Plainfield Township
Little Bushkill Creek
Restoration Plan

Prepared for:
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Executive Summary

Little Bushkill Creek is a tributary to Bushkill Creek with an approximately 17.5 square mile ($mi.^2$) watershed. Portions of Plainfield Township and Stockertown Borough, and all of Wind Gap Borough are within the Little Bushkill Creek watershed. Little Bushkill Creek is designated as a High Quality, Cold Water Fishery (HQ-CWF) (25 Pa. Code § 93.9); however, based on the results of sampling efforts conducted in 2010 and 2011, Little Bushkill Creek was not meeting the criteria for its designated use (25 Pa. Code § 93.7). Specifically, Little Bushkill Creek was not meeting the requirements for water contact (i.e., recreational use) due to elevated concentrations of fecal coliform bacteria.

In 2012, the Pennsylvania Department of Environmental Protection (PADEP) listed Little Bushkill Creek as impaired for recreational use due to elevated concentrations of fecal coliform bacteria in 2012 (PADEP, 2012). To address this, and work towards delisting Little Bushkill Creek as impaired, the Plainfield Township Board of Supervisors (BOS) retained URS Corporation (URS) to further evaluate Little Bushkill Creek and assist with meeting the following objectives:

- Identify potential sources of elevated fecal coliform concentrations;
- Evaluate the status of reaches in Little Bushkill Creek in Plainfield Township and potentially work towards delisting reaches that are not impaired for recreational use; and
- Develop management and restoration strategies to support Little Bushkill Creek in attaining its designated use in respect to fecal coliform bacteria.

To meet these objectives, URS conducted an assessment of Little Bushkill Creek in July and September of 2013 in accordance with DEP protocols and an approved Sampling Plan (URS, 2013b). This assessment included fecal coliform bacteria, and ancillary water quality parameters (fecal streptococcus, nitrate-nitrogen, and total Kjeldahl nitrogen (TKN), dissolved oxygen, temperature, specific conductivity, total dissolved solids, salinity, and pH), bacteroides (total, human, and several host animals), and a riparian corridor assessment.

Based on the results of the 2013 fecal coliform sampling of Little Bushkill Creek, the majority of the watershed reaches are meeting or potentially meeting Water Quality Standards. Overall, the results indicate that:

- Of a total of 38.8 miles of stream (West, East, and Main Branch plus tributaries), approximately 75% (29.2 miles) attain or potentially attain water quality criteria and should therefore be eligible for listing by PADEP as meeting designated requirements for recreational use.
- The results from five reaches (8.6 miles of primarily tributary waters, or 22% of the total stream miles) suggest these areas are either impaired or potentially impaired, with respect to fecal coliform bacteria.
- Results are inconclusive for 1.0 mile (3%) of the West Branch and an associated tributary.

The 2013 sampling program provides results that serve to refute the findings of previous studies and the listing of the entire Little Bushkill Creek as impaired for recreational use due to elevated

fecal coliform bacteria. Given inconsistency with previous studies (Plainfield, 2010 and 2011) in regards to PADEP guidance to conduct sampling during low flow conditions, some data used to list Little Bushkill Creek as impaired may not be valid. Subsequently, the results of the 2013 sampling assessment, conducted in accordance with the PADEP guidance, could be used to support delisting of the following reaches of Little Bushkill Creek as impaired:

- West Branch - The main stem and tributaries from Mile 2.0 to 0.0;
- East Branch – The main stem and tributaries from Grand Central Woods to Mile 0.9, excluding Grand Central Landfill Tributary 1, and
- Main Branch – The main stem and tributaries from Mile 5.7 to 1.5, excluding Browntown Road Tributary.

The following reaches have been identified as potentially impaired:

- West Branch – The main stem upstream from Mile 2.5

  Based on the results of the assessment, impairment in the West Branch begins at the boundary of Plainfield Township and Wind Gap Borough. Therefore, it is recommended to coordinate with Wind Gap Borough to assess and address sources of impairment in the West Branch. Additional recommendations that may help support improvements in water quality in the West Branch upstream from Mile 2.5 are to evaluate outfalls that were identified during the riparian corridor assessment and improve the condition of riparian buffers.

- East Branch
  - Grand Central Landfill Tributary 1

    Sources of impairment in the Grand Central Landfill Tributary were not clear; therefore, additional sampling in this tributary is recommended to understand potential sources of impairment and identify potential approaches to improve conditions.

  - The main stem from 0.9 to 0.3, including the Heimer Road Spring Tributary and the Benders Church Road Tributary; and

    Based on the results of the assessment, agricultural considerations, such as cattle in and along the stream, are a potential source of impairment. Recommendations to work towards improved water quality include encouraging the use of agricultural best management practices and riparian buffer enhancement.

- Main Branch – Browntown Road Tributary

  Cattle in and adjacent to the stream in an upper reach are a potential source of impairment. Other considerations include wildlife, other domestic animals, such as dogs, and outfalls. Recommendations include implementing agricultural BMPs and riparian buffer enhancements.

Executive Summary

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1.0 Introduction

This Little Bushkill Creek Restoration Plan (Plan) was prepared by URS Corporation (URS) on behalf of Plainfield Township. Little Bushkill Creek is designated as a High Quality, Cold Water Fishery (HQ-CWF) (25 Pa. Code § 93.9) and an Approved Trout Stream (PFBC, 2013). However, based on the results of sampling efforts conducted by Plainfield Township volunteers and the Pennsylvania Department of Environmental Protection (PADEP) in 2010 and 2011, Little Bushkill Creek was not meeting the criteria for its designated use and in 2012 was listed as impaired for recreational use due to elevated concentrations of fecal coliform bacteria.

1.1 Setting

Little Bushkill Creek is a tributary to Bushkill Creek with an approximately 17.5 square mile watershed. Portions of Plainfield Township and Stockertown Borough, and all of Wind Gap Borough are within the Little Bushkill Creek watershed (Figure 1). Two fourth order streams (the East and West Branches of Little Bushkill Creek) originate near the base of Blue Mountain, before converging to form the Main Branch of Little Bushkill Creek, a fifth order stream.

- The West Branch originates in Wind Gap Borough before entering Plainfield Township. In Plainfield Township, land use in the West Branch primarily consists of residential, commercial, forested, and agricultural areas.
- The East Branch originates in Grand Central Woods and near Grand Central Sanitary Landfill. It has a primarily agricultural watershed, although the majority of the riparian corridor along the main stem is wooded. Recreational (i.e., Plainfield Township Recreation Trail) and residential land uses are also common.
- The Main Branch forms at the confluence of the East and West Branches near Rasleytown Road. Land use along the Main Branch consists of agricultural, wooded, recreational, and residential areas.

These three branches of Little Bushkill Creek, as well as the majority of the primary tributaries are identified on Figure 1.

1.2 Background

Bushkill Stream Conservancy volunteers have been monitoring general water quality in Little Bushkill Creek since 2001. Volunteers and PADEP have also collected fecal coliform measurements in Little Bushkill Creek on multiple occasions in 2010 and 2011 (Plainfield, 2010 and 2011). Based on the results of these surveys, PADEP determined that Little Bushkill Creek was not meeting the water quality criteria for fecal coliform bacteria for recreational use identified in the Pennsylvania Code (25 Pa. Code § 93.7) and presented below:

> *"During the swimming season (May 1 through September 30), the maximum fecal coliform level shall be a geometric mean of 200 per 100 milliliters (ml) based on a minimum of five consecutive samples each sample collected on different days*

during a 30-day period. No more than 10% of the total samples taken during a 30-day period may exceed 400 per 100 ml."

As a result, Little Bushkill Creek was listed as impaired for recreational use in the 2012 Pennsylvania Integrated Water Quality Monitoring and Assessment Report (PADEP, 2012). To address this, and work towards delisting Little Bushkill Creek as impaired, the Plainfield Township Board of Supervisors (BOS) retained URS to further evaluate Little Bushkill Creek and assist with developing a restoration plan.

1.3 Project Objectives

The objectives of this project were to:

- Identify potential sources of elevated fecal coliform concentrations;
- Evaluate the status of reaches in Little Bushkill Creek and potentially work towards delisting reaches that are not impaired for recreational use; and
- Develop management and restoration strategies to support Little Bushkill Creek in attaining its designated use in respect to fecal coliform bacteria.

The following section describes how the project objectives were met, including the organization of this plan.

1.4 Scope of Work

To meet the project objectives, a Scope of Work (SOW) was prepared that initially included the development of a sampling plan, a stream survey, a draft technical report, and a restoration plan. During the development of the Sampling Plan, PADEP committed to supporting the analysis of human and total bacteroides samples and concurrent fecal coliform measurements with the agreement that Plainfield Township (via URS) will conduct the sampling efforts. This data collection was added to the SOW to help assess if human sources contribute to elevated fecal coliform measurements. Furthermore, Plainfield Township added additional animal source tracking samples to the SOW to assist with understanding the contribution of fecal coliform bacteria from different animal sources.

This Plan builds upon the Sampling Plan (URS, 2013b) and a Draft Technical Report (URS, 2013a) that were submitted to Plainfield Township in July and August, 2013, respectively. This Plan is organized as follows:

- Section 2.0 Sampling Approach
- Section 3.0 Results
- Section 4.0 Discussion
- Section 5.0 Restoration Recommendations

Selected photographs are provided in Attachment A. Attachment B contains a data disk that includes all photographs, as well as the field data forms, laboratory reports, a published map file (PMF) that allows for the viewing of the GIS data that was developed through this project, and the benthic macroinvertebrate report.

2.0 Sampling Approach

Field activities were conducted by URS during July (July 5, 9, 16, 18, 26, and 31, 2013) and September (September 6, 11, 19, 24, and 26, 2013) in accordance with PADEP requirements and the Sampling Plan (URS, 2013b). On July 16, field activities were conducted with Megan Bradburn of PADEP and Terry Kleintop of Plainfield Township.

Field activities included the collection of water samples for laboratory analysis of fecal coliform bacteria, and ancillary water quality parameters (fecal streptococcus, nitrate-nitrogen, and total Kjeldahl nitrogen [TKN], dissolved oxygen, temperature, specific conductivity, total dissolved solids, salinity, and pH), bacteroides (total, human, and several host animals), and a riparian corridor assessment. The July and September 2013 sample identification, sampling period, description and coordinates, and parameters are summarized in Table 1 with locations shown on the Sample Location Map (Figure 1).

2.1 Sample Locations

Following consultation with Plainfield Township and PADEP, sample locations for water quality parameters were identified throughout Little Bushkill Creek watershed (Table 1 and Figure 1). In addition, a riparian habitat assessment was conducted throughout the main stems of the West Branch, East Branch, Main Branch, Browntown Road Tributary, and the Benders Church Road Tributary (Figure 1). As described below, the sample locations were selected to collect the data necessary to evaluate Little Bushkill Creek; to identify potential sources of impairment; and to address data gaps.

2.1.1 Water Quality Sample Locations

Sample locations were selected for measuring fecal coliform and ancillary water quality parameters (human and total bacteroides, fecal streptococcus, nitrate-nitrogen, TKN, field parameters, and bacteroides) (Table 1). The initial Sampling Plan specified water sampling at ten sample locations; however, a total of eighteen sample locations in July and a total of 22 sample locations in September were assessed for fecal coliform bacteria. These sample locations are summarized below and shown on Figure 1.

West Branch Sample Locations

- W-2.8 - *Wind Gap Borough / Plainfield Township Boundary*

  Based on a review of data from previous sampling efforts conducted by Plainfield Township (Plainfield Township, 2010 and 2011), the West Branch of Little Bushkill Creek is impaired near the boundary between Wind Gap Borough and Plainfield Township. Sample location W-2.8 was selected to evaluate if the stream is impaired as it leaves Wind Gap Borough and to determine the potential sources.

- W-2.7 – *Abel Colony Road*

  PADEP selected this sample location for collecting total and human bacteroides samples since previous fecal coliform data samples from 2011 collected at this location had elevated results (Plainfield Township, 2011).

Table 1. Little Bushkill Creek Sampling Summary, July and September 2013.

