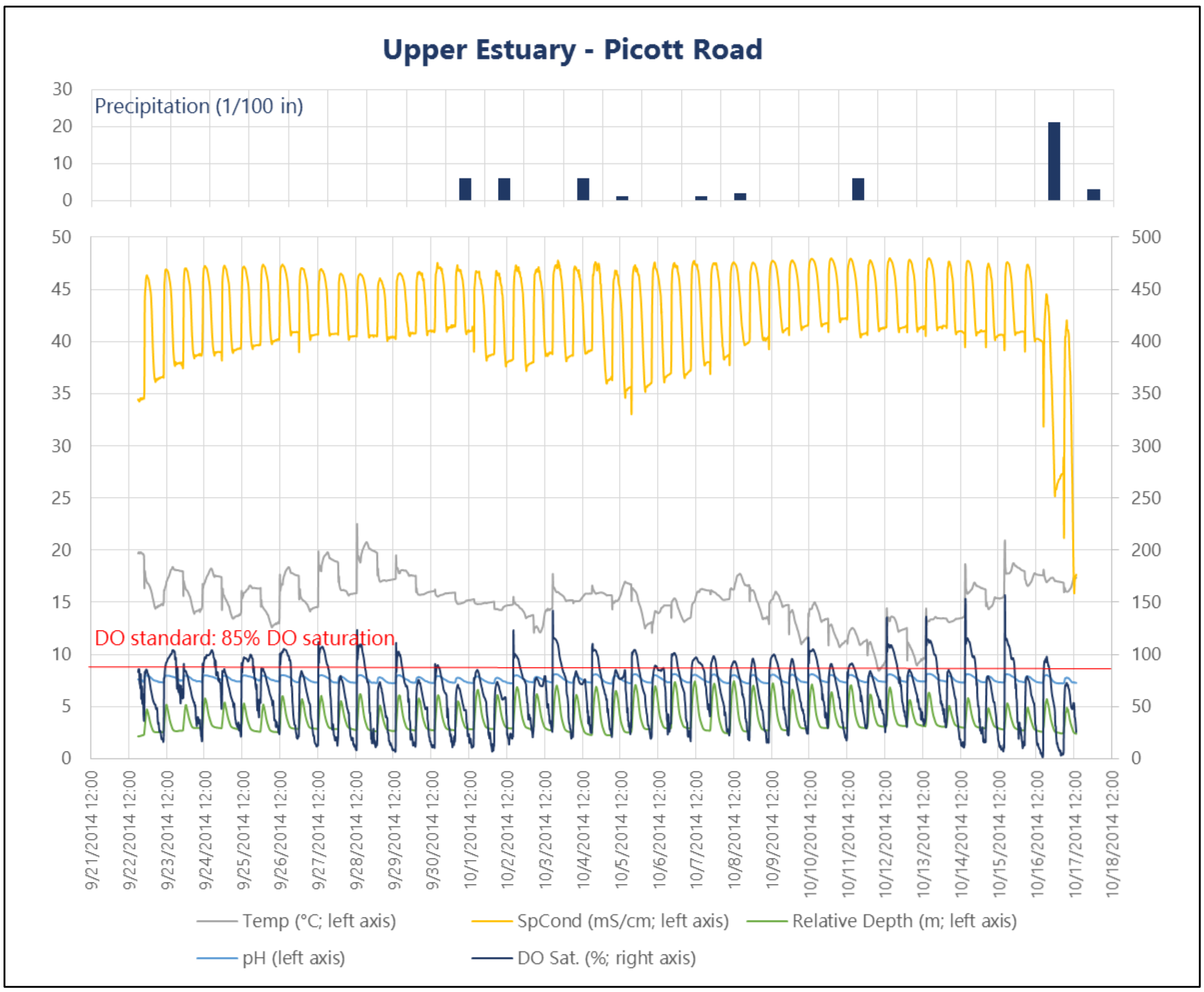
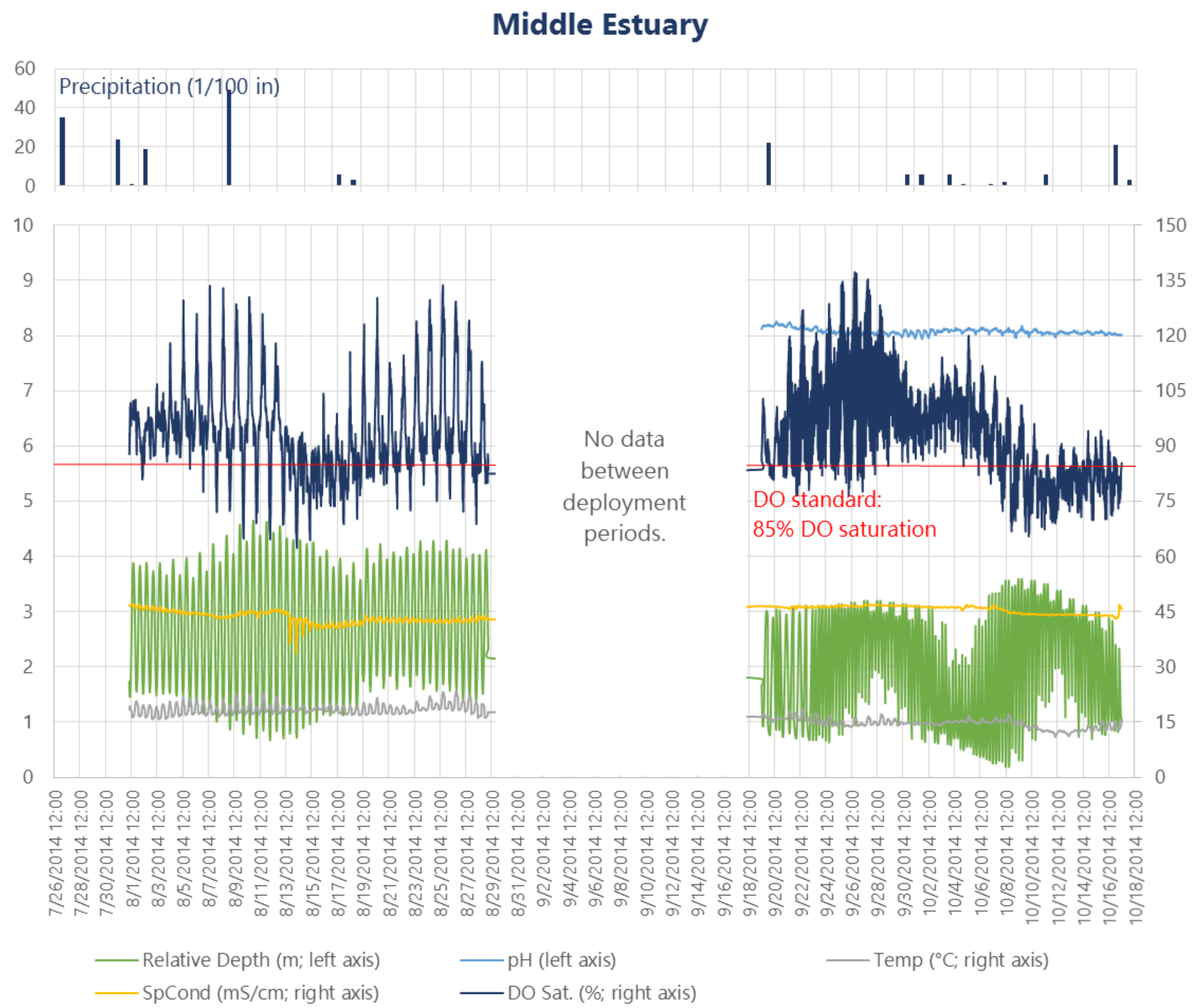
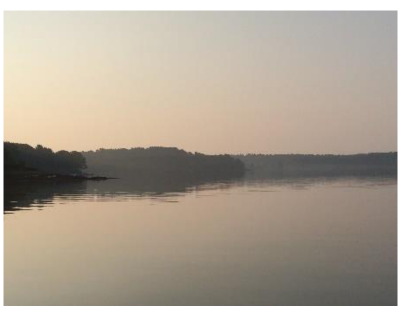


