MILL RIVER WATERSHED MANAGEMENT PLAN

FAIRFIELD COUNTY, CONNECTICUT

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1.0 EXECUTIVE SUMMARY

The Mill River Watershed Management Plan or WMP is primarily intended to provide a path to improve water quality throughout the watershed, including the river itself, the tributary network of various streams and brooks, and the many lakes, ponds, and reservoirs found within its watershed. The document follows the requirements for the Environmental Protection Agency's watershed-based plans (WBP) that addresses nine specific elements. This type of plan therefore covers a wide range of topics including identification of water quality problems, determining the cause of those problems, identifying measures to correct the problems, securing the technical and financial assistance to implement the plan, and developing criteria, schedules, and a monitoring program to track progress. This executive summary will distill some of that crucial information to provide a big picture perspective of the plan and the actions needed to improve water quality in the watershed.

1.1 GENERAL SETTING

The Mill River Watershed is located in Fairfield County in southwestern Connecticut. It has a watershed area of approximately 32 mi^2, encompassing parts of six municipalities. Mill River discharges to Southport Harbor, an embayment of Long Island Sound. The lower parts of the river may be considered estuarine and exhibit weak tides up to Sturges Road, a point also called the head of tide. Upstream of this point it behaves as a typical inland river system, including various impoundments within the main stem of the river and larger reservoirs along some of the tributaries, including Easton Reservoir and Hemlock Reservoir.

The watershed is quite varied in many respects. At nearly 14 miles in length along the north-south axis, elevations range from sea level up to 630'. Because of its glacial geology the topography includes low hills, while the main river valley features steep escarpments. The development patterns essentially divide the watershed in two: the developed southern and eastern portions of the watershed, and the rural headwaters to the north and west. The developed areas are primarily residential with lots of varying sizes, although there are also institutional facilities, transportation corridors, and similar land uses that accompany and support residential communities. The rural areas are primarily wooded, with deciduous forest accounting for over 47% of the total area, with a substantial portion protected to maintain the water supply value of the reservoirs. Rural residential land uses are interspersed throughout this area as well as farms and wetlands.

1.2 WATER QUALITY CLASSIFICATION AND TMDL

The Connecticut Department of Energy and Environmental Protection (CT DEEP) assigns water quality classifications for all waters in the State as well as corresponding water quality standards. Hemlock Reservoir, Easton Reservoir, and all waters within their subwatersheds are designated Class AA, a high classification meant to protect drinking water supplies and provide fish and wildlife habitat. Downstream of these areas Mill River and other waters are designated Class A, while the tidal portion is Class SA (saline A). Class A waters must support fish and wildlife habitat, recreational uses, agricultural and industrial supply, and potentially drinking water supply. Class SA waters are regulated for marine or estuarine organisms such as fish and shellfish, and the harvesting of those resources, and recreation and navigation.

Unfortunately, Mill River does not meet some of the water quality standards or designated uses. In 2004, Mill River was added to the 303(d) List of Impaired Waterbodies, which is named after a section of the Clean Water Act that mandates tracking and reporting of impaired waters, for exceeding the standards associated with indicator bacteria. In particular, Mill River has had problems with excessive concentrations of *Escherichia coli*, more commonly *E. coli*. This bacterium originates within the guts of warm-blooded animals but can be widespread both on land and in water due to the presence of animals or inadequate treatment of waste. It is often called an indicator bacteria, meaning that its presence indicates the potential for disease-causing microbes or pathogens including viruses and other bacteria, although some strains of *E. coli* can be pathogenic on their own.

Because of these documented issues with bacteria concentrations, a Total Maximum Daily Load (TMDL) analysis was completed for the Mill River and two adjacent river systems and adopted in 2005. A TMDL is an analysis that calculates loads and concentrations and the required reductions needed to satisfy the water quality standards. Successfully reducing these pollution sources, here being *E. coli*, will lead to improvements in water quality and the de-listing of the affected water. The TMDL calculated required reductions for *E. coli* at two sites on Mill River ranging from 19% to 55%. Recent Harbor Watch data may indicate that the required reductions to meet water quality standards may be even higher.

1.3 WATERSHED MANAGEMENT PLAN INITIATION

The Fairfield Conservation Commission, part of the municipal government for the Town of Fairfield, applied for a Clean Water Act Section 319(h) Nonpoint Source Program grant with CT DEEP to help address the TMDL and other nonpoint source (NPS) pollutant loading and stormwater management concerns in the Mill River. The grant was awarded for the development of this WMP. Project partners include:

- CT DEEP
- Harbor Watch
- Trout Unlimited
- Fairfield Shellfish Commission
- FairPLAN
- Mill River Wetland Committee
- Lake Hills Association

These partners lend a variety of support to the proceedings, help to maintain communications with the watershed residents, and contribute their specialized local knowledge.

As mentioned above, the WMP follows the nine EPA elements. Here, the primary goal is the control of *E. coli* and other indicator bacteria. In addition, other NPS pollutants will be addressed including the nutrient pollutants phosphorus and nitrogen, as well as solids or sediments derived from erosion. Stormwater management will also be a component of the plan.

It also is worth mentioning that the WMP also increases the chances of securing funding and other assistance in order to implement projects. For the 319 grant, a WMP can be an important qualifier because it demonstrates the serious intent of improving water quality as well the vast amount of supporting work that goes into the plan. It should function similarly for other grant programs.

1.4 ONGOING POLLUTION CONTROL MEASURES

While over a decade has elapsed between the TMDL and the start of this project, efforts to control pollutant loading have been continuous and ongoing in this interval. One of the main program efforts, and one that was specifically identified in the TMDL to address its reduction goals, is the Municipal Separate Storm Sewer Systems (MS4) Program. MS4s are the series of inlet, basins, pipes, ditches, and related infrastructure typically along roadways or in developed areas that manage stormwater. Stormwater is a major vector for pollutant loading, as it mobilizes and transports pollutants from the land surface, and is especially problematic for impervious surfaces like pavement, sidewalks, and roofs which do not allow rainwater (and snowmelt) to naturally infiltrate into the ground. Furthermore, this stormwater is often discharged directly to receiving waters without treatment, and because of its higher volumes and higher flow rates can also exacerbate erosion within streams and contribute to flooding.

The MS4 program is designed to offset the pollutant loading issues inherent to storm sewers and ultimately discharges from them are not to contribute to toxicity, impair biological functions, or pose human health risks. Some of the specific permit conditions that promote these goals include public involvement, illicit discharge detection and elimination (IDDE) to identify when sewage or wastewater is illegally connected to the storm sewers, construction site runoff control, post-construction stormwater management through Low Impact Development (LID) techniques, pollution prevention and good housekeeping, and finally monitoring. Fairfield, and the other municipalities, continue to implement these various permit conditions and program requirements, and Fairfield is particularly well advanced in these areas.

Other measures have been taken to reduce pollution as well. Some of these are done in conjunction with the MS4 program, some are complementary, and some pre-date the program but largely serve the same ends. Some of the programs and other efforts include the management of pet waste through ordinance, updates to land use regulations and the use of LID designs, management and oversight of septic system installation, repair, and similar measures.

1.5 CURRENT WATER QUALITY

A major component of the study was to understand current water quality in the system. For this, the plan relied on the excellent monitoring reports produced by Harbor Watch, a citizen science organization. Harbor Watch monitors under a strict plan approved by CT DEEP, samples a number of water chemistry parameters, and has expanded the number of sampling stations up to 16 providing good coverage of the watershed.

The parameter of greatest concern in Mill River is *E. coli*. For the non-tidal portions of Mill River or the Class AA and A waters there are two water quality standards for *E. coli*. One is based on the geometric mean (an alternative method of calculating an average), so this standard includes multiple samples collected under both dry and wet conditions; the standard states the geometric mean shall not exceed 126 cfu/100 mL (cfu is colony forming units). There is also a single sample maximum that cannot be exceeded and is 576 cfu/100 mL unless otherwise specified, for example swimming areas may have a lower standard. In 2016, five of the stations exceeded the geomean standard, most of these concentrated in the lower portions of the watershed, but one of the stations is upstream of Samp Mortar Reservoir. A similar pattern was observed in 2017. In 2018, 11 of the 16 stations exceeded the geomean including one point upstream of Easton Reservoir. The difference between the first two years and the last was rainfall, and the much higher precipitation totals in the sampling period in 2018 indicate that rain mobilizes much higher loads of bacteria. In 2018 all stations, except the first one downstream of Easton Reservoir, exceeded the single sample maximum at least once. This indicates there is an ongoing water quality issue related to *E. coli* in the watershed.

Harbor Watch also conducts Pollution Track-Down monitoring, a program designed to sample within the storm sewers to identify hot spots or even detect illicit connections and discharges of wastewater. In 2018, many different points were sampled within three sewer networks. The results are very variable between stations and over time, but there is no doubt that some very high readings were detected. In fact, ten of the sampled points had geomean concentrations of *E. coli* exceeding 2,000 cfu/100 mL, a high number by any accounting. Clearly, continued work is required to limit *E. coli* loading in the storm sewers.

1.6 SOURCE IDENTIFICATION AND PRIORITIZATION

The next part of addressing the ongoing *E. coli* water quality impairments is to identify the sources or causes of this impairment; this was accomplished through computer modeling. The MapShed model was the primary tool to model both hydrology, essentially the water budget for the watershed, and the pollutant loading; these two components are very closely linked. The pollutants that were modelled included phosphorus, nitrogen, sediment, and bacteria. To describe its basic function, the model works by applying loading coefficients, essentially the quantity of a pollutant produced per unit area, to specific land cover types (for instance low density development or forested wetland) and areas. A series of algorithms modifies these results according to weather data, soils, and slopes among many other factors. Furthermore, the program allows the user to include modifications to the inputs for septic system function, the number of animals per farm, population density, and many other factors that change pollutant loads. Overall, modelling is used as a way to provide estimates of the loads and their various sources, but it does not replace sampling.

The model was then run for the entire watershed as well as nine subwatersheds that corresponded to some of the major hydrographic units of the watershed. The outputs could then be used to determine the overall state of pollutant loading throughout the watershed and at a subwatershed level, and to also identify which subwatersheds were the greatest contributors to the loading. This approach also fosters prioritization and ranking to best address pollutant loading issues. The following section will discuss the key findings depending on pollutant class.

For indicator bacteria, the primary source in the watershed was determined to be septic systems. There are a number of reasons for this including that only 12% of the watershed area is sewered with the remainder relying on onsite septic system for wastewater treatment needs. The age of the systems is also a factor, with the lifecycle of these systems often rated around 25-30 years; system density and proximity to waterbodies also contribute to increased loading. Overall, septic systems are thought to contribute up to 50% of the total load according to the models. Farm animals are still a surprisingly large contributor at roughly 36% of the load and the upper portions of the watershed in particular contain a number of farms. Runoff from urban areas is also significant at 9% and wildlife account for roughly 5%.

Over 98% of the sediment loading in the watershed is attributable to streambank erosion. This is somewhat misleading as it paints a dire picture of erosion within the watershed, but the movement of sediment is a primary and natural function of streams. Despite that, this is still somewhat elevated in the watershed and points to the need for better stormwater management. If runoff alone is considered, a more typical picture is painted in which agriculture accounts for up to 65% of the sediment load, mostly from hay/pasture lands. Over 30% is attributed to the various mixed developed land uses, mostly residential in nature.

Phosphorus is an important nutrient, but can negatively contribute to plant and algae growth in water at excess concentrations. Most of the phosphorus load is related again to stream bank erosion as phosphorus pollution is often related to the mobilization of soil particles. If runoff only is considered, the breakdown of phosphorus sources is similar to that for sediment, dominated by hay/pasture lands, with about 30% attributable to runoff from urban areas.

For nitrogen, the primary contributor to Mill River is actually groundwater. Nitrogen compounds are extremely soluble and easily enter the groundwater. Indeed, rainfall is a major contributor to groundwater nitrogen amongst many sources. Even in undeveloped watersheds groundwater has much higher concentrations than surface waters generally. In addition to the natural seemingly-high concentrations in groundwater, groundwater also contributes greatly to stream baseflow, the component of streamflow not related to storm events. Septic systems specifically only account for about 3% of the nitrogen load, although they also contribute to the background of groundwater concentrations. Nitrogen attributable to runoff is dominated by the developed lands at about 50%, but agricultural runoff contributes about 20%.

Not surprisingly, the level of pollutant loading is strongly correlated with the intensity and type of development. As mentioned above, at a high level the watershed can be split into two groups, the rural northern subwatersheds (Mill River Headwaters, Easton Reservoir, and Cricker Brook), and the six developed southern subwatersheds (Canoe Brook, Lake Mohegan, Browns Brook, Samp Mortar Reservoir, Greenfield Hill/Riverfield, and Mill River Upper Estuary). A ranking structure was developed for the subwatersheds based both on total loading of the pollutants and the specific loading of pollutants, essentially the quantity of pollutant load per unit area which helps account for differences in area.

Overall, the subwatersheds were assigned one of four priorities: highest, high, medium, and low. The two highest ranked subwatersheds are 4 and 8, Canoe Brook and Greenfield Hill/Riverfield. For almost every metric they had the highest loads and highest specific loads. These are among the larger subwatersheds, the most densely populated, and with the highest impervious surface coverage. On the other end of the spectrum, Subwatersheds 1, 2, and 3 to the north were all ranked as low priority as these areas are least developed and generally had relatively low pollutant loading rates. While they are low priority, that does not indicate that they are not contributors to water quality impairments in Mill River. These areas will need to be addressed as part of comprehensive, watershed-wide effort to reduce loading, but the higher ranked areas are of more immediate concern and will contribute more to managing bacteria, solids, and nutrients. Included below is a table indicating the appropriate general management measures for each subwatershed and the corresponding priority.

Table 1.1: Generalized Management Measure Summary and Prioritization

SubWS ID	SubWS Name	Management Measures	Priority
1	Mill River Headwaters	Manure management and livestock-centric stream buffer enhancement; agricultural BMPs for soil preservation; open space preservation.	Low
2	Easton Reservoir	Manure management and livestock-centric stream buffer enhancement; agricultural BMPs for soil preservation; streambank stabilization; open space preservation.	Low
3	Cricker Brook	Manure management and livestock-centric stream buffer enhancement; agricultural BMPs for soil preservation; streambank stabilization; open space preservation; septic management.	Low
4	Canoe Brook	Septic management; streambank stablilization; stormwater management for quality and volume; manure management; agricultural BMPs.	Highest
5	Lake Mohegan	Stormwater management; septic management; IDDE.	Medium
6	Browns Brook	Septic management; streambank stabilization, buffer enhancements; stormwater management for bacteria.	High
7	Samp Mortar Reservoir	Stormwater management; septic management.	Medium
8	Greenfield Hill/Riverfield	Stormwater management; septic management; streambank stabilization, buffer enhancement; waterfowl/pet waste management.	Highest
9	Mill River Upper Estuary	Stormwater management; septic management; streambank stabilization, buffer enhancement; waterfowl/pet waste management.	High

1.7 FIELD ASSESSMENT, PROJECT CONCEPTS, AND CANDIDATE SITES

Towards the beginning of the project a field assessment was conducted which involved the identification of potential candidate sites for implementation projects or Best Management Practices (BMPs). These were suggested by the Conservation Commission, Trout Unlimited, other project partners, and citizens. The sites were then field investigated to assess what the problems were and whether a BMP installation would aid in managing stormwater and pollutant loading in the watershed. Ultimately, nine such projects were selected and conceptual designs were prepared for each that included a calculation of the drainage area and the appropriate BMP or BMPs that would address the site issues with estimates of pollutant removal efficacy. All except one of the project concepts are located within Subwatersheds 4 and 8, the highest priority watersheds.

Overall, these projects incorporate a variety of BMP types and address a wide range of stormwater management and pollutant loading problems. In addition to the primary goal of managing the loading of pollutants and stormwater, these projects are also meant to serve as demonstration projects to showcase the various management measures and their implementation to improve water quality within Mill River. The table below shows the variety of suggested BMP types and a list of problems that will be addressed at the sites; both of the sub-lists are presented alphabetically and do not necessarily correspond with the adjacent column.

Table 1.2: Project Concept BMP Types and Problems Addressed

BMP Types	Site Problems
Inlet Retrofit	Bank Erosion
Parking Lot Diversion	Channel Instability
Riparian Buffer Restoration	Impervious Surfaces
Step Bioretention Basin	Pet Waste
Tree Filters	Pollutant Loads
Stormwater Pond Retrofit	Poor Basin Maintenance/Design
Riparian Buffer Plantings	Riparian Buffer Encroachment
Stormwater Pond	Road/Parking Lot Runoff
Stormwater Wetlands	Stream Sedimentation
Infiltration Basin	Unmanaged Stormwater

In addition to these nine concepts a number of other locations and sites have been selected as good candidates to implement management measures. The Fairfield Conservation Commission has identified 20 such project sites and all represent problem areas known to the Town. Once again, project implementation at these sites would address many NPS issues and specifically includes agricultural BMPs, pet waste and wildlife management, stormwater management, and stream bank and riparian (river corridor) enhancement projects. As with other projects identified so far, these have also been prioritized on the basis of which subwatershed they are located in.

Further, an additional 60 project sites have also been identified throughout the watershed using a geographic analysis. This analysis was based on trying to include examples of most of the general management measure types including stormwater management, agricultural BMPs, stream bank stabilization and riparian enhancement, and pet waste and wildlife management. As such, using GIS, areas or features such as intersections, storm sewers, existing detention basins and stormwater management structures, parking lots, farms, and parks were identified. These were then further examined using aerial imagery and other pertinent data to see if they were good candidates. Similar to the Fairfield nominated sites, these sites were also prioritized on the basis of their subwatershed location. In total, nearly 90 project sites have been located throughout the Mill River watershed. This provides a considerable backlog of projects to assess and implement over time.

1.8 GENERAL MANAGEMENT MEASURES

Zooming out again to a broader perspective, the report covers a variety of classes of management measures that address the pollutant loading in the Mill River watershed. Some of these measures have already been incorporated in the project concepts, others will be used in the other identified project site locations, while others can be implemented by residents and homeowners. The following section summarizes some of these management measures.

Septic management techniques will be very important in reducing loading of bacteria in the watershed. This is one of the most difficult areas to manage because septic systems are mostly sited on private lands at houses and many of the problems could be subsurface. As mentioned above, density of septic systems and proximity to waterways can also cause excessive bacteria loading. Problems are not easily detectable to outside observers, even if there is ponding or the system backs up to the structure. There are however basic good stewardship practices that can avert some of these problems. This includes regular inspections of the tank and leach field. Maintenance and best management practices are important as well and include activities such as: regular pump outs, avoiding compacting the field, diverting runoff away from the system, limiting vegetation to lawn grass, avoiding septic system additives, and not disposing non-degradable materials. Repairs, replacements, and new construction will be very important in the coming years as average system lifespan draws near an end in the watershed. In particular, the rules governing septic system design and placement continue to advance and issues related to poor design, depth to groundwater, density, and proximity to water are all addressed to limit impacts. Performance is also increased through the mandated use of two-chamber tanks. The permitting and review process will be crucial in this respect. Education and outreach to the community will also need to be utilized to advance the various BMPs. While not technically a part of septic management, efforts to expand the sanitary sewer service and continuing efforts to detect and sever illicit discharges will also help control septic-related loading of bacteria as well as nutrients.

Stormwater management covers a very large number of techniques and structures, but the basic goal is to manage runoff from both pervious and impervious areas and improve the quality of the water to reduce pollutant loading to surface waters. Stormwater management is highly regulated at the State and local level through various programs, laws, and ordinances. This is especially important in redevelopment or new development and the use of LID techniques to reduce stormwater loading from the outset. For existing development, or in areas where there are known problems or simply an expressed desire to improve stormwater management, the focus is on correcting issues through the use of various structural BMPs or retrofitting existing systems to improve the performance. Performance metrics generally include reductions of solids, nutrients, bacteria, as well as total flow and peak rate. Some of the major classes of stormwater management designs include: stormwater ponds, stormwater wetlands, infiltration practices, filtering practices, and water quality swales.

Agricultural BMPs not surprisingly are a class of practices and structures meant to deal with the special demands of agricultural lands. While accounting for just 4% of the watershed, these lands can contribute high bacterial loads from livestock, as well as solids from surface erosion. For this watershed, three broad classes of agricultural BMP are considered although they are often used in an overlapping fashion. Erosion is a problem not just for the receiving waterways, but also represents a loss of valuable topsoil which farmers have a special interest in preserving as a resource. As such, one class of agricultural BMPs is especially targeted on erosion and soil management, pasture and hay land management, conservation tillage, contour farming, cover and green manure crops, and crop residue management among others. Stormwater management at farms is used to reduce erosion, protect buildings and other infrastructure, and limit mobilization of fertilizers and manure. Some of the agricultural stormwater management BMPs include diversion, grassed waterways, irrigation water management, riparian buffer enhancements, and water and sediment control basins. Last, manure management is a major component of managing livestock. Not only is there the need to control the release of bacteria and nutrients, but the physical reality of dealing with a large volume of waste. Used properly, manure is also an important farm resource to amend soils and fertilize fields. A waste management system describes a linked series of various BMPs include waste utilization for crop or forage production, storage, drainage and erosion control, having adequate land area, managing herd size, and other items. Field stacking and composting are also important, and spreading is governed by season, precipitation, slopes, and other factors.

Stream bank stabilization and riparian buffer enhancements seek to control erosion, increase channel stability, help improve flooding, provide water quality treatment, and improve habitat quality. Riparian buffer enhancements include no mow zones near the stream bank, planting native trees and shrubs, and protecting these areas from development or stormwater discharges. Bed and bank stabilization techniques are very varied and associated strictly with the channel, although these are often used in conjunction with riparian enhancements in a holistic riparian corridor restoration approach. Bank stabilization may include the use of brush mattresses, bank grading, toe protection with boulders or organic material like rootwads from trees, planting, or even gabions (rock filled cages). Flow deflection structures such as J-hooks or bendway weirs can help to limit erosion on bends, while engineered riffles and cross vanes help arrest headcuts (a pattern of erosion that migrates upstream) and set bed elevation.

Lastly, pet waste and wildlife management need to be considered. While the model showed this to be a relatively low contributor, the contribution is likely higher than indicated. As with some other management measures, regarding pets much of the burden will be on pet owners to responsibly manage their waste, but pet waste ordinances, education and outreach, excluding pets from areas near waterways, and providing waste receptacles and baggies are all important strategies. Wildlife management can also be an important consideration, especially when it comes to Canada geese, which besides producing a high quantity of waste, also deposit the waste directly to waterways and thereby have an even bigger impact on water quality. For the most part, behavioral modification is the preferred method and could include scaring birds with dogs, mylar tape, loud noises, and other similar methods. Chemical repellents can also work, as well as habitat modification including maintaining tall vegetation around ponds and streams.