	Sample Location ID	Description	State Plane Coordinates (Pennsylvania South)		Parameter / # of Sampling Events															
					Fecal Coliform								Microbial Source Tracking							
			X (Feet)	Y (Feet)	July	September	Fecal Streptococcus	Nitrate - Nitrite	Nitrate	Nitrite	Total Kjeldahl Nitrogen	Field Parameters	Total Bacteroides	Human Bacteroides	Dog Bacteroides	Ruminant Fecal ID	Cow Bacteroides	Bird Fecal ID	Geese Bacteroides	Horse Bacteroides
West Branch	W-2.8	West Branch at Wind Gap Borough / Plainfield Township Boundary	2647391.59	556361.40	5	2	3	3	2	2	3	3								
	W-2.7	West Branch at Abel Colony Road	2647817.09	555635.09	1	2						2	3	3	1	1		1		
	W-1.6	West Branch at Sandt Road	2650504.96	551470.05	5	5	3	3	2	2	3	3								
	W-0.5	West Branch at Getz Road	2654404.06	548963.01	5	5	3	3	2	2	3	3	3	3		1	1		1	1
	W-0.1	West Branch at Recreational Trail	2655551.76	547823.18	5	5	3	3	2	2	3	3								
East Branch	E-GCW3	Tributary to East Branch - Grand Central Woods Tributary 3 at Recreation Trail	2654766.74	562728.98	5	5						3								
	E-GCW1	Tributaries to East Branch - Grand Central Woods Tributaries 1 & 2 at Recreation Trail	2655126.72	560749.20	5	5						3								
	E-GCL1	Tributary to East Branch - Grand Central Landfill Tributary 1 - Between Utility Easement & Quarry	2655563.61	561651.13	5	5						3								
	E-GCL2	Tributary to East Branch - Grand Central Landfill 2 - Below Sedimentation Basin Number 4 Outfall	2655694.52	559942.08	4	5						3								
	E-2.8	East Branch at Grand Central Road	2655505.00	559903.38	1	2						2	3	3	1	1		1		
	E-GCR-0	Grand Central Road Tributary to East Branch	2655736.32	559620.28		5						2								
	E-HRS-0	Heimer Road Spring Tributary to East Branch	2655390.52	551998.77		2						1								
	E-DRT-0	Delabole Road Tributary to East Branch	2655473.51	556203.74		5						2								
	E-BCR-0.7	Benders Church Road Tributary to East Branch at Heitzman Road	2658571.85	551454.55	1	2						2	3	3		1	1		1	1
	E-0.3	East Branch at Rasleytown Road	2655816.04	549386.47	5	2	3	3	2	2	3	3	2	2	1	1	1		1	1
Main Branch	M-5.1	Main Branch Upstream of Confluence with Books Hill Road Tributary	2656717.29	544924.65	5	5	3	3	2	2	3	3								
	M-BHR-0	Books Hill Road Tributary to Main Branch at Books Hill Road	2656906.63	544506.54	5	5	3	3	2	2	3	3								
	M-BT-0.35	Browntown Road Tributary to Main Branch at Browntown Road	2655168.58	539681.13	5	2	3	3	2	2	3	3				1	1		1	1
	M-BT-0.5-E	East Reach of Browntown Road Tributary to Main Branch	2655095.55	540440.45		2														
	M-BT-0.5-W	West Reach of Browntown Road Tributary to Main Branch	2655000.00	540436.78		2														
	M-BT-0.1	Browntown Road Tributary to Main Branch - Between Bangor Road and Recreation Trail	2656502.32	539610.97	1								1	1						
	M-WRT-0	Weiss Road Tributary to Main Branch - Between Engler Road and Main Branch	2657570.53	537940.29	5	5	3	3	2	2	3	3								
	M-1.5	Main Branch at Sawmill Golf Course Entrance Road	2655338.65	531049.25	5	5	3	3	2	2	3	3	3	3	1	1	1		1	1

Note: Field parameters included temperature, pH, specific conductivity, dissolved oxygen, salinity, and total dissolved solids.

- W-1.6 - *Sandt Road* & W-0.5- *Getz Road*

  W-1.6 and W-0.5 were selected to encompass a 1.1 mile segment of the West Branch that was potentially suitable for delisting as impaired for recreational use based on the results of previous sampling efforts (Plainfield, 2010).

- W-0.1 - *End of West Branch at the Recreational Trail*

  W-0.1 is the downstream most sample location on the West Branch. This location was selected to provide information on the overall condition of the West Branch and how it contributes to fecal coliform concentrations in the Main Branch. Previous sampling results at this location indicated that fecal coliform concentrations were higher at this location than at sample location W-0.5.

East Branch Sample Locations

- E-GCW1/E-GCW2, E-GCW3, & E-GCL1, & E-GCL2 - *Grand Central Woods Tributaries*

  Five unnamed tributaries in Grand Central Woods form the headwaters of the East Branch of Little Bushkill Creek. Existing water quality data was not available for these tributaries, so sample locations were included, with PADEP's support, to gain an understanding of the condition of the East Branch of Little Bushkill Creek. It was initially proposed to collect samples at E-GCW1, E-GCW2, E-GCW3, and E-GCL1; however, due to low flow conditions in E-GCW2 during the July sampling event and the observation that the E-GCW2 tributary converged with the E-GCW1 tributary upstream of the sample location, the E-GCW2 location was eliminated. During the second sampling event, at which PADEP was present, the E-GCL2 sample location was observed and added since funding was available for four tributaries in the Grand Central Woods area.

  E-GCW1 and E-GCW2 are on tributaries that begin near Wind Gap Borough and are in the vicinity of relict quarry pits. E-GCW3 is on a tributary that originates near an older neighborhood on Buss Street, Sanders Road, and Glass Street. Based on conversations with the Plainfield Township Sewage Enforcement Officer (SEO), there have been septic system repairs in this area and some homes have older septic systems that do not meet current standards (C. Noll, personal communication with K. Hoffman, May 24, 2013), (25 Pa. Code § 73). E-GCL1 runs along the base of Grand Central Sanitary Landfill. Based on conversations with the SEO and Plainfield Township, leachate and runoff from the landfill are collected and treated and seagulls are generally not a concern for water quality in this area. This location was included to provide information on the condition of this headwater tributary as it represents a different type of land use than the rest of the watershed. E-GCL2 was located downstream of the confluence of the discharge from Grand Central Sanitary landfill sedimentation pond and an unnamed tributary.

- E-2.8 - *Grand Central Road* & E-BCR-0.7 - *Benders Church Road Tributary at Heitzman Road*

  E-2.8 and E-BCR-0.7 are sampling locations that were selected by PADEP for the bacteroides sampling and were subsequently included with the Plainfield Township

study. E-2.8 was not selected for the Plainfield Township fecal coliform study since samples during low flow conditions did not have elevated concentrations of fecal coliform and data from the upstream reaches will help understand the status of the headwaters of the East Branch. E-BCR-0.7 was not included in the Plainfield Township study since this tributary has been previously identified as impaired.

- E-0.3 - *End of East Branch at Rasleytown Road*

  Similar to W-0.1, this location was selected to understand the overall condition in the East Branch. Previous sampling at this location had shown elevated concentrations of fecal coliform bacteria (Plainfield, 2010 and 2011) and, based on conversations with the SEO, there have been documented septic system malfunctions in the vicinity of this sample location.

- E-GCR-0, E-HRS-0, and E-DRT-0 – *East Branch Tributaries*

  During the September sampling round, fecal coliform measurements were added to assess these locations to better understand the extent and/or potential sources of fecal coliform bacteria in Little Bushkill Creek.

Main Branch Sample Locations

- M-5.1 - *Start of Main Branch*

  M-5.1 is at the upper extent of the Main Branch, downstream of the confluence and likely mixing zone of the West and East Branches and prior to input from any Main Branch tributaries. This reach was not previously sampled and was included to provide insight on the condition on the Main Branch prior to inputs from potential sources of impairment along the Main Branch or originating from the tributaries.

- M-BHR-0 - *Books Hill Tributary at Books Hill Road* & M-WRT-0 - *Weiss Road Tributary at Engler Road*

  During previous sampling efforts, fecal coliform concentrations in these tributaries met PADEP's requirements, and therefore, would not have been considered impaired. Therefore, these sample locations were included to confirm if they are meeting PADEP's requirements, and if so, to obtain the data that demonstrate they are potentially suitable for delisting as impaired.

- M-BT-0.35, M-BT-0.1, M-BT-0.5E, and M-BT-0.5W - *Browntown Road Tributary*

  Sample locations were identified in the Browntown Road Tributary since some fecal coliform samples in this reach were elevated during previous sampling efforts. In addition, based on conversations with the SEO, there were potential concerns regarding septic system conditions along this tributary. M-BT-0.35 was included to capture water quality conditions near residential properties and is located prior to a small unnamed tributary that may dilute upstream sources. M-BT-0.1 was included by PADEP for the collection of one total and human bacteroides sample. M-BT-0.5E and M-BT-0.5W were added during the September sampling round to assess the influence of the two streams that form the Browntown Road Tributary.

- M-1.5 - *Plainfield Township / Stockertown Borough Boundary at Saw Mill Golf Course*

  M-1.5 is the last sample location in Plainfield Township before Little Bushkill Creek flows into Stockertown Borough. This location was included to provide data on the overall status of the watershed and to serve as a gauge of the response of the watershed to the implementation of management and restoration strategies.

2.2 Methods

Water quality parameters included fecal coliform and ancillary water quality parameters (fecal streptococcus, nitrate, TKN, bacteroides, and field parameters). Samples were collected in accordance with USGS and PADEP guidelines (USGS, various dates; PADEP, 2012). Table 1 summarizes the parameters that were assessed at each sample location.

In general, water quality samples were collected as follows:

- Approach sample location from downstream to minimize substrate disturbances.
- Document coordinates of samples locations using a Trimble GeoXH handheld Global Positioning System (GPS) data collector with sub-foot accuracy, or similar.
- Measure water quality field measurements using a YSI 600 XL or similar water quality meter (pH, temperature, specific conductivity, total dissolved solids, salinity, and dissolved oxygen) and record data.
- Collect grab sample by dipping an unpreserved container in the water and filling the appropriate sample bottle to the pre-determined level. Certain sample bottles required rinsing.
- Record date, time, and sample collectors on sample label and keep on ice until ready to be packaged for the laboratory.
- Record sample information on the chain of custody.
- Pack coolers according to instructions.
- Deliver samples to laboratory via courier, UPS, or Federal Express.
- Record all appropriate data and field observations

2.2.1 Fecal Coliform Bacteria

Samples were collected for fecal coliform bacteria at a total of 22 locations to assist with the evaluation of the status of Little Bushkill Creek and help identify potential sources of impairment. Fecal coliform bacteria may be associated with a variety of sources, including wastewater, agricultural sources (e.g., manure), wildlife, and domestic pets, such as dogs. Elevated nutrients and water temperatures can allow fecal coliform to multiply in the environment, and they can persist in association with sediments (Wetzel, 2001).

Samples were collected in accordance with the methodology specified in "PADEP's Bacteria Sampling Protocol" (PADEP, 2013) and were sent to Benchmark Analytics, Inc. (Benchmark) for analysis.

For a stream to be delisted as impaired, PADEP requires that the geometric mean of five samples over a 30-day period are consistent with PADEP's Water Quality Standards for fecal coliforms for two months. For this assessment, the first 30-day period was in July (July 5, 9, 16, 18, 26, and 31, 2013) and the second was in September (September 6, 11, 19, 24, and 26, 2013).

Fecal coliform samples were collected from one to ten times (five times during each sampling round) at the sample locations depending on the purpose of the sample. For example, ten samples were collected at ten locations that had potential to meet PADEP's water quality criteria, and one sample was collected at M-BT-0.1 because it was intended to support the analysis of a human and total bacteroides sample that was collected.

PADEP requires sampling be conducted during low flow conditions to evaluate attainment of recreational use criteria and to help with identification of potential sources of impairment. Sampling during high flow conditions can support understanding sources of impairment; however, sampling during high flow was beyond the scope of this study.

2.2.2 Additional Water Quality Parameters

Additional water quality parameters included in the assessment were requested by Plainfield Township. The additional parameters included: fecal streptococcus, nutrients (nitrate and TKN), field parameters (temperature, pH, specific conductivity, dissolved oxygen, salinity, and total dissolved solids), and bacteroides (human and total bacteroides), and animal source tracking.

2.2.2.1 Fecal Streptococcus

Fecal streptococci have been used to help differentiate between human and non-human sources of fecal coliform bacteria. Samples were collected on July 18, September 6, and September 26, 2013 for fecal streptococcus at ten locations. Samples were collected in accordance with the PADEP Bacteria Sampling Protocol and analyzed by Benchmark.

2.2.2.2 Nutrients

Nutrient samples were collected for nitrate and TKN at ten locations. These parameters were included to help identify sources of pollutants since nitrate and TKN concentrations may be higher in streams with agricultural watersheds, wastewater treatment plant discharges, or septic system influence (Wetzel, 2001 and Allan, 1995).

Samples were collected on July 18, September 6, and September 26, 2013 and analyzed by Benchmark. The July 18 samples were inadvertently analyzed for nitrate-nitrite (as opposed to nitrate as specified in the Sampling Plan)Nitrate is the dominant form of nitrogen in streams, but nitrite can occur in lower concentrations in streams, therefore, nitrate-nitrite concentrations could be higher than nitrate (Wetzel, 2001). In order to understand if the inclusion of nitrite influenced the July results, an additional sampling round was added in September (for a total of three sampling events), and samples from

September were analyzed for nitrate and nitrite. Samples were analyzed for TKN during all events.

2.2.2.3 Field Parameters

Field parameters were measured using a handheld YSI 600 XL and included temperature, pH, specific conductivity, dissolved oxygen, salinity, and total dissolved solids. Field parameters were proposed to be measured two times at the ten sample locations where nutrient samples were collected; however, a third event was added to match the adjusted nutrient sampling schedule. In addition, URS measured field parameters at additional locations to better understand water quality. Field parameters were measured concurrent with the collection of water quality samples on July 18, 2013 at 14 locations; September 6, 2013 at 20 locations; and September 26, 2013 at 19 locations.

Water temperature is a valuable parameter since fecal coliform bacteria have been shown to increase due to higher water temperatures allowing for the bacteria to multiply (Wetzel, 2001 and Town, 2001). pH was included since it can influence the survival of fecal coliform bacteria. Specific conductivity, salinity, and total dissolved solids are related parameters that are reflective of the ionic composition of the water and are often used to help identify sources of pollutants. Dissolved oxygen measurements are helpful since anaerobic conditions can change the nutrient composition in reach and can influence bacteria reproduction. Additionally, breakdown of organic matter by bacteria can reduce dissolved oxygen.

2.2.2.4 Bacteroides

Similar to fecal coliform, bacteroides are types of bacteria; however they are in a different phylum than fecal coliform. To demonstrate the difference, the following provides a comparison of the taxonomic hierarchy of *Bacteroides* and *Escherichia*, a type of fecal coliform bacteria:

	TAXONOMIC HIERARCHY	
Bacteria	KINGDOM	Bacteria
Bacteroidetes	PHYLUM	Proteobacteria
Bacteroidia	CLASS	Gammaproteobacteria
Bacteroidales	ORDER	Enterobacteriales
Bacteroidacea	FAMILY	Enterobacteriaceae
Bacteroides	GENUS	*Escherichia*

Bacteroides sampling is a valuable tool in evaluating impairment for the following reasons:

- Bacteroides occur in high concentrations in animal waste (including human waste). They are typically in higher concentrations than fecal coliform bacteria.
- Different species of bacteroides are associated with different hosts, so they can be used to help identify sources of fecal contamination.

