Pequabuck River Watershed Based Plan

Hartford County, Connecticut

Connecticut Department of Energy and Environmental Protection - Project #14-03e

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FARMINGTON RIVER WATERSHED ASSOCIATION

Connecticut Department of ENERGY & ENVIRONMENTAL PROTECTION

Executive Summary

The Pequabuck River Watershed Based Plan or WBP is primarily intended to provide a path to improve water quality throughout the watershed, including the river itself and the tributary network of various streams and brooks found within its watershed. The document follows the requirements for the United States Environmental Protection Agency's (USEPA) watershed-based plans (WBP) and addresses nine specific elements including identification of: Water pollutant causes and sources, pollutant load reduction estimates, measures to correct the problems, technical and financial assistance needed to implement the plan, education and outreach components, and criteria, schedules, interim milestones, and a monitoring program to track progress.

The Pequabuck River begins in Litchfield County and flows for approximately 19 miles before draining into the Farmington River in Farmington, Connecticut. Its watershed covers 58 square miles in area, and is comprised of three subregional drainage basins: the Poland River, Coppermine Brook, and the Pequabuck River subregional basin. The river lies in a heavily developed watershed with elevated impervious areas, particularly, along the main stem through the City of Bristol and Town of Plainville. These conditions lead to impaired water quality and altered river function through the alteration of the hydrologic cycle and elevated non-point source (NPS) loading of bacteria, nutrients, and sediments to the river.

The Connecticut Integrated Water Quality Report to Congress indicates that water quality in the Pequabuck River (CT 4315) and segments of its two major tributaries – the Poland River (CT 4313) and Coppermine Brook (CT 4314) - are "not supporting" for recreational uses due to indicator bacteria. The Pequabuck River and the lower section of Coppermine Brook are also "not supporting" for aquatic life, primarily due to unknown causes from a variety of potential sources. Consequently, these waterbodies have been placed on Connecticut's Impaired Waters List and/or included in a Total Maximum Daily Load (TMDL) analysis. This TMDL requires load reductions of *E. coli* with percent reductions ranging from 14% of the load to 89% of the load.

Modeling of pollutants of concern has shown the majority of bacteria to be derived from stormwater-based sources in the Coppermine and Pequabuck subregional basins while wildlife contributions are the greatest source in the less developed Poland River basin. Prioritization of local basins has been conducted in order to recommend twelve (12) specific best management practices (BMPs) to address areas of concern. These BMPs include the utilization of pervious pavement, stormwater wetlands, bioinfiltration basins, vegetated filters, tree wells, and other secondary BMPs.

In addition, more generalized watershed-based management measures are also provided within this document which address agricultural sources, septic contributions, pet and animal wastes, overall restoration of stream channels and establishment of riparian buffers. These recommendations, in conjunction with MS4 requirements and LID integration into municipal codes, aim to reduce NPS loading of bacteria, nutrients, and sediments in order to advance progress towards load reductions highlighted in the TMDL.

1.0 Introduction

The Pequabuck River begins in Litchfield County and flows for approximately 19 miles before draining into the Farmington River in Farmington, Connecticut. Its watershed is 58 square miles in area, is comprised of three subregional drainage basins: the Poland River subregional basin (10.2 square miles), the Coppermine Brook subregional basin (18.6 square miles) and the Pequabuck River subregional basin (29.1 square miles). The watershed contains seven communities and intersects three counties: Bristol, Burlington, Farmington, Harwinton, Plainville, Plymouth, and Wolcott are municipalities within the watershed which lie within Hartford, Litchfield, and New Haven counties. The headwaters, arising in a rural landscape, flow into more urbanized areas such as downtown Bristol where impervious surfaces heavily dominate the landscape.

Starting in the mid-1800s, the Pequabuck River and its watershed experienced rapid urbanization and industrialization. Grist and saw mills were developed along the river as manufacturing developed in the area. Inadequately treated municipal sewage and industrial waste released into the Pequabuck River resulted in water quality degradation to the point where, in the early 1900s, it was recognized as one of Connecticut's most polluted rivers. Development has continued through the 21st century as commercial shopping areas and new businesses have replaced many historical manufacturing and industrial hubs.

Although the 1972 Clean Water Act brought attention and aid to the Pequabuck River, the water quality is still impaired by various non-point sources (NPS) carrying pollutants into the River and its two major tributaries. Indicator bacteria have identified all three rivers as "not supporting" for recreation. The Pequabuck River and the lower section of Coppermine Brook are also "not supporting" for aquatic life primarily due to unknown causes from a variety of potential sources.

The Central Connecticut Regional Planning Agency, in cooperation with FRWA, Pequabuck River Watershed Association (PRWA) and Management Plan Stakeholder Committee, developed the Pequabuck River Watershed Management Plan (June 2005) with Clean Water Act Section 319 funding. That plan consisted of 18 Action Items and identified the steps that need to be taken by various public and private entities to improve the quality of the river. The 2005 plan, however, did not include the data needed to identify, quantify and prioritize pollutant loading sources. The pollutant load analysis data generated through this Watershed Based Plan (WBP) will enable the identification of the most feasible load reduction projects and BMP installations and see to fruition many of the action items and recommendations identified in the 2005 plan. Specifically, this WBP will enable the FRWA, Pequabuck River municipalities and other stakeholders to get closer to meeting the Habitat, Land Use, Water Quality and Protected Open Space goals and Action Items 1,2,3,4, 12,13, 15 and 18 (as summarized in the 2005 Plan).

Project partners for the task include:

- The municipalities of Bristol, Burlington, Harwinton, Farmington, Plymouth, Plainville, and Wolcott
- Farmington River Watershed Association (FRWA)
- Pequabuck River Watershed Association (PRWA)
- Connecticut Department of Energy and Environmental Protection (CT DEEP)
- Connecticut River Conservancy
- Naugatuck Valley Council of Governments (NVCOG)
- Capitol Region Council of Governments (CRCOG)

The overarching goals of the Pequabuck River Watershed Based Plan are:

- Identify and quantify the river’s primary sources of nutrient, sediment and bacteria loading
- Use these data to develop a comprehensive Watershed Based Plan (WBP) that identifies specific actions and pollutant load reduction best management practices (BMPs) needed to decrease the water quality impairments of the Pequabuck and its tributaries
- Incorporate stakeholder involvement, education and identification of funding sources

This document will be formatted to address the nine (9) elements of a Watershed Based Plan as laid out by the United States Environmental Protection Agency (US EPA). These nine elements are meant to address all phases of a restoration plan from characterization to conceptual mitigation and practical design, cost, implementation, and evaluation. The following list represents a summarized and abbreviated description of the nine elements as outlined in the Handbook for Developing Watershed Plans to Restore and Protect Our Waters (EPA, 2008).

1. Identification of causes and sources of pollution
2. Estimation of load reductions expected from management measures
3. Description of NPS management measures and implementation sites
4. Estimation the amount of technical and financial assistance to implement
5. Provide information and education
6. Schedule for implementing the NPS management measures
7. Describe interim measurable milestones for implementation
8. Develop criteria to measure progress
9. Develop a monitoring component

By addressing these elements, a thorough and comprehensive plan can be created that ultimately yields improvements in water quality and stream function. This document is, therefore, based on several key concepts that are implicit in the stated nine elements: that characterization and assessment are based on the best available science and data; public participation of residents and stakeholders is tantamount to success; design and implementation must be thoroughly addressed and planned; and the proper performance and implementation of management measures is met through monitoring and adaptive management.

2.0 Identification of Sources of Pollution

The Connecticut Integrated Water Quality Report to Congress, prepared biennially by CT DEEP, indicates that water quality in the Pequabuck River (CT 4315) and segments of its two major tributaries – the Poland River (CT 4313) and Coppermine Brook (CT 4314) - are “not supporting” for recreational uses due to indicator bacteria. The Pequabuck River and the lower section of Coppermine Brook are also “not supporting” for aquatic life, primarily due to unknown causes from a variety of potential sources. Consequently, these waterbodies have been placed on Connecticut’s Impaired Waters List and/or included in a Total Maximum Daily Load (TMDL) analysis.

It is suspected that these water quality impairments are related, at least in part, to NPS pollution. NPS pollution is most commonly linked to watershed development. Put simply, watersheds that are more extensively developed and have a greater amount of impervious surface cover are more likely to be characterized by receiving waterways that are in some way impaired for water quality dependent uses. Basically, as the amount of impervious cover increases, the amount of naturally vegetated land decreases. We also expect developed lands to generate more pollutants as a result of various human activities related to vehicles, fertilizer, pet waste, litter, illegal dumping, septic systems, etc. However, these problems are exacerbated by impervious surfaces that increase the amount of stormwater runoff generated during storm events. The more impervious cover, the less opportunity for rainfall to be absorbed by soils and taken up by plants and trees or to recharge groundwater supplies. The increased amount of surface runoff, in turn, causes pollutants to be more easily mobilized and transported to nearby receiving waters, i.e.- streams, rivers, lakes or wetlands.

Currently, US EPA estimates that over 70% of the nation’s waterways cannot meet their designated uses due to NPS pollution. As a result, over the past two decades, increased attention has been focused on ways to reduce NPS pollution loading through the implementation of measures that address sources of NPS pollution and/or decrease the amount of stormwater runoff. These measures are collectively termed Best Management Practices (BMPs). BMPs are used to eliminate or reduce specific sources of NPS pollution, decrease the volume and rate of runoff, filter and decrease the amount of pollutants transported by runoff, and increase the recharge opportunity for captured runoff.

With funding support provided in part by the CT DEEP through a US EPA Clean Water Act Section 319 Nonpoint Source Grant, the FRWA worked with the consulting group, Princeton Hydro (PH), to quantify NPS pollution loading to the Pequabuck River and identify sources within the watershed responsible for this loading. These data were subsequently used in the preparation of this US EPA nine element watershed-based plan.

As part of this process, FRWA has organized and worked with a stakeholder group that included representatives from the seven affected watershed municipalities of Bristol, Burlington, Farmington, Harwinton, Plainville, Plymouth and Wolcott, as well as other partners. This project builds upon the 2005 Pequabuck River Watershed Management Plan, also developed with support of Section 319 funding by the (former) Central Connecticut Regional Planning Agency, in cooperation with FRWA, the Pequabuck River Watershed Association and the Management Plan Stakeholder Committee.

The following section provides detailed information related to the determination of the sources of pollution. Specifically, this section discusses a review of existing information, historic water quality, watershed land use, and the results of the watershed visual field assessments.

2.1 Review of Existing Information – Summary of Available Data and Reports

As part of this project, FRWA is required to characterize NPS pollution in the Pequabuck River watershed. This was to be accomplished by reviewing existing, available third-party reports, maps and related information as well as through conducting, original site-specific field assessments. Together, the combination of existing information and the results of the field studies were to be used to identify causes and sources of NPS-related water quality impairments. Based on earlier studies of the Pequabuck River watershed, this could include runoff from agricultural and urban lands, septic systems, pet waste and other ubiquitous sources of pollutants (nutrients, sediment, pathogens, heavy metals and petroleum hydrocarbons). This section presents and summarizes the information compiled through the review of existing, available reports.

The reports and sources of available data reviewed by Princeton Hydro consist of the following:

Water Quality Data

- CT River Watch, 2003: E. coli, turbidity, nutrients (2004)
- CT DEEP, 1999: metals, nutrients, bacteria
- CT DEEP, 1998-2011: metals, nutrients, bacteria
- CT DEEP, 2009 A Total Maximum Daily Load Analysis for the Pequabuck River Sub-Regional Basin

Reports

- Hagstrom *et al.,* 1989 Bureau of Fisheries Survey of CT Streams & Rivers F-66-R-1
- Brawerman, J., 2002 Pequabuck River 2002 Water Quality Survey Summary Report, CT River Watch Program
- Central CT Regional Planning Agency, 2004 State of the Watershed Report – 604(b) DEP grant
- Central CT Regional Planning Agency, 2005 Pequabuck River Watershed Management Plan
- Milone & MacBroom, Inc., 2008 Coppermine Brook Drainage Evaluation Executive Summary
- Milone & MacBroom, Inc., 2008 Coppermine Brook Drainage Evaluation full report
- Rogozinski, R. & Aboelata, M., 2015 Pequabuck River Flooding Study & Flood Mitigation Plan
- CT DEEP, 2016 Integrated Water Quality Report, CT DEEP

Other Data

- Plainville Land Use Regulations, Town of Plainville

Bristol CT

- MS4 Sampling Results 2012-2015
- Stormwater Testing Locations
- Brownfields Information (15 Downs St., 43 East Main St., JH Sessions Building)

GIS Data

- Full complement of available CT DEEP / CT GIS data
- Current FEMA Proposed AECOM Flooding Findings, Town of Plainville
- Pequabuck River Flooding Study GIS Layers (FINAL Sept 2015) – AECOM
- National Land Cover Database Land Use and Land Cover

CT DEEP Water Quality and Stormwater Fact Sheets

- Fact Sheets on water quality and stormwater for the City of Bristol, Town of Burlington, Town of Farmington, Town of Harwinton, Town of Plainville, Town of Plymouth, Town of Wolcott (Attached as Appendix D)

The materials were used for both background information as well as data analysis. The following reports were utilized in order to put the data and review materials into an effective context for the purpose of water quality and each of the watershed systems.

<u>1989 Bureau of Fisheries Survey of CT Streams & Rivers F-66-R-1</u>

This report reviews a comprehensive Connecticut stream and river survey initiated by the CT Department of Environmental Protection Bureau of Fisheries in 1988. This was the first survey to investigate streams and rivers in Connecticut and was launched in response to the state's growing angler usage, rising development pressure, and conflict among patrons of Connecticut's streams and rivers. Some goals of the survey included the development of a trout stocking formula; identification and quantification of cold-water, warm-water, and anadromous stream resources; and the development of tools to predict fish biomass and species in Connecticut streams. As the project had begun one year prior to the report's publication, the report contains a mix of final and progress reports for its objectives. The report provides data regarding species, location, and abundance of fish found at specific Connecticut sites, including Pequabuck River, during the project's first year. It also informs of angler behavior, effort, and success on Connecticut streams in 1988. Methodology and design parameters for the project's database are also described in detail.

<u>2002 Pequabuck River Water Quality Survey Summary Report, CT River Watch Program</u>

This report details an effort led by the Connecticut River Watch Program to survey the water quality of the Pequabuck River in the summer of 2002. This project, completed in cooperation with the Pequabuck River Watershed Association and the Connecticut Department of Environmental Protection (DEP), focused on the Pequabuck River and its two major tributaries, the Poland River and Coppermine Brook. Organizers aimed to collect results concerning the condition of the Pequabuck River and its tributaries, locate areas best suited for protection or restoration, and to raise awareness in the community about the River's value and need for protection. Data was largely gathered via water samples, which were analyzed for *E. coli* and an array of chemical and physical indicators such as pH and turbidity. The study provided several conclusions about the Pequabuck River, the highlight being that water quality issues were formidable and widespread throughout the study area. Two other conclusions stated that elevated bacteria levels threatened public health while phosphate and nitrogen loading of already turbid waters suggested a reduction in aesthetic values of streams. Organizers used these and other conclusions to recommend actions such as investigating data from sewage treatment plants discharging into the Pequabuck River to compare permitted versus observed discharge limits, identifying sources of pollutants by initiating a more detailed water quality investigation of the study area, and building a long-term database with water quality and benthic macroinvertebrate assessments to allow for the elucidation of trends over time.

<u>State of the Watershed Report (Central CT Regional Planning Agency, July 2004 604(b) DEP grant</u>

This report offers background information regarding the Pequabuck River Watershed's demographics, history, water quality and quantity, wastewater, land use, open space, and habitat to a degree that is sufficient for use in creating a comprehensive watershed management plan.

<u>2005 Pequabuck River Watershed Management Plan</u>

Drawing upon findings of the July 2004 Pequabuck River Watershed State of the Watershed Report, this Management Plan, delivered by the Pequabuck River Watershed Coalition in 2005, outlines management goals, actions, and strategies for preserving and restoring the Watershed's environmental features. The report is divided into Focus Areas, each with Actions and Strategies to provide concrete tasks and ways to accomplish those tasks. The coalition designated "Habitat", "Land Use", "Protected Open Space", and "Water Quality" as its Focus Areas, each supported by about 6 to 11 Actions with a handful of Strategies per Action. As its Focus Areas suggest, the coalition devised the following priorities: 1) Improving and maintaining a biodiverse, cohesive Watershed habitat, 2) Promoting and maintaining land uses which benefit the River, 3) Protect existing and potential open land, and 4) improve the Watershed's water quality.

2008 Coppermine Brook Drainage Evaluation Executive Summary, Milone & MacBroom

This 2008 report, authored by consulting firm, Milone & MacBroom, describes the characteristics of Coppermine Brook and its watershed, in concert with recommendations to reduce flooding problems along the channel corridor. The study's results include a recognition of changing rainfall patterns and their relationship to increasing streamflow, an assertion that then-current FEMA maps were out-of-date and posed issues for properties ineligible for federal flood insurance, and the finding that some bridges along the Coppermine Brook channel are susceptible to overtopping during storm events due to their insufficient size. The recommendations for these challenges include encouraging the construction of watershed storage areas in order to reduce downstream flow rates and steps to manage flooding at three specific locations involving various dike, bridge, and channel improvements.

2008 Coppermine Brook Drainage Evaluation full report

This document shares the same basic information as the Executive Summary detailed above. It offers the background, results, conclusions, and recommendations of the prior document in greater detail. It is organized into an analysis of existing conditions, hydrology, hydraulics, watershed management and land use regulations, and finally conclusions and recommendations. Several visual aids including maps and tables are present.

2015 Pequabuck River Flooding Study & Flood Mitigation Plan (SEP 2015 Final), AECOM (with Appendices)

This 2015 study by consulting firm, AECOM, aimed to evaluate existing flooding conditions in order to recommend steps to reduce flooding and its consequences within the Pequabuck River watershed. A fundamental objective was to update the then-outdated FEMA FIS and FIRMs for the Pequabuck River. The study also developed new discharges for an array of recurrence interval events such as 2- to 500-year floods and includes a major revision to the Pequabuck River's FEMA hydraulic model which better calculates flood elevations and can map 100- and 500-year floodplains. Finally, the study provided several options for the towns of Plainville, Bristol, and Plymouth to reduce flooding in their communities. Examples include the removal of flood-prone structures such as houses, construction of floodwalls, and dredging areas of the Pequabuck River.

2016 Integrated Water Quality Report, CT DEEP

This 2016 report, published by CT DEEP, reviews the quality of Connecticut's waters in compliance with Sections 305(b) and 303(d) of the federal Clean Water Act (CWA). Table 2-3 lists the assessment results for rivers and streams, including those in the Pequabuck River Watershed such as Coppermine Brook. The assessment provides each waterbody segment with a status for its level of support for aquatic life and recreation. Table 3-4 lists the EPA Category 5 Connecticut Impaired Waters, including details such as the impaired designated use and its cause. For example, the Pequabuck River is featured in this list with impairments to faunal habitat for causes that are yet unknown. Table 3-5 lists waterbodies with adopted TMDLs. Poland River is listed as impaired for recreation because of elevated *E. coli* levels. Table 3-7 lists non-pollutant impairments, such as faunal habitat caused by flow alterations surrounding Coppermine Brook.

CT DEEP Water Quality and Stormwater Fact Sheets

These fact sheets summarize water quality and/or stormwater information for all towns in Connecticut, and include the monitoring data submitted by each town that falls under the current Small Municipal Separate Storm Sewer System (MS4) General Permit. Impervious cover, pollution reduction strategies or Total Maximum Daily Loads (TMDLs), and stormwater quality monitoring results for the 5 parameters reported under the current MS4 General Permit- bacteria, total suspended solids, total nitrogen, total phosphorus, and turbidity- are analyzed graphically and verbally. Water quality data and impervious cover are also displayed cartographically in the “Town Maps” section.

The amount of data analyzed differed by municipality based on participation time in the MS4 General Permit program. Samples are obtained from six locations from different areas around the municipality. Of the seven towns within the Pequabuck watershed, all but one (Harwinton) are under the current MS4 General Permit (effective July 1, 2017).

Total Maximum Daily Load (TMDL) Summary

A Total Maximum Daily Load (TMDL) analysis was conducted for the Pequabuck River on a sub-regional basis. This TMDL included those catchments associated with this Watershed Based Plan (WBP) including the Pequabuck River, Coppermine Brook, and Poland River. All of these waterbodies were listed on the *2008 List of Connecticut Water bodies Not Meeting Water Quality Standards* (CTDEEP, 2008). As such, under section 303(d) of the Clean Water Act (CWA), a TMDL was developed. This document serves to compute the maximum loading these waterbodies can receive while not exceeding water quality criteria.

The Pequabuck, Coppermine and Poland were all listed as impaired for Recreation due to excessive *Escherichia coli* loading with a priority of ‘High.’ Potential source areas of bacteria for each waterbody were listed as *Unspecified Urban Stormwater, Source Unknown* for non-point sources and *Regulated stormwater runoff, illicit connections/Hook ups to storm sewers* for point sources.

Water quality standards for the waterbodies of analysis show a criteria for *E. coli* to be a single sample maximum to not exceed 576/100 mL with a geometric mean less than 126/100 mL. The TMDL analysis was conducted by sampling various stations along the target waterbodies. One segment was sampled at Coppermine Brook, two at Poland River and six at the Pequabuck River. Mean percent reductions in *e. coli* ranged from 14% at CT4313-00_01 and CT4313-00_02 to 88% at CT4314-00_01. Waste Load Allocation reductions ranged from 17% at CT4313-00_01 and CT4313-00 to 89% at CT4314-00_01.

2.2 Historic Water Quality

A number of studies conducted over the years of the Pequabuck River watershed involved actual water quality sampling. The majority of these sampling efforts focused on the main stem of the Pequabuck River and the lower portions of the river's major tributaries. This includes the MS4 stormwater monitoring data compiled by the City of Bristol (2012 through 2015). It should be noted though that this sampling was limited to one sampling event per year, with the data collected in November or December. This section summarizes some key water quality parameters as based on these available data, which span the period of 1998 through 2015. Please note that these data are not part of a continuous monitoring program. Not all stations were sampled on any given date or within any given year. Although the data may be considered limited in terms of consistency, these events and the resulting data do provide a good assessment of the river system's overall water quality. A table (Table A1) and map of the station locations is provided in Appendix A.

Climate

Annual climate conditions for the period of record (1998 – 2016) are presented in Figure 2.1 using the NOAA NCDC station USC00060973 at Burlington, CT. Only years with complete data records were analyzed. This figure presents the average daily minimum temperature, average daily maximum temperature, average daily temperature, calculated on an annual basis, in addition to total annual precipitation. The average daily temperature conditions were quite similar from year to year, whereas total annual precipitation varied considerably. The average annual daily temperature for the period ranged from 48.0 °F to 52.9 °F. The average annual daily minimum temperature ranged from 37.8 °F to 42.3 °F while the average annual daily maximum temperature ranged from 57.6 °F to 63.4 °F. Total annual precipitation ranged from 35.97 inches in 2016 to 79.01 inches in 2011. The average annual precipitation for all years was 54.43 inches, meaning 2016 was over 18 inches drier than normal and 2011 was 24.58 inches wetter than normal.

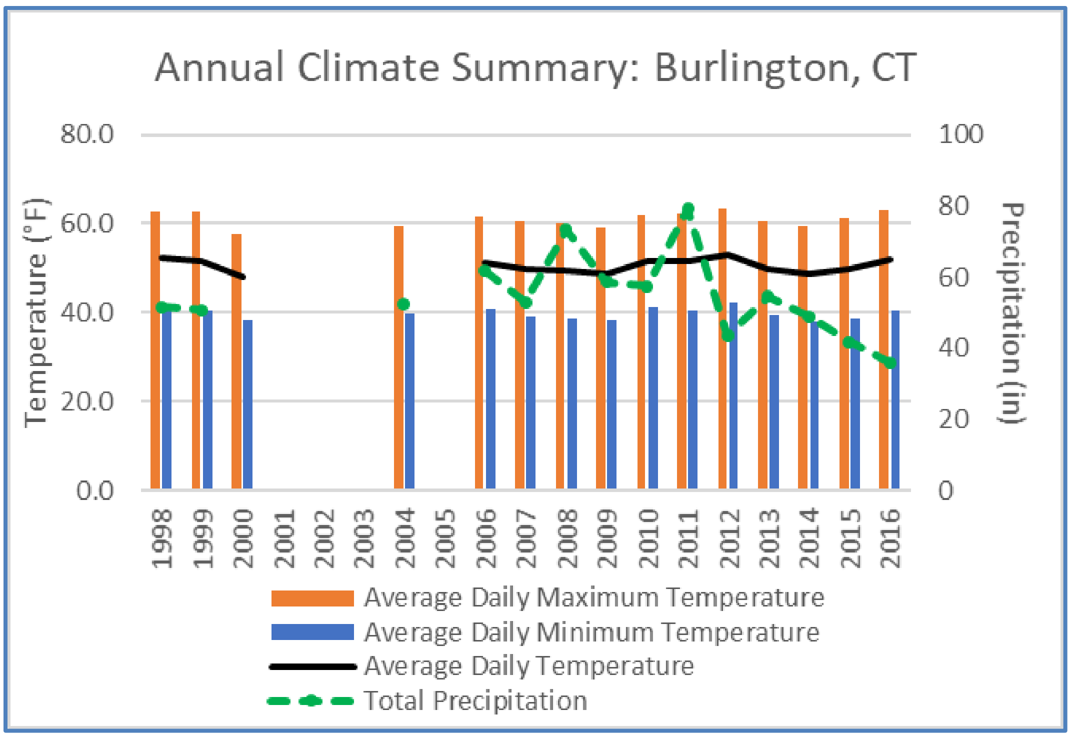

Figure 2.1: Annual Climate Summary for Burlington, CT

Total Phosphorus

Phosphorus is one of the three main nutrients of life, along with nitrogen and carbon, and is the primary limiting nutrient in most freshwater ecosystems. Total phosphorus is a measure of all forms of phosphorus, both organic and inorganic. Total phosphorus concentrations are naturally low in most rivers and streams, but high in rivers and streams located in agricultural and urban areas, or that receive wastewater discharges. High phosphorus levels in streams increase the growth of plants and algae, reducing the quality of the habitat and causing low oxygen levels at night when the plants and algae are respiring but not photosynthesizing.

Figure 2.2 presents average annual total phosphorus measurements at each monitoring location. The sites are ordered from upstream to downstream, with sites located on tributaries noted on the graphs. Figure 2.3 presents all total phosphorus data, including outliers, as box plots, also ordered from upstream to downstream. The box plot figure shows the median concentratons of phosphorus at each site and the relative amount of variability (illustrated as the line extending up and down from the box). Station locations are identifed on the Sampling Station Map provided in Appendix A.

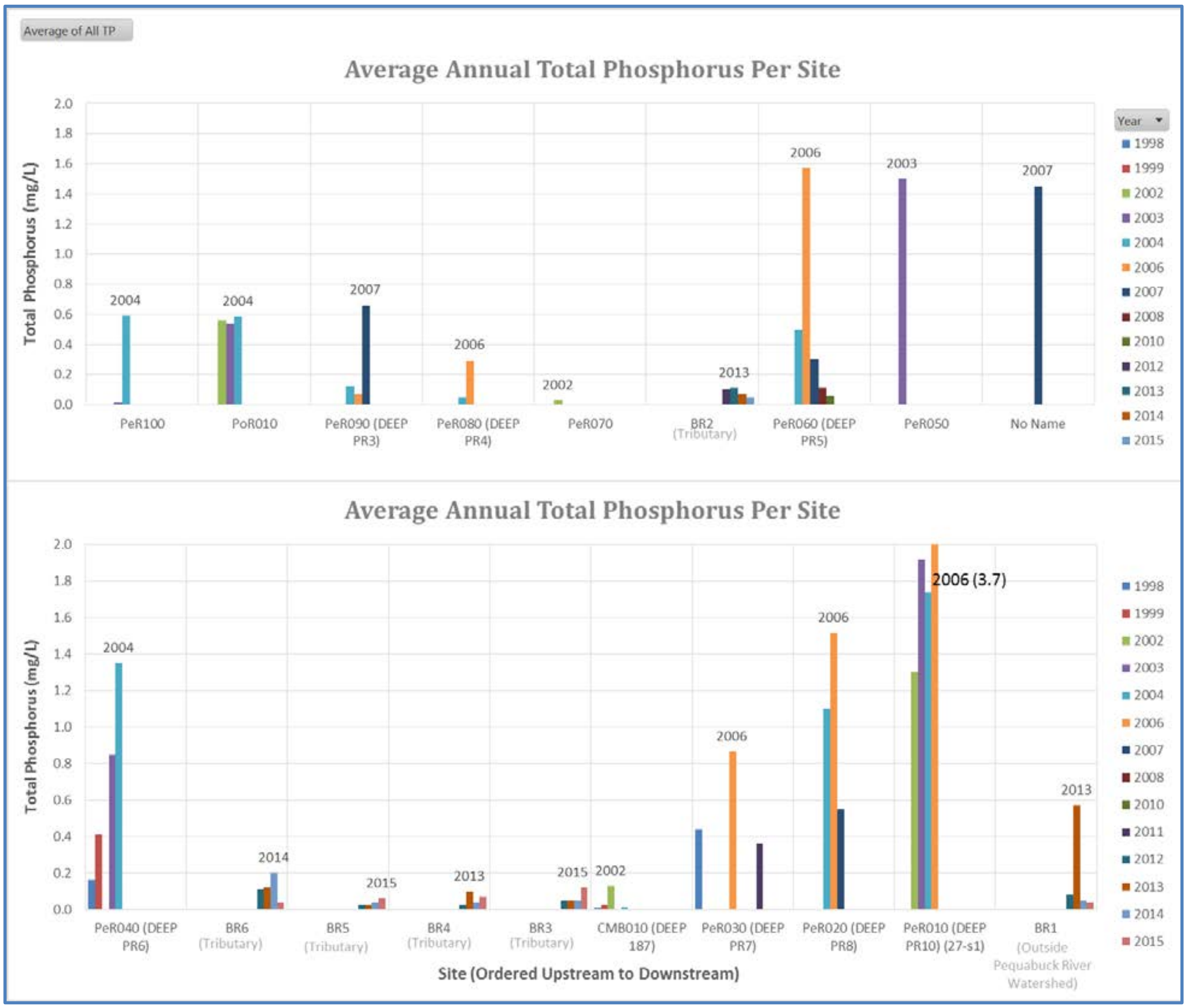

Figure 2.2: Mean TP per site (1998-2015). Data read left to right correlate with upstream through downstream

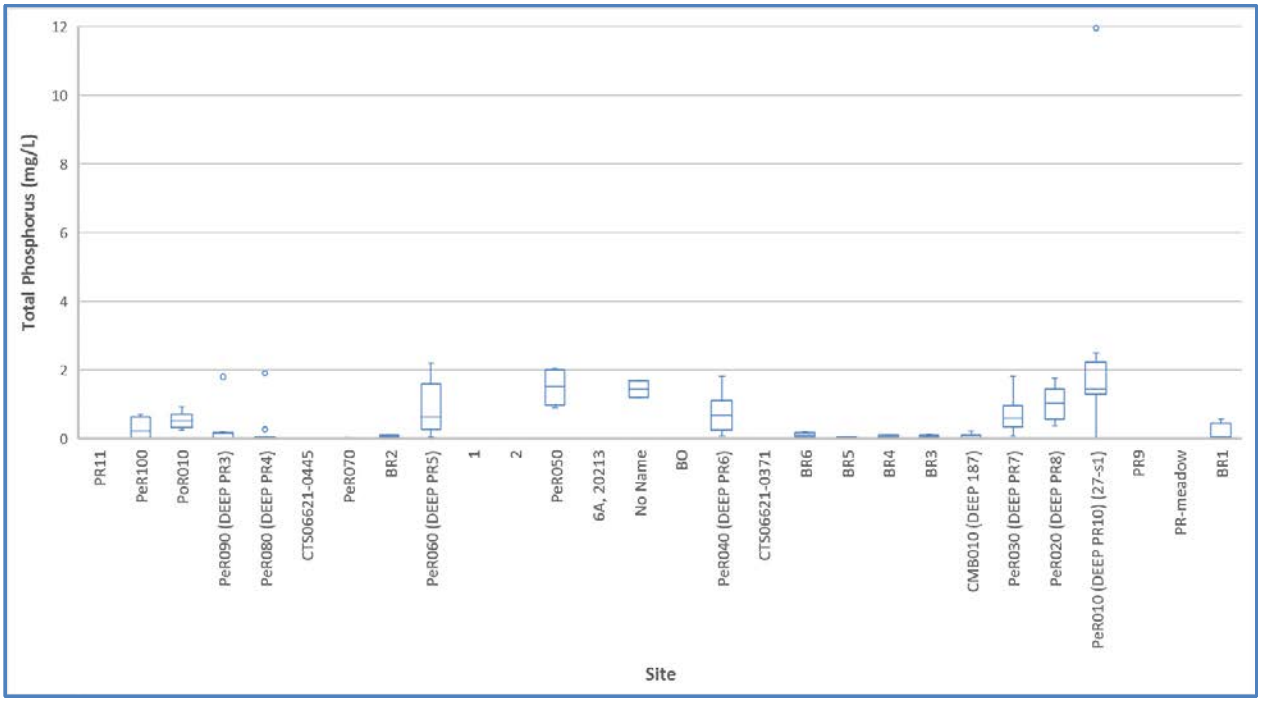

Figure 2.3: TP per site (1998-2015). Data read left to right correlate with upstream through downstream

Escherichia coli (E. coli)

E. coli is a type of fecal coliform bacteria that comes from human and animal waste. EPA recommends *E. coli* as the best indicator of health risk from water contact in recreational waters. Disease-causing bacteria, viruses and protozoans may be present in water that has elevated levels of *E. coli*. Certain strains of *E. coli*, such as *E. coli O157:H7*, produce powerful toxins. The Connecticut water quality standard for *E. coli* bacteria in waters designated for “Recreation - All Other Uses” (which is separate and distinct from waters with a designated use of: “Recreation - Designated Swimming” or “Recreation - Non-Designated Swimming”) is that *E. coli* bacteria counts shall not exceed a single sample maximum of 576 CFU per 100 mL a geometric mean of 126 CFU per 100 mL (State of Connecticut, 2015).

Figure 2.4 presents average annual *E. coli* measurements at each monitoring location. The sites are ordered from upstream to downstream, with sites located on tributaries noted on the graphs. Figure 2.5 presents all *E. coli* data, including outliers, as box plots, also ordered from upstream to downstream.

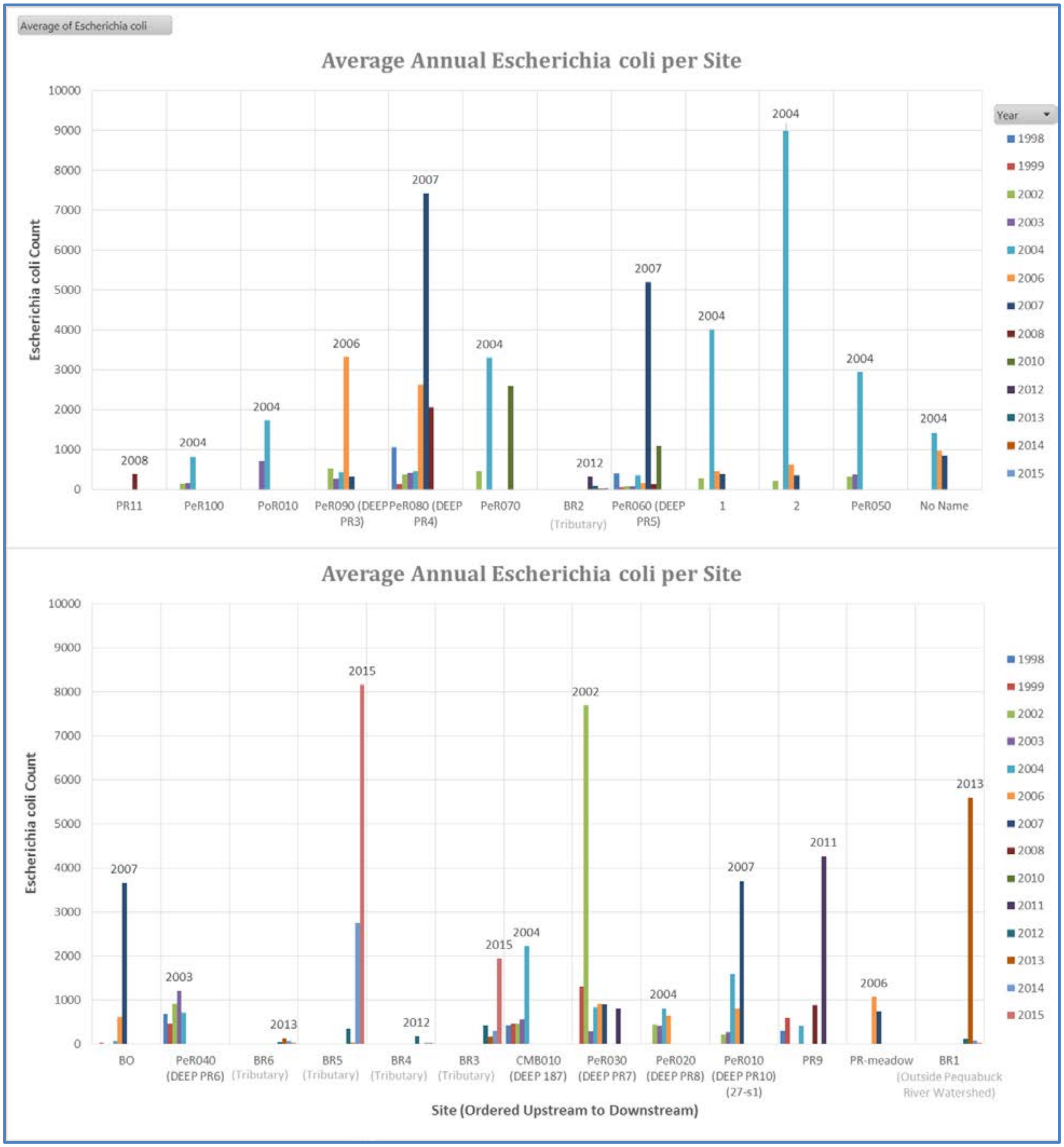

Figure 2.4: Mean annual E. coli per site (1998-2015). Data read left to right correlate with upstream through downstream

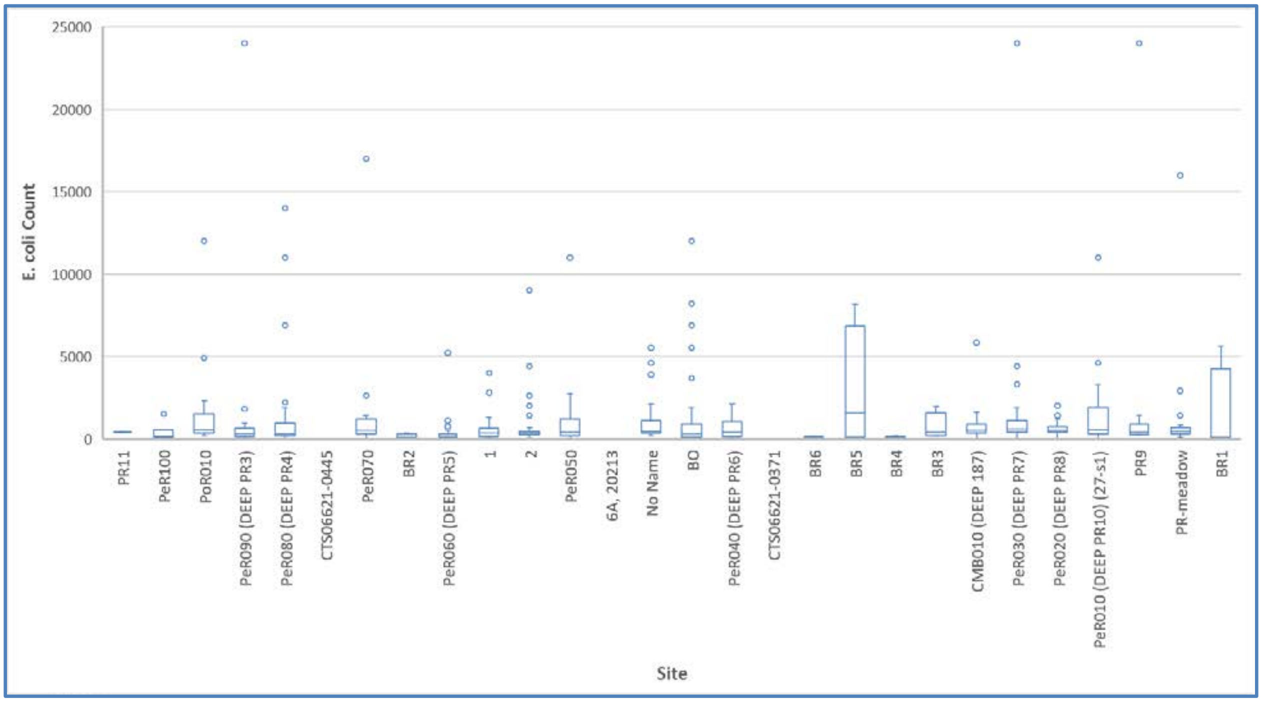

Figure 2.5: Annual E. coli per site (1998-2015). Data read left to right correlate with upstream through downstream

Turbidity

Turbidity is a measure of the cloudiness of a river or stream. Turbidity in water is caused by suspended matter, such as silt and clay, finely divided organic and inorganic matter, soluble organic color compounds, and plankton and other microscopic organisms. Turbidity measures the optical scattering and absorption of light by the presence of these factors in water. Higher turbidity values are indicative of the presence of one or more of the turbidity-causing factors is present in a sample, but cannot indicate which factor or factors is at fault.

Figure 2.6, presents average annual turbidity measurements at each monitoring location. The sites are ordered from upstream to downstream, with sites located on tributaries noted on the graphs. Figure 2.7 presents all turbidity data, including outliers, as box plots, also ordered from upstream to downstream.

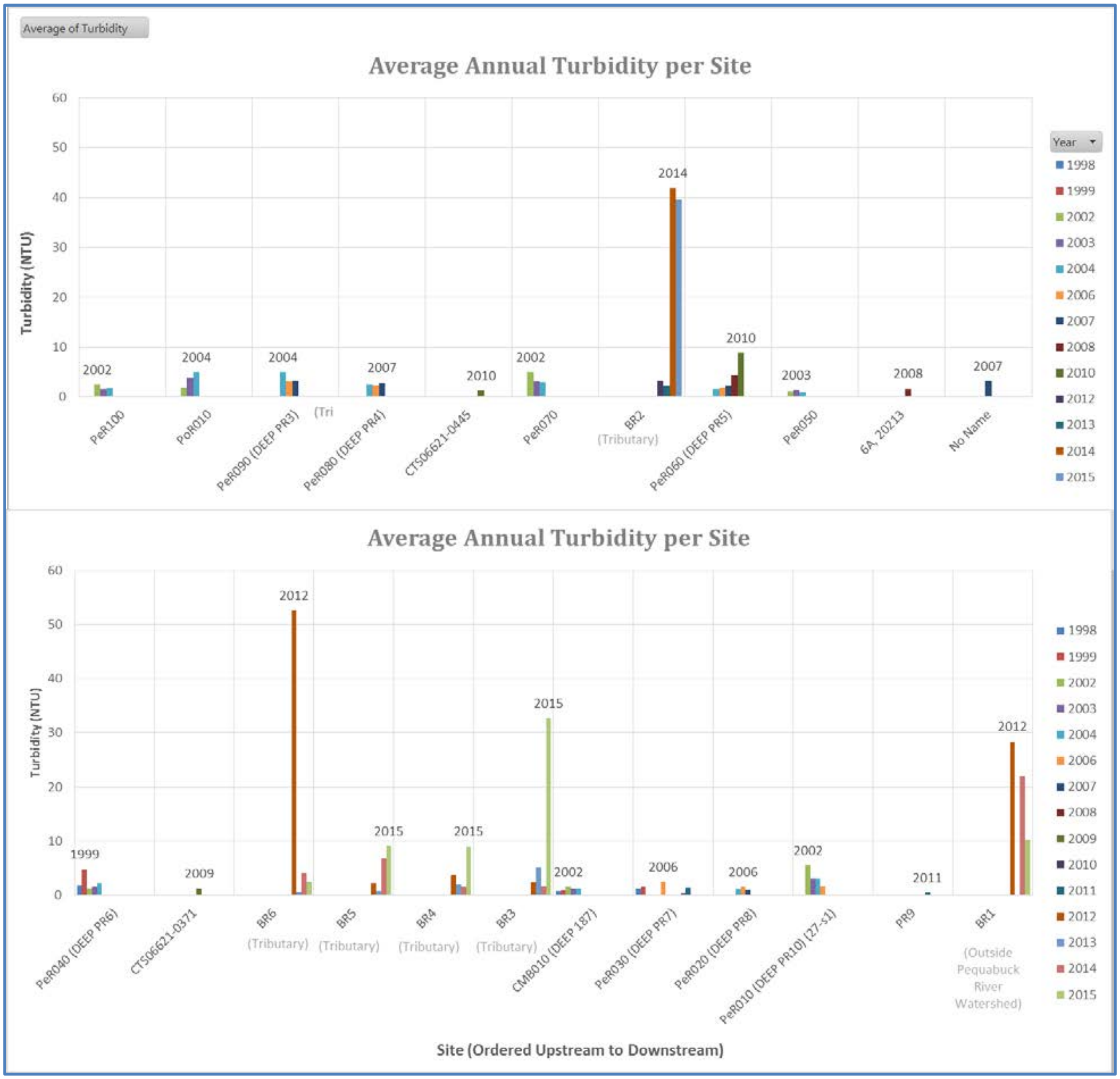

Figure 2.6: Mean annual Turbidity per site (1998-2015). Data read left to right correlate with upstream through downstream

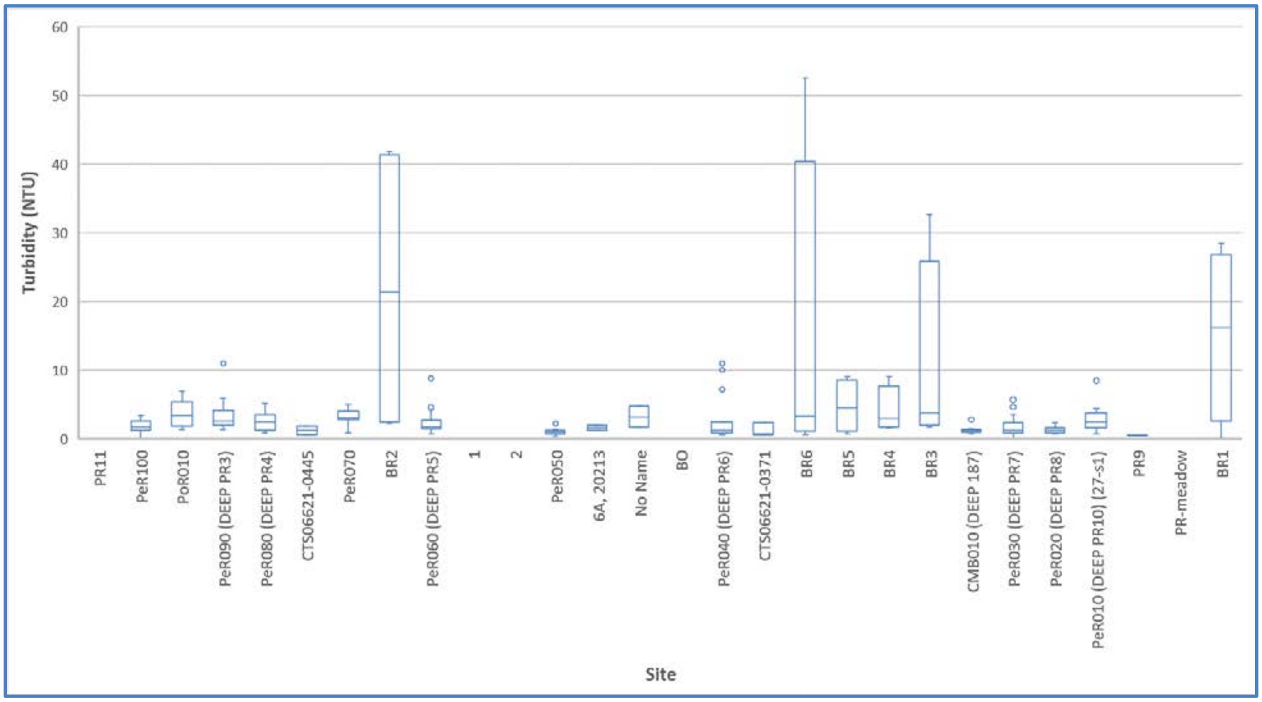

Figure 2.7: Annual Turbidity per site (1998-2015). Data read left to right correlate with upstream through downstream

Total Suspended Solids

Total suspended solids (TSS) is a measure of particles smaller than 2 microns suspended in the water column of a river or stream. Suspended matter may take form as silt, clay, finely divided organic and inorganic matter, plankton or other particulate matter. Waters with high TSS values may carry elevated concentrations of phosphorus as this nutrient is often tightly bound to soil particles.