Figure 8. Continuous sonde data collected in the middle estuary of Spruce Creek.





2.2 HISTORICAL BACTERIA RESULTS

The main stem of Spruce Creek is considered impaired for bacteria by the State of Maine. Its shellfish growing areas have been closed since 2005 and classified as restricted for depuration harvesting due to high levels of fecal coliform, lead, mercury, and other metals (e.g. silver, cadmium, chromium, copper, nickel, zinc, aluminum, and iron). In an effort to highlight portions of the channel impacted by high bacteria counts, all historical bacteria results for the main stem of Spruce Creek were compiled from the Town of Kittery, the Department of Marine Resources (DMR), and Maine Healthy Beaches (MHB). The types of bacteria data, timeframes, sites, and summarized results are presented in Table 5. Annual summaries of these data can be found in Tables 3, 4, 6, and 7. A map of all sites with bacteria results is shown in Figure 9.

As described in Section 2.1.1 above, *E. coli* and fecal coliform are both fecal indicator bacteria, with *E. coli* being a subgroup of fecal coliform. *E. coli* is used by the Town of Kittery to compare freshwater and estuarine waters since different bacteria indicators are not directly comparable. Typically, *E. coli* is used to track bacteria in freshwater. Fecal coliform are used to monitor shellfish harvesting in estuarine waters, and is the bacteria indicator monitored by the DMR. The State of Maine uses *Enterococci* bacteria as the standard for coastal beaches, and is the bacteria indicator monitored by MHB at their beach sites. *Enterococci* are a subgroup of fecal streptococcus more specifically related to human feces, and are more prevalent in salt water.

- The Maine freshwater *E. coli* water quality standard for recreational use of Class B waters is 236 colonies/100mL for instantaneous samples and 64 colonies/100mL for geometric means.
- The Maine marine/estuarine fecal coliform water quality standard for shellfish harvesting in Class SB waters is based on the National Shellfish Sanitation Program, which sets a geometric mean of 88 col/100 mL and a 90th percentile of 163 col/100mL for restricted growing areas (NSPP, 2009).
- The Maine *Enterococci* water quality standard for coastal beaches is 104/100mL for instantaneous samples and 35/100mL for geometric means.

According to historical bacteria data, the majority of exceedances occurred in the upper to middle estuary of the main stem of Spruce Creek. Lower bacteria counts observed in the lower estuary are likely a result of dilution and mixing with marine waters. Coastal beaches also show multiple single sample exceedances. The upper estuary was particularly high for *E. coli* in 2014 and should be monitored at greater frequency in future years to account for bacteria fluctuations in dry and wet weather. Although it is assumed that the high *E. coli* counts in the middle estuary came from bacteria flushing from the upper estuary, multiple tributaries (e.g. Wilson Brook, Fuller Brook, Hill Brook, and Chickering Creek) just upstream of the middle estuary sonde location may also be contributing bacteria to this site.

Table 5. Summary of all bacteria data near or along the main stem of Spruce Creek. Data compiled from the Town of Kittery, the Department of Marine Resources (DMR), and Maine Healthy Beaches (MHB). Red text indicates exceedance.

Source	Site	Type of Bacteria	State Standard	Years Collected	Total Samples Collected	Bacteria Result (Annual Geomean)	Bacteria Result (Annual 90th Percentile)	Bacteria Result (Percent Instantaneous Exceedances)
Town of Kittery	Middle Estuary	Fecal Coliform	Geomean not to exceed 88/100mL; 90th percentile not to exceed 163/100mL	2013-2014	5	6.1	42.5	--
	Upper Estuary - Picott Road			2014	5	97.0	1424.0	--
Town of Kittery	Middle Estuary	E.coli	Geomean not to exceed 64/100mL; single samples not to exceed 236/100mL	2013-2014	7	34.4	--	14%
	Upper Estuary - Picott Road			2014	5	1848.3	--	100%
DMR	WA028.00	Fecal Coliform	Geomean not to exceed 88/100mL; 90th percentile not to exceed 163/100mL	2006-2014	51	7.1	166.1	--
	WA029.10			2007-2014	49	9.2	135.0	--
	WA031.00			2006-2014	51	5.9	131.6	--
	WA032.00			2014	1	3.8	46.4	--
	WA033.00			2006-2014	51	5.1	24.6	--
	WA034.00			2006-2014	51	3.1	45.8	--
	WA035.00			2008-2014	51	3.6	69.2	--
	WA036.00			2006-2014	51	3.1	19.0	--
	WA024.00			2006-2014	53	2.5	17.8	--
MHB	K1	Enterococci	Geomean not to exceed 35/100mL; single samples not to exceed 104/100mL	2005-2014	146	14.3	--	9%
	K2			2005-2014	145	15.1	--	9%
	K3			2005-2014	186	11.2	--	1%
	K4			2005-2014	143	11.9	--	3%
	K5			2005-2014	138	10.0	--	1%
	K6			2012-2013	24	9.8	--	4%