- They do not persist or multiply in the environmental like fecal coliform bacteria do; therefore, they are associated with recent fecal contamination (Ballesté and Blanch, 2010).

Bacteroides persistence in streams varies based on the type of bacteroides and the conditions (e.g., temperature and dissolved oxygen), but typically, they break down within a few weeks. As such, bacteroides samples should be collected multiple times and during various conditions to support identification of intermittent sources of fecal contamination (such as ones that are runoff dependent or associated with timed discharges). For example, it may be beneficial to collect samples throughout the season and during a range of flow conditions.

As described below, bacteroides sampling for this study included collecting total and human bacteroides measurements three times and animal source tracking data once; all were collected during low flow conditions as required to meet PADEP protocols.

Human and Total Bacteroides

PADEP provided support for human and total bacteroides samples at seven locations in Little Bushkill Creek. Human bacteroides are a measurement of bacteroides that occur in the digestive tract of humans. Their presence can indicate that human waste or untreated wastewater is entering a stream. Total bacteroides are a measure of the amount of Bacteroidales in a stream. Bacteroides are a genus of bacteria in the order Bacteroidales. They are used as a general marker to determine if animal (including human) fecal contamination is present.

Human and total bacteroides samples were collected three times over the course of the summer (July 16, September 6, and September 26, 2013) to capture temporal variation. In accordance with PADEP protocol, samples were collected during low flow conditions to provide information during recreational use conditions. Samples were collected by URS in accordance with the "Instructions for Collecting Bacteroides Source Tracking Samples and Fecal Samples" (PADEP, 2013). Samples were collected three times at five locations, once at one location, and two times at one location. Bacteroides samples were shipped by Plainfield Township to EMSL Analytical, Inc. (EMSL) for analysis using quantification Polymerase Chain Reaction (qPCR) to replicate Deoxyribonucleic acid (DNA) fragments of the target bacteroides species (or Bacteroidales for total bacteroides measurements).

Animal Source Tracking

Similar to human bacteroides, animal source tracking tests can be conducted to identify different species of bacteria that are associated with different hosts. For example, the ruminant test is a measure of a type of bacteria that commonly occurs in cow, deer, sheep, and goats; and that the cow test is a measure of a separate type of bacteria that is associated with cows, but not with deer, sheep, and goats. Animal source tracking measurements were added to the September 26, 2013 sampling round since human bacteroides were only detected once at one location during the first two bacteroides sampling events (see Section 3.2.4). To support identification of non-human sources of fecal coliform bacteria, Plainfield Township identified a combination of dog, ruminant

(includes cow, deer, sheep, and goats), cow only, bird, geese, or horse biomarker tests for seven sample locations (Table 1).

Samples were collected on September 26, 2013 in accordance with the "Instructions for Collecting Bacteroides Source Tracking Samples and Fecal Samples" (PADEP, 2013). In accordance with PADEP protocol, samples were collected during low flow conditions. Samples were shipped by URS to Source Molecular for analysis using qPCR.

2.2.3 Quality Assurance and Quality Control

Quality Assurance and Quality Control (QA/QC) for this assessment included:

- Training and Field Audit - Megan Bradburn of PADEP trained and audited Kristy Hoffman of URS in the collection of fecal coliform and human and total bacteroides samples on July 3, 2013. During training, Ms. Bradburn approved Ms. Hoffman to train URS personnel involved in this study, and as such, Ms. Hoffman trained Gavin McBrien, Christian Hauser and David Yezuita. Ms. Hoffman led all field sampling and was present during all but one sampling event (July 9, 2013), Gavin McBrien and Christian Hauser collected the fecal coliform samples on July 9, 2013 (bacteroides samples were not included during that event).
- Sampling Conditions - As per coordination with Megan Bradburn of PADEP, sampling targeted low flow conditions (i.e., less than 0.25 inch rain during the previous 24 hours) (M. Bradburn, personal communication with K. Hoffman, May 24, 2013). Sampling was delayed after storm events longer than 24 hours to allow more time for the stream to return to low flow conditions.
- Blank and duplicate samples were collected during each sampling event for fecal coliform, fecal streptococcus, nitrate, and TKN samples. Blank samples were collect for human and total bacteroides samples during each sampling event. A duplicate sample was collected during the first sampling event for human and total bacteroides samples. Blank and duplicate samples were not collected for the other animal source tracking samples.

2.2.4 Riparian Corridor Assessment

A riparian corridor assessment was performed while sampling to evaluate surrounding land use, geomorphic features, invasive species, bank stability, instream aquatic habitat, and riparian vegetation. This included a habitat assessment, documentation of outfalls, and general observations. URS conducted the riparian corridor assessment in the main stems of the West Branch, East Branch, Main Branch, Browntown Road Tributary, and Benders Church Road Tributary.

2.2.4.1 Habitat Assessment

The habitat assessment was completed for a 100-meter reach at the ten primary sample locations using the approach outlined in PADEP's Instream Comprehensive Evaluation Surveys Guidance (PADEP, 2009). The Water Quality Network Habitat Assessment form was completed and photographs were taken to document the area. In addition, a habitat assessment was completed throughout the watershed to help understand the overall

condition of the watershed, support identification of potential sources of impairment, and to help identify potential restoration needs.

2.2.4.2 Outfall Documentation

Observations of outfalls were documented during the stream walk. Outfalls were photographed and located using a GPS, and relevant information was recorded on an Outfall Log.

2.2.4.3 General Observations

A General Observation Log was kept to document relevant features observed during the survey (i.e.: aquatic vegetation, bridges, culverts, dams, eroding banks, fine-grained sediment deposits, invasive species, large woody debris, livestock access/ use, mid-channel bars, recreational use, retaining walls, trash, waterfowl, or other channel modifications, etc.). Photographs and the GPS coordinates of these features were collected.

2.2.5 Statistical Analysis

The purpose of the statistical analysis was to identify general associations between habitat properties and fecal coliform counts. Data used in the analysis included the fecal coliform and water quality data collected on July 18, September 6, and September 26, 2013, in addition to the individual habitat assessment scores.

General associations were identified with a non-parametric Spearman rank-order correlation coefficient (R_s). Statistically significant associations were reported where $p \leq 0.05$ alpha probability levels. SYSTAT was used to conduct the analysis.

2.2.6 Benthic Macroinvertebrate Study

A separate benthic macroinvertebrate study of Little Bushkill Creek was completed concurrent with this study by Aquatic Resource Consulting in on April 27 and 29, 2013. The macroinvertebrate study was completed to better understand water quality in Little Bushkill Creek. Due to the variable species sensitivity to water quality conditions, benthic macroinvertebrates are a frequently used indicator of stream water quality. Sampling was conducted in accordance with PADEP protocols (PADEP, 2009b). Samples were collected at 11 stations: three in the West Branch, two in the East Branch, three in the Main Branch, one in the Benders Church Road Tributary, and two in the Browntown Road Tributary. Four of the macroinvertebrate stations were in approximately the same location as fecal coliform sample locations:

- Station 1 = W-2.7
- Station 3 = W-0.1
- Station 9 = M-BT-0.35
- Station 11 = M-1.5

A report that includes the methods, sample locations, results, and discussion has been included in Attachment B (ARC, 2013).

3.0 Results

The results from the July and September 2013 sampling period are summarized below including fecal coliform bacteria (Section 3.1), additional water quality parameters (Section 3.2), and a riparian corridor assessment (Section 3.3).

3.1 Fecal Coliform Bacteria

Overall, fecal coliform bacteria counts were highest in July, when runoff events were typically more frequent and water temperatures often at their highest. In contrast, fecal coliform bacteria counts in September were lower. Specific results are presented below.

The fecal coliform measurements at the 22 stations are presented in Table 2. In addition, a geometric mean was calculated for locations that had five sampling events in a sampling round, with the exception of E-GCL2, which was assessed four times during the July sampling round. The fecal coliform results are presented on Figure 2.

As shown in Table 2, eight sample locations had favorable results:

- W-1.6, E-GCW1, M-5.1, and M-1.5 – These four locations met both criteria (i.e., a geometric mean of 200 CFU/100 ml[1] and no more than 10% of the total samples taken exceeding 400 CFU/100 ml) in July and September.
- E-GCL2 – This location met water quality criteria; however, only four samples were collected at this location during the July sampling round.
- W-0.5, E-GCW3, and M-WRT-0 – These locations met the geometric mean requirements during July and September; however, these locations did not meet the second requirement that less than 10% of the samples exceed 400 CFU/100ml since one sample exceeded 400 CFU/100 ml. [2]

Four locations met water quality criteria during September (W-0.1, M-BHR-0, E-GCR-0, and E-DRT-0). The first two did not meet criteria due to high results in two days during the July sampling round, and the latter two were only assessed during September. Four locations (W-2.8, E-GCL1, E-0.3, and M-BT-0.35) did not meet water quality criteria and had several high results.

[1] CFU = Colony Forming Units
[2] Based on a conversation with Megan Bradburn of PADEP on August 13, 2013, PADEP may be able to rely more on the geometric mean for considering the status of these sample locations.

Table 2. Fecal coliform results in Little Bushkill Creek, July and September 2013.

		Fecal Coliform (CFU/100ml)													
		July Sampling Round							September Sampling Round						
		07/09/13	07/16/13	07/18/13	07/26/13	07/31/13	% Exceeding 400	Geometric Mean	09/06/13	09/11/13	09/19/13	09/24/13	09/26/13	% Exceeding 400	Geometric Mean
West Branch	W-2.8	460	600	> 4000	620	500	**100%**	**807**	229				265		
	W-2.7		1460						220				137		
	W-1.6	131	66	320	70	101	0%	114	114	54	46	42	37	0%	54
	W-0.5	121	157	> 4000	52	82	**20%**	200	175	72	44	48	37	0%	63
	W-0.1	460	162	> 4000	39	75	**40%**	**244**	60	78	40	78	33	0%	55
East Branch	E-GCW3	53	119	420	57	65	**20%**	100	100	141	58	46	20	0%	60
	E-GCW1	104	133	85	48	149	0%	97	220	153	76	96	76	0%	113
	E-GCL1	760	500	1040	96	720	**80%**	**487**	167	2600	58	56	72	**20%**	159
	E-GCL2		133	53	300	41	0%	96	48	25	8	14	118	0%	28
	E-2.8		102						80				52		
	E-GCR-0								225	169	200	153	300	0%	**204**
	E-HRS-0								229	900					
	E-DRT-0								235	92	384	31	100	0%	121
	E-BCR-0.7		900						1200				42		
	E-0.3	320	500	> 4000	540	240	**60%**	**608**	225				249		
Main Branch	M-5.1	160	135	161	136	72	0%	128	40	188	58	92	72	0%	78
	M-BHR-0	170	102	> 4000	2280	23	**40%**	**325**	118	216	114	50	46	0%	92
	M-BT-0.35	800	620	1420	145	186	**60%**	**453**	341				48		
	M-BT-0.5-E								106	1100					
	M-BT-0.5-W								276	314					
	M-BT-0.1		28												
	M-WRT-0	3	13	440	21	13	**20%**	22	46	68	ND	8	2	0%	10
	M-1.5	151	187	181	109	147	0%	152	153	143	110	114	54	0%	108

CFU = Coliform Forming Units
ml = Milliliters
Bold values indicate that the result exceeded PADEP's Water Quality Criteria (*During the swimming season (May 1 through September 30), the maximum fecal coliform level shall be a geometric mean of 200 per 100 milliliters (ml) based on a minimum of five consecutive samples each sample collected on different days during a 30-day period. No more than 10% of the total samples taken during a 30-day period may exceed 400 per 100 ml)*

[1] The results reported for M-1.5 on July 18, 2013 are the results that were reported by the laboratory for the blank sample. The reported results were <2 CFU/100ml for M-1.5 and 181 CFU/100ml for the blank sample on July 18, 2013. Since other blank samples had results consistent with <2 CFU/100ml and the blank water that was used was certified blank water provided by PADEP, it is anticipated that the samples were confused. Coordination with the laboratory confirmed that this was a possibility.

The fecal coliform results collected on July 18, 2013 were generally higher than the other dates, with results of greater than 4,000 CFU/100 ml at multiple locations. This sampling event was two days after the previous sampling date, and no precipitation had occurred between the two days. Potential reasons for this difference may include the time of day that the samples were collected, or the increased air/water temperatures on July 18, 2013. Although laboratory error can also result in anomalous results, based on consultation with the laboratory and the acceptable results of the QA/QC samples, it is unlikely that the issue was due to laboratory error.

Sample collection timing could influence fecal coliform concentrations if the results are associated with wastewater sources since certain discharges (i.e. failing septic systems or point source discharges) may be intermittent. The samples on July 18, 2013 were collected throughout the afternoon (between 1:00 PM and 4:00 PM), whereas other samples during July were collected in the morning (between 7:15 AM and 9:45 AM) or late morning to early afternoon (between 10:00 AM and 2:15 PM). Sample timing is also a consideration since water temperature would increase as air temperature increases throughout the day.

Under the assumption that higher water temperatures will cause an increase in bacterial population size, it might be expected that the highest fecal coliform counts would be associated with higher instream water temperatures. Although water temperature accounts for only 43 percent of the variance, fecal coliform concentrations are positively associated with water temperature and the association is highly significant($R_s = 0.43$; $p = 0.001$). This indicates that fecal coliform counts were generally higher in segments of the stream that experienced higher surface water temperatures.