Although TSS is often associated with stormwater runoff, the occurrence of TSS in a stream, river or lake is not only the result of material mobilized and transported by stormwater. As is often the case, storm related spikes in TSS occur as a result of the physical erosion of the stream bed and banks caused by elevated flows. In many cases the storm event increases in TSS resulting from stream bed and bank erosion can greatly exceed the increase in TSS attributable to runoff related transport of sediment. This is in part the reason why comprehensive stormwater management must encompass not only pollutant load reduction but actions that decrease the rate, flow and volume of runoff conveyed to streams and rivers.

Figure 2.8 presents average annual total suspended solids measurements at each monitoring location. The sites are ordered from upstream to downstream, with sites located on tributaries noted on the graphs. Figure 2.9 presents all total suspended solids data, including outliers, as box plots, also ordered from upstream to downstream.

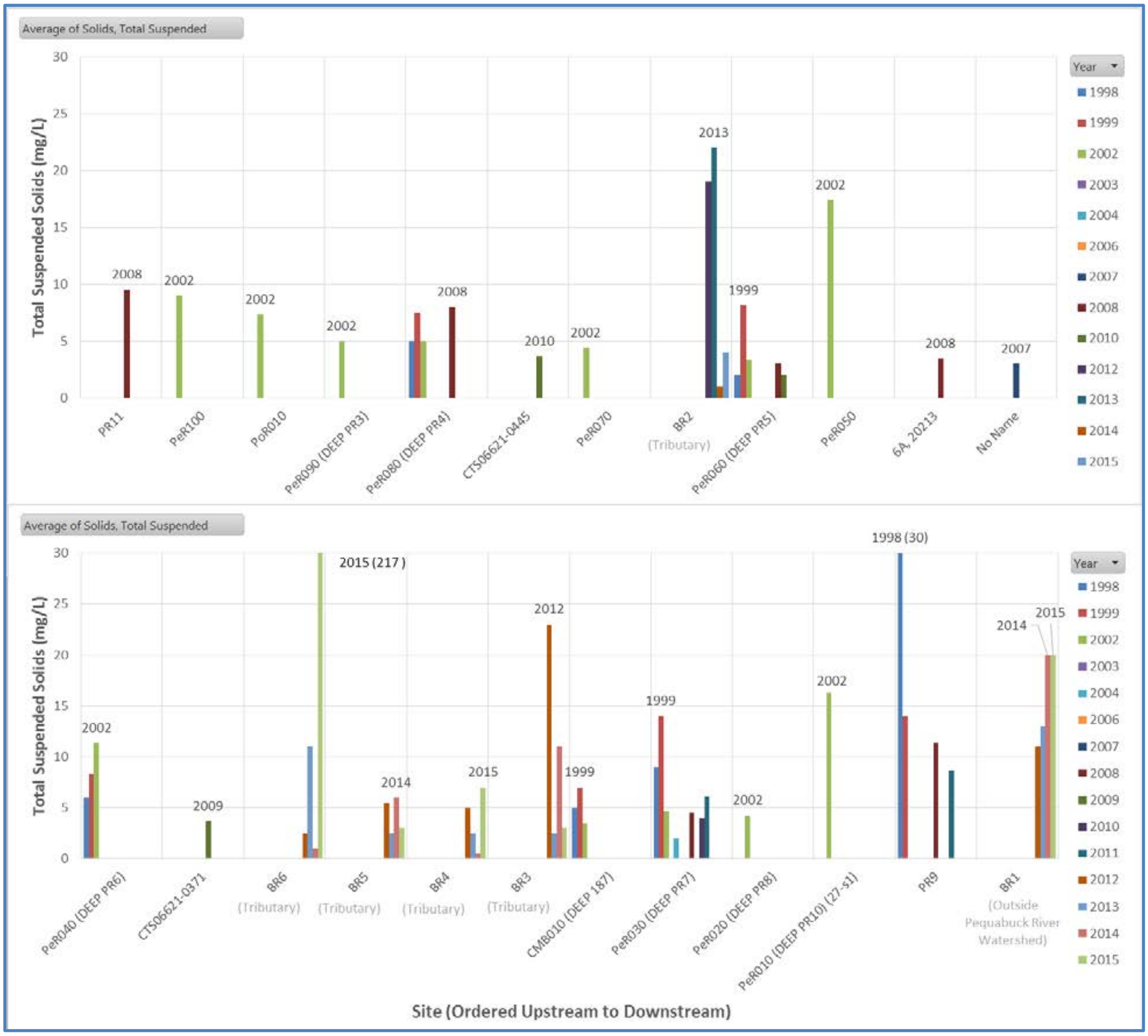

Figure 2.8: Mean annual TSS (1998-2015). Data read left to right correlate with upstream through downstream

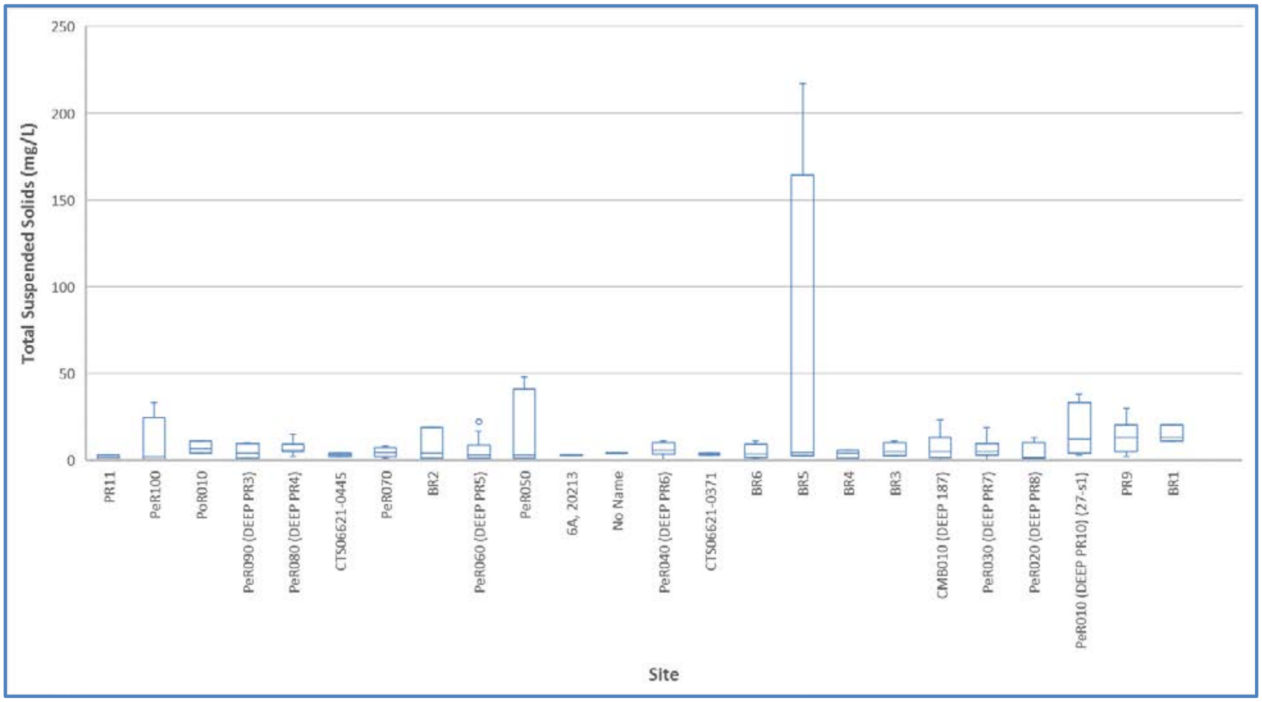

Figure 2.9: Annual TSS (1998-2015). Data read left to right correlate with upstream through downstream

2.3 Watershed Land Use

This section provides an analysis of land use by major drainage, subregional basin and local basin using the National Land Cover Database Land Use and Land Cover data (2011). The vast majority of the roadways and developments within the watershed, from urban to rural, consist of paved roads with curbs and gutters (storm drains) with no stormwater detention and no stormwater treatment. Rooftop drains are discharged to lawns and driveways. There is no detention, retention or treatment built into the system other than online (in stream) reservoirs. This leads to rapid peak storm hydrographs, higher peak storm velocities and flooding, along with the attendant transport of pollutants, including sediments, nutrients and pathogens (bacteria).

Methodology

Boundaries of local basins, subregional basins, and the combined subregional basins which make up the greater Pequabuck watershed were provided through the CT DEEP data repository as three distinct shapefiles (polygons). These data delineated the edges of three size-dependent levels of watersheds. The National Land Cover Database 2011, obtained from the Multi-Resolution Characteristics Consortium, represented land use/land cover in the form of a raster. Each pixel, or cell, was a square 100 feet in length.

The identification of subregional and local basins are presented in Figure 2.10 for reference in the following sections.

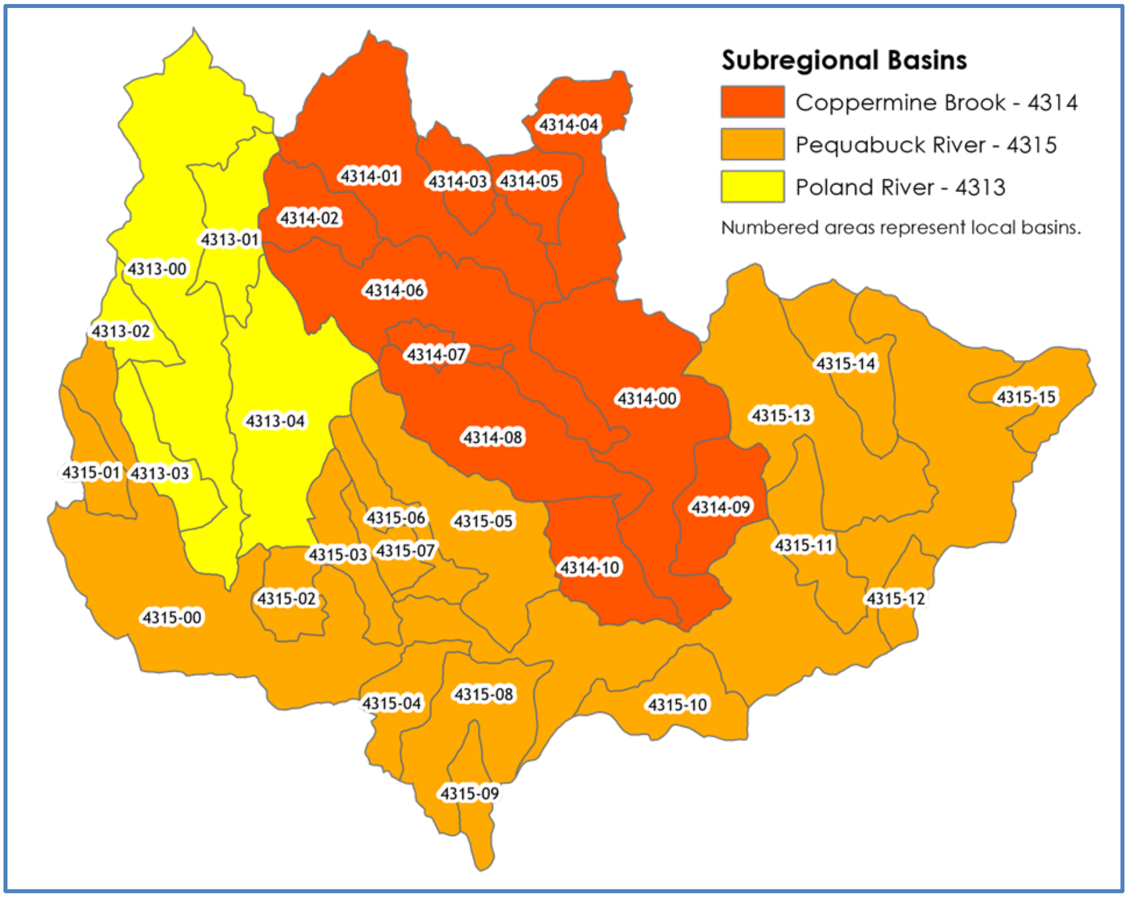

Figure 2.10: Location of Subregional and Local Basins within the Pequabuck River Watershed

Pequabuck Watershed (Greater Pequabuck)

Land use in the Pequabuck Watershed is evenly split between developed areas (44%) and deciduous forest (43%) (Table 2.1 and Figure 2.11). Low and medium intensity development add up to 28% of the watershed's total built-up areas while developed open space contributes 14% and high intensity development, 2%. Woody and emergent herbaceous wetlands combined account for 5% of the land cover, as does pasture. Open water, barren land, evergreen forest, mixed forest, scrub, grassland, and cultivated crops claim the remaining 5% of the land uses. Full classification description for each land use category can be found in Appendix B, Table B1.

Table 2.1 – Land Use Breakdown of the Pequabuck River Watershed		
	Acres	**Percent**
Open Water	488.4	1%
Developed, Open Space	5,149.0	14%
Developed, Low Intensity	6106.0	17%
Developed, Medium Intensity	3,918.5	11%
Developed, High Intensity	612.5	2%
Barren Land	96.5	0%
Deciduous Forest	15,735.7	43%
Evergreen Forest	694.6	2%
Mixed Forest	294.5	1%
Shrub/Scrub	330.9	1%
Grassland/Herbaceous	8.7	0%
Pasture/Hay	1,819.7	5%
Cultivated Crops	84.7	0%
Woody Wetlands	1,442.5	4%
Emergent Herbaceous Wetlands	192.8	1%
Total	*36,975*	*~100%*

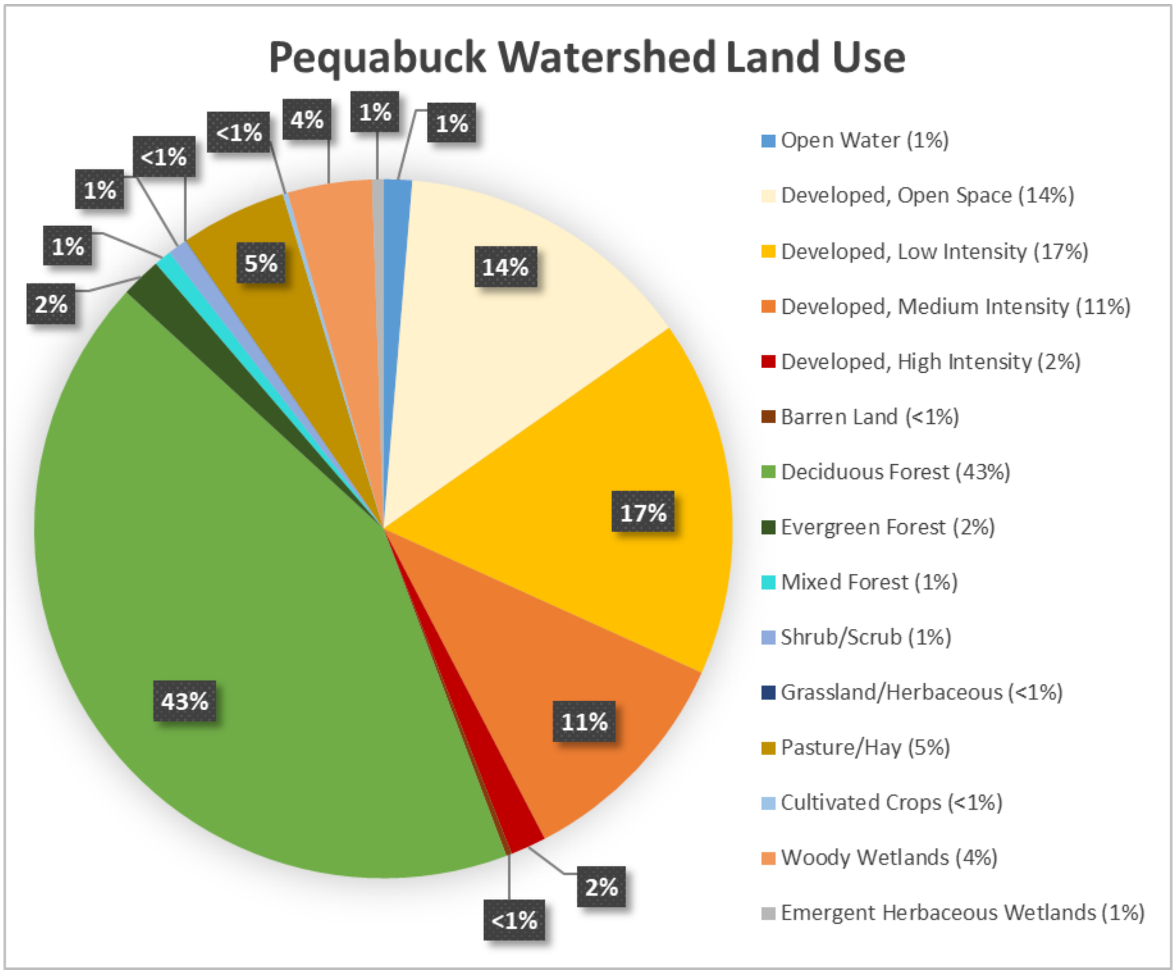

Figure 2.11 –Land Use Categories within Pequabuck River Watershed

Poland River Subregional Basin

The Poland River subregional basin is highly vegetated, with forests, wetlands, grassland, and scrub comprising 80% of the 6482 total acres (Table 2.2). Of these, deciduous forest is the highest contributor (70%), with woody wetlands, emergent herbaceous wetlands, and evergreen forest composing most of the remaining forested areas. Development accounts for 11% of the watershed with the majority (7%) functioning as developed open space. Pasture and open water each contribute 4% and 5%, respectively, while 9.3 acres of cultivated crops are also present.

Table 2.2: –Poland River Subregional Basin – Land Use

	Acres	Percent
Open Water	318.5	5%
Developed, Open Space	426.2	7%
Developed, Low Intensity	220.2	3%
Developed, Medium Intensity	57.0	1%
Developed, High Intensity	4.6	0%
Deciduous Forest	4,546.3	70%
Evergreen Forest	222.8	3%
Mixed Forest	71.2	1%
Shrub/Scrub	49.1	1%
Grassland/Herbaceous	3.5	0%
Pasture/Hay	262.6	4%
Cultivated Crops	9.3	0%
Woody Wetlands	254.4	4%
Emergent Herbaceous Wetlands	36.3	1%
Total	*6,482*	*~100%*

Pequabuck River Subregional Basin

The Pequabuck River subregional watershed is more urbanized than either of the Coppermine Brook or Poland River subregional watersheds. As illustrated in Table 2.3, 57%, its land use is dominated by development with an emphasis on low and medium intensity areas (22% and 15%, respectively). Deciduous forests cover just over a quarter of the watershed at 28%. Woody and emergent herbaceous wetlands combined account for 5% of the land cover, as does pasture. Open water, barren land, evergreen forest, mixed forest, scrub, grassland, and cultivated crops claim the remaining 4% or 886 acres.

Table 2.3 : Pequabuck River Subregional Basin – Land Use

	Acres	**Percent**
Open Water	147.1	1%
Developed, Open Space	3,226.3	17%
Developed, Low Intensity	4,071.8	22%
Developed, Medium Intensity	2,844.1	15%
Developed, High Intensity	496.8	3%
Barren Land	87.4	0%
Deciduous Forest	5,248.9	28%
Evergreen Forest	324.0	2%
Mixed Forest	92.0	0%
Shrub/Scrub	163.9	1%
Grassland/Herbaceous	5.1	0%
Pasture/Hay	1,019.6	5%
Cultivated Crops	66.5	0%
Woody Wetlands	683.6	4%
Emergent Herbaceous Wetlands	99.1	1%
Total	*18,576*	*~100%*

Coppermine Brook Subregional Basin

The Coppermine Brook subregional watershed mostly consists of deciduous forest (50%) and developed areas (38%, combined) for a total of 88% (Table 2.4). Developed open space and low intensity development contribute 13% and 15%, respectively, while medium and high intensity development cover 9% and 1% of the basin, respectively. Pasture and woody wetlands are the next highest categories at 4% or about 500 acres each. Open water, barren land, evergreen and mixed forests, scrub, cropland, and emergent herbaceous wetlands account for the remaining 492 acres of the watershed.

Table 2.4: Coppermine Brook Subregional Basin – Land Use

	Acres	**Percent**
Open Water	21.0	0%
Developed, Open Space	1,495.1	13%
Developed, Low Intensity	1,824.5	15%
Developed, Medium Intensity	1,019.0	9%
Developed, High Intensity	114.8	1%
Barren Land	8.9	0%
Deciduous Forest	5,936.2	50%
Evergreen Forest	148.9	1%
Mixed Forest	130.9	1%
Shrub/Scrub	117.0	1%
Pasture/Hay	533.9	4%
Cultivated Crops	8.4	0%
Woody Wetlands	500.6	4%
Emergent Herbaceous Wetlands	57.2	0%
	11,916	*~100%*

The following figures (2.12, 2.13, & 2.14) present the land use data of Poland River subregional basin, Pequabuck River subregional basin, and Coppermine Brook subregional basin, respectively.

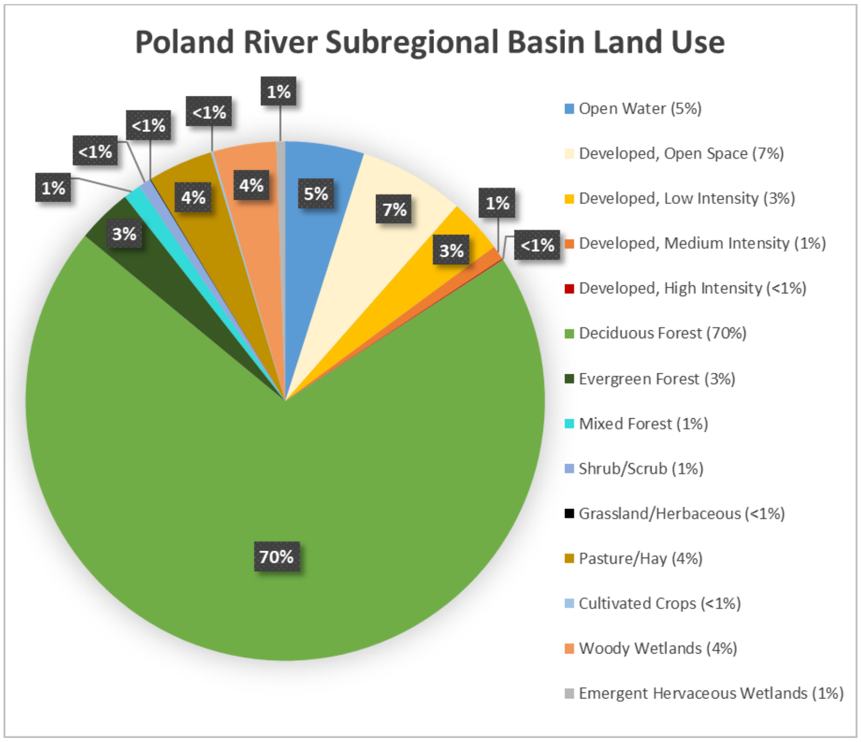

Figure 2.12: Poland River Subregional Basin – Land Use

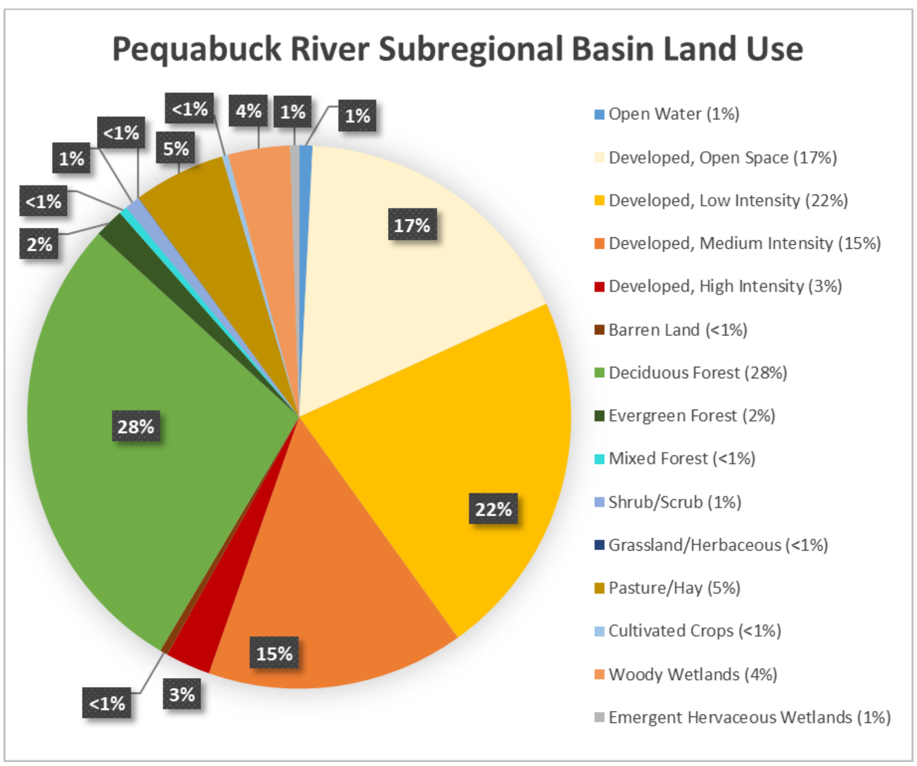

Figure 2.13: Pequabuck River Subregional Basin – Land Use

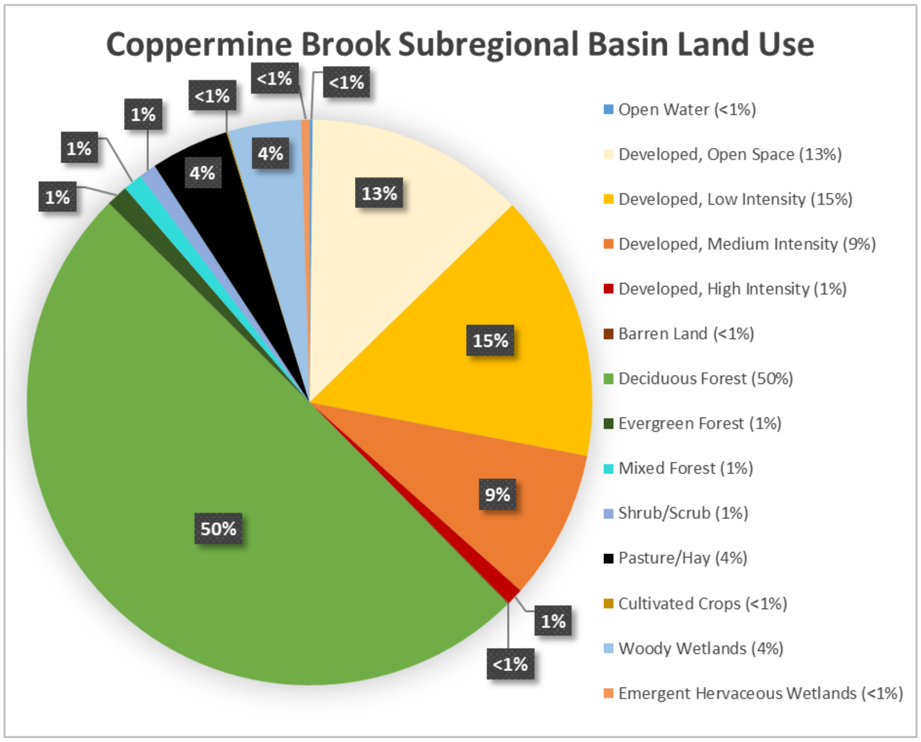

Figure 2.14: Coppermine Brook Subregional Basin – Land Use

Local Basins

Land use within the individual local basins is presented in Appendix B. Local Basin categories are hereby presented in figures 2.15 and 2.16.

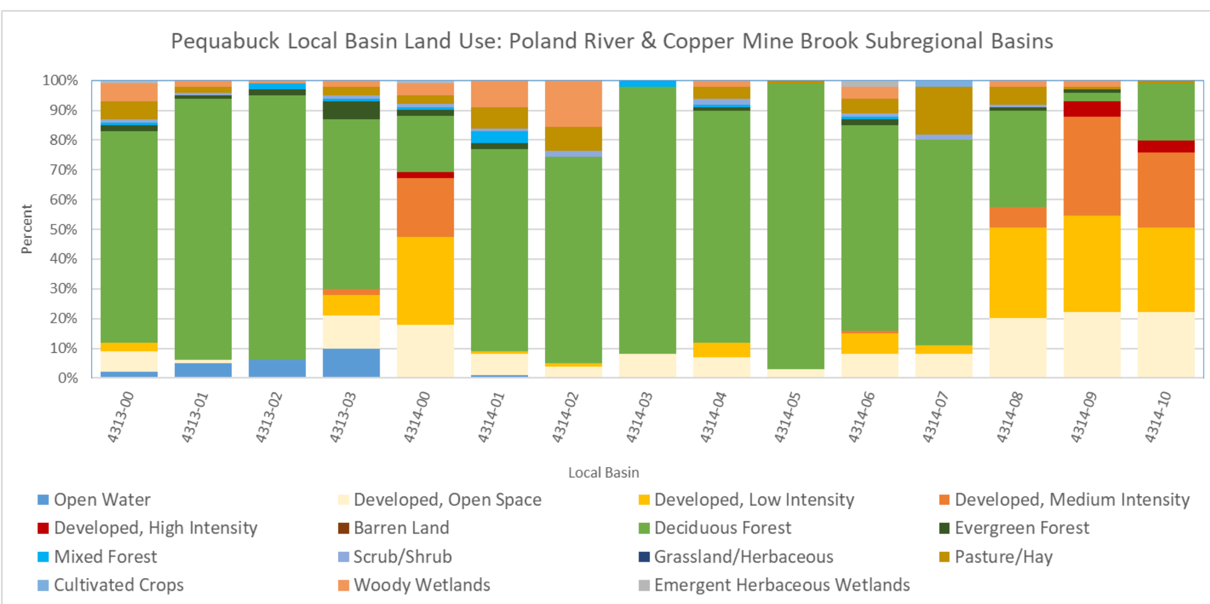

Figure 2.15: Poland River and Coppermine Brook Local Basins – Land Use

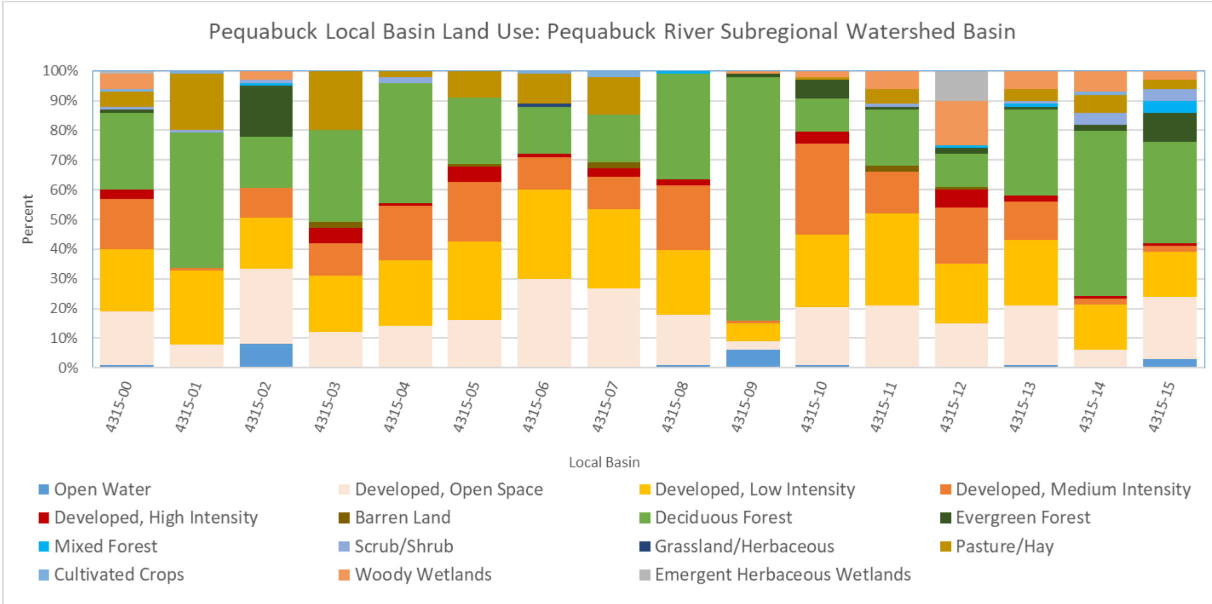

Figure 2.16: Pequabuck River Local Basins – Land Use

2.4 Watershed Investigation – Visual Field Assessments

Within this section of the report, the field assessment information gathered for the Pequabuck River Watershed is presented. The underlying objective of the field assessments was to further identify and document causes and sources of non-point source (NPS) pollution related water quality impairments.

Methodology

Visual field assessments were conducted in November and December 2016. This essentially entailed driving nearly every road within the Pequabuck River watershed, observing and recording (and in some cases photo-documenting) land use conditions, identifying potential NPS problem areas, and conducting visual stream assessments at a number of points along the mainstems of the Pequabuck River, Poland River and Coppermine Brook, as well as their major and minor tributaries. Conditions were documented in field notes, visual assessment forms (for streams) and photographs. (See project Quality Assurance Project Plan (QAPP) for further detail.) Additional watershed investigations took place during the spring of 2017.

As a result of this effort, approximately 75% of the watershed was inspected as part of our direct visual assessment effort. We were able, in turn, to utilize the field reconnaissance information in combination with information obtained through the available data sources (as summarized, mapped and illustrated in Section 3 of this report). Urbanized areas were also verified by means of our review of recent aerial photographs of the study area. A total of 48 stations were created and attributed with photographs, representative conditions, and stream assessments. Of this total, 14 stream assessments were conducted along tributaries and streams, including impaired reaches such as the Pequabuck River, within the watershed. Stream visual assessments were conducted following the Stream Visual Assessment Protocol (NRCS 1998 & 2009), as identified in the project QAPP. A map of the assessed locations is provided in Appendix A.

Results

Table 2.5 presents a summary of field notes from the visual assessments. A map of the site locations is provided in Appendix A. Stream assessment scores are discussed later. Site photographs are presented in Appendix C.

Table 2.5 – Field Assessment Notes Sorted by Local Basin

Local Basin	Subregional Basin	Station	Field Notes
4313-00	Poland River	PQ001	Stream assessment, Upper Poland River
4313-00	Poland River	PQ002	Stream assessment, Poland River on Route 72
4313-00	Poland River	PQ012	Small hobby farm (cattle or horse?); 120 High Street
4313-04	Poland River	PQ023	Pinnacle Road; very suburban development – green lawns, sidewalk, grass strip between sidewalk and road, curb & gutter – increase size of grassed area between sidewalk and road, redirect flow and add raingarden
4313-04	Poland River	PQ024	Ravine where stormwater is discharged on Hopmeadow Road; no treatment taking place; ephemeral stream, large concrete outlet structure, some erosion
4314-00	Coppermine Brook	PQ035	Stream assessment, Coppermine Brook on South Main Street
4314-01	Coppermine Brook	PQ005	Whigville Brook, tributary to Coppermine Brook; stream dry, unable to do assessment
4314-01	Coppermine Brook	PQ006	Whigville Brook, standing water but no flow
4314-01	Coppermine Brook	PQ007	Stream assessment, Whigville Brook
4314-01	Coppermine Brook	PQ029	Sessions Woods Conservation Education Center; lots of trails, some logging activity; run by CT DEEP, not open – good spot for outreach & education
4314-02	Coppermine Brook	PQ021	Small feedlot; angus beef, small number of cattle
4314-04	Coppermine Brook	PQ036	Wildcat Brook headwaters; deep ravine off Wildcat Road
4314-06	Coppermine Brook	PQ022	Stream assessment, Negro Hill Brook on West Chippens Hill Road; water present but not flowing, very close to headwaters
4314-06	Coppermine Brook	PQ025	Stone House Estates: future development, paved with curbed and drained roads; nice multi-tier treatment basin at end of cul de sac; no homes constructed yet
4314-06	Coppermine Brook	PQ026	Stormwater treatment at Nadeau Estates/Nicole Road
4314-06	Coppermine Brook	PQ027	Home under construction – bare soil, no straw, no silt fence; need improved E&S ordinances and/or enforcement
4314-06	Coppermine Brook	PQ028	Negro Hill Brook on East Chippens Hill Road, Burlington. State lands and extensive wetlands upstream; grate over twin culverts, downstream culverts are hanging above stream (no organism passage)
4314-06	Coppermine Brook	PQ030	Stream assessment, Negro Hill Brook on Route 69; sign in woods says “wild trout stream”
4314-08	Coppermine Brook	PQ034	Pokeville Brook on Nelson Farm Road; upstream is braided small stream, downstream is single channel; lots of cover (shrubs and trees) but no cobbles, riffles or pools
4315-00	Pequabuck River	PQ003	Stream assessment, headwaters of Pequabuck River; very small stream with little flow. Any impairment may be due to natural conditions
4315-00	Pequabuck River	PQ008	Stream assessment, small tributary to Pequabuck River at Napco Road. Upstream of road is ditched without tree cover; downstream first 100’ is straight w/angular cobble and not much habitat (root mats, undercut banks); below study reach

			stream starts to meander, bed still rock covered (round stone) but more undercut banks and large & small woody debris
4315-00	Pequabuck River	PQ009	Stream assessment, Pequabuck River at Napco Road, extensive wetland floodplain upstream and downstream, very little flow; herbaceous vegetation in stream
4315-00	Pequabuck River		Bernice Ave/Armbruster Road: lawns, wooded areas, curbs & gutters on main roads (Armbruster/Harwinton) but not side roads; roof gutters discharge to lawns or driveways with no collection/retention
4315-00	Pequabuck River	PQ010	Ravine of Holt Road; west side of Holt no evidence of stream, deep ravine on east side
4315-00	Pequabuck River	PQ011	Outlet of Zeiner Pond/Lake Winfield; perennial/ephemeral stream, flow dependent on dam release
4315-00	Pequabuck River	PQ013	Stream assessment, Pequabuck River off Emmett Street; across from 24 Emmett; east bank has nice wooded riparian zone, narrow on west bank due to apartment lawn
4315-00	Pequabuck River	PQ014	McDonald's parking lot; entire lot slopes down to exit land and storm drain; room for long rain garden/infiltration area
4315-00	Pequabuck River	PQ015	Plymouth Motor Lodge; could drain parking lot to an infiltration area between motel and McDonalds
4315-00	Pequabuck River	PQ016	Ditch behind houses off corner of Pine and Walnut Streets; enters small (approx. 12") culvert and doesn't reappear; leaves piled knee high in ditch near culvert mouth by adjacent landowner (= maintenance/clogging issues); perhaps stabilize ditch (although erosion isn't bad); educate homeowners about ditch/culvert maintenance & proper disposal of yard waste
4315-00	Pequabuck River	PQ016A	Fairgrounds on Washington St, Plymouth; erosion and manure management could be issues during fair season
4315-00	Pequabuck River	PQ017	Stream assessment, Pequabuck River; more like ditch than river, with old stone and concrete banks & abutments; old factories butt up against stream bank; site is parking lot for "Allread Products," a powdered metal factory
4315-00	Pequabuck River	PQ018	Pequabuck River behind Dollar General; no assessment, just photos; paved with water directed by curb to very small stone basin with plastic pipe draining to stream; no detention or water quality benefit; rock-lined ditch along edge of parking lot, not sure whether it is designed for treatment or not
4315-00	Pequabuck River	PQ020	West End Pizza; regrade lot to direct flow to bricked area, convert bricked area between sidewalk and road to rain garden
4315-00	Pequabuck River	PQ039	Pequabuck River in Rockwell Park downstream of confluence with Cuss Gutter – channel appears straight and not natural
4315-00	Pequabuck River	PQ043	Abandoned, partially remediated industrial area on Route 72: Old mill raceway behind buildings; good site for fish ladders
4315-00	Pequabuck River	PQ044	Abandoned, partially remediated industrial area on Route 72: defunct stream crossing - remove and rehabilitate stream, second road down to stream – bank needs restoration
4315-00	Pequabuck River	PQ045	Abandoned, partially remediated industrial area on Route 72: bank cut on opposite bank eroded into stream
4315-00	Pequabuck River	PQ046	Stream Assessment, Pequabuck River at entrance to "201 Route 72 – EconoTransmission;" Owner states A-1 Scrap Dealer just upstream frequently dumps unsaleable material into river and he cleans it out; some metal visible in stream below transmission driveway; large lot drains to stormwater drain and

			into river; river bank heavily armored. Improvements to stream: kill invasive knotweed, plant trees and shrubs.
4315-00	Pequabuck River	PQ048	Bridge over Pequabuck River on Broad Street in Bristol.
4315-01	Pequabuck River	PQ004	Small CAFO s: two small farms with cattle (encourage community off-site composting)
4315-02	Pequabuck River	PQ019	Unnamed tributary to Pequabuck River on Kearney Street; downstream no riparian zone, lawn on one side; narrow band of weeds on other side; upstream Japanese knotweed on one side, masonry wall on other; stream width about 3 ft, flowing and relatively deep
4315-03	Pequabuck River	PQ031	Bristol Wellness Center & adjacent apartments; opportunity to retrofit parking lots with stormwater management/treatment; flows to Cuss Ditch, a tributary to the Pequabuck River
4315-03	Pequabuck River		Cuss Ditch – small ephemeral stream, not high quality
4315-03	Pequabuck River	PQ037	Sand pit off Farrel Road; E&S basins in place; pit not active
4315-03	Pequabuck River	PQ038	Stream assessment, Cuss Gutter; deep ravine, drains under Farrel and railroad tracks; lovely looking stream (relatively wide riparian zone, tree cover); old stone culvert (1800s) w/drop under Farrel Road; lots of Japanese knotweed at gulley bottom around stream
4315-04	Pequabuck River	PQ040	Small intermittent stream at end of Miller Rd/St, Bristol
4315-04	Pequabuck River	PQ042	Dollar General – huge paved lot between Divinity and Route 72, empties into several storm drains; could convert unused lot along Divinity west of entrance into basin for treatment
4315-04	Pequabuck River	PQ047	Unnamed tributary to Pequabuck River behind building across from Muzzy Field on Route 72
4315-05	Pequabuck River	PQ032	School parking lot and driveways; opportunity for pavement islands or create treatment in lawn facing Route 69
4315-05	Pequabuck River	PQ033	Row crop field on Peacedale Street; dry, erodible soils being windblown, corn or other crop fully tilled under, leaving exposed soil. Good site for conservation tillage and ag BMPs
4315-05	Pequabuck River		Bridge Pond Brook near PQ033, small and not flowing
4315-06	Pequabuck River	PQ030A	Horse farm on corner of Marsh Road and Hill Street, Bristol. Paddocks, pastures; no sign of manure pile (encourage community off-site composting)
4315-06	Pequabuck River	PQ030B	Golf course across from Marsh Road
4315-08	Pequabuck River	PQ041	Parking lot at the corner of Route 69 and Upson Street, Bristol (former car dealership?); paved to sidewalk and sidewalk to road; slopes into road; whole block is entirely paved from South Street to Upson Street and down both streets; good example of problem in urbanized area (all impervious, no treatment); Houses on Route 69 & Upson Street have room for narrow rain gardens in grassed strip between sidewalk and road, need gutter diversion and treatment

Stream Assessments

Stream Visual Assessments were based on 14 factors used collectively to evaluate tributary conditions:

- Channel condition,
- Hydrologic alteration,
- Bank condition,
- Riparian area quantity,
- Riparian area quality,
- Canopy cover,
- Water appearance,
- Nutrient enrichment,
- Manure or human waste,
- Pools,
- Barriers to movement,
- Fish habitat complexity,
- Aquatic invertebrate habitat, and
- Riffle embeddedness.

Following the protocol of NRCS (1998 & 2009), each factor was assigned a score based on conditions observed. The average score of all the factors for that stream assessment point was then used to assess the overall condition of the tributary, ranging from “Severely Degraded” to “Excellent.” Fourteen (14) sites were assessed along the Pequabuck River, Coppermine Brook, Poland Brook and their tributaries, including Whigville Brook, an unnamed tributary, Negro Hill Brook and Cuss Gutter (see Appendix A). Of the 14 sites assessed, the overall scores ranged from 4.6 (Poor) to 8.9 (Good), with an average score of 7.3 (Good). In general, the tributaries in the watershed are in good condition, with good bed conditions, minimal impaction and excellent cover. The worst scores tended to be in urbanized areas along the Pequabuck River.