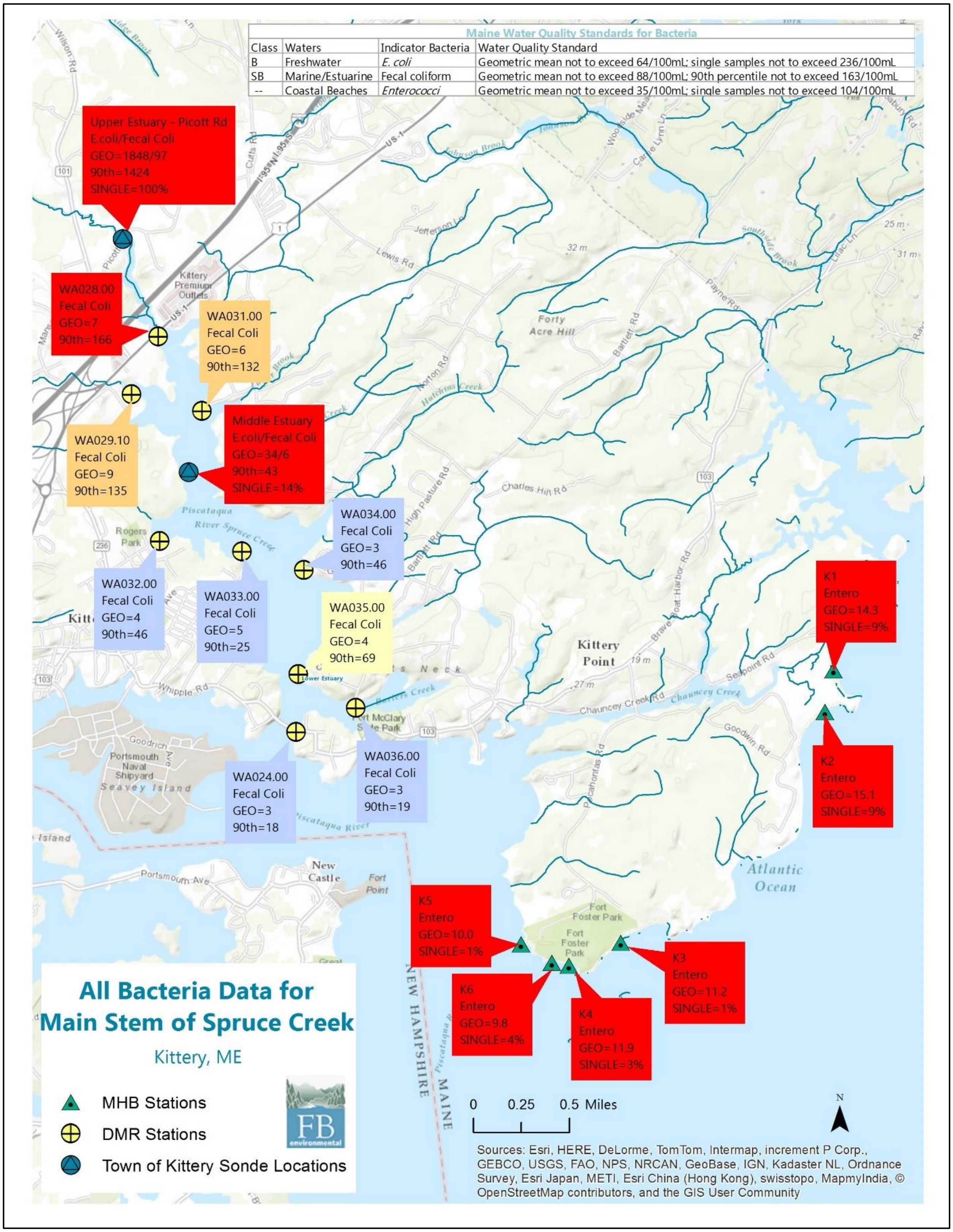
Table 6. Annual summary of bacteria data obtained from the Department of Marine Resources (DMR) stations along Spruce Creek. Red text indicates exceedance.