1.9 PROJECT IMPLEMENTATION

With all the background information, site selection, and management measures in place, the focus turns to the implementation of the plan. At a project level, there are usually two steps that are taken in parallel, the formation of a project team and securing funding. First, the project sponsor gauges interest in the project, secures the necessary permissions of landowners, and may even involve some stakeholders. For these projects it is expected that Fairfield is the likely sponsor, although community associations, CT DEEP, environmental advocacy groups and similar non-profits, or even private landowners may act in this role. The next step is to identify funding as project costs are a significant limiting factor for implementation. For most of the projects listed above, it is anticipated that grant funding is likely to be the most important source of funding. The Section 319 grants, the funding vehicle for this study, are likely going to be an important source of money moving ahead. CT DEEP offers a number of other grants, as does the EPA, US Fish and Wildlife Service, United States Forest Service, Natural Resources Conservation Service, and other federal agencies. Other grantors include American Rivers, National Fish and Wildlife Foundation, and Trout Unlimited among others. Municipal bonds, low interest loans, Federal, State, and local appropriations, and even donations may all be used to fund projects. It should be noted that the money available through grants varies, is often limited, and the award process is often competitive. Even at this stage, professional consultants that have experience in grant writing can be of value in helping to develop the submission packages.

As mentioned above, project costs can be high. For the nine project concepts costs of the individual projects ranged from $54,000 to over $1,000,000. Many people tend to think of costs primarily in material terms, but these types of projects are complex. Indeed, construction costs, including materials, labor, and equipment use is typically in the range of 35-50% of the estimated fees. Professional services are also necessary to provide land surveying, wetlands consultation, engineering and design, permitting, and other services. Contingency fees also need to be considered because construction projects change due to unforeseen circumstances.

To go along with funding, it is also necessary to secure technical assistance. In many cases this will require the assistance of engineers, scientists, planners, and surveyors, in addition to contractors and vendors. Beside this though, there are many, many sources of technical assistance available. In fact, grant programs often have a technical assistance element built-in. Undoubtedly, CT DEEP has many programs, technical manuals, regulations, and community outreach programs designed to provide guidance for these processes. Many of these assistance documents are listed in the body of the WMP. This type of assistance again can be found at many levels, with EPA and NRCS both being particularly prolific in this respect.

For Mill River, there is no doubt that a very broad effort will be needed to meet TMDL requirements. This is largely a function of the nature of *E. coli* loading, which is quite diffuse in the watershed, and also because it can be harder to manage bacteria loads relative to some of the other pollutants, such as sediment. To accomplish this, an implementation schedule has been developed. The EPA element for implementation indicates that the schedule is to be reasonably expeditious. Here, it is recommended that most of the nine project concepts be initiated within the first two years, with at least monies secured to initiate the projects. Within five years, an attempt should be made to initiate the highest priority projects, those within Subwatersheds 4 and 8. By year 10, the high priority projects should be in development. Past ten years it is hard to forecast, but there will still be a number of medium and low priority jobs awaiting. It is suggested that the WMP be updated at this point, to reflect not only the work that has been completed, but to address any other concerns at that time. Within this time frame, it is also important to maintain a strong education and outreach program to keep the public attuned to the issues, solicit their help, and make sure that BMPs that can be implemented at their homes or on their properties are also being addressed.

Lastly, it is important to monitor the state of progress. This is to be done on a few different fronts. First, the programs should be tracked according to metrics like number of projects installed, how much money has been secured, how many acres of riparian buffers have been restored and similar such measures. This shows the program is moving forward. The second component is to measure how the individual projects are performing, by first selecting the appropriate criteria, such as concentrations of bacteria or nutrients, and through direct sampling or modelling determine how pollutant loads have been reduced. Finally, it is important to continue to monitor the Mill River and other surface waters to determine how water quality has improved over time and whether water quality standards and designated uses are being met.

2.0 INTRODUCTION

Princeton Hydro, LLC was contracted by the Town of Fairfield, located in Fairfield County, Connecticut, to develop a watershed management and restoration plan (WMP) for the Mill River Watershed. This project is funded through a Clean Water Act Section 319(h) Nonpoint Source Program grant administered by the Connecticut Department of Energy and Environmental Protection (CT DEEP). The Mill River Watershed spans portions of six municipalities, although the majority of the watershed lies within the towns of Fairfield and Easton. The 32.0 mi^2 watershed (20,448 acres) encompasses two large reservoirs, numerous other smaller online and offline impoundments and other surface waters, and a number of named and unnamed tributaries. Mill River discharges to Southport Harbor, a tidal embayment of Long Island Sound, with the head of tide extending approximately 1.0 mile upstream of the harbor.

Mill River, as is typical of coastal rivers in the region, has a long history of cultural utilization supporting fishing, navigation, and water-powered industry and more recently water supply and recreation. The largest land use in the watershed is deciduous forest accounting for nearly half of the basin area, so there is a rural character to the watershed, yet over one-third of the landmass is developed, primarily for residential uses. This development pattern, especially in watersheds where development pre-dates various pollutant control and stormwater management regulations, fosters nonpoint source pollution (NPS), a diffuse loading of nutrients, pathogens, sediment, and other pollutants accompanied by increased stormwater loading. In this watershed, this has manifested in the non-attainment of various water quality standards. In particular, Mill River was listed on the 2004 *List of Connecticut Waterbodies Not Meeting Water Quality Standards*, sometimes known as the 303(d) list, named after the pertinent section of the Clean Water Act, for indicator bacteria. These indicator bacteria are more accurately characterized as fecal bacteria, the gut-bacteria of warm-blooded organisms that are recognized as disease vectors in contaminated waters. As a result, CT DEEP developed a *Total Maximum Daily Load Analysis for the Mill River, Rooster River, and Sasco Brook* (TMDL) that was approved in 2005. The TMDL document outlines the sources of bacterial pollution, required reductions to achieve the water quality standards, and, in a very general way, methods to achieve these reductions.

The goal of this project therefore is to expand upon and complement the TMDL to successfully address NPS pollution in the watershed, especially bacterial pollution and secondarily nutrient pollution, to improve water quality within the watershed in order to attain water quality standards and designated uses, including contact recreation, protect water supplies, and generally improve the environmental function of the river network and attendant watershed. It is also important to point out that downstream considerations are important; indeed, Southport Harbor, the receiving estuary for Mill River, is also on the 303(d) list for indicator bacteria and does not attain direct shellfish uses. This WMP is specifically focused on identifying sites and developing concept designs for implementation projects in order to meet several objectives and surpass certain criteria. The most important objective is that the WMP includes well-described and illustrated design concepts at defined locations for the implementation of specific best management practices (BMPs) that address loading, infrastructure, slopes, soils, natural features, and other relevant concerns at that site. Second, these implementation project sites must be realistic projects that stand a high chance of successfully undergoing construction/implementation and must meet the following criteria:

- Has a reasonable expectation of being permitted
- Is of sufficient size to have measurable load reduction capacity
- Generally, is simple in concept
- Ownership should be on public lands when possible, or have public uses or access
- Costs should be limited where possible, but funding must be sufficient to achieve reductions
- Stakeholder and community support/sponsorship needs to be obtained early in the process
- Overall, the projects should be “do-able”

The final objective is that the projects and NPS management measures discussed in the WMP must be viewed in their proper context: as part of a far-reaching and long-lasting, iterative process where the completion of each project is seen to be working towards the ultimate goal of meeting load allocations and achieving water quality standards and designated uses. No single project can achieve the required reductions, and outlining, identifying, and initiating every required project to achieve those goals is neither feasible nor, given the cost, realistic. This WMP is poised near the beginning of the timeline of the comprehensive program to improve water quality in the Mill River watershed and provides the framework to move forward, which is pre-dated by previous efforts to improve water quality within the watershed through adoption of environmental regulations, recognition of water quality impairments through sampling, development of a TMDL, implementation of stormwater BMPs, and preservation of open spaces among other factors. This WMP will include concept designs for implementation, that while achieving significant load reductions in their own catchments, are viewed as only part of a larger effort to address NPS pollutant loading. Additionally, these projects should be viewed as demonstration projects, exemplifying those concepts and designs that can be used on a broad basis throughout the watershed.

One of the criteria or requirements for selecting implementation projects is community support; this holds true for the WMP as a whole. The Town of Fairfield is the grantee and project sponsor, overseen and administered by the Fairfield Conservation Commission, but the project has the support of various stakeholder groups. Project partners include CT DEEP, Harbor Watch, Trout Unlimited, Fairfield Shellfish Commission, FairPLAN, Mill River Wetland Committee, and Lake Hills Association. All of these stakeholders are represented on the Steering Committee for the project to assist in the preparation of the WMP and to engage the community through outreach.

Lastly, this document will follow the Nine Element format required by the USEPA. From a practical perspective, this format is widely used and incorporates all essential elements of these plans to ensure pertinent concerns are properly addressed. Of equal importance, is that this format is required for some Federal and State grant monies, an extremely important concern for ensuring project implementation. The Nine Elements include:

a) Identification of causes of impairment and pollutant sources that need to be controlled to achieve needed load reductions
b) Estimate of the load reductions expected from management measures
c) Descriptions of the NPS management measures that need to be implemented to achieve load reductions and description of the critical areas in which those measures will be needed
d) Estimates of the amounts of technical and financial assistance needed, associated costs, and sources and authorities that will be relied upon to implement this plan
e) Information and education component to enhance public understanding of the project and encourage early and continued participation in selecting, designing, and implementing NPS measures
f) Schedule for implementing the NPS management measures identified in the plan
g) Description of interim measurable milestones for determining whether NPS measures are being implemented
h) Set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards
i) Monitoring component to evaluate the effectiveness of the implementation efforts measured against criteria (item h)

3.0 WATERSHED CHARACTERIZATION

This section corresponds with the first of the nine watershed plan elements and consists of a synthesis of existing watershed data including general characteristics such as soils, slopes, and floodplains, a review of existing water quality data, identification of source impairments, review and synthesis of hydrology data, and a calculation of pollutant loads.

3.1 GENERAL CHARACTERIZATION

3.1.1 STUDY AREA

The Mill River Watershed has an area of 32.0 mi^2 or 20,448 acres, accounting for approximately 5% of the land mass of Fairfield County, the largest county in Connecticut. The watershed lies between the Norwalk and Bridgeport urban centers in the southwestern portion of the State. The watershed is approximately 13.7 miles along the long axis and 4.3 miles wide. Mill River flows in a southerly direction from the headwaters before discharging to Southport Harbor, an approximately 1.0-mile-long estuary connected to Long Island Sound. The lower mile of Mill River is tidal, although the Tide Mill Dam severely restricts tidal expression within the reach.

The watershed encompasses six municipalities. The bulk of the watershed lies within the Towns of Fairfield and Easton, with smaller areas in the Towns of Monroe, Redding, and Trumbull, and the City of Bridgeport. The Mill River watershed includes CT DEEP Subregional Basins 7108 and 7107. The watershed base map is provided in Appendix I. A table showing municipality, ranked by area, is provided below.

Table 3.1: Subwatershed Areas (By Municipality)

Municipality	Area	
	acres	%
Easton	10829.9	52.9
Fairfield	6938.1	33.9
Trumbull	1549.3	7.6
Monroe	1096.4	5.4
Bridgeport	37.8	0.2
Redding	36.2	0.2
Total	**20487.7**	**100.0**

For this study the watershed was divided into nine subwatersheds to provide a better level of analytical detail, especially as it pertains to the development of pollutant loads. These may be thought of as discrete management units, and a prioritization tool for management activities. The subwatershed map is provided below and a brief description of each subwatershed including identification number and name:

- Subwatershed 1 Mill River Headwaters - is northernmost, encompassing the main stem Mill River and headwaters upstream of Easton Reservoir; total area is 2611.4 acres
- Subwatershed 2 Easton Reservoir - corresponds to the catchment for Easton Reservoir, excepting Subwatershed 1 and Mill River, and includes all direct tributary inputs including two named streams, Patterson Brook and Tatetuck Brook; the area is 5655.4 acres, the largest of the delineated subwatersheds
- Subwatershed 3 Cricker Brook - occupies the west central portion of the watershed and is equivalent to the Cricker Brook watershed, the largest tributary of the Mill River; this subwatershed encompasses Hemlock Reservoir and is second largest at 4582.8 acres

- Subwatershed 4 Canoe Brook - is bisected by Mill River and covers the east central portion of the watershed including a small incursion into Bridgeport; it incorporates numerous unnamed tributaries, as well as Canoe Brook, and discharges to Lake Mohegan; total area is 3432.3 acres
- Subwatershed 5 Lake Mohegan - incorporates Lake Mohegan and Mill River and is the smallest watershed at 273.9 acres
- Subwatershed 6 Browns Brook - drains much of the southwestern portion of the watershed but does cross Mill River and includes Perrys Mill Pond and Browns Brook; total area is 1357.6 acres
- Subwatershed 7 Samp Mortar Reservoir - is centered on Samp Mortar Reservoir, an impoundment of Mill River, and includes those areas that drain directly to the reservoir, with a total area of 548.5 acres
- Subwatershed 8 Greenfield Hill/Riverfield - is located in the southeast incorporating the mainstem Mill River south of Samp Mortar Reservoir down to the Subwatershed 6 boundary; the area for the subwatershed is 1667.7 acres
- Subwatershed 9 Mill River Upper Estuary - is the southernmost and terminates at the mouth of Mill River at the Tide Mill Dam located at the head of Southport Harbor; total area is 348.2 acres

As this plan was being developed, it was discovered that another subwatershed discharges to Mill River. This subwatershed, called here Subwatershed 10 Upper Canoe Brook, lies to the east of Subwatersheds 2 and 4 and includes Canoe Brook Lake, which discharges to Canoe Brook. CT DEEP mapping including the DEEP Subregional Basins indicates that Canoe Brook lake lies within the adjacent basin, 7106. The USGS Watershed Boundary Data Hydrologic Unit Code 12 maps also indicates this area to be in the adjacent basin, and does not show direct hydraulic connection to the Mill River watershed. This subwatershed has never been included in any of the previous studies for Mill River, including the Total Maximum Daily Load report. As such, this area has not been included in any of the analyses, but is mapped. In total, it encompasses 1169.5 acres and is most similar to the Canoe Brook subwatershed in land use pattern.

Table 3.2: Subwatershed Areas

Subwatershed	Area	
	Acres	% of Total
1 - Mill River Headwaters	2611.37	12.7
2 - Easton Reservoir	5655.37	27.6
3 - Cricker Brook	4582.75	22.4
4 - Canoe Brook	3432.31	16.8
5 - Lake Mohegan	273.89	1.3
6 - Browns Brook	1357.56	6.6
7 - Samp Mortar Reservoir	548.53	2.7
8 - Greenfield Hill/Riverfield	1677.71	8.2
9 - Mill River Upper Estuary	348.18	1.7
Total	**20487.67**	**100.0**

3.1.2 CULTURAL AND DEMOGRAPHIC CHARACTERISTICS

CENSUS DATA

Fairfield County is a slowly-growing county and also the largest by area in Connecticut. According to the US Census Bureau, the population of the county grew by 3% between 2010 and 2016 to a total population of 944,177. The CT State Data Center projects the county will grow 0.5% between 2016-2020. The area has a median age of 39.7 years, slightly below the State average, and a median household income 20% higher than the State median. The watershed is located to the west of the city center of Bridgeport, the largest city in the State, and encompasses a small portion within the city bounds.

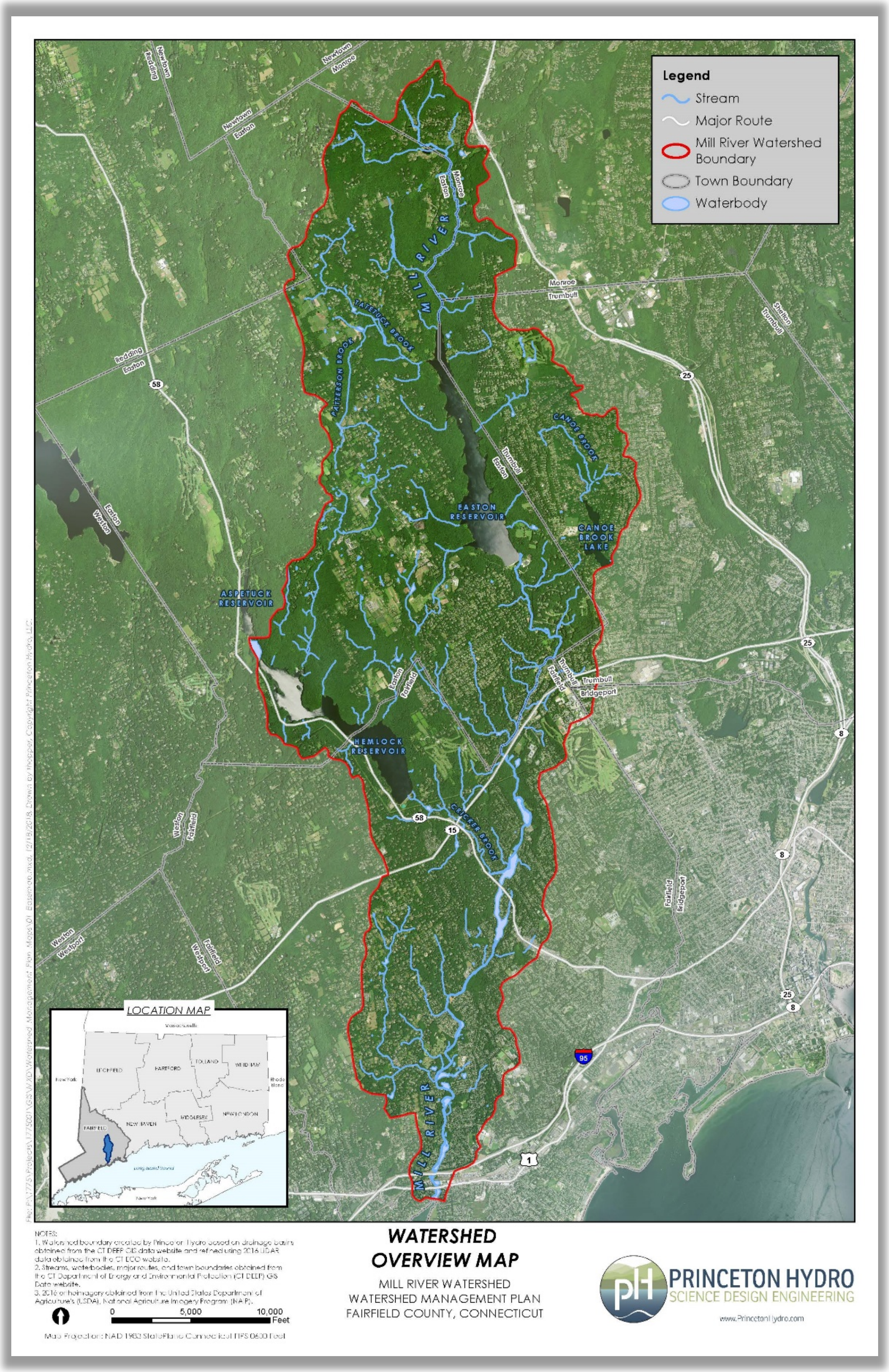


Figure 3.1: Overview Map

HISTORIC DISTRICTS

There are five historic districts and structures recognized by the National Park Service's National Register of Historic Places in the Mill River watershed. The David Mallett, Jr. House and Christ Episcopal Church and Tashua Burial Ground are located in northwest Trumbull. The David Ogden House, the Jonathan Sturges House, and the Restmore house are located in south central Fairfield. The majority of the Greenfield Hill Historic District and approximately two miles of the Merritt Parkway, also recognized as a historic district, are also situated within the watershed. The southernmost portion of the watershed borders the Southport Historic District, which extends southwest along the Mill River/Southport Harbor towards Long Island Sound.

SEPTIC AND SEWER SERVICE

The majority of the Mill River watershed is not located within a Sewer Service Area; only about 12% of the watershed, mostly situated in the southeastern area, has sewer service. Of this 12%, 11% is located within Fairfield and the remaining 1% of the sewered area is parsed among the towns of Easton, Bridgeport, and Trumbull. The remaining 88% of the watershed is primarily served by individual, on-site septic systems. This includes the areas of Redding and Monroe which intersect the Mill River watershed.

3.1.3 GEOLOGY

GEOLOGIC TERRANE AND BEDROCK GEOLOGY

The watershed is situated within the Connecticut Valley Synclinorium of the Iapetos (Oceanic) Terrane. This area is also known as the Western Uplands physiographic province. Bedrock geology consists mostly of metamorphosed igneous and sedimentary rocks formed during the plate collision that formed the Appalachian. The most prominent rock types include schists, gneiss, and granofels. A summary table of geologic formations is provided below.

Table 3.3: Geological Formations

Unit	Formation	Rocks
Dst	The Straits Schist	schist
Oc	Collinsville Formation	schist, amphibolite, and hornblende gneiss
Og	Ordovician granitic gneiss	granitic gneiss
Ogh	Golden Hill Schist	schist and granofels
Ohb	Beardsley Member of Harrison Gneiss	gneiss
Ohp	Pumplin Ground Member of Harrison Gneiss	gneiss
Or	Ratlum Mountain Schist	schist and granofels
Otf	Trap Falls Formation	schist
Otfc	Carrington Pond Member of Trap Falls Formation	schist and granofels
Stb	Basal member of The Straits Schist	schist with amphibolite, marble, and quartzite

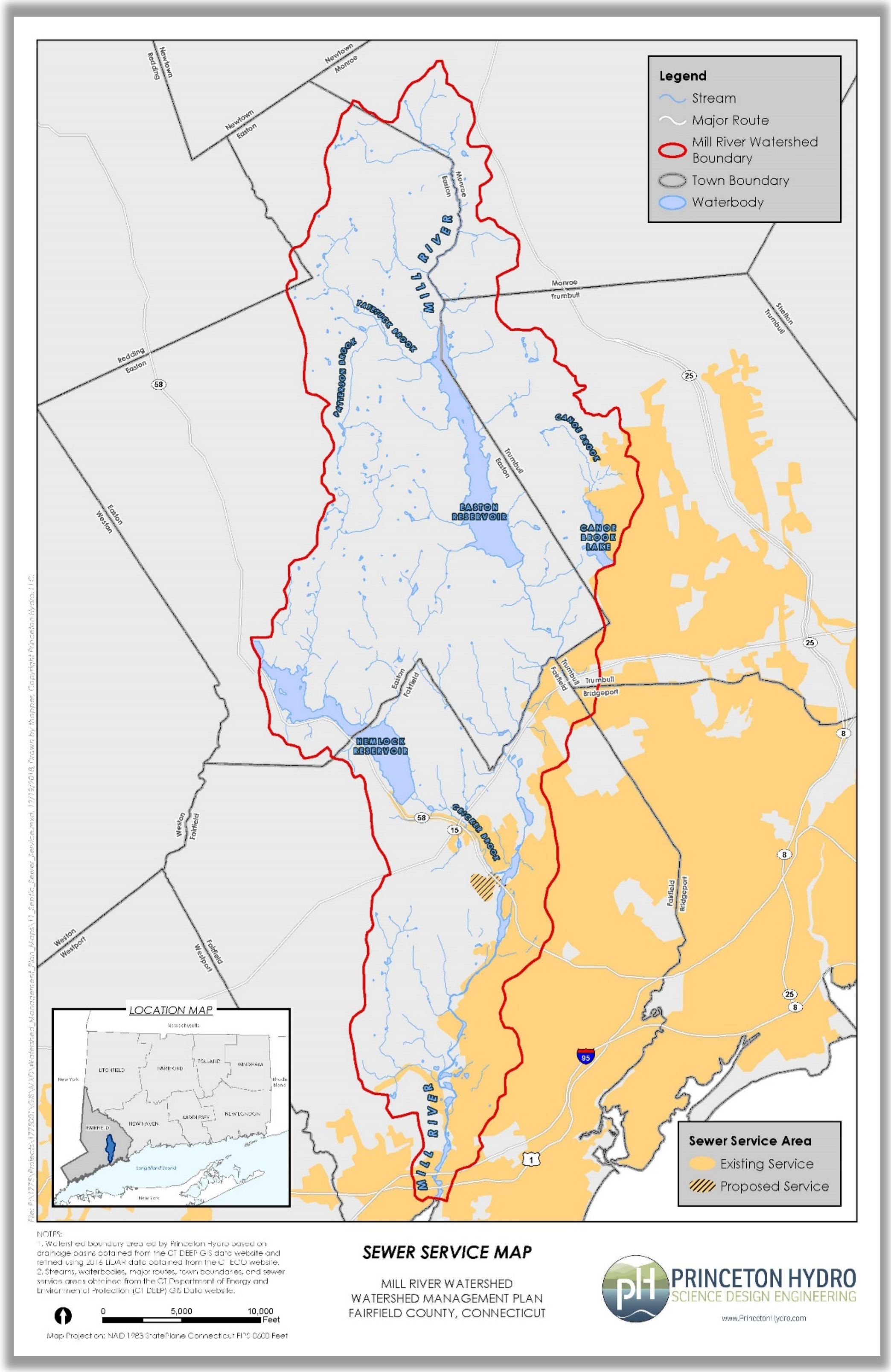


Figure 3.2: Sewer Service Map

SURFICIAL GEOLOGY

This watershed is dominated by glacial geology, or the deposition of glacially-deposited sediments over underlying bedrock. Approximately 85% of the watershed is overlain by till or thick till, glacial sediments ranging from less than 10-15 feet thick with occasional bedrock outcrops, to areas of a greater depth, commonly 100 feet and in some locations in excess of 200 feet. This non-sorted material contains a variety of particle sizes from clays to large boulders deriving from glacial ice. This material is often poorly drained.