3.2 Additional Water Quality Parameters

The results of the additional water quality parameters (fecal streptococcus, nutrients, field parameters, and bacteroides) are presented in the following sections.

3.2.1 Fecal Streptococcus

Fecal streptococci are a type of bacteria that occur in warm blooded animals and are an indication of fecal contamination. They have been used in conjunction with fecal coliform measurements to differentiate between human and non-human sources, but are no longer typically used due to their variability (USEPA, 1997). Similar to fecal coliform results, fecal streptococcus results were mostly higher in July (Table 3). They were detected at all locations and were the highest at W-0.1 in July. Higher concentrations (based on a low ratio of fecal coliform to fecal streptococcus) have been associated with non-human warm-blooded animals (USEPA, 1997). Therefore, the high concentration (>20,000 CFU/100ml) at W-0.1 may indicate that the fecal coliform concentration at W-0.1 on July 18 was primarily associated with non-human sources; however, as mentioned, fecal streptococci bacteria are not a reliable indicator, and therefore, additional data would be required to support this conclusion. Since fecal streptococci results at this location were not elevated to the same order of magnitude over the other upstream

locations as the July 18, 2013 result, the high concentration may be associated with other factors, such as water temperature.

Table 3. Fecal Streptococcus Results, July and September 2013.

		Fecal Streptococcus CFU/100ml		
		07/18/13	09/06/13	09/26/13
West Branch	W-2.8	400	210	130
	W-1.6	300	160	160
	W-0.5	500	150	70
	W-0.1	> 20000	190	56
East Branch	E-0.3	1400	170	70
Main Branch	M-5.1	400	180	66
	M-BHR-0	900	250	130
	M-BT-0.35	5700	1000	120
	M-WRT-0	130	33	800
	M-1.5	1100	170	94

3.2.2 Nutrients

The nitrate samples were reported by the lab as nitrate-nitrite for the July 18 sampling event, and were detected at all of the sample locations. Nitrite results from September 6 and 26 were in the thousandths (e.g., 0.002 mg/l) (Attachment B). Since nitrate-nitrite is reported in the hundredths (e.g., 1.2 mg/l) nitrite-nitrate would have equaled the nitrate results, and would not result in a change in the interpretation of the nitrate results. TKN was detected at W-0.1 and M-BT-0.35 (Table 4). Total nitrogen (nitrate + nitrite + TKN) greater than 5 mg/l is considered to be high and may be associated with agricultural land use such as fertilizer application practices and livestock (Allen, 1995). The U.S. Environmental Protection Agency (EPA) National Recommended Water Quality Criteria (consumption of water and organism) for human health for nitrates is 10 mg/l (EPA, 2009).

No sample results exceeded 10 mg/l; however, M-BT-0.35 and M-WRT-0 had values that exceeded 5 mg/l, both locations are influenced by agricultural land use (Table 4). Nitrate was lowest in the West Branch, which has the least agricultural land use.

Table 4. Nitrate-nitrite, nitrate, and TKN results, July and September 2013.

		Nitrate - Nitrite	Nitrate		Total Kjeldahl Nitrogen		
		mg/l	mg/l		mg/l		
		07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13
West Branch	W-2.8	0.8	1.1	1.0	ND	ND	ND
	W-1.6	1.2	1.8	2.0	ND	ND	ND
	W-0.5	1.2	2.1	2.7	ND	ND	ND
	W-0.1	1.3	2.1	2.6	0.6	ND	ND
East Branch	E-0.3	2.5	2.6	2.4	ND	ND	ND
Main Branch	M-5.1	1.9	2.7	2.5	ND	ND	ND
	M-BHR-0	3.2	5.1	3.7	ND	ND	ND
	M-BT-0.35	4.3	5.8	4.8	0.7	ND	ND
	M-WRT-0	5.7	7.1	6.8	ND	ND	ND
	M-1.5	2.9	3.7	3.0	ND	ND	ND

mg/l = Milligrams per liter

3.2.3 Field Parameters

In situ field parameters included temperature, pH, specific conductivity, dissolved oxygen, salinity, and total dissolved solids (Table 5). In accordance with Chapter 93 of the Pennsylvania Code, HQ-CWF waters should not receive inputs warmer than 66°F, have a pH of 6.0 to 9.0, and should have a minimum dissolved oxygen concentration of 7.0 mg/l, (25 Pa. Code § 93.7). Requirements for the other parameters are not specified in Chapter 93. Water temperature was high on July 18, 2013, which was expected due to the air temperature of 98°F, making it the hottest day of the summer. In addition, air temperatures had been above 90°F earlier in the week. pH results were within acceptable ranges. Dissolved oxygen values met the minimum concentration requirement.

Table 5. Field parameters in Little Bushkill Creek, July 18, 2013.

		Temperature						pH			Specific Conductivity			Dissolved Oxygen						Salinity			Total Dissolved Solids		
		°C			°F			pH units			mS/cm			%			mg/L			ppt			g/l		
		07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13	07/18/13	09/06/13	09/26/13
West Branch	W-2.8	24	17	13	75	62	55	7.8	8.0	7.6	0.369	0.381	0.415	94.5	128.4	93.3	8.0	12.4	9.9	0.18	0.18	0.20	0.239	0.247	0.270
	W-2.7		17	13		62	55		7.9	7.6		0.381	0.415		119.3	93.3		11.6	9.9		0.18	0.20		0.247	0.270
	W-1.6	25	17	14	77	63	56	8.1	8.1	7.6	0.368	0.372	0.436	93.9	128.8	96.6	7.8	12.4	10.0	0.17	0.18	0.21	0.239	0.242	0.283
	W-0.5	26	17	13	79	63	56	8.4	8.3	8.0	0.348	0.343	0.408	101.8	122.7	105.2	8.3	11.8	11.1	0.16	0.16	0.20	0.226	0.223	0.265
	W-0.1	26	17	13	79	63	55	8.3	8.3	7.9	0.341	0.329	0.396	95.6	113.8	99.1	7.7	10.9	10.5	0.16	0.16	0.19	0.222	0.214	0.258
East Branch	E-GCW3	20	16	20	68	61	68	7.8	8.1	6.7	0.152	0.199	0.111	92.3	116.1	104.9	8.4	11.5	11.1	0.07	0.09	0.05	0.099	0.130	0.072
	E-GCW1	23	16	13	73	61	55	7.7	8.0	7.4	0.259	0.144	0.299	91.3	114.4	99.3	7.9	11.2	10.5	0.12	0.07	0.14	0.168	0.014	0.194
	E-GCL1	20	15	12	67	59	54	7.7	7.9	6.9	0.665	0.740	0.931	91.0	125.5	100.2	8.3	12.6	10.7	0.33	0.36	0.46	0.434	0.481	0.605
	E-GCL2	22	21	17	71	70	63	7.7	7.6	7.2	1.010	0.385	0.934	90.5	104.9	88.3	7.9	9.3	8.5	0.55	0.18	0.46	0.716	0.250	0.607
	E-2.8		17	14		63	58		7.9	7.5		0.493	0.596		126.9	91.1		12.2	9.3		0.24	0.29		0.320	0.388
	E-GCR-0		15	12		58	54		7.9	7.4		0.092	*		118.8	89.0		12.1	9.5		0.04	*		0.060	*
	E-HRS-0		13			56			7.8			0.086			116.8			12.2			0.04			0.056	
	E-DRT-0		16	13		60	55		7.9	7.6		0.200	0.250		126.5	98.7		12.6	10.5		0.01	0.12		0.130	0.162
	E-BCR-0.7		15	13		58	55		7.7	7.8		0.114	0.255		112.2	96.4		11.4	10.1		0.05	0.12		0.074	0.166
	E-0.3	24	15	12	75	58	54	8.0	7.9	8.0	0.321	0.306	0.398	94.2	120.6	106.5	7.9	12.3	11.4	0.15	0.15	0.19	0.208	0.199	0.259
Main Branch	M-5.1	25	15	13	77	59	55	8.4	7.8	7.8	0.325	0.312	0.390	101.1	115.7	107.1	8.3	11.7	11.4	0.15	0.15	0.19	0.211	0.203	0.253
	M-BHR-0	23	14	12	73	56	54	7.5	7.8	8.0	0.169	0.164	0.197	94.7	114.3	103.5	8.2	11.9	11.1	0.08	0.08	0.09	0.110	0.107	0.128
	M-BT-0.35	23	14	13	73	57	55	7.6	7.8	8.2	0.223	0.220	0.248	85.0	111.8	98.3	7.3	11.5	10.4	0.11	0.10	0.12	0.145	0.143	0.161
	M-WRT-0	20	18	16	68	65	61	7.2	7.5	7.9	0.243	0.226	0.267	79.0	99.3	97.4	7.2	9.3	9.6	0.12	0.11	0.13	0.158	0.147	0.173
	M-1.5	26	16	14	79	60	57	8.7	8.0	8.4	0.290	0.227	0.341	105.2	119.0	121.6	8.6	11.8	12.6	0.14	0.13	0.16	0.188	0.180	0.222

C = Celsius
F = Fahrenheit
mS/cm = milliSiemens per centimeter
mg/l = milligrams per liter
ppt = parts per thousand
g/l = grams per liter

* Measurement could not be collected due to low water level.

Total dissolved solids, specific conductivity, and salinity were high in the two landfill tributaries (E-GCL1 and E-GCL2). These parameters are influenced by geology as well as land use considerations. In fresh water systems, specific conductivity can range from 0.050 to 1.500 mS/cm, but is generally less than 0.500 mS/cm (USEPA, 1997 and Cowardin et al, 1979). The mean salinity in rivers in North America is 0.140 ppt (Wetzel, 2001). At E-GCL1 the results were consistently over this concentration, and at E-GCL2, the results were over this concentration two of the three times. The increased values in the landfill tributaries for total dissolved solids, specific conductivity/conductivity, and salinity are not explained by the geology of the area (i.e., non-karst).. High specific conductivity at E-2.8 was higher than other locations in Little Bushkill Creek, but lower than the values observed at E-GCL1. The Grand Central Woods (which had low specific conductivity, salinity, and total dissolved solids) converge with the Grand Central Sanitary Landfill tributaries just upstream of this sample location, and help to dilute the ions in the Grand Central Sanitary Landfill tributaries.

3.2.4 Bacteroides

Bacteroides samples were collected to better understand sources of fecal coliform bacteria. Based on the bacteroides and animal source tracking results, human wastewater is not a primary source of fecal coliform bacteria in Little Bushkill Creek. In addition, since bacteroides are indicative of recent fecal contamination, and do not persist in the environment as long as fecal coliform bacteria, the limited detections of specific hosts may support the conclusion that fecal coliform bacteria inputs are temporally limited (e.g., associated with runoff events) and that fecal coliform bacteria persist and multiply in Little Bushkill Creek. Results of "Not Detect" for bacteroides (Table 6) on a single event do not necessarily indicate that fecal contamination is not present in that reach, or that fecal contamination is not associated with a specific host. Multiple samples at different times, and during different conditions (e.g., during low flow and after a storm flow), are necessary to make this conclusion with confidence.

Human and Total Bacteroides

Total bacteroides were detected at all locations and human bacteroides were detected at one location in the West Branch (W-2.7). At W-0.5 in the West Branch, total bacteroides were not detected on September 26, 2013. The detection limit for total and human bacteroides was 50 CEs/ 100ml, so it is possible that total bacteroides were present at very low levels. This is consistent with the low fecal coliform results at W-0.5 on the same date (37 CEs/100 ml). Since human bacteroides were only detected once, and the result was low; the bacteroides samples do not support a conclusion that human wastewater is a primary source of impairment in Little Bushkill Creek.

Animal Source Tracking

Dog, bird, geese, and horse biomarkers were not detected in Little Bushkill Creek on September 26, 2013. Dog, bird, and geese biomarkers may not have been detected since they are sources that are often introduced into a stream through precipitation runoff. Sampling on this date was five days after the last rain event; therefore, waste from these sources may have been limited during the previous 5 days. Results for geese may be higher in late fall and winter when snow geese migrate to the area.

Table 6. Bacteroides Results, July and September 2013.

		Bacteroides (CEs/100ml)						Bacteroides (Copies/rxn)					
		Total			Human			Dog	Ruminant	Cow	Bird	Geese	Horse
		07/16/13	09/06/13	09/26/13	07/16/13	09/06/13	09/26/13	09/26/13	09/26/13	09/26/13	09/26/13	09/26/13	09/26/13
West Branch	W-2.7	6122	1337	1332	72	ND	ND	ND	ND		ND		
	W-0.5	2004	1383	ND	ND	ND	ND		ND	ND		ND	ND
East Branch	E-2.8	1578	1374	779	ND	ND	ND	ND	ND		ND		
	E-BCR-0.7	2775	1364	986	ND	ND	ND		465	ND		ND	ND
	E-0.3	2497		1528	ND		ND	ND	28900	212		ND	ND
Main Branch	M-BT-0.35								ND	ND		ND	ND
	M-BT-0.1	964			ND								
	M-1.5	1709	1413	777	ND	ND	ND	ND	ND	ND		ND	ND

CEs = Cell equivalent units
rxn = reaction
ml = Milliliters
ND – Not Detect
Note: Detection limits were 50 CEs/100ml for total and human bacteroides; 10 copies/rxn for bird, cow, and goose; 50 copies/rxn for dog and ruminant; and 100 copies/rxn for horse.

Ruminants and cow were detected in Little Bushkill Creek at two locations. Specifically, E-BCR-0.7 in the Benders Church Road Tributary had low levels of the ruminant biomarker, and E-0.3 in the East Branch had high levels of the ruminant biomarker and low levels of cow biomarker. High and low levels are based on the order of magnitude of the result and are given by the laboratory (refer to laboratory reports in Attachment B).