Site	Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	Annual	All Data
WA028.00	GEO*	19	26	13	11	5	4	3	7	2	7	7
	90**	21	151	122	99	18	10	12	227	12	166	78
	N	2	6	6	6	7	6	6	6	6	51	51
WA029.10	GEO*	--	18	11	11	10	2	6	9	20	9	9
	90**	--	82	61	55	54	5	35	111	191	135	72
	N		6	6	6	7	6	6	6	6	49	49
WA031.00	GEO*	21	16	11	8	4	4	2	4	2	6	5
	90**	101	101	253	59	22	7	7	49	6	132	46
	N	2	6	6	6	7	6	6	6	6	51	51
WA032.00	GEO*	--	--	--	--	--	--	--	--	4	--	--
	90**	--	--	--	--	--	--	--	--	46	--	--
	N	--	--	--	--	--	--	--	--	9	--	--
WA033.00	GEO*	14	12	6	5	4	3	3	4	3	5	5
	90**	19	43	17	20	15	9	19	17	15	25	20
	N	2	6	6	6	7	6	6	6	6	51	51
WA034.00	GEO*	5	4	3	7	8	2	2	1	1	3	3
	90**	24	29	54	17	44	5	8	4	3	46	18
	N	2	6	6	6	7	6	6	6	6	51	51
WA035.00	GEO*	--	--	9	3	6	2	2	5	4	4	4
	90**	--	--	22	14	67	5	5	73	16	69	18
	N	--	--	3	6	6	6	6	8	16	51	51
WA036.00	GEO*	1	4	6	4	3	4	2	3	2	3	3
	90**	2	12	15	14	19	12	11	19	20	19	15
	N	2	6	6	6	7	6	6	6	6	51	51
WA024.00	GEO*	4	2	3	3	3	2	1	2	3	3	2
	90**	16	4	11	13	9	7	4	2	24	18	10
	N	2	8	6	6	7	6	6	6	6	53	53
*GEO=geometric mean (not to exceed 88/100mL)												
**90=90th percentile (not to exceed 163/100mL)												

Table 7. Annual summary of bacteria data obtained from Maine Healthy Beaches (MHB). Red text indicates exceedance.

Site	K1			K2			K3			K4			K5			K6		
Year	GEO *	SINGLE *	N	GEO *	SINGLE *	N	GEO *	SINGLE *	N	GEO *	SINGLE *	N	GEO *	SINGLE *	N	GEO *	SINGLE *	N
2005	33	3	15	18	2	15	9	1	15	15	2	15	14	1	14	--	--	--
2006	15	1	13	10	0	12	11	0	12	15	0	12	13	0	12	--	--	--
2007	8	0	13	12	0	13	7	0	13	8	0	13	8	0	13	--	--	--
2008	7	0	13	20	2	14	10	0	13	9	0	13	8	0	13	--	--	--
2009	24	4	19	23	0	15	18	1	64	20	0	19	13	0	15	--	--	--
2010	32	4	17	19	1	14	18	0	14	10	1	15	10	0	15	--	--	--
2011	12	0	13	21	3	16	7	0	13	10	1	14	9	1	14	--	--	--
2012	11	1	15	20	4	17	18	0	14	18	0	14	8	0	14	14	1	10
2013	14	0	14	8	0	14	16	0	14	7	0	14	7	0	14	7	0	14
2014	8	0	14	10	1	15	7	0	14	15	0	14	15	0	14	--	--	--
Annual	14	13	146	15	13	145	11	2	186	12	4	143	10	2	138	10	1	24
All Data	15	13	146	15	13	145	9	2	186	11	4	143	9	2	138	9	1	24
*GEO=geometric mean (not to exceed 35/100mL)																		
*SINGLE=number of single sample exceedances (each single sample not to exceed 104/100mL)																		

Figure 9. All bacteria data for the main stem of Spruce Creek. Red boxes indicate sites exceeding bacteria water quality standards; orange boxes indicate sites close to exceeding bacteria water quality standards; yellow boxes indicate sites with slightly elevated bacteria counts; and blue boxes indicate sites meeting bacteria water quality standards.