Glacial meltwater deposits, which are stratified and left in glacial waterbodies, are also present in the watershed. Such materials including coarse deposits (gravel, sand, and a gravel/sand matrix) are located near existing hydrologic features including the Mill River. Postglacial deposits (such as swamp and alluvial deposits) are also present in the watershed. Typical of glaciated regions the watershed displays a drumlin topography with an undulating land surface.

3.1.4 SOILS

In general, soils are derived largely from the weathering of underlying geological formations. Various soils properties such as particle size, water-holding capacity, nutrient content, and erodibility, among others, are determined by the bedrock, topography, and hydrology. In this setting, soils are more closely linked to surficial geology rather than bedrock geology, because glacial till includes materials derived from outside the watershed, and may include particles and rock-types completely absent in the bedrock.

In total, there are 62 soil mapping units within the watershed. Of these 62 units, four soil series complexes comprise over 60% of the landscape including Canton and Charlton (15.8%), Charlton-Chatfield (23.9%), Paxton and Montauk (12.2%), and Ridgebury, Leicester, and Whitman (8.7%). The individual soil series forming those complexes are also found in other complexes, but at a reduced contribution. A summary of several of these important soils follows.

The Charlton series consists of well drained and non-stony to extremely stony soils formed in loamy glacial till uplands. Slopes range from 3 to 45%. The Paxton series consists of well drained, non-stony to extremely stony soils formed in compact loamy glacial till derived from gneiss and schist. These soils are found on the tops and side slopes of drumlins and hills. Slopes range from 3 to 35%. The Ridgebury series consists of poorly drained non-stony to extremely stony soils formed in compact glacial till. It is found on side slopes, shallow valleys, and drainageways from 0 to 8% slopes. Leicester soils are similar to Ridgeway soils, poorly drained, but found at slopes of 0 to 3%. Whitman series is very poorly drained, and extremely stony forming in compact loamy glacial till, found in drainageway and depressions. A soils map is provided in Appendix I, as are relevant soil characteristics reports.

Erosion susceptibility is based on a statewide survey of eroding terrace escarpments, physical evidence of erosion that is based on a combination of soil properties and topography characteristics. Highly erodible soils are concentrated in the hilly portions of the upper watershed and the valley walls of the tributary network. Erodible surficial materials, including glacial deposits are concentrated in the southern flatter areas and valley bottoms and wetlands. An erosion susceptibility figure is provided below.

Prime Farmland Soils are found throughout the watershed, but are most common in the lands bounding Easton Reservoir and southwestern portion of the watershed. Statewide Important Farmland Soils comprise a lower area than Prime Farmland Soils, but these soil units are often found in conjunction with each other.

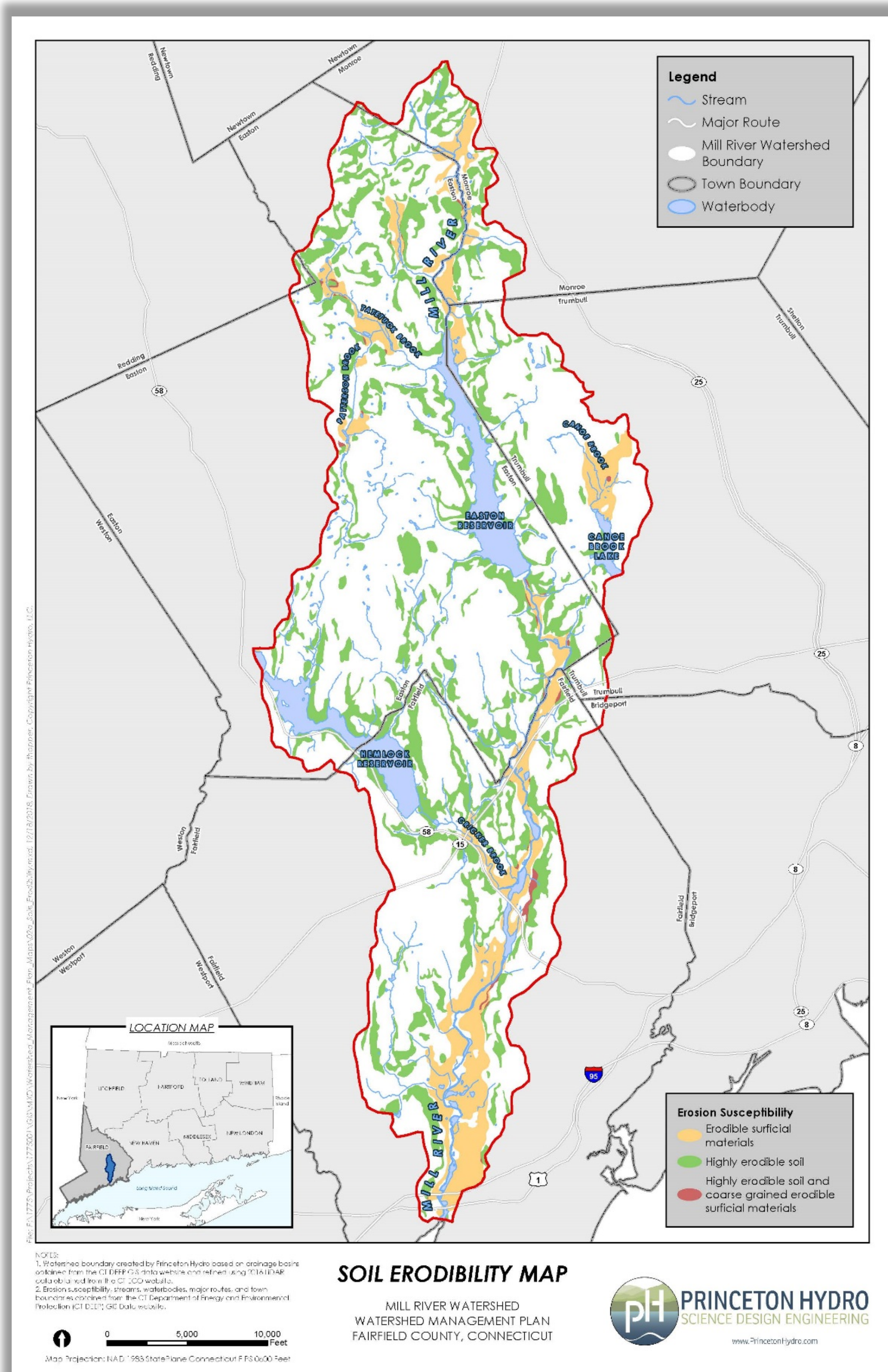


Figure 3.3: Soil Erodibility Map

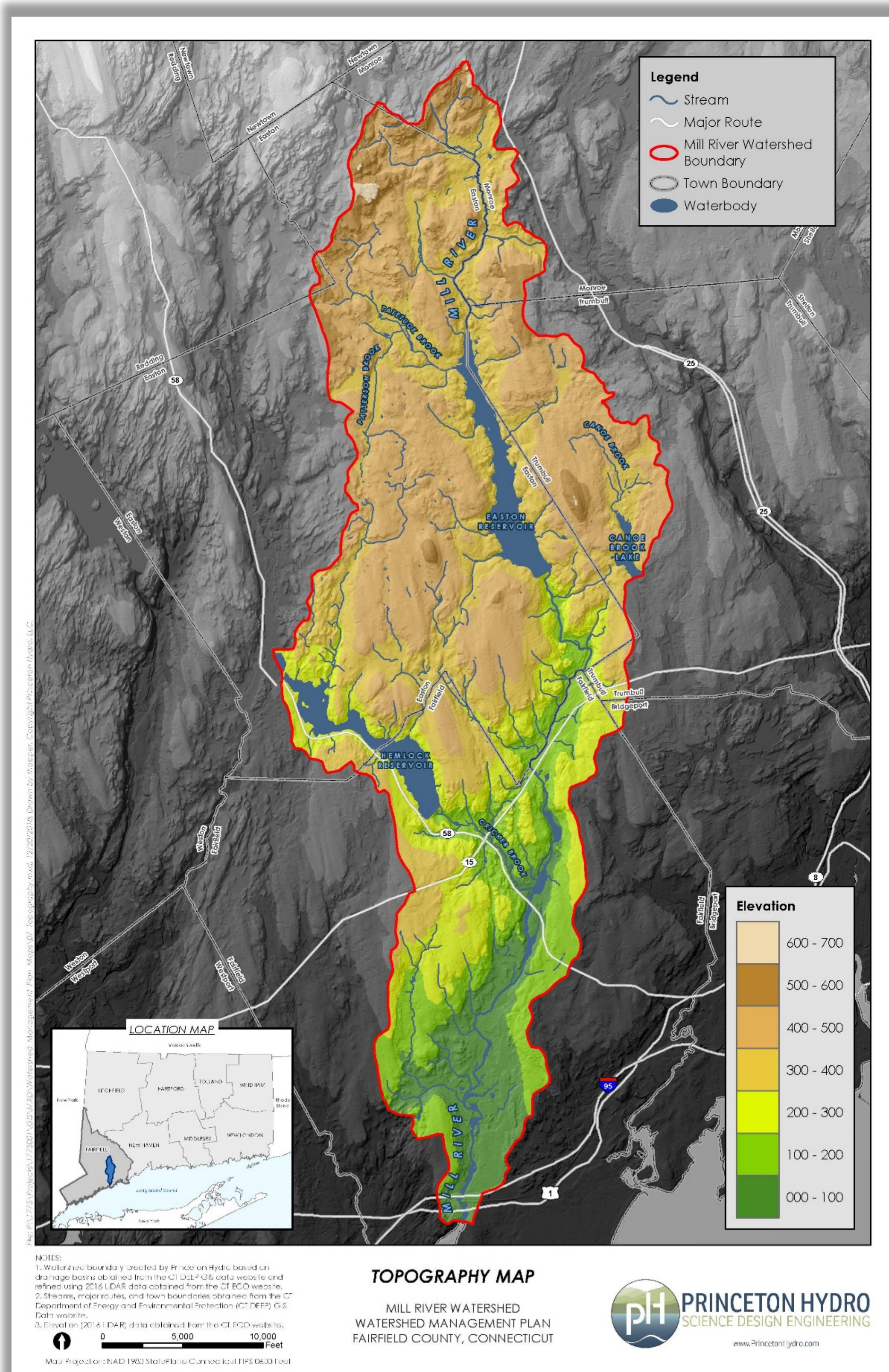


Figure 3.4: Topography Map

3.1.5 TOPOGRAPHY

The topography of the Mill River watershed consists primarily of gently sloping land punctuated by hills and drumlins (glacial hillform features). The primary slope is expressed along the north-south axis sloping in a southerly direction towards Long Island Sound. The Mill River valley parallels the eastern watershed boundary, typically offset from the boundary by a distance of less than one mile. The tributaries primarily flow in a southeasterly direction in the western portion of the watershed, and southwesterly on the east side of the river. The high point, 630 feet (NAVD88), is located on the boundary between Subwatersheds 1 and 2 northwest of the intersection of Judd Road and Maple Road. The lowest point is at the outlet approximating sea level.

3.1.6 SLOPES

A large majority of the watershed has slopes ranging from 5% to 25%, but slopes of 100 to 200% are observed at a low frequency on some hillsides and valley walls. Subwatersheds 1 and 2 in the northern portion of the watershed exhibit the highest average slopes associated with the hilly topography and higher elevations in this area. Steep slopes, in excess of 25%, are observed throughout the watershed but are concentrated on the western boundary north of Hemlock Reservoir, the margins of both Hemlock and Easton Reservoir, and the valley walls of the tributaries discharging to Mill River from the west, especially in Subwatersheds 3 and 4. Slopes of less than 5% are most prevalent in the southern portion of the watershed, increasing in coverage moving south of Hemlock Reservoir. To the east of Mill River, these areas tend to be developed, while to the west of the river these flatter slopes are generally identified as headwater wetlands or hayfield/pastureland.

3.1.7 HYDROGRAPHY

Mill River originates in the headwaters of Subwatershed 1, at the northern extent of the subwatershed, within Monroe. The river flows in a southerly fashion throughout the watershed. While the watershed is approximately 13.7 miles along its long axis, Mill River has a flow path of approximately 38.0 linear stream miles.

Mill River is not free-flowing, and has several major impoundments along its course. Mill River is dammed at its mouth at Tide Mill Dam on Harbor Road. The dam acts as a severe tidal restriction, although the head of tide extends upstream through the impoundment at a distance of 0.96 miles to the bridge at Sturges Road. There are also other constrictions in between including the Route 1, railroad, and I-95 bridges that likely further restrict tidal flow. The next barrier upstream, approximately 0.17 stream miles from Sturges Road is the Perrys Mill Pond Dam, which creates a 5.6 acre impoundment. The next barrier on Mill River occurs at the outlet of Samp Mortar Reservoir; surface area of the reservoir is 47.5 acres. Just upstream of Samp Mortar Mill River is impounded to form the 14.9 acre Lake Mohegan. The final impoundment on the main stem occurs several miles upstream at Easton Reservoir. This is the largest waterbody in the watershed, with an area of 485.1 acres.

In total (including Tide Mill Dam at the mouth of the river) there are 30 mapped dams within the watershed. The abundance of dams to create small impoundments within the watershed, specifically mill ponds, reflects the colonial industrial development patterns of the region, which were heavily reliant on hydropower. More recently, impoundments may serve different purposes including the creation of recreational waterbodies, private ponds on residential lots, and stormwater management features. Additionally, two major impoundments, Easton Reservoir on the Mill River and the 419.3 acre Hemlock Reservoir, an impoundment of Cricker Brook, serve water supply purposes. In addition, there are numerous other small ponds throughout the watershed that may represent natural water features or created systems that are not mapped as dam features likely because they do not meet regulatory definitions.

The tributary network is well distributed throughout the watershed. The tributary network includes ephemeral and intermittent headwaters and low-order streams. Most of the surface features are unnamed, but some of the named streams, starting near the northern extent of the watershed include Wicker Brook, Tatetuck Brook and its tributary Patterson Brook, Chub Brook, Canoe Brook, Morehouse Brook, Cricker Brook, and Browns Brook.

3.1.8 WETLANDS

The National Wetland Inventory (NWI) shows 2,169 acres of mapped wetlands, including surface waters, within the Mill River watershed. The mapped wetland type designated lakes is limited to the littoral zones of Hemlock and Easton Reservoirs, accounting for 839.5 acres or 38.7% of total wetlands (note: the lake boundaries on this coverage are different than State-derived data and therefore surface area is different). The predominant wetland type is freshwater forested/shrub wetlands. Other identified wetland types include riverine, freshwater ponds (including Samp Mortar Reservoir and Lake Mohegan among others), freshwater emergent wetlands, and estuarine and marine. The National Land Cover Database (NLCD) accounts for and classifies these areas somewhat differently. Open waters have an area of 1,121 acres, woody wetlands are 1,157 acres, and emergent herbaceous wetlands account for just 39 acres.

Wetlands are fairly well distributed throughout the watershed. In the lower portions of the watershed wetlands are typically correlated with surface water features, water courses, and valley bottoms; in the upper portions of the watershed wetlands are found in the same areas and at the origination of headwater streams. One of the largest contiguous wetlands is found in the headwaters of Patterson Brook to the west of State Route 59.

3.1.9 FLOODPLAINS

The Federal Emergency Management Agency (FEMA) issues floodplain maps that describe flood events in the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood zones. These areas are based upon exceedance probabilities and not explicit periodicity of flood events. The 1 percent flood zone is also known as the Special Flood Hazard Area, and these areas are further split into two designations: Zone AE and Zone A. Zone AE represents the 100-year floodplain for which Base Flood Elevations (BFE) have been established; the BFE is based on detailed, area-specific hydraulic analyses and is tied to vertical datum. Zone A, which has no BFE, is based on best available data including historic flood levels, soils, and topographic data.

In the Mill River watershed, Tatetuck Brook is associated with the 100-year A designation throughout all stream reaches. Cricker Brook is also associated with this designation from its northernmost reach south to Hemlock Reservoir. Along its southern reach, which confluences with Mill River, it is associated with the 100-year AE designation. The 100-year AE designation is most prevalent along the Mill River in the more developed southeastern portions of the watershed, which are more prone to flooding.

3.1.10 AQUIFERS AND WATER SUPPLY

Aquifers are water-bearing geological formations that include permeable rock, fractured rock, or unconsolidated materials. CT DEEP has established Aquifer Protection Areas, commonly known as wellhead protection areas, in sand and gravel aquifers that contribute groundwater to active public water supply wells which serve at least 1,000 people; no such areas are currently identified on the GIS layer.

Connecticut Geological Survey has also mapped potential surficial aquifers in areas based on the thickness and quality of glacial sediments. The thickness of coarse-grained deposits is directly correlated with potential for water supply development. Areas of deposits between 0-50 feet thick exist almost exclusively adjacent to Mill River. Several units are also mapped along sections of Tatetuck Brook and Patterson Brook.

The Aquarion Water Company services approximately 58% of the Mill River Watershed. This area covers most of Fairfield and the upper eastern half of the watershed. This area corresponds to the areas of highest development density. The remaining portions of the watershed have lower intensity development as well as agricultural and forested land uses. Potable water is supplied by private onsite wells.

3.1.11 LAND USE AND LAND COVER

Land use and land cover (LU/LC) is a primary determinant of water quality in most watersheds. Water quality deteriorations are often closely associated with the level of development in a watershed and are specifically tied to the amount of impervious surface, disturbed soils, non-native vegetation, and the generation of a variety of pollutants that are then delivered via stormwater runoff. These factors contribute to erosion, sedimentation, nutrient enrichment, and a general increase in the concentration of pollutants thereby resulting in a loss of ecologic and hydrologic function. Typically, development is simply thought of as urban land uses, such as residential, commercial, and industrial development as well as supporting infrastructure such as roadways and utilities, although the degradation of water quality is observed when there is any deviation from natural LU/LC such as forest and wetlands. Therefore, analysis of development must account for other land uses that qualify as disturbances or alteration to natural LU/LC, such as agriculture.

Land use data utilized in this study is sourced from the National Land Cover Database (NLCD), developed by a consortium of federal agencies. The primary coding of LU/LC is derived from aerial imagery. This data is one of the key inputs in executing pollutant load modeling.

In total fourteen land use/land cover types were identified within the watershed. Land use generally refers to land development patterns and characteristic alterations to support varied uses, while land cover refers to the mapped surfaces including natural resources such as forests and wetlands, as well as artificial systems including impervious surfaces and lawns. Together both these metrics impact the function of watershed. Land cover that is impervious (i.e. roads and buildings) reduces the watershed's ability to absorb runoff which can have negative impacts. Land uses can impact watersheds by providing sources of potential contaminates, including nutrient pollutants and microbes.

A brief summary of the LU/LC types are provided here to aid in the interpretation of the data. According to the NLCD 2011 data, a parcel is categorized as open water if at least 75% of the area is comprised of open water. Developed open space refers to areas with a mixture of constructed materials and vegetation with a heavy emphasis on the latter. Lawn grasses make up most of the vegetation although large-lot single-family housing units, golf courses, parks, and planted vegetation also contribute. Developed low intensity parcels are also areas with a mixture of constructed materials and vegetation although impervious surfaces cover about 20%-49% of the parcels. Single-family housing units are included in this category. Developed medium intensity areas are similar in character but are 50-79% covered by impervious surfaces. Developed high intensity areas are comprised of 80-100% impervious surfaces and indicate areas where people live and work in dense quarters. Apartment complexes and industrial buildings are most commonly associated with this land cover category.

Forested areas are broken into deciduous, evergreen, and mixed forest categories. The first indicates an area dominated by trees that undergo seasonal foliage changes while the latter maintains leaves throughout the year. Mixed forest refers to forest comprised of less than 75% of either class. Scrub/shrub are areas dominated by small woody plants with the shrub canopy accounting for more than 20% of total vegetation. Grassland/herbaceous areas are those that may be used for grazing purposes and are generally covered by at least 80% graminoid or herbaceous vegetation. Pasture/hay refers to areas where the main purpose is to provide grasses, legumes, or grass-legume mixtures for livestock grazing or perennial crop production. Cultivated crops parcels typically contain annual crops such as corn, soybeans, or vegetables, as well as woody crops including orchards. All land that is actively tilled is included in this class. Woody wetlands refer to areas with either soil or substrate that is periodically saturated or covered with water and where forest or shrubland vegetation make up at least 20% of the vegetative cover. Emergent herbaceous wetlands are characterized by perennial herbaceous vegetation that makes up at least 80% of the area, which is also subject to periodic saturation or coverage by water. Table 3.4 shows the overall land use patterns within the watershed.