At E-BCR-0.7, the ruminant biomarker may be associated with cow, deer, sheep, and/or goats. Based on the Riparian Corridor Assessment, cows and deer occur in the watershed upstream of this point and may be potential sources. Direct and indirect observations of deer were made in the Benders Church Road Tributary. Cows were also observed in the watershed; however, none were along the stream during the Riparian Corridor Assessment, and pastures along the stream were mostly fenced. Additional sampling at different times of the year and after storm events may help explain these results.

The high level of ruminant biomarker at E-0.3 may be associated with cow and deer, sheep, and/or goats. The positive results from the ruminant biomarker and the cow biomarker both support the conclusion that E-0.3 receives fecal contamination from cows. E-0.3 is downstream from the outlet of the Benders Church Road Tributary. Based on the Riparian Corridor Assessment of the Benders Church Road Tributary, a

reach downstream from E-BCR-0.7 receives fecal contamination from cows. This was evident through trampled banks and the observation of multiple cow droppings in and along the stream. Other sources of the ruminant biomarker may be deer, sheep, and/or goats. Sheep and goats were not observed along the stream in this area; so deer may also be a source. Testing just upstream of the Benders Church Road Tributary, or at the end of the tributary, would help determine if the Benders Church Road Tributary is the primary source for E-0.3. Additionally, collection of additional samples during a period with higher concentrations of fecal coliform bacteria (e.g., July), or collecting samples shortly after a runoff event, would be helpful in understanding these results.

3.3 Riparian Corridor Assessment

In general, riparian and aquatic habitat condition in Little Bushkill Creek is good. The condition in the West Branch is strongly influenced by human uses (such as stream crossings, power lines, outfalls, and remnant milldams). The East Branch is primarily influenced by agricultural activities. The Main Branch has few impacts along the main stem, and may be more influenced by its tributaries. Figure 3 presents the results of the habitat assessment and locations of outfalls and general observations. Completed forms are provided in Attachment B.

3.3.1 Habitat Assessment

A total of fifty habitat assessment forms were completed throughout the West Branch, East Branch, Main Branch, Browntown Road Tributary, Benders Church Road Tributary, and at each of the ten primary sample locations (Table 7). Ranks were assigned to the assessed reach based on the total habitat assessment score. Habitat scores greater than 180 were classified as optimal, scores ranging from 180-120 were classified as suboptimal, and scores from 60 to 120 were classified as marginal. No reaches scored lower than 60, so a poor category was not included.

Habitat scores were optimal and suboptimal throughout the majority of the assessed area. Of the 13.8 stream miles that were assessed for habitat, 62% were optimal, 36% were suboptimal, and 2% were marginal. The West Branch was suboptimal from Mile 2.8 to 1.6, and optimal from 1.6 to 0. The East Branch and Main Branch were primarily optimal, and the Benders Church Road and Browntown tributaries were mostly suboptimal.

Parameters that commonly resulted in low scores were embeddedness, epifaunal substrate, and sediment deposition. Parameters that generally scored well were associated with higher structural complexity and riparian habitat conditions. Maintained utility right-of-ways occur throughout the watershed and influenced habitat quality.

A strong positive association was observed between water temperature and the habitat parameters of velocity/depth regime (R_s=0.72; p=0.008), and to a lesser degree, channel flow status (R_s=0.60; p=0.02). These associations support the conclusion that temperature likely influenced fecal coliform concentrations on July 18, 2013. Furthermore, these results mirror the positive association between fecal coliform concentrations and water temperature that have been documented in other stream studies conducted in Pennsylvania (Town, 2001).

Table 7. Habitat Conditions, July and September 2013.

	Sample Location / Reach	Habitat Parameter												
		Instream Cover (Fish)	Epifaunal Substrate	Embeddedness	Velocity/Depth Regimes	Channel Alteration	Sediment Deposition	Frequency of Riffles	Channel Flow Status	Condition of Banks	Bank Vegetative Protection	Grazing or Other Disruptive Pressure	Riparian Vegetative Zone Width	Total Score
West Branch	W-2.8	11	11	9	14	7	7	13	14	13	14	14	5	132
	2.8 to 2.75	11	11	12	10	12	16	13	10	10	12	10	10	137
	2.75 to 2.6	13	12	8	11	12	10	11	13	12	14	15	17	148
	2.6 to 2.4	12	14	14	10	6	15	18	18	12	11	18	10	158
	2.4 to 2	14	15	10	10	13	10	14	15	13	13	19	17	163
	2 to 1.6	15	10	15	10	16	13	12	15	16	15	16	16	169
	W-1.6	18	16	15	15	15	13	18	16	15	18	19	18	196
	1.6 to 1.3	19	18	16	19	15	15	18	18	15	18	20	18	209
	1.3 to 1.3	13	15	15	15	16	17	17	19	18	19	15	15	194
	1.3 to 1.05	19	19	15	20	19	17	18	19	17	17	18	17	215
	1.05 to 0.75	18	18	15	17	19	15	18	18	13	16	14	16	197
	0.75 to 0.5	16	15	18	15	18	15	19	16	19	18	19	19	207
	W-0.5	14	13	14	18	13	17	16	18	19	16	15	15	188
	W-0.1	17	18	16	18	13	16	17	16	18	18	17	19	203
East Branch	E-GCL-1	15	15	10	14	19	10	12	14	15	15	18	20	177
	E-GCW-2	5	8	4	10	11	3	8	16	16	15	3	11	110
	E-GCW-1	5	8	4	5	11	15	5	16	16	16	19	16	136
	E-GCW-3	14	18	13	11	15	12	19	16	15	19	20	17	189
	2.85 to 2.76	18	18	18	15	17	18	18	17	16	20	20	20	215
	2.76 to 2.75	5	8	3	3	13	10	5	16	11	20	20	20	134
	2.75 to 2.5	19	19	16	16	20	16	18	18	18	20	20	20	220
	2.5 to 2.3	18	17	18	16	18	18	18	15	16	19	20	20	213
	2.3 to 1.9	19	20	18	19	20	18	19	19	19	20	20	20	231
	1.9 to 1.7	19	19	19	17	20	17	18	16	18	20	20	16	219
	1.7 to 1.4	18	19	10	19	18	13	18	17	15	13	19	20	199
	1.4 to 1.3	14	9	17	10	14	18	8	16	16	18	20	20	180
	1.3 to 1.15	13	16	17	15	14	18	18	18	15	16	20	15	195
	1.15 to 1.09	10	8	14	10	16	11	13	15	19	18	15	13	162
	1.09 to 0.3	16	17	14	18	20	12	16	17	18	16	20	20	204
	E-0.3	15	15	14	16	20	16	14	18	18	18	18	16	198
Benders Church Road Tributary	South Tributary	11	7	13	9	17	13	6	18	13	19	18	18	162
	2 to 1.1	11	10	13	10	17	11	5	16	17	20	19	19	168
	1.1 to 0.7	14	13	12	12	15	14	13	15	15	17	16	15	171
	0.7 to 0.55	8	6	5	10	17	4	5	16	5	13	4	11	104
	0.55 to 0.35	8	4	5	9	20	3	3	16	16	16	18	19	137
	0.35 to 0	10	9	10	13	19	10	11	16	16	18	17	17	166
Main Branch	5.7 to 5	15	18	18	14	20	16	18	19	19	17	19	20	213
	5.1 to 5.1	16	18	17	14	18	15	16	19	16	17	20	17	203
	5 to 4	17	16	15	10	13	15	15	19	15	15	20	13	183
	4 to 3	17	18	15	20	16	11	18	15	14	18	20	20	202
	3 to 1.5	18	18	18	17	16	16	18	19	19	17	13	13	202
	M-1.5	15	15	14	15	15	16	17	18	17	17	10	13	182
Books Hill Road Tributary	M-BHR-0	15	18	16	12	15	16	17	17	19	19	20	16	200
Browntown Road Tributary	West Branch	8	8	8	10	17	14	11	13	17	18	16	10	150
	East Branch	12	15	9	11	16	5	15	10	11	16	18	18	156
	East/West Confluence to 0.25	16	16	11	10	14	15	14	11	16	16	19	17	175
	M-BT-0.35	16	16	11	10	14	15	14	11	16	16	19	17	175
	0.35 to 0.15	10	11	13	9	18	17	6	8	18	17	17	18	162
Weiss Road Tributary	M-WRT-0	10	14	15	13	9	17	14	10	15	14	14	13	158

Habitat Category: Optimal Suboptimal Marginal

3.3.2 Outfall Documentation

URS documented 25 outfalls during the riparian corridor and habitat assessment (Table 8). Twelve outfalls showed signs of active use, such as dripping or flowing water. Three of the outfalls (E-1.3-OF, M-BT-0.35-OF, and M-2.6-OF) are identified in Plainfield Township's Municipal Separate Storm Sewer System (MS4) Plan and Report dated March 9, 2012. The sources of many of the other outfalls were not clear. Some outfalls appeared to come from tile drain systems in agricultural fields, others may have been associated with residential sources, such as sump pumps or gutters. Odors associated with septic systems were not evident at any of the outfalls.

Table 8 summarizes the outfalls that were observed. The GIS data included on the CD in Attachment B includes photographs and tax parcel information for these features. The supporting information can be accessed by clicking on the outfall point in the published map file (PMF).

3.3.3 General Observations

General observations throughout Little Bushkill Creek included features that influence fecal coliform bacteria and / or habitat quality, such as bridges, cattle, and erosion. In the West Branch, notable features included unknown outfalls, remnant milldams, areas of extensive periphyton, invasive species (especially Japanese knotweed (*Polygonum cuspidatum*)), channel alteration and other impacts associated with human use. Brown trout (*Salmo trutta*) ranging in size from 4 to 12 inches were observed in the West Branch. In the East Branch, notable observations consisted of the Recreation Trail and other more common features (e.g., bridges, log jams, and limited areas of invasive species). In the Main Branch, common observations included bridges and log jams.

3.3.4 Benthic Macroinvertebrate Study

Based on the results of the benthic macroinvertebrate study, the West Branch upstream of 1.9 is impaired for Aquatic Life Use (ALU) and the other locations throughout the watershed were determined to be meet ALU attainment (ARC, 2013). Of the four sample stations that were approximately co-located with fecal coliform bacteria sample locations, two (Station 3 / W-0.1 and Station 11 / M-1.5) were in reaches designated as potentially meeting recreational use for fecal coliform bacteria, and two (Station 1 / W-2.7 and Station 9 / M-BT-0.1) were in reaches that are potentially impaired for recreational use. There was not a relationship between Index of Biotic Integrity (IBI) score and the fecal coliform results at these locations (i.e., the IBI scores were not higher for both of the reaches that are potentially attaining recreational use, or lower for the two reaches that are potentially impaired); however, the percentage of sensitive macroinvertebrate taxa was higher at the Stations 3 and 11, but it was only slightly higher than the result at Station 9. A more detailed discussion of the macroinvertebrate results is provided in the report in Attachment B.

Table 8. Summary of Outfalls in Little Bushkill Creek.

	GPS ID	Size	Material	Indication of Active Use?	Notes
West Branch	W-2.8-OF-1	24"	CMP	Yes	Clear, flowing water
	W-2.8-OF-2	36"	Concrete	Yes	Small trickle; elliptical shape; flared end section
	W-2.79-OF-1	4"	Perforated HDPE	Unknown (partially submerged)	Potentially from house adjacent to stream; silt fence along stream
	W-2.79-OF-2	2"	PVC	Yes	Dripping; orange/brown staining; potentially from house adjacent to stream; silt fence along stream
	W-2.67-OF	4"	Perforated HDPE	No	Not flowing; water behind pipe; two pipes
	W-2.55-OF	12"	CMP	No	Rust and corrosion present; may no longer be active
	W-2.50-OF	24"	Concrete	Yes	Outfall from waste water treatment plant; slow trickle; pipe into concrete spillway with rip rap 3 feet wide; outfall is elevated 3 feet above stream
	W-2.48-OF-1	10"	Plastic	No	From waste water treatment plant property; outfall is elevated 3 feet above stream
	W-2.48-OF-2	1.5"	PVC	Yes	From waste water treatment plant property; flowing water
	W-2.4-OF	1.5"	Rubber hose	Yes	Potentially an old spring-fed watering trough; black pipe comes out of bank into an orange hose, which flows into an old bath tub before discharging to stream; steady flow was observed
	W-1.6-OF	161.5"	Concrete	No	Left bank; upstream of Sandt Rd. Bridge
	W-1.05-OF-1	24"	HDPE	Yes	Flowing water; could not determine source, did not appear to be connected to a storm inlet; low area upstream from road did not appear to be source
	W-1.05-OF-2	24"	CMP	No	Connected to inlet on Church Rd.
East Branch	E-1.3-OF	24"	Multiple Pipes	Yes	Some water flow
	E-BCR-0.7-OF-A	6"	Metal	Unknown (partially submerged)	Left bank, potentially associated with field drains
	E-BCR-0.7-OF-B	6"	Metal	Yes	Pond outfall, right bank
	E-0.3-OF	24"	Concrete	No	Left bank, just upstream from bridge
Main Branch	M-BT-E-OF-A	4"	Plastic	No	Potentially from cabin
	M-BT-E-OF-B	8"	Metal	Unknown (partially submerged)	Potentially from field drains; downstream from driveway
	M-BT-0.35-OF	24"	HDPE	No	Flared end section
	M-2.6-OF	18"	CMP	No	In bridge abutment
	M-1.6-OF-A	6"	PVC	Yes	Abundant amount of clear water flowing out; potentially a piped spring
	M-1.6-OF-B	4", 4", 6"	PVC	Yes	Flowing water coming from both 4" pipes (not from 6" pipe); pipe appears as though it may be coming from house
	M-1.5-OF	3 closed 4" pipes	In cement	No	Potentially to drain golf course pond
	M-BT-OF1	Not a pipe	Rock	Yes	Overflow from pond; flowing over rock; duckweed present

Table 9. General Observations, July and September 2013.