2.2.1 NEXT STEPS

Continued sampling of the main stem of Spruce Creek at these locations will provide valuable information and allow the Town of Kittery to track progress toward improving water quality to Spruce Creek. Creating a trend for data collected via sondes and through grab sampling will play a key role in future planning and restoration management processes within the Spruce Creek watershed. It is recommended that the Town of Kittery re-deploys a sonde at the same locations in Spruce Creek in the summer and fall of 2015 (August 1 – September 30) to continue tracking water quality in the main stem of Spruce Creek. It is also recommended that a third sonde be deployed in the lower estuary, if additional resources are available. Three grab sampling events should be conducted for each sonde location at the beginning, middle, and end of the deployment period.

In addition to yearly sonde deployments, a grab sampling program should be created and put into action for 2015. This can either be accomplished through reactivation and expansion of the Spruce Creek Association Volunteer Monitoring Program or through the use of consultants. Weekly grab samples in Spruce Creek would provide the best data, but monthly sampling would also be valuable. It is recommended that five grab sampling events for at least bacteria (*E. coli*) and possibly nutrients (N, P) and sediment be conducted at each of the seven major tributaries to Spruce Creek (Wilson Brook, Fuller Brook, Hill Brook, Hutchins Creek, Chickering Creek, Barter's Creek, and Crockett's Brook). Three of these sampling events should be in conjunction with the sonde grab samples, and two sampling events should be reserved for extreme weather events (dry or wet conditions). This monitoring plan will help evaluate the fate and transport of bacteria sources from the landscape to Spruce Creek and target high priority tributaries.

The upper estuary of Spruce Creek exceeded the maximum laboratory detection limit (>2,419.6 col/100mL) on four of the five sampling events in 2014. It is highly recommended that at least one wet and one dry weather sampling be conducted in 2015 at multiple locations moving upstream from the Picott Road crossing to determine hotspots of bacterial contamination.

FORT FOSTER BEACH FOLLOW-UP INVESTIGATION

Figure 10. Sub-watershed and drainage area for Fort Foster beach 2014.

In 2012 and 2013, FB Environmental worked with Environmental Canine Services to identify sources of bacteria to Fort Foster Beach. Though some of these sources have been successfully remediated, other sources are still present and have been shown to contribute large amounts of bacteria to the beach. To address this concern, FBE conducted a watershed investigation to identify potential bacteria sources to the beach in 2014. This investigation included mapping, water quality sampling, and the use of canine detection to identify bacteria sources. The sub-watersheds/drainage area for the beach was mapped and sampling locations were chosen to bracket the inputs of bacteria to the beach. All samples were taken under dry weather conditions and sent to the laboratory for analysis. Figure 10 shows the delineated sub-watershed.

All bacteria samples were analyzed for *Enterococci* bacteria at Nelson Analytical Water Testing Laboratory in Kennebunk, Maine. *Enterococci* bacteria are used as an indicator of the presence of fecal material in saltwater by the Maine Healthy Beaches Program. In Maine, the State water quality standard for *Enterococci* is 104 colonies/100mL for a single grab sample and 35 colonies/100mL for the geometric mean of multiple samples.

3.1 CANINE AND BACTERIA RESULTS

The canines alerted to the presence of human sources of bacteria at three locations on Fort Foster beach. Both dogs alerted on a seep on the west side of the beach (FF04L), while only Logan alerted on a seep at the far end of the beach towards the east (FF01R) (Figure 11). Two other large seeps on the east side of the beach were noted and sampled; however the dogs did not alert on either seep (Figure 11).

A large algal mat that stretched the length of the east section of beach was also observed. Canine Logan alerted to the presence of human-sourced bacteria at both the northern end of the marsh along the access road as well as the southern end of the marsh near the beach (MB01), while canine sable did not (Figure 10 and 11).

The bathrooms near the west boundary of the sub-watershed and Fort complex and were investigated by the canines. Both canines alerted on a plumbing vent pipe on the north side of the building where the plumbing joint was cracked. It was noted that the only potential septic leach field for the building was a small grassy area to the north of the building. Canine Logan investigated the grassy area and alerted on human fecal scent in the ground at the northeast edge of the area. It was also noted that the Fort and surrounding trail system near the beach is popular for dog-walkers, and although most people observed had bags to dispose of their pets' waste, this could also be a potential bacteria input.