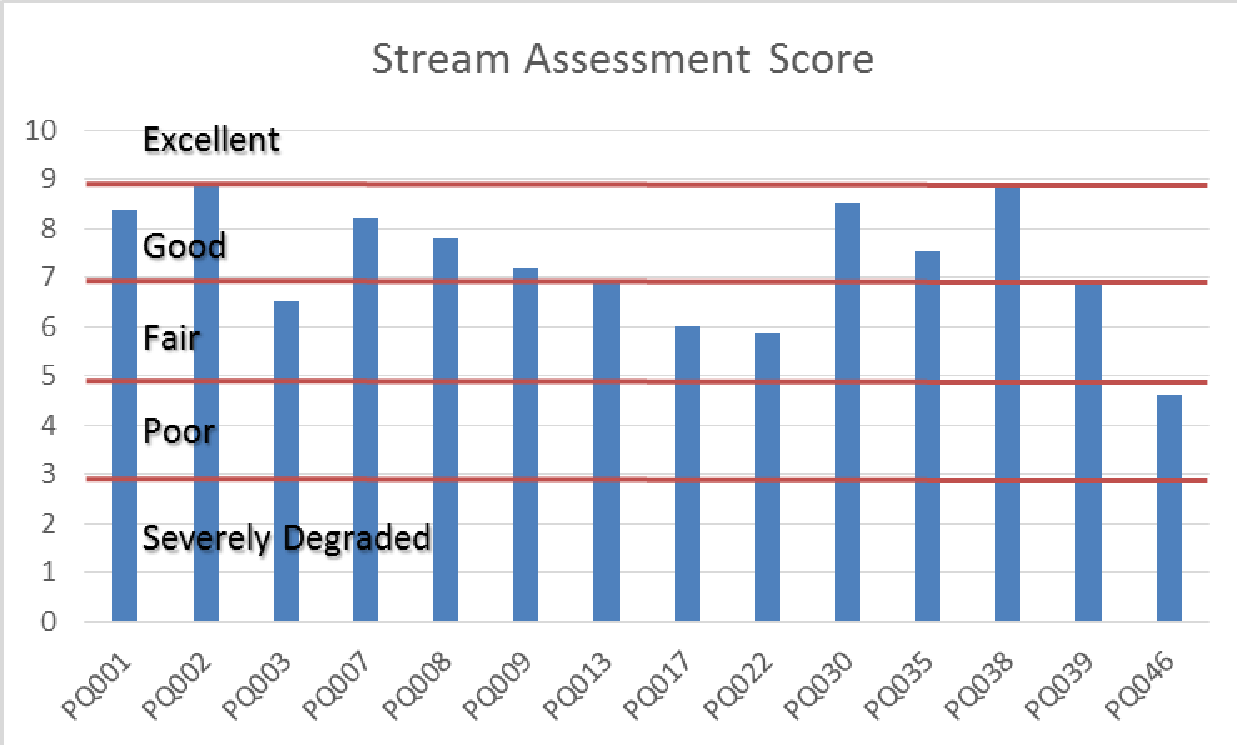

Figure 2.17: Pequabuck River – Visual Stream Assessment Scores

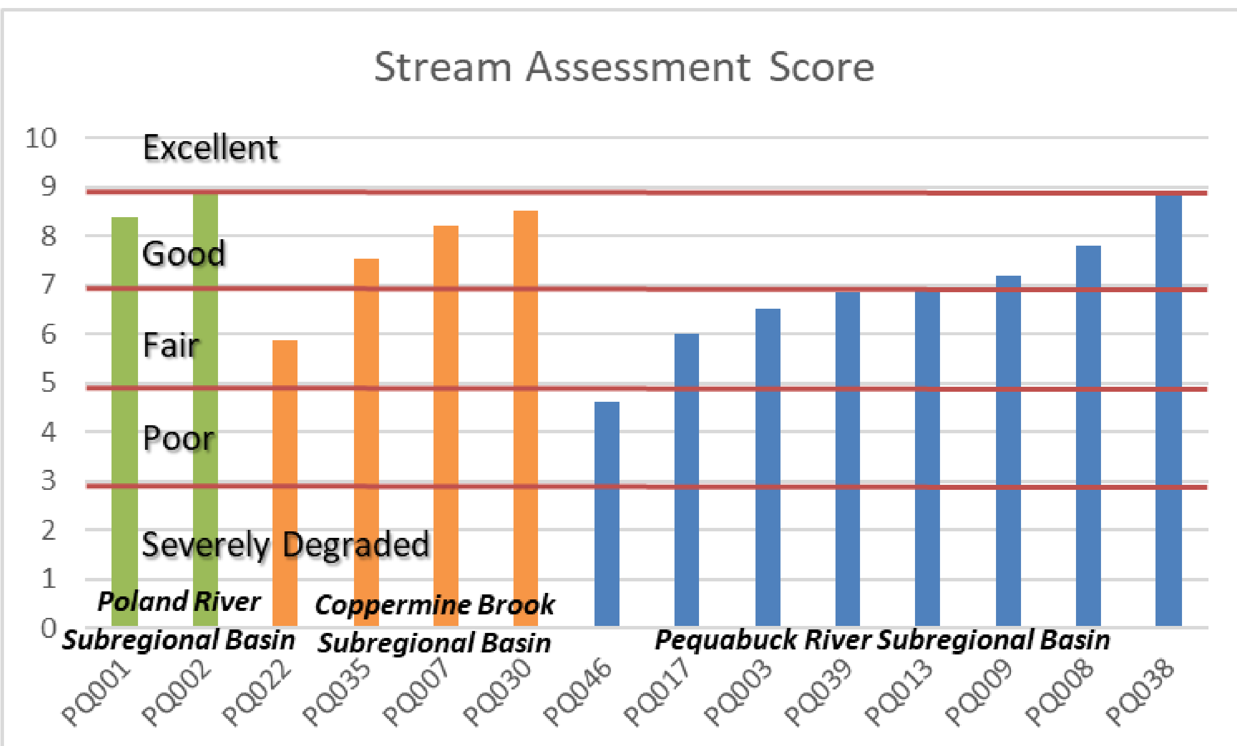

Figure 2.18: Pequabuck River – Visual Stream Assessment Scores Sorted by Subregional Basin

Based on the fourteen evaluation factors, the three waypoints with the lowest scores were PQ046 (score of 4.6), PQ022 (5.88), and PQ017 (6) and are classified as "Poor" or "Fair." Stations PQ003, PQ039, and PQ013 scored between 6.5-6.96 and are also considered "Fair." The remaining eight (8) stations scored above 7 and are classified as "Good", with none reaching the "Excellent" status. Refer to Appendix C for photographs of the stream assessment locations.

As seen in Figures 2.16 and 2.17 above, two (2) (PQ046, PQ017) of the three (3) lowest stream assessment sites are present in the Pequabuck River subwatershed (blue), with the third (PQ022) in the Coppermine Brook subwatershed (orange). The factors which most contributed to the 4.6 afforded to PQ046 were riparian area quantity, canopy cover, riparian area quality, and aquatic invertebrate habitat. The stream assessment was performed on the Pequabuck River at the entrance to the EconoTransmission at 201 Route 72 in Bristol. The heavy armor on the bank, lack of native vegetation and overgrowth of invasive Japanese knotweed (*Reynoutria japonica*) contributed to low riparian area quantity and quality scores. Relatedly, the very low canopy cover lowered its category rating. The low aquatic invertebrate habitat score was borne out of the few aquatic invertebrate habitat types present at the site. Examples of habitat types include but are not limited to logs/large wood, cobble within riffles, boulders within riffles, and leaf packs.

Poor fish habitat complexity, aquatic invertebrate habitat, and a lack of pools contributed to the low stream assessment score at PQ022. At this site at Negro Hill Brook on West Chippens Hill Road, very few fish habitat features were present. Examples include but are not limited to logs/large wood, small wood accumulations, deep and secondary pools, and overhanging vegetation. The low aquatic invertebrate habitat score was borne out of the few aquatic invertebrate habitat types present at the site. Owing to the stream's lack of flow, the site earned a very low score for category assessing pools.

While the Pequabuck River station PQ017 did not merit extremely low element scores like the previous two site assessments, its low score stems from several elements with scores hovering around 4-5. The lowest element scores are attributed to hydrologic alteration, riparian area quantity and quality, pools, and fish habitat complexity. The site scored slightly higher in the latter four categories than PQ046 and PQ022. Old concrete and stone abutments altered the natural flow regime and were responsible for lowering the hydrologic alteration category score.

Aerial Interpretations

The purpose of this section is to characterize the Pequabuck River Watershed based on aerial imagery. Figures 2.19-2.21 focus on assessing the land surrounding longer reaches of the Pequabuck River while Figures 2.22-2.29 showcase areas with extensive impervious surface coverage. These areas may be suitable for the implementation of green infrastructure; such determinations were made on qualitative assessment of the areas and professional judgement relative to practicality of potential for BMP implementation.

Riverside Avenue

Pequabuck River, along Route 72 in Bristol, passes through dense residential and small commercial properties tightly adjacent to river on both sides from Jacobs Street to the west to Blakeslee Street to the east. At one point, the river appears to be underground for a distance of at least 1,700 feet. The close proximity to the river, along with the type of use and lack of any buffers in most cases, means this area has high potential to impact the river (Figures 2.19 to 2.21).

Figure 2.19: Pequabuck River Near 132 Jacobs Street

Figure 2.20: Pequabuck River Near 4 Riverside Avenue and Main Street

Figure 2.21: Pequabuck River Near Blakeslee Street and Memorial Boulevard

Figure 2.22: Bristol Plaza, 641 Farmington Avenue, Bristol: 18.5+ acres of Impervious. Source: Google Earth

Figure 2.23: Home Depot 1149 Farmington Avenue, Bristol: 8 acres of Impervious Area. Source: Google Earth

Figure 2.24: Goodwill/Town Fair Tire 1212 Farmington Ave, Bristol & Bristol Farm Plaza 1235 Farmington Ave, Bristol: Combined 19.75 acres of Impervious Area. Source: Google Earth

Figure 2.25: LA Fitness Plaza (top) 1379 Farmington Ave, Bristol: 12 acres; Walmart (bottom); 1400 Farmington Ave, Bristol: 11 acres (appears to have some stormwater management in place). Source: Google Earth

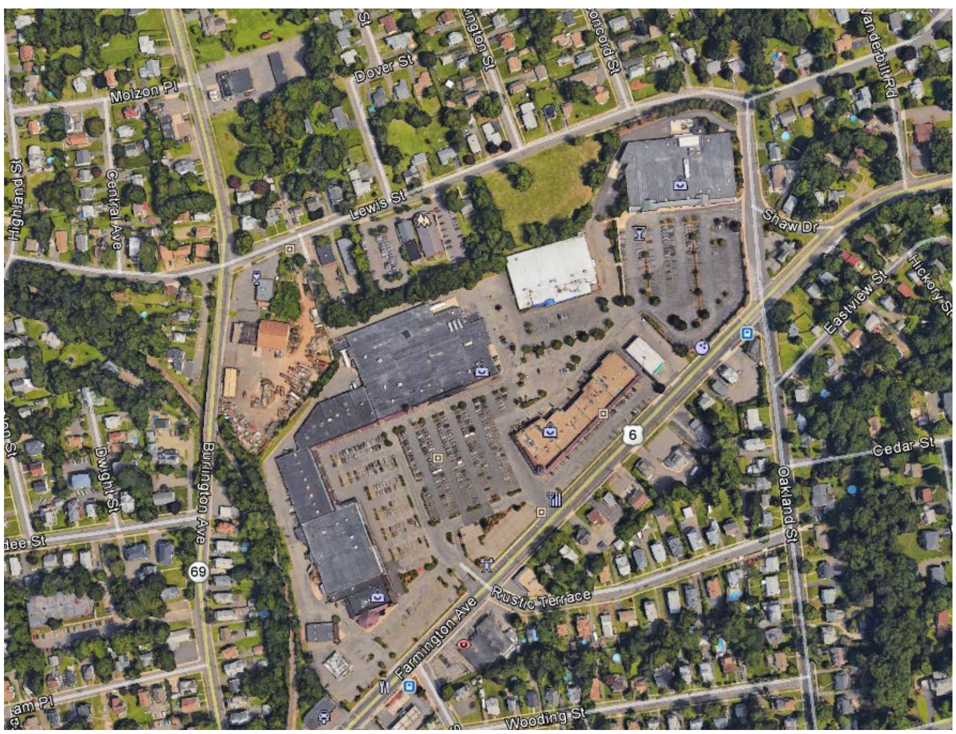

Figure 2.26: Bristol Commons, 99 Farmington Ave, Bristol: nearly 25 acres. Source: Google Earth

Figure 2.27: Shops & Businesses, Downtown Terryville, Corner of Route 6, N. Main Street, Federal Street: 9.4 acres. Source: Google Earth

Figure 2.28: Connecticut Commons Shopping Center Source: Google Earth

Figure 2.29: Rite Aid/Terryville Congregational Church, 8 S Main Street/233 Main St, Terryville: 2.7 acres roofs, 1.2 acres of paving. Source: Google Earth

2.5 Potential Additional Sources of Impairment

Upper Poland River watershed is characterized by mixed hardwood forest, little development and reservoirs. The lower Poland River watershed and upper Pequabuck River watersheds contain residential developments with curbed roads, storm drains and lawns. The historical documents reviewed as part of this study repeatedly linked the decline in the water quality of the Pequabuck River, Coppermine Brook and the Poland River to increases in land use development that started in the mid-1900s. As noted in the Introduction of this report, the non-attainment classification of the Pequabuck River is largely a function of recreational (bacterial) and aquatic impairment. This section of the report briefly discusses the roles of nonpoint source and point source pollution, including different land use activities, stormwater runoff, and improperly functioning septic systems, on increasing the concentration and loading of bacteria, pathogens, and agents in the stormwater runoff conveyed to the Pequabuck River system that cause recreational and aquatic impairment.

Agricultural Activities

As documented in our assessment and modeling of the watershed, there is a minimal amount of agricultural land use activity (e.g. cultivated cropland, pasture/hay fields) throughout the Pequabuck River, Poland River and Coppermine Brook watersheds. As such, given the focus of this report to identify the major sources of NPS loading and establish how best to manage the major NPS sources, agricultural loading has been deemed of minor importance. Nevertheless, general BMPs related to agricultural sources will be discussed later in this document.

Developed Land and Anthropogenic Sources

Elevated bacteria in stormwater runoff and during wet weather flow conditions in urban streams is well documented. Recent findings from monitoring programs around the United States show that bacterial concentrations in stormwater runoff are typically elevated well above primary contact recreational standards, regardless of the watershed's land use profile (Clary et al., 2008). This occurs due to changes in land use that increase the occurrence of bacteria sources (faulty septic systems, leaking sanitary sewer lines, pet waste, and even waterfowl waste). This also occurs as a result of the increased volume and rate of runoff associated with increasingly developed lands with impervious surfaces. As previously noted, the more runoff, the greater the opportunity exists for the mobilization and transport of pollutants. The increased volume and rate of runoff also increases the rate of stream bed and bank erosion, with this again resulting in an increase of various pollutants including bacteria, sediment and nutrients. Given that the land use assessments and pollutant loading analyses (described in separate pollutant loading report) conducted as part of this project document urban lands as the largest generator of NPS pollution, the primary focus of the FRWA Pequabuck River Watershed Based Plan will be on reducing and controlling urban sourced runoff and decreasing the amount of pollutants (including bacteria) transported with urban runoff.

Pet Wastes

Human-related NPS bacteria loading is associated with human wastewater, whether generated via improperly functioning septic systems, cess pools, or faulty sanitary lines. However, DEEP recognizes that significant bacterial abundance may be the result of the pets. Pet waste is recognized to be a major source of fecal coliform bacteria and pathogens, including salmonella and giardia, in many urban watersheds (Schueler, 1999). In a bacterial ribotyping analysis study of bacterial sources in the Spring Creek watershed, 12.5 percent of the bacteria were attributable to non-agricultural domestic animals (mostly dogs). This was true despite the Spring Creek watershed being decidedly more agricultural in nature than the Pequabuck River watershed (SD DENR, 2008). A TMDL study of the Chickahominy River in Virginia found that cats and dogs were the predominant contributors of fecal coliform in the watershed, with fecal coliform daily loadings of dogs 10^6 times greater than cats (VA DEC, 2012). Although these data are from other watersheds and were conducted in other States, they do reflect the role that pet waste plays, especially in suburban and urban watersheds, in pathogen loading and related water quality impairments. This is one of the reasons the CT DEEP specifically targets the control of pet waste as part of the MS4 state-wide general permit (CT DEEP, 2016). As such, pet waste management will need to factor into the recommendations set forth in the FRWA's Pequabuck River Watershed Based Plan.

Septic Systems

Based on the pollutant loading results, septic systems within the Pequabuck River, Coppermine Brook and Poland River watersheds are not a major source of either pathogen or nutrient loading. As per the 2005 CCRPA "State of the Watershed" report, pathogen and nutrient water quality problems associated with septic systems are very limited and mostly a function of the remaining older, failing septic systems located within the Pequabuck River watershed proper. Although a minor source of pathogen and nutrient loading, those residents still relying on septic systems should be educated about septic system management and maintenance. Multiple studies have shown that proper management and maintenance of septic systems can be a very cost-effective means of minimizing pathogen or nutrient loading. Proper septic system maintenance is also the most cost-effective means of protecting against septic failures. Successful septic management involves the integration of public education, product modification, septic system inspection and maintenance, and water conservation practices. In addition, it may rely on the use of advanced on-site wastewater renovation/treatment designs to correct failing systems or to dictate the construction of new systems in environmentally sensitive sections of the watershed. Managing the performance of septic systems to decrease pathogen and nutrient loading is consistent with the overall pollutant load reduction objectives needed for the Pequabuck River watershed. Thus, although not a major source of pathogen and bacteria loading, the FRWA's Pequabuck River Watershed Based Plan should at a minimum include guidance related to proper septic system maintenance.

Leaking Sewer Lines

Faulty wastewater (sanitary) lines are a known source of pathogen and bacteria loading, especially in older communities where the infrastructure has aged. While this may be a source of bacteria loading for the Pequabuck River system, the analysis of leaking sewer lines is beyond the scope of this field assessment. Still, it is recommended that municipalities routinely incorporate the inspection of their water infrastructure for faulty lines and repair as soon as possible.

3.0 Mapshed Modeling

3.1 Methodology

Mapshed version 1.3 was used for modeling total phosphorus (TP), total suspended solids (TSS), total nitrogen (TN), and bacteria (fecal coliform) loadings within the Pequabuck watershed, its three subregional watersheds, and 32 local basins. This modeling effort was conducted within the framework established under the Quality Assurance Project Plan for the Pequabuck River Watershed Based Plan (Approved August 2016). Please note, 'pathogen' is the default nomenclature utilized in the Mapshed model and is utilized to refer to fecal coliform loading. This naming is kept, for the sake of consistency, in sections of this document. The Mapshed model integrates existing GIS data layer information and generates data that can be used to identify pollutant loading on a subwatershed level. The Mapshed model simulates surface runoff using daily weather inputs of rainfall and temperature. Erosion and sediment yields are estimated using monthly erosion calculations based on land use, soil composition, and slope values for each source area. A sediment delivery ratio based on the area of the watershed and a transport capacity based on average daily runoff is then applied to the calculated erosion figures. Sediment/pollutant loading for each source area (i.e., land cover category) is then determined. This information was used to identify and prioritize specific areas within the watershed and subwatersheds for targeted load reductions and select appropriate management measures to be used towards accomplishing desired NPS load reductions.

Mapshed models runoff, sediment loads and nutrient (N & P) loads, all of which are potential causes for aquatic life impairment. Additionally, it can model directly for bacteria which serve as an indicator for potential pathogens, the primary cause of recreational impairment. Bacteria loading in Mapshed is, by default, fecal coliform. As this is an indicator organism for potential pathogens, it represents a suitable surrogate for *Escherichia coli (E. coli)*. Mapshed models bacteria contributions via the following sources: Farm animals, wastewater treatment plants, urban landscapes, septic systems and wildlife. Wildlife loading is based on an assumption of 25 deer (*Odocoileus virginianus*) per acre, with a loading of 5.0×10^8 fecal coliform organisms per animal per day (from USEPA, 2001) of 'natural area' within the watershed. Within Mapshed, 'natural areas' are forested lands. A full explanation of bacteria load estimation is also provided in Appendix B of the Mapshed Users Guide (Evans & Corradini, 2016). The Mapshed output, on a local basin level, was used to assist in the identification of priority subwatersheds based on the amount of runoff and NPS pollutant loads. These areas were targeted for further investigation during the field assessment portion of this project in order to develop a set of recommended best management practices (BMPs).

Input GIS data included soils, streams, weather station locations, land use and digital elevation model (DEM) layers. Input weather data consisted of daily precipitation and temperature data in Excel spreadsheets. Primary data input layers were obtained from the Penn State Mapshed website. On the website's Mapshed Downloads tab, these layers were available under the New York/New England Regional dataset (version 1.2.0, last updated October 22, 2013) and the New York/New England Section 6 dataset (version 1.2.0, last updated February 4, 2016). Please note, the land use data provided in the updated data (Updated February 4, 2016) is from 1995. While more recent GIS data is available, the utilization of such information would require manual formatting and execution which is outside of the scope of this project. The New York / New England Regional Dataset was calibrated and identified as an acceptable watershed-based model for this region under a separate New England Water Pollution Control Commission (NEIWPCC) project (Weidman, 2007).

Model Assumptions

As with any model, Mapshed is run under a set of assumptions. The following assumptions were pertinent to our analysis of the Pequabuck watershed.

1. *There were no major surface or ground water withdrawals in the watershed for the years examined* - Various entities withdraw water for drinking purposes. However, since this data is not widely publicly available and was not provided to Princeton Hydro, it is not included in this modeling effort.

2. *Tile drainage is not present in the watershed* - Although tile drainage is popular throughout agricultural areas in New England, there was little data available for this region at the time of the model's construction. Furthermore, agricultural land is a minor component of overall land use and, as such, we do not expect significant impacts on the model from the exclusion of this source.

Input Data Collection and Formatting

Soils, streams, and weather station location data were in the form of shapefiles. Shapefiles best portray location, attributes, and shape of spatial data and take form as points, lines, or polygons. Stream files (lines) were downloaded from the Mapshed website's New York/New England Section 6 dataset while weather stations (points) and soils (polygons) were obtained from the New York/New England Regional dataset.

The soils layer contained various soil property information such as the map unit identifier and composition description. The data used was published by the U.S. Department of Agriculture (USDA) and acquired as generalized soil maps available in the State Soil Geographic (STATSGO) datasets. The streams layer depicted a stream network compatible with 12-digit HUC boundaries. Stream data originated from the National Hydrography Dataset (NHD), produced by the United States Geologic Survey (USGS). The weather station location data layer conveyed the coordinates of stations that recorded daily temperature and precipitation data for the period 1990-2004. There were 157 weather stations across the New York/New England Regional dataset. Thirteen weather stations were within a fifty-mile radius of the Pequabuck watershed. Weather station location data originated from a commercial database containing National Weather Service climate data. Please note, the selection of the weather database included with the model, as opposed to collecting and curating more recent climate data, was chosen due to the strict formatting requirements of Mapshed in order to run the algorithms and sub-routines. This decision was made in consultation with the model's primary author, Dr. Barry Evans, and will provide reasonable estimates of NPS loading for this project. Boundaries of local basins, larger subregional watersheds, and the major Pequabuck watershed were provided through the Connecticut Department of Energy and

Environmental Protection (DEEP) data depository as three distinct shapefiles (polygons). These data delineated the edges of three size-dependent levels of watersheds.

Land use and DEM layers took the form of raster data. Land Use and DEM layers were downloaded from the Mapshed website's New York/New England Section 6 dataset. Please note, the utilization of the land use file derived from the Mapshed website, over the 2011 National Land Cover Dataset (NLCD), was at the explicit direction of the model's primary author, Dr. Barry Evans. The reasoning for utilizing this dataset is that the land use data was properly formatted for the execution of the model's algorithms and various sub-routines. While this dataset is not the most up to date, it was the most appropriate source for accurate modeling of NPS pollution in the Pequabuck watershed.

The land use layer mapped the watershed land use/cover through categorization into sixteen classes, as shown in Table 3.1.

Table 3.1: Grid values for land use and land cover type

Cell Value	Land Use Type	Cell Value	Land Use Type
1	Water	**10**	Woody Wetland
2	Low-Density Development	**11**	Emergent Wetland
3	High-Density Development	**12**	Quarries
4	Hay/Pasture	**13**	Coal Mines
5 or 6	Row Crops	**14**	Beaches
7	Coniferous Forest	**15**	Transitional
8	Mixed Forest	**16**	Turfgrass/Golf Course
9	Deciduous Forest		

The DEM layer portrayed through a dense network of pixels whose values indicated surface elevation in meters. A 30-meter digital elevation set was used for the DEM input layer, which had better resolution than the other 100-meter DEM available.

Daily summaries of precipitation and temperature were extracted from a folder containing Excel spreadsheets with data from the 157 weather stations across the New York/New England Regional area. All input shapefiles and raster files were projected into the NAD 1983 (2011) State Plane Connecticut FIPS 0600 (Meters) coordinate system with a Lambert Conformal Conic projection in ArcMap 10.2.2. The files were then imported into the Mapshed program through the "Load GIS Data Layers" interface.

A Note on Data Selection

When beginning the task of compiling input data, we used the most up-to-date data downloaded from sources such as the National Land Cover Database for land use and the National Oceanic and Atmospheric Administration (NOAA) climate depository for daily precipitation and temperature data. However, several problems arose with both the weather and GIS data such as an excess of land use/cover categories, which Mapshed could not process, and an abundance of missing weather data values that made creating a complete, robust set difficult. In personal correspondence, the Mapshed creators highly recommended we utilize the available datasets in lieu of creating our own for greater efficiency and accuracy in the final product. The creators obtained the data used to create their downloadable datasets from the Cornell University Geospatial Information Repository (CUGIR) and the National Weather Service.

Importing Data into Mapshed

Data layers were loaded into their respective “Required Layers” boxes; e.g. “Basins (Polygon)” was loaded with the watershed shapefile being used for the specific iteration, “DEM (Grid)” was loaded with the DEM raster, “Landuse (Grid)” loaded with the land use raster, and so on. The “Weather Directory” was loaded with one Excel file that acted as a link to the entire weather directory folder. After layers were loaded, both boxes next to “Check Data Layers” and “Check Layer Alignment” were selected in order to assure the input data were created properly and aligned sufficiently and then the layers were imported. The process of data importation was ultimately conducted three times with a different shapefile for “Basins (Polygon)” being chosen each time; one contained the entire Pequabuck Watershed boundary, another containing the three subregional watersheds boundaries (Coppermine Brook, Poland River, and Pequabuck River), and the third containing the 32 local basin boundaries.

After a basin was selected with the “Select Basin(s)” tool, GWLF-E was run after pressing the “Run GWLF-E” button. With the exception of the growing season set from May through September and the selected years being 2000-2004, the GWLF-E settings were maintained as default values. This process was completed for all basins: the entire Pequabuck Watershed, the subregional watersheds, and the local basins. The data for each model run, by basin group, were saved in appropriate folders.

The entire study area, subregional basins, and local basins used in the modeling and subsequent analyses are presented in Figure 3.1.

3.2 Mapshed Results

The model generated daily, monthly, and annual watershed output data. The variables of interest – Phosphorus (TP), Total Suspended Solids (TSS), Total Nitrogen (TN), Pathogens (Fecal Coliform Bacteria), and Monthly Flows – were categorized in the output spreadsheets, respectively: “Tot P”, “Sediment”, “Tot N”, “Organisms per Month”, and “Stream Flow.” Please note, “Organisms per Month” refers to fecal coliform loading which is also noted as “Pathogens” in Mapshed nomenclature.

In order to compare the TP, TSS, and discharge of the subregional and local basins, the values representing the monthly sums were selected and divided by each basin’s area in order to yield areal (per-acre) results. This allowed for a more comprehensive comparison of watershed loading by removing the effect of watershed size on pollutant loading. Furthermore, this normalization may be utilized to fairly compare local subwatersheds for NPS management prioritization.

Land Use

The following figure (Figure 3.1) depicts the entire Pequabuck River watershed along with each subregional and local basin. Subregional watershed size and land use composition of the watershed as a whole is described after Figure 3.1.

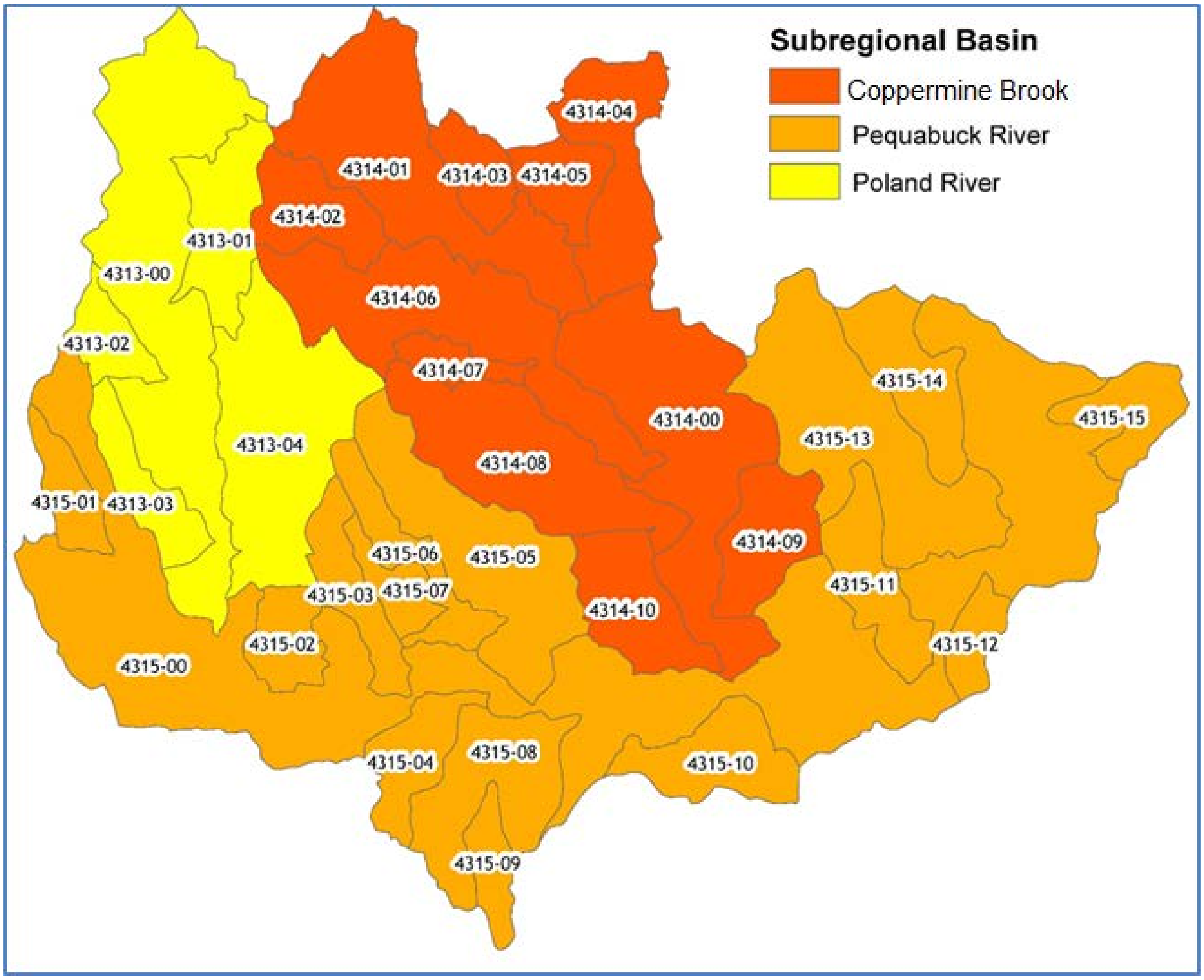

Figure 3.1: Subregional and Local Basins Within the Pequabuck River Watershed

The total watershed area, as depicted in Figure 3.1, is 14,759 ha (36,470 ac). The Poland River subregional basin occupies an area of 2,497 ha (6,170 ac), the Coppermine Brook subregional basin occupies an area of 4,810 ha (11,886 ac), and the Pequabuck River subregional basin occupies an area of 7,453 ha (18,417 ac).

Based on the 1995 Mapshed dataset categorizations, forest is the primary land use which comprises 55% of the total area. The second greatest land use type is urban / residential development which comprises 30% of the area. Meanwhile, agriculture, only comprises approximately 9% of land use by area.

Subregional Watershed Pollutant Loading

The annual, areal TP, TSS, and TN loading by subregional basin are presented in Figure 3.2 and Table 3.2. As shown below, the Pequabuck River subregional watershed is contributing the most TSS, TP, and TN per unit area. The Coppermine Brook and Poland River subregional watersheds contribute the second and third most non-point source pollution, respectively.

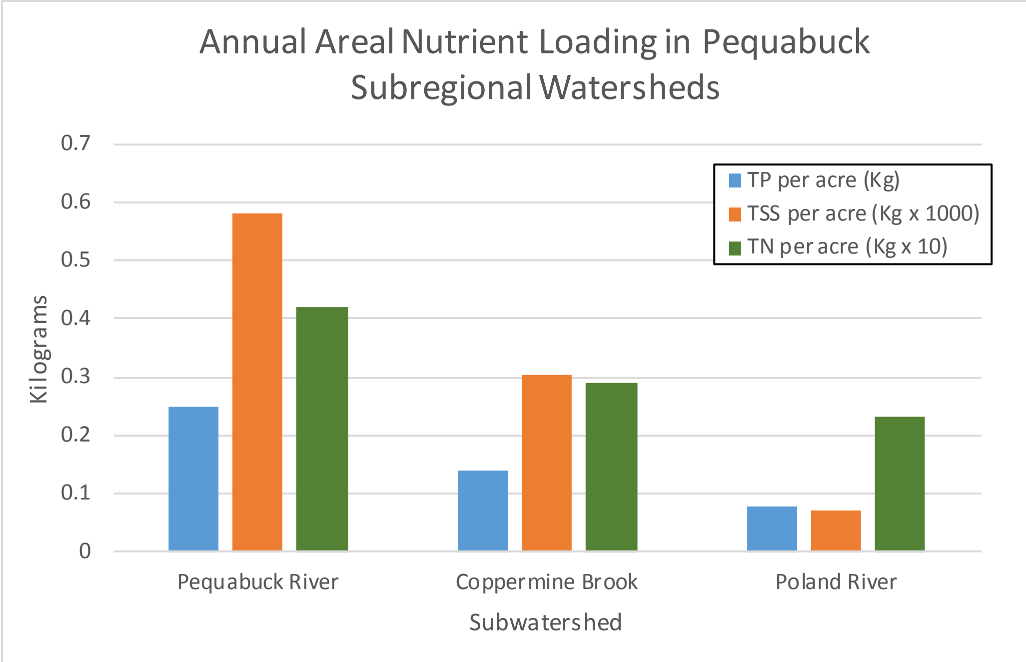

Figure 3.1: Subregional Watershed - Areal Pollutant Loading (Annual)

Table 3.2: Annual TP, TSS, and TN areal loading in Pequabuck River subregional watersheds				
Rank	Subregional Watershed	Annual TSS per Acre (Kg)	Annual TP per Acre (Kg)	Annual TN per Acre (Kg)
1	Pequabuck River	582	0.25	4.21
2	Coppermine Brook	302	0.14	2.92
3	Poland River	71	0.08	2.33

The estimated primary source areas of TSS in the Pequabuck River subregional basin is that of stream bank erosion which contributes approximately 90% of the sediment load from this basin. The remaining TSS load is derived from various land use sources throughout the subwatershed. The primary source for TP loading in the Pequabuck River subregional basin is derived from over land sources which comprise 55% of the load followed by streambank erosional sources which comprise 30% of the load. Of the over land TP source, High Density Residential provides the greatest source contributor at 29% of the total P load. Followed by Low Density Mixed Development which comprises 15% of the load. Groundwater derived sources of TP comprise 16% of the load. Nitrogen loading is derived primarily by groundwater sources (55%) followed by septic systems (10%) and stream bank erosion (6%).

Subregional Watershed Bacteria Loading

The annual areal bacteria (pathogen) loading by subregional basin are presented in Figure 3.3 and Table 3.3. As shown below, the Pequabuck River subregional watershed is contributing the most total bacteria (fecal coliform) per acre followed by the Coppermine and Poland River subwatershed. Source area contributions of bacteria/pathogens (fecal coliform) include urban areas and wildlife. The highest contributor from urban area sources, per unit area, are derived from the Pequabuck basin followed by Coppermine and Poland River. The highest contributor, per unit area, for wildlife-based sources is the Poland River basin followed by Coppermine and Pequabuck River subregional watersheds.

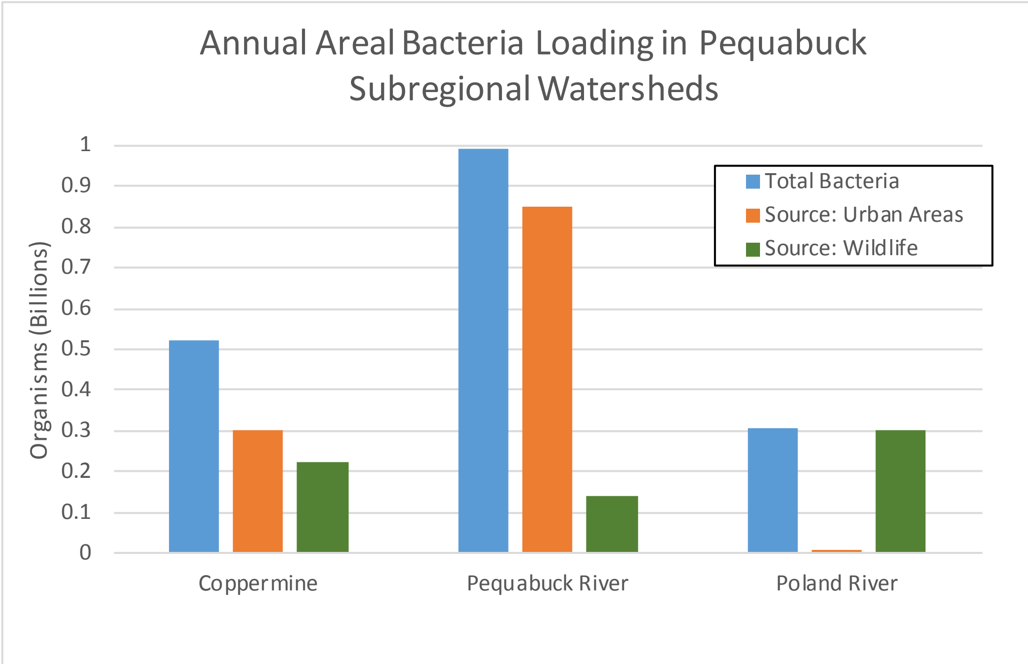

Figure 3.3: Subregional Watershed - Areal Fecal Coliform Loading (Annual)

Table3.3: Annual Areal Fecal Coliform **loading in Pequabuck River Subregional Watersheds From Urban and Wildlife Sources** and Mean Monthly Concentrations				
Subregional Watershed	Annual Organisms per Acre*: Total	Annual Organisms per Acre: Urban Areas	Annual Organisms per Acre: Wildlife	Mean Monthly Concentration (cfu/100ml)
Pequabuck River	1.0×10^9	8.0×10^8	1.0×10^8	25
Coppermine Brook	5.0×10^8	3.0×10^8	2.0×10^8	14
Poland River	3.0×10^8	9.0×10^6	3.0×10^8	9
***- e.g. 1.0×10^9 = 1,000,000,000**				

Local Basin Pollutant Loading

Pollutant loading for the Pequabuck River watershed was further refined by delineating 32 local basins from the subregional watersheds. Five local basins are located within the Poland River subregional basin, eleven local basins are located within the Coppermine Brook subregional basin, and sixteen local basins are located within the Pequabuck River subregional basin. The ranking of each basin was conducted with a rank of “1” equating to the highest load per unit area of that group and the lowest number associated with the lowest load of that group. The refinement of the larger basins into smaller, local basins was conducted in order to assist in the prioritization and guidance of establishment of best management practices (BMPs).

The following figures and tables present the annual areal TP, TN and TSS loading by local basin. Figure 3.4 provides annualized TP loading at each local basin while normalized for area while figure 3.5 presents the same data just sorted from the lowest to highest loading. Table 3.4 provides the normalized loading data in table form within the context of the larger subregional basins. Figure 3.6 depicts the loading data as a heat map with blue coloration associated with lowest loading and red coloration associated with highest loading. Finally, figure 3.7 depicts the five highest loading local basins in a subregional context. The same general format discussed immediately above was followed for total nitrogen (Figures 3.8-3.11, table 3.5) and also sediment (Figures 3.12- 3.15, table 3.6).