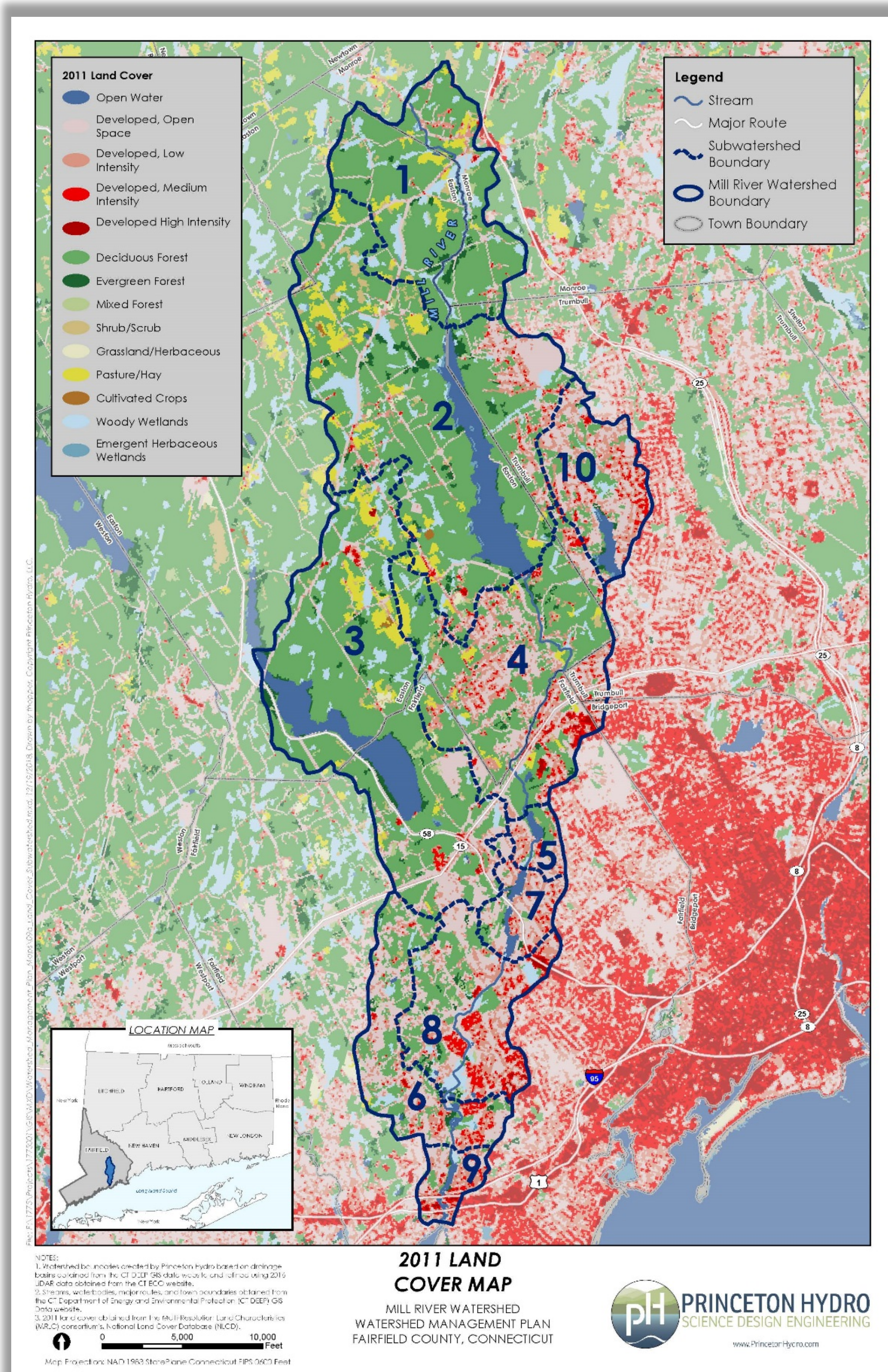


Figure 3.5: 2011 Land Cover Map

Table 3.4: LU/LC in the Mill River Watershed by Type

Land Use/Land Cover Type	Area	
	acres	%
Open Water	1,121	5.5
Developed, Open Space	4,079	19.9
Developed, Low Intensity	2,100	10.2
Developed, Medium Intensity	696	3.4
Developed, High Intensity	100	0.5
Deciduous Forest	9,644	47.1
Evergreen Forest	396	1.9
Mixed Forest	107	0.5
Shrub/Scrub	219	1.1
Grassland/Herbaceous	55	0.3
Pasture/Hay	763	3.7
Cultivated Crops	10	0.1
Woody Wetlands	1,157	5.6
Emergent Herbaceous Wetlands	39	0.2
Total	**20488**	**100.0**

The dominant LU/LC in the watershed in Deciduous Forest, accounting for over 47% of the land mass; forests are not equitably distributed, but are concentrated in the upper two-thirds of the watershed. When combined with evergreen and mixed forests, as well as scrub/shrub land (likely representing early successional development or the reversion of agricultural lands to forest), these forested LU/LC types account for over 50% of the watershed land mass.

Developed, Open Space is the second most common LU/LC type, at over 4,000 acres or nearly 20% of the watershed. As described above, this includes a mix of true open space settings, like parks and preserves, as well as large-lot type residential uses. The disposition of open space will be described in greater detail in the Open Space section, but this coverage does not distinguish typical open space from low-intensity/large lot residential uses. This LU/LC type is concentrated in the southern third of the watershed, often associated with water features and Mill River proper. There is also a significant distribution of this type between Hemlock and Easton Reservoirs. One of the largest contiguous spaces, to the east of the head of Easton Reservoir, is the Tashua Knolls and Tashua Glen Golf Course.

The third most common LU/LC type is Developed, Low Intensity at 10.2% of the watershed; no other type exceeds 6%. Together, Developed, Low, Medium, and High Intensity development accounts for approximately 2,900 acres or 14.1% of the watershed. Again, these land types are most prevalent in the southern third of the watershed, with a noted increase in intensity moving east towards Bridgeport.

The final major groupings include wetlands, water, and agricultural uses. Open Water, represented primarily by Hemlock, Easton, and Samp Mortar Reservoirs, and Lake Mohegan in addition to all other waterbodies, account for 1,121 acres or 5.5% of the watershed. Note that all of the large named features are impoundments with associated dams indicating these are constructed waterbodies. Collectively wetlands, dominated by Woody Wetlands most often called swamps, cover nearly 1,200 acres or 5.8% of the watershed. The agricultural land types include Grassland/Herbaceous, Pasture/Hay, and Cultivated Crops, and together account for 828 acres or 4.1% of the watershed. Pasture/Hay alone is 763 acres. Agricultural land uses are most highly represented in the Town of Easton in the northwestern sector of the watershed.

As mentioned above, one of the approaches of the WMP is to divide the watershed into subwatersheds to not only represent the functional hydrography of the system but to focus on smaller units to better describe potential water quality issues. Review of the land cover data on a subwatershed basis reveals a continuum of development intensity starting with the least developed subwatersheds in the northern headwaters to the mostly highly developed subwatersheds in the south. Grouping the LU/LC types is useful to look at larger patterns. The Forest group (three forest types plus shrub/scrub) account for 73% of the area of Subwatershed 1 and nearly 60% for 2 and 3. This continues to decline in a nearly stepwise manor to a low of just 8.3% in Subwatershed 9. The Developed group (four developed LU/LC types) is below 20% coverage for Subwatersheds 1 through 3, and above 50% thereafter, peaking at 85% is Subwatershed 9. Significant agriculture lands are found only in Subwatersheds 1 through 4. Wetlands are distributed throughout but peak in Subwatershed 1 at 10.6% and account for just 0.2% of the area of Subwatershed 7. Open water accounts for more than 8% of the area of Subwatersheds 2, 3, 5, and 7, 4.6% in Subwatershed 9, and at or below 1% in the remaining four subwatersheds.

Table 3.5 a, b, c: LU/LC in the Mill River Watershed by Subwatershed

Land Use/Land Cover Type	LU/LC Area (acres) by Subwatershed								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Open Water	2	511	487	7	23	13	55	8	16
Developed, Open Space	211	710	673	892	89	539	256	598	109
Developed, Low Intensity	79	315	161	619	78	224	143	364	116
Developed, Medium Intensity	11	61	62	197	17	70	29	187	60
Developed, High Intensity	1	4	16	30	2	2	4	33	10
Deciduous Forest	1790	3047	2547	1390	49	418	48	334	23
Evergreen Forest	57	134	93	44	1	20	9	33	6
Mixed Forest	24	18	34	9	5	2	3	12	0
Shrub/Scrub	37	97	46	26	4	5	0	5	0
Grassland/Herbaceous	0	22	21	7	0	5	0	0	0
Pasture/Hay	123	333	192	111	0	4	0	0	0
Cultivated Crops	0	10	0	0	0	0	0	0	0
Woody Wetlands	273	365	249	97	8	54	1	104	9
Emergent Herbaceous Wetlands	4	28	3	3	0	1	0	0	0
Total	**2611**	**5655**	**4583**	**3432**	**274**	**1358**	**549**	**1678**	**348**

Land Use/Land Cover Type	LU/LC Area (%) by Subwatershed								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Open Water	0.1	9.0	10.6	0.2	8.4	1.0	10.0	0.5	4.6
Developed, Open Space	8.1	12.6	14.7	26.0	32.5	39.7	46.6	35.6	31.3
Developed, Low Intensity	3.0	5.6	3.5	18.0	28.5	16.5	26.0	21.7	33.3
Developed, Medium Intensity	0.4	1.1	1.4	5.7	6.2	5.2	5.3	11.1	17.2
Developed, High Intensity	0.0	0.1	0.3	0.9	0.7	0.1	0.7	2.0	2.9
Deciduous Forest	68.6	53.9	55.6	40.5	17.9	30.8	8.7	19.9	6.6
Evergreen Forest	2.2	2.4	2.0	1.3	0.4	1.5	1.6	2.0	1.7
Mixed Forest	0.9	0.3	0.7	0.3	1.8	0.1	0.5	0.7	0.0
Shrub/Scrub	1.4	1.7	1.0	0.8	1.5	0.4	0.0	0.3	0.0
Grassland/Herbaceous	0.0	0.4	0.5	0.2	0.0	0.4	0.0	0.0	0.0
Pasture/Hay	4.7	5.9	4.2	3.2	0.0	0.3	0.0	0.0	0.0
Cultivated Crops	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Woody Wetlands	10.5	6.5	5.4	2.8	2.9	4.0	0.2	6.2	2.6
Emergent Herbaceous Wetlands	0.2	0.5	0.1	0.1	0.0	0.1	0.0	0.0	0.0
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Land Use/Land Cover Groups	LU/LC Area (%) by Subwatershed								
	1	2	3	4	5	6	7	8	9
Water	0.1	9.0	10.6	0.2	8.4	1.0	10.0	0.5	4.6
Wetlands	10.6	6.9	5.5	2.9	2.9	4.1	0.2	6.2	2.6
Developed	11.6	19.3	19.9	50.6	67.9	61.5	78.7	70.4	84.8
Forested	73.1	58.3	59.3	42.8	21.5	32.8	10.9	22.9	8.3
Agriculture	4.7	6.1	4.2	3.2	0.0	0.3	0.0	0.0	0.0

3.1.12 IMPERVIOUS SURFACES

Impervious surfaces were also mapped for this exercise. Areas are calculated by multiplying the percent impervious for each raster cell (the fundamental grid block of the NLCD coverage) by the associated area. Percent impervious ranged from 0% to 100%; waterbodies and some natural areas are defined as having no impervious coverage, while buildings and other manmade structures are classified as 100% impervious. In total, 8.2% of the watershed is classified as impervious. The distribution of impervious surfaces is well correlated with general development patterns in the watershed. The northern half and west central portions of the watershed have few impervious surfaces, and the majority of the land is rated as 0% impervious. Road networks, institutional or campus settings, neighborhoods, and other low-intensity development are easily identified in this area. The area between Hemlock and Easton Reservoirs contains areas of residential development with much of the land rated between 1 and 20% impervious with discrete areas ranging up to 60%. The southern portion of the watershed, south of Merritt Parkway, has a wide array of impervious surfaces, and while much of this area is classified as between 1 and 20% impervious, significant portions are between 41 and 80%, with discrete areas of 100% imperviousness.

Generally, the distribution of impervious surfaces throughout the watershed show a watershed of two different natures, the rural north and the developed south. While urban, commercial, and industrial land uses are often implicated as the main contributors to NPS loading, less urbanized uses can also degrade stream quality and contribute to pollutant loading. It is generally true that these less intensely developed watersheds do have smaller loads of toxics such as metals and petroleum hydrocarbons, but rural watersheds are more likely to contribute nutrient pollutants and solids. Where agriculture is an important component of the makeup of the land, it is typically the primary loader of nutrients like phosphorus nitrogen, microbes including fecal bacteria, and may contribute large solids loads as well. Similarly, low density residential development may act in a similar fashion although the unit areal load may be smaller than agricultural uses. In the end, the loading related to residential and agricultural uses can contribute to eutrophication in streams as well as deposition of solids. In more heavily developed watersheds other factors such as wastewater, pet waste, and lawn fertilizers can be problematic in addition to the metals, hydrocarbons, and other sources linked to transportation infrastructure. Additionally, the density and contiguity of impervious surfaces leads to increased stormwater loading, more efficient delivery of pollutant loads, and hydraulic impacts to receiving waterways chief among them bank instability. The role of LU/LC will be examined in further detail in the pollutant load analysis and hydrologic modeling later in the document.

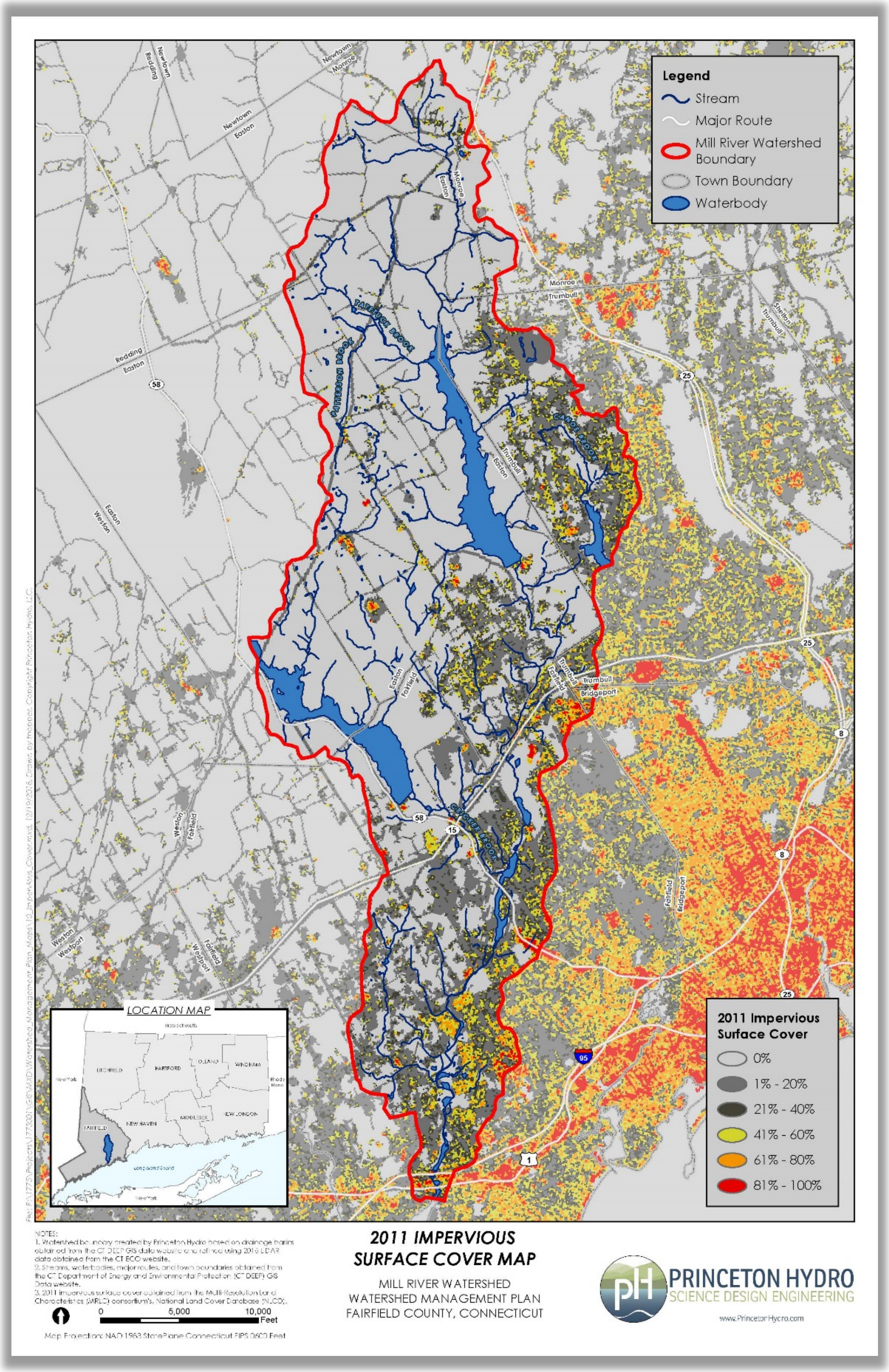


Figure 3.6: 2011 Impervious Surface Cover Map

3.1.13 OPEN SPACE

Open space preservation has been a key planning tool in Fairfield County to preserve rural characteristics of the municipalities and maintain the ecological integrity and environmental services associated with open spaces. Multiple towns within the watershed, including Fairfield, Easton, and Redding, maintain programs or plans to preserve undeveloped parcels. Open space preservation works through several means to protect the integrity of the watershed. Primarily, it preserves natural features that have important ecologic and hydrologic functions, including species diversity, habitat, pollution mitigation, groundwater recharge, and stream baseflow. Second, it limits further development, which is intrinsically tied to water quality and other ecological impairments. Third, it benefits the public by providing recreational opportunities.

There are no federal open space parcels within the watershed. CT DEEP owns 1495 acres of open space within the Mill River watershed, the entirety of which belongs to the Centennial Watershed State Forest. These parcels are located in the northern part of the watershed, extending about a mile south of the Easton-Fairfield border.

About 1432 acres of municipally- and privately-owned open space parcels are present within the watershed. The majority of this area is municipal: fifty-four parcels ranging from 0.01 to 161 acres provide 1160 acres of open space. The Tashua Recreation Area and Mohegan Trails and Cascades Open Space Area provide the largest municipally-owned parcels to the community.

Thirteen privately-owned open space parcels contribute 272 acres to the Mill River watershed. The Lake Hills Association owns two parcels which combine to form the largest parcel in this category of 73 acres. The Oaklawn Cemetery is second-largest at 68 acres.

3.1.14 WILDLIFE, FISHERIES RESOURCES, AND ENVIRONMENTALLY SENSITIVE AREAS

NATURAL DIVERSITY DATA BASE AREAS

CT DEEP maintains the Natural Diversity Data Base to document the occurrence of Federal and State endangered, threatened, and special concern species and significant natural communities. The publicly available maps mask the exact locations and identities of the listed-species as a security measure to protect the integrity of the habitat or the species itself, as well as the property rights of landowners. The maps serve as a screening tool, and additional information can be requested as needed that is subject to a review process.

Several significant areas are mapped within the watershed. This includes the entirety of the Mill River corridor starting at Tide Mill Dam through Samp Reservoir. The entirety of Easton Reservoir is also mapped. At least eleven additional areas are mapped, some of which are contiguous to the features described above or areas that appear to include multiple listings. Most of these tend to remain focused on waterbodies including several areas around and including Hemlock Reservoir, and several other areas on Mill River or on a nearby tributary. It is also worth noting that the lower Mill River mapping extends south through Southport Harbor and along the shoreline of Long Island Sound. No significant natural communities are located within the watershed, however estuarine beachshore is found at the mouth of Southport Harbor.

FISHERIES

Several trout management areas are mapped within the watershed. These include the Mill River Trout Management Area from the Merritt Parkway south to Lake Mohegan; this area was last stocked on October 15, 2018. Other open stocking areas are mapped on the Mill River and its impoundments including Lake Mohegan and the next reach south, from Samp Mortar to the confluence with Browns Brook, and from Perrys Mill Pond to Mill Hollow Park. The reach of Mill River extending from Merritt Parkway in the south to near Easton Reservoir is identified as the Mill River Class 1 Wild Trout Management Area. This is a special regulation area that is not stocked, but contains abundant wild trout populations. Angling is open year-round and is catch and release, artificial lures only, with barbless hooks.

ENVIRONMENTALLY SENSITIVE AREAS

Environmentally sensitive areas (ESA) are resources recognized by the EPA for their value and sensitivity. Some examples include wetlands, biological resources, tribal lands, and wildlife areas. The Mill River Watershed, located in EPA Region 1, contains three ESAs: the Easton, Hemlock, and Samp Mortar Reservoirs.

3.2 WATER QUALITY CHARACTERIZATION

3.2.1 WATER QUALITY CLASSIFICATION

CT DEEP has developed and implemented the Connecticut Water Quality Standards and Classifications for surface and groundwaters to: provide guidance and policy for maintaining or improving water quality; establishing designated uses; indicating allowable discharges; segregating drinking water supply from waters used for waste assimilation; providing standards to protect aquatic life and human use; developing pollution abatement and remediation measures; and providing guidance for business, industry, and economic development.

SURFACE WATERS STANDARDS AND CLASSIFICATION

Within the Mill River watershed, all waterbodies, including both lentic (still waters) and lotic (flowing waters), are designated as one of three classifications. The main stem Mill River from its mouth at Tide Mill Dam upstream through the head of tide at Sturges Road is classified as Class SA (Saline A). Mill River, its impoundments, mapped tributaries, and other ponds within the drainage from Sturges Road to the Easton Reservoir Dam along the mainstem, and up Cricker Brook to Hemlock Reservoir Dam are Class A waters. This includes Lake Mohegan, Samp Mortar Reservoir, and Perrys Mill Pond, and all other waters in this area. Hemlock Reservoir, Easton Reservoir, and all waterbodies and tributaries within their catchments, to the northern bounds of the watershed, are classified as Class AA waters. A summary is provided in the table below.

Table 3.6: Summary of Designated Uses and Discharge Restrictions

Class	Uses/Restrictions	Description
AA	Designated Uses	Existing or proposed drinking water supply; fish and wildlife habitat; recreational use (may be restricted); agricultural and industrial supply
	Discharges restricted to:	Discharges from public or private drinking water treatment systems; dredging and dewatering; emergency and clean water discharges
A	Designated Uses	Potential drinking water supply; fish and wildlife habitat; recreational use; agricultrual and industrial supply; other legitimate uses including navigation
	Discharges restricted to:	Same as allowed in AA
SA	Designated Uses	Marine fish, shellfish, and wildlife habitat; shellfish harvesting for direct human consumption; recreation; all other legitimate uses including navigation
	Discharges restricted to:	Same as for AA or A surface waters

A summary of pertinent surface water quality criteria is provided below.