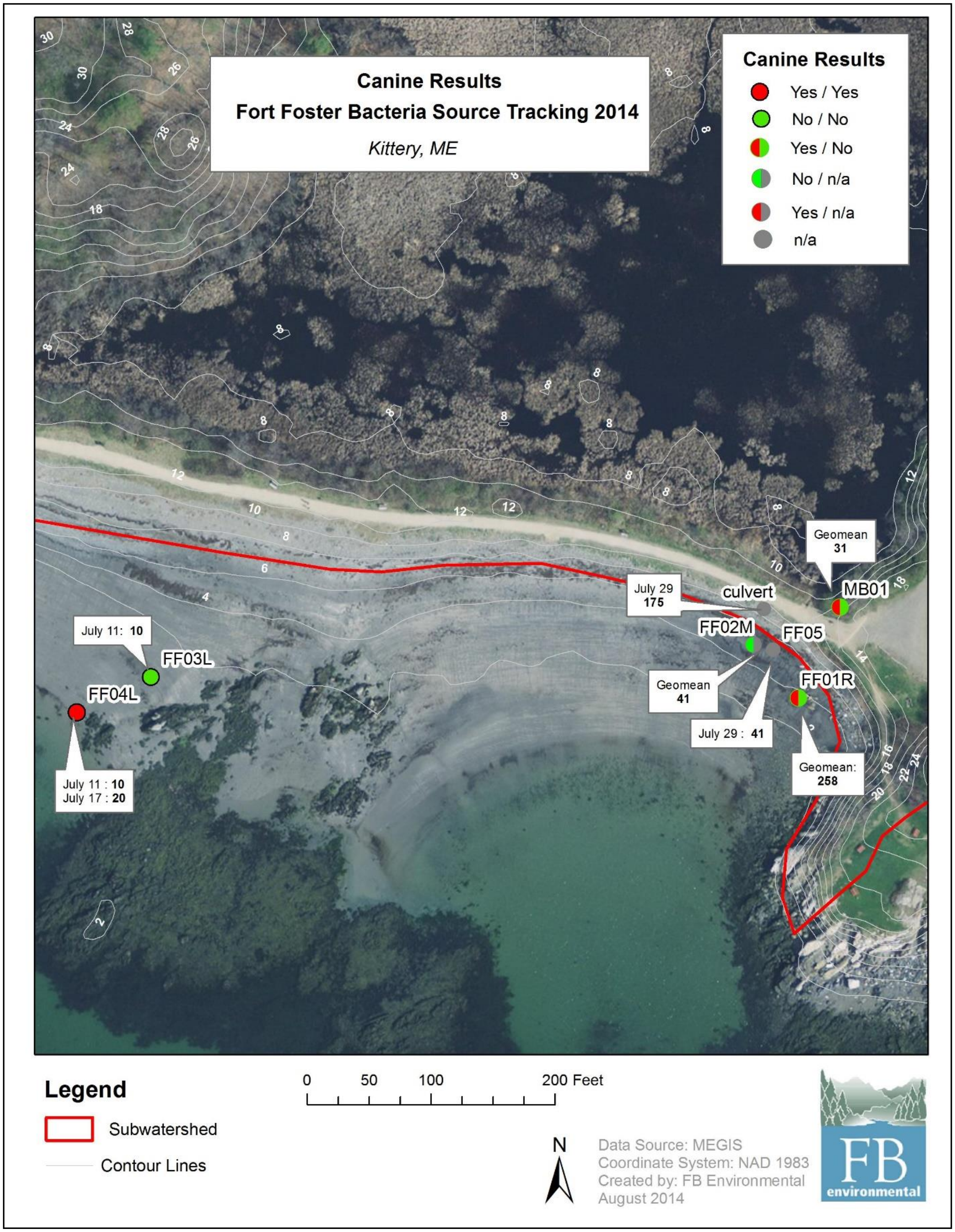
Bacteria results exceeded the State standard at three locations on the beach throughout the three sampling events (Table 8). Site FF01R, on the east side of the beach, exceeded the standard on every sample date and had a geometric mean that was also above the State standard. Site FF02M only exceeded the standard on one sample date, but also displayed a geometric mean that was above the standard over the course of the sample season (Table 8). Seeps on the west side of the beach had consistently low bacteria levels (<50 colonies/100mL). Bacteria levels at the outlet of the marsh (MB01) also had bacteria levels that were low throughout and did not exceed State standards (Table 8). A culvert on the beach that connects to the marsh outlet was exposed part-way through the sample season. This culvert had a small amount of flow on July 29, 2014, and was sampled for bacteria. The levels were high (175 colonies/mL) and above the State standard (Table 8). This culvert was not assessed by the canines for the presence of human-sourced bacteria; therefore, the source is unknown.