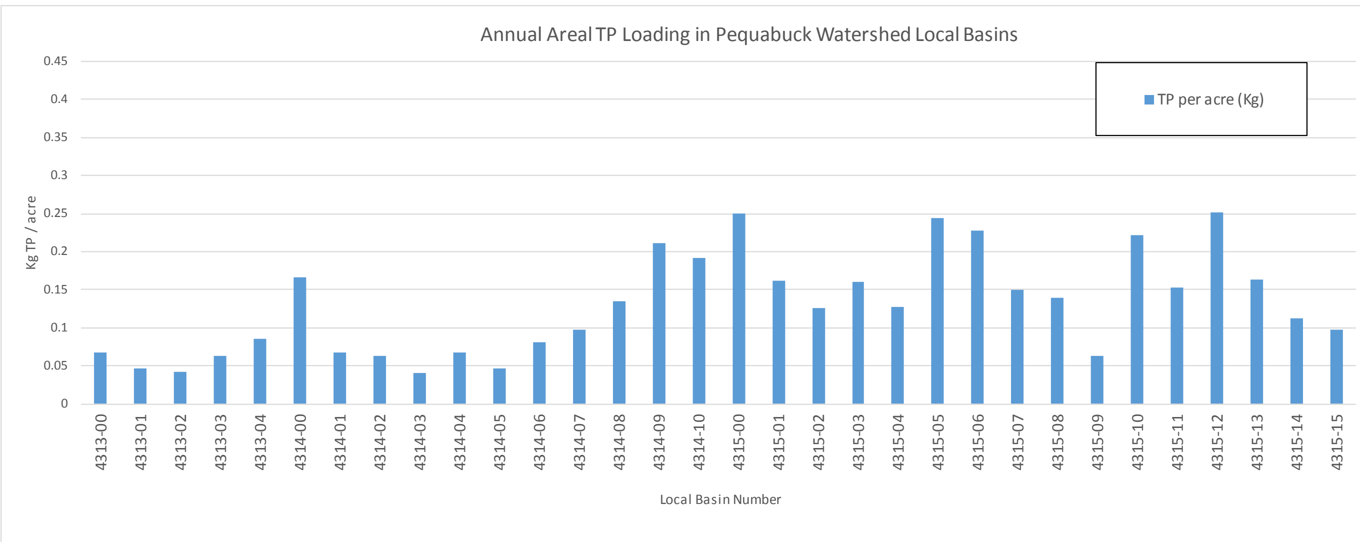

Figure 3.4: Annual Areal TP Loading for Local Basins within the Pequabuck River Watershed

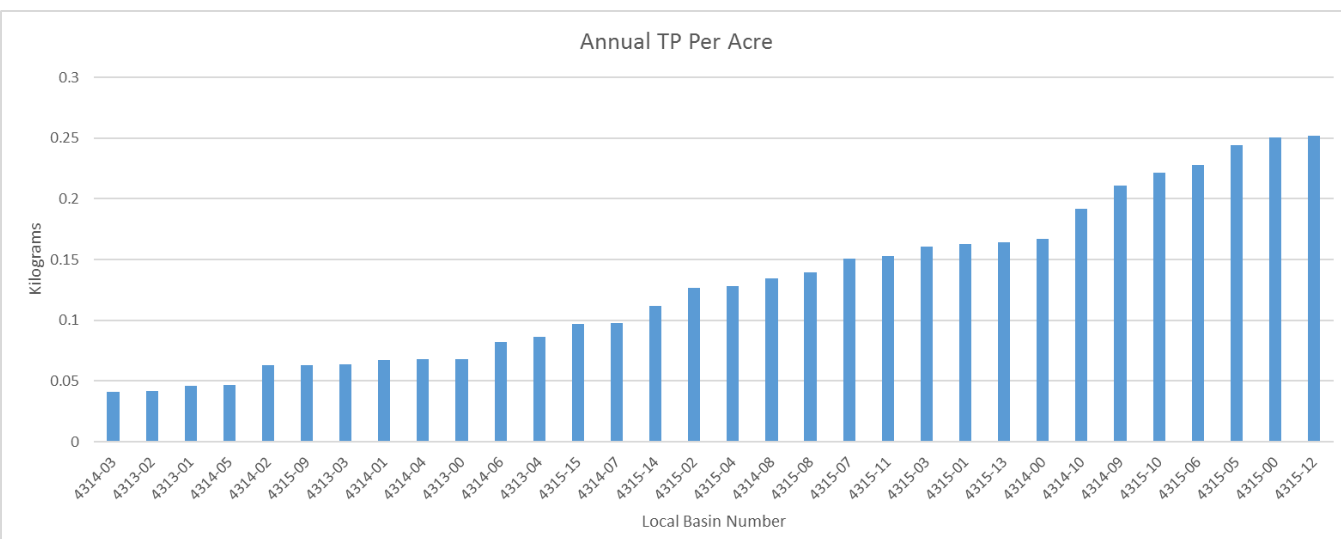

Figure 3.5: Local Basins Ordered by Annual Areal TP Loading

Table 3.4: Annual areal TP Pollutant Loading for Pequabuck River Watershed Local Basins (Rank of 1 = Highest Loading)

Subwatershed	Rank	Local Basin Number	Annual TP per Acre (Kg)
Pequabuck	1	4315-12	0.252
	2	4315-00	0.250
	3	4315-05	0.244
	4	4315-06	0.228
	5	4315-10	0.221
	6	4315-13	0.164
	7	4315-01	0.163
	8	4315-03	0.161
	9	4315-11	0.153
	10	4315-07	0.151
	11	4315-08	0.139
	12	4315-04	0.128
	13	4315-02	0.126
	14	4315-14	0.112
	15	4315-15	0.097
	16	4315-09	0.063
Coppermine	1	4314-09	0.211
	2	4314-10	0.192
	3	4314-00	0.167
	4	4314-08	0.135
	5	4314-07	0.097
	6	4314-06	0.082
	7	4314-04	0.068
	8	4314-01	0.067
	9	4314-02	0.063
	10	4314-05	0.047
	11	4314-03	0.041
Poland	1	4313-04	0.086
	2	4313-00	0.068
	3	4313-03	0.064
	4	4313-01	0.046
	5	4313-02	0.042

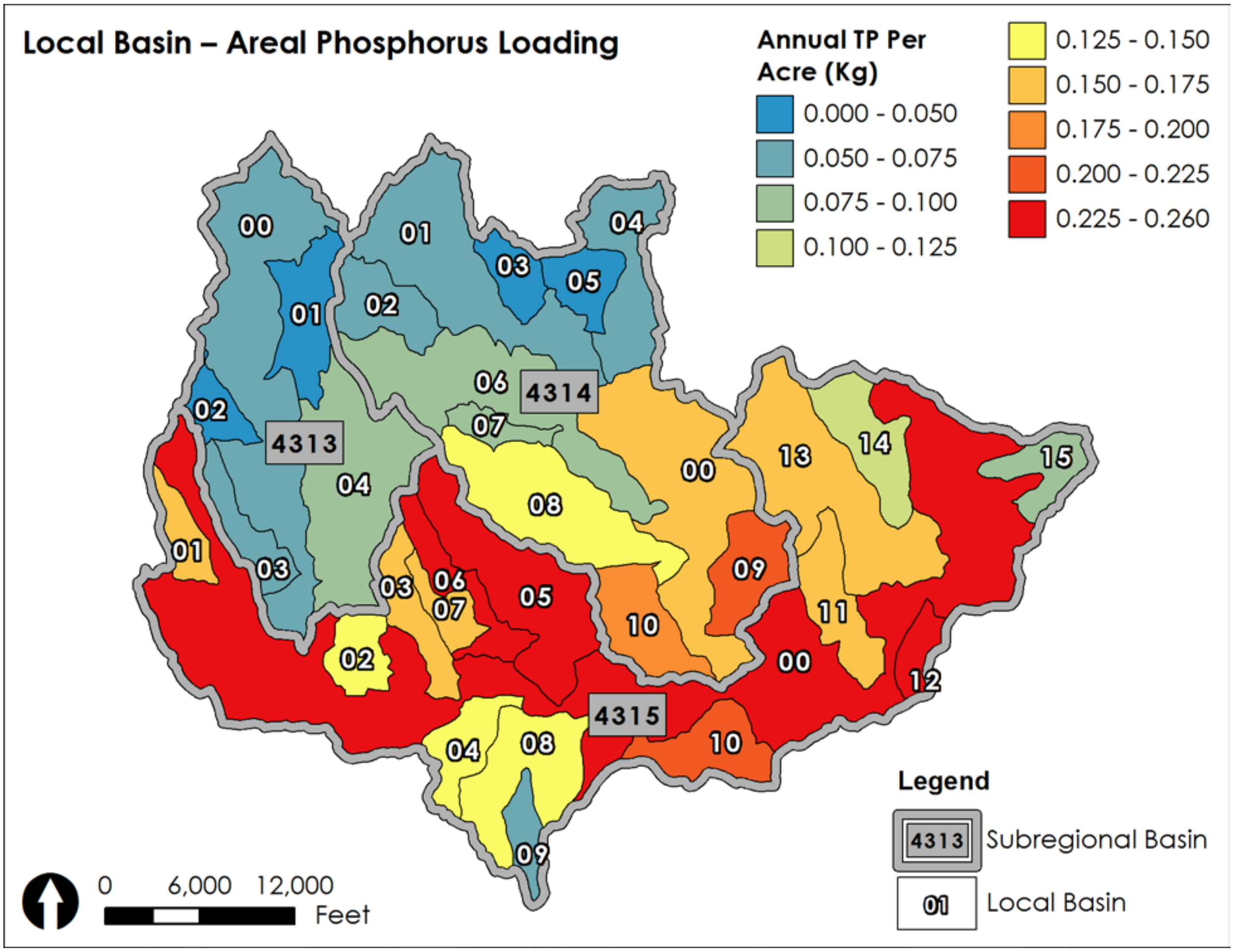

Figure 3.6: Annual Areal TP Loading by Local Basin

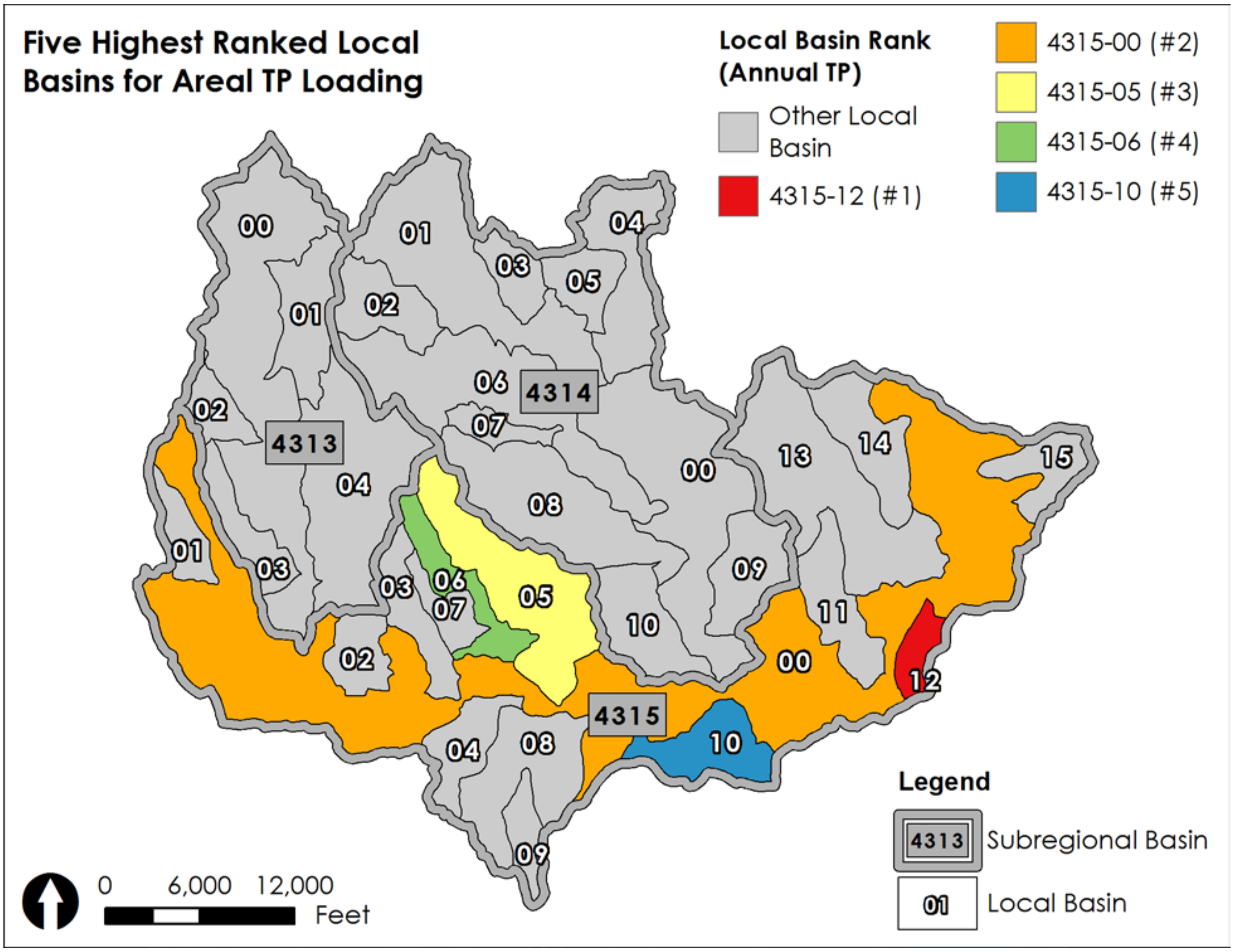

Figure 3.7: Five Highest Ranked Local Basins for Areal TP Loading

The local basins contributing the highest amount of TP per acre were 4315-12, 4315-00, 4315-05, 4315-06, and 4315-10. All of these local basins are located within the Pequabuck River subregional basin (Figure 3.7).

Next, the same type of figures and tables are presented for total nitrogen.

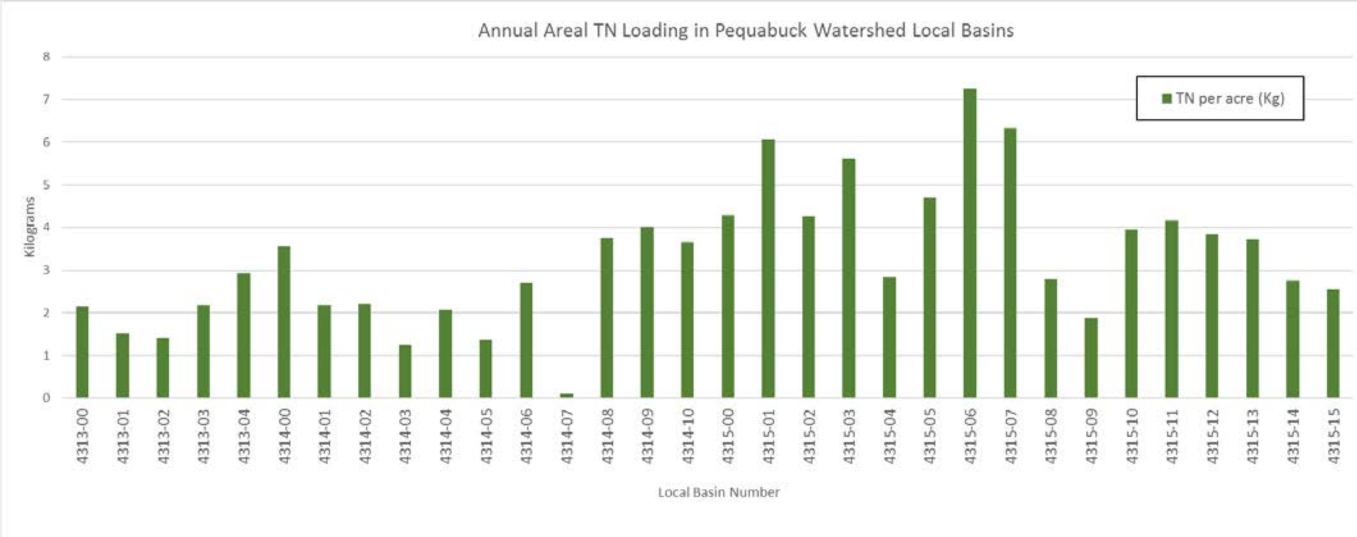

Figure 3.8: Annual Areal TN Loading for Local Basins within the Pequabuck River Watershed

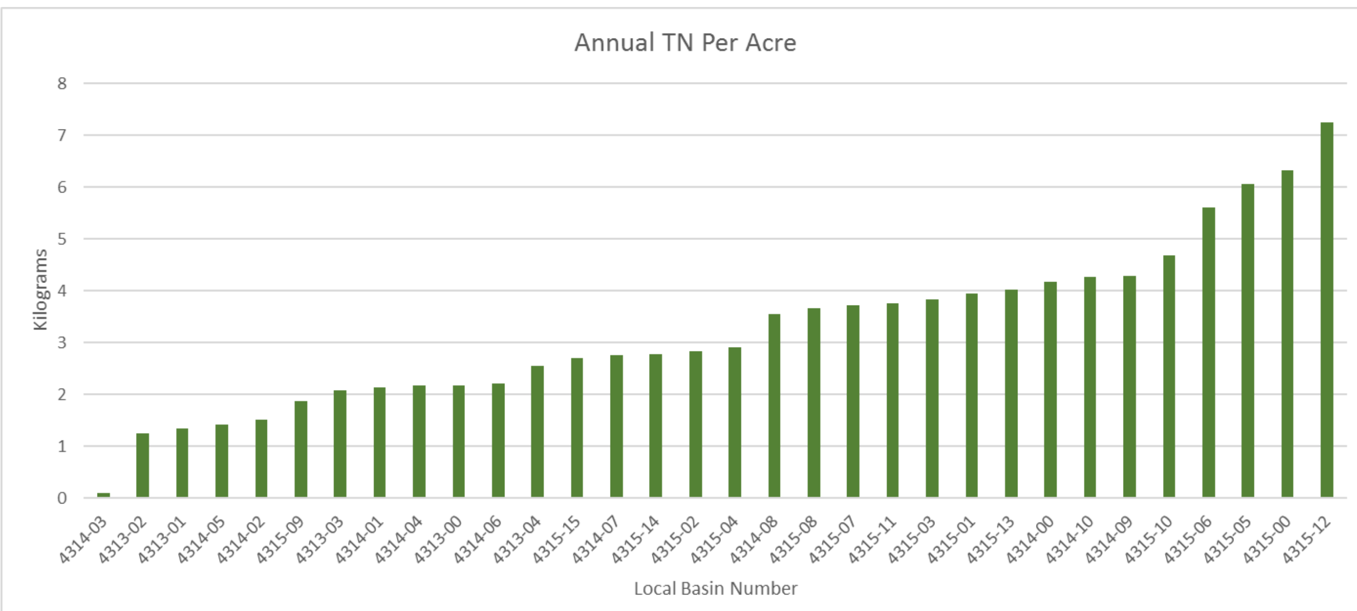

Figure 3.9: Local Basins Ordered by Annual Areal TN Loading

Table 3.5: Annual Areal TN Pollutant Loading for Pequabuck River Watershed Local Basins (Rank of 1 = Highest Loading)

Subwatershed	Rank	Local Basin Number	Annual TN per Acre (Kg)
Pequabuck	1	4315-06	7.248
	2	4315-07	6.321
	3	4315-01	6.066
	4	4315-03	5.616
	5	4315-05	4.690
	6	4315-00	4.284
	7	4315-02	4.265
	8	4315-11	4.166
	9	4315-10	3.945
	10	4315-12	3.839
	11	4315-13	3.719
	12	4315-04	2.841
	13	4315-08	2.784
	14	4315-14	2.752
	15	4315-15	2.545
	16	4315-09	1.865
Coppermine	1	4314-09	4.017
	2	4314-08	3.765
	3	4314-10	3.656
	4	4314-00	3.553
	5	4314-06	2.701
	6	4314-02	2.205
	7	4314-01	2.172
	8	4314-04	2.073
	9	4314-05	1.351
	10	4314-03	1.240
	11	4314-07	0.097
Poland	1	4313-04	2.918
	2	4313-03	2.173
	3	4313-00	2.136
	4	4313-01	1.505
	5	4313-02	1.413

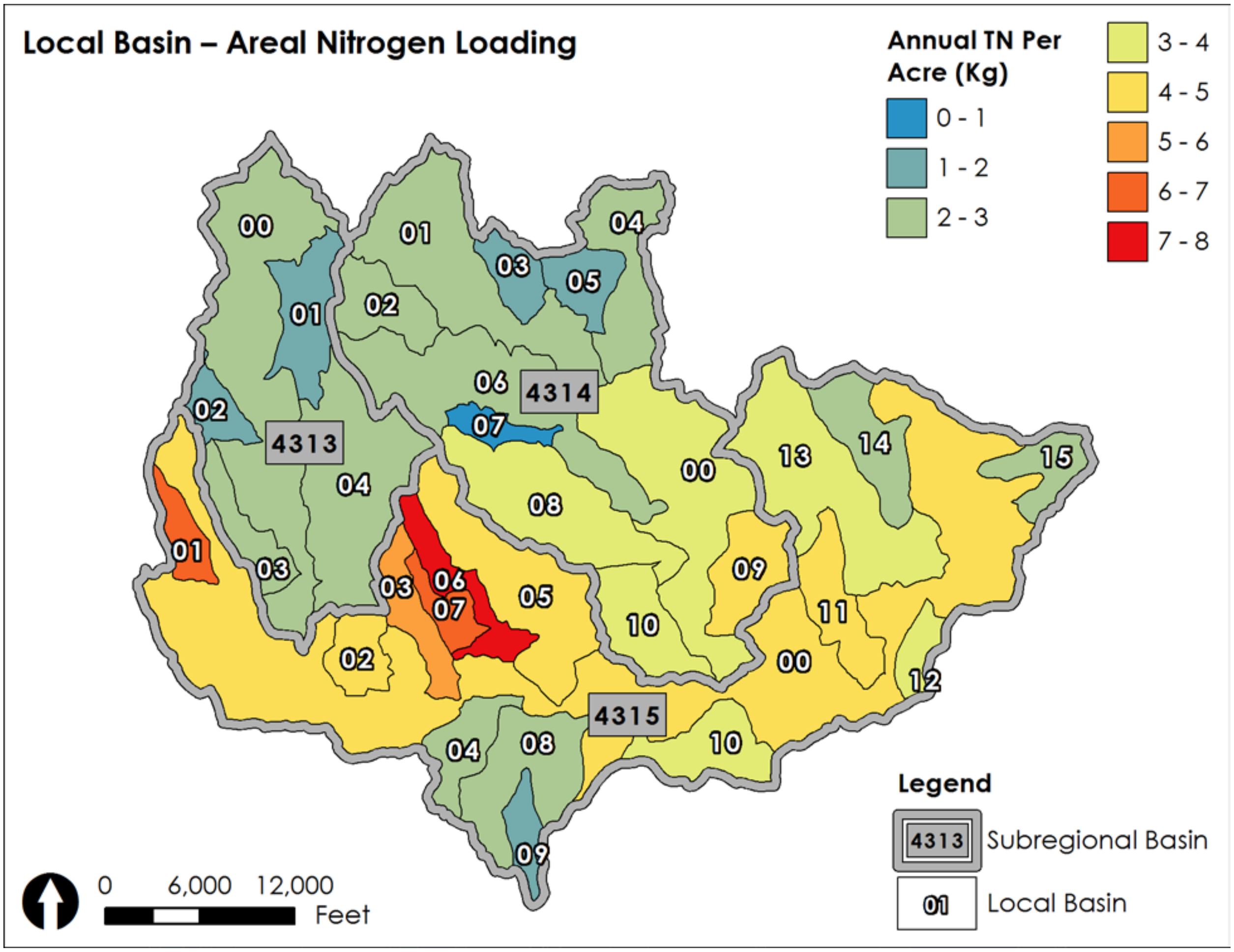

Figure 3.10: Annual Areal TN Loading by Local Basin

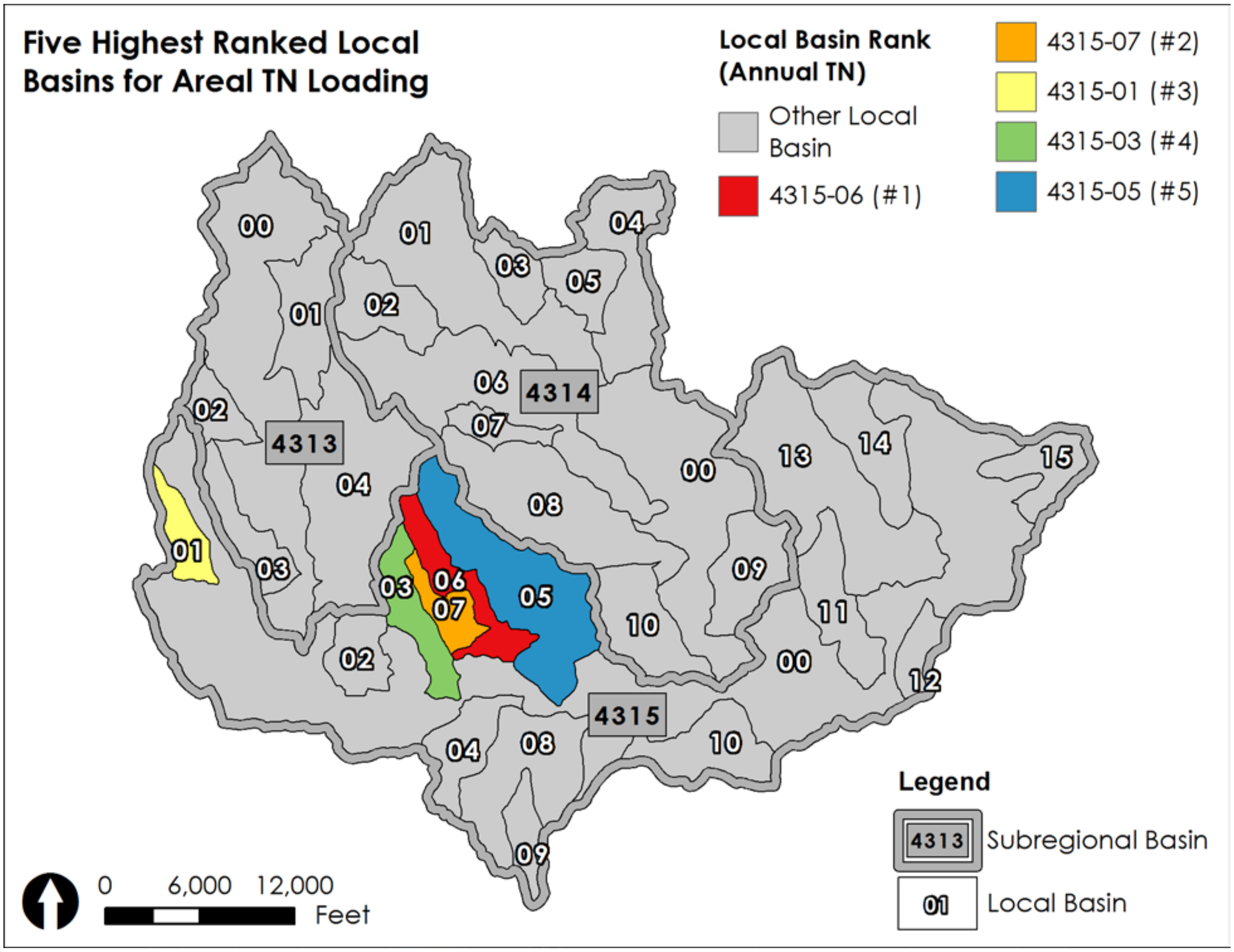

Figure 3.11: Five Highest Ranked Local Basins for Areal TN Loading

The local basins contributing the highest amount of TN per acre were 4315-06, 4315-07, 4315-01, 4315-03, and 4315-05. All of these local basins are located within the Pequabuck River subregional basin. The locations of these local basins are shown in Figure 3.11.

The following section provides the local basin results for TSS loading.

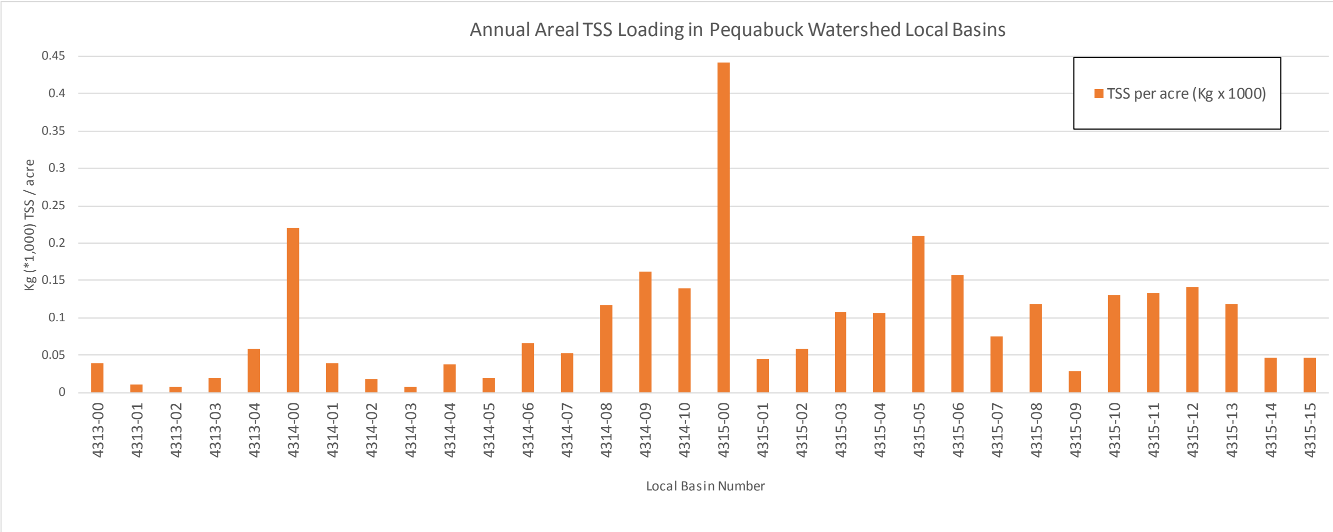

Figure 3.12: Annual Areal TSS Loading for Local Basins within the Pequabuck River Watershed

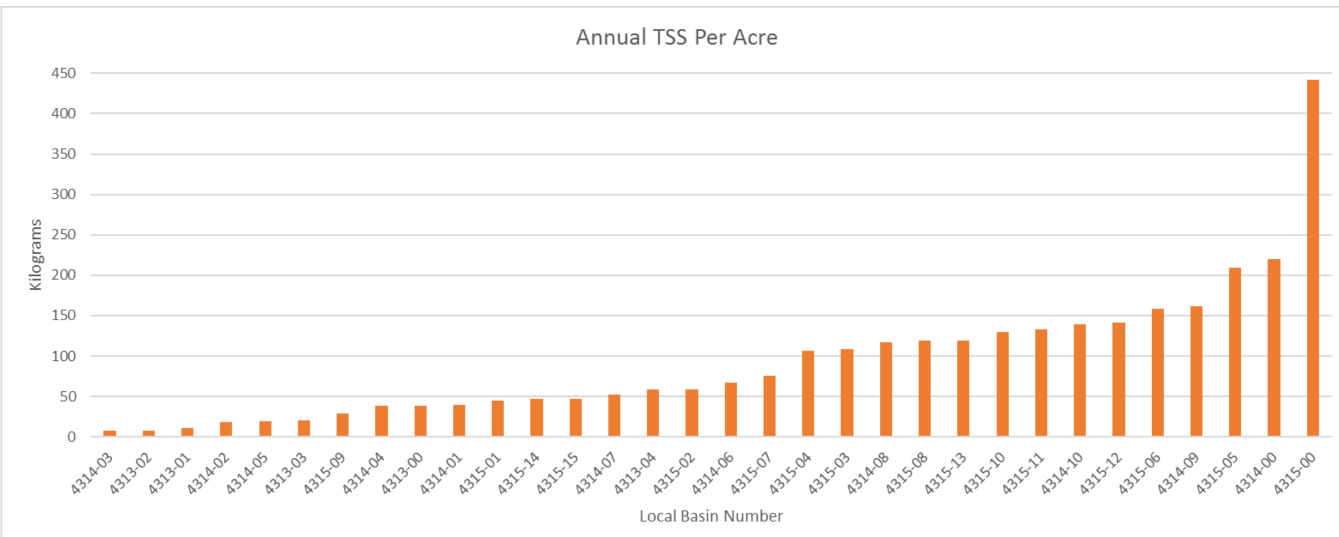

Figure 3.13: Local basins Ranked by Annual Areal TSS Loading

Table 3.6: Annual areal TSS Pollutant Loading for Pequabuck River Watershed Local Basins (Rank of 1 = Highest Loading)

Subwatershed	Rank	Local Basin Number	Annual TSS per Acre (Kg)
Pequabuck	1	4315-00	441.52
	2	4315-05	209.52
	3	4315-06	158.10
	4	4315-12	141.52
	5	4315-11	133.36
	6	4315-10	130.02
	7	4315-13	118.91
	8	4315-08	118.91
	9	4315-03	108.23
	10	4315-04	106.59
	11	4315-07	75.58
	12	4315-02	58.70
	13	4315-15	47.04
	14	4315-14	46.54
	15	4315-01	45.12
	16	4315-09	29.00
Coppermine	1	4314-00	219.79
	2	4314-09	161.40
	3	4314-10	139.04
	4	4314-08	116.50
	5	4314-06	66.95
	6	4314-07	52.52
	7	4314-01	40.03
	8	4314-04	38.13
	9	4314-05	19.81
	10	4314-02	18.09
	11	4314-03	7.80
Poland	1	4313-04	58.22
	2	4313-00	38.89
	3	4313-03	20.27
	4	4313-01	10.38
	5	4313-02	7.88

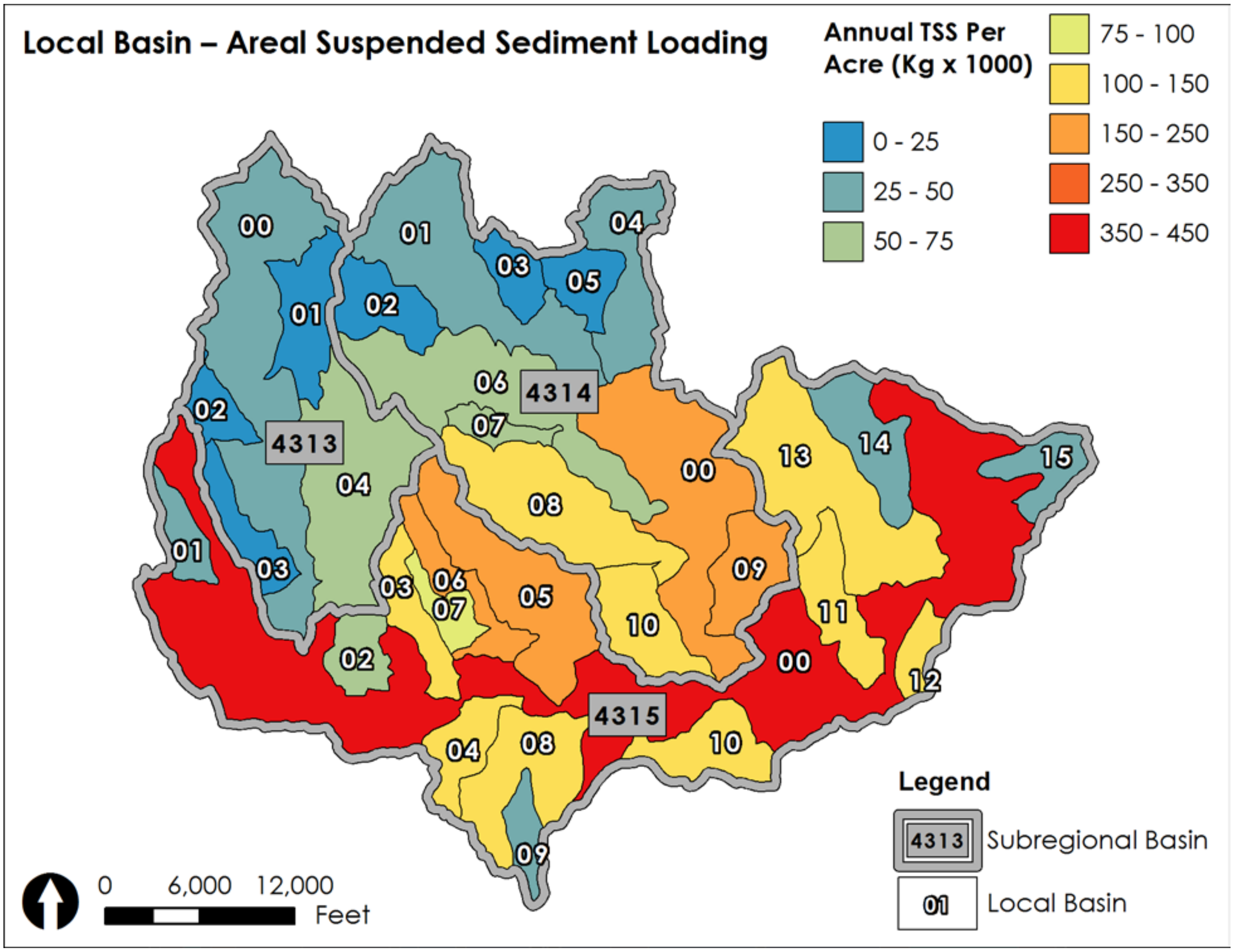

Figure 3.14: Annual Areal TSS Loading by Local Basin

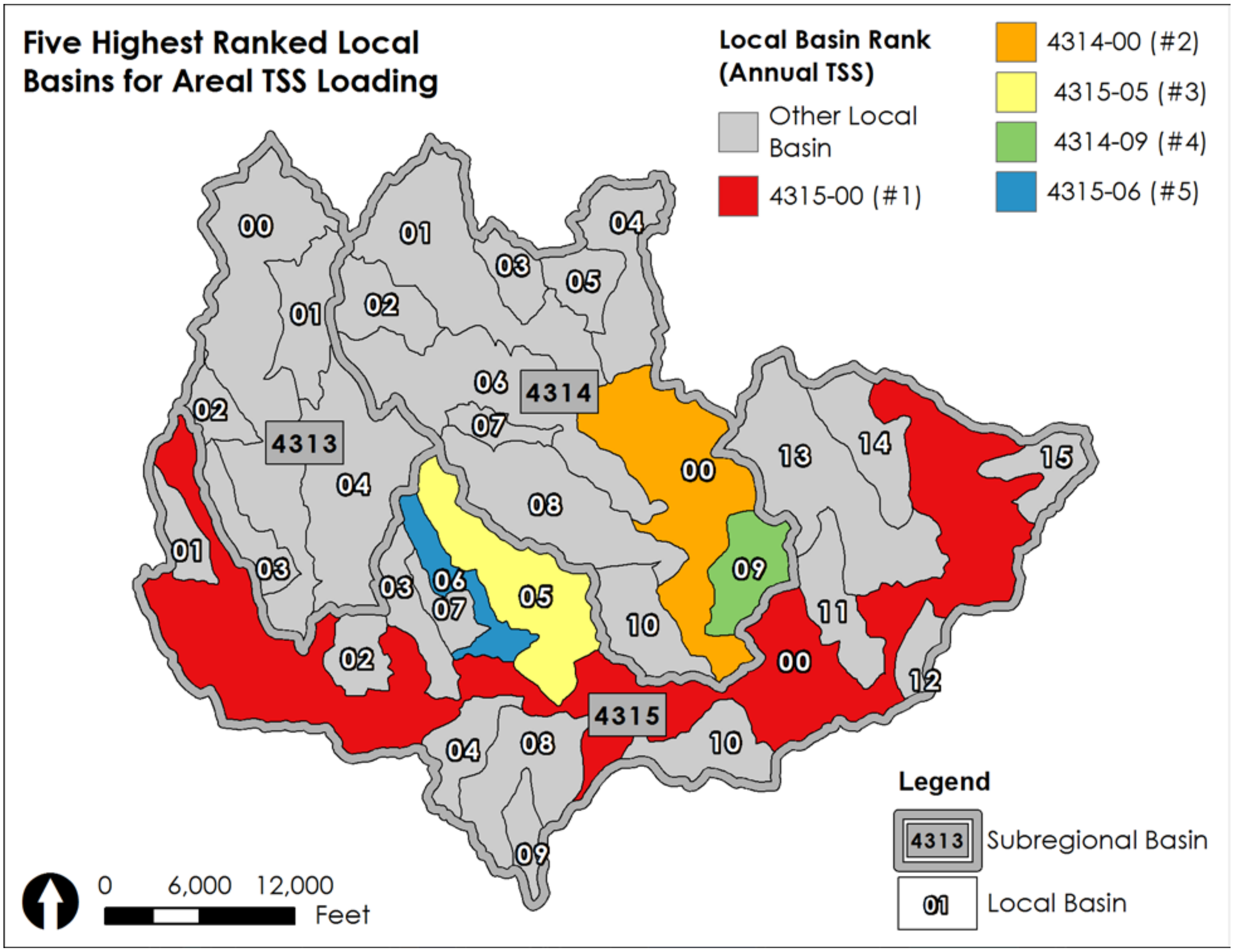

Figure 3.15: Five Highest Ranked Local Basins for Areal TSS Loading

The local basins contributing the highest amount of TSS per acre were 4315-00 (Pequabuck), 4314-00 (Coppermine), 4315-05 (Pequabuck), 4314-09 (Coppermine), and 4315-06 (Pequabuck). The location of these local basins are depicted in figure 3.15.

Local Basin Pollutant Loading by Subregion

The local basin pollutant loading information identified above was also broken down by subregional basins with TSS, TP and TN loading in a single figure. Figures for ranked TP, TN and TSS loading, per subregional basin, are hereby depicted in figures 3.16-3.18.

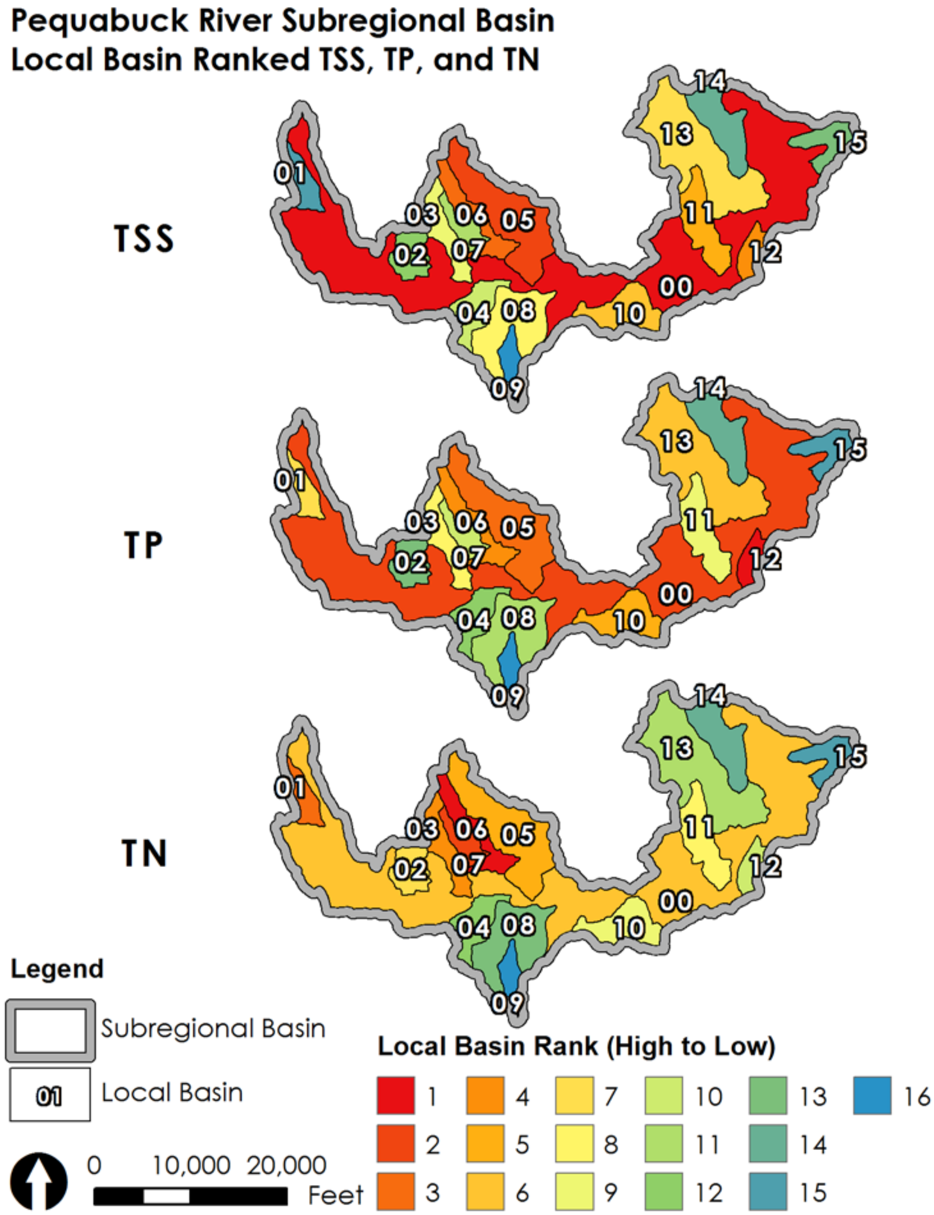

Figure 3.16: Pequabuck Subregional Basin – Local Basin Ranked TSS, TP, and TN

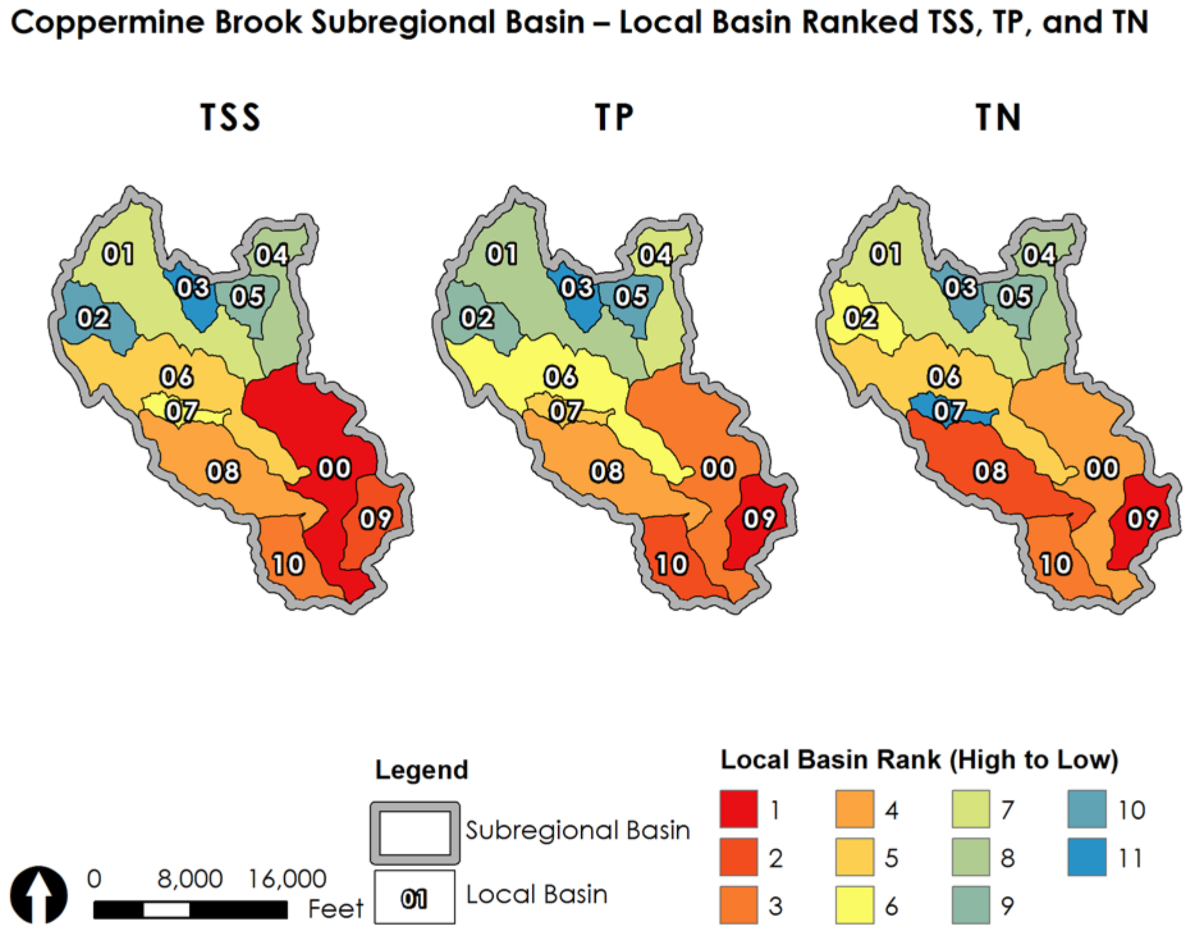

Figure 3.17: Coppermine Subregional Basin: Local Basin Ranked TSS, TP, and TN

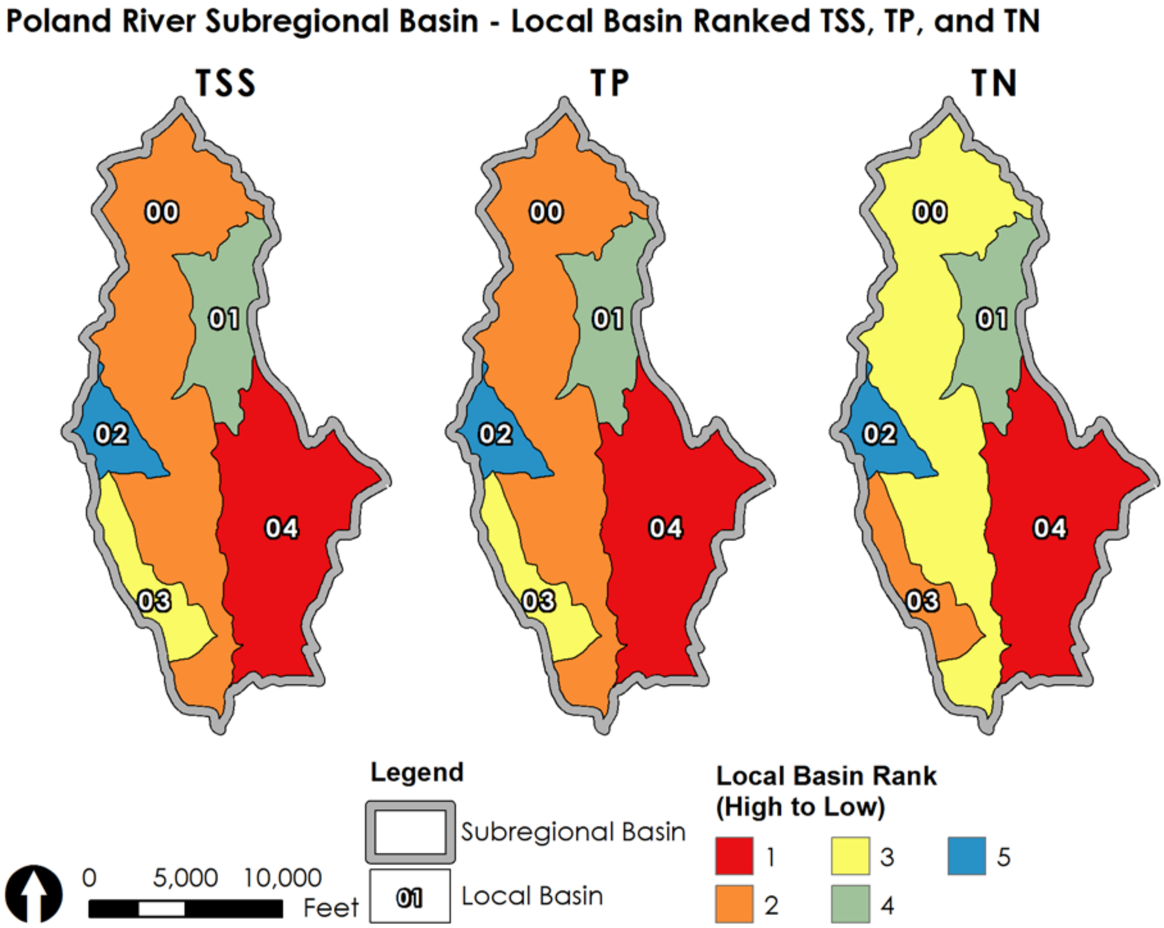

Figure 3.18: Poland Subregional Basin: Local Basin Ranked TSS, TP, and TN

Local Basin Pathogen Loading

The following figures (Figures 3.19 and 3.20) and tables present the annual areal fecal coliform (pathogen) loading by local basin. A shaded map of annual areal loading is shown in Figure 21 while Table 7 presents this data in table format. Figure 22 shows the top five local basins based on annual areal bacteria as well as the proportions of bacteria contributed by urban areas and wildlife for these basins. The local basins contributing the most bacteria per acre were 4314-09 (Coppermine), 4315-10 (Pequabuck), 4315-12 (Pequabuck), 4314-10 (Coppermine), and 4314-00 (Coppermine).