- Aesthetics: Class AA, A, and SA – uniformly excellent
- Dissolved Oxygen: Class AA and A – not less than 5 mg/L at any time. Class SA- Acute: Not less than 3.0 mg/L, Chronic: Not less than 4.8 mg/L
- Suspended and Settleable Solids: Class AA and A – None in concentrations or combinations which would impair designated uses; none aesthetically objectionable; none which would significantly alter the physical or chemical composition of the bottom; none which would adversely impact aquatic organisms living in or on the bottom substrate. Class SA – None other than of natural origin
- Turbidity: Class AA and A - Shall not exceed 5 NTU over ambient levels and none exceeding levels necessary to protect and maintain all designated uses. Class SA - None other than of natural origin except as may result from normal agricultural, road maintenance, or construction activity, dredging activity, or discharge of dredged or fill materials
- pH: Class AA and A – As naturally occurs; Class SA – 6.8-8.5
- Allowable Temperature Increase; Class AA and A - There shall be no changes from natural conditions that would impair any existing or designated uses assigned to this Class and in no case exceed 85°F, or in any case raise the temperature of surface water more than 4°F. Class SA – There shall be no changes from natural conditions that would impair any existing or designated uses assigned to this Class and, in no case exceed 83°F, or in any case raise the temperature of the receiving water more than 4°F. During the period including July, August, and September, the temperature of the receiving water shall not be raised more than 1.5°F unless it can be shown that spawning and growth of indigenous organisms will not be significantly affected.
- Nutrients: Class AA, A, and SA – The loading of nutrients, principally phosphorus and nitrogen, to any surface water body shall not exceed that which supports maintenance or attainment of designated uses
- Biological Condition: Class AA and A – Sustainable, diverse biological communities of indigenous taxa shall be present. Moderate changes, from natural conditions in the structure of the biological communities, and minimal changes in ecosystem function may be evident; however, water quality shall be sufficient to sustain a biological condition within the range of Connecticut Biological Condition Gradient Tiers 1-4 as assessed along a 6 tier stressor gradient of Biological Condition Gradient. Class SA - Sustainable, diverse biological communities of indigenous taxa shall be present. Moderate changes, from natural conditions in the structure of the biological communities, and minimal changes in ecosystem function may be evident; however, water quality shall be sufficient to sustain a healthy, diverse biological community.
- Ammonia: Class AA and A – Criteria for ammonia vary in response to ambient surface water temperature (T, °C) and pH. Biological integrity is considered impaired when:
  A: The one-hour average concentration of total ammonia exceeds: $[0.275/(1+10^{(7.204-pH)})] + [39.0/(1+10^{(pH-7.204)})]$ when salmonids are present or $[0.411/(1+10^{(7.204-pH)})| + [58.4/(1+10^{(pH-7.204)})]$
  B: The four-day average concentration of total ammonia exceeds 2.5 times the value obtained from the formula in C below.
  C: The 30-day average concentration of total ammonia exceeds:
  $[0.0577/(1+10^{(7.688-pH)})]+[2.487/(1+10^{(pH-7.688)})] \times [MIN92.85, 1.45 \times (10^{(0.028(25-T))})]$ when early life stages are present; or
  $[0.0577/(1+10^{(7.688-pH)})]+[2.487/(1+10^{(pH-7.688)})] \times [1.45 \times (10^{(0.028(25-MAX(T,7))})]$ when early life stages are absent.
  Class SA – acute 235 µg/L; chronic 35 µg/L.

The various indicator bacteria, be it total coliform, *Escherichia coli* (*E. coli*), fecal coliform, or Enterococci, warrant special attention since the Mill River has an approved TMDL for indicator bacteria. A summary of the applicable criteria is provided below.

Designated Use	Indicator	Criteria by Classification AA	A
Drinking Water Supply[1]	Total Coliform	Monthly moving average less than 100/100 mL Single sample maximum 500/100 mL	
Recreation[2] - All other uses	Escherichia coli	Geometric mean less than 126/100 mL Single sample maximum 576/100 mL	
Designated Use	**Indicator**	**SA**	
Shellfishing - Direct Consumption	Fecal coliform	Geometric mean less than 14/100 mL 90% of samples less than 31/100 mL	
Recreation - All other uses	Enterococci	Geometric mean less than 35/100 mL Single sample maximum 500/100 mL	

1- Criteria applies only at the drinking water supply intake structure.
2- TMDL and mapped sources do not indicate classification of any waterbodies within the watershed as designated swimming or non-designated swimming, which carry other criteria

GROUNDWATER STANDARDS AND CLASSIFICATION

The Mill River watershed has several mapped groundwater classifications. About half of the watershed, specifically the portion that carries a surface water classification of Class AA, the catchments of Hemlock Reservoir and Easton Reservoir, is classified as Class GAAs for groundwater. Class GAA designated uses are existing or potential public supply of water suitable for drinking without treatment and baseflow of hydraulically connected surface waters; Class GAAs is a subclass related to groundwater that is tributary to a public supply reservoir. Most of the remainder of the watershed is Class GA, a general class with designated uses including existing private and potential public or private supplies of water suitable for drinking without treatment and baseflow for hydraulically-connected waterbodies; this class includes all areas not otherwise specifically designated. Two small areas, each approximately 14.9 acres, on either side of Mill River between I-95 and Route 1 are mapped as Class GA-Impaired. Finally, a 16.9 acre unit near Mill River between Cynthia Drive and Brookside Drive is mapped as a GAA-Well; this marks a public water supply well with an associated 500-foot radius buffer.

3.2.2 TMDL FOR *E. COLI*

In 2004, Mill River was included on the 303(d) List of Impaired Waterbodies due to exceedances for indicator bacteria criteria which triggered the development of a Total Maximum Daily Load Analysis (TMDL). These documents are prepared to evaluate water quality and calculate the TMDL of a given pollutant or series of pollutants a waterbody can receive without exceeding applicable water quality criteria. These TMDLs calculated Wasteload Allocations (WLA) which are attributable to point sources observable under “wet” conditions following precipitation events, and Load Allocations (LA), the nonpoint source fraction of the total load discernible during “dry” periods or baseflow. These plans identify the required load reductions to achieve the TMDL, as well as broad identification of measures to accomplish the reductions.

A TMDL Analysis for the Mill River, Rooster River, and Sasco Brook was approved by the EPA in 2005 and included two adjacent watersheds. Mill River was listed for stream reaches CT7108-00_02a and -b, which extend from the upper end of Samp Mortar Reservoir upstream to Easton Reservoir, which included approximately 4.0 linear stream miles and a calculated drainage basin of 24.89 mi^2 or 15,929.6 acres. Sampling showed that the Mill River contravened applicable water quality standards for indicator bacteria leading to failure to meet the designated use for contact recreation. Indicator bacteria is a varied description of gut bacteria that indicate the presence of pathogens including viruses and bacteria or are pathogenic in their own right, such as certain strains of *E. coli*. As a Class A water in the segment of interest, the applicable water quality criteria for *E. coli* is that the geometric mean shall not exceed 126 col/100 mL (colonies or colony forming units) or a single sample maximum of 576 col/100 mL.

Nonpoint source load identification included source(s) unknown and urban runoff/storm sewers. Point sources included regulated urban runoff/storm sewers. Specifically, this refers to the municipal separate storm sewer system, more commonly known as MS4, which includes conveyances for stormwater (e.g. roads with drainage systems, streets, catch basins, curbs, gutters, ditches, channels, storm drains) owned or operated by any municipality or by any State or federal institution and discharging to surface waters of the State. While discharge from a pipe may properly be classified a point source discharge, and is considered as such by CT DEEP subject to regulation under the NPDES (National Pollution Discharge Elimination System) program, the origin of this stormwater is of a nonpoint source nature, i.e. it is diffuse, collected from a wide area, without a single originating source; indeed, the piping only represents the collection of stormwater, not its origin.

E. coli sampling was conducted at two sites which represented both impaired segments of the river, M2S and M3. Sampling was initiated in June of 1999 and continued through May 2002 and was conducted during each year in the May to September window. Samples were collected under both baseflow and stormflow or dry and wet conditions. Monitoring site M2S is located on the Mill River between Lake Mohegan and Samp Mortar Reservoir, while M3 is on Mill River at Congress Street. At M2S, 26 samples were collected. The geometric mean (geomean) was 105 col/100 mL, which met the standard for average concentration, with four samples exceeding the maximum standard. At M3, 31 samples were collected and analyzed. The geomean was 299 col/100 mL, an exceedance of the average standard, with seven samples exceeding the maximum value. According to the TMDL, the site is equally impacted by bacteria loading under both wet and dry conditions. The high required LA reduction may indicate illegal sanitary sewer discharges to the storm sewers. At M2S, the WLA is lower than the LA, indicating greater bacterial loading under wet conditions and the importance of regulated stormwater features. The lower WLA and LA for the downstream M2S site may indicate that Lake Mohegan, located upstream of the site, is acting as a regional retention feature and settling particulate bacterial matter. The results of the TMDL will be included in Appendix I.

In 2019, between the public presentation of this document in May and completion of the final draft, CT DEEP released the 2018 Draft Integrated Water Quality Report (IWQR). The accompanying Appendix B-5 Reconciliation List of Impaired Waters indicated that Mill River segment CT7108-00_02a has been delisted, and that the applicable water quality standard for recreational use has been attained. Additional materials provided by CT DEEP note that despite the delisting, that the TMDL will still be applied to the segment.

3.2.3 HARBOR WATCH MONITORING PROGRAM

Harbor Watch initiated a water quality monitoring program of rivers in Fairfield County in 2016 which included sampling Mill River. The goal of the project according to the 2016 *Fairfield County River Report* is to: "Assist in the location of sources of sewage pollution from point and non-point sources, using *Escherichia coli* (*E. coli*) as an indicator." The project is ongoing with monitoring continuing through 2017 and 2018. Harbor Watch is a citizen science organization, primarily focused on addressing pollution threats to Long Island Sound, to which Mill River is tributary.

Sampling was conducted under CT DEEP approved Quality Assurance Project Plans (QAPPs) to ensure the proper methodologies were employed and the acceptability of the resultant data and reports. Each river was sampled twice monthly from May through September. Sampling consisted of the in-situ parameters water temperature, dissolved oxygen, and conductivity. Water samples were also collected and analyzed for fecal coliform (Standard Method SM9222D) and *E. coli* (Standard Method SM9222G). The results were evaluated against the appropriate water quality standards; for Mill River the *E. coli* standards are a geomean less than 126 cfu/100 mL and single sample maximum of 576 cfu/100 mL. The Harbor Watch sampling figure for 2017 is included below.

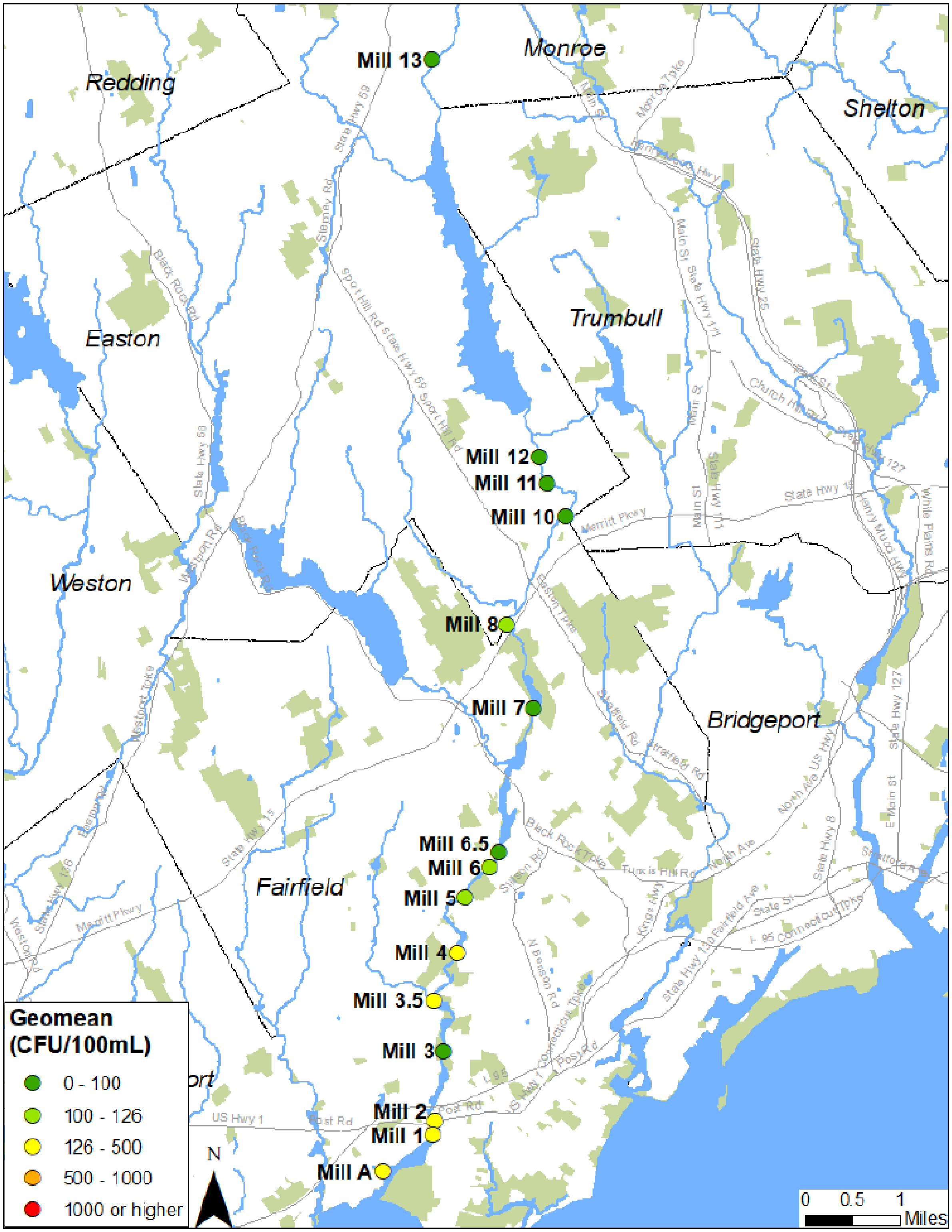


Figure 3.7: Harbor Watch Sampling Map

ESCHERICHIA COLI

In 2016, fourteen sampling stations were monitored starting at Mill 1 at Tide Mill Dam to Mill 13 on Mill River upstream of Easton Reservoir. Seven of the ten sampling days are classified as wet events, although the criterion for wet is very conservative; an event reflects wet conditions if more than 0.1 inches of rainfall was recorded two days prior to sampling. Five of the sampling stations exceeded both geomean and single sample maximum criteria. Four of the stations were clustered in the lower reaches from Duck Farm Road south to the mouth, including sampling stations Mill 1, 2, 3.5, and 4, with only Mill 3 excluded. The concentration of failing sites in this area is not surprising given that this area of the watershed coincides with the highest intensity development and greatest imperviousness, especially in areas directly adjacent to the river. The reason that the Mill 3 does not exceed the geomean is not clear, although the dilutionary effect of Browns Brook discharging upstream (which may not have been well captured at Mill 3.5 which was sampled in that vicinity) as well as the two intervening impoundments, including Perrys Mill Pond, may act as settling basins. The remaining station that exceeded both the geomean and maximum criteria was Mill 8, located on Congress Street just north of the Merritt Parkway, which had a geomean of 172 cfu/100 mL, and a maximum of 5800 cfu/100 mL. This station too has a relatively large direct catchment with a high density of residential development. Interestingly, this area is relatively close to the TMDL M3 sampling station, which also reported high geomeans during that investigation at 299 cfu/100 mL. The Harbor Watch report expresses concerns at the high concentrations occurring at the Mill 1 and 2 stations because of their tidal nature which is reported to typically have a dilutionary effect that was not observed. Whether this is an artifact of poor tidal exchange and tidal restriction, or even loading attributable to Southport Harbor is not known, but the addition of a sampling station within the harbor in the 2017 program may aid in the analysis.

The single sample maximum criterion alone was exceeded at four additional stations including Mill 3 (discussed above), 7, 10, and 11. Together with Mill 8 all the stations between Mill 7 and Mill 11, which represents the middle reaches of Mill River, exceeded the single sample maximum criteria. This is representative of both the higher position in the watershed and the larger general trend of decreasing *E. coli* concentrations moving upstream, as well as the fact that residential development in the area, including attendant storm sewer networks, are sufficiently dense to continue to exceed applicable standards.

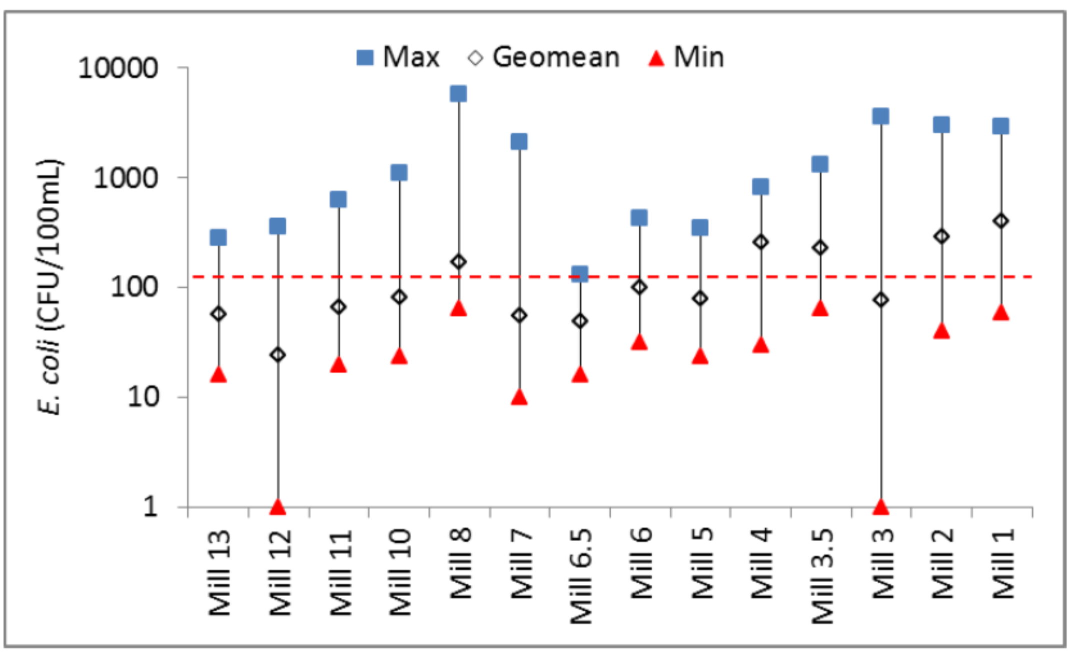


Figure 3.8: 2016 *E. coli* Results: source Harbor Watch

The five remaining stations exceeded neither the geomean or maximum water quality criteria. These include Mill 5, 6, and 6.5, 12, and 13. The Mill 5 through 6.5 stations are located in the reach between Samp Mortar Reservoir upstream and Mill Plain Road, which only extends approximately 3200 stream feet. Development density is slightly reduced relative to areas upstream and downstream, but more significantly this reach is immediately downstream of Samp Mortar Reservoir, which again is likely acting as a regional settling basin. Again, this mimics the findings of the TMDL for station M2S; while this station is about 1.3 miles upstream of the reach of interest, it is immediately downstream of Lake Mohegan, the impoundment immediately upstream of Samp Mortar. Geomean at M2S was only 105 cfu/100 mL, and it was theorized that the reservoir is acting to reduce bacterial concentrations. Mill 12 and 13 are located, respectively, downstream and upstream of Easton Reservoir. The Harbor Watch figure depicting sampling results is provided above.

In 2017, the program continued and expanded with the addition of the Mill A sampling station located within Southport Harbor. Overall, many of the same patterns were observed. Concentrations tended to be somewhat lower a result of both the addition of another dry event, and the fact that average precipitation preceding events was lower and thus mobilized few bacterial pollutants.

Once again, Mill 1 and 2, and the newly sampled A, all exceeded both the geomean and single sample maximum criteria. The continued high concentrations in these tidal reaches again caused Harbor Watch to express concern, especially since higher salinity water increases *E. coli* mortality. While tidal expression is reduced in Mill 1 and 2 due to the Tide Mill Dam, Mill A in Southport Harbor is fully tidal and its geomean concentration was 277 cfu/100 mL, well above the 126 cfu/100 mL standard, and within 72 to 93% of the upstream concentrations on Mill River. This may lend some credence to the idea that some loading of *E. coli* in the tidal portions of Mill River is attributable to the harbor, but in the absence of a detailed hydraulic study it is difficult to ascertain. In fact, it raises the question of what are the sources to the harbor. Certainly, Mill River is implicated, and the most likely scenario may be a sloshing back and forth of *E. coli* enriched waters.

In addition to the stations above, Mill 3.5 and 4 also exceeded the geomean, consistent with the 2016 data. However, Mill 5, 6, and 8 all exceeded 120 cfu/100 mL and thus were just below the standard. In addition to Mill A, 1, and 2, Mill 3.5, 5, 6, 6.5, 8 and 10 all exceeded the single sample maximum. Once again, just five stations met the water quality standards for *E. coli* (Mill 3, 7, 11, 12, and 13), with most of them in the mid- to upper watershed. The 2017 *E. coli* figure, reproduced from Harbor Watch, is provided below.

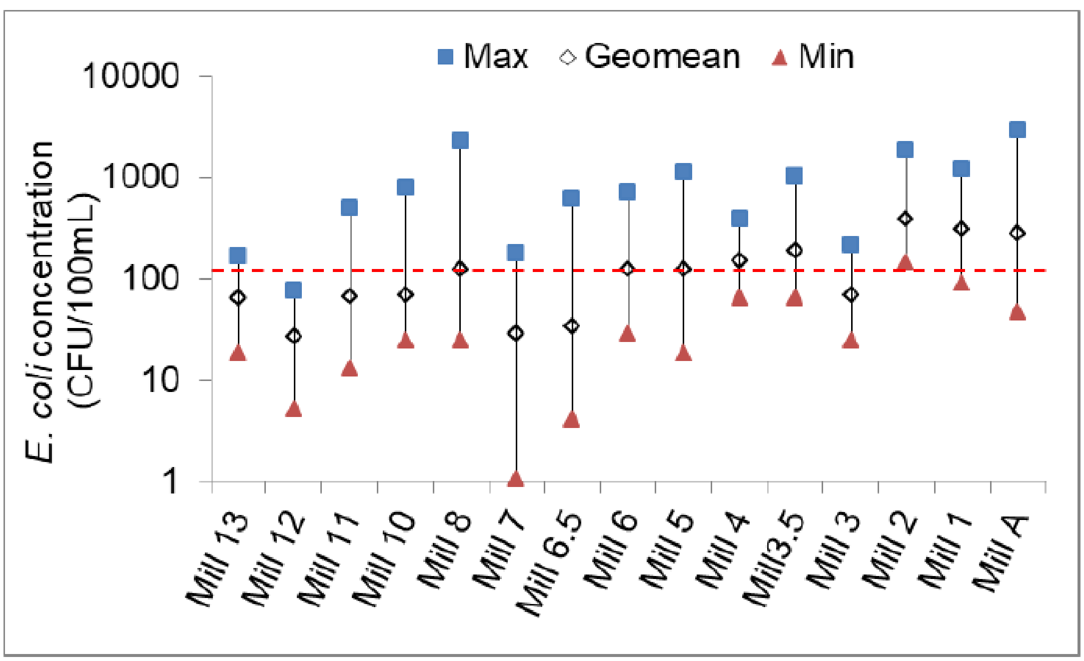


Figure 3.9: 2017 *E. coli* Results: source Harbor Watch

In the 2018 report Harbor Watch altered the reporting format slightly to include summaries of both current and historic data, presented below in Table 3.7. Sampling protocols were consistent, and the Cricker 1 site on Cricker Brook was added.