A large algal mat on the east side of Fort Foster beach was observed throughout the sample season.

Table 8. *Enterococci* (colonies/100mL) results, geometric mean, and canine results for Fort Foster investigation. Red text indicates exceedance of State standard.

Sample	Location	Sample Date				Canine Results	
		7/11/2014	7/17/2014	7/29/2014	Geomean	Logan	Sable
		Dry	Wet	Wet			
FF01 R	Seep on far right of beach	231	228	327	258	Yes	No
FF02 M	Seep between FF01 R and FF05 on beach	169	41	10	41	No	n/a
FF05	Seep to the left of culvert on east side of beach	No sample	41	No sample	n/a	n/a	n/a
MB01	Outlet of the marsh into culvert	30	10	95	31	Yes	No
FF03 L	Seep on left side of the beach	<10	No sample	No sample	n/a	No	No
FF04 L	Seep on far left side of the beach	10	20	No sample	n/a	Yes	Yes
culvert	Culvert on the beach	No sample	No sample	175	n/a	n/a	n/a
Maine Enterococci standard = 104 col/100mL (single sample) and 35 col/100mL (geometric mean)							

Figure 11. Sub-watershed canine results for sampling of Fort Foster in the Kittery, Maine (July – October 2014).



3.2 DISCUSSION

Three locations on Fort Foster beach were found to have seeps with the presence of human-sourced bacteria:

1) FF04L on the west side of the beach;
2) FF01R on the east side of the beach; and
3) Outlet to the marsh.

Of these two locations, the seep on the west side of the beach had consistently low levels (<25 colonies/100mL; Table 8). Due to the low levels at this seep throughout during all sample events, this location is not an area of concern. The site on the east side of Fort Foster beach (FF01R) had bacteria levels that were above the standard on all three sample days, and an overall geometric mean that also exceeded State standards (Table 8). Canine Logan altered to the presence of human bacteria at this location; however, canine Sable did not. This indicated that although there is a presence of human-sourced bacteria, it may not be in a high concentration. Much of the bacteria resulting at that site could be non-human sourced from the marsh in close proximity. The area surrounding the east section of beach with elevated bacteria levels was thoroughly investigated for any infrastructure or other human sources that could be causing high levels on the beach. Due to the drainage area/sub-watershed being completely located within the park, there are very few potential human sources. All potential human sources were addressed and found to not be a contributor to the bacteria on the beach.

Bacteria levels at the outlet of the marsh (MB01) were high during one sample event, and had an overall geometric mean that was above the state standard (Table 8). Canine Logan alerted to the presence of human bacteria at MB01 as well as the north end of the marsh along the access road; however, canine Sable did not. This suggests that although some of the bacteria coming from the marsh are of human-origin, there could also be other sources. Other potential sources could include wildlife, or natural processes originating from the marsh. Due to the large amount of dog traffic in the park, this could also represent a large pollution source. The only other location the canines alerted to the presence of human-sourced bacteria was around the bathrooms near the fort structure and the west side of the watershed boundary. Due to the distance away from the beach, this does not represent a potential source for the elevated levels on the beach.

3.3 NEXT STEPS

1. Continue to monitor bacteria levels on the Fort Foster beach to ensure levels do not increase.
2. Continue to pump/maintain septic tanks on the Fort Foster property on a regular basis.
3. Educate Fort Foster park visitors to dispose of pet waste properly.
4. Continue to monitor bacteria levels in the storm drain system of Manson Ave and at the outlets.

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