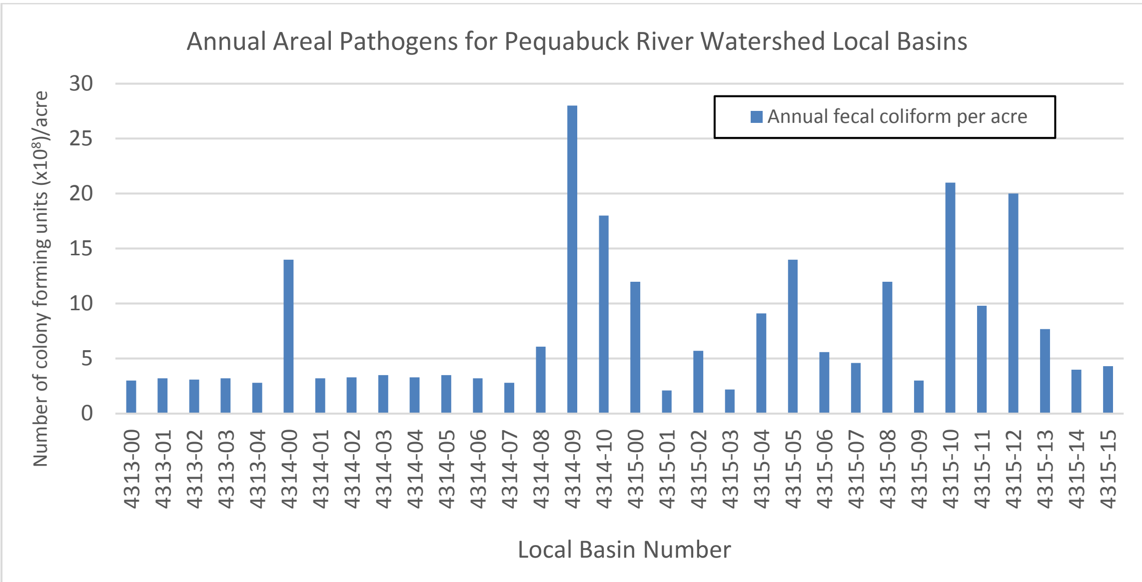

Figure 3.19. Annual Areal fecal coliform Loading for Local Basins within the Pequabuck River Watershed

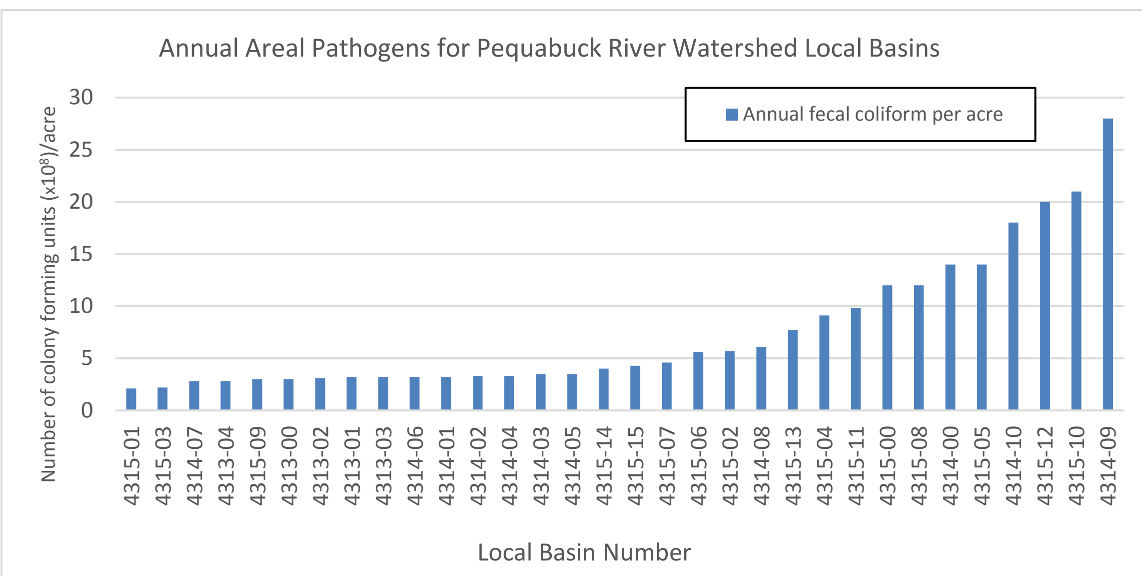

Figure 3.20. Local basins Ranked by Annual Areal fecal coliform loading

Table 3.7: Total Annual Areal Pathogens for Pequabuck River Watershed Local Basins

Rank	Local Basin Number	Annual Fecal Coliform per Acre	Annual Fecal Coliform from Urban Areas	Annual Fecal Coliform from Wildlife
1	4314-09	2.8×10^9	2.81×10^9	3.72×10^7
2	4315-10	2.1×10^9	2.01×10^9	9.05×10^7
3	4315-12	2.0×10^9	1.90×10^9	1.33×10^8
4	4314-10	1.8×10^9	1.70×10^9	1.05×10^8
5	4314-00	1.4×10^9	1.32×10^9	1.11×10^8
6	4315-05	1.4×10^9	1.31×10^9	9.17×10^7
7	4315-00	1.2×10^9	1.09×10^9	1.36×10^8
8	4315-08	1.2×10^9	1.01×10^9	1.66×10^8
9	4315-11	9.8×10^8	8.64×10^8	1.16×10^8
10	4315-04	9.1×10^8	7.32×10^8	1.82×10^8
11	4315-13	7.7×10^8	6.21×10^8	1.54×10^8
12	4314-08	6.1×10^8	4.38×10^8	1.73×10^8
13	4315-02	5.7×10^8	4.33×10^8	1.42×10^8
14	4315-06	5.6×10^8	4.93×10^8	6.42×10^7
15	4315-07	4.6×10^8	3.92×10^8	6.78×10^7
16	4315-15	4.3×10^8	2.07×10^8	2.19×10^8
17	4315-14	4.0×10^8	1.32×10^8	2.64×10^8
18	4314-03	3.5×10^8	1.42×10^5	3.51×10^8
19	4314-05	3.5×10^8	1.10×10^5	3.48×10^8
20	4314-02	3.3×10^8	4.61×10^5	3.28×10^8
21	4314-04	3.3×10^8	2.76×10^7	2.98×10^8
22	4313-01	3.2×10^8	1.50×10^5	3.25×10^8
23	4313-03	3.2×10^8	7.41×10^5	3.23×10^8
24	4314-06	3.2×10^8	3.65×10^7	2.82×10^8
25	4314-01	3.2×10^8	2.30×10^6	3.16×10^8
26	4313-02	3.1×10^8	0.00	3.13×10^8
27	4315-09	3.0×10^8	1.80×10^7	2.86×10^8
28	4313-00	3.0×10^8	5.14×10^6	2.95×10^8
29	4314-07	2.8×10^8	2.73×10^7	2.53×10^8
30	4313-04	2.8×10^8	3.52×10^7	2.42×10^8
31	4315-03	2.2×10^8	1.13×10^8	1.07×10^8
32	4315-01	2.1×10^8	5.36×10^7	1.54×10^8

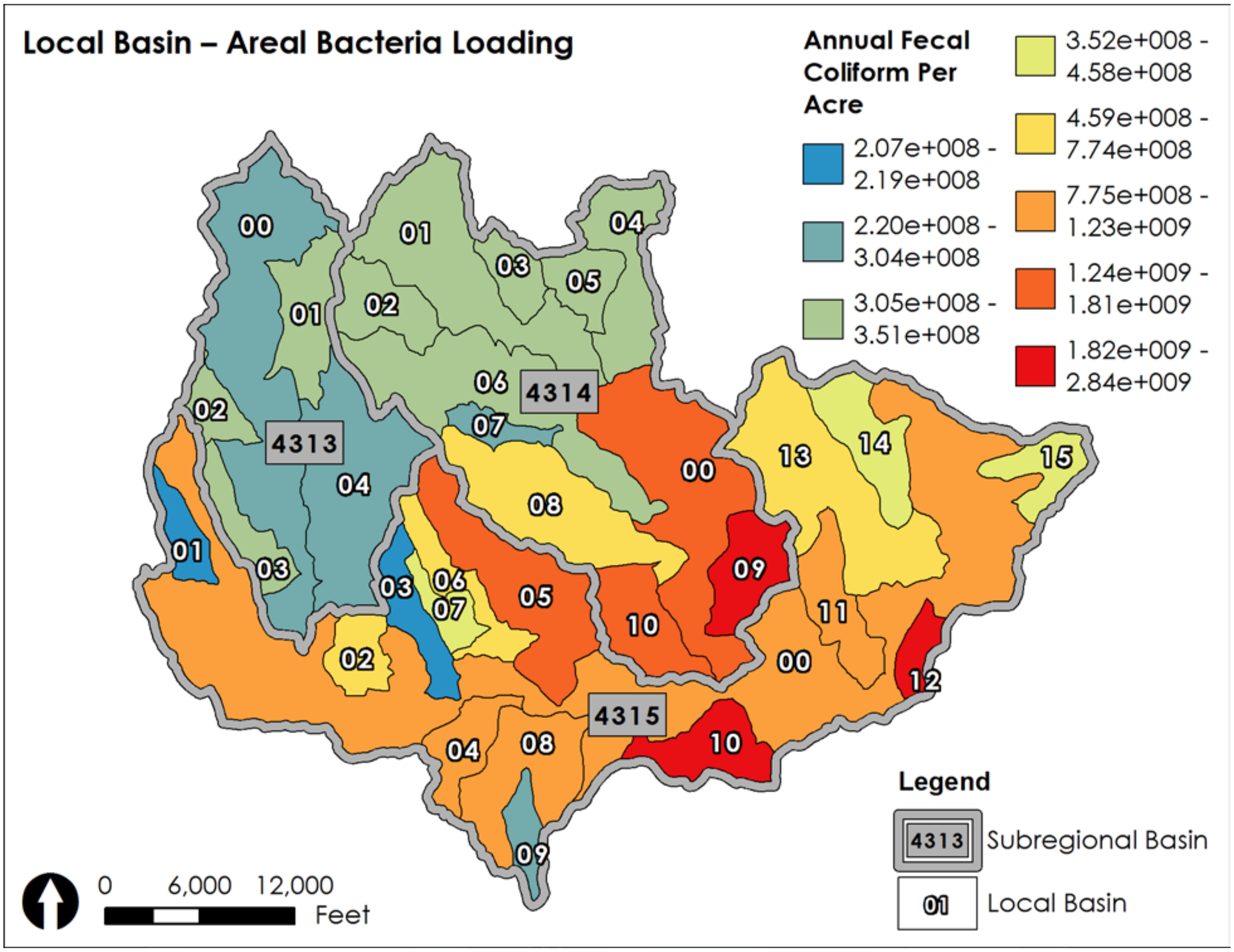

Figure 3.21: Annual Areal Pathogens by Local Basin

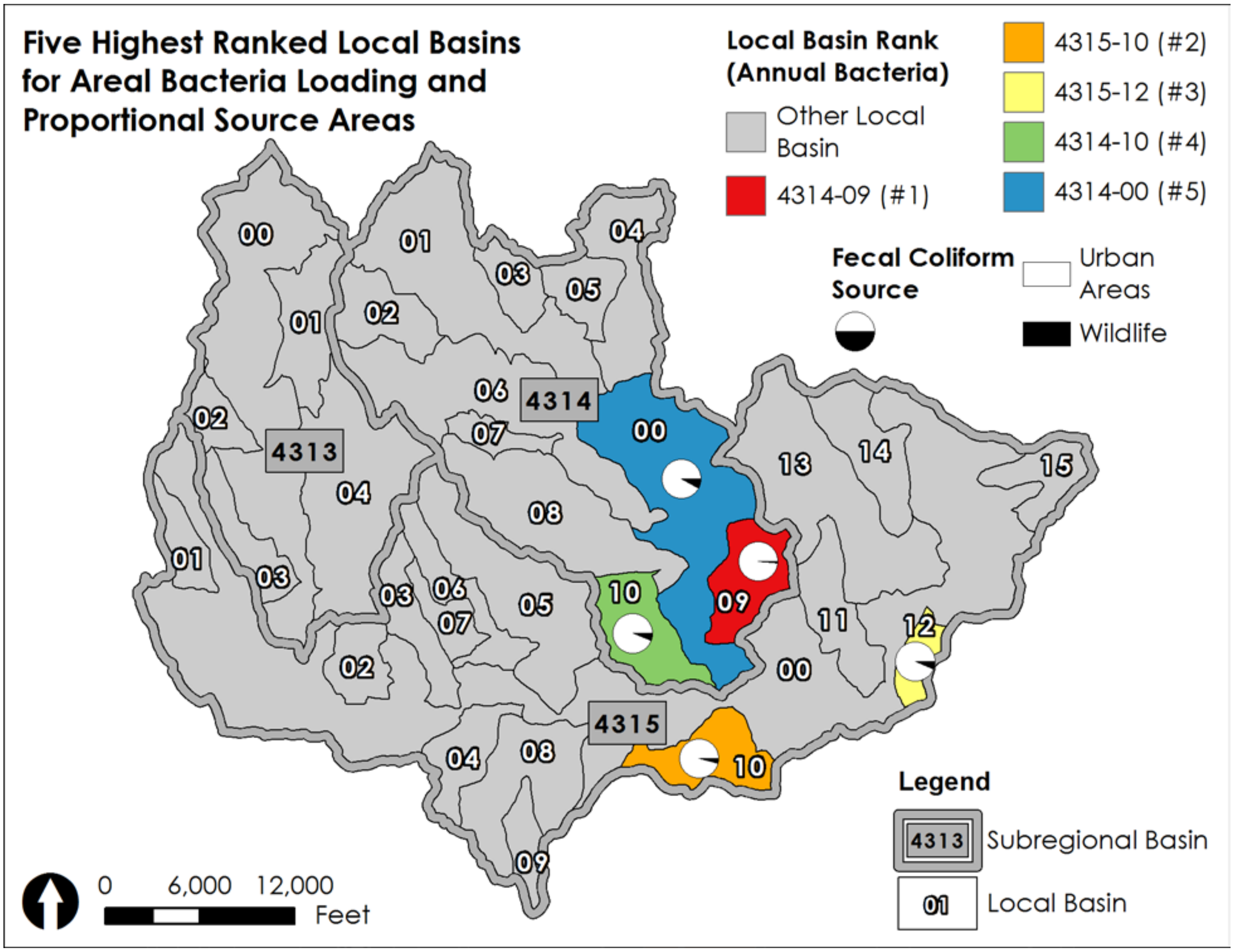

Figure 3.22: Five Highest Ranked Local Basins and Proportional Source Areas for Areal Pathogens

As illustrated above (Figure 3.22), Urban Areas are presented as the primary source contributor to pathogen loading in the Pequabuck River while Wildlife is a minor portion. In Mapshed, urban sourced pathogen loading is derived from multiplying surface runoff by an event mean concentration of 9.6 x 10^3 colony forming units (cfu)/100 ml of fecal coliform (from USEPA, 2001). Sources of pathogens in urban waters are numerous and often difficult to track but are often common in stormwater. As such, it will be necessary to implement vigorous stormwater management efforts to curb NPS loading of all pollutants, and not just fecal coliform bacteria.

Local Basin Annual Discharges

Annual areal discharge was calculated for each local basin and then normalized for catchment area (cfs/acre). The results were then brought into ArcMap 10.2.2 as a table and transferred into shapefile format. Figure 3.23 presents the local basins shaded for annual areal discharge. This data is useful in calculating amount of water moved through the subwatershed in relation to the amount of nutrient/pollutant modeled to be present in the watershed.

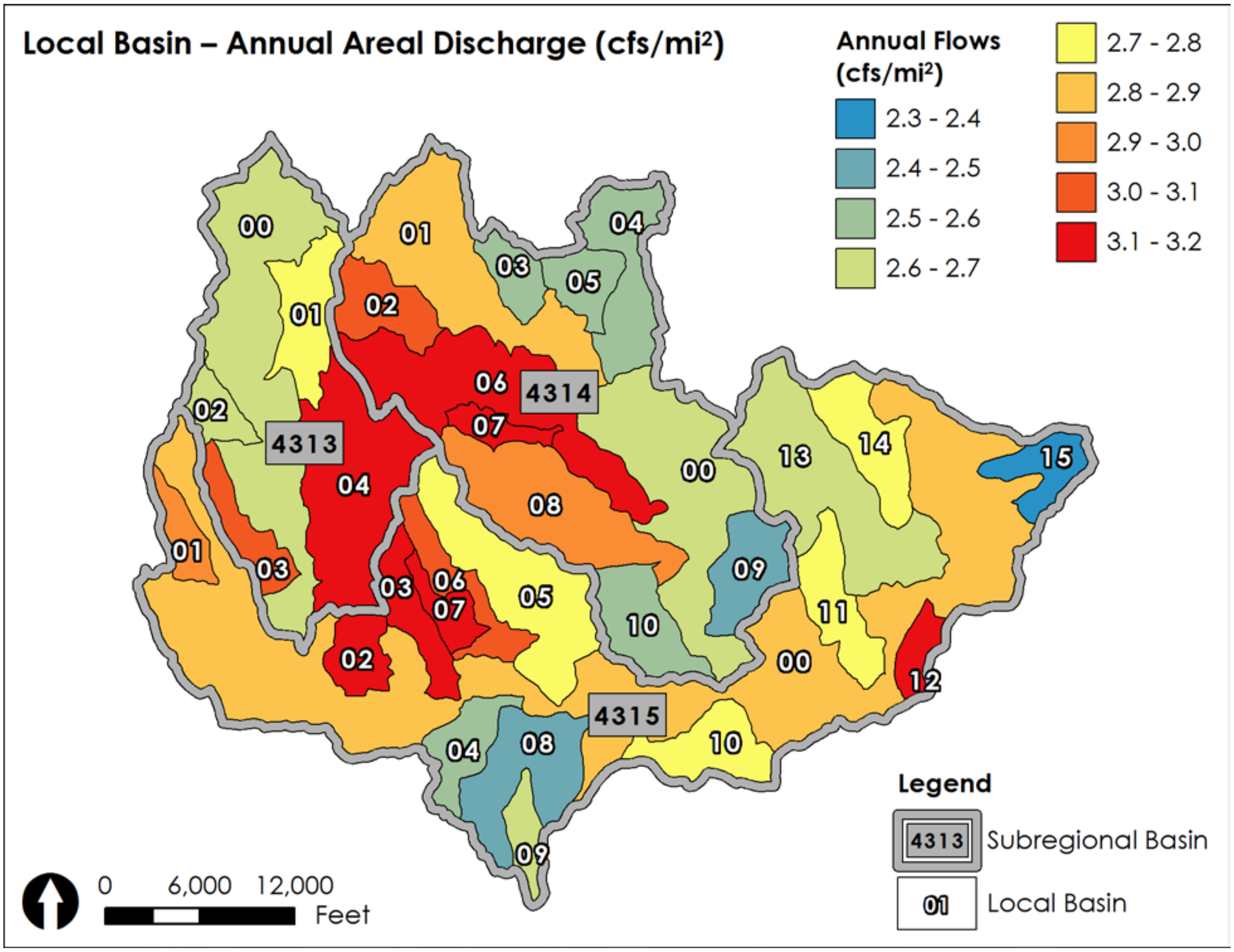

Figure 3.23: Annual Areal Flows for Each Local Basin

3.3 Local Basin Prioritization

Each local basin was assigned a rank from 1-32 based on its annual areal TSS, TP, TN, and total pathogen (bacteria) values; as noted, 'pathogen' is the default nomenclature utilized in the Mapshed model and is utilized to refer to fecal coliform loading. A higher loading merited a ranking closer to 1. The rankings per parameter were averaged and a cumulative ranking was generated. Each parameter was weighted equally in this analysis. While *E. coli* is targeted as a cause for impairment, there are reaches where aquatic use impairment is listed based on "unknown causes." Since coliforms and nutrients/sediment impairments are often linked, this grouping will provide the best overall assessment for prioritization. The results of this analysis are presented in Table 3.8 and Figure 3.24. The local basins contributing the highest amount of non-point source pollution (cumulatively ranked by TSS, TP, TN, and total pathogens) are 4315-00, 4315-05, 4314-09, 4315-12, and 4315-06, respectively. These areas will be focused on first when proposing BMPs and preferred locations as stormwater quality improvement efforts in these subwatersheds will be most effective at reducing pollutant load to the rivers; other basins will still be considered for BMP installation-based integration of information from the Field Assessment Report, but after the those in the priority subwatersheds.

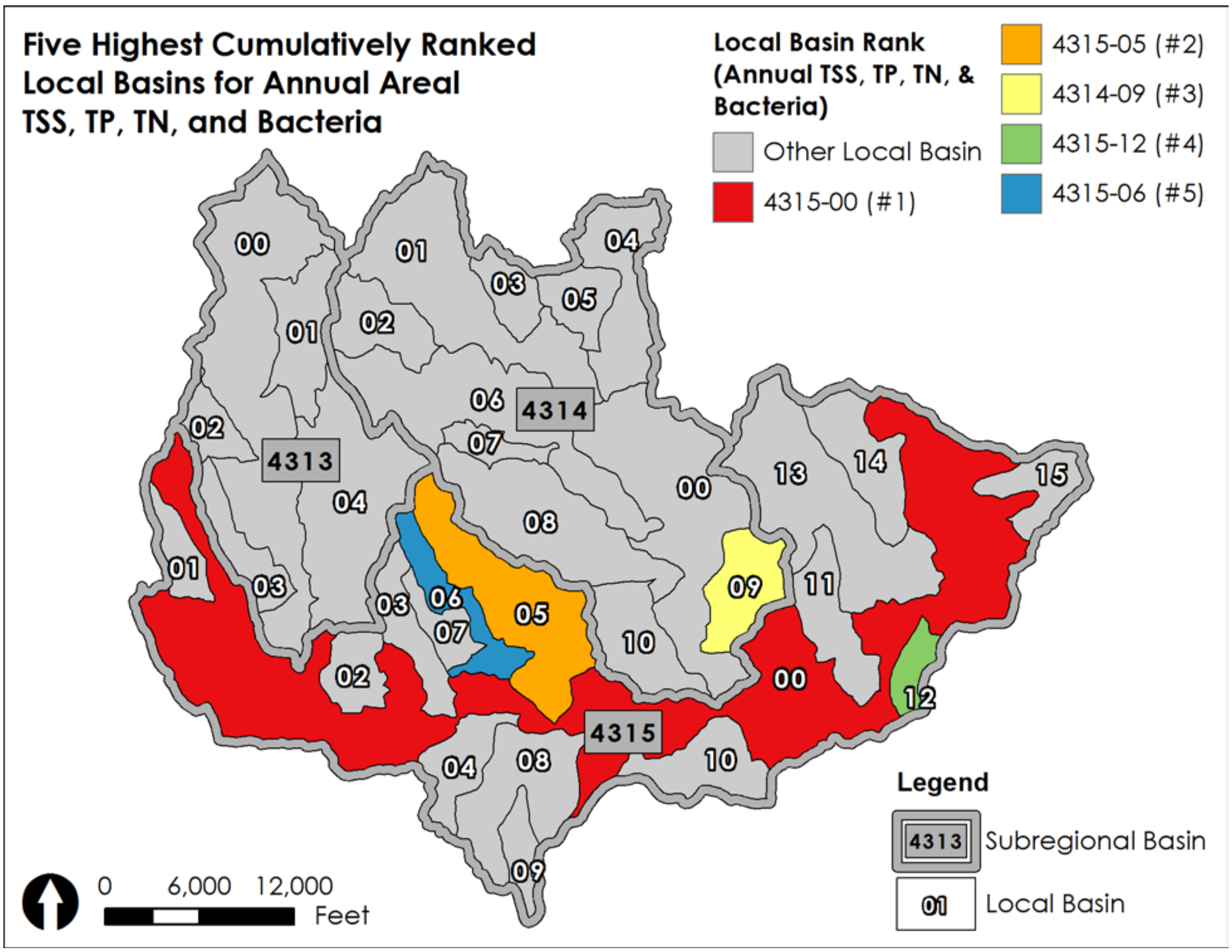

Figure 3.24: Five Highest Cumulatively Ranked Local Basins for Annual Areal TSS, TP, TN, and Fecal Coliform

Table 3.8: Cumulative Pollutant Load Ranking for Local Basins		
Local Basin Number	Cumulative Rank	Real Rank
4315-00	4.00	1 (Most loading)
4315-05	4.25	2
4314-09	5.00	3
4315-12	5.25	4
4315-06	6.00	5
4315-10	6.50	6
4314-00	7.50	7
4314-10	8.00	8
4315-11	9.25	9
4315-13	10.75	10
4315-07	11.25	11
4314-08	12.75	13
4315-08	12.75	13
4315-02	13.50	14
4315-04	14.25	15
4315-03	14.75	16
4315-01	16.75	17
4315-14	18.75	18
4315-15	19.25	19
4314-06	20.50	20
4313-04	21.25	21
4314-04	24.00	22
4314-01	24.25	23
4313-03	24.75	26
4314-02	24.75	26
4314-07	24.75	26
4313-00	25.00	27
4314-05	26.50	28
4315-09	26.75	29
4313-01	27.50	30
4314-03	28.25	31
4313-02	29.25	32 (Least loading)

3.4 Model Quality Control

The USGS National Water Information System (NWIS) is a program that provides current and historic hydrologic information in the United States. Annual surface water statistics were obtained for four Connecticut sites located within or near the Pequabuck watershed (Table 3.9). This data provided annual discharge data, in units of cubic feet per second (cfs). These data were compared to the flows calculated by Mapshed, in order to assess its accuracy. Data was not available for the Pequabuck River Gauge for the time period analyzed; the waterways utilized for comparison were most comparable in the metrics shown for analysis.

Table 3.9: Summary Information for the Four USGS Stations In or Near the Pequabuck River Watershed

Name	Farmington River	Bunnell Brook	Naugatuck River	Quinnipiac River
Site Number	01188090	01188000	01206900	01195490
Town	Unionville	Burlington	Thomaston	Southington
County	Hartford	Hartford	Litchfield	Hartford
Coordinates (Datum)	41°45'19.97", 72°53'13.35" (NAD 83)	41°47'10”, 72°57'55" (NAD 27)	41°40'25”, 73°04'12" (NAD 27)	41°36'12.50”, 72°52'59.52" (NAD83)
Years Active	1978-present	1932-present	1961-present	1988-present
Datum of Gage	178.20 feet above NGVD29	714.00 feet above NGVD29	354.39 feet above NGVD29	138.47 feet above NGVD29
Hydrologic Unit	01080207	01080207	01100005	01100004
Drainage Area (square miles)	378	4.1	99.8	17.4

Table 3.10 presents the mean annual areal flow (cubic feet per second per square mile) from the four closest USGS gaging stations, along with the Mapshed-derived flows for the entire Pequabuck watershed. Data from 2000-2004, the five most recent years available in the Mapshed dataset, was included.

Table 3.10: Average Discharges: 2000-2004: cfs/sq mi					
	Pequabuck (Mapshed)	Farmington	Bunnell Brook	Naugatuck	Quinnipiac
Jan	1.974	1.937	2.268	2.385	2.069
Feb	2.046	1.754	2.195	2.375	2.069
Mar	4.193	2.725	3.902	3.948	2.989
Apr	3.299	3.228	3.659	3.798	2.816
May	2.551	2.048	2.439	2.224	2.299
Jun	3.476	1.944	1.707	1.723	1.954
Jul	1.694	1.087	0.951	0.822	1.149
Aug	1.967	1.180	1.024	0.822	1.092
Sep	2.855	1.159	1.073	0.952	1.149
Oct	2.629	1.392	1.439	1.453	1.552
Nov	2.544	1.640	1.976	1.874	1.667
Dec	3.435	1.921	2.293	2.465	2.069
Average	***2.722***	***1.834***	***2.077***	***2.070***	***1.906***

As illustrated above, the model tended to overestimate stream discharge during several periods of the year but appeared to have the closest agreement overall with Bunnell Brook average discharge.

The Nash–Sutcliffe model efficiency coefficient was also calculated in order to verify that Mapshed model results were acceptable. The Nash-Sutcliffe coefficient is an indicator of the "goodness of fit" between observed and modeled data and is a metric recommended by the American Society of Civil Engineers (Yen 1995) for use in hydrological studies. The efficiency E is defined as "one minus the sum of the absolute squared differences between the predicted and observed values normalized by the variance of the observed values during the period under investigation" (Krause 2005). The coefficient can range from −∞ to 1.0 (a perfect fit). An efficiency greater than or equal to zero signifies that the model possesses utility, with larger values indicating better fit.

The Nash-Sutcliffe coefficient is calculated according to equation 1:

$$NS = \frac{\sum(y-x)^2}{\sum(\mathrm{x}-\bar{\mathrm{x}})^2} \qquad \text{(Equation 1)}$$

where $\bar{x}$ is the mean of the observed (x) data, and y is the model-simulated value. In order to calibrate model hydrology, Princeton Hydro compared mean monthly discharge values normalized for watershed area, obtained from the USGS gaging site to those modeled utilizing Mapshed. For monthly comparisons of hydrology, a Nash-Sutcliffe coefficient for the major Pequabuck watershed and subwatersheds were both 0.17.

While this value is low, it does indicate that the model possesses utility in accurately characterizing discharge in the watershed given a range of possible values from −∞ to 1.

3.5 Mapshed Summary

Princeton Hydro utilized the modeling package *Mapshed* to model the total phosphorus, nitrogen, sediment and fecal coliform loading to the Pequabuck River watershed. The watershed was broken down into three subregional watersheds which were subsequently refined to 32 local basins to provide detailed information related to areas which may be contributing the most pollutants per unit area.

The largest source contributor of pollutants on a subregional basis is the Pequabuck River subregional basin. The estimated primary source areas of TSS in the Pequabuck River subregional basin is that of stream bank erosion which contributes approximately 90% of the sediment load from this basin. The remaining TSS load is derived from various land use sources throughout the subwatershed. The primary source for TP loading in the Pequabuck River subregional basin is derived from over land sources which comprise 55% of the load followed by streambank erosional sources which comprise 30% of the load. Of the over land TP sources, High Density Residential provides the greatest source contributor at 29% of the total P load followed by Low Density Mixed Development which comprises 15% of the load. Groundwater derived sources of TP comprise 16% of the load. Nitrogen loading is derived primarily by groundwater sources (55%) followed by septic systems (10%) and stream bank erosion (6%). Pathogen loading by fecal coliform bacteria seems to be mostly from the Coppermine Brook subwatershed, and from local basins adjacent to the Pequabuck subwatershed. A majority of the pathogen loading can be attributed to Urban sources.

The data contained herein illustrated the necessity of proper stormwater management for the approximately 40% developed land cover of the Pequabuck subregional basin. Urban land use types not only contribute significant NPS pollution from surface water flows over these areas but the high impervious coverage significantly alters the hydrologic cycle through the promotion of increased rate and volume of surface water flow and lesser infiltration and aquifer replenishment. Unspecified Urban Stormwater was identified as potential sources for bacteria in all three subregional watersheds in the TMDL (CT DEEP, 2009).

4.0 Best Management Practices

4.1 Bacteria Load Reductions

This section corresponds to EPA element three of the EPA nine-elements and consists of a description of the management measures necessary to achieve required load reductions as well as a description of the areas where those measures will be implemented. In essence, this is the heart of the Watershed Based Plan (WBP), and describes the actions, practices, rules, and devices that can be used to address nonpoint source loading in the watershed. The management measures will build upon the strategies highlighted in both the TMDLs and the MS4 permit requirements as the antecedents to the WBP and will incorporate the findings of the technical watershed characterization and pollutant loading models as refinements and criteria for prioritization. The remainder of this section will summarize and synthesize known problems, identify general management measures for the pollutants of concern, briefly review some of the governing regulations, and discuss specific implementation projects. These projects are meant to serve as templates for similar implementation projects throughout the watershed. Where possible, the designs and management measures will build on existing, proven, and approved management schemes and programs; the Connecticut Stormwater Quality Manual, published by CT DEEP (https://www.ct.gov/deep/cwp/view.asp?a=2721&q=325704, 2004 (Updated 2012)), contains a wealth of information and will be a primary source for much of this information. The pollutant removal efficacy and the field methodology for assessing candidate implementation sites will also be discussed.

Princeton Hydro identified twelve (12) locations that could potentially be utilized to implement various stormwater based BMPs. Princeton Hydro choose sites based on their relative contributions of NPS loadings with preference for those areas which are contributing elevated bacteria, nutrient, and sediment loading to the river(s). Where appropriate, Princeton Hydro looked for public sites such as schools, libraries, or municipal buildings, where buy in for implementation would potentially be higher than privately owned land. Still, some private land was identified due to proximity to impacted waterbodies and overall potential for restoration. The sites chosen are identified in the figure below (Figure 4.1). Following these twelve (12) specific sites, general watershed-based measures which may be applied throughout the watershed to reduce NPS loadings and improve water quality are described.

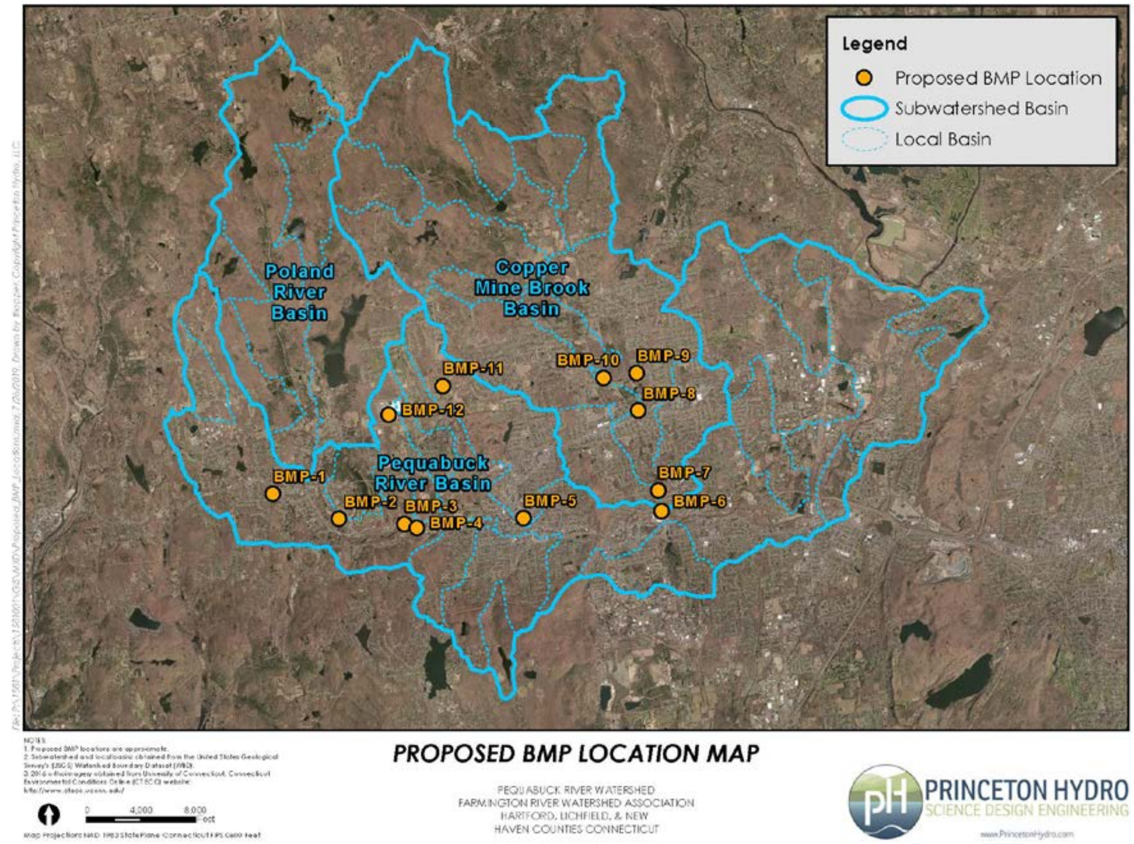

Figure 4.1: Proposed BMP Locations

An estimation of the pollutant load that would be flowing through or treated by each site-specific BMP is provided in Table 4.1 below.

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Table 4.1: Annual Pollutant Loading for BMP Stations						
Station	Local Basin	Catchment Area (Ha)	TN Load (Kg/yr)	TP Load (Kg/yr)	TSS Load (Kg/yr)	Fecal Coliform Load
BMP-1	4315-00	0.95	11.93	2.50	2,012.13	8.61E+10
BMP-2	4315-00	2.84	35.68	7.48	6,010.09	2.58E+11
BMP-3	4315-00	0.97	12.19	2.55	2,054.77	8.80E+10
BMP-4	4315-00	0.80	10.05	2.11	1,695.07	7.26E+10
BMP-5	4315-05	1.26	15.83	3.31	2,662.59	1.14E+11
BMP-6	4315-00	0.42	3.22	0.88	292.57	3.81E+10
BMP-7	4314-00	0.45	3.96	0.93	403.24	4.08E+10
BMP-8	4314-00	0.61	7.66	1.61	1,292.74	5.53E+10
BMP-9	4314-00	1.00	8.79	2.07	897.66	9.07E+10
BMP-10	4314-00	0.42	3.69	0.87	377.84	3.81E+10
BMP-11	4315-05	0.25	2.20	0.52	225.44	2.27E+10
BMP-12	4315-03	11.36	142.72	29.89	24,032.21	1.03E+12

Please note, for computation of annual loading on a site-specific basis, Princeton Hydro utilized resources from the Minnesota Stormwater Manual MPCA calculator for nitrogen, phosphorus and solids. Fecal coliform modeling was computed by utilizing the event mean concentration listed in the Mapshed manual for urban areas (9.6×10^3/100 mL) which was subsequently multiplied by the depth of water over the site area on an annual basis. This load was subsequently reduced by 90% to account for bacteria die-off as indicated in the Mapshed User's Manual. Please note that fecal coliform represents all coliform bacteria in feces but only a portion constitute *E. coli*.

As this WBP is focused on working towards specified TMDL reductions it is appropriate to provide a summary of pollutant removal efficacies for the examined stormwater management measures. This is a surprisingly difficult task; while there is voluminous scientific literature examining different aspects of pollutant removal efficacy tied to various management practices, there is little in the way of a comprehensive, unified repository. This is partially due to the manner of implementation, research practices, and funding sources, which includes homeowners, corporate entities, academic institutions, commercial purveyors of structures and technologies, and all levels of government. This includes various grant processes in which federal monies are made available to the States for distribution and administration and implementation through sponsorship at a municipal level. This disconnected process impedes development and population of a centralized database.

Some of the difficulty in ascertaining these values in estimating load reductions is also related to the physical realities of these types of projects, which is that project sites and conditions are inherently variable throughout the country, as is the pollutant loading regime, and the uncertainties associated with the design and construction. For this reason, among others, the *Connecticut Stormwater Quality Manual* advocates that removal efficacy and load reductions are best determined through empirical sampling, that is measuring loads or concentrations and determining the differences between influent and effluent values and integrating these values for a period of time or area. For planning purposes though, it is important to determine at least an estimate of load removals. It should also be mentioned that while these difficulties persist for abiotic pollutants, like nutrients, solids, hydrocarbons, metals, and other substances, the problems are compounded for the investigation of bacteria and pathogens which are living organisms and therefore subject to reproduction and senescence and other factors. For the purposes of this WBP, some of this data will be synthesized using several sources including estimated load removal efficiency from the EPA STEPL model (Spreadsheet Tool for the Estimation of Pollutant Load), the *Pennsylvania Stormwater Best Management Practices Manual*, and several literature review papers on the removal of indicator bacteria as well as commercial studies of certain products. A synthesis table is provided below.

Table 4.2: Pollutant Removal Efficiency				
Management Measures	Removal Efficiency			
	Nitrogen	Phosphorus	Solids	Bacteria
Stormwater Wetlands	50%	30%	90%	70%
Infiltration Practices	50%	60%	80%	70%
Vegetated Filter Strips	30%	30%	80%	10%
Tree Well / Tree Filter	50%	60%	83%	85%
Permeable Pavers	Insufficient Data	45%	74%	Insufficient Data
Catch Basin Inserts	20%	50%	60%	77%

An overview of the design, limitations, costs and technical considerations of various BMPs mentioned in this document are provided below.

4.2 BMP Types

Stormwater Wetlands

Stormwater wetlands are a stormwater management measure meant to mimic wetlands and thus provide some of the same ecological benefits. Pollutant removal is based on some of the same mechanisms observed in natural wetlands: mechanical filtration and sedimentation through wetland vegetation; microbial decomposition; adsorption to sediments and vegetation; biological uptake; and exposure to sunlight. Maintaining wetted conditions is important in order to foster the growth of wetland plants which may be accomplished through interception of the water table or through use of a liner.

There are several design types including shallow wetlands, extended detention shallow wetlands, and pond/wetland systems, which vary chiefly in the size, depth, and conformation of standing water features.

These systems exhibit efficient removal of particulates (including bacteria) and soluble pollutants, are often attractive especially when utilizing native wildflowers, provide some wildlife habitat value, and help to attenuate peak flows. As mentioned above, they are sensitive to maintaining moisture levels capable of supporting wetland vegetation, are more expensive than traditional basins, require a large area relative to the catchment, can potentially create thermal impairments (which is common to all ponding structures), and can provide a safety hazard and potential habitat for mosquitoes.

All designs must account for pretreatment (often a forebay or similar device), treatment in the system, conveyance, maintenance reduction (including trash racks and proper orifice sizing), and landscaping.

Where site conditions allow, stormwater wetland designs should be incorporated as a treatment method to limit bacteria loading. Implementation will depend on opportunities of funding and land acquisition. A pond/wetland system schematic showing the various design elements is provided below.

Treatment Practice Type

Primary Treatment Practice ●
Secondary Treatment Practice

Stormwater Management Benefits

Pollutant Reduction

Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	▣
Floatables*	■
Oil and Grease*	■
Dissolved Pollutants	▣

Runoff Volume Reduction

Runoff Capture	■
Groundwater Recharge	□

Stream Channel Protection	■
Peak Flow Control	■

Key: ■ Significant Benefit
▣ Partial Benefit
□ Low or Unknown Benefit

*Only if a skimmer is incorporated

Implementation Requirements

Cost ....Moderate
Maintenance..........................Moderate

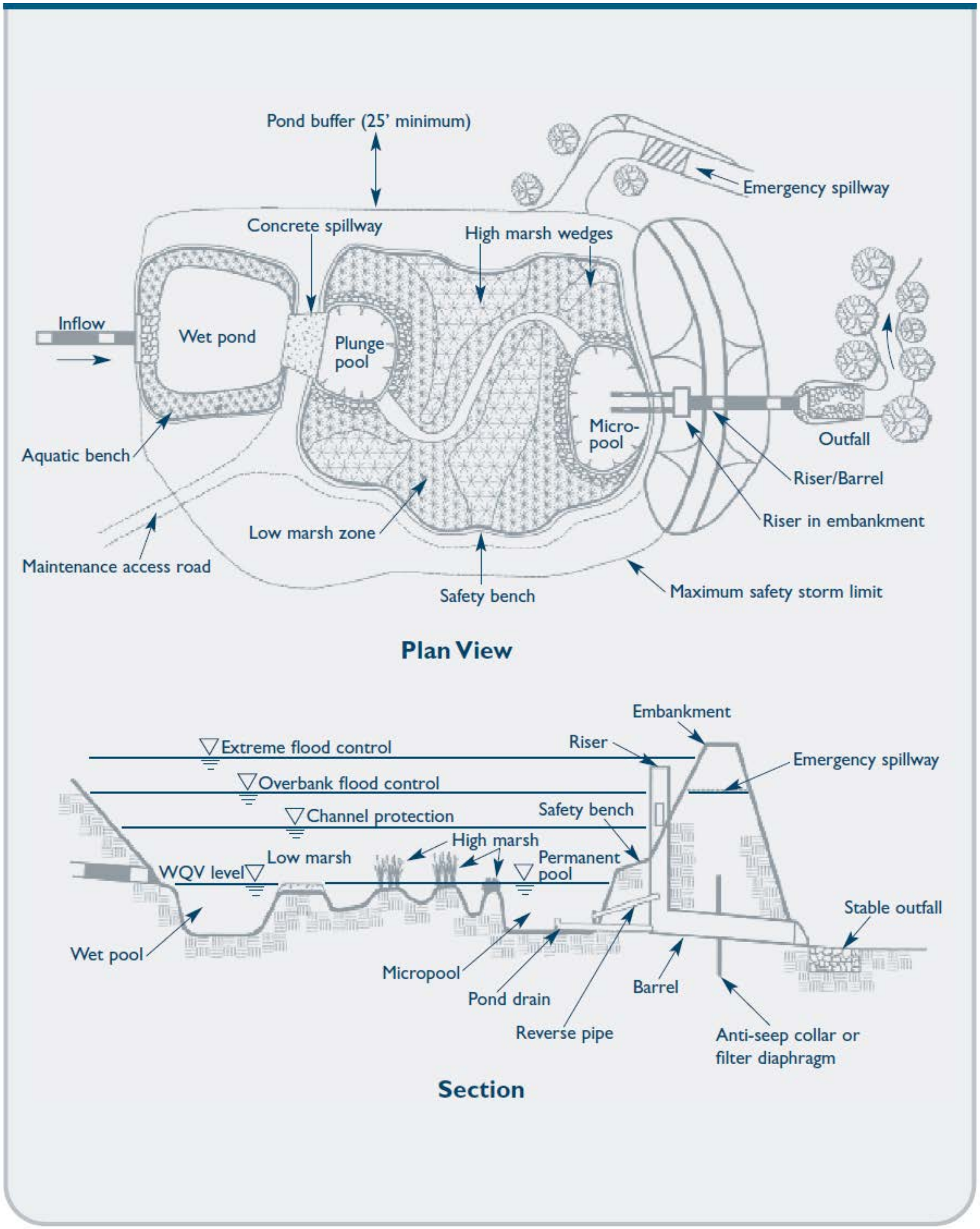


Figure 4.2: Pond/Wetland System. Source: CT Stormwater Quality Manual

Infiltration Practices

As the name suggests, these structures work by capturing runoff and then infiltrating the captured volume into the groundwater over a design period. This BMP is one of three primary treatment types considered effective for the treatment of bacteria. Because of their mode of action, infiltration of captured runoff, these types of structures are effective for removing fine and coarse particulates and associated nutrients. Soluble materials and dissolved solids may adsorb to soil materials. Vegetations components can aid in nutrient uptake and provide substrate stability.

There are two basic design variants, the infiltration trench, a longitudinal feature (like a bioswale), and the infiltration basin (Including some types of rain gardens). Besides solids, pathogen, and nutrient control, these systems provide groundwater recharge, reduce runoff volume and peak flows, avoid thermal impairments, and can be sited in small spaces. They are prone to clogging and failure due to site constraints such as soil infiltration rates, and if ponding may provide mosquito habitat. There is also the potential for groundwater contamination depending on the characteristics of the drainage basin (i.e. Industrialized drainage areas) and they require frequent maintenance.