Table 3.7: Harbor Watch 2016-2018 *E. coli* Results

Site	Geomean			Single Sample Maxima
	2016	2017	2018	2018
Mill A	NS	*277*	*669*	50%
Mill 1	*406*	*298*	*502*	40%
Mill 2	*293*	*382*	*469*	40%
Mill 3	78	68	*138*	30%
Mill 3.5	*228*	*183*	*397*	40%
Mill 4	*258*	*147*	*352*	30%
Mill 5	80	122	*166*	20%
Mill 6	101	120	106	20%
Mill 6.5	49	33	107	10%
Cricker 1	NS	NS	*294*	40%
Mill 7	56	28	*196*	40%
Mill 8	*172*	121	*245*	40%
Mill 10	83	66	86	20%
Mill 11	67	66	73	10%
Mill 12	24	27	38	0%
Mill 13	57	63	*128*	10%

While 2016 and 2017 data were overall relatively similar, each marked by contravention of the geomean water quality standard at five stations throughout the course of sampling, conditions had deteriorated notably in 2018. In 2018, 11 of the 16 sampling stations exceeded a geometric mean of 126 cfu/100 mL, denoted in red and italicized in the table. What was particularly interesting was that of the 11 stations that exceeded the geomean standard, 2018 marked the first time that five of those stations exceeded the standard. These were primarily clustered in the lower and middle portions of the watershed, but even Mill 13, located upstream of Easton Reservoir in the headwaters of Mill River exceeded the standard. Only two small segments were able to meet the standard, those areas immediately downstream of Samp Mortar Reservoir and Easton Reservoir respectively.

Taken as a whole, *E. coli* geomean concentration increased by 88% in 2018 relative to 2016 and 2017. Base loading of bacteria is unlikely to have increased during this period, especially at the observed magnitude and given ongoing efforts to manage bacterial loading. The cause therefore is likely to be an increase in delivery of that load rather than its generation, and that points to precipitation. A review of climate data very strongly makes the case. Using data collected at Sikorsky Airport, located about 6 miles east of the watershed selected because it was the nearest site with long-term climate data, both 2016 and 2017 were drier than 30-year (1980-2010) climate normals during the May through September sampling period (Table 3.8). 2018 was much wetter than normal and was 45-50% higher than the corresponding period in 2016 and 2017. Higher rainfall totals work to promote bacterial loading in two important ways: increased runoff and mobilization from land surfaces and elevated groundwater tables that increase mobilization related to septic systems. This may have important implications if changes in climate result in increasingly wet summers.

Table 3.8: Precipitation Summary 2016-2018

Igor Sikorsky Memorial Airport Precipitation (inches)				
	2016	**2017**	**2018**	**30-Year Norms**
May	3.50	5.49	3.41	3.80
June	1.26	2.40	4.06	3.61
July	4.80	2.54	4.08	3.46
August	3.16	3.81	2.95	3.96
September	2.73	1.73	8.59	3.48
Total	15.45	15.97	23.09	18.31

DISSOLVED OXYGEN

Dissolved oxygen (DO) was also monitored during the 2016 and 2017 sampling programs. The DO water quality criteria for Class AA and A waters, which includes all of the non-tidal portions of Mill River, its tributary network, and watershed is that DO concentration shall not be less than 5.0 mg/L (ppm) at any time. Portions of Mill River downstream of Sturges Road at the head of tide and Southport Harbor are Class SA waters, which includes stations Mill A, 1, 2, and 3. There are two criteria for DO in these waters: acute criterion states that DO shall not be less than 3.0 mg/L at any time, while the chronic standard states that DO concentration shall not be less than 4.8 mg/L.

DO is an interesting water quality parameter because it is impacted by both abiotic and biotic processes. Temperature is an important factor regulating DO concentrations; as temperature decreases the solubility of oxygen increases thus leading to higher DO concentrations. The converse is true also and DO concentrations decrease with increasing temperature. As a result, DO is often expressed as percent saturation which normalizes DO concentrations for temperature. Biological processes, namely respiration and primary production via photosynthesis also impact DO concentrations. Respiration refers to biological processes, often the breakdown of carbohydrates, that result in the consumption of oxygen. In aquatic ecosystems this is linked most strongly to microbial organisms, but other organisms, including animals, also respire and deplete oxygen. Photosynthesis, the process of carbon fixation by autotrophs or primary producers including algae, cyanobacteria (blue-green algae), and plants produces oxygen as a byproduct thus increasing DO concentrations when these organisms are actively photosynthesizing. This is dependent on the availability of light among other factors, and in systems where there is a high abundance of autotrophs DO concentrations can vary significantly throughout the course of the day. During daylight hours when autotrophs are photosynthesizing DO concentrations often increase often exceeding 100% saturation, a condition known as supersaturation. At night, this same biomass respires to maintain physiological processes resulting in the depletion of free DO. A last factor to consider is flow and turbulence. Generally, the source of DO in aquatic ecosystems is the diffusion of atmospheric oxygen gas in water; this process tends to be more vigorous in turbulent flows or during wind-driven mixing. In general, headwaters, which are shaded, cooler as a result of groundwater contributions, and tend to have turbulent flows through coarse substrates and steep channels, tend to have the highest and most stable DO concentrations. Where wetlands and flatter channel slopes predominate at headwaters these concentrations may be lower. Moving downstream into larger rivers water temperatures generally increase, turbulence may decrease, and the biomass of planktonic algae, periphyton, or plants may increase which leads to lower concentrations and more variability. Lakes and ponds tend to be the most variable, especially eutrophic waterbodies impaired by nutrient pollution in which DO concentrations can vary widely throughout the course of a day and seasonally. Waters with high organic loading, either in flowing or ponded systems, may have chronically low DO.

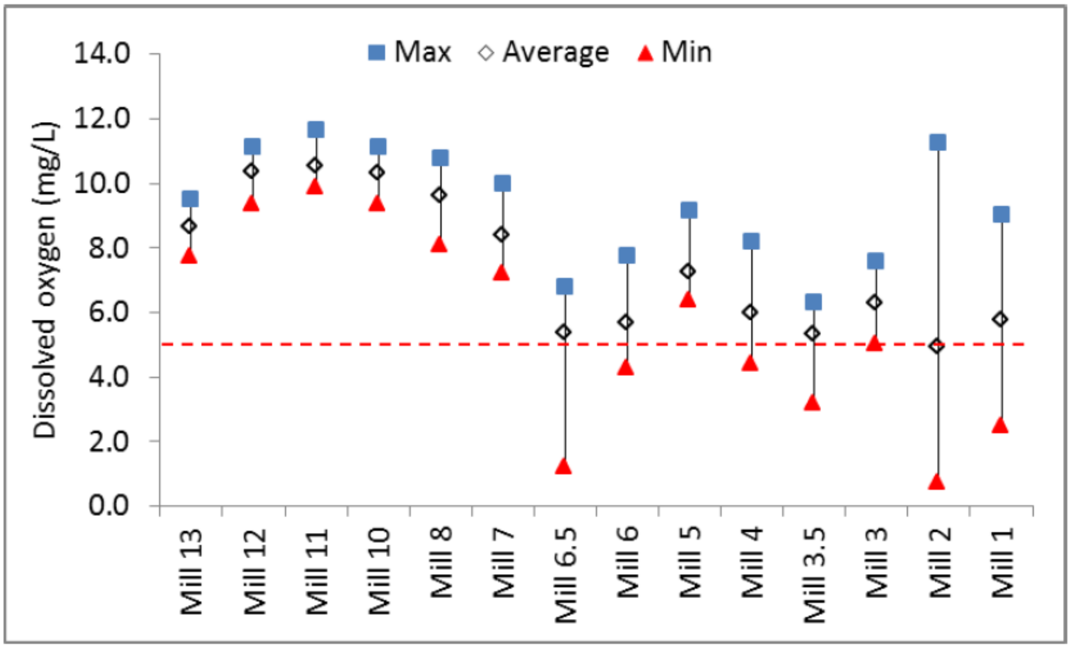


Figure 3.10: 2016 Dissolved Oxygen Results: source Harbor Watch

In general, the upper portions of Mill River (Mill 7 and above) met the applicable water quality standard for DO, while the lower portions, with the exceptions of Mill 3 and 5, did not. Note, while the Harbor Watch data is the basis of this analysis, the report mischaracterizes the criterion for non-tidal waters as an average, rather than an instantaneous value, and does not address the Class SA water criteria. Mill 3.5, 4, 6, and 6.5, while averaging above 5 mg/L, all fell below the standard at least twice and all did so in August. It seems likely that there are several factors that contributed to the observed patterns. First, water temperatures always exhibited a drastic increase between Mill 8 and Mill 7. These stations are interrupted by Lake Mohegan, that as a relatively shallow, small impoundment, leads to significant, measurable stream warming in Mill River. While DO also decreases between the stations, it still meets the applicable DO standard. The points downstream of Mill 7, again excepting Mill 5, all have significant DO depletion and contravention of the standards. Mill 6 and 6.5 are immediately downstream of Samp Mortar Reservoir, which likely experiences significant DO depletion events. In addition, a review of the temperature data shows unusually low temperatures at these stations at times, indicating periodic hypolimnetic or deep water releases, likely at times of low flows when water is not discharging over the dam. Hypolimnetic waters, in moderately to highly productive waterbodies, are often anoxic during the summer months, which would explain the low DO at these stations. Moving downstream, Mill 5 shows a nice recovery of DO and no contravention of the 5.0 mg/L standard. Mill 4, and the subsequent downstream stations all show oxygen depletion (although Mill 3 barely met the standard with a minimum value of 5.03 mg/L), and all are intimately linked with online impoundments of Mill River. Mill 1 and 2, subject to the Class SA standards, both met the chronic criterion, but fell below the acute criterion of 3.0 mg/L. The Harbor Watch 2016 DO figure is provided above.

The general patterns held for the 2017 DO data. In general, DO concentrations fell and the intrastation variability increased moving downstream. Mill 3.5, 4, and 6 all fell below the 5.0 mg/L DO criterion for Class AA and A waters. Mill A, 1, 2, and 3, all Class SA waters, all fell below the acute criterion of 3.0 mg/L. The 2017 figure is provided below.

2018 data seems to indicate some degree of improvement in DO values. In the non-tidal portions of the river, upstream of Mill 3, the minimum measured value was 4.1 mg/L at Mill 6, which previously exhibited the poorest DO quality in the non-tidal Mill River. This contravened the instantaneous standard of 5.0 mg/L, but during the course of sampling the average was an acceptable 6.8 mg/L. The stations in the tidal portion of Mill River met the Class SA standards. Mill A, which is located in Southport Harbor and thus outside of Mill River proper, had a minimum concentration of 2.9 mg/L, just below the 3.0 mg/L standard. Increased concentrations and decreased contravention of the standards is likely a function of increased flow in 2018. Increased flow, and more importantly increased velocity, can aid in gaseous oxygen dissolution as a function of increased turbulence. It could also signal decreased respiration of phytoplankton and microbes due to increased flushing. Overall, while increased precipitation negatively impacted indicator bacteria concentrations, it positively benefited the DO regime.

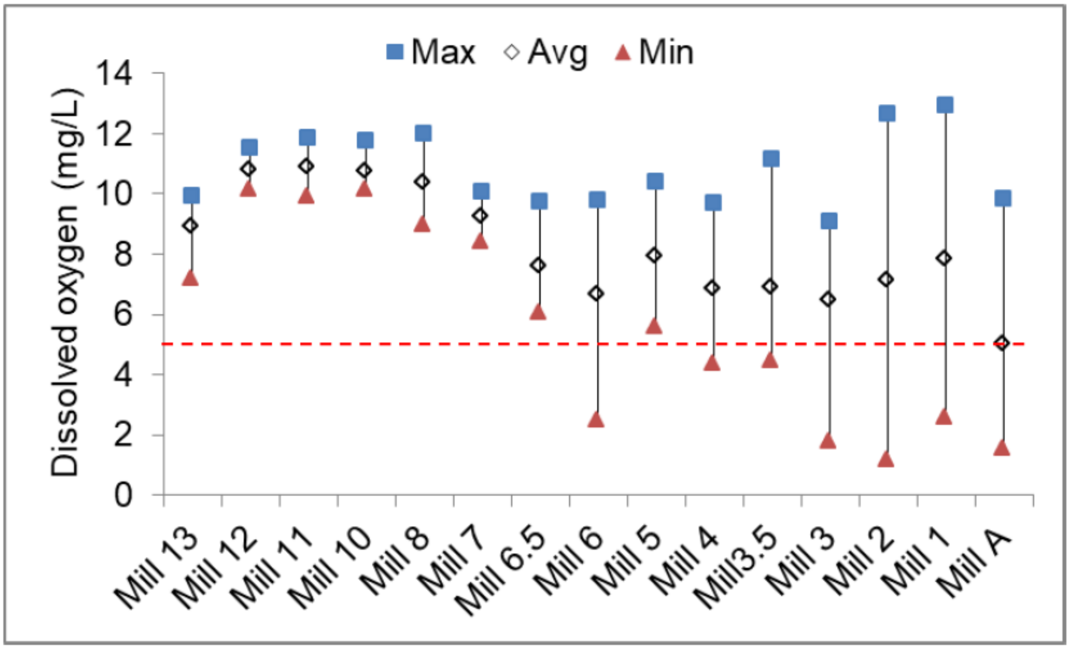


Figure 3.11: 2017 Dissolved Oxygen Results: source Harbor Watch

CONDUCTANCE

Conductance or specific conductivity (conductance normalized for temperature) is a measure of electrical conductivity associated with dissolved solids and solutes in water. There is no specific correlated water quality standard associated with this parameter, yet it can be used to ascertain watershed processes, such as septic leachate and untreated stormwater runoff, that lead to the loading of dissolved solids, and in this watershed, which has a tidal portion, can be used to evaluate tidal flushing and incursion.

In developed watersheds, conductance tends to increase moving downstream, a pattern observed here. Besides the tidal stations, which includes Mill 3 in this analysis as the head of tide, conductance was relatively low and fairly stable throughout the non-tidal portions of the river. Of interest, however is Mill 8 and Mill 6. Mill 8 shows a fairly large jump in mean conductance relative to Mill 10 the station upstream, as well as greater variability, although conductance remains within expected levels. Once again, Mill 8 is an analog to the TMDL M3 station; M3 was linked to potential illicit discharges to the storm sewers and a signature of sanitary discharges is increased conductance. Mill 6 shows higher variability than the other non-tidal stations, which could be related to the supposed hypolimnetic releases from Samp Mortar Reservoir, but that signal is not reflected at Mill 6.5 which is nearer to Samp Mortar.

Of the tidal stations, there was no strong evidence of a tidal signal at the head of tide Mill 3 station, which exhibited values typical of freshwaters. At Mill 1 and 2 the average conductance for both stations was approximately 25,000 µS/cm, values consistent with estuaries, with each peaking at over 35,000 and 40,000 µS/cm; pure seawater is considered to have a conductance of approximately 50,000 µS/cm. Harbor Watch commented that Mill 2 at times had higher conductance values than Mill 1, which likely indicates poor flushing in that reach.

The 2017 conductance was largely similar to 2016, and conductance increased moving downstream through the watershed. Mill 13, the only station upstream of Easton Reservoir, which may be considered a headwater, had somewhat higher conductance than the succeeding three stations below the reservoir. This is likely due to the greater groundwater signal at Mill 13, which has higher values than surface waters, relative to the dilutionary impacts of the reservoir, especially the direct capture of rainwater. Once again, Mill 8 showed a fairly significant jump in average conductance, which could be a signal of illicit sanitary water discharge to the stormwater management system, although conductance was still acceptable.

The tidal stations, Mill A, 1, 2, and 3 all indicated the presence saline waters or saline mixing. While the Mill 3 conductance at the head of tide averaged below 3,000 µS/cm it did spike during one event to 23,371 µS/cm, although the report indicates the reason is unknown even though a high tide event seems the most likely explanation. Mill A, 1, and 2 were typical of estuary systems.

In 2018 there was a modest decrease in conductance measures in the non-tidal portions of watershed, with individual stations exhibiting average conductance of 185 µS/cm to 240 µS/cm. The head of tide station at Mill 3, which has previously shown infrequent major intrusions of saline water, had a maximum recorded conductance of just 256 µS/cm. The other tidal stations including Mill A within Southport Harbor however showed major reductions in conductance. In the past, the average seasonal conductance was in the range of 20,0000 µS/cm and greater; in 2018 Mill 1 and Mill 2 in the Mill River were less than 5,000 µS/cm and Mill A in the harbor was approximately 10,450 µS/cm less than a third of calculated value in 2017. Increased volumetric discharge as a result of higher than normal precipitation during the monitoring period resulted in changes in conductance in both the non-tidal and tidal portions of Mill River. In the non-tidal portions increased hydrologic loading has a dilutionary affect relative to dissolved solids leading to lower conductance. In the tidal portions, there are likely several concurrent mechanisms driving the observed decreases including simple dilution, displacement or a downstream migration of the salt-wedge in the estuary, and the development of a freshwater lens sitting atop the denser saline waters.

FECAL COLIFORM

Fecal coliform is a broader measure of other fecal bacteria besides *E. coli*, including different genera. The only applicable water quality standard for that parameter is related to Shell Fishing, Direct Consumption, a designated use of Class SA waters. The criteria are a geometric mean less than 14 cfu/100 mL, and 90% of samples less than 31 cfu/100 mL. Southport Harbor and the tidal portions of Mill River do not support the consumption of shellfish; indeed the 2016 and 2017 geometric means of Mill 1, 2, and 3 are respectively, 449 cfu/100 mL, 414 cfu/100 mL, and 102 cfu/100 mL, near or over an order of magnitude above the standard. Additionally, previously crabbing had been closed in the tidal portions of Mill River due to lead contamination, although the site has been remediated.

Princeton Hydro was furnished the Harbor Watch data to perform additional analyses. This included a comparison of fecal coliform and *E. coli* loading. In the Mill River watershed, *E. coli* accounted for the vast bulk of the fecal coliform load. This data is being utilized to refine bacterial loading analyses in the watershed. A box and whisker plot is provided showing fecal coliform and *E. coli* concentrations at each station.

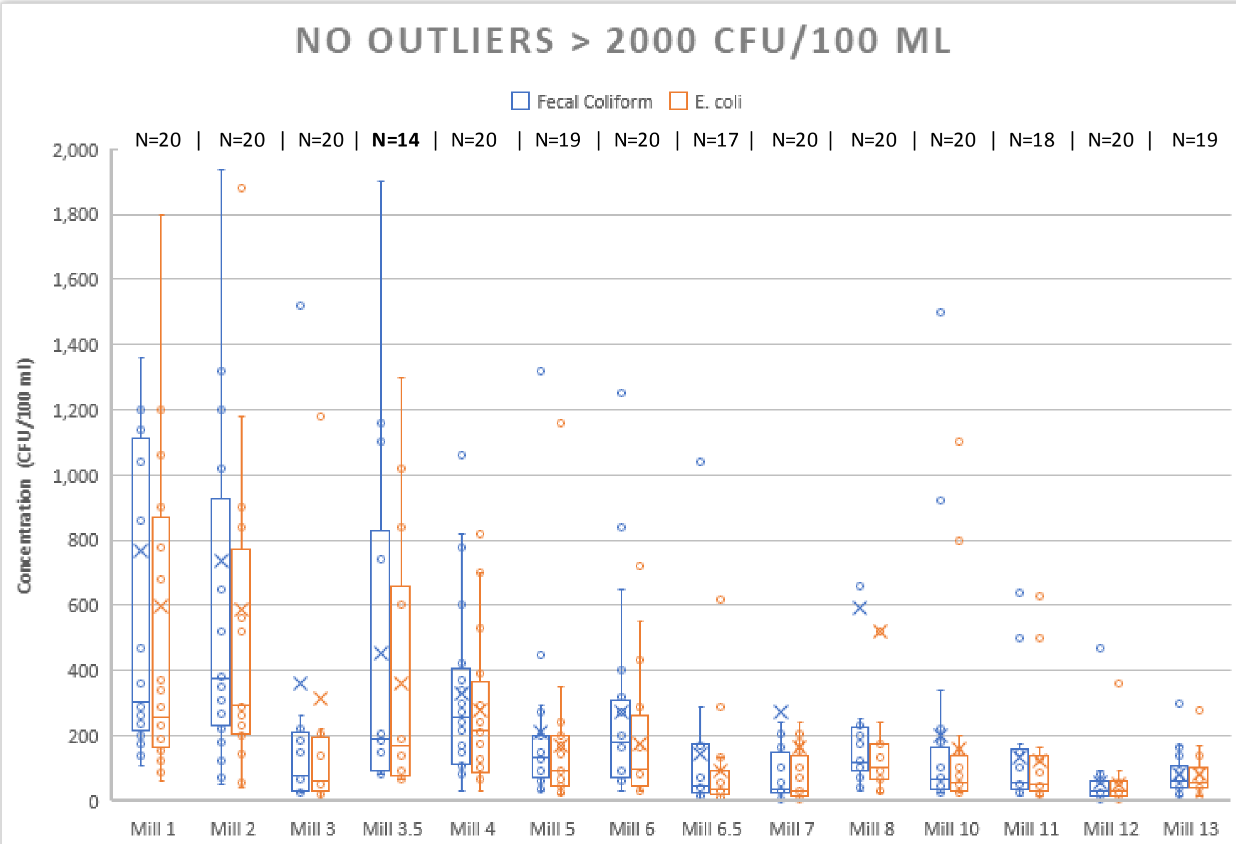


Figure 3.12: Fecal Coliform and *E. coli* Concentrations, 2016 and 2017

POLLUTION TRACK-DOWN SAMPLING

In addition to the broader monitoring of Mill River, Harbor Watch has included a source tracking program to identify sources of *E. coli* loading linked to the various storm sewer systems in the watershed. This type of sampling focused on a linked sewer network and included sampling at the terminal outfall as well as at various basins and pipes upstream within the network. In 2018, the sampling focused on three primary storm sewer systems:

- OUT-003 at River Street near Mill 1, consisting of 8 discrete sampling points
- OUT-018 at Cider Mill Lane with 18 sampling points
- OUT-021 at Twin Brooks Lane with 4 points
- OUT-001 and OUT-002, three grabs were collected in total from these two systems

Samples were collected on eight dates, but not all stations were sampled during each event, nor were the same number of samples collected for each station. While this promoted a variability in sample collection, it also mirrored the variability of flow conditions, and ultimately the results.