	GPS ID	Feature Type	Description
West Branch	W-2.8-IS-Phrag	Invasive Species	*Phragmites* growing to the edge of stream bank on left bank for 80 feet
	W-2.8-IS-KW	Invasive Species	Japanese knotweed growing in rip rap on right bank; some on left bank, extends downstream
	W-2.7-LJ-2	Log Jam	Not blocking stream flow Photo facing downstream
	W-2.7-LJ-1	Log Jam	Only blocking 1/2 of stream, no collection of fine sediment, photo facing down stream
	W-2.79-EB	Eroding Bank	Erosion on right bank for 100 feet (40 feet bare of vegetation), photo facing upstream, no riparian zone and grass/lawn covered banks
	W-2.6-B	Bridge	Small footbridge
	W-2.67-RW	Retaining Wall	Right bank, 6 feet high and 80 feet long
	W-2.67-B	Bridge	Facing downstream- 25 feet wide, 7 feet high; open grate (not paved)
	W-2.65-Pipe	Pipe	4 inch metal pipe crossing stream, not discharging to stream
	W-2.65-EB	Eroding Bank	Eroding bank along residential property Grass lawn leads to sparsely vegetated bank with some rock stabilization Vegetation dead due to herbicide on left bank
	W-2.65-B	Bridge	Footbridge
	W-2.5-Trib	Tributary	Some flow, approximately 3 to 4 feet wide
	W-2.5-OF/B	Bridge	Footbridge at waste water treatment plant outfall
	W-2.5-IS-KW	Invasive Species	Knotweed on right bank
	W-2.55-IS-KW	Invasive Species	Knotweed on both banks
	W-2.4-EB	Eroding Bank	Heavy erosion on left bank, bank is approximately 5 feet high
	W-2.35-Trib	Tributary	Small flowing tributary next to junkyard; approximately 4 feet wide
	W-2.2-D	Dam	Dam originally greater than 4 feet tall and 3 feet wide ; Broken throughout / trees laying on dam Water breaches on left side with fine sediment built up behind dam in pool Concrete structure
	W-2.2-FGS	Fine Grained Sediment	Photo taken facing upstream
	W-2.2-AV	Aquatic Vegetation	Curly leaf pondweed (*Potamogeton crispus*) growing in stream
	W-1-OB	Trout	Trout- multiple brown trout, approximately 5 inches long
	W-1-EB	Eroding Bank	Left bank, approximately 5-6 feet high, eroding, held together by tree roots, cobble, nearly vertical Approximately 50 feet long
	W-1.8-KP	Knick Point	Knick point on right bank.
	W-1.5-IS	Invasive Species	Large patch of Japanese knotweed on left bank approximately 100 feet long; growing on legacy sediment from former dam
	W-1.5-D	Dam	Breached dam, ~ 5 feet high, unsure how wide; Looks as though mill race went towards power line right of way; Structure made of concrete and stone; Some deposition upstream, some erosion
	W-1.55-TRIB	Tributary	Small tributary comes from right bank Approximately 2 feet wide, good flow, two smaller tributaries form tributary Flows through culvert under old trail
	W-1.55-IS	Invasive Species	Japanese Knotweed growing on transverse bar and left bank Continues sporadically downstream on point bars
	W-1.05-D	Dam	Remnant mill dam, old wheel still in place; Channel braided downstream
	W-1.05-B	Bridge	Church Road Bridge, approximately 7 feet high x 30 feet wide Concrete with open bottom
	W-0.7-RU	Recreational Use	Recreational use- chair, small handmade rock dam, trails/dirt roads nearby
	W-0.7-LJ	Log Jam	Log jam, spans channel, water flowing through
	W-0.5-RW	Retaining Wall	Retaining wall, buildings along bank, unstable
	W-0.5-B	Bridge	Getz Road Bridge, 20 feet wide x 6 feet high
	W-0.27-B	Bridge	Footbridge for access to pasture on either side of creek; some areas of pasture open to creek
	W-0-OB	Observation	Upstream from end of West Branch
East Branch	E-0.3-B	Bridge	Rasleytown Road Bridge; ~25 feet wide x ~5 feet high
	E-GCW2-C	Culvert	
	E-GCL1-D	Dam	Dam extends to culvert, portion retaining water is about 20 feet wide, 3 feet high; made out of stone/slate
	E-GCL1-C	Culvert	Almost 5 feet high, open bottom stone arch w/ rock above. Approx. 8 feet wide; Can't see any light inside (may turn 90 degrees)
	E-2.8-OB	Observation	Two pipes transect channel
	E-2.8-B	Bridge	
	E-2.75-B	Bridge	Wood bridge in power line right of way
	E-2.65-RU	Recreational Use	Remnant four wheeler crossing
	E-2.45-I	Invasive Species	Power line right of way; multiflora rose abundant
	E-2.3-EB	Eroding Bank	Eroding bank where channel turns at edge of right of way
	E-2.3-B	Bridge	Recreation Trail bridge
	E-1-B	Bridge	
	E-1.95-OB	Observation	Orange iron discharge from wetland
	E-1.95-B	Bridge	
	E-1.8-OB	Observation	Wet swale
	E-1.85-OB	Observation	Piped discharge
	E-1.7-OB	Observation	Channel drainage
	E-1.7-EB	Eroding Bank	Erosion on left bank - About 30 feet long, 2 feet high, mowed to edge; Generally at 90 degree angle, but some undercut areas. Rooting depth ~.75 feet with more erosion below ~ 15 feet long.
	E-1.7-B	Bridge	Bridge at Gum Road

East Branch (continued)	E-1.7-B	Bridge	Gum Road bridge, open bottom, approximately 3.5 feet high and 20 feet wide. Natural substrate
	E-1.7-AV	Aquatic vegetation	Periphyton/filamentous algae on rocks
	E-1.6-OB	Observation	Side channel in stream has formed island, does not appear to have been formed as result of mid channel bar
	E-1.5-AV	Aquatic Vegetation	Duckweed in pool.
	E-1.53-TRIB	Tributary	Tributary (shown on map); approximately 3 feet wide and 2 feet deep; gravel/cobble substrate, clear water, moderate velocity
	E-1.4-PB	Point Bar	Point bar, mostly gravel, vegetated with smart weed, opposite of steep embankment with same bedrock outcrop
	E-1.3-KP	Knick Point	Bedrock
	E-1.3-B	Bridge	Knitters Hill Rd bridge, 12 feet high, 30 feet wide, natural substrate
	E-1.3-AV	Aquatic Vegetation	Hydrilla growing in stream (not extensive), periphyton/ algae common
	E-1.35-LJ	Log Jam	Logjam; has caused fine sediment to deposit upstream
	E-1.2-PIC	Picture	Power line right of way
	E-1.2-EB	Eroding Bank	Eroding bank along recreational trail (left) Slumped areas are vegetated, 90 degrees, bank is healing
	E-1.2-AV	Aquatic Vegetation	Hydrilla growing in stream
	E-1.25-PIC	Picture	Photo upstream & downstream
	E-1.1-LJ	Log Jam	Log jam, water passing through
	E-1.15-PIC	Picture	Picture of stream
	E-1.15-PB	Point Bar	Point bars, mid channel bars in stream
	E-0-OB	Observation	Upstream from end of East Branch
	E-0.9-TRIB	Tributary	Heimer Road spring tributary, much cooler than main channel
	E-0.5-TRIB	Tributary	Old toe rock, right bank, 75 feet, stable, just upstream from Benders Church Road
	E-0.5-LJ	Log Jam	Log jam, fine sediment accumulating upstream
Benders Church Road Tributary	E-BCR-2.05-B	Bridge	Driveway bridge, concrete pipe, 3-4 inches diameter
	E-BCR-1.8-LS	Livestock In/Along Stream	Cattle access to stream (drinking area?) Finger off of main channel, main channel is fenced off
	E-BCR-1.6-FGS	Fine Grained Sediment	Silt deposition on upstream side of culvert (fine grained sediment deposit)
	E-BCR-1.6-C	Culvert	Culvert under driveway, ~ 2 feet wide
	E-BCR-1.4-B	Bridge	Stream crossing for livestock, electric fence prevents access to stream
	E-BCR-0.7-OB	Observation	Pool below bridge with brown trout (~4 to 8 inches) & white suckers
	E-BCR-0.7-LS	Livestock In/Along Stream	Cattle stream crossing, trampled, eroding bank, mucky, cow droppings along stream
	E-BCR-0.7-C	Culvert	Culvert under Heitzman Rd, corrugated metal pipe, 4 inches diameter, potential barrier to fish passage
	E-BCR-0.7-B	Bridge	Wooded farm bridge
	E-BCR-0.7-AV	Aquatic vegetation	Hydrilla growing in stream- continues downstream, algae present
	E-BCR-0.55-OB	Observation	Fencing along property boundary Excludes cattle from stream
	E-BCR-0.4-OB	Observation	Confluence of braided channels, braided channels do not seem conducive to trout movement, very shallow
	E-BCR-0.2-B	Bridge	Stream crossing for cattle- more like a ford; Electric fence upstream and downstream help prevent cattle access in stream Minor barrier to fish passage, ~8 feet wide
	E-BCR-0.15-B	Bridge	Heimer Road Bridge- 5 feet wide, submerged metal pipe
	E-BCR-0.05-B	Bridge	Cattle ford, similar to upstream one
Main Branch	M-5.7-OB	Observation	Downstream from confluence of East & West
	M-5.7-KP	Knick Point	Bedrock outcrop (at start of main branch)
	M-5.45-OB	Observation	Abandoned channels/oxbows
	M-5.1-LJ	Log jam	Start of log jam- no fine sediment
	M-5.0-LJ	Log jam	Log jam
	M-4.85-RW	Retaining Wall	Cinderblock retaining wall (falling down) Upstream from little red building
	M-4.75-B	Bridge	Rec train bridge approximately 35 feet wide; Not perpendicular to steam 6 feet to base of I-Beam
	M-4.74-B	Bridge	Jones Hill Bridge- 40 feet wide, 8 feet high
	M-4.2-B	Bridge	Bangor Rd Bridge- 40 feet wide, 15 feet high
	M-3.4-OB	Observation	Water coming out of left bank, almost like a tributary with fill on top, probably same source as WRT
	M-3.4-KP	Knick Point	Bedrock outcrop (across most of stream bank)
	M-3.4-B	Bridge	Engler Road Bridge; ~30 feet wide, arc bridge 12 feet high
	M-3.2-LJ	Log jam	Log jam, functioning as low head dam, fine grained sediment deposits upstream
	M-2.9-KP	Knick Point	Bedrock outcrop
	M-2.6-B	Bridge	Gall Road Bridge- 40 feet wide, 10 feet high
	M-2.65-IS	Invasive Species	Japanese Knotweed along left bank
	M-2.1-LJ	Log jam	Log jam- ~5 feet high, catching a lot of debris, no fine sediments accumulated upstream, blocking channel
	M-1.8-IS	Invasive Species	Japanese Knotweed along left bank

Main Branch (Continued)	M-1.8-B	Bridge	Driveway bridge- old tractor trailer bed? Approximately 8 feet high x 25 feet wide
	M-1.6-OB	Observation	Old RR bridge abutment
	M-1.6-CM	Other Channel Modification	Rock along bank, mowed to edge
	M-1.5-D	Dam	Timber structure, reverse log flume
	M-1.5-B	Bridge	Golf course bridge, 30 feet wide x 12 feet high
Browntown Road Tributary	M-BT-OB1	Observation	Stream comes out of shallow outcrop- no satellite
	M-BT-E-SPR	Spring	Spring at start of tributary Slate around former pool area; clear water; moderate flow
	M-BT-E-OB-B	Observation	Outhouse
	M-BT-E-OB-A	Observation	Outhouse; about 15 feet from tributary
	M-BT-E-LS	Livestock In/Along Stream	Cow pasture along stream; little riparian vegetation; cows have free access to stream
	M-BT-E-B-A	Bridge	Driveway bridge; 8 feet wide, sediment deposition upstream
	M-BT-C1	Culvert	Culvert under 191 N; 3 feet wide, branches in front
	M-BT-0.4-B	Bridge	Old stone bridge; 3 feet wide x 2 feet high

4.0 Discussion

The following sections provide an overview of the West Branch, East Branch, and Main Branch based on the results of the July and September sampling rounds. Reaches that are potentially attaining or impaired were identified and are shown on Figure 2.

4.1 Attaining and Potentially Attaining Reaches

Based on the results of the July and September 2013 sampling rounds, five reaches were identified as largely meeting water quality criteria and three reaches showed potential for meeting water quality criteria based on one round of sampling. In certain instances, additional sampling is recommended.

4.1.1 West Branch

Mile 2.0 to 0.5

In the West Branch, the fecal coliform results at W-1.6 and W-0.5 had a geometric mean that was less than 200 CFU/100 ml, and therefore support designating this reach as attaining water quality criteria and not impaired for recreational use. The results of previous sampling also support this finding since both locations had low concentrations of fecal coliform bacteria during low-flow (based on rain events) sampling events in 2011 that were not conducted after storms (Plainfield Township, 2011). W-0.5 did have a single measurement in July that exceeded 400 per 100ml, which results in W-0.5 exceeding the second criteria (no more than 10% of the samples are to exceed 400 CFU/100ml), however, based on a conversation with Megan Bradburn of PADEP on August 13, 2013, it is understood that PADEP may rely more on the geometric mean for considering the status of a sample location and therefore this reach is considered to meet water quality criteria. The extent of the attaining reach may potentially extend to at least Mile 2.0, since all tributaries and other sources of dilution for W-1.6 are upstream of Mile 2.0. Furthermore, based on the results of the riparian corridor assessment, no outfalls or other potential sources of fecal coliform bacteria were identified between W-1.6 and Mile 2.0. Similarly, the 2013 sample results for this reach are anticipated to be representative of attaining conditions in the Church Road Tributary that extends to the north from approximately Mile 1.08.