A schematic design of an infiltration trench in a parking lot application is provided below.

Treatment Practice Type

Primary Treatment Practice	●
Secondary Treatment Practice	

Stormwater Management Benefits

Pollutant Reduction	
Sediment	■
Phosphorus	■
Nitrogen	■
Metals	■
Pathogens	▪
Floatables*	▪
Oil and Grease*	▪
Dissolved Pollutants	▪
Runoff Volume Reduction	
Runoff Capture	■
Groundwater Recharge	■
Stream Channel Protection	▪
Peak Flow Control	▪

Key: ■ Significant Benefit
▪ Partial Benefit
□ Low or Unknown Benefit

*Only if a skimmer is incorporated

Implementation Requirements

Cost ....Moderate
Maintenance..........High

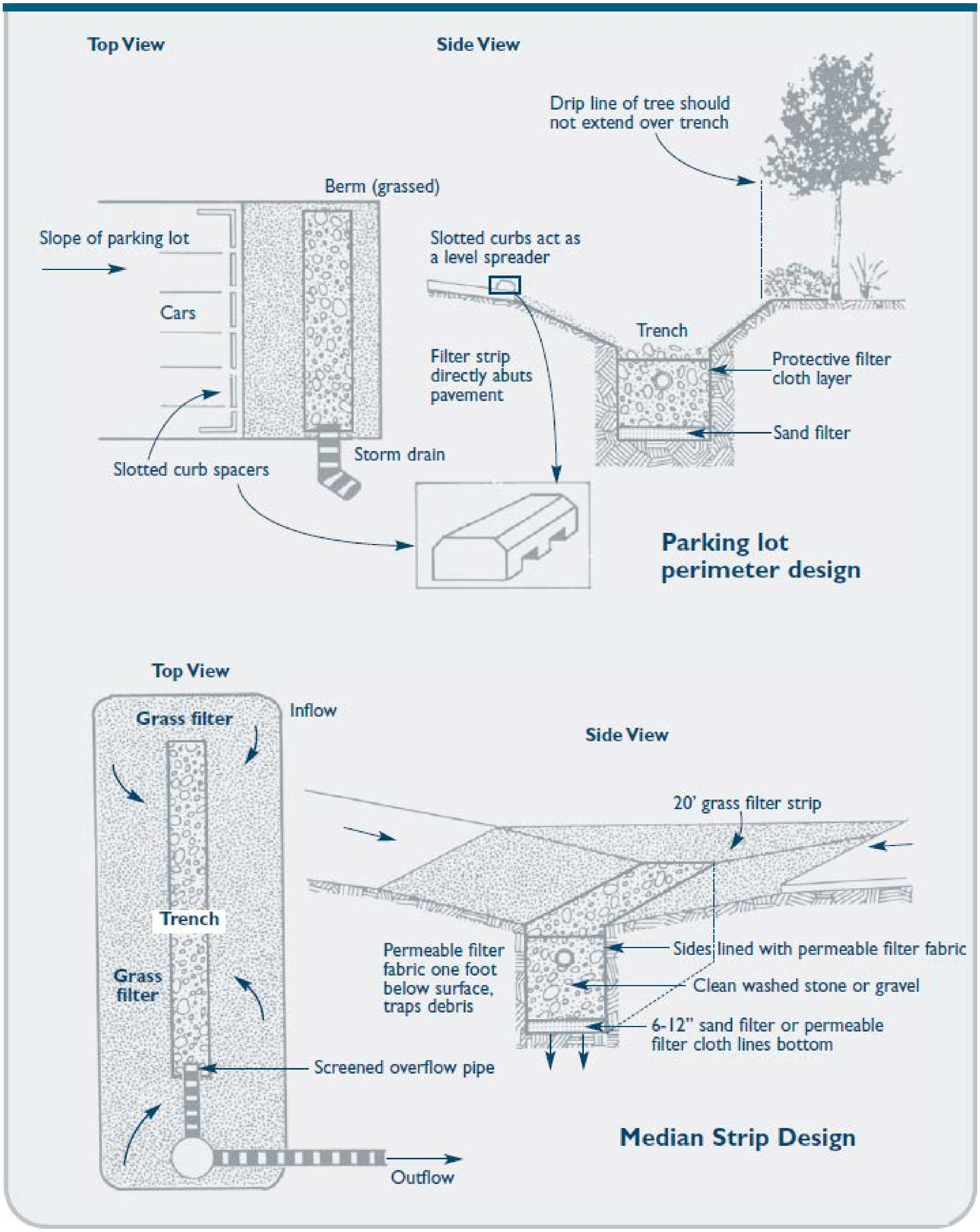


Figure 4.3: Infiltration Trench Design for Parking Lots. Source: CT Stormwater Quality Manual

Vegetated Filter Strips

Vegetated filter strips are grassed or otherwise vegetated slopes sited between a source of pollution, typically an impervious area such as a parking lot, and a receiving waterbody. Overall, they are of somewhat limited utility for the control of pollutants and stormwater, but are beneficial as pre-treatment devices. However, they do have some particular application strengths when they are paired with other stormwater management practices, where they can infiltrate or filter runoff from discrete areas, reduce directly connected impervious areas, serve as retrofits or receive treated runoff from other BMPs, or be used as part of stream buffer systems, or applied to side slopes.

In particular their suitability in this watershed, is best envisioned as part of a larger system of BMPs, in what might be called a treatment train; in between parking lots, roads, or other impervious areas, and streams; and in conjunction with other riparian buffer enhancements. General conformation would be a linear feature on a side slope. A schematic design is provided below.

Treatment Practice Type

Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	▣
Phosphorus	▣
Nitrogen	▣
Metals	▣
Pathogens	□
Floatables	□
Oil and Grease	□
Dissolved Pollutants	□
Runoff Volume Reduction	
Runoff Capture	▣
Groundwater Recharge	▣
Stream Channel Protection	▣
Peak Flow Control	□

Key: ■ Significant Benefit
▣ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	■
Treatment Train	■
Ultra-Urban	□
Stormwater Retrofits	■
Other	□

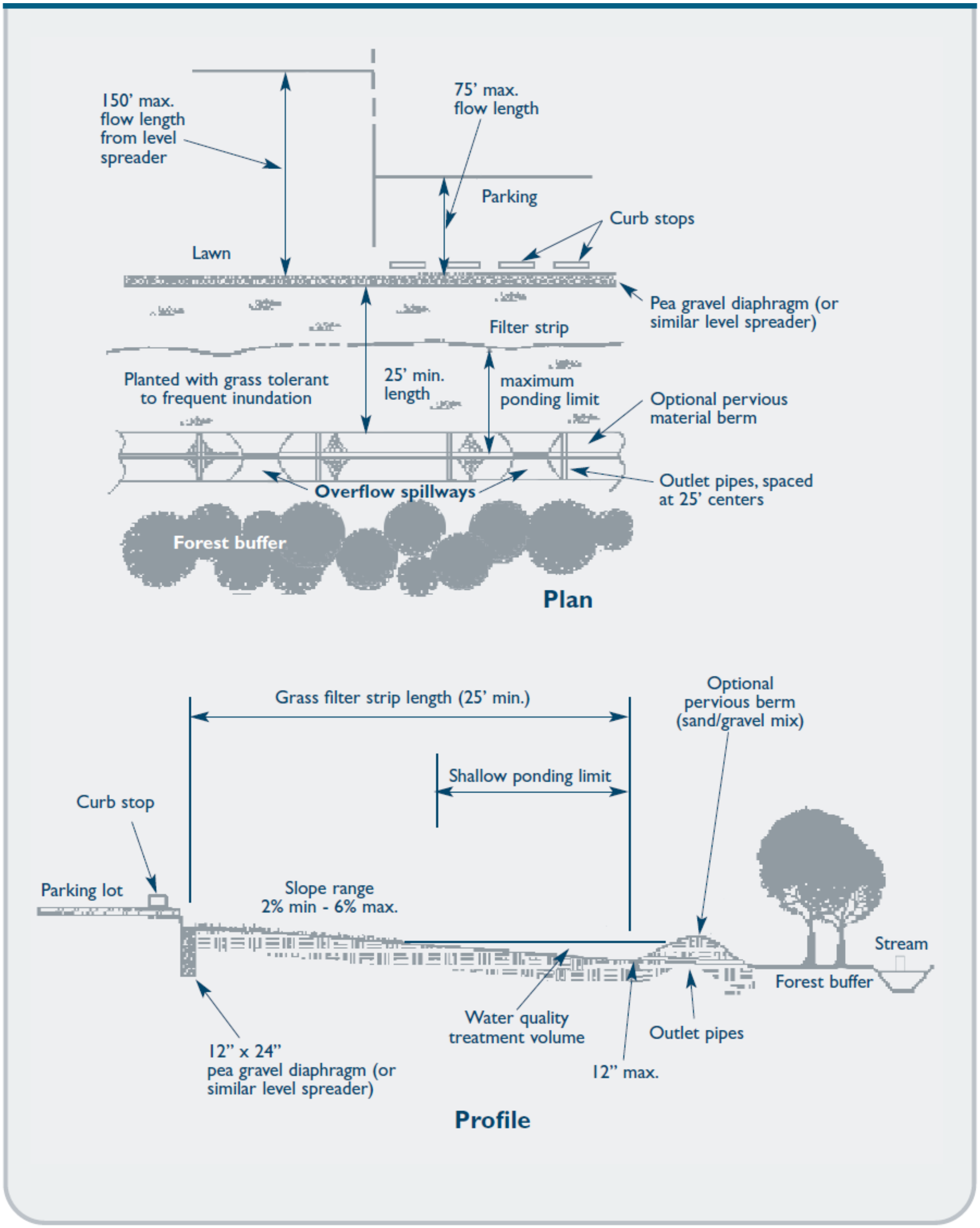


Figure 4.4: Vegetated Filter Strip Schematic. Source: CT Stormwater Quality Manual

Tree Well/Tree Filter Unit

Tree wells and tree filters may be considered hybrid types of design, an intersection of bioretention, bioinfiltration, catch basin insert, and media filter technology. In practice, the stormwater is intercepted through a curb cut or surface grate and treatment is provided by a soil or filter media in tandem with a central tree and other plantings. Treated stormwater can then be discharged via an underdrain to existing conveyance structures for tree filter design or simply infiltrated into groundwater for tree wells if soils and groundwater table are suitable. Pollutant removal efficiency is reportedly high.

The main advantage is that these systems are compact, may act as standalone BMPs, or be integrated as retrofits to existing stormwater systems. Mechanical filtration and adsorption to soils particles is the main treatment method for nutrients, solids, and pathogens, but nutrient assimilation through vegetative uptake is also important. Removal efficacy can be improved by altering composition of the filter media. For instance, the commercial media Bacterra has reported removal rates of pathogens of up to 99%. The soil/filtering media are commercially available or may be created and amended to specification. The units are also available as manufactured treatment devices (MTD) or may be constructed onsite. The disadvantages are common to all infiltration methods, namely that site constraints, such as soil confining layers, could preclude the installation of tree wells, and also that infiltration can serve as a pollution vector to groundwater. There are few drawbacks to tree filter designs, although costs can be high.

Schematics of a tree well, an infiltration system, as well as a commercial tree filter concept are provided.

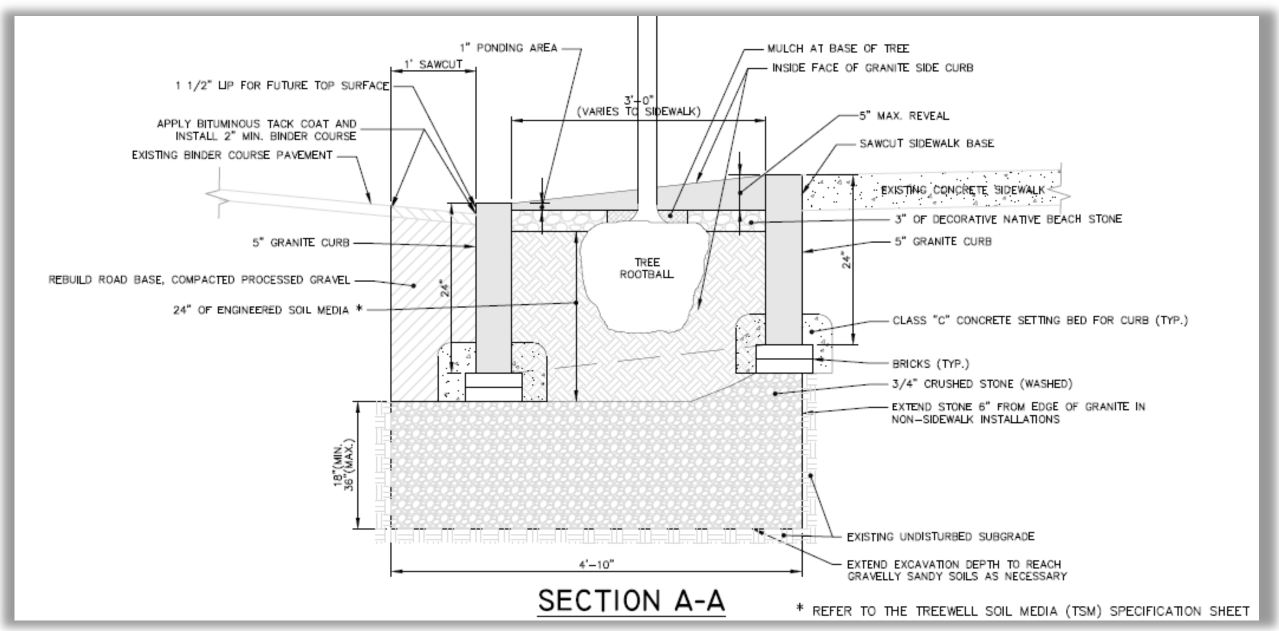


Figure 4.5: Tree Well Schematic. Source: Eastern Connecticut Conservation District

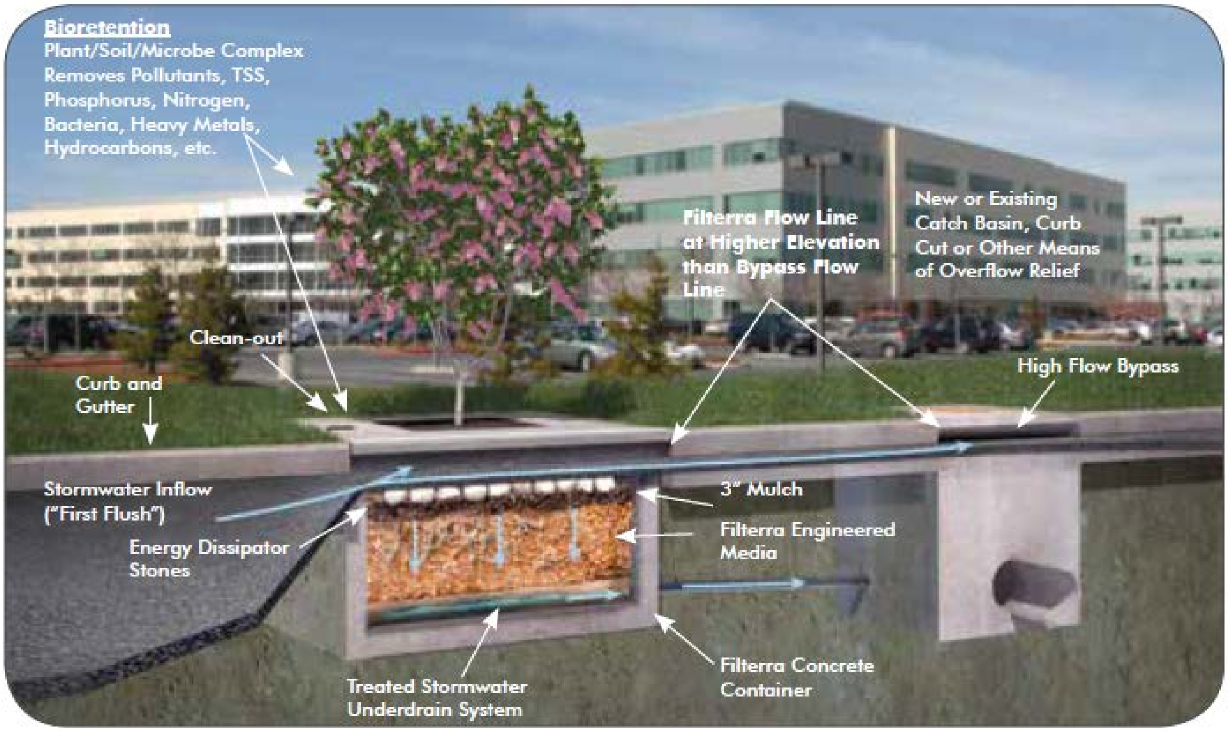


Figure 4.6: Tree Well Schematic. Source: Contech Engineered Solutions

Princeton Hydro identified twelve (12) locations that could potentially be utilized to implement various stormwater based BMPs mentioned above. Where appropriate, Princeton Hydro looked for public sites such as schools, libraries, or municipal buildings, where buy in for implementation would potentially be higher than privately owned land. Still, some private land was identified due to proximity to impacted waterbodies and overall potential for restoration. Each of the twelve (12) sites is described below.

Permeable Pavers

Permeable pavement is designed to allow rain and snowmelt to pass through it, thereby reducing runoff from a site, promoting groundwater recharge, and filtering NPS pollutants. Permeable pavers are an alternative to conventional asphalt or concrete paving surfaces. Various materials may be utilized depending on the site constraints and load bearing restrictions of a project and may include: Modular concrete paving blocks, modular concrete or plastic lattice, soil enhancement technologies, or other natural materials such as gravel, cobble, wood, mulch, and natural stone.

These practices may be utilized as a single BMP or, more frequently, utilized as a secondary BMP in conjunction with other practices to further improve water quality from a site.

Treatment Practice Type

Primary Treatment Practice
Secondary Treatment Practice ●

Stormwater Management Benefits

Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Partial Benefit
Nitrogen	Partial Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Low or Unknown Benefit
Oil and Grease	Low or Unknown Benefit
Dissolved Pollutants	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Significant Benefit
Groundwater Recharge	Significant Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Partial Benefit

Key: Significant Benefit
Partial Benefit
Low or Unknown Benefit

Suitable Applications

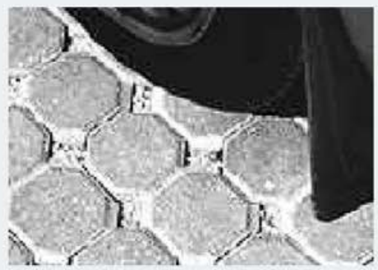
Pretreatment	Significant Benefit
Treatment Train	Significant Benefit
Ultra-Urban (low traffic)	Significant Benefit
Stormwater Retrofits	Significant Benefit
Other	Low or Unknown Benefit

Figure 11-S6-1 Examples of Permeable Pavement Applications

Modular Concrete Pavers

Parking Lot with Porous Surface

Overflow Parking Area



Concrete Paver Driveway

Low Use Parking Area

Plastic lattice Turf Pavement

Source: Nonpoint Education for Municipal Officials (NEMO) web site.

2004 Connecticut Stormwater Quality Manual

11-S6-3

Figure 4.7: Types of Permeable Pavement Solutions

Catch Basin Inserts

Catch basin inserts are a general category of proprietary devices that have been developed to filter runoff entering a catch basin. Catch basin inserts function similarly to media filters but on a localized, catch basin scale. While these units are not highly recommended by CT DEEP due to limited peer-reviewed performance data, there is some proprietary data from certain manufacturers that has shown considerable promise regarding their ability to reduce NPS pollutants of concern, particularly, bacteria and phosphorus.

Catch basin inserts would likely not be utilized as a sole BMP measure but instead may be utilized to augment larger-scale, more site-specific BMPs. A possible exception to this may be on sites with significant limitations where other BMPs would not be feasible.

Treatment Practice Type

Primary Treatment Practice	
Secondary Treatment Practice	●

Stormwater Management Benefits

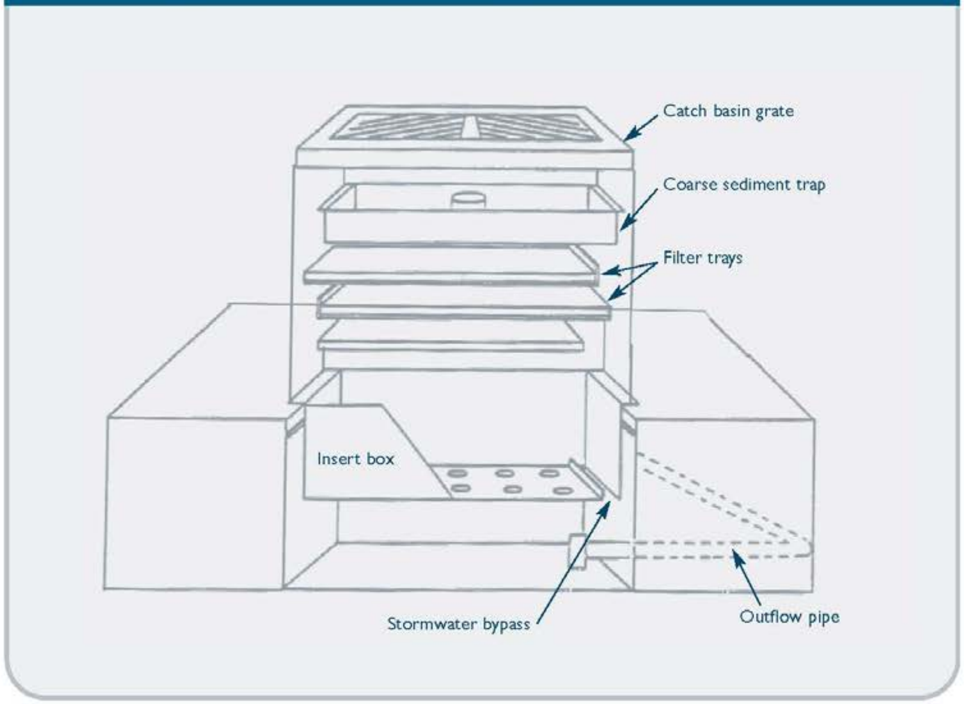
Pollutant Reduction	
Sediment	Partial Benefit
Phosphorus	Low or Unknown Benefit
Nitrogen	Low or Unknown Benefit
Metals	Partial Benefit
Pathogens	Low or Unknown Benefit
Floatables	Partial Benefit
Oil and Grease	Partial Benefit
Dissolved Pollutants	Low or Unknown Benefit
Runoff Volume Reduction	
Runoff Capture	Low or Unknown Benefit
Groundwater Recharge	Low or Unknown Benefit
Stream Channel Protection	Low or Unknown Benefit
Peak Flow Control	Low or Unknown Benefit

Key: ■ Significant Benefit
■ Partial Benefit
□ Low or Unknown Benefit

Suitable Applications

Pretreatment	Significant Benefit
Treatment Train	Significant Benefit
Ultra-Urban	Significant Benefit
Stormwater Retrofits	Significant Benefit
Other	Low or Unknown Benefit

Figure 11-S9-1 Example of Tray-Type Catch Basin Insert



Source: City of Knoxville, 2001.

2004 Connecticut Stormwater Quality Manual

11-S9-3

Figure 4.8: General Catch Basin Schematic

4.3 BMP and Site Selection Process

The BMPs identified in section 4.2 were selected as they represent green stormwater management techniques that have the ability to reduce bacteria, phosphorus, nitrogen, and sediment. These practices are recognized in State BMP manuals and have been proven in the field to provide measurable water quality improvements.

The sites presented in section 4.3 were selected as sites where stormwater management could have a high probability of implementation and success. They were first identified through use of information from the Field Assessment (Section 2.4). Sites were further selected through the consideration of the pollutant data with effort placed on selecting sites along the most impacted portion of the river (relative to priority areas as modeled in Section 3). These sites are not inclusive off all potential problem sites in the watershed but include sites where a high probability of improvement is likely. Implementation of these projects would need landowner and local buy-in and funding, likely, through grant sources.

Broader-scale recommendations are also included in this document and include topics such as ordinances related to pet wastes and impervious area coverage. Furthermore, discussions are provided related to the upkeep of MS4 requirements associated with street sweeping, outfall identification, and routine water quality monitoring. Coordination of municipalities, watershed stakeholders, and local residents is critical in patching a mosaic of funding sources to implement projects to improve water quality.

4.4 Pequabuck River Watershed Recommended BMPs

BMP-1

BMP-1 is located at a Rite Aid pharmacy which sits at the corner of Main Street and South Main Street in the Town of Plymouth. The area consists of approximately 2.35 acres of impervious area associated with the parking area and roof of the pharmacy.

A vegetated swale could be implemented on the south side of the parking area near the river proper. This swale would serve to receive sheetflow from the surrounding impervious area prior to entering the river. In addition, this area was marked as poor during the visual assessment phase of the project with issues related to bank stability and infilling from concrete and other commercial / industrial products.

Installation of a vegetated swale would be the least costly but would still require buy-in from the property owner. In addition, the strip of parking on the south side of the property would need to removed. Maintenance would be associated with annual inspections of the filter strip and removal of invasives. The strip could be planted with a mixture of native, water tolerant species and may include those that are beneficial to pollinators such as milkweed (*Asclepias* sp.) and bee balm (*Monarda* sp.).

Costs for design, permit and installation may range from $30,000 to $75,000 while maintenance would be low.

An overview of the potential project area is provided in Figure 4.9 below.

BMP-1

Pequabuck River Basin - 4315-00

Town of Plymouth

41.67755499, -73.01270404

Catchment ~ .95 Ha (2.35 Ac)

Management Measures

Vegetated Swale

Estimated Load Reductions

Nitrogen (Kg)	3.58
Phosphorus (Kg)	0.75
Solids (Kg)	1,609.71
Bacteria	8.61E+09

Other Benefits

Stream Channel Protection

Groundwater Recharge

Cost	Low
Maintenance	Low

Figure 4.9: BMP-1 Site

BMP-2

BMP-2	
Pequabuck River Basin - 4315-00	
Town of Plymouth	
41.672611°, -72.994882°	
Catchment ~ 2.84 Ha (7.02 Ac)	
Management Measures	
Riparian Restoration	
Stormwater Wetlands	
Estimated Load Reductions	
Nitrogen (Kg)	17.84
Phosphorus (Kg)	2.24
Solids (Kg)	5,409.08
Bacteria	1.80E+11
Other Benefits	
Stream Channel Protection	
Groundwater Recharge	
Thermal Regulation	
Cost	Medium
Maintenance	Low

BMP-2 is located downstream from BMP-1 at an old commercial / industrial site, also in Plymouth. This property, which abuts directly to the river, is comprised of 100% impervious area with no observed stormwater treatment. Information from local residents indicated that this site may be contaminated and in process of clean-up. As such, recommendations contained herein could be implemented post restoration, if chemical pollution is cleaned up accordingly and poses no more risk of transport to the river from stormflow.

Management of sheetflow and associated pollutant loading from this area could again be achieved with installation of a wetland-based stormwater basin combined with restoration of the riparian buffer. The former would assist in achieving capture and retention of pollutants while the riparian buffer would serve to increase stream function through shading of the stream channel, increased in-stream assimilation of nutrients and pollutants, and a myriad of other benefits.

Installation of a basin would likely occur on the south side of the property and require buy-in from the property owner as a portion of the property, which is now parking and access, would be reverted to a naturalized state. Maintenance would be associated with checking for invasive species and the overall structural integrity of the basin annually.

Cost for such a basin would be moderate due to the need to remove asphalt and retool a previously constructed area. Estimated costs for design, permitting and installation would range from $150,000 to $200,000. An aerial view of the potential project site is provided in Figure 4.10 below.

This site has been identified by stakeholders as currently undergoing work to clean up some sort of soil contamination making it only viable as a BMP once proper site remediation has taken place, if at all. However, it still serves as an example for sites with similar topographic and NPS pollutant loading characteristics. This BMP will remain listed to serve as a template for other potential sites.

Figure 4.10: BMP-2 Site

BMP-3

BMP-3 is associated with a bus depot on river left along Route 72 in Bristol. This area shows a mixture of impervious asphalt in addition to areas of gravel parking lots. As with many areas in the watershed, this location does not appear to have adequate stormwater management and may transport a disproportionally high level of pollutants to the river during rain events.

A mixture of pocket rain gardens and a smaller stormwater wetland basin could help ameliorate high flow velocities from this site in addition to reducing target pollutants. As with the previously mentioned BMPs, this site is on private property and as such would require the buy-in of the owners for implementation. Nevertheless, the close proximity to an impaired stretch of the river would lead to a higher priority for this and similar locations.

Cost would likely be moderate while maintenance would be on the low end consisting of annual inspections and removal of invasive species. It is estimated that the design, permitting and installation of a wetland basin and select rain gardens would range from $100,000 to $150,000. Installation of a basin at this location may require the removal of some larger trees thereby increasing cost.

An aerial image of the project site is provided in Figure 4.11 below.

BMP-3
Pequabuck River Basin - 4315-00
City of Bristol
41.671527°, -72.977096°
Catchment ~ 0.97 Ha (2.40 Ac)

Management Measures

Stormwater Wetland
Rain Gardens

Estimated Load Reductions

Nitrogen (Kg)	6.09
Phosphorus (Kg)	0.77
Solids (Kg)	1,849.29
Bacteria	6.16E+10

Other Benefits

Pollinator Habitat
Volume Regulation

Cost	Medium
Maintenance	Low

Figure 4.11: BMP-3 Site

BMP-4

BMP-4 is located immediately downstream from BMP-3 and is also associated with a commercial operation in Bristol. This area consists of a paved commercial area which abuts an uncovered materials storage area. There are catch basins associated with the paved area but no stormwater management of the unpaved areas.

Management practices associated with this property may include the retrofitting of catch basins to include insert filters which would filter and retain pollutants of concern. Nearer Route 72 the property owner could potentially install some vegetated filter strips of limited size/width to filter sheet flow prior to entering the main roadway and river.

Cost to retrofit the catch basins and install a vegetated filter strip would be low at an estimated range of $20,000 to $40,000. Maintenance would require checking and replacing the filter inserts routinely throughout the year while the filter strip maintenance would essentially entail checking for and removing invasive species.

An overview of the potential project site is listed below in Figure 4.12. As with the previous sites, this higher priority location is on private property.

It has been noted that there is development being done on this site and that bank swallow (*Riparia riparia*) habitat can be found onsite.

BMP-4	
Pequabuck River Basin - 4315-00	
City of Bristol	
41.670796°, -72.973738°	
Catchment ~ 0.80 Ha (1.98 Ac)	
Management Measures	
Vegetated Filters	
Catch Basin Retrofits	
Estimated Load Reductions	
Nitrogen (Kg)	3.02
Phosphorus (Kg)	0.63
Solids (Kg)	1,356.06
Bacteria	7.26E+09
Other Benefits	
Pollinator Habitat	
Groundwater Recharge	
Cost	Low
Maintenance	Medium

Figure 4.12: BMP-4 Site

BMP-5

BMP-5	
Pequabuck River Basin - 4315-05	
City of Bristol	
41.672764°, -72.944945°	
Catchment ~1.26 Ha (3.11 Ac)	
Management Measures	
Infiltration Basin	
Estimated Load Reductions	
Nitrogen (Kg)	7.91
Phosphorus (Kg)	1.99
Solids (Kg)	2,130.07
Bacteria	8.00E+10
Other Benefits	
Groundwater Recharge	
Cost	Medium
Maintenance	Medium

BMP-5 is associated with a large, approximately 3.11-acre, parking lot located at the corner of North Main Street and Riverside Avenue in Bristol. This large expanse of impervious area may transport significant pollutants and high velocity sheet flow through the storm conveyance system leading to impaired conditions in the river.

An infiltration basin may be able to be integrated into this parking lot and serve to slow the incoming water and allow it to slowly recharge the local aquifer. In doing so, pollutants such as pathogens, nutrients and heavy metals could be filtered and retained within the structure.

The size and cost of an infiltration basin would be higher than less complex vegetated basins but may remove more pollutants and certainly serve to have a better impact from a hydrologic perspective.

The cost to design, permit and install such a basin would likely be between $250,000 to $300,000. Maintenance would be moderate and include routine inspections to monitor infiltration capacity. Routine debris removal from the Public Works Department or similar would be necessary to ensure ongoing functionality.

An overview of this site is presented in Figure 4.13 below.

Redevelopment of this site is underway and likely to continue. As development progresses, it will be imperative that review of plans for any further development includes non-structural stormwater management techniques as recommended in this plan for this site.

The river runs underground in this area and would benefit from daylighting as well as installation of BMPs to accompany any future development. There are other potential areas for BMPs just upstream from this site that would also benefit from the strategies listed here.

Figure 4.13: BMP-5 Site

BMP-6

BMP-6 is a relatively small area of 1.04-acres in the Forrestville section of Bristol that is currently entirely impervious. This site offers the unique opportunity for conversion into a small park with direct river access. Within the park, the community could integrate vegetated stormwater filters filled with beneficial pollinator plants. Such a park could therefore help link visitors to the natural beauty of the river while educating them on the importance of stormwater management, pollution to the river, and overall river health and usability.

The cost for park conversion is unknown at this this time but installation of vegetated filter strips would be low at an estimate of approximately $10,000 to $20,000. Maintenance would also be low and consist of checking for and removing invasive species.

An aerial image of this location is provided in Figure 4.14 below.

BMP-6	
Pequabuck River Basin - 4315-00	
City of Bristol	
41.674296°, -72.907660°	
Catchment ~0.42 Ha (1.04 Ac)	
Management Measures	
Pocket Park / River Access	
Vegetated Filter	
Estimated Load Reductions	
Nitrogen (Kg)	0.97
Phosphorus (Kg)	0.27
Solids (Kg)	234.05
Bacteria	3.81E+09
Other Benefits	
Creation of Park / Access	
Pollinator Habitat	
Cost	Low
Maintenance	Low

Figure 4.14: BMP-6 Site

BMP-7

BMP-7 is located on the property of the Ellen P Hubbell School in Bristol. This site has extensive impervious area associated with the school structure and associated parking areas. There is a vegetated area at the entrance of the school surrounded by catch basins. Management for this area could include retrofitting of the catch basins with tree filters and conversion of the vegetated area to a wetland type basin for additional pollutant removal.

Since this area is not private property the barrier to installation of stormwater management features would potentially be lower. The modification of the current stormwater system could also be utilized as a demonstration project for other schools, libraries, and similar properties. In addition, stormwater management could be integrated into the local science and/or engineering curriculum.

Costs for four (4) tree filters, design, engineered and installed would likely range from $100,000 to $200,000. Installation of a small wetland basin including engineering, design, permitting and construction would likely also be in the ballpark of $100,000 bringing total project cost to the $200,000 to $300,000 range.

An aerial view of this site is provided in Figure 4.15 below.

It has been noted that brown trout spawning habitat has been identified down stream of this site, adding to the importance of having improved water quality here.

BMP-7
Coppermine Brook Basin - 4314-00
City of Bristol
41.678494°, -72.908561°
Catchment ~0.45 Ha (1.11 Ac)

Management Measures
Stormwater Wetland
Tree Filters

Estimated Load Reductions

Nitrogen (Kg)	1.98
Phosphorus (Kg)	0.28
Solids (Kg)	362.92
Bacteria	2.86E+10

Other Benefits
Pollinator Habitat
Education Opportunity

Cost	Medium
Maintenance	Low

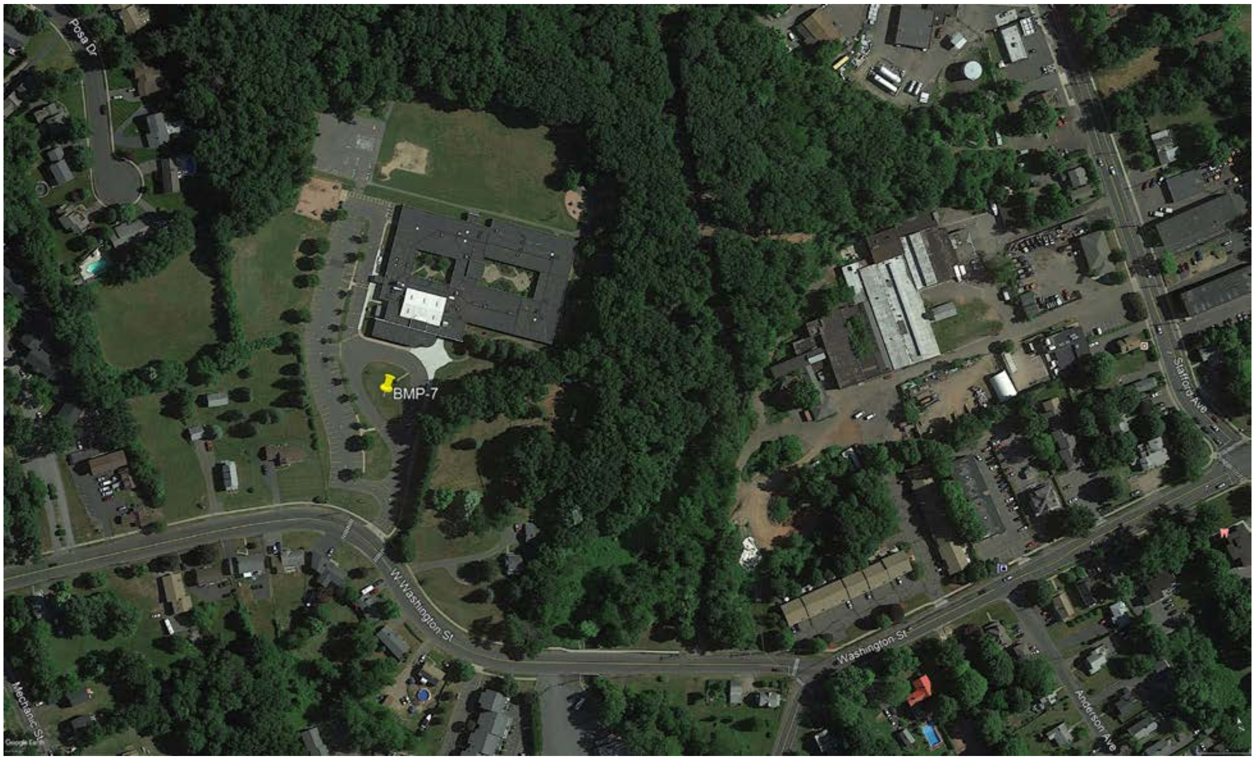


Figure 4.15: BMP-7 Site

BMP-8

BMP-8 is associated with an expansive area of impervious parking lots and buildings on river right and river left of Coppermine Brook in Bristol. For this exercise, Princeton Hydro delineated an approximately 1.51-acre area along river left and targeted this for the potential installation of a wetland type stormwater basin to ameliorate peak flows from these parking lots and to capture and retain pollutants.

Implementation would depend on the buy-in from the private property owners and conversion of what is now parking to a stormwater treatment facility. As such, costs would likely be higher than other candidate sites but priority would be elevated due to the close proximity to the brook. Consideration of replacing some areas with pervious pavement can also be considered but these types of BMPs have the potential to clog with finer particulates thereby decreasing their treatment capacity. As such, like all BMPs, it is imperative to conduct regular maintenance to maintain BMP functionality.

Cost estimates for such a basin including design, permitting, engineering and construction are approximately $125,000 to $200,00. Maintenance would include inspection of the structural integrity of the basin and survey for invasive species at least annually.

An overview of the potential project site is provided in Figure 4.16 below.

It has been noted that this is another area in which CT DEEP is focusing efforts on protecting for trout habitat, adding to the importance of having improved water quality here as well.

BMP-8	
Coppermine Brook Basin - 4314-00	
City of Bristol	
41.694677°, -72.914030°	
Catchment 0.61 Ha (1.51 Ac)	
Management Measures	
Stormwater Wetlands	
Estimated Load Reductions	
Nitrogen (Kg)	3.83
Phosphorus (Kg)	0.48
Solids (Kg)	1,163.46
Bacteria	3.87E+10
Other Benefits	
Cost	High
Maintenance	Low

Figure 4.16: BMP-8 Site

BMP-9

BMP-9 is associated with St. Paul Catholic High School in Bristol. This private site may improve stormwater management through the installation of catch basin inserts and creation of a wetland-based stormwater basin similar to previous locations.

Currently, it appears there is land on the southwest side of the property in-between the large parking lot and brook that could potentially be converted to a wetland type basin. In addition, there are approximately eight (8) catch basins that may be modified with filter inserts to improve pollutant removal as a secondary means of treatment.

Estimated cost for construction, permitting, and engineering of the tree filters and basin would be approximately $275,000 to $350,000. Maintenance would be similar to the requirements specified above.

A depiction of this location is provided in Figure 4.17.

It was noted that there is a blue heron rookery nearby, emphasizing the need for improved water quality and maintain foraging habitat for the birds in this area.

BMP-9	
Coppermine Brook Basin - 4314-00	
City of Bristol	
41.702250°, -72.914361°	
Catchment 0.61 Ha (1.51 Ac)	
Management Measures	
Stormwater Wetland	
Catch Basin Filters	
Estimated Load Reductions	
Nitrogen (Kg)	4.40
Phosphorus (Kg)	0.62
Solids (Kg)	807.89
Bacteria	6.35E+10
Other Benefits	
Pollinator Habitat	
Groundwater Infiltration	
Educational Opportunities	
Cost	Medium
Maintenance	Low

Figure 4.17: BMP-9 Site

BMP-10

BMP-10 is associated with the Edgewood School in Bristol. Like many schools this large piece of property has extensive impervious area associated with the buildings and parking infrastructure. Currently, there is a turf grass basin located along the west edge of the property that has potential for conversion into a wetland type basin. The large size of this area may allow for some significant treatment of runoff prior to entering the Coppermine Brook.

As a public school, this area offers an abundance of educational opportunities associated with ecologically based stormwater management. Furthermore, this public space may be easier to implement a recommended BMP measure compared to private properties.

The cost to design, engineer and construct a retrofit for this basin is on the order of $75,000 to $150,000 depending on various site-specific factors. Maintenance would be similar to that described above.

An overview of this area is provided in Figure 4.18 below.

BMP-10	
Coppermine Brook Basin - 4314-00	
City of Bristol	
41.701283°, -72.923430°	
Catchment ~0.42 Ha (1.04 Ac)	
Management Measures	
Stormwater Wetland	
Estimated Load Reductions	
Nitrogen (Kg)	1.85
Phosphorus (Kg)	0.26
Solids (Kg)	340.06
Bacteria	2.67E+10
Other Benefits	
Pollinator Habitat	
Educational Opportunity	
Groundwater Recharge	
Cost	Medium
Maintenance	Low

Figure 4.18: BMP-10 Site

BMP-11

BMP-11 is associated with Chippens Hill Middle School in Bristol. This public area could also benefit from enhanced stormwater management including the installation of a wetland type basin on the west portion of the bus round-a-bout. Furthermore, there is potential to integrate tree filters.

The close proximity of the school to Coppermine Brook offers abundant educational opportunities to be tied in with stormwater management and stream ecology. Furthermore, as a public institution, the likelihood of implementing this project would theoretically be higher than that on private lands.

The cost to for a wetland type basin would be on the order of $100,000 to $150,000 while installation of two tree boxes would likely amount to $50,000 bringing the total project cost to $150,000 to $200,000.

An overview of the site is provided in Figure 4.19 below.

It has been noted that there is a small headwater stream that runs southeast behind the school (due east of the building) that has been identified as brook trout habitat. This information underscores the importance of having improved water quality at this site.

BMP-11
Pequabuck River Basin - 4315-05
City of Bristol
41.699566°, -72.966863°
Catchment 0.25 Ha (0.62 Ac)

Management Measures

Stormwater Wetland
Tree Filters

Estimated Load Reductions

Nitrogen (Kg)	1.10
Phosphorus (Kg)	0.16
Solids (Kg)	202.89
Bacteria	1.59E+10

Other Benefits

Pollinator Habitat
Educational Opportunity

Cost	Medium
Maintenance	Medium

Figure 4.19: BMP-11 Site

BMP-12

BMP-12 is associated with an expansive commercial warehouse complex in Bristol comprised of approximately 28.07 acres of impervious parking lot, gravel parking lot and building infrastructure.

There is the potential for installation of several stormwater basins along the southern boundary of the property to intercept and treat stormwater.

The cost for two stormwater basins would likely be on the order of $300,000 to $400,000 and maintenance would be similar to that described above.

An aerial image of the site is provided in Figure 4.20 below.

It has been noted that this is a privately-owned property and that the owners of the land have already reached out to express interest in developing better stormwater management practices and green infrastructure on site.

BMP-12 Pequabuck River Basin - 4315-03 City of Bristol 41.693737°, -72.981464° Catchment 11.36 Ha (28.07 Ac)	
Management Measures	
Stormwater Wetland	
Estimated Load Reductions	
Nitrogen (Kg)	71.36
Phosphorus (Kg)	8.97
Solids (Kg)	21,628.99
Bacteria	7.22E+11
Other Benefits	
Pollinator Habitat	
Groundwater Recharge	
Cost	Medium
Maintenance	Low

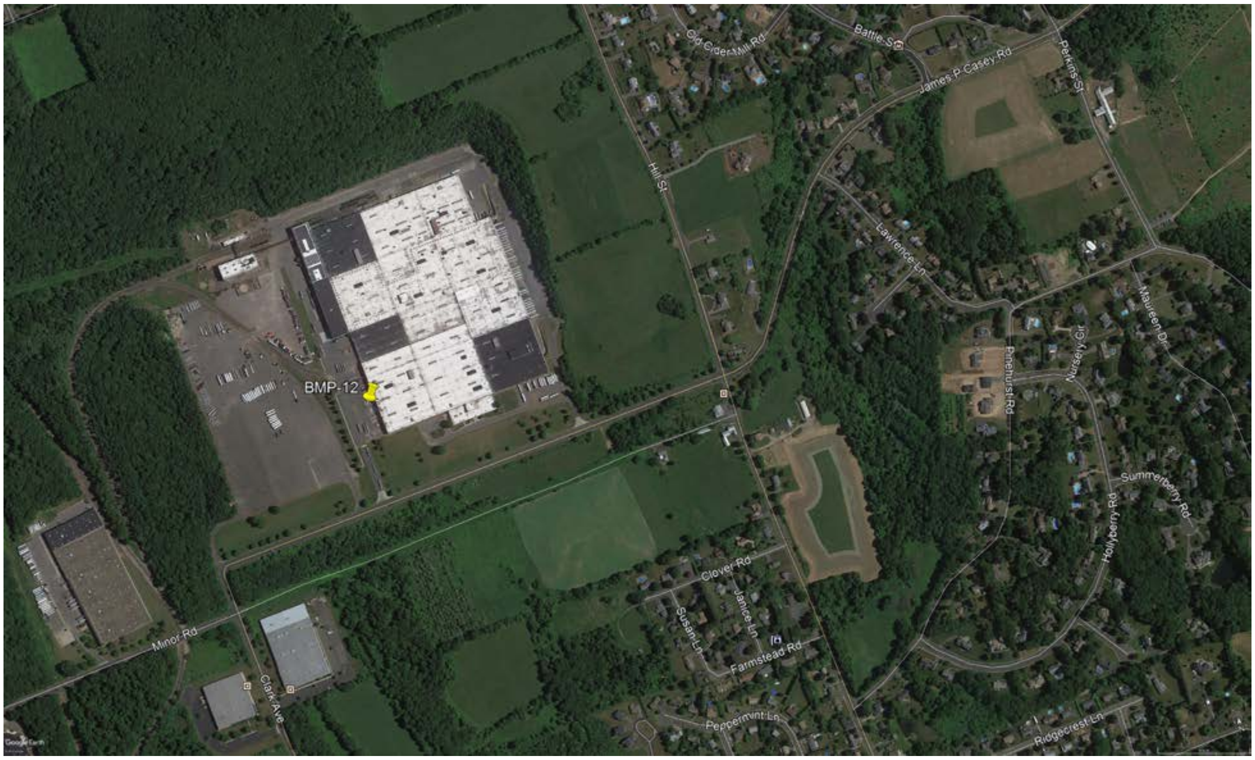


Figure 4.20: BMP-12 Site

4.5 Watershed Wide BMPs

The following section provides general information related to BMPs to address potential, non-site-specific areas of loading such as septic systems, agricultural land, riparian buffer establishment, streambank stabilization, pet wastes, and wildlife management. Review of regulatory programs aimed at reducing stormwater-based pollutant loading, such as the MS4 program, are addressed in Section 4.5.