The results of the pollution track-down sampling are rather interesting. First, bacterial loads in the storm sewers are undoubtedly high and all of the monitored systems showed a discrete sample in excess of 1600. Maximum values at OUT-003, OUT-018, and OUT-021 were 10,000, 100,000, and 81,000 cfu/100 mL respectively. Undoubtedly, storm sewers are collecting high bacterial loads and discharging these loads within the tributary network of Mill River. Second, the results were extremely variable between station, sewer systems, and longitudinally, exhibiting the complexities in understanding indicator bacteria as a living pollutant affected by base loading rate, mobilization, weather, and flows among other factors. For instance, on September 5, 2018 station OUT-018C exhibited an *E. coli* concentration of 96,000 cfu/100 mL. Two weeks later, on September 19, 2018 the concentration had fallen over 99.5% to 430 cfu/100 mL, although in its own right still a high value. By contrast, OUT-018N peaked at just 60 cfu/100 mL, just 10% of the single sample maximum standard for *E. coli*. Harbor Watch also indicated difficulty in using the data to ascertain sources, despite some very high observed loading. This is because flow is very variable in these systems, some of which seems to be a function of the expected difference between dry and wet events, but also because some flows do not correspond to network mapping, or because some trunk lines never exhibit flow, while others continuously flow. Pinpointing exact sources can be difficult because the lines are not uniformly well-mapped, but certainly some discrete samples locations and more broadly sample groups, can help to identify enhanced loading. What is certainly clear however is that the storm sewer network contributes greatly to loading in Mill River and often exhibit concentrations an order of magnitude higher than those in the tributary network.

3.2.4 ADDITIONAL TMDLS

In addition to the 2005 TMDL for Mill River, Rooster River, and Sasco Brook issued for bacteria and discussed in detail above, Mill River and its receiving waterbodies, namely Southport Harbor and Long Island Sound, are subject to additional TMDLs. A brief summary of these documents is provided below, as well as any relevant water quality data and documented impairments.

LONG ISLAND SOUND TMDL FOR DISSOLVED OXYGEN

In 2000, CT DEEP in conjunction with the New York State Department of Environmental Conservation (NYSDEC) published *A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound*. This TMDL, while focused on Long Island Sound, is applicable throughout the Sound's watershed, including the Mill River watershed. This was the culmination of the Long Island Sound Study initiated in 1985, which documented the occurrence of hypoxia, or zones of depleted dissolved oxygen concentrations, which led to a variety of use impairments including:

- A decrease in bathing area quality
- Increase in unhealthy areas for aquatic marine life
- An increase in mortality of sensitive organism (including larval fish)
- Poor water clarity
- Reductions in commercial and sport fishery values
- Reduction in wildlife habitat value
- Degradation of seagrass beds
- Impacts to tourism and real estate
- Poor aesthetics

The cause of these impairments is eutrophication, the increase in the biomass of algae as a result of nutrient pollution which in turn has created higher concentrations of organic carbon. The respiration of organic carbon, as described above in the dissolved oxygen discussion, is what creates the depletion of oxygen. The pollutant of concern driving the increase in primary productivity reflected in algal productivity and organic carbon is nitrogen, which is shown to be the limiting nutrient, or the nutrient in shortest supply relative to biological demand. Limiting nutrients are the ideal targets for reduction to affect reductions in trophic state or limit or reverse eutrophication. Interestingly, phosphorus is not declared a pollutant of concern in this study, because it is not limiting algae growth in Long Island Sound. Four primary sources of nitrogen were identified in the TMDL. These include: municipal and industrial wastewater treatment facilities, combined sewer overflows (CSOs), nonpoint sources including runoff from various land uses activities including stormwater from urban areas, and atmospheric deposition.

NORTHEAST REGIONAL MERCURY TOTAL MAXIMUM DAILY LOAD

This TMDL was Developed by CT DEEP and representatives of similar agencies in Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, and the New England Interstate Water Pollution Control Commission (NEIWPCC). In general, throughout the northeastern United States, over 10,000 waterbodies and 46,000 river miles were listed as impaired for fish consumption due to mercury contamination. Most of the member states utilized the EPA recommended fish criterion for methylmercury of 0.3 ppm; Connecticut is the most stringent with a set standard of 0.1 ppm.

There are two general sources of mercury in the region, wastewater discharges and atmospheric deposition. Wastewater was calculated in 2007 during the development of the document to account for roughly 141 kg/yr of mercury. Atmospheric deposition, related to the release of mercury-bearing materials, including smelting of ores and the combustion of petroleum products among other sources, is approximately 6,500 kg/yr with approximately 4,900 kg attributable to anthropogenic sources. Over 97% of the total load is of atmospheric origin. It is important to recognize that not all of the load originates within the New England region, and out-of-region sources are significant, including international sources. Much of the reduction is expected to be achieved through the regulation of power plant emissions, including limits set through Section 112(d) of the Clean Air Act.

All Connecticut freshwaters are subject to this TMDL, although Mill River is not specifically identified as having significant mercury concentrations due to localized sources, although two ponds within Bridgeport, but outside the Mill River watershed, do. Connecticut has adopted the following summary of State fish consumption advisories for freshwaters:

- Sensitive Populations – No more than 1 meal/month of fish other than trout caught in any Connecticut fresh waterbody; no limits on the consumption of trout.
- General Population – 1 meal/week for all freshwater fish other than trout caught in any Connecticut fresh waterbody; no limits on consumption of trout.

TMDL FOR SOUTHPORT HARBOR SHELLFISHING AREAS

Southport Harbor, including the estuarine portions of Mill River, were included on the 303(d) list in 2006 for exceedance of indicator bacteria criteria, specifically fecal coliform, water quality standards. This followed closure at Southport Beach in 2002, and a follow-up investigation spearhead by CT DEEP and the Connecticut Department of Agriculture/Bureau of Agriculture (DA/DB), with the EPA and Fairfield. This led to a downgrading of several shellfishing areas within the harbor. The inner portion of Southport Harbor, including the lower tidal reach of Mill River upstream to the head of tide at Sturges Road has been classified a Restricted-Relay Shellfishing Area, in which aquaculture activities in the area are limited to the relay of shellfish to designated beds or approved areas for natural cleansing. Other areas in the harbor are conditionally restricted-relay, and seasonally approved, each with more relaxed standards. A hydrodynamic analysis, including dye studies, suggests that: "Water from the inner harbor and Mill River are a more likely source of contamination to Southport Beach due to advection of the dye along the western shore of the Harbor than Sasco Brook." Offshore sampling in Long Island Sound does not contain elevated fecal coliform concentrations under normal conditions.

While the sampling conducted in support of the TMDL development in 2007 and prior did not show exceedance of the appropriate coliform standard at Station M1 near the head of tide, more recent sampling conducted by Harbor Watch shows the tidal Mill River well exceeds the standards. Per the TMDL, potential sources of fecal coliform bacteria include illicit discharges, wildlife such as resident Canada geese, stormwater sheetflow, failing septic systems, and improper handling of domestic animal waste.

TMDL FOR ESTUARY 4: WESTPORT-FAIRFIELD

This TMDL largely covers the same topics as the Southport Harbor TMDL described above; indeed, this is one of nine segments identified in the Westport and Fairfield. Again, direct shellfish harvesting as a designated use is impaired by elevated fecal coliform concentrations in exceedance of the water quality standards. Sampling conducted for this TMDL indicated geometric means and 90% less than values exceeded water quality standards for all years and all stations for the Southport Harbor/Mill River segment, including a station sited at Tide Mill Dam on Harbor Road (2000 through 2008 at this station). Again, illicit discharges, failing septic systems, stormwater runoff, and nuisance wildlife and pets are implicated as potential sources of bacterial contamination, but permitted sources and marinas within the harbor proper are also identified and because of bi-directional flow in the tidal portions of Mill River may contribute to the loading in that area as well.

IWQR LIST OF WATERS FOR ACTION PLAN DEVELOPMENT BY 2022

In the 2018 Draft IWQR, made public in June 2019, both Mill River and its tributary Cricker Brook (Subregional Basins CT7108 and CT7107) were included in Appendix C2 List of Waters for Action Plan Development by 2022. Both are listed for impairments related to nutrients and not meeting designated uses as habitat for fish, other aquatic life and wildlife. This suggests that future management of the system will focus heavily on the control of nutrients and managing the systems as fishery and wildlife habitat.

3.3 HYDROLOGY

Hydrology describes the water budget of a watershed, an accounting of inputs, losses, and fluxes resulting in observed flow within the tributary network. Three hydrology datasets were reviewed or developed for this study. This includes United States Geological Survey (USGS) discharge data from Mill River, climate data from a regional network of weather stations, and modeled hydrology data utilizing various watershed characteristics and climate data that is subsequently calibrated using the USGS data.

3.3.1 USGS GAGE DATA

The USGS installed and operated a gaging station, designated USGS 01208925 Mill River near Fairfield, CT. The gage was operational from October 1972 through 2017, although various services were dropped over time and the last available monthly discharge data is from November 2016. The station was located just downstream of the bridge on Duck Farm Road on the main stem of Mill River; this station is approximately 1.35 stream miles upstream of the head of tide.

USGS site notes are worth examining. First, watershed area is given as 28.6 square miles, considerably larger than the delineated watershed used for Mill River. The difference is apparently related to the inclusion of Aspetuck Reservoir and its attendant watershed including the headwaters of the Aspetuck River. While it seems reasonable to assume there were or are interbasin transfers between Aspetuck Reservoir and Hemlock Reservoir, which are separated at a distance of just 100 feet at the Aspetuck Reservoir Dam, the Aspetuck River clearly flows to the southwest outside of the Mill River watershed; as such, any exchange between the basins would be artificial and achievable only through conscious operational means. No data is available regarding these transfers, however, whatever the pattern of diversions is, that would be reflected in the discharge measured at the Mill River gage.

Related to the transfer of water, is the general relevance of reservoirs in the watershed. The USGS noted in the description for the station: “Flow completely regulated by Easton, Hemlock, and Samp Mortar Reservoirs, usable capacity 609,900,000 ft^3, diversions into Hemlock Reservoir from Aspetuck Reservoir in the Aspetuck River basin and by diversions from Hemlock and Easton Reservoirs and the Bridgeport and Fairfield water companies.” It is clear, therefore, that the system is manipulated. Peak flows in the river would be impacted, however the basins are not utilized explicitly as flood-control structures.

In addition to the hydraulic connection between Aspetuck Reservoir and Hemlock Reservoir, Aquarion Water Company also maintains regulated diversions from the West Branch Pequonnock River to Easton River, although again no operational records regarding transfer volumes are publicly available.

A hydrograph depicting monthly mean discharge and a summary table of pertinent statistics are provided below; the preferred unit for discharge measurements is cubic feet per second or cfs. As is typical of regional rivers, flows peak in spring, typically March or April, due to elevated reservoir stage, high water tables, spring precipitation, snow/ice melt, and reduced evapotranspiration. July and August represent the nadir of annual flows consistent with high temperatures and evapotranspiration and likely increased water consumption. A review of monthly minimum and maximum discharges shows the extreme variability not just on a monthly basis, but during the period of record. Maximum monthly discharge in the Mill River was 276.3 cfs measured in April of 1983, while the monthly minimum was just 0.9 cfs in July 1987.

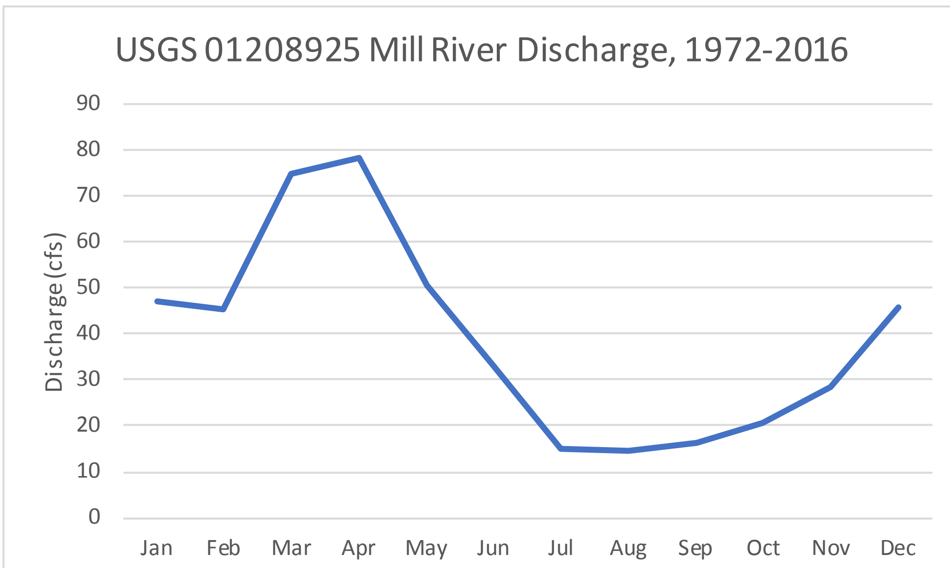


Figure 3.13: Mean Monthly Discharge at Mill River, 1972-2016

Table 3.9: Mean Monthly Discharge at Mill River, 1972-2016

Discharge	Monthly Discharge (cfs)											
Parameter	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean	42.2	43.4	73.7	78.6	49.1	34.7	14.6	15.1	16.3	21.0	28.1	42.8
Median	36.3	44.7	62.1	70.0	37.5	21.2	12.9	11.7	9.8	14.2	21.5	31.0
Minimum	3.1	6.6	15.1	12.1	10.2	2.7	0.9	1.7	2.2	3.0	8.0	7.0
Maximum	176.0	89.0	263.4	276.3	215.8	195.0	71.8	63.6	109.8	75.8	98.7	165.2

3.3.2 CLIMATE DATA

Watershed pollutant loading and hydrology was modeled using the MapShed model and its web-based counterpart Model My Watershed (used here interchangeably), both versions of the GWLF model and its various descendants. As mentioned above, the model employs climate data as one of its primary inputs. The data is a compilation of records from weather stations located throughout the region. More specifically, it uses daily temperature and precipitation records spanning a 30-year period (1961-1990) and runs the models for each of those days, nearly 11,000 in total, compiling and synthesizing the data through the model execution run. While the records are viewable, only precipitation is output in a summarized fashion. This is provided in the table below. In general, monthly average precipitation tends to be stable in the region from an annual low of 3.02 inches in February (reduced in part because of fewer days in the month) to a peak of 3.81 inches in November. The annual precipitation average during the period of record is 41.67 inches.

Table 3.10: Mean Monthly Precipitation, 1961-1990

Month	Precip (in)
January	3.24
February	3.02
March	3.74
April	3.76
May	3.93
June	3.46
July	3.78
August	3.25
September	3.07
October	3.11
November	3.81
December	3.50
Annual	41.67

3.3.3 MODELED HYDROLOGY

Model My Watershed includes hydrology modeling as a key aspect of the pollutant load development. While the hydrology is interesting in its own right, hydrology and water serves as vectors for pollutants. As such, the model describes stormwater and surface runoff, in-stream bank and bed erosion, and groundwater fluxes. Additionally, hydrology outputs can be compared to empirical data, in this case the USGS Mill River discharge data, to calibrate both the hydrology and pollutant load modules of the model. Hydrology was calculated for the entire watershed and each of the nine delineated subwatersheds. Model Calibration

Model calibration for the Mill River study relied on iteratively adjusting model input parameters until a best fit was obtained between modeled and observed data. In particular, these adjustments focused on reservoir retention, attenuation, and evapotranspiration. Model calibration focused mainly on hydrology as this variable is a primary determinant in accurately assessing pollutant loading. Furthermore, a substantial amount of data was available for the modeling period (1972-1990) through the USGS gaging station 01208925 - Mill River, which facilitated calibration. This modeling period was chosen because it encompasses the overlapping time periods between Model My Watershed (1960-1990) and the USGS gage (1972-2016).

In order to calibrate model hydrology, mean monthly discharge values, normalized for watershed area, obtained from the USGS gaging site were compared to those modeled utilizing GWLF. In order to statistically evaluate correlation, the Nash-Sutcliffe coefficient was used. The Nash-Sutcliffe coefficient is calculated according to the equation:

$$NS = \frac{\sum (y - x)^2}{\sum (x - \bar{x})^2}$$

where $\bar{x}$ is the mean of the observed (x) data, and y is the model-simulated value. 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 (ASCE, 1993) for use in hydrological studies. In regards to this coefficient, values may range from - ∞ to 1. A Nash-Sutcliffe coefficient of 1 is indicative of a perfect fit between observed and modeled data while values equal to and less than zero indicate that the model is predicting no better than using the mean of the historical observed data. For monthly comparisons of hydrology, a Nash-Sutcliffe coefficient of 0.84 was obtained. Some of the variance is likely due to the unknown withdrawal/diversion regime. A figure showing predicted versus observed discharge is provided below.

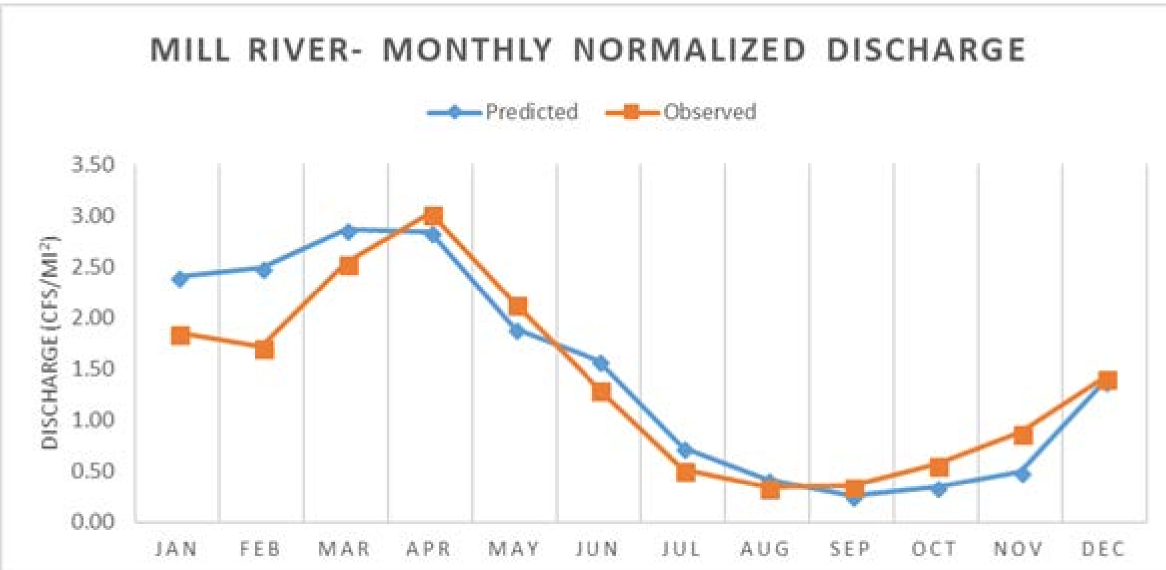


Figure 3.14: Predicted vs. Observed Specific Discharge at Mill River

HYDROLOGY RESULTS

The model summarizes five components of hydrology. All units for successive analysis and discussion are provided as a one-dimensional unit, centimeters (cm). There are several benefits to this approach. First, the results are more intuitive and easier to grasp by comparing the originating unit of hydrology, precipitation, in its native format as a one-dimensional length to derived elements. For instance, it is easy to understand that if 10 cm of monthly precipitation is expressed as 5 cm of streamflow, then 50% of the rainfall contributes to stream discharge. Second, expressing all units in cm normalizes the hydrology for area which allows easier comparisons across the subwatershed units. While the total volume of rainfall will vary across subwatersheds as a function of area, with an assumed uniformity of rainfall, precipitation expressed in cm will be equal between the subwatersheds. Furthermore, it avoids the problems of expressing rainfall as a depth and flows as a volume per unit time. Last, the numbers are small and easier to review in context as opposed to volumes or other measures.

The five components output by the model include precipitation (in actuality a model input that is summarized), evapotranspiration, groundwater flows, runoff, and stream flow. Evapotranspiration (ET) is a dual measure of the abiotic process evaporation and the biotic process transpiration driven by plants where water is taken up through the roots and discharged through the leaves to the atmosphere. Both processes are temperature dependent and affected by land cover. Groundwater flows incorporate water that infiltrates the soil; while some may reach deeper aquifers much of it is eventually expressed as streamflow. Groundwater is also what sustains stream baseflow. Runoff refers to sheetflow at the land surface that contributes to streamflow; this is heavily dependent on LU/LC, soils, and imperviousness. Finally, streamflow represents what can be considered the endpoint of described hydrology, passage of water out of a watershed through channelized flow. It should be noted that due to the delineation methods, streamflow associated with each subwatersheds represents the contribution of that subwatershed to the streamflow, rather than the cumulative contributions that would be observed in the field. The hydrology for the entire watershed is summarized in the figure and table provided below.

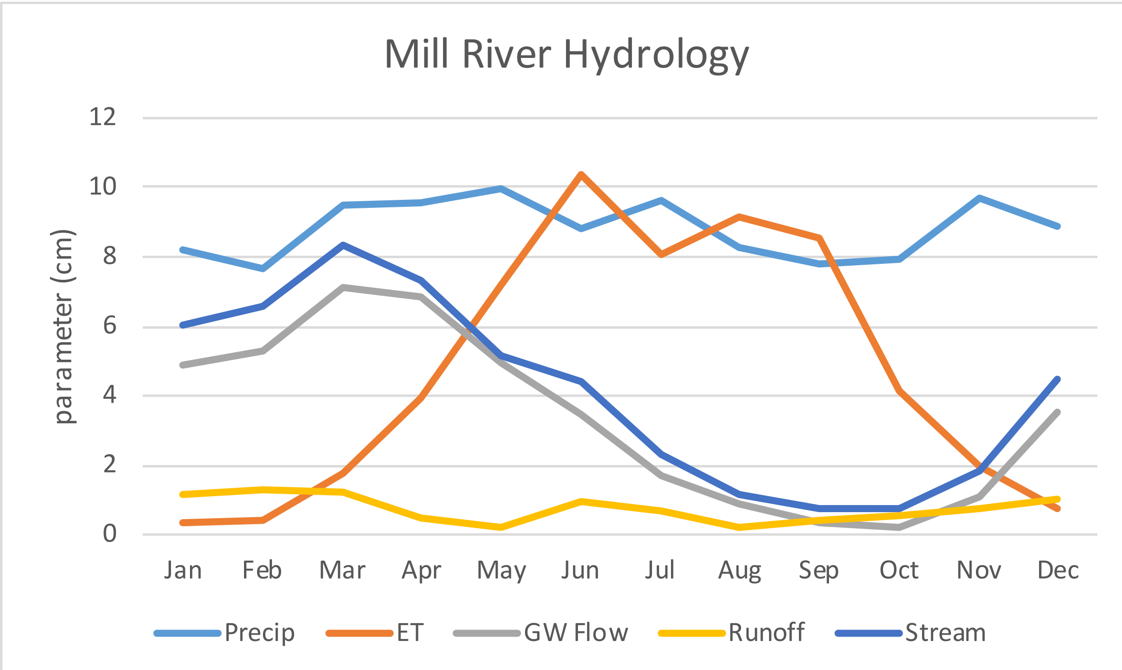


Figure 3.15: Mill River Hydrology, Modeled

Table 3.11: Mill River Hydrology, Modeled (cm)

Month	Precip	ET	GW	Runoff	Streamflow
Jan	8.23	0.36	4.85	1.15	6.01
Feb	7.66	0.44	5.26	1.31	6.57
Mar	9.51	1.79	7.09	1.25	8.34
Apr	9.55	3.94	6.83	0.47	7.30
May	9.97	7.22	4.92	0.23	5.15
Jun	8.80	10.39	3.49	0.94	4.43
Jul	9.61	8.07	1.69	0.65	2.33
Aug	8.25	9.16	0.90	0.24	1.14
Sep	7.80	8.56	0.33	0.39	0.73
Oct	7.91	4.15	0.20	0.57	0.77
Nov	9.69	1.96	1.08	0.75	1.83
Dec	8.89	0.72	3.50	0.99	4.49
Total	105.87	56.76	40.14	8.94	49.09

A closer examination of several of the hydrology components on a subwatershed scale is instructive in understanding the processes affecting pollutant loading in the watershed. Streamflow, or discharge, exhibits clinal differences between the subwatersheds, increasing moving south from the headwaters to the mouth. This is most likely related to development intensity and increasing impervious coverage. Increased streamflow is not necessarily a benefit, and indeed likely represents increasing contribution of runoff and vectors for pollutant loads. A summary table is provided below.