Mile 0.5 to Mile 0.1

W-0.1 results met water quality criteria during the September sampling round; however the July results somewhat exceeded the geometric mean requirement, and 40% of the samples exceeded the second criteria. Given the limited level of the exceedance and the positive September results, this section has been designated as a potentially attaining reach. This designation is also assigned to the Getz Road Tributary that enters the West Branch at Mile 0.3, and downstream to Mile 0.

4.1.2 East Branch

Grand Central Woods Tributaries 1, 2, and 3

The results for E-GCW1 and E-GCW3 met the geometric mean requirements during July and September. As mentioned in Section 2.1.1, the results at these locations are

considered representative of the conditions in the Grand Central Woods Tributaries; therefore, the Grand Central Woods Tributaries 1, 2, and 3 attain water quality criteria and meet requirements for delisting these reaches as impaired for recreational use. In E-GCW-3, the result from one sampling event marginally exceeded 400 CFU/100 ml (420 CFU/100 ml); however, since all of the other results were very low (<141 CFU/100 ml), and the geometric mean was low (100 CFU/100 ml in July and 60 CFU/100 ml in September), this tributary is considered to be attaining water quality criteria and being suitable for recreational use. Note, since these tributaries have not been previously sampled, there is no data to the contrary.

Grand Central Landfill Tributary 2

All results for Grand Central Landfill Tributary 2 (E-GCL2) met water quality criteria; however, since only four samples were collected at this location during the July sampling round, two rounds of data were not available for this location. As noted in Section 2.1.1, only four samples were collected here since this location was added based on field coordination with PADEP and Plainfield Township on the second sampling event. With the favorable results for the available sample rounds, it is suggested that this reach meets water quality criteria for recreational use and should be considered for delisting as impaired.

Grand Central Road and Delabole Road Tributaries

The Grand Central Road Tributary (E-GCR-0) and Delabole Road Tributary (E-DRT-0) were each assessed during the September sampling. Based on this single round of sampling the Grand Central Road reach just exceeded the 200 CFU/100 ml requirement (204 CFU/100 ml) and, as such, is considered to be representative of a reach that potentially attains water quality criteria. The result for the Delabole Road reach (121 CFU/100 ml) suggests that conditions in that stream are acceptable and that this stream also potentially meets water quality criteria. These reaches (as part of the entire Little Bushkill Creek) were previously designated as impaired based on a single round of sample results (i.e., 5 weeks during high flow conditions in August / September, 2011); in the same vain, given the 2013 results these reaches should be delisted. However, PADEP guidelines suggest that an additional sampling round will likely be necessary to confirm these acceptable conditions.

Mile 2.8 to 0.9

Three fecal coliform measurements collected during 2013 at E-2.8 had low results (102, 80, and 52 CFU / 100 ml). Based on sampling of the main tributaries to the East Branch (Grand Central Road Tributary, Delabole Road Tributary, Heimer Road Spring Tributary, and Benders Church Road Tributary) and the riparian corridor evaluation, sources of fecal coliform bacteria were not observed between E-2.8 and the Heimer Road Spring Tributary. Therefore, this reach and its tributaries were identified as potentially attaining. Additional sampling in 2014 may be warranted to confirm attainment of water quality criteria.

4.1.3 Main Branch

Mile 5.1 to 1.5[3]

Samples collected in the Main Branch at sample locations M-5.1 and M-1.5 met water quality criteria during both the July and September sampling rounds and were well below water quality criteria for fecal coliform. These samples are considered to be representative of the entire lower reach of the Main Branch and, thereby, suggest that this reach attains water quality criteria and supports delisting of the Main Branch as impaired for recreational use. These findings are also considered to be representative of water quality conditions in the Berhel Road, Gall Road, Bangor Road, Mintbrook Spring, and Batts Switch Road tributaries that join the Main Branch at approximately Mile 2.52, 2.62, 4.55, 4.73, and 4.73, respectively. Potentially attaining conditions are expected to extend upstream of Mile 5.1, possibly to the confluence with the West Branch at approximately Mile 5.7, however, less than attaining upstream influences on the East Branch may limit these conditions.

Weiss Road Tributary

The Weiss Road Tributary is the primary tributary to the Main Branch. Results from the tributary sampled at M-WRT-0 met the geometric mean requirements during July and September and were well below the threshold criteria (22 and 10 CFU/100 ml, respectively). One sample collected during July marginally exceeded 400 CFU/100 ml; however, the results from July and September, and results from previous sampling events during low flow conditions (based on rain events) (Plainfield Township, 2011) indicate the tributary meets water quality criteria and are supportive of delisting this reach as impaired for recreational use. As the primary tributary, these findings further support the assertion that Mile 5.1 to 1.5 of the Main Branch should also be delisted.

Books Hill Road Tributary

Books Hill Road Tributary (M-BHR-0) samples met water quality during the September sampling round, but not during the July sampling round. Given the lower result associated with the September sampling round and the previous samples collected at this location during low flow (based on rain events) , which had low concentrations of fecal coliform bacteria (i.e., a geometric mean of 97 CFU / 100 ml during June and July 2011) (Plainfield Township, 2011) this reach was assigned potentially attaining designation during this study. However, the July geometric mean is elevated and an additional round of sampling in 2014 may be warranted to support delisting this reach as impaired.

4.2 Potentially Impaired Reaches

Four locations (W-2.8, E-GCL1, E-0.3, and M-BT-0.35) did not meet the geometric mean or percentage criteria; and had multiple high fecal coliform results. Aside from E-GCL1, which has not been previously assessed; previous results from samples collected at or near the above locations have also been elevated (Plainfield Township, 2010 and 2011) and suggests ongoing challenges to meeting water quality criteria in these limited

[3] Samples were not collected below M-1.5 because it is at the boundary of Plainfield Township and Stockertown Borough, and this study was limited to Plainfield Township. Additional sampling could be conducted at Mile 0 to assess if low fecal coliform concentrations extend through the rest of the Main Branch.

portions of the watershed. Sampling was also conducted in the Benders Church Road Tributary (E-BCR-0.7) (but not a full five sample round), to confirm previous data results that indicate the likely continuation of impaired conditions in this reach. The following sections identify the reaches that may be potentially impaired.

4.2.1 West Branch

Upstream from Mile 2.5

In the West Branch, results from samples collected at W-2.8, near the Wind Gap / Plainfield Township boundary and additional samples collected at W-2.7 support the listing of this this reach as impaired for recreational use. The impairment potentially extends to Mile 2.5, which is where the Wind Gap Wastewater Treatment plant discharges to Little Bushkill Creek, and may provide dilution of fecal coliform bacteria. W-2.7 was the only location where human bacteroides were detected; therefore, there is the potential for human sources of fecal coliform bacteria to this reach. It should be noted that human bacteroides were only detected one time, and at low levels, therefore, human wastewater may not be a substantial source of impairment, a continuous source of impairment, and/ or inputs may be limited to a further distance upstream. If human wastewater is entering the West Branch, potential sources could include degraded sanitary sewer pipes in Wind Gap or illicit discharges. Additional data would be required to understand this finding.

4.2.2 East Branch

Grand Central Landfill Tributary 1

The Grand Central Sanitary Landfill Tributary 1 (E-GCL1) flows along the eastern base of the Grand Central Sanitary Landfill. In addition to elevated fecal coliform measurements, specific conductivity was consistently high at this location, and the two parameters may be related since some sources of fecal coliform bacteria typically are associated with high conductivity (e.g., wastewater) (EPA, 2010). Additional information to identify a potential source was not collected; however, based on land use, potential sources of impairment may include wildlife (deer, seagulls), failing or inadequate septic systems in an older neighborhood off of Pennsylvania Avenue, or possibly an unknown landfill related influence.

Benders Church Road Tributary

The Benders Church Road Tributary (E-BCR-0.7) originates in a primarily agricultural area to the east of the East Branch. A complete fecal coliform sampling round was not conducted in this tributary since data from previous sampling indicated that this reach is impaired for recreational use. Based on the riparian assessment of this tributary and bacteroides measurements, potential sources of impairment include wildlife and cows. Ruminant (deer, cow, sheep, and goat) biomarkers were identified at E-BCR-0.7; however, cow biomarkers were not. Deer, cow, and one goat were observed in the watershed upstream of this sample location. Cow may not be a major source since upstream of E-BCR-0.7, pastures were fenced to prevent livestock from accessing streams and cattle crossings were installed at multiple locations. Abundant deer, tracks, and droppings were observed adjacent to the stream in multiple locations. The one goat

was observed in an upper tributary, and it not considered a probable source. Additional sampling at different times of the year and after storm events would help explain these results.

Mile 0.8 to 0.0

Based on the 2013 samples and previous data, the East Branch at E-0.3 is impaired for recreational use. The start and end of the impaired reach is not apparent based on the available data. Fecal coliform measurements at E-2.8 were not elevated, and the two main tributaries (Grand Central Road Tributary and Delabole Road Tributary) upstream of Mile 2.0 are attaining water quality criteria and are suitable for being delisted as impaired. In addition, other than the Recreation Trail, potential sources of fecal coliform bacteria were not evident during the riparian assessment. Based on the available data, water quality at E-0.3 is influenced by the Benders Church Road Tributary; therefore, impairment in the East Branch may be associated with the Benders Church Road Tributary. Two samples collected in the Heimer Road Spring Tributary (E-HRS-0) were elevated, so the main stem of the East Branch was identified as potentially impaired from the confluence of the Heimer Road Spring Tributary (Mile 0.8) to the confluence with the Benders Church Road Tributary (Mile 0.5). The reach downstream of 0.3 was identified as inconclusive since data to delineate the extent of the potentially impaired reach was not available.

Sources of impairment in the East Branch are likely associated with wildlife and domestic animals. Although signs were not observed during the riparian corridor evaluation, deer may be common in the wooded areas along the stream. This was supported by the results of the animal source tracking, which identified high level of ruminant biomarkers at E-0.3. The ruminant test includes cows, deer, sheep, and goats, but based on separate testing for cow biomarkers at E-0.3, the ruminant results are not entirely accounted for by cow. Sheep and goat pastures were not observed in this area, therefore, it is possible that deer are associated with the elevated ruminant results. Dogs may also be a source of fecal coliform bacteria since dog walking was commonly observed along the Recreation Trail, but this was not supported by the animal source tracking results. Cow sources of fecal coliform bacteria may originate in the lower portion of the Benders Church Road Tributary. Although fenced pastures and cattle were observed downstream of Heitzman Road, cows were able to freely access the stream at several locations. This was evident through trampled banks and numerous cow droppings in and along the stream.

4.2.3 Main Branch

Browntown Road Tributary Based on the results of previous sampling efforts, the Browntown Road Tributary was identified as potentially impaired (Plainfield Township, 2010 and 2011). During the July 2013 sampling round, samples collected at M-BT-0.35 in the Browntown Road Tributary supported the conclusion that sources of impairment are located upstream of this point. In September, samples were collected twice in the East and West tributaries that converge upstream of M-BT-0.35. Sample results were elevated in both tributaries; however the East tributary had the highest documented fecal coliform result of 1,100 CFU/100 ml. Based on the riparian habitat study, this tributary originates in a pasture. Cows were observed in and around the tributary. In addition, two

unknown outfalls and two outhouses were observed along this tributary. It was not apparent if the outhouses are currently in use. In the West tributary, sources may include wildlife (e.g., deer), or domestic animals (e.g., dogs).

4.3 Conclusions

Based on the results of the 2013 fecal coliform sampling of Little Bushkill Creek, the majority of the watershed reaches are meeting or potentially meeting Water Quality Standards. Of a total 38.8 miles of stream (West, East, and Main Branch plus tributaries), 29.2 miles (75%) attain or potentially attain water quality criteria and should therefore be eligible for listing by PADEP as meeting designated requirements for recreational use. The results from five reaches (8.6 miles of primarily tributary waters or 22% of total stream miles) suggest these areas are either impaired or potentially impaired, in respect to fecal coliform bacteria. Results are inconclusive for 1.0 miles (3%) of the West Branch and an associated tributary.

The 2013 sampling program was designed by Plainfield Township in cooperation with PADEP and provides consistent results that serve to refute the findings of the previous study and the listing of the entire Little Bushkill Creek as impaired for recreational use due to elevated fecal coliform bacteria (Plainfield Township, 2010 and 2011). During the previous assessments, multiple sampling events were conducted after storms, some of which exceeded 3 inches of rain. Based on communications with Megan Bradburn of PADEP, sampling should be conducted during low flow conditions, therefore, some of the historical data that were used to list Little Bushkill Creek as impaired, may not be valid. Subsequently, the results of the 2013 sampling assessment could be used to support delisting of the following reaches of Little Bushkill Creek as impaired:

- West Branch - The main stem and tributaries from Mile 2.0 to 0.0;
- East Branch – The main stem and tributaries from Grand Central Woods to Mile 0.9, excluding Grand Central Landfill Tributary 1, and
- Main Branch – The main stem and tributaries from Mile 5.7 to 1.5, excluding Browntown Road Tributary.

The following reaches have been identified as potentially impaired:

- West Branch – The main stem upstream from Mile 2.5;
- East Branch:
  - Grand Central Landfill Tributary 1
  - The main stem from 0.9 to 0.3, including the Heimer Road Spring Tributary and the Benders Church Road Tributary
- Main Branch – Browntown Road Tributary

Implementing restoration strategies, as described in Section 5.0, would support maintaining attaining conditions and may result in reducing fecal coliform bacteria concentrations in the reaches identified as potentially impaired and would be helpful in working towards delisting the entire watershed as impaired for recreational use.