Septic Systems

As discussed in Section 2 and as based on the pollutant loading results, septic systems within the Pequabuck River, Coppermine Brook and Poland River watersheds are not a major source of either pathogen or nutrient loading. Although a minor source of pathogen and nutrient loading, those residents still relying on septic systems should be educated about septic system management and maintenance.

Inspections and routine maintenance are usually the two controversial elements of most septic management programs. However, as has been demonstrated in studies conducted as part of nationwide septic management studies, routine inspections help decrease the occurrence of large-scale failures by identifying the more easily corrected, less costly problems (NYSDEC, 1994). Similarly, routine pump outs decrease the buildup of sludge and grease in the septic tank itself, both of which can be transported into the leach field and create clogging problems. In general, the inspections and pump outs should be viewed as an insurance policy for the long-term proper operation of the septic system and not an imposition of the property rights of a homeowner.

Water conservation is another tool that can be used along with routine pump out and inspection to help protect and increase the operational longevity of septic systems. These measures are intended to reduce hydrologic loading to the leach field. Included in this category are the use of low flush toilets, flow reduction fixtures and other similar devices designed to reduce water usage. It can also encompass lifestyle habits such as spreading out laundry wash loads over a number of days, shorter showers, and other similar cooperative techniques.

A component of septic system management is product modification. Product modification usually refers to the use of non-phosphorus or low phosphorus products that minimize septic-related phosphorus loading to the environment. However, it also applies to the education of homeowners regarding the use of septic tank chemical additives or the disposal of paint, solvents or left-over household chemicals and cleaning products in septic systems. There are no specific regulations in place pertaining to the disposal of such materials in septic systems. However, public education fliers and brochures advising against such practices are readily available through the CT DEEP and regional watershed groups, and especially the USEPA's Small Flows Clearing House, which specializes in the dissemination of information pertaining to all types of on-site waste water treatment systems. Such educational material would prove beneficial in this respect. All residents should be educated about the serious impacts to their septic systems of improperly disposed household chemicals and degreasing agents. These products can cause serious upsets to the biological treatment processes that occur in the septic tank itself and in the soils of the disposal field. Equally important, these products can result in serious groundwater pollution and the contamination of drinking water wells.

Although all of the above measures will aid in the reduction of nitrogen and phosphorus loading, they still rely on the use of conventional septic designs to accomplish nutrient removal. Non-traditional, advanced on-site wastewater treatment systems (OWTS) can more fully renovate wastewater compared to standard septic systems. For example, with respect to nutrient control, intermittent (recirculating) sand filters, peat filter systems, and aerobic systems all generate a higher quality effluent than a typical septic system. Although it may be argued that each can be more costly than conventional septic systems and that each have their limitations, data show that they are superior to conventional septic designs in the removal of nutrients, and peat filter systems are proven to have high phosphorus removal capability.

Agriculture

Overall, agricultural lands currently comprise a minor portion of the watershed and pollutant load. While there are a number of agricultural BMPs that can be implemented, many are variations on a theme, and the WBP will examine BMPs designed to limit erosion, manage stormwater, and manage manure. The primary source of information is the CT DEEP *Manual of Best Management Practices for Agriculture*.

Agricultural Erosion BMPs

Agricultural management is focused on proper treatment of the land to improve the quality and quantity of forage, conserve water, and most importantly here to protect soil and watercourses and minimize adverse effects on groundwater and surface water. This is best accomplished through simply maintaining vegetation throughout the year to provide soil stability. For pastures this means limiting the number of grazing animals; one acre of improved pasture will support a 1,000-pound animal unit per year. In addition, rotational grazing of short duration is recommended to provide a period for regrowth of grasses and limit overgrazing. Avoid grazing in early spring or on soft, wet soils, and exclude livestock from watercourses.

For hay land management, yield can be improved by proper fertilization using manure where possible rather than chemical fertilizers. Hay cuttings should only begin at specified heights for each species to maintain yield potential and viable root stock. Replanting or renovating should be pursued to reduce erosion and increase high quality forage on poor quality pasture and hay land or upon conversion of other cover types.

On croplands or areas that are tilled a number of BMPs are recommended. These include:

- Conservation Tillage – A tillage and planting system which minimizes physical disturbance of the soil and leaves at least 30 percent of the surface covered by plant residue after planting.
- Contour Farming – Performing tillage, planting, and harvesting operations across slope on the contour to reduce surface runoff and the transport of pesticides, nutrients, and sediment.
- Cover and Green Manure Crop – A crop of close-growing grasses, legumes, or small grain grown primarily for seasonal protection and soil improvement.
- Crop Residue Management – Managing plant residues to protect cropped fields from erosion.
- Crop Rotation – The successive planting of different crops in the same field; this disrupts insect pests and increase soil fertility.
- Mulching – Applying plant residues or other suitable materials to the soil surface.

Agricultural Stormwater Management BMPs

Stormwater management in agricultural areas is important in several respects. As with urban runoff, runoff from agricultural lands can be a major source of solids, nutrients, and bacteria loads. Proper management is also required to avoid destruction of crops, surface erosion, or flooding of outbuildings. The following represent some of the agricultural stormwater management BMPs.

- Diversion – A drainageway constructed across a slope to divert runoff to protect cropland, barnyard, or runoff through areas high in potential pollutants. Not to be used downstream of high sediment producing areas unless those areas are otherwise managed or on high slopes.
- Grassed Waterway and Outlet – A natural or constructed channel or outlet, shaped or graded, and vegetated with a suitable grass/legume mix for the controlled disposal of runoff. These provide the outlet for diversions or other concentrated flow.
- Irrigation Water Management – Determining and controlling the rate, amount, and timing of irrigation water in a planned and efficient manner. This is both a water conservation practice and a way to prevent soil erosion and minimize leaching or runoff of nutrients, soils, or pesticides.
- Riparian Buffer – An area of trees and other vegetation located on land next to and upgradient from water courses, waterbodies, and associated wetlands. There are a variety of pollutant control, bank stabilization, and wildlife habitat value benefits associated with these enhancements. These typically involve the planting of native vegetation, including woody plants, to enhance the buffers.
- Streambank Protection – Stabilizing and protecting banks of streams, lakes, or excavated channels from scour and erosion, using vegetative or structural means. Streambank protection can run the gamut from simple to complex projects, but are best developed and overseen by professionals.
- Water and Sediment Control Basin – An earthen basin constructed to intercept sediment-laden runoff and to trap and retain the sediment. This is essentially a simple detention basin design that can be effective in removing gross particulates.

Manure Management BMPs

Managing manure is important in reducing agricultural loads of bacteria and associated nutrients in the upper subwatersheds. Because the scale of farm operations in the Pequabuck River watershed is generally small, intensive BMPs designed for major waste disposal are probably not appropriate, although they will be reviewed in part. Less intensive measures can also help control loading, including maintaining herd sizes at an appropriate level for the given acreage, keeping manure away from waterways, and fencing riparian areas to prevent livestock movements near and through the tributary network. Various manure management measures are discussed below.

A waste management system describes a program of various BMPs to manage farm-generated wastes, primarily manure in this case, to minimize degradations of air, soil, and water quality and to protect public health and safety. Regarding water quality impacts, these programs are designed to prevent pollutants being mobilized in runoff or leaching to groundwater by inducing nutrient uptake through crops, containing leachate and runoff, and treating the waste to reduce nutrients and pathogens. The complexity of any given system will depend on the quantity of waste to be managed as well as the physical and hydrographic properties of the farm. Some of the elements or practices that could be included in a waste management system are as follows:

- Waste Utilization – Waste should be used to the fullest extent possible as a source of nutrients for crop or forage production. Seasonal restrictions will guide the application of waste and include the winter months, early spring when soils are subject to compaction and erosion, and summer when crops occupy the land.
- Storage – Waste needs to be treated or stored until conditions permit safe spreading or disposal. Daily land applications may be acceptable and if not, sufficient storage must be maintained until applications are possible, typically during planting/seeding and in the fall after harvest.

- Clean Water Exclusion – To the maximum extent practical, clean water should be diverted from any concentrated waste areas.
- Polluted Runoff – Runoff and seepage from waste areas should be intercepted and directed to storage or treatment areas or applied to the land in a controlled manner. This may incorporate those BMPs discussed above, such as diversions, grassed waterways, or detention basins.
- Drainage and Erosion Control – Adequate drainage, erosion, and soil and water management practices need to be incorporated. Again, this would include various BMPs discussed above.
- Adequate Land Area – Commensurate with the number of livestock, adequate land areas are required for proper use or disposal of wastes at locations, times, rates, and volumes that maintain water quality and other environmental conditions. If adequate land is not available, the waste will need to be treated through the use of lagoons, oxidation ditches, or composting and failing the availability of those measures, offsite disposal.
- Location – Storage structures should be located to minimize odors and visual impacts and according to land use and zoning regulations.

A field stacking area is used to temporarily stockpile manure for up to six months where groundwater and surface water contamination is least at risk and at time when daily spreading is not feasible. These areas should be located: near the receiving field, on minimal slopes with small or no catchment, away from buildings, outside drainageways and floodplains, accessible during wet or snowy conditions, according to land use, wetlands, health and other pertinent regulations, at least 200 feet from occupied buildings (other than farm buildings), 200 feet from a private well, 500 feet from a public, and at least 100 feet from a watercourse. Stacking should not be done on highly permeable soils, at least 18 inches above the seasonal high-water table, and at least four feet above bedrock. Runoff should be managed and may include BMPs such as vegetated filter strips. It should be of sufficient size to ensure adequate storage.

Agricultural waste composting is designed to accelerate aerobic biodegradation and stabilization of waste. When properly conducted this can destroy pathogens and stabilize nutrients so the material is usable with less risk of leaching. There are three main methods to accomplish this: windrows are linear piles of waste which are periodically turned for aeration and overtime the rate of turning is decreased; static aerated piles are initially mixed for homogenization but are not subsequently turned but perforated pipes are installed through the piles with air forced into the pile; and in-vessel composting is conducted in an enclosed structure with controlled temperature and air flow which is usually quicker than other methods but costlier and potentially with higher storage requirements. Many of the same siting concerns for field stacking would need to be observed here with increased setback distances. Composting can also allow for nitrogen loss through denitrification and off-gassing.

A major component of waste management on farms is utilization to improve soil fertility and enhance crop production. A major component of utilization programs is minimizing pollutant loading related to these practices. A waste utilization plan therefore must acquire all necessary permits and follow a Plant Nutrient Management Plan BMP. The following seasonal recommendations apply:

- Fall – Apply manure to those fields containing the greatest amount of vegetation or crop residues. Avoid spreading on fields with high pollutant delivery potential.
- Winter – Spread in November or early December, prior to beginning of continuous snow cover. Spreading on snow greatly increase the potential for transport of pollutants.
- Spring – Apply on fields that are to be plowed or disced, or in no-till fields spread before planting, if applied to meadows or hay field select fields in the last year of production.
- Summer – On growing crops apply waste on no more the 25% of the leaf surface.

A waste utilization flow chart (adapted from CT DEEP) is provided below.

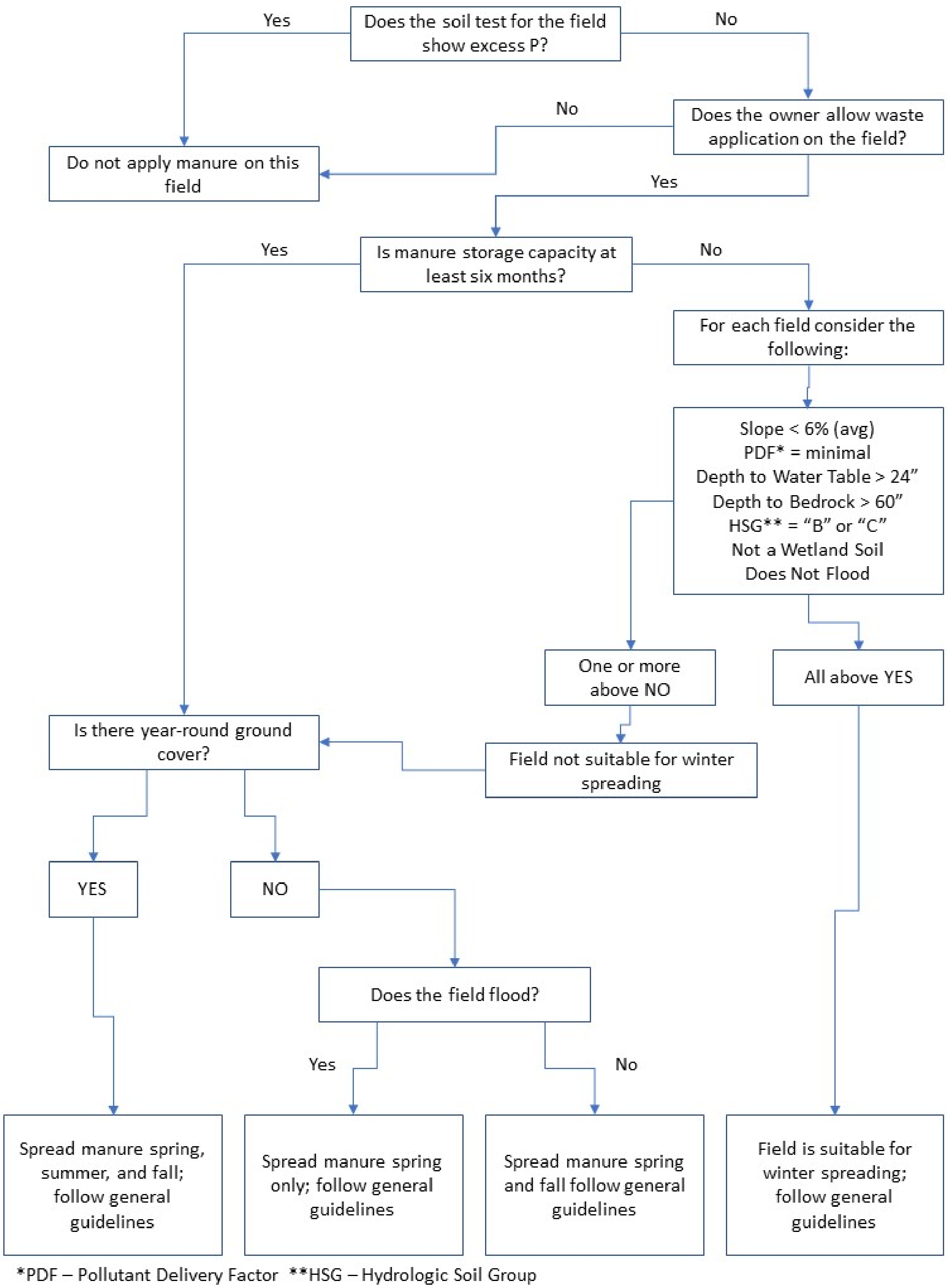


Figure 4.21: Waste Utilization Flow Chart

Finally, waste storage structures should be considered for use in larger applications. These structures include storage tanks, stacking facilities, and earthen embankments. Tanks are used for liquid or slurry wastes in a variety of settings, while stacking facilities are used for wastes that behave as solids. Embankments are ponded systems. As with other measures, these are primarily used for temporary storage purposes and offer little in the way or treatment.

Streambank Stabilization and Riparian Buffer Establishment or Enhancement

Another important set of NPS management measures in the Pequabuck River watershed will focus on streambank stabilization and riparian buffer enhancements. Streambank erosion accounts for approximately 90% of all solids loading in the watershed, a high figure. While this seems to be an extremely high value, one of the most important functions of streams is sediment transport. In this system there are a variety of factors that contribute to the observed fluvial geomorphology of the watershed and sediment transport in streams including natural factors such as moderate grades through much of the system due to topography and landscape position which means that flows can be energetic, as well as relatively fine, easily mobilized sediments as a result of the glacial till geology. There are anthropogenic stressors however, that increase bed load and erosion including high impervious coverage and stormwater loading, as well as buffer impairments related to general development patterns. While these stressors are an important component of the load and need to be addressed both at the source and through in-situ measures, sediment loads from in-stream processes are always going to represent a majority of the load.

Stream restoration and riparian buffer enhancements have advanced considerably over the last twenty years. Previously, channel management focused on hard engineering designs meant to lock channels in place, channel “cleaning” exercises to remove substrate, large woody debris, and increase flow velocities, and straightening. These actions have largely proven futile, are subject to high failure rates, and ultimately do not account for naturalistic stream functions; indeed, many stream restoration efforts today focus on correcting those earlier management activities. This is due to better understanding of riverine dynamics and a different management approach, one that is dependent on the theory of dynamic equilibrium, as well as floodplain connectivity, and improving aquatic habitat value. A brief primer on riparian dynamics is necessary to understand restoration approaches.

The form and function of rivers, streams, and the river corridor as a whole is dependent on the movement of both water and sediment and when these factors equilibrate a river system is said to be in a state of dynamic equilibrium. A number of factors affect this equilibrium including channel slope and sediment size (as demonstrated by Lane’s Balance in Figure 4.22), but a system in equilibrium will maintain a constant channel type defined by a narrow range of parameters like sinuosity, slope, and substrate type, as well as meeting flow and sediment transport requirements. While this represents a state of equilibrium the river corridor remains dynamic and continues to evolve and will exhibit changes in channel alignment over time, particularly a lateral and downstream migration of the channel. For instance, bed erosion in a certain part of the channel is counteracted by depositional processes elsewhere under stable flow and sediment transport regimes. The continued movement of the channel also introduces the concept of the meander belt, a corridor in which the channel will naturally migrate back and forth over time to accommodate equilibrium conditions. Man-made confinements, like levees, elevated roadways and bridges, bank armoring, and other development in the meander belt can limit the natural channel migration processes and cause disequilibrium. In a developed watershed, the need to protect infrastructure will of course be an important consideration and require the use of some of these engineering measures, but a more naturalistic approach is recommended where it can be accommodated.

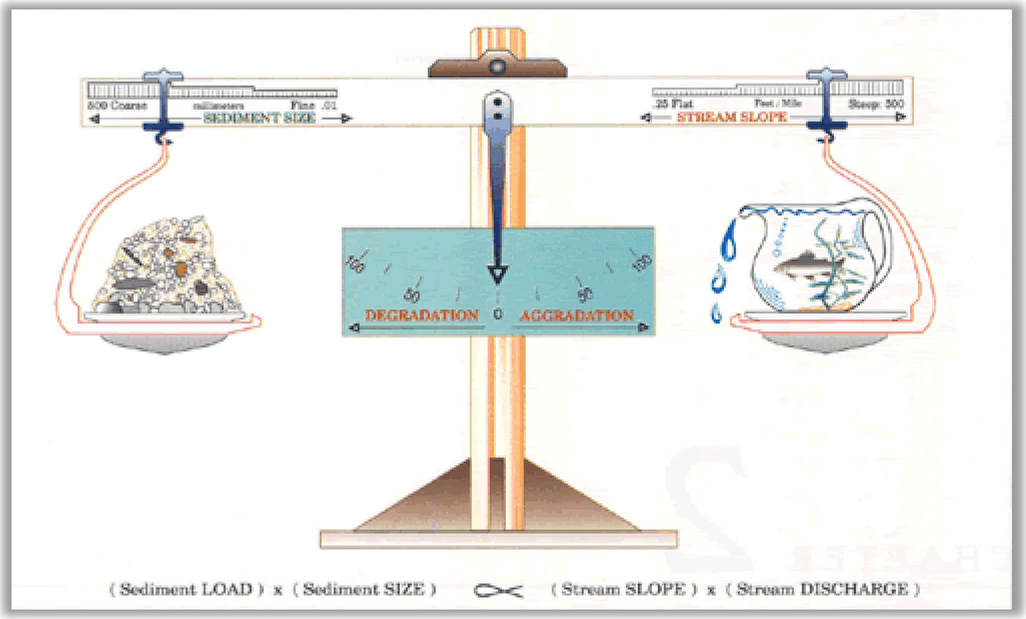


Figure 4.22: Lane's Balance. Source: Fluvial Geomorphology, SUNY

Disequilibrium occurs when there are modifications to hydraulic loading (i.e. increased stormwater inputs), sediment supply (from surficial erosion or within the channel), channel slope (including straightening), boundary conditions, and riparian modifiers (buffer degradation). River systems respond to these changes by significant changes in form and function often manifested in excessive erosion and sedimentation particularly as the channel widens or downcuts to handle larger volumes of water. Rivers that are developing a new state of dynamic equilibrium are said to be in adjustment. A way to assess this is to examine its departure from reference conditions, that is either historical measures of the river or departure from a theorized natural state exhibited by undeveloped systems.

Prioritizing Riparian BMPs

The general scheme for prioritization seeks to first protect and preserve functional values of stream corridors. Restoration actions then follow after protection actions and priority generally decreases with increasing project complexity. This type of scheme therefore seeks to maintain the functional values of stream corridors through protection rather than restoration reacting to impairments. It is also expected that the generally feasibility of projects will follow a similar pattern. The following section explores assessing the priority of various project groups.

1. Protect River Corridors

   Higher: Highly sensitive reaches critical for flow and sediment attenuation or sensitive reaches where there is a major departure from equilibrium conditions from the threat of encroachment. Prioritizing these types of projects has an outsized influence on protecting areas downstream. In addition, this type of project involves resources that are particularly sensitive to change or are under threat and immediate moves to protect the resources would be very valuable.

   Lower: Wooded corridors with little threat from encroachment, with low sensitivity, and not significantly contributing to flow or sediment attenuation. In a sense, these types of reaches are already more robust and resistant to adjustment or impairment and because they are well vegetated their functional value is presumed high. These types of systems already enjoy a defacto protection and thus are rated lower. It should be noted though that these types of projects offer ideal opportunities for expanding public access and promoting permanent protection of riparian lands and thus might rate higher in terms of feasibility.

2. Plant Stream Buffers

   Higher: Priority is given to revegetation projects on relatively geomorphically stable reaches. Planting buffers is important in regaining functional value, especially for habitat quality, thermal moderation, and water quality. Trees and other woody plants are favored for increasing bank stability.

   Lower: Stream reaches exhibiting a higher degree of sensitivity are less well suited for stand-alone buffer planting projects as the sites are at higher risk of failure. That said, buffer planting should be incorporated in conjunction with other restoration activities, especially those addressing channel integrity where there has been significant work to stabilize or move the channel and banks.

3. Stabilize Stream Banks

   Higher: Streams that are overall relatively stable and where bank stabilization measures could slow channel migration and allow revegetation of the banks are given priority. Higher priority would also be assessed for projects that are impacting sensitive downstream reaches or where there is a need to protect active and functional infrastructure or other encroachments.

   Lower: Highly sensitive project sites that are at risk for project failure are assessed a lower priority.

4. Arrest Head Cuts

   Higher: The placement of grade controls is a priority where incision will lead to a loss of floodplain connectivity or place structures at risk.

   Lower: Reaches with natural grade controls within a meander wavelength upstream of the nick point or where there is high bed load deposition (coarser materials such as gravel and larger) are more likely to naturally recover and achieve equilibrium.

5. Remove Berms

   Higher: Removal of berms that would allow floodplain connectivity and lateral channel migration, in situations where the berm is directly responsible for reach incision, or where there is no increased risk to structures from flooding or erosion after removal have high priority. These types of projects are linked by the high potential for significant increases in functional value and relatively low risk.

   Lower: Projects that have less clear potential for functional value improvements are ranked lower. This includes reaches where the berms are well vegetated by trees and removal would cause major habitat disruptions or where removing the berms would not help to counteract channel incision.

6. Remove or Replace Structures

   Higher: Highest priority is given to derelict and non-functional structures such as dams and culverts. This is especially true where the structures are in an advanced state of disrepair and represent a significant liability. Structures that are causing major sediment accretion upstream and degradation downstream or structures that may cause channel avulsion during flood events are also given preference. In some cases, restoration of diadromous fish migration is also given very high priority especially if it coincides with State or federal management plans. See Appendix E for details of the Bristol Brass Dam Removal, an example of such a BMP.

   Lower: Lower priority is assessed to more complex projects that would require significant channel creation or realignment or where the risk of changes in equilibrium conditions upstream or downstream is deemed too high. Removal of structures that would contribute little to affecting lower erosion hazards are also lower ranked.

7. Restore Incised Reaches

   Higher: Implementation of projects that can take advantage of certain corridor conditions, such as restoration of recently avulsed channels or where there are few encroachments allowing for the creation of new floodplain benches, is favored.

   Lower: Highly developed reaches where allowing natural channel migration within the meander belt is impractical or where mitigation requires bank armoring or other similar methods are ranked low. Similarly, projects where many of the stressors that cause the impairments are located outside of the reach or outside of the riparian corridor with a low chance of reaching equilibrium conditions are also rated low; these types of projects are considered higher risk. There may be however a strong imperative to protect infrastructure when incision is also accompanied by extreme bank instability.

8. Restore Aggraded Reaches

   Higher: Priority is assigned to projects that address aggradation as a result of localized conditions.

   Lower: Projects in which aggradation is driven by conditions outside the reach, especially on a watershed scale, are given a lower priority.

Riparian Buffer Enhancements

The enhancement, preservation, and protection of riparian buffers are important measures for protecting water quality in the Pequabuck River watershed. One of the reasons that riparian buffer enhancement is so important is that the benefits are multi-lateral. For instance, the enhancement of a degraded buffer, one that is characterized by lack of native vegetation including shrubs and trees, soil disturbances, and impervious surfaces among other problems, offers improved canopy coverage and stream shading which reduces stream temperature thereby improving benthic macroinvertebrate and fisheries habitat with resultant improvements in community structure, as well as decreased biological productivity related to periphyton growth thus leading to improvements both in excessive DO and pH. The following list exhibits some of the benefits of riparian buffer enhancement:

- Increased shading and maintenance of lower temperatures
- Decreased algal productivity

- Nutrient removal through vegetative uptake
- Vegetative trapping of solids and other pollutants
- Reduced runoff velocity and increased infiltration and evapotranspiration
- Increased bank stability and decreased erosion and sedimentation
- Functional wildlife habitat and protection of rare species
- Barrier to waterfowl access and decreased coliform loading
- Reduced flood damage
- Improved carbon cycling and allochthonous material deposition
- Reduced invasive vegetation colonization

No Mow Zones - The establishment of no-mow zones is probably the most easily implemented BMP that can improve stream function. The mowing of riparian buffers or the establishment of maintained lawn space is typical in developed watersheds and mowing often continues to the very top of the streambank within feet of the wetted channel. This leads to severe bank instability often characterized by mass wasting and severe undercutting. Besides the erosion and subsequent sediment deposition of the unstable banks much of the function associated with vegetated buffers, including shading, nutrient uptake, and wildlife habitat, among others, is lost.

Riparian Buffer Planting - The next step in riparian buffer enhancement is a more thorough approach focused on the restoration of native vegetation. Crucial to this scheme is the replication of natural riparian vegetation communities which integrate multiple vegetation types including herbaceous plants, shrubs, and trees, and may be structured to match different communities including riparian forests and herbaceous and scrub/shrub wetlands. In addition, these planting plans can be tailored as necessary to provide enhancement of existing but degraded buffers or the complete mitigation of severely degraded or non-existent buffers such as in maintained lawns. The design philosophy of riparian buffer planting is to restore the natural pollutant removal capabilities and stabilizing properties of fully functioning riparian buffers by adapting to site specific conditions such as soil moisture and incorporating those considerations into a three-dimensional plan that prominently features vertical design elements, such as trees, to produce a self-sustaining plant community. A figure showing various riparian zones along with minimum buffer widths to achieve various functional value improvements is provided below.

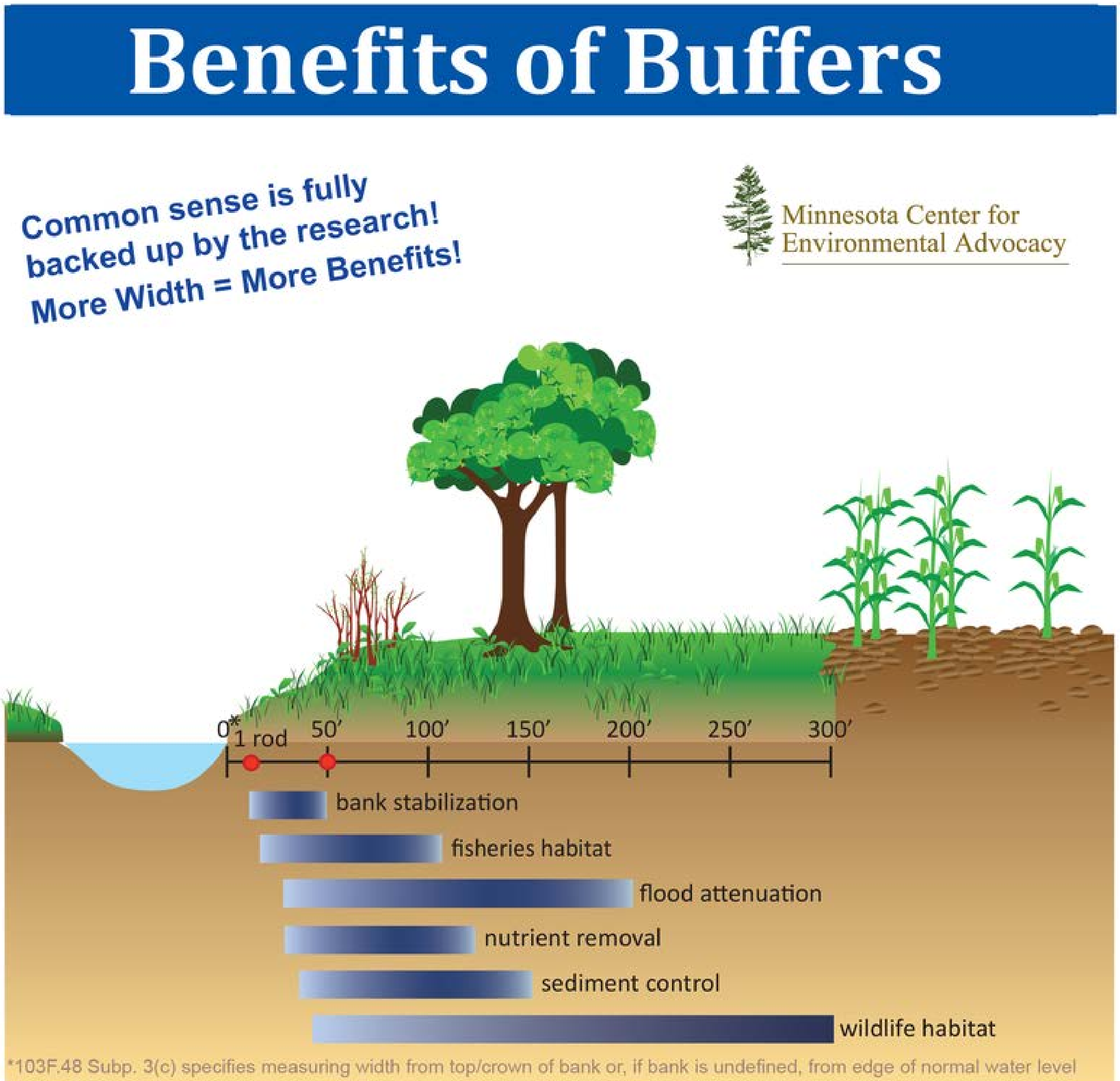


Figure 4.23: Riparian Buffer Zones and Functional Value Widths (Source: Minnesota Center for Environmental Advocacy)

Prior to initiating planting site preparation may be necessary to remove debris and invasive plants. The planting or re-planting of riparian buffers is designed to restore functionality and work within the confines of a selected site with minimal earthmoving. More intensive streambank stabilization projects requiring extensive engineering, excavation, and grading that incorporate planting will be discussed elsewhere in this document. For the most part buffer planting should be relatively low intensity and require primarily hand tools to dig holes to insert plants. Coir fiber mats may be installed in areas where there is extensive soil disturbance to help herbaceous vegetation become established, but other materials, like coir fiber logs that are typically installed along the toe of the bank, are not consistently effective in riparian settings and may not persist after bank full discharge events. The relatively low-key planting and removal of vegetation can, for the most part, be conducted without securing permits although consultants and sponsors collaborating on the design and installation need to be cognizant of potential restrictions.

As mentioned above several different plant types are to be utilized in the planting plan. While all plant types should be incorporated together the composition will change when moving away from top of bank such that wetland indicator species or those adapted for periodic inundation will be placed closer to the channel with a gradient shift towards upland species with increasing distance from stream. As such, the idealized planting plan would consist of three zones corresponding roughly to the bank, the floodplain, and the terrace (although different sources adopt widely varying naming schemes) with each zone incorporating three plant types.

The herbaceous layer is planted to prevent surface erosion and provide much of the stormwater filtering capacity as well as reducing runoff velocity. There are a wide variety of herbaceous plants, particularly grasses that are used in enhancing riparian buffers. Seeding rates vary considerably between mixes from 3 to 35 pounds per acre, but most mixtures require about 15 pounds per acre; in a 50' buffer this is equal to almost 900 linear feet parallel to the channel. It may also be desirable, especially where aesthetics are an important component of the restoration goal, to add wildflower mixes and other herbaceous plants as well as the grasses and groundcovers. Many of these herbaceous plants may be purchased and planted as plugs.

The shrub and small tree component begin to provide much of the bank stability with increased root zone depth, as well as providing shading and wildlife habitat. Finally, the large trees are responsible for creating canopy cover, transpiring water, and contributing to mass soil stability. Spacing guidelines vary, but the *PA Stormwater BMP Manual* recommends a mature tree density of approximately 320 trees per acre. Because the goal is the enhancement of natural systems it is important to plant in a fluid fashion with clustering and other natural features maintained to the exclusion of straight lines and other ordered designs.

A schematic concept of riparian plantings is provided below as well as a tree list. Please note, area specific research should always be conducted in order to select appropriate native vegetation.

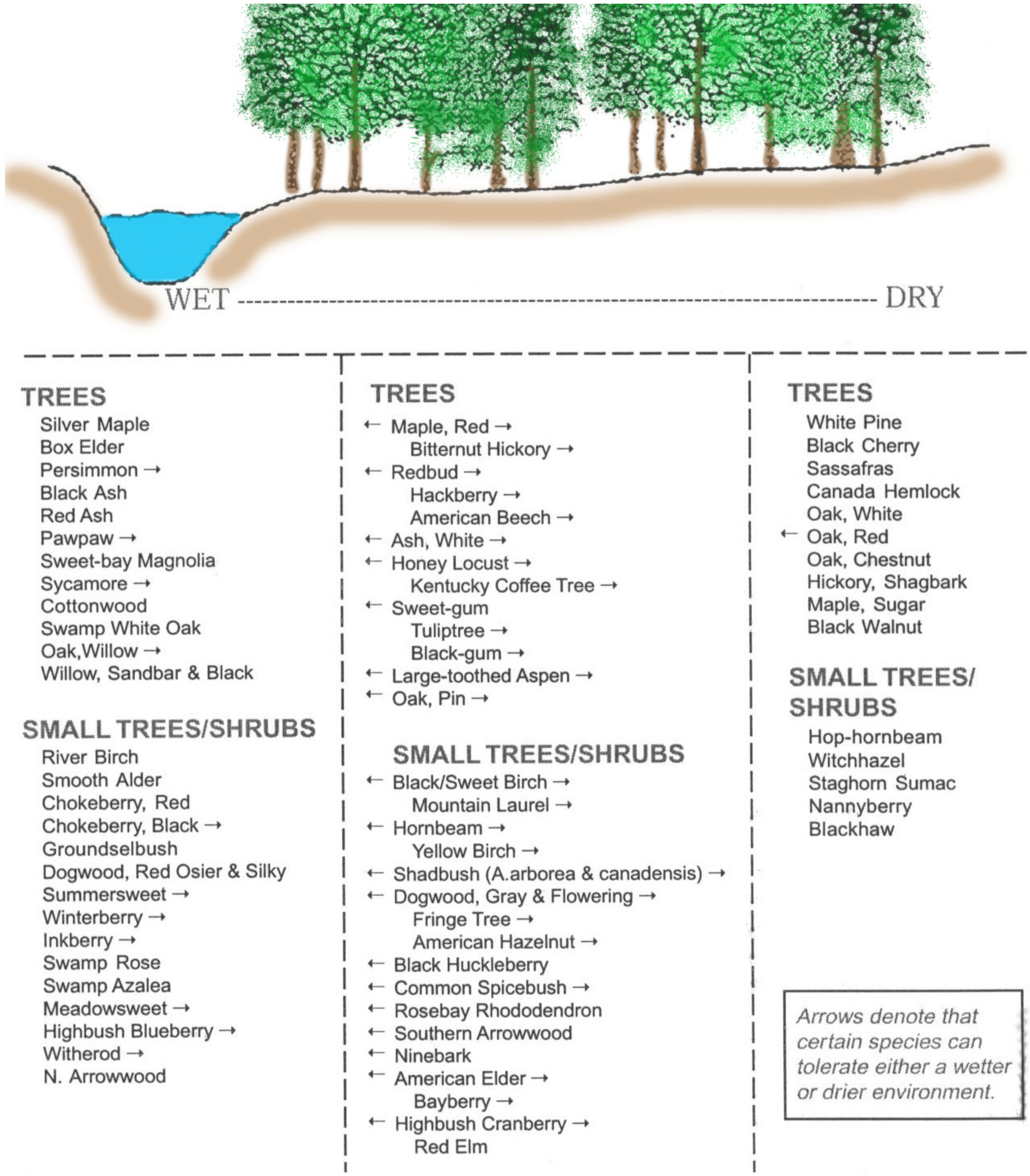


Figure 4.24: Trees and Shrubs for Planting Zones (Source: Malvern.org)

Pet Wastes and Wildlife Management

Pet waste and wildlife management is the last of the major management measure items to be discussed.

Pet Waste Management

Pet waste management is described as a conditional element of the MS4 permits, and as such the major municipalities are already addressing these elements through ordinances and outreach. Because the WBP is meant to supplement and complement MS4 requirements, existing pollutant abatement programs under the aegis of that permit will generally not be discussed in this document. However, since the control of bacteria is the primary goal of this WBP and managing the waste of domestic animals is one of the easiest loads to reduce those programs merit recognition. As with many NPS pollutant management measures the key is widespread implementation followed by consistent outreach and education and, where appropriate, enforcement thereafter. As such, the towns will be best served by continuing their current programs. That said, it is important to highlight some of the primary elements of these programs in this document.

- Education and Outreach – As a program that is dependent on individual pet owners, education and outreach is key to the success. Educational elements should address public health and water quality impacts. Outreach can be done through multiple means including educational brochures, public meetings and committee formation, signage, and media campaigns including press releases and website publishing.
- Investigation – Identifying and prioritizing problem areas is important for managing the problem and will direct where waste management tools should be employed. Researching pet owner behavior through surveys and field studies can also be utilized.
- Waste Management – Providing waste receptacles and bags in public spaces encourages proper waste disposal.
- Public Policy – Leash laws, pet waste ordinance, and policy regarding animals in public spaces should be implemented with reasonable enforcement mechanisms.

Wildlife Management

In the Pequabuck River watershed, wildlife has been modeled as a relatively small contributor to the overall loading of nutrients and bacteria, but Canada geese have been noted as a nuisance species, particularly in the park settings with water features. Bacteria and nutrient loading associated with geese can be particularly problematic as they defecate directly in or near waterbodies and thus represent a direct loading source. CT DEEP recommends the following non-lethal controls:

- Prohibit the feeding of geese and provide signage in public areas reinforcing the prohibition.
- Employ hazing methods designed to modify behavior with the intention of displacing the geese. Some hazing techniques include the use of visual deterrents like mylar tape, balloons, flags, and scarecrows. Trained dogs can be used to chase geese, as can remote control devices such as drones and boats. Noisemaking devices of various types can be used; some of these may be simple loud or startling noises while others can replicate distress calls. Laser pointers can displace roosting birds.
- Chemical repellents are applied to turf grasses to make grazing unpalatable. Other products may act as irritants.
- Habitat modification can be used including fencing to prohibit free passage between waterways and adjacent turf grass, shoreside planting of trees and shrubs can block views and decrease

passage, and allowing grasses to grow or replacing turf with ground covers decreases foraging habitat quality.

Lethal techniques could be considered, but this tends to be a sensitive topic and one largely dependent on community opinion. Egg addling is often employed to halt continued reproduction of non-migratory birds. This technique is less controversial than other lethal methods since no birds are dispatched, but it is a long-term measure that takes time to achieve its goals. Hunting is an important management measure on a regional scale, but is of limited utility in developed areas. Depredation permits are issued which can allow for the harvest of several birds per day. Finally goose roundups could be used during the molt, when the birds are replacing feathers and are essentially flightless. The birds are herded into portable nets and euthanized; often the meat is donated.

4.5 Regulatory Programs Aimed at Reducing NPS Loading

MS4 Program

The majority of the municipalities within the Pequabuck River watershed are participants in the MS4 Program, subject to the MS4 General Permit (See map at: https://cteco.uconn.edu/viewers/ctms4/). This program is designed to protect water quality through the regulation of the small storm sewer systems with minimum requirements. While the permit requirements are generally narrative and not specifically load based, aligning with the presentation of most of the water quality standards, an exploration of these requirements and adherence to them is important in meeting water quality and load reduction goals. Additionally, the MS4 Permit is legally enforceable and provides reasonable assurance that municipalities will implement the required actions to achieve TMDL targets. Some of the pertinent requirements are discussed below, including how these requirements will be addressed in the WBP, and progress in meeting the requirements.

General Permit Conditions

Section 5 of the MS4 General Permit identifies several permit conditions. The principal, guiding conditions state that stormwater discharges shall not contribute to acute or chronic toxicity, impair biological integrity, or pose unacceptable human health risks. Similarly, these discharges should not cause or contribute to the exceedance of applicable water quality standards. These are obvious conditions, but also point to attaining water quality standards as outlined in the surface water quality section above. In addition, new discharges, to the Maximum Extent Practicable, will prevent the discharge of the Water Quality Volume to the receiving waterbody; the Water Quality Volume is the volume of runoff generated by 1 inch of rain. Finally, stormwater discharges to waterbodies with an applicable TMDL shall manage stormwater quality for the Stormwater Pollutant of Concern. As discussed above, the Pequabuck River watershed is subject to a TMDL. The primary bacteria would be *E. coli* within the Pequabuck River watershed which contravenes recreational uses.

Stormwater Management Plans

One of the permit conditions is the development of a stormwater management plan (SMP). The design of the plan is to reduce the discharge of pollutants originating within small MS4s to the Maximum Extent Practicable (MEP) to protect water quality. It is noted that MEP is not precisely defined, and therefore there is wide latitude in meeting this condition, however, the attempt to control water quality must be serious with a focus on practical solutions. A variety of elements are considered in the determination of whether the condition is met, but addressing the characteristics of the receiving water, site specific characteristics, and appropriate design and operation of BMPs is chief among them.

There are six minimum control measures however that must be met. These will be discussed below. The SMPs from constituent municipalities (That had these SMPs readily available) are provided below:

- City of Bristol: www.ci.bristol.ct.us/DocumentCenter/View/12592
- Town of Plainville: https://www.plainvillect.com/engineering-department/pages/stormwater-management-program
- Town of Plymouth: http://www.plymouthct.us/Public-Works/

The required six (6) minimum measures below are referenced in terms of MS4 requirements to be undertaken by the constituent municipalities.

Public Education and Outreach

The goals of this measure are simple: to raise awareness of the significance of polluted stormwater; to motivate the public to adopt and utilize BMPs; to reduce pollutant loading as a function of public participation. The municipalities are active in meeting this measure with continued ongoing efforts, documented in the annual MS4 Reports prepared by the municipalities. Some of these measures include classroom education, distribution of literature, the development of the WBP, public environmental-themed fairs and activities, creation of table top displays, creation of pet waste management materials, and updates of the town stormwater websites.

Public Involvement/Participation

The goal of this measure is to actively engage the community and solicit participation. This includes participation in the development of the WBP, among other activities. Specific requirements include publishing public notices in various media and enlisting local organizations in implementation efforts. The towns have both submitted public notices regarding activities, have published the results of efforts and required reporting, partnered with local organizations, sponsored cleanups and household hazardous waste programs, stenciled storm drains, and established municipal committees addressing stormwater management.

Illicit Discharge Detection and Elimination

This is one of the most technical elements, with a large number of criteria, as befits a measure that could have substantial benefit in reducing pollutant loading. As the name suggests, Illicit Discharge Detection and Elimination (IDDE) focuses on finding illegal connections to the MS4 systems and severing those connections as major potential loaders. While detection, identification, and severing/correcting the illicit connection is the base goal, this also requires:

- Developing a protocol for detection
- Creating a means for citizen reporting of illicit discharges
- Maintaining records of findings, reports, and sampling
- Establishing legal authority to prohibit illicit discharges, controlling spills and dumping, authorizing fines, and any other related authority
- Developing a database and map showing size and type of each discharge, interconnection, receiving waterbody, and other related information
- For areas where phosphorus, nitrogen, or bacteria are a concern, such as this watershed, prioritizing the IDDE program to areas with the highest potential to discharge those pollutants based on the presence of historic onsite septic failures, proximity to bacteria impaired waters, poor percolation, and shallow groundwater

Many of the requirements have been satisfied by the towns, but some elements are in progress as work continues or as refinements suggest themselves.