5.0 Restoration Recommendations

Based on the July and September 2013 sampling results, recommendations to reduce fecal coliform bacteria in Little Bushkill Creek have been identified. Recommendations have been included for improving reaches that have been identified as potentially impaired (Section 4.2), as well as general watershed-wide recommendations to support an overall reduction in fecal coliform bacteria throughout the watershed. It should be noted that the recommendations presented herein only represent suggestions of measures that could be implemented to support reductions in fecal coliform bacteria, and may also support general improvements in water quality. These recommendations are summarized below and presented in Table 10.

Table 10. Summary of Restoration Recommendations.

		Outfall Evaluation	Riparian Buffer Enhancement	Agricultural Best Management Practices	Coordination with Wind Gap Borough
West Branch	Upstream of Mile 2.7	✓	✓		✓
East Branch	Benders Church Road Tributary		✓	✓	
East Branch	Grand Central Landfill Tributary 1		✓		
East Branch	Mile 0.8 to 0.0		✓	✓	
Main Branch	Browntown Road Tributary	✓	✓	✓	

5.1 Outfall Evaluation

Outfalls that could be prioritized for assessment are W-2.8-OF-1, W-2.8-OF-2, W-2.79-OF-1 and W-2.79-OF-2 since they are located in an impaired reach, were discharging at the time of assessment, and the outfall source was not apparent. Other outfalls identified during the Riparian Corridor Assessment that are not addressed in the MS4 plan could also be evaluated to determine if they are a concern for general water quality. Several outfalls showed evidence of active use (e.g., discharging water), and since the assessment was completed more than 24 hours after rain events, these discharges may not be associated with stormwater. Some of these outfalls may be associated with springs or piped tributaries, and may not be a concern for water quality in Little Bushkill Creek. However, there is potential for illicit outfalls (i.e., outfalls that are not strictly limited to

stormwater), which flow outside of rain events and which may be sources of fecal coliform bacteria or other sources of impairment. These outfalls may flow continuously, or periodically, and depending on their source, could negatively impact water quality in Little Bushkill Creek. An outfall evaluation may include the following steps:

- Review documentation collected as part of this study. Information about the outfall is included on Table 8. Additional information (including the tax parcel number and a photograph) can be accessed via the outfall markers in the PMF in Attachment B.
- Coordinate with public works and other township personnel to determine if some outfalls are storm drains that are not identified in the MS4 Plan.
- Coordinate with property owners who have outfalls along their properties. Property owners may know if the outfall is associated with sump pumps, downspouts, or field drains, and may be familiar with when it was installed.
- Assess outfalls that need additional confirmation during wet and dry periods to determine if they flow continuously, during rain events, or intermittently. It may also be beneficial to determine if outfalls are flowing at different times during the day.
- For outfalls that may be a concern, measure flow and water quality parameters such as fecal coliform bacteria, specific conductivity, and detergents.
- Based on the information collected, it may be possible to determine if any of the outfalls are potentially illicit discharges. If illicit discharges are detected, determine who is responsible for fixing them. If a property owner is responsible, the township can educate the property owner about the benefits of addressing the problem, and work with them to identify a cost effective solution.

Additional information is available in: *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments*. (Brown et al, 2004).

5.2 Riparian Buffer Enhancement

Based on the results of the habitat survey and riparian corridor assessment, riparian buffers are generally in good condition throughout the watershed. Healthy riparian buffers can reduce fecal coliform bacteria since they filter pollutants (e.g., fecal coliform bacteria and sediment) from runoff and they reduce conditions that may cause fecal coliform bacteria to multiply (e.g., high nutrient concentrations, high stream temperature).

Although wooded riparian buffers are common throughout Little Bushkill Creek, certain areas could benefit from enhancement. Some specific recommendations include:

- Increase riparian buffer widths at locations that had habitat scores of 15 or less (suboptimal or less) for the riparian vegetative zone width.
- Work with property owners to improve riparian zones in areas where riparian vegetation is impacted through grazing or mowing. This may include areas that

had a score of 15 or less (suboptimal or less) for the grazing or other disruptive pressure.

- Coordinate with utility companies to determine if shrubs or low-growing trees (e.g., dogwoods, alders, or sumacs) can be planted along streams in utility right of ways. This may help with stream shading and reduce stream temperatures. It would be beneficial to assess the potential for plantings at all utility line crossings of Little Bushkill Creek.
- Plant understory vegetation that includes shrubs and herbaceous species in riparian zones that consist primarily of open woods.

Priority reaches for riparian buffer enhancement are those that are potentially impaired for fecal coliform bacteria, had poor riparian buffer widths, and were impacted by grazing or mowing:

- West Branch – Mile 2.8 to 2.75
- Benders Church Road Tributary – Mile 0.7 to 0.55
- Browntown Road Tributary – Along pasture in upper portion of East Branch (Note, a separate habitat form was not completed for the pasture, however, these conditions were observed during the Riparian Corridor Assessment)

Secondary priorities are reaches in areas that are potentially impaired for fecal coliform bacteria and had a poor result for riparian buffer width or for grazing/mowing:

- West Branch – Mile 2.75 to 2.4
- Benders Church Road – Mile 1.1 to 0.7
- Browntown Road Tributary – West Branch

PADEP published a Riparian Forest Buffer Guidance in 2010 that contains recommendations about riparian buffers. The guidance document can be accessed on PADEP's Online Library at: http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-82308/394-5600-001.pdf.

5.3 West Branch

Upstream of Mile 2.5

In the West Branch, the reach upstream of Mile 2.5 (upstream of Abel Colony Road) was identified as potentially impaired. Recommendations for restoring water quality in this reach include coordination with Wind Gap Borough and evaluating the outfalls that were identified during the riparian corridor assessment (See Section 5.1.1).

Identifying and reducing sources of fecal coliform bacteria in Wind Gap Borough would result in downstream improvements in water quality. In support of this, Wind Gap Borough could assess the condition of the sanitary sewer system and collect additional fecal coliform samples in Little Bushkill Creek within Wind Gap. It may also be helpful for Wind Gap Borough to evaluate outfalls to Little Bushkill Creek within the borough.

Several outfalls were identified upstream of W-2.7 during the riparian corridor assessment. The sources of some of the outfalls that exhibited signs of active use were not apparent. These outfalls should be evaluated to determine if they could contribute fecal coliform bacteria.

5.4 East Branch

Recommendations for addressing impairment in the East Branch target the Grand Central Landfill Tributary 1, the Benders Church Road Tributary, and the lower portion of the East Branch. The extent of impairment in the main stem of the East Branch was not confirmed during this assessment. Additional fecal coliform measurements upstream of E-0.3 could assist with delineating the extent of impairment; however, it may be possible to implement restoration measures, and then resample at E-0.3 to determine if the restoration strategies were sufficient in addressing potential impairment in the East Branch.

Grand Central Landfill Tributary 1

Sources of impairment in the Grand Central Landfill Tributary are not clear, and may be associated with multiple sources (e.g., residential, industrial, and/or wildlife); therefore, additional sampling in this tributary may be helpful for identifying the source of the problem. Since specific conductivity in this reach was high, and potentially indicates a source of pollutants, it may be possible to use a specific conductivity meter to qualitatively map the zone of elevated specific conductivity upstream of the E-GCL1 sample location. Specific conductivity measurements could be collected in the tributaries adjacent to Buss Street, at the base of each of the two tributaries along the northwestern edge of the landfill, at the base of the tributary just upstream from the landfill detention pond, at the outlet of the landfill detention pond, and at an additional location north of the utility easement. Based on this information, it may be possible to identify an approximate location where elevated conductivity begins. Fecal coliform measurements collected above and below the point may help determine if the results are related, and may help identify sources. Alternately, fecal coliform samples could be collected at the base of each tributary upstream of E-GCL1.

Benders Church Road Tributary

Restoration recommendations in the Benders Church Road Tributary include encouraging the use of agricultural best management practices and evaluating the influence of deer.

Agriculture best management practices (BMPs) that could help reduce fecal coliform contributions include:

- Vegetated Filter Strips – Vegetated Filter Strips are strips of vegetation (such as grasses) that help infiltrate stormwater and remove pollutants from runoff. They can be used to increase the width of riparian buffers or placed along fields and pastures. They are effective at removing pollutants, including fecal coliform bacteria and sediment.
- Reduce Livestock Access to Streams – Using fencing and stream crossings to prevent livestock from accessing streams can help reduce sources of fecal coliform bacteria, as well as improve other conditions (such as erosion and

sedimentation) that may arise from livestock moving in and around streams. Many farms in the Benders Church Road Tributary prevent cattle from accessing the stream by fencing pastures and using cattle crossings, some areas, such as just downstream from Heitzman Road, may benefit from these BMPs. Grants and other types of support for implementing BMPs are available through the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The conservation district can help farms identify and develop specific strategies for reducing runoff and protecting water quality.

- Manure Management – Proper management of manure can help reduce fecal coliform bacteria in streams. Strategies may include using BMPs to reduce runoff from manure storage areas and pastures, not applying manure to fields during winter, and delaying incorporation of manure after spreading.

Deer and signs of them were observed during the riparian corridor evaluation throughout this tributary. Coordination with property owners to assess the size of the deer population may be helpful to determine if deer are possibly contributing to fecal contamination in this reach. This may be beneficial to consider in other locations in the watershed as well, especially in the East Branch. Additional bacteroides sampling in this reach could also assist with understanding the contribution. Quantification tests for deer are being developed, but if sampling occurs before they are available for use, ruminant samples or deer presence/absence sampling could be conducted.

Mile 0.8 to 0.0

Implementing the recommendations in the Benders Church Road Tributary would likely improve the overall condition in the East Branch of Little Bushkill Creek. Because high results (229 and 900 CGU/100ml) were observed in the Heimer Road Spring Tributary, which has similar land use as the Benders Church Road Tributary, the recommendations for the Benders Church Road Tributary could be applied to the Heimer Road Spring Tributary. A Riparian Corridor Evaluation along the Heimer Road Spring Tributary would help identify specific areas to implement BMPs. In addition, riparian buffer enhancement upstream of Rasleytown Road (Mile 0.3 to 0.5) would likely result in water quality improvements in the East Branch.

5.5 Main Branch

Browntown Road Tributary

Recommendations for improving the condition of the Browntown Road Tributary include implementing the same agricultural BMPs as were identified for the Benders Church Road Tributary in the pasture in the headwaters of the Eastern Tributary. In particular, using fencing to prevent cattle from accessing the stream in the headwaters of the Eastern Tributary would support improvements in water quality.

Two outfalls and two outhouses that were identified during the riparian corridor assessment along the Eastern Tributary could be evaluated to determine if they are a source of fecal coliform bacteria.

While sources of fecal coliform in this reach are uncertain, field observations suggest that it may be beneficial to work with property owners to educate them about the benefits of riparian buffers and domestic animal best management practices.

5.6 Recommendations for Additional Sampling

Additional sampling may be helpful to better understand the extent and sources of impairment. Some recommendations include:

- West Branch

  Mile 2.0 (W-2.0) and Mile 2.5 (W-2.5)

  To determine the status of this reach, additional fecal coliform sampling could be conducted below the wastewater treatment plant (W-2.5) and below the confluence with the Abel Colony Road Tributary (W-2.0).

  W-2.8

  Human bacteroides were detected in low levels one time at W-2.7. To understand if this detection was due to a distant source (i.e., upstream in Wind Gap Borough), it may be beneficial to request that Wind Gap Borough collect additional human bacteroides samples upstream of Plainfield Township. Alternately, collecting human bacteroides samples at W-2.8 during high and low flow conditions may help determine if upstream sources are present.

- East Branch

  Upstream of E-GCL1 in Grand Central Landfill Tributary 1

  As mentioned above, collecting fecal coliform samples upstream of E-GCL1 may help with identifying the source of impairment. In addition, additional specific conductivity measurements may help identify locations to collect fecal coliform samples. Due to land use considerations (e.g., adjacent landfill), it may be helpful to collect additional measurements to determine if landfill leachate is influencing water quality in this reach. Some parameters that could be tested to determine if landfill leachate is a concern include chloride, iron, ammonia, chemical oxygen demand (COD), hardness, and alkalinity, as well as field measurements of specific conductivity, pH, and salinity. If this type of testing is conducted, it would be helpful to collect samples in a reference location as well. One of the Grand Central Woods Tributaries may be a suitable reference location.

  E-GCR-0, E-DRT-0, E-2.8

  Two rounds of fecal coliform sampling at these locations in 2014 may support delisting the Grand Central Road Tributary, the Delabole Road Tributary, and the East Branch upstream of Mile 2.8 as impaired.

  Mile 0.9 (E-0.9, upstream of the confluence with the Heimer Road Tributary)

  Additional fecal coliform sampling at E-0.9 may help determine the upstream extent of impairment in the East Branch.

E-BCR-0.7

To help understand sources of impairment, additional animal source tracking at this location may include ruminant, cow, and deer. Sampling should be conducted multiple times and during different flow conditions.

E-0.3

Additional animal source tracking at E-0.3 could assist with understating sources of impairment. Potential tests could include ruminant, cow, deer, and dog. Tests should be conducted after storm events since these sources are associated with runoff.

- Main Branch

  M-BHR-0

  An additional round of fecal coliform sampling at M-BHR-0 with favorable results (Geometric Mean $\leq$ 200 CFU/100ml) may support delisting this reach as impaired for recreational use.

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Figures

Attachments

Attachment A

Photographs

Attachment B

Data Disk:

- Read Me File
- Software
- Published Map Package
- Photographs
- Laboratory Reports
- Field Data Forms
- Benthic Macroinvertebrate Report