Construction Site Stormwater Runoff Control

This measure refers to the short-duration regulation of the development process. Site development including earthmoving activities can have a major impact to pollutant loading, particularly the generation of solids and erosion, during the construction phase. In general, this element, historically, has been the basis of much land use regulation across local, county, and State governance. More recently, stormwater management BMPs have been required to address post-construction conditions as well. As with other measures, there are a number of conditions that must be satisfied.

Post-Construction Stormwater Management in New Development or Redevelopment

This measure refers to stormwater management requirements for future development, whether new development or redevelopment of existing sites. It is largely focused on the implementation of newer, better performing stormwater designs, and where possible consistency with low impact development (LID) goals. As usual, there are a number of conditions that must be addressed. These include the following:

- Establish legal authority through updates of environmental regulations through the use of LID consistent with the requirements of the Stormwater Quality Manual and retention of half or all of the water quality volume dependent on the amount of Directly Connected Impervious Area (DCIA) and whether it is new development or redevelopment, and reduce barriers to implementing LID and runoff reduction practices
- Minimize impervious surfaces, preserve ecologically sensitive areas that provide water quality benefits, reduce or prevent thermal impairments, avoid hydromodifications of receiving waters, protect trees, and protect native soils
- Map DCIA
- Implement a maintenance plan for installed BMPs
- For waters in which nitrogen, phosphorus, or bacteria is a Stormwater Pollutant of Concern address erosion and sediment problems through a prioritized program for retrofits with attendant plans for short and long-term maintenance

The municipalities are cognizant of LID and the benefits of this design approach on improving water quality. The Town of Plainville had integrated LID in advance to the State's LID addendum to their erosion and sediment guidelines. A copy can be viewed at:

https://www.plainvillect.com/sites/plainvillect/files/uploads/low_impact_development_stormwater_management_design_manual.pdf

Utilization of LID is promoted throughout the Stormwater Management Plans developed by the City of Bristol and Town of Plymouth and has been incorporated into municipal codes and ordinances. Further integration of LID throughout all pertinent legal avenues should be continued in order to preserve open space and foster advanced stormwater management through low impact, natural means.

Pollution Prevention/Good Housekeeping

While seemingly simple, this measure involves the use of many cultural BMPs to reduce source loading. It also addresses retrofitting, upgrading, and maintaining existing infrastructure. The pertinent requirements are summarized below and are currently being addressed in both towns, although largely implemented in practice.

- Employee training for awareness of water quality issues including identification and reporting and spill response
- Repair and rehabilitation of MS4 infrastructure in a timely manner to improve performance
- Disconnection of DCIA through retention of the Water Quality Volume through retrofits using LID, infiltration, or reuse
- Develop proper operations and maintenance for parks and open space including fertilizer reduction and trash management; pet waste management through public education, enforcement, signage, disposal receptacles; waterfowl management including discouraging feeding and discouraging congregation; facilities should properly dispose waste and maintain Spill Prevention Plans; vehicles and equipment should be managed to prevent leaks and retain wash water; leaf management to prevent deposition in, on, or near infrastructure
- Street, parking, and MS4 maintenance should including regular sweeping and proper disposal, inspection of catch basins, and catch basin cleaning dictated by inspection
- Snow management should minimize the use and handling of deicing materials and consider alternative materials where available, and establish practices regarding snow and ice control
- Coordination with other responsible parties with interconnected MS4s
- Control contributions to the MS4 from commercial, industrial, municipal, institutional, or other facilities
- Develop and prioritize specific procedures for impaired waters where the Stormwater Pollutant of Concern includes nitrogen, phosphorus, or bacteria

Monitoring Requirements

There are specific monitoring requirements for the program. Outfalls that discharge to impaired waters, either waters listed on the 303(d) list or with a TMDL, must be monitored to reduce loading and ascertain BMP efficacy for the pollutant of concern. If wet weather data is available for that outfall or other monitoring program, that may be used in lieu of dedicated efforts. Once screened, the results may dictate a follow-up investigation. For total nitrogen concentrations exceeding 2.5 mg/L shall be investigated; for total phosphorus that value is greater than 0.3 mg/L. Bacteria shall be sampled for *E. coli* and total coliform for Class AA and A waters, and fecal coliform and Enterococci for discharges to Class SA waters. Follow up investigations should be initiated at *E. coli* concentrations > 410 cfu/100 mL for areas other than swimming areas, total coliform > 500 cfu/100 mL, fecal coliform > 31 cfu/100 mL, and Enterococci > 500 cfu/100 mL outside of swimming areas. The follow up investigating involves an inspection of the drainage area with focus on land use activities, DCIA, maintenance issues, and other potential contributors. Following this, a BMP control program should be implemented. Outfall screening should be conducted on at least half of the outfalls in the first year, and following that, the results should be prioritized and six outfalls be monitored thereafter.

There is also normal stormwater monitoring that must be observed, including from rain storms that produce discharge from monitored outfalls at least 48 hours after any previous discharge producing event.

5.0 Technical and Financial Assistance

Implementation of plan elements and project concepts is dependent on securing the funding and technical assistance to support those goals. As a crucial element of a WBP, this section addresses the fourth of the EPA nine elements.

5.1 Financial Assistance

From a practical perspective, one of the major limiters on successfully managing NPS pollution, meeting water quality standards and designated uses, and controlling stormwater is funding. The expense of these items is two-pronged: first, the management of NPS pollution requires action on a broad front because the loading by definition is diffuse and effective management requires the implementation of many projects; second, while the management measures are often simple from a conceptual perspective, the permitting, design, materials, labor, and monitoring, not to mention land acquisition and easements, all incur real and significant costs. These costs are further amplified because implementation is typically sponsored at a local level, be it municipality, landowner, or NGO, where ready access to capital may be difficult.

Despite the costs of implementing individual implementation projects or enacting a watershed management plan such as this document, there are a wide array of funding resources available to help offset the costs. Grants are typically the primary source of these funds, but other streams are available including the issuance of bonds, typical governmental budgeting and appropriations, and low-interest loans. These funds help defer the costs of such projects and typically carry a number of conditions to both maximize the funding and ensure the delivery of a high-quality product often requiring matching funds, in-kind contributions, and stringent reporting and monitoring requirements. The availability of these funds is predicated on meeting the goals of the grantor which can range from simple environmental restoration and conservation, more focused efforts to meet the objectives of a program, regulation, or law such as the Clean Water Act, or targeted efforts to meet the needs of a specific requirement such as satisfying an existing TMDL. Many of the programs provide not only financial assistance, but technical assistance. The following sections will explore some of the available funding opportunities.

Section 319 Non-Point Source Management Program

One of the best known and widely utilized programs developed to manage NPS pollution throughout the Nation is the Section 319 Nonpoint Source Management Program. This program was established in 1987 under amendments to the Clean Water Act and created a funding mechanism in which monies were allocated to the States, territories, and tribal authorities that award and administer grants for State and local level projects. According to the EPA website, billions of dollars have been allocated over the life cycle of the program, and from 2000 through 2017 (the last posted update) at least $150 million has been made available, nationwide, annually. While this funding covers an array of activities, the 319 grants are recognized by the EPA as particularly important in implementing TMDLs. In Connecticut, 319 funds are utilized to fund implementation projects identified in WBPs which may or may not have an existing TMDL.

There are a number of requirements under federal statute and governing technical regulations. Thematically, the grants are to cover projects that provide for the management of nonpoint source pollution. There is a continued focus on watershed-based plans (WBP) that meet the EPA Nine Elements. As this project is funded by a 319 grant and is meant to address loading issues for the TMDL and also existing water quality impairments for aquatic life use support, this WBP adheres to these requirements.

There are a number of reporting and tracking requirements to ensure and document the success of the projects.

The States have considerable latitude in the administration and award of grant monies to applicants. In Connecticut, 319 Grants fall under the support of the CT DEEP Nonpoint Source Pollution Management Program. In particular, the prioritization of projects and the scale of projects is set at the State level. For 2019, CT DEEP has identified the following priorities:

- Watershed Based Plan Implementation Projects – Project priorities for FY 2019 will continue to stress implementation projects in watersheds that have approved Watershed Based Plans (WBP) and that lead to targeted pollutant load reductions, improved habitat conditions, or dam removal. Implementation projects should have a clear connection to the management goals and objectives of the WBP and show progress towards attaining water quality goals.
- Implementation Projects Not Associated with WBPs – DEEP may consider implementation projects that are not connected to an existing WBP, but target impaired waters. Applicants must be able to document benefits toward pollutant load reduction and attainment of water quality standards. For implementation projects not covered under a WBP, applicants should consider including development of a WBP as part of the project proposal where practical, or documenting how the 9 Elements of Watershed Based Planning process are addressed.
- Watershed Based Plan Development – In 2019 DEEP will focus first on Action Plan development for waters which are prioritized in DEEP's Integrated Water Resource Management. DEEP may also consider WBP development for bodies listed as impaired that are not listed in DEEP Integrated Water Resources Management program (See Chapter 3 of the 2016 State of Connecticut Integrated Water Quality Report for a list of impaired waters). EPA has provided detailed guidance on WBP structure and content. See requirements for Watershed Based Plans. When the impairment is not specific to a pollutant, or when addressing a small scale water quality problem, DEEP will consider alternative Watershed Based Plans.

Implementation of Non-Structural Best Management Practices will also be considered, but is of a lower priority. Those elements will include:

- Monitoring, Assessment, and Trackdown Projects – DEEP will consider using Section 319 funds to support monitoring, modeling, assessment, and trackdown studies relevant to the control of nonpoint source pollution.
- Watershed or Statewide Education and Outreach Projects – Demonstration, technical assistance, public outreach and education, and watershed management projects may also be funded. Pollution prevention outreach activities that promote better pet waste, lawncare, or reduce the pollution in runoff from impervious surfaces fit in this category. Projects that can demonstrate water quality improvements or have technical transfer capability rank higher.
- Land Use Management Projects – These projects may include municipal land use evaluations and modification to existing regulatory programs that promote green infrastructure and low impact development techniques, integrated pest and/or nutrient management planning, site plan reviews, education for municipal officials or land use boards, and other activities that benefit nonpoint source pollution control.

These priorities evolve over time and are subject to change in response to emerging issues or completion of historical objectives. The grant process is competitive and therefore those grant submissions that best address the priorities, demonstrate project understanding, and have a sound technical approach have the best chance of successful award. Fund matches are not always required, but are encouraged and help to expand the scope of a work plan. One of the benefits of preparing a WBP that adheres to the EPA Nine

Elements is that the management measures and implementation projects identified within the document often conform to priority action items thus increasing the likelihood of successful award. 319 Grants are likely to play a partial role in meeting the funding requirements for this WBP but cannot be the only funding mechanism utilized. In fiscal year 2019, less than $1 million was dispersed throughout the entire State of Connecticut.

Other Federal Funding Sources

In addition to the 319 NPS Grants, the federal government has enacted a host of additional programs and grants designed to address broad environmental protection goals. The origin, statutory authority, responsible agency, and objectives of these programs are variable, as are year-to-year to funding which can be Congressional appropriation, environmental damages settlements, excise taxes, or other sources. A summary table, adapted from the *Connecticut Nonpoint Source Management Program Plan*, is provided below that identifies the responsible agency, the name of the grant or program, and URLs to the program web page. A brief summary of the highlights is discussed below.

The EPA maintains a broad portfolio of programs and responsibilities, as well as providing technical guidance to the States and other stakeholders. As such, EPA programs run the gamut from community health initiatives to straight environmental conservation efforts and many programs in between. As such, some programs deal with meeting water quality or air quality criteria, targeting specific geographic locations or sensitive environmental features, outreach and education, and habitat improvements. As with all of the grants, while each program and grant has specific requirements to meet the stated objectives, environmental restoration, protection, and NPS pollution management broadly overlap and one project can fulfill many different goals. For instance, the creation of a stormwater wetland may be constructed to meet water quality goals, but may also be viewed as habitat creation. This type of approach allows various funding avenues to be explored.

The United States Fish and Wildlife Service (USFWS) also is a major federal grantor. Unlike EPA, USFWS programs tend to have a tighter focus on habitat-oriented projects. These can include many different habitat types such as wetlands and uplands, and may foster habitat improvements for various species like migratory fishes, shorebirds, or imperiled species. The United States Forest Service also has a more singular focus and implemented primarily at a landscape level.

Table 5.1: Federal Grant Sources		
Entity	Program	Link
EPA	Urban Waters Small Grants	https://www.epa.gov/urbanwaters/urban-waters-small-grants
	Healthy Communities Grant Program	https://www3.epa.gov/region1/eco/uep/hcgp.html
	Five Star Restoration Grant Program	https://www.epa.gov/urbanwaterspartners/five-star-and-urban-waters-restoration-grant-program-2018
USFWS	North American Wetlands Conservation Act	https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php
NFWF	Long Island Sound Futures Fund	https://www.nfwf.org/lisff/Pages/home.aspx
NOAA	Coastal Nonpoint Pollution Control Program	https://coast.noaa.gov/czm/pollutioncontrol/
NRCS	Conservation Stewardship Program	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/
	Emergency Watershed Protection Program	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/landscape/ewpp/

The Natural Resources Conservation Service (NRCS) also has a rather broad portfolio and many of their programs are designed around responsible resource utilization and extraction. As such, this agency provides many programs that focus on agriculture and forestry management. As part of their resource conservation mission, there is also a strong stormwater management component, including relief from natural emergencies such as repeated flooding, and general wildlife habitat creation. Unlike some of the other agencies and funds many of the programs sponsored by NRCS are made available to landowners. This recognizes the vast amount lands privately held and managed in the country that merit the same environmental protections as public lands.

CT DEEP Funding Sources

CT DEEP, much like the EPA at the federal level, is tasked with “conserving, improving, and protecting the natural resources and the environment of the State of Connecticut,” as well as being tasked with overseeing energy concerns. As such, CT DEEP oversees a number of programs meant to satisfy those charges. The objectives are varied and include open space acquisition, outreach, infrastructure and wastewater, hazard mitigation, lake restoration, and similar measures. While many of the programs are focused on providing funding and technical assistance to municipalities, counties, and conservation organizations, some of the programs are designed to reach other stakeholders including landowners and water suppliers. The source of these funds is varied, much like the federal grants, and includes monies sourced from federal agencies to be administered by CT DEEP, appropriated by the General Assembly, sourced from taxes and fines, or drawn from the department budget.

Table 5.2: CT DEEP Programs and Grants	
Program	Link
Connecticut Clean Water Fund	https://www.ct.gov/deep/cwp/view.asp?a=2719&q=325576&deepNav_GID=1654
Hazard Mitigation Grant	https://portal.ct.gov/DEMHS/Grants/Hazard-Mitigation-Grant-Program
Open Space and Watershed Land Acquisition	https://www.ct.gov/deep/cwp/view.asp?a=2706&q=323834&deepNav_GID=1641
Recreation and Natural Heritage Trust Program	https://www.ct.gov/deep/cwp/view.asp?a=2706&q=323840
Urban Forestry Grant	https://www.ct.gov/deep/cwp/view.asp?a=2697&q=322872&deepNav_GID=1631

Private Funding Sources

Table 5.3: Private Programs and Grants	
Program	Link
Rivers Alliance – Watershed Assistance	http://www.riversalliance.org/WASGP/WASGPmain.php
Connecticut Association of Conservation and Inland Wetlands Commission	https://www.caciwc.org/pages/cc/cc_grants.html
New England Grassroots Environment Fund	https://grassrootsfund.org/dollars

5.2 Technical Assistance

As much as funding is necessary to implement management programs and projects, technical assistance is required to properly design and oversee implementation of management measures, be it structural or cultural BMPs, outreach, training, or a related course of action. The following section will discuss project roles, key players, and sources of technical information and assistance.

- **Project Sponsor** – The project sponsor serves as the hub of project implementation. Pequabuck watershed municipalities may serve as project sponsor, although non-profits and even landowners may also serve this role. They are responsible for all project activities, usually starting with identifying the need for a project in response to a regulatory requirement, proposed project in existing plan (e.g. This WBP), identified problem, emergency need, or general policy. They subsequently interface with the landowner or manager, and identify stakeholders to move the project forward. This is followed by securing funding or submitting grant applications. If awarded they hire consultants, contractors, and vendors, interface with regulators, oversee the financials, and ensure all steps are followed. Experience is of great benefit in navigating the complexity of the process.
- **Landowner/Manager** – Landowners or managers have a vested interest in project success, and grant permission to proceed. In some cases, they may serve as project sponsor, but more typically either approach the project sponsor to correct a problem or are approached by the project sponsor after having identified significance to a particular parcel of land (i.e. Land area contributing NPS pollution).
- **Stakeholders** – Stakeholders consist of many people, but a large component would include the community that are directly or indirectly affected by the project. Identifying stakeholders early in the project and soliciting their input is very important. In watershed projects, there is a strong link between project success and stakeholder involvement, particularly those stakeholders downstream who stand to gain the most by its success. While technical contributions may be limited, this is not always the case, as stakeholders and residents often have the best understanding of system deficiencies, a resource that should be utilized.
- **Grantor** – The grantor at the most basic level is responsible for financial assistance and project awards. As noted above, financial assistance is usually not offered in a vacuum and grant awards are often associated with programs that offer technical assistance. In addition, the grantor usually imposes stringent reporting requirements as a condition of the grant award that may include technical reporting, design, and financial management.
- **Regulators (Local, State, and/or Federal)** – A major function of regulatory agencies is to ensure that projects, whether implementation, planning, or other types of projects, meet the technical regulations. In particular, implementation projects are often subject to various land use and other permitting requirements although exceptions and waivers may be offered depending on the scope and objective of the project. Besides overseeing the regulatory matters, regulators may function as the grantors or project sponsors. They typically act as contributing partners in these types of projects.
- **Professionals and Consultants** – This class includes ecologists, hydrologists, engineers, planners, geologists and related professions that are typically hired by the project sponsor at the onset of the project. They serve multiple roles, but core functions may include monitoring, project design, preparation of permit applications, construction oversight, and reporting and interface with all other project roles. Coordinating the varied project components is a fundamental responsibility of consultants. In particular, consultants offer their project experience to navigate the various

intricacies of the project and thus must demonstrate technical, regulatory, outreach, and project management knowledge and the ability to identify sources of assistance.

- **Contractors and Vendors** – Contractors and vendors both offer deep technical knowledge of project implementation and necessary materials. The best contractors are also well-versed in the regulations to ensure project success.

Sources of Technical Assistance

This section will identify some of the various programs, regulations, agencies, and guidance manuals that will be of assistance. It is organized by the broad classes of management measures and BMPs discussed above. Sections of text are adapted from the Connecticut Nonpoint Source Management Program Plan.

Septic Management

As with many of the management measures, there a number of parties that regulate and assist with many of these matters. Septic management in this context refers primarily to subsurface sewage disposal systems (SSDS), but other wastewater disposal may be considered as well.

- At the municipal level, the Health Department is responsible for regulating onsite septic systems.
- Bristol also maintains a Water Pollution Control Division of the Public Works Department that accounts for overseeing wastewater treatment
- CT DEEP Subsurface Sewage Disposal Program regulates SSDS at the State level and systems exceeding 5,000 gpd: http://www.ct.gov/deep/subsurfacedisposal
- The Connecticut Department of Public Health Environmental Engineering – Subsurface Sewage Program (CT DPH) regulates systems with design flows of 2,000 to 5,000 gpd: http://www.ct.gov/dph/subsurfacesewage

Guidance documents, regulations, and educational resources include:

- CT DEEP Guidance for Design of Large-Scale On-Site Wastewater Renovation Systems: http://www.ct.gov/deep/lib/deep/water_regulating_and_discharges/subsurface/2006designmanual/designmanual2006.pdf
- CT DPH Design Manual Subsurface Sewage Disposal Systems for Households and Small Commercial Buildings http://www.ct.gov/dph/lib/dph/environmental_health/environmental_engineering/pdf/DESIGN_MANUAL_Part_1.pdf
- EPA Septic System Website: http://water.epa.gov/infrastructure/septic/

Stormwater Management

Much of the on-the-ground measures of stormwater management are implemented and managed at the local level, and incorporate regulatory requirements of municipal land use law, as well as State and federal requirements. The major departments, agencies, organizations, and programs concerning stormwater management include:

- Water Departments
- Municipal Aquifer Protection Agencies
- Engineering Departments
- Building Departments
- Conservation Commissions

- Public Works
- Connecticut Conservation Districts: https://www.conservect.org/
- CT DEEP Stormwater Management Program
- Municipal Inland Wetland Commission

Guidance materials include:

- 2004 Connecticut Stormwater Quality Manual: http://www.ct.gov/deep/cwp/view.asp?a=2721&q=325704&deepNav_GID=1654
- Low Impact Development Appendix to the Connecticut Stormwater Quality Manual: http://www.ct.gov/deep/lib/deep/water/nps/swgp/lid_apdx_ctstormwatermanual.pdf
- 2002 Connecticut Guidelines for Soil Erosion and Sediment Control and Low Impact Development Appendix: September 2014
- 2014 Connecticut Nonpoint Source Management Program Plan: http://www.ct.gov/deep/cwp/view.asp?a=2720&q=325660&deepNav_GID=1654%20
- Connecticut's Coastal Nonpoint Source Pollution Control Program - Urban Sources: http://www.ct.gov/deep/cwp/view.asp?a=2705&q=323572&deepNav_GID=1709
- CT DEEP Municipal Outreach for Green Infrastructure and Low Impact Development: http://www.ct.gov/deep/cwp/view.asp?a=2719&q=464958&deepNav_GID=1654
- CT DEEP Low Impact Development Resources Fact Sheet: http://www.ct.gov/deep/lib/deep/water/watershed_management/wm_plans/lid/lid_resources.pdf
- University of Connecticut NEMO Program: http://nemo.uconn.edu/
- University of New Hampshire Stormwater Center: http://www.unh.edu/unhsc/
- Green and Growing Tool Box - inventory of policies, plans, or programs administered by Connecticut State Agencies represented on the Inter-Agency Responsible Growth Steering Council: http://www.dir.ct.gov/opm/IGP/Tools/index.asp
- CT DEEP Organic Lawn Care: http://www.ct.gov/deep/cwp/view.asp?A=2708&Q=382644

Agricultural Best Management Practices

Agriculture has a long heritage and is an important economic driver in Connecticut. Because of its operational needs including fertilization, manure management, and tillage, as well as the specialized demands of related forestry programs and aquaculture or commercial fishing, and because it is land intensive it is necessary to manage these lands and resources. From a resource conservation perspective there is a long history of resource management to conserve soil, increase production, and to provide stewardship. The federal government has a long-standing interest in promoting agricultural BMPs as does the State. Please note, while agriculture is not an expansive land use in the watershed, it is present as a small portion overall. Therefore, some relevant programs, agencies, and sources of information include:

- Connecticut Department of Agriculture: http://www.ct.gov/doag/
- Connecticut Farm Bureau Association: http://www.cfba.org/
- USDA Connecticut Farm Service Agency: http://www.fsa.usda.gov/FSA/stateoffapp?mystate=ct&area=home&subject=landing&topic=landing
- Connecticut Farmland Trust: http://www.ctfarmland.org/
- Natural Resources Conservation Service: http://www.ct.nrcs.usda.gov/
- University of Connecticut Cooperative Extension System: http://www.extension.uconn.edu/
- CT DEEP Pesticide Management Program: http://www.ct.gov/deep/pesticides

- CT DEEP Manual of Best Management Practices for Agriculture, Guidelines for Protecting Connecticut's Water Resources: http://www.ct.gov/deep/lib/deep/aquifer_protection/bmps_agriculture.pdf

Stream Bank Stabilization and Riparian Buffer Enhancements

In-stream and riparian buffer enhancements work in conjunction with stormwater quantity and quality management measures to correct both localized and systemic functional impairments of riparian areas, wetlands, and flowing waters. Besides correcting deficiencies, part of the strategy is to restore the functionality of these systems to aid in flood storage and water quality improvements. CT DEEP plays a particularly important role in these restoration activities in addition to the federal government through the United States Fish and Wildlife Services (USFWS), United States Geological Survey (USGS), and others. Furthermore, non-profit groups (e.g. American Rivers) are also an important player in restoration.

The following provides some of the primary sources of technical guidance, regulations, and permitting requirements for Connecticut:

- CT DEEP Inland Water Resources Division Permits: http://www.ct.gov/deep/inlandwaterpermitapps
- U.S. Army Corps of Engineers Connecticut General Permit: http://www.nae.usace.army.mil/Portals/74/docs/regulatory/StateGeneralPermits/CT_GP.pdf
- Connecticut Stream Flow Standards and Regulations: http://www.ct.gov/deep/streamflow
- CT DEEP Resident's Guide to Vegetated Riparian Areas: http://www.ct.gov/deep/lib/deep/water/watershed_management/wm_plans/lid/what_is_a_vegetated_riparian_area.pdf
- CT DEEP Inland Wetlands and Watercourses Program: http://www.ct.gov/deep/inlandwetlands
- CT DEEP Stream Habitat Restoration Projects: http://www.ct.gov/DEEP/cwp/view.asp?a=2696&q=322734&deepNav_GID=1630
- CT DEEP Inland Fisheries Division Stream Crossing Guidelines: http://www.ct.gov/deep/lib/deep/fishing/restoration/streamcrossingguidelines.pdf
- CT DEEP Inland Fisheries Division Large Woody Debris Fact Sheet: http://www.ct.gov/deep/lib/deep/fishing/restoration/largewoodydebrisfactsheet.pdf

Pet Waste and Wildlife Management

Pet waste and wildlife management tends to be a simpler management solution, with municipalities and homeowners often taking the lead. Parks and Recreation departments are especially important when it comes to the management of public lands where dog walking is popular or in areas of high goose utilization. The city of Bristol maintains ordinances related to pet wastes. CT DEEP and other sources have also developed a variety of guidance.

- "Give a Bark for a Clean State Park" Pet Waste Outreach Program: http://www.ct.gov/deep/lib/deep/p2/newsletter/p2viewfall08.pdf

- CT DEEP Canada Geese Management Fact Sheet: http://www.ct.gov/deep/cwp/view.asp?a=2723&q=325984&deepNav_GID=1655

- CT DEEP Deer Management Program: http://www.ct.gov/deep/deerlottery

- Connecticut River Coastal Conservation District Pet Waste Outreach: http://conservect.org/ctrivercoastal/PetWaste/tabid/317/Default.aspx

- City of Bristol Dog Waste Ordinance:

  https://library.municode.com/ct/bristol/codes/code_of_ordinances?nodeId=PTIICOOR_CH4ANFO_S4-3PIDIDOWAFI

6.0 Education and Outreach

This section reviews the information and education (I/E) aspect of the WMP. Specifically, it deals with identifying and building stakeholder involvement, developing educational and outreach programs and materials, and encouraging the adoption of measures and practices to protect the watershed and water quality. This section corresponds to the fifth of the EPA nine elements.

6.1 Outreach Development

The protection and preservation of water quality and the ability to address the existing TMDL concerns and other water quality impairments in the Pequabuck River watershed is contingent upon the education of the target audience including public officials, residents, landowners, farmers, businesses, and other stakeholders in the watershed. Goals of I/E programs should include:

- Improving communication, training, and coordination among local, County, and State governments and environmental and stakeholder organizations. Improve public education and raise awareness to promote stewardship of watershed resources, improve water quality, and reduce NPS pollutants, particularly indicator bacteria.
- Celebrating successes to recognize continuing and noteworthy efforts, encourage participation, and continue the implementation of the WMP.
- Focusing on development of ordinances that impact water quality and impacts to the watershed, including development

One of the best and most comprehensive sources for the development of outreach programs is the EPA's *Getting in Step: A Guide for Conducting Watershed Outreach Programs,* 3rd ed.:

https://cfpub.epa.gov/npstbx/files/getnstepguide.pdf.

This document discusses outreach program development and implementation. The EPA also maintains the *Nonpoint Source Outreach Digital Toolbox* (https://cfpub.epa.gov/npstbx/index.html), a clearinghouse for various educational materials including surveys, evaluations, and media campaigns.

Some of the key outreach methods include:

- Demonstration projects
- Watershed tours and hikes
- Workshops and staff training seminars
- Volunteer opportunities for cleanups, planting, and monitoring

- Planning efforts and local ordinance

The Programs and Institutions identified in the financial and technical assistance section should be consulted, as appropriate. Other groups or sources that may provide appropriate materials are:

- The Groundwater Foundation: https://www.groundwater.org/
- The River Network: https://www.rivernetwork.org/
- Green Values Stormwater Toolbox: http://greenvalues.cnt.org/
- Center for Invasive Species and Ecosystem Health: https://www.invasive.org/

Continuing to identify stakeholders is also an important component of this project. Specifically, efforts need to be made to engage not only the community at large, but a targeted pro-active effort is necessary to include property owners or managers that own land that contains and/or is adjacent to waterways, ponds, wetlands, and floodplains.

6.2 Ongoing Outreach Efforts

Through this project there are current and active outreach programs. The WBP has already successfully identified project partners and stakeholder groups that have the ability and capacity to promote the goals of the plan and disseminate educational materials. In addition to the grantee, the following project partners have been identified:

- CT DEEP
- Farmington River Watershed Association (Grantee)
- Pequabuck River Watershed Association
- City of Bristol
- Town of Plymouth
- Town of Plainville
- Town of Harwinton
- Town of Burlington
- Town of Farmington
- Town of Wolcott
- Naugatuck Valley Council of Government
- Capitol Region Council of Governments
- Environmental Learning Centers of Connecticut, Inc.
- Connecticut River Conservancy (Formerly the Connecticut River Watershed Council)
- Farmington Valley Trout Unlimited
- Rivers Alliance of Connecticut
- Northwest Hills Council of Governments
- Northwest Conservation District
- North Central Conservation District
- Southwest Conservation District
- Lower Farmington River & Salmon Brook Wild & Scenic Committee

Together, these partners are represented on the Steering Committee for the project. To date, the following outreach has been conducted.

- Pequabuck Stakeholders Work Group – December 3, 2015 – Bristol City Hall
- Pequabuck Stakeholders Work Group – January 19, 2016 – Bristol City Hall

- Project Kick-Off – March 9, 2016 – Bristol Public Library
- FRWA Public Presentation – May 4, 2016 – Town of Plainville Inland Wetland Meeting
- Pequabuck Stakeholders Work Group – January 11, 2017 – Bristol City Hall
- Public Information Meeting – January 14, 2017 – Hosted by PRWA and FRWA
- Pequabuck Stakeholder Meeting – January 17, 2017 – Bristol Public Library
- Draft Modeling and Field Assessment Meeting & Presentation – March 19, 2019 – Bristol City Hall
- Stakeholder Meeting and Presentation of Draft WBP – August 29, 2019 – Bristol City Hall
- Stakeholder Meeting and Presentation of Final WBP – September 26, 2019 – Bristol City Hall

Appendix E provides an example of an ongoing outreach efforts aimed at highlighting successful BMPs in the Pequabuck River Watershed.

Both the Farmington River Watershed Association and the Pequabuck River Watershed Association are active entities in the Pequabuck River Watershed engaging in homeowner, business and municipal outreach on ways to protect the resources of the Pequabuck River Watershed. There are also numerous entities that support and complement the outreach efforts of PRWA and FRWA including the local Conservation Districts, the municipalities and local non-profits such as the Environmental Learning Centers of Connecticut and their 2 educational properties; the Barnes Nature Center and the Indian Rock Nature Preserve. Existing educational programs from these stakeholders include (but are not limited to):

- Workshops, presentations and events including annual spring and fall river cleanups, participatory river monitoring including aquatic insect and water sampling, best management practices tours for municipal officials, workshops including river friendly landscaping and organic lawn care, and participation in regional fairs including the Rockwell Park Festival and the Bristol Mum Festival.
- Best Management Practices demonstration sites including rain gardens installed at Bristol's Page Park and at the Bristol Eastern High School campus,
- Website, and social media accounts that distribute event and educational programing,
- Print publications including newsletters, postcards, event announcements, and press releases to area newspapers and magazines,
- Encouraging individuals and businesses to pledge to Connecticut's RiverSmart program (riversmartct.org) which educates homeowners and businesses on what causes polluted runoff and makes suggestions on how they can reduce the amount of pollution they may be individually producing,

Youth education programs in the local water treatment plant and summer camps hosted by municipalities and the local nature center properties.

As required by the sixth EPA element, this document contains an implementation schedule. This is intended to provide a timeline such that measurable actions are implemented in a reasonably expeditious way.

7.0 Implementation Schedule

However, from a practical perspective, it should be noted that one of the major limitations on successfully managing NPS pollution, addressing water quality impairments as to meet water quality standards and designated uses, and simply implementing a comprehensive watershed management plan is securing funding. Project implementation can be an expensive proposition, especially where watershed-wide implementation is necessary to meet pollution reduction goals and align with the TMDL goals as in the Pequabuck River watershed. As such, there will likely be a heavy reliance on grants and other financial vehicles. In turn, securing such funding can be challenging for a number of reasons. Assistance programs are subject to changing appropriations from year to year and may be entirely defunded. Grant programs often have relatively low levels of funding relative to demand, and as a consequence the process tends to be quite competitive. Further, funding and management priorities may change over time.

The remainder of this section will explore the implementation schedule.

7.2 Years 1 to 2

In the short term, local non-profits and watershed stakeholders should form partnerships with landowners, schools, and municipal buildings identified in the BMP section above. As many potential projects are on private property, these partnerships will be critical to securing buy-in from those landowners.

Projects with the highest probability to be implemented, due to property ownership, are associated with schools or municipal buildings and other public properties. One of the primary reasons these projects are most likely to be implemented is that grant applications typically look for non-profit or municipal applicants which coincide with the tax status of these organizations. Furthermore, buy-in on projects at these sites is typically streamlined as stormwater projects may be used as an educational opportunity for the community.

7.3 Years 3 to 5

This phase of project implementation is primarily focused on projects which have either been identified as a high priority of those that have the greatest chance of funding and implementation. This phase is focused on securing funding and implementation for BMP projects.

Table 7.1: Implementation Schedule – Years 3 to 4		
BMP	**Subregional Basin**	**Local Basin**
BMP-7	Coppermine Brook	4314-00
BMP-9	Coppermine Brook	4314-00
BMP-10	Coppermine Brook	4314-00
BMP-11	Pequabuck River	4315-00
BMP-12	Pequabuck River	4315-03

7.4 Years 5 to 10

This phase is focused on the implementation of the longer-term projects. These projects may include areas owned by private entities or more complex projects from a logistical and stakeholder standpoint.

Table 7.2: Implementation Schedule – Years 5 to 10		
BMP	**Subregional Basin**	**Local Basin**
BMP-1	Pequabuck River	4315-00
BMP-3	Pequabuck River	4315-00

BMP-4	Pequabuck River	4315-00
BMP-5	Pequabuck River	4315-00
BMP-6	Pequabuck River	4315-00

7.5 Years 10 to 15

This phase is focused on much longer-term projects that would likely require considerable coordination between property owners and regulatory authorities.

Table 7.3: Implementation Schedule – Years 11 to 15		
BMP	Subregional Basin	Local Basin
BMP-2	Pequabuck River	4315-00

8.0 Interim Measurable Milestones

In order to track implementation progress and assess how implementation compares with the schedule a set of interim milestones needs to be developed. These milestones are distinct from water quality monitoring, load reductions, and performance metrics. This corresponds to seventh of the nine EPA plan elements.

8.1 Milestones

Milestone metrics are meant to function as tracking tools or program indicators. In most cases, individual projects will be subject to a number of reporting requirements often involving various monitoring programs. These milestones can be used to encapsulate individual project data within the framework of the larger WBP program. Some of the milestones that should be tracked include:

- Number of grant application packages developed and submitted
- Successful grant awards
- Funding secured
- Outreach programs implemented
- Number of project demonstrations, watershed walks, cleanup events and similar
- Mailers sent, attendance at events, volunteers recruited
- Number of septic management projects in-progress or completed
- Tanks pumped, systems repaired, malfunctions corrected, and new sanitary sewer connections and related measures
- Number of stormwater projects in-progress and completed
- Acres of runoff managed, number of retrofits, number of BMPs installed

- Agricultural BMPs projects in-progress or completed
- Number of acres managed, farms involved, animals managed, and related
- Bank stabilization and riparian buffer enhancement projects in-progress and completed
- Number of stream feet stabilized, acres of buffer improved, trees and shrubs installed, in-stream grade controls installed, and other related metrics
- Pet waste and wildlife management projects in-progress and completed.
- Signage erected, waste receptacles installed, waste bags provided, and similar items
- Number of tracts and acres of land preserved
- Changes to land use regulations, adoption of new ordinance, dedication of funds, modification of operations, and similar initiatives enacted at the local government scale
- Attainment of designated uses, de-listing of impaired waters, and similar compliance with environmental quality standards

9.0 Evaluation Criteria

While the milestones serve as programmatic indicators, evaluation criteria are performance metrics used to ascertain load reductions, concentrations, flows, and similar evaluations. This corresponds to the eighth EPA element.

Evaluation criteria can be applied to three basic levels regarding watershed management: project specific criteria, field measurements of surface waters, and regulatory requirements including water quality standards. The following section discusses these three elements.

9.1 Project Specific Criteria

At a project specific level evaluation criterion will be formulated to address the objectives of that individual project. Therefore, evaluation criteria cannot be uniformly applied across project types. Criteria are likely to also be dictated by the technical assistance program if employed, conditions of the funding source, and regulatory and permit conditions. A list of some of the likely evaluation criteria are provided for each of the generalized management measures. Most of the criteria are anticipated to be directly measured, although modeling will likely play an important role as well due to the scope of the project or difficulty in obtaining measurements.

9.1.1 Stormwater Management Criteria

Stormwater management projects encompass a wide range of project types, but generally address either stormwater quality or stormwater quantity with wide overlap between the two as addressing hydrology and hydraulics often results in quality improvements.

Many of the commonly measured or modeled stormwater quality metrics include:

- Solids, particularly total suspended solids, total solids, or total settleable solids

- Nutrient pollutants including various phosphorus species such as total phosphorus, orthophosphates, and nitrogen species including total nitrogen, nitrate, total Kjeldahl nitrogen
- Indicator bacteria including *E. coli*, fecal coliform, or total coliform
- In urbanized settings or associations with transportation infrastructure hydrocarbons are often measured as these are associated with fuels
- In the same areas and industrial facilities metals, particularly the RCRA metals like chromium, lead, mercury, may be explored

Stormwater quantity criteria focus on the hydrology and hydraulics of the catchment and project and include:

- Peak flows
- Average flow
- Volume reduction
- Recharge
- Storage volumes

A subset of the hydrology and hydraulics metrics would include projects that address instability in which metrics like channel geometry and channel protections would be evaluated.

9.1.2 Agricultural Best Management Practices Criteria

Agricultural BMPs refers to a catch-all class of BMPs primarily united by their association with agricultural lands, although many are concerned with nutrient abatement and soils conservation. The primary set of criteria for agricultural BMPs would include:

- Nutrients, including various species of nitrogen and phosphorus
- Solids analytes
- Bacterial concentrations and loads
- Peak flow
- Recharge/Infiltration
- Flood storage
- Vegetative cover
- Containment/management of animal waste as a volume or weight
- Area of conservation tillage or other measures
- Pesticides

9.1.3 Streambank Stabilization and Riparian Buffer Enhancements

This class of management measures includes in-stream and riparian area projects to address instability, erosion and sedimentation, hydraulics, habitat quality, and aquatic organism passage.

Measures related to modifying local hydraulics are typically evaluated on the following metrics:

- Channel and floodplain hydraulic geometry
- Flows including peak flow
- Velocity
- Flood storage capacity
- Channel roughness

- Shear stress

Substrate and solids characterization include:

- Particle size metrics such as D_{50} and D_{84}
- Bed load
- Solids metrics including total suspended solids and total solids

Riparian buffer enhancements have many benefits including cooling, improved habitat quality, enhanced pollutant and nutrient trapping, and soil stability. Criteria to evaluate these benefits include:

- Vegetative cover
- Water temperature
- Canopy cover/insolation
- Infiltration

Measuring localized nutrient and solids loads can be difficult because runoff is not necessarily concentrated in these areas. Biological surveys can be useful indicators for both these projects and may include:

- Fishery composition and related community metrics
- Macroinvertebrate community metrics
- Mussel surveys
- Plant and periphyton metrics

9.1.4 Pet Wastes and Wildlife Management Criteria

These types of management measures are designed to specifically reduce bacterial and pollutant loading, accomplished through behavioral modification and other techniques. The following criteria can be used to evaluate these programs:

- Bacteria concentrations
- Nutrient concentrations
- Waste density
- Wildlife use metrics including frequency, density, and duration

9.2 Surface Waters Evaluation Criteria

Monitoring surface waters is where the cumulative effect of the various management measure and implemented projects is best expressed and consequently measured. The Pequabuck River watershed-based plan is primarily focused on recreation impairments related to bacteria. However, it also touches upon aquatic life use impairments which may be related to many factors including NPS pollution caused by excess nutrients and sediments.

Of course, concerns regarding pollutants and their generation within the watershed, as well as their impact on the environment demand evaluation through a broad suite of criteria. Many of these criteria are already employed throughout the watershed, although, some additional criteria may be added as necessary.

Regarding water quality sampling, there are field measured parameters collected in-situ and the collection of water quality samples for discrete laboratory analysis. In-situ criteria should include:

- Water temperature
- Dissolved oxygen
- Specific conductance
- pH
- Clarity or Secchi depth where appropriate

Discrete water quality criteria would include:

- *E. coli* in Class A and Class AA surface waters
- Phosphorus species including total phosphorus, soluble reactive phosphorus, organic phosphorus, etc.
- Nitrogen species including total nitrogen, nitrate, nitrate, ammonia, total Kjeldahl nitrogen
- Solids including total solids, total dissolved solids, total suspended solids, and total settleable solids
- Standard limnological parameters such as alkalinity and hardness
- Additional discrete analytes as necessary including hydrocarbons, metals, semi-volatile organic compounds

Hydrology is a key concern regarding the functions of rivers, as well as an important factor in pollutant loading. It is therefore important to monitor:

- Discharge
- Precipitation

Biological sampling, both within the river corridor and in adjacent riparian corridors can be important in evaluating system function. This may include:

- Fishery community metrics
- Macroinvertebrate metrics
- Submerged aquatic vegetation composition
- Chlorophyll a, a proxy measure of algal biomass
- Phytoplankton and zooplankton metrics
- Cyanotoxin concentrations produced by cyanobacteria or blue-green algae
- Wetland plant composition
- Vegetative coverage

9.3 Regulatory Criteria

The regulatory criteria provide not only a statutory standard, but a means to evaluate the field sampling and modeling activities. Here, the *Connecticut Water Quality Standards* are of primary concern (https://www.ct.gov/deep/cwp/view.asp?a=2719&q=325618&deepNav_GID=1654). These include classifications of surface and groundwaters with accompanying designated uses. There are also assigned water quality standards, both numerical and narrative. For the waterbodies within the Pequabuck River watershed the following criteria are especially important:

- Aesthetics

- Dissolved oxygen
- Turbidity
- pH
- Allowable temperature increases
- Nutrients
- Biological Condition
- Ammonia
- Indicator bacteria

While not strictly a criterion, the TMDL for the Pequabuck River also specifies the total maximum daily load for *E. coli* in the river, and an estimate of the required reduction (14% to 88% reduction) to achieve compliance with the *E. coli* standard:

(http://www.ct.gov/deep/lib/deep/water/tmdl/tmdl_final/pequabucktmdl_final.pdf).

There are of course a host of other legislation, technical regulations, and ordinances that govern wastewater treatment and discharge, pesticide application, production and supply of potable water, septic system design, land use, and stormwater management. These issues are particularly important at a site level and will need to be addressed for the implementation projects. Professional consultants, regulators, public officials, and technical assistance programs work in concert to identify those concerns and meet the criteria through permitting requirements and other programs.

10.0 Monitoring

Monitoring is used to supply the data necessary to evaluate pollution reduction goals. Following the criteria cited above, monitoring occurs at two levels, project specific and larger watershed-scale surface water monitoring efforts. This section corresponds to the last of the EPA nine elements.

10.1 Project Site Monitoring

Monitoring at project sites is often a condition of project funding. There are several basic monitoring program designs that can be employed at the site level. All of these varying monitoring program designs may require the preparation of a quality assurance project plan or QAPP to ensure the correct criteria are being evaluated, the proper methods employed, and the program is consistent with quality assurance standards.

10.1.1 Influent and Effluent

The most basic site monitoring program, particularly those for stormwater management designs, consists of monitoring the influent and effluent streams (i.e. stream sites ‘above’ and ‘below’ established BMPs). This allows direct comparisons of concentrations to determine removal rates. If paired with flow data, concentrations can be integrated to determine load removals. The criteria monitored will depend on the objectives of the project, as well as the dictates of funding and regulatory requirements.

10.1.2 Pre- and Post-Monitoring

Another common method of determining reductions and adherence to water quality or other standards is to conduct monitoring prior to project implementation and again after completion. This may be a particularly useful methodology in situations where influent concentrations are hard to measure because they are not neatly concentrated or where there was no influent concentration prior to project implementation. In any case, monitoring prior to construction or other implementation, and again afterward provides an effective means of determining concentration and load reductions specific to the project.

10.1.3 Longitudinal Monitoring

Monitoring over time can also be important in assessing design performance. This is particularly true where the project contains an element of site evolution (e.g. stream changing position, maturation of riparian corridor, etc.). This would be especially true in situations where there is a biological element, such as increasing vegetative coverage over time or the development of the macroinvertebrate community for stream grade controls. There may also be a reason for event-based sampling, such as assessing erosion after a channel forming flow event or a flood. These sampling programs may rely on quarterly sampling or some other set frequency, or by a triggering environmental condition or event.

10.1.4 Control-Impact

Comparative monitoring can also be useful, by monitoring within a control area and an impact area corresponding to the project site. Monitoring of reference conditions can also be useful in the design phase. When paired with a time element this type of sampling design is called before-after-control-impact (BACI), and is especially powerful from a statistical perspective in determining project efficacy.

10.1.5 Modeling

Modeling is also a valid way to ascertain site specific function. Simple models like STEPL are endorsed by the EPA for use in determining BMP removal rates. Certainly, a host of other models of varying complexity exist that are used in a similar role. Modeling presents an alternative to in-field sampling, can reduce costs, and is useful for projects where measurable changes in water quality are difficult to sample, such as when infiltration is enhanced.

10.2 Surface Waters Monitoring

At a higher scale, continued monitoring of surface waters is required to determine if water quality standards are being met, designated uses attained, and the cumulative effect of the various implemented management project have a measurable effect in improving water quality goals. In particular, it will be important for MS4 based monitoring to continue. An annual monitoring program implemented by local stakeholders, such as the Farmington River Watershed Association or Pequabuck River Watershed Association, will be critical in documenting changing water quality conditions.

Additional monitoring programs would also be useful. For instance, the installation of a network of temperature logging probes could be easily and inexpensively established within the tributary network. This would provide valuable data for establishing the performance of implemented projects, as well as monitoring shorter term seasonal variation and long-term impacts related to climate change. The data could also be key to managing in-stream flows.

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