Table 3.12: Streamflow by Subwatershed

		Streamflow (cm) by Subwatershed								
Month	**Precip**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Jan	8.23	5.49	6.06	6.15	6.10	6.43	5.65	6.70	5.88	6.60
Feb	7.66	6.31	6.58	6.64	6.65	6.81	6.41	6.88	6.56	6.91
Mar	9.51	8.29	8.43	8.44	8.31	8.36	8.09	8.35	8.11	8.21
Apr	9.55	7.38	7.49	7.45	7.07	7.08	6.96	7.09	6.86	6.81
May	9.97	5.07	5.33	5.43	4.87	4.99	4.93	5.01	4.90	5.05
Jun	8.80	4.26	4.54	4.68	4.22	4.40	4.30	4.43	4.31	4.56
Jul	9.61	2.11	2.36	2.51	2.26	2.48	2.41	2.58	2.50	2.89
Aug	8.25	0.97	1.18	1.25	1.04	1.23	1.10	1.43	1.18	1.61
Sep	7.80	0.59	0.74	0.82	0.71	0.83	0.76	0.95	0.83	1.14
Oct	7.91	0.57	0.74	0.84	0.83	1.04	0.82	1.23	0.96	1.43
Nov	9.69	1.33	1.81	1.96	1.97	2.38	1.71	2.74	1.99	2.85
Dec	8.89	3.66	4.56	4.73	4.63	5.18	3.98	5.66	4.32	5.51
Total	105.87	46.03	49.82	50.90	48.66	51.21	47.12	53.05	48.40	53.57

Runoff shows significant variation between subwatersheds; in fact, it doubles on an annualized basis from Subwatershed 1 in the headwaters north of Easton Reservoir to Subwatershed 9 at the mouth of Mill River. The steady increase in runoff from the headwaters to the mouth is strongly correlated with impervious coverage in each of the subwatersheds. Managing stormwater volume in Subwatersheds 5, 7, 8, and 9 will be an important goal for the WMP. While runoff is a function of precipitation and land cover, antecedent moisture conditions and groundwater storage are also important modifiers. Runoff peaks in February, but a secondary peak is also observed in June. A runoff hydrograph is found below with a summary table.

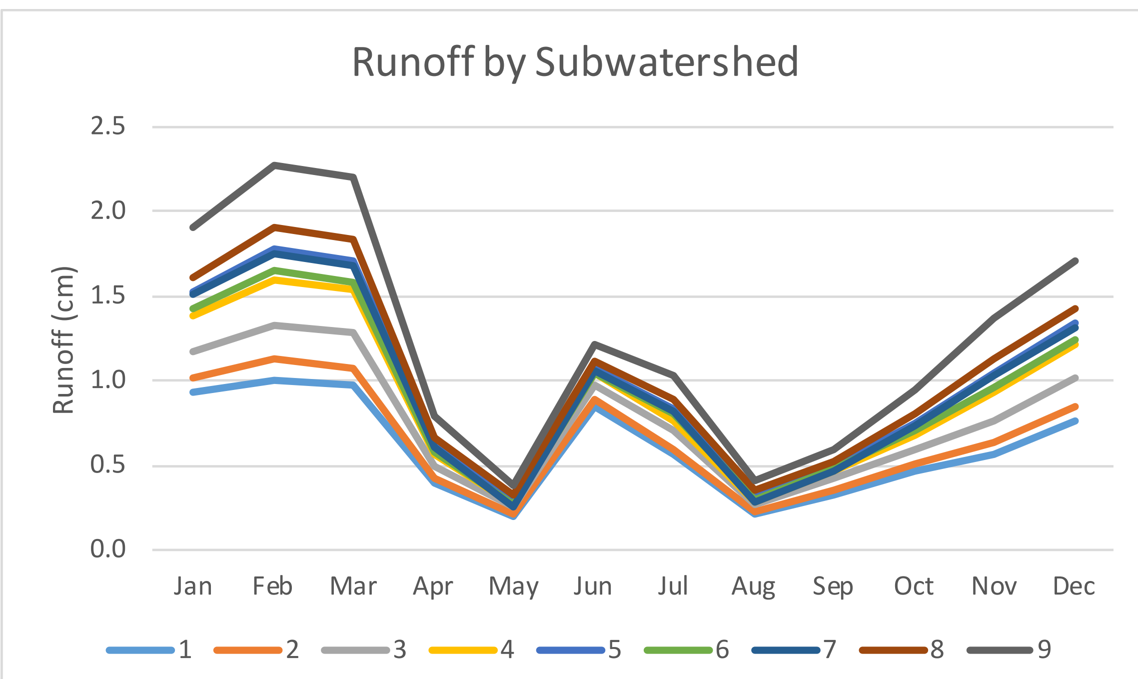


Figure 3.16: Runoff by Subwatershed

Table 3.13: Runoff by Subwatershed

Month	Precip	Runoff (cm) by Subwatershed 1	2	3	4	5	6	7	8	9
Jan	8.23	0.93	1.02	1.17	1.38	1.52	1.42	1.51	1.61	1.90
Feb	7.66	1.00	1.13	1.33	1.60	1.78	1.65	1.75	1.90	2.27
Mar	9.51	0.97	1.08	1.28	1.54	1.71	1.58	1.68	1.84	2.20
Apr	9.55	0.39	0.42	0.49	0.56	0.62	0.58	0.61	0.67	0.79
May	9.97	0.20	0.21	0.25	0.27	0.28	0.27	0.25	0.33	0.38
Jun	8.80	0.85	0.89	0.97	1.04	1.08	1.05	1.06	1.11	1.21
Jul	9.61	0.56	0.59	0.70	0.77	0.84	0.80	0.82	0.89	1.03
Aug	8.25	0.21	0.22	0.27	0.29	0.31	0.30	0.29	0.35	0.41
Sep	7.80	0.33	0.36	0.43	0.47	0.50	0.48	0.47	0.53	0.60
Oct	7.91	0.47	0.51	0.60	0.68	0.75	0.70	0.73	0.80	0.94
Nov	9.69	0.57	0.64	0.77	0.93	1.05	0.96	1.03	1.13	1.37
Dec	8.89	0.76	0.85	1.02	1.21	1.34	1.25	1.31	1.43	1.71
Total	105.87	7.24	7.92	9.28	10.74	11.78	11.04	11.51	12.59	14.81

Groundwater fluxes are also important to analyze. On a seasonal basis, groundwater flows mirror the general streamflow patterns observed in the watershed. Variability between stations is muted, but there are several important patterns. First, Subwatersheds 2, 3, and 7 show higher groundwater flux relative to the other subwatersheds which is likely a result of increased groundwater capture/interaction due to the presence of the large surface waters found in each, respectively Easton, Hemlock, and Samp Mortar Reservoirs. Besides those three subwatersheds, trends are weaker, but there is a slight decline in groundwater flow moving from the headwaters to the mouth, probably as a result of increasing impervious coverage and increased runoff limiting groundwater infiltration. Subwatershed 9, the most highly developed watershed, does have somewhat higher groundwater flux than would be expected, but this subwatershed does have increased open water and wetland land cover and flatter slopes that would all contribute positively to groundwater flow. A summary table of groundwater is provided below.

Table 3.14: Groundwater Flow by Subwatershed

Month	Precip	Groundwater Flow (cm) by Subwatershed 1	2	3	4	5	6	7	8	9
Jan	8.23	4.57	5.04	4.98	4.72	4.90	4.23	5.19	4.26	4.70
Feb	7.66	5.31	5.46	5.31	5.05	5.03	4.77	5.13	4.66	4.64
Mar	9.51	7.33	7.35	7.16	6.77	6.65	6.51	6.67	6.27	6.01
Apr	9.55	7.00	7.07	6.96	6.51	6.45	6.38	6.48	6.19	6.02
May	9.97	4.87	5.12	5.18	4.60	4.71	4.66	4.76	4.57	4.67
Jun	8.80	3.41	3.65	3.70	3.18	3.32	3.25	3.38	3.20	3.35
Jul	9.61	1.55	1.76	1.81	1.49	1.64	1.61	1.76	1.61	1.86
Aug	8.25	0.76	0.96	0.98	0.75	0.91	0.80	1.14	0.83	1.19
Sep	7.80	0.26	0.38	0.39	0.24	0.33	0.29	0.48	0.30	0.54
Oct	7.91	0.10	0.23	0.24	0.15	0.29	0.12	0.51	0.16	0.49
Nov	9.69	0.75	1.17	1.19	1.04	1.34	0.75	1.71	0.86	1.48
Dec	8.89	2.90	3.71	3.71	3.42	3.84	2.73	4.35	2.89	3.80
Total	105.87	38.81	41.90	41.61	37.92	39.41	36.10	41.56	35.80	38.75

3.4 POLLUTANT LOAD ANALYSIS

As discussed above, hydrology and pollutant load modeling were conducted using the MapShed/Model My Watershed model. Regarding pollutants, the models were used to develop loads for nitrogen, phosphorus, and sediment/solids, as well as indicator bacteria. At its most basic, the model assumes differential loading rates of these various pollutants based on LU/LC and modified by slopes, soils, hydrology, and a host of other factors. In addition to modeling runoff processes, the model computes the loads of solids and certain nutrients resulting from stream bed and bank erosion, which can account for significant portions of the load. Loads attributable to dissolved pollutants are calculated, as modified by onsite septic system loading. Loading related to farm animals, wildlife, wastewater treatment plants, and other point sources may also be calculated depending on the characteristics of the watershed being studied.

For functions or data not yet integrated in the Model My Watershed application model project files are imported back into MapShed. The input data is edited for accuracy to reflect the conditions in the watershed, and results regenerated. This process was used to update septic system, evapotranspiration values, and reservoir drainage area information for the Mill River watershed and subwatersheds. A summary of some of those activities follows. For the hydrology calibration, percent drainage to a major surface water was modified to reflect the drainage area ratio within the catchments of the two major reservoirs. Evapotranspiration values were modified from the default values to improve the fit of modeled stream discharge to the observed discharge records collected by USGS. Septic system population data was changed to reflect a malfunction rate of 15%. Septic failure is highly site specific and while it is impossible to know the true failure rate without an extensive field survey, a 15% malfunction rate is a conservative estimate based on the scientific literature. The 15% malfunction rate was assigned to the “Short Circuiting Systems” category. This category represents malfunctioning systems that discharge waste to underlying water tables or groundwater without sufficient renovation. Consultation with the Town Sanitarian indicated an estimated septic system failure rate based on a random sample of files at roughly 0.6%, but that would refer to obvious failures, such as surficial ponding, while the assumed short circuiting or interception of the groundwater table would be much harder to detect.

MapShed, as indicated above, calculates loads and concentrations of indicator bacteria, specifically fecal coliform. While fecal coliform has associated water quality standards based on shellfishing uses in Class SA estuaries, the bacterial indicator of greatest concern for this project is *E. coli* which triggered the development of a TMDL for this watershed. Therefore, a method to transform fecal coliform data to *E. coli* was required. Some analysis was made comparing paired *E. coli* and fecal samples collected by Harbor Watch within Mill River during 2016 and 2017, which showed that the *E. coli* fraction typically accounted for the vast majority of observed fecal coliform. The sample size was limited however and not deemed sufficiently strong to use as a basis for modeling. A literature review was conducted to find relationships between these two indicator bacteria. Based on that review, the regression equation based on a sample size of nearly 5,000 pairs developed by Ohio EPA was utilized to transform fecal coliform concentrations to *E. coli* in this watershed. The equation is:

$$[\textit{E. coli}] = 0.403\ [\text{fecal coliform}]^{1.028}$$

The remainder of this section will discuss the results of the pollutant load analysis by each pollutant of concern. The first component of discussion will include the model of the entire of watershed with a focus on individual load fractions, essentially a source type analysis. The second component will focus on the relative results from each of the nine subwatersheds, including prioritization and ranking in order to best focus pollution management efforts in subwatersheds where the need is indicated. Because of the artificial nature of the subwatershed delineations, which represent fragments of watersheds often excluding major elements of the hydrologic catchment upstream, the subwatershed analysis is best viewed on a relative scale. Subwatershed 5 is a good example of this; while this subwatershed captures direct loading to Lake Mohegan and areas adjacent to the Mill River downstream to Samp Mortar Reservoir, it exclude portions of the true subwatershed apportioned to Subwatersheds 4, 2, and 1. Stated differently, it excludes the nested nature of subwatersheds draining to a single point as well as the cumulative effects of this drainage as loading and attenuation will vary with stream miles, cumulative areas, and other features. Since the entire watershed model of the Mill River does include all areas of its catchment, the modeled output for the entire watershed carries the highest confidence. However, as a tool to identify sources correlated to discrete areas and to rank those areas by loads and loads per unit area, the subwatershed approach is both valid and useful.

3.4.1 NITROGEN

Nitrogen is a vital macronutrient that sustains algae and plant growth in aquatic ecosystems. Most forms tend to be highly soluble, and as such is usually found in dissolved form. Atmospheric deposition is an important source of nitrogen, and in some ecosystems, nitrogen fixers, such as cyanobacteria, can capture dissolved gaseous nitrogen. Anthropogenic sources include wastewater streams, and in agricultural settings animal wastes and fertilizers. Because of its solubility it is often found at relatively high concentrations in groundwater and in much lower concentrations in surface waters due to biological assimilation by primary producers. In freshwaters it is typically not a limiting nutrient, although in marine settings, such as Long Island Sound, it is often limiting. Since the inception of the Clean Water Act, major strides have been made in reducing nitrogen loading throughout the country.

In Mill River, total nitrogen loading is estimated at 31,526 kg. The largest source is groundwater loading accounting for approximately 81% of the total load (Table 3.15 and Figure 3.17). The next highest source is stream erosion at 8%, and loading attributable to septic systems at roughly 3%. An examination of loading related to specific LU/LC types excluding specific sources such as farm animals, stream bank erosion, groundwater, and septic systems, indicates that the Low Density Mixed Developed LU/LC type contributes the greatest fraction of nitrogen at 33%, with Medium Density Mixed Developed and High Density Mixed Developed contributing another 18%. Agricultural lands, primarily Hay/Pasture contribute another 21% of the load, and natural lands including Open Land, Wetland, and Forest contribute about 28% of the nitrogen load attributable to LU/LC types.

Table 3.15: Total Nitrogen Loads by Source

Category	Description	TN	
		kg	%
Runoff	Hay/Pasture	418.5	1.3
	Cropland	23.5	0.1
	Forest	344.8	1.1
	Wetland	194.3	0.6
	Open Land	25.6	0.1
	Low Density Mixed Developed	690.1	2.2
	Medium Density Mixed Developed	322.9	1.0
	High Density Mixed Developed	47.2	0.1
Other Sources	Farm Animals	463.8	1.5
	Stream Bank	2452.0	7.8
	Groundwater	25604.2	81.2
	Septic Systems	939.3	3.0

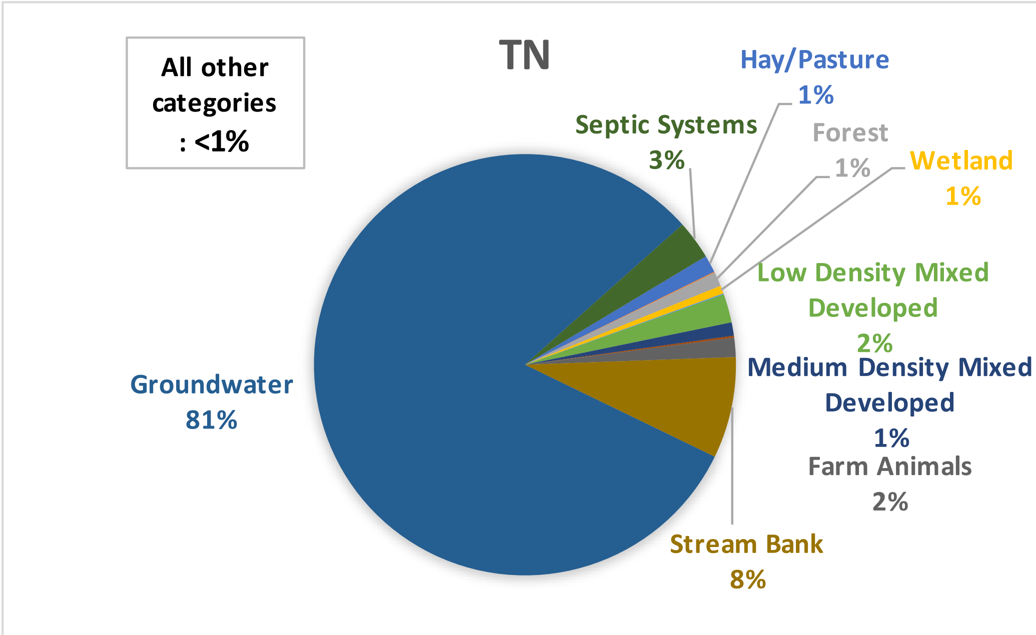


Figure 3.17: Total Nitrogen Loading by All Sources

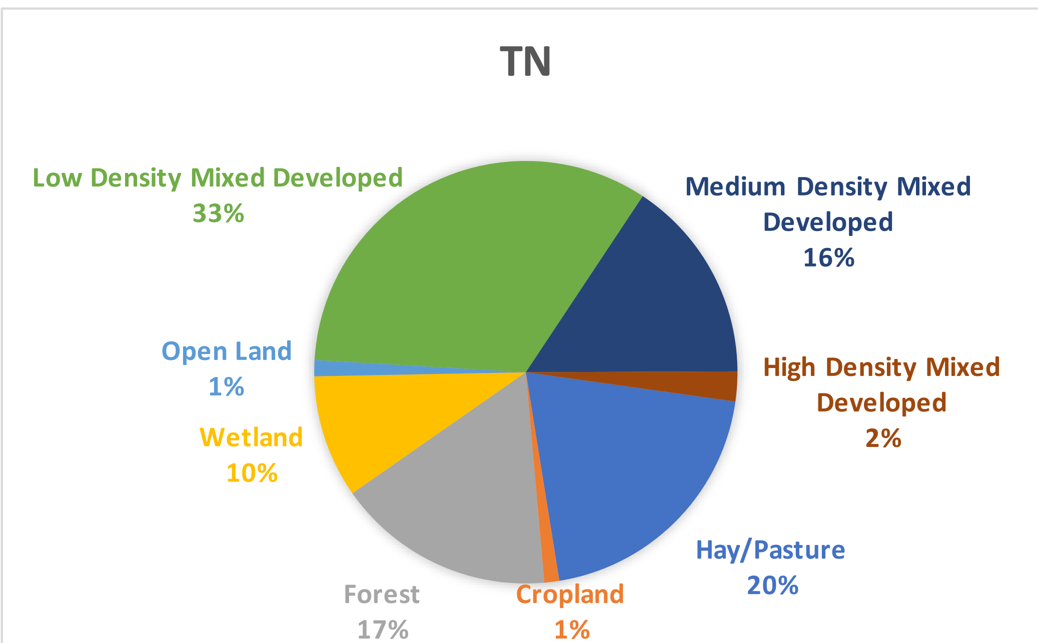


Figure 3.18: Total Nitrogen Loading by All Sources (By Land Use)

Next, the subwatersheds were ranked in terms of total nitrogen load and specific nitrogen load, that is nitrogen load per unit area which normalizes the data across the subwatersheds and enables the identification of higher loading rates which provide better opportunities as management targets (Table 3.16). Finally, percent total nitrogen for each subwatershed is provided in Table 3.17 in order to identify the types of management measures or Best Management Practices (BMPs) that would best address specific loading in the subwatershed of interest.

Table 3.16: Subwatershed Total Nitrogen Loads Ranked

Rank	SubWS	Area acres	Total Load TN (kg)	Rank	SubWS	Area acres	Specific Load TN kg/acre
1	8	1677.7	4696.8	1	8	1677.7	0.111
2	6	1357.6	3591.5	2	4	3432.3	0.107
3	2	5655.4	3559.3	3	9	348.2	0.095
4	4	3432.3	2886.1	4	6	1357.6	0.092
5	3	4582.7	2821.8	5	7	548.5	0.077
6	1	2611.4	1526.7	6	2	5655.4	0.055
7	9	348.2	1043.9	7	3	4582.7	0.054
8	7	548.5	413.6	8	5	273.9	0.053
9	5	273.9	203.8	9	1	2611.4	0.036

Table 3.17: Subwatershed Total Nitrogen Load Percentage by Source

Source	Subwatershed ID								
	1	2	3	4	5	6	7	8	9
Hay/Past	4.3%	6.1%	4.7%	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%
Cropland	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Forest	4.2%	3.0%	4.6%	2.8%	1.6%	0.7%	0.4%	0.3%	0.1%
Wetland	2.7%	1.7%	1.4%	0.6%	0.6%	0.3%	0.1%	0.4%	0.2%
Open_Land	0.0%	0.3%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
Ld_Mixed	2.0%	3.1%	3.2%	6.3%	9.9%	2.6%	11.5%	2.5%	2.6%
Md_Mixed	0.3%	0.7%	1.0%	3.5%	4.3%	0.9%	3.5%	2.0%	3.0%
Hd_Mixed	0.1%	0.0%	0.2%	0.5%	0.4%	0.0%	0.4%	0.3%	0.5%
Farm Animals	3.4%	3.4%	3.4%	2.4%	2.1%	0.7%	2.2%	0.7%	0.4%
Stream Bank	2.1%	5.6%	5.6%	9.0%	1.5%	0.6%	2.7%	0.6%	0.0%
Groundwater	79.9%	73.1%	72.9%	61.9%	67.1%	91.3%	68.4%	87.4%	84.9%
Septic Systems	1.0%	2.3%	2.7%	10.0%	12.5%	2.9%	10.8%	5.8%	8.4%

Subwatersheds 8, 9, 6, and 4 exhibit high total loads of nitrogen as functions of both watershed size and unit area loading. Examining the percent loads by source for each of those subwatersheds shows that nitrogen loading related to septic systems is a major source. In Subwatershed 6 the percent contribution of septic is low due to the very high groundwater loading, but the septic load total is actually the third highest of the examined subwatersheds. In some of the more rural subwatersheds, farm animals and streambank erosion percent loads are high, representing management targets for those watersheds. Stormwater management opportunities are presented in Subwatersheds 4, 5, 6, and 7 consistent with high percent loads associated with the varying intensity mixed development LU/LC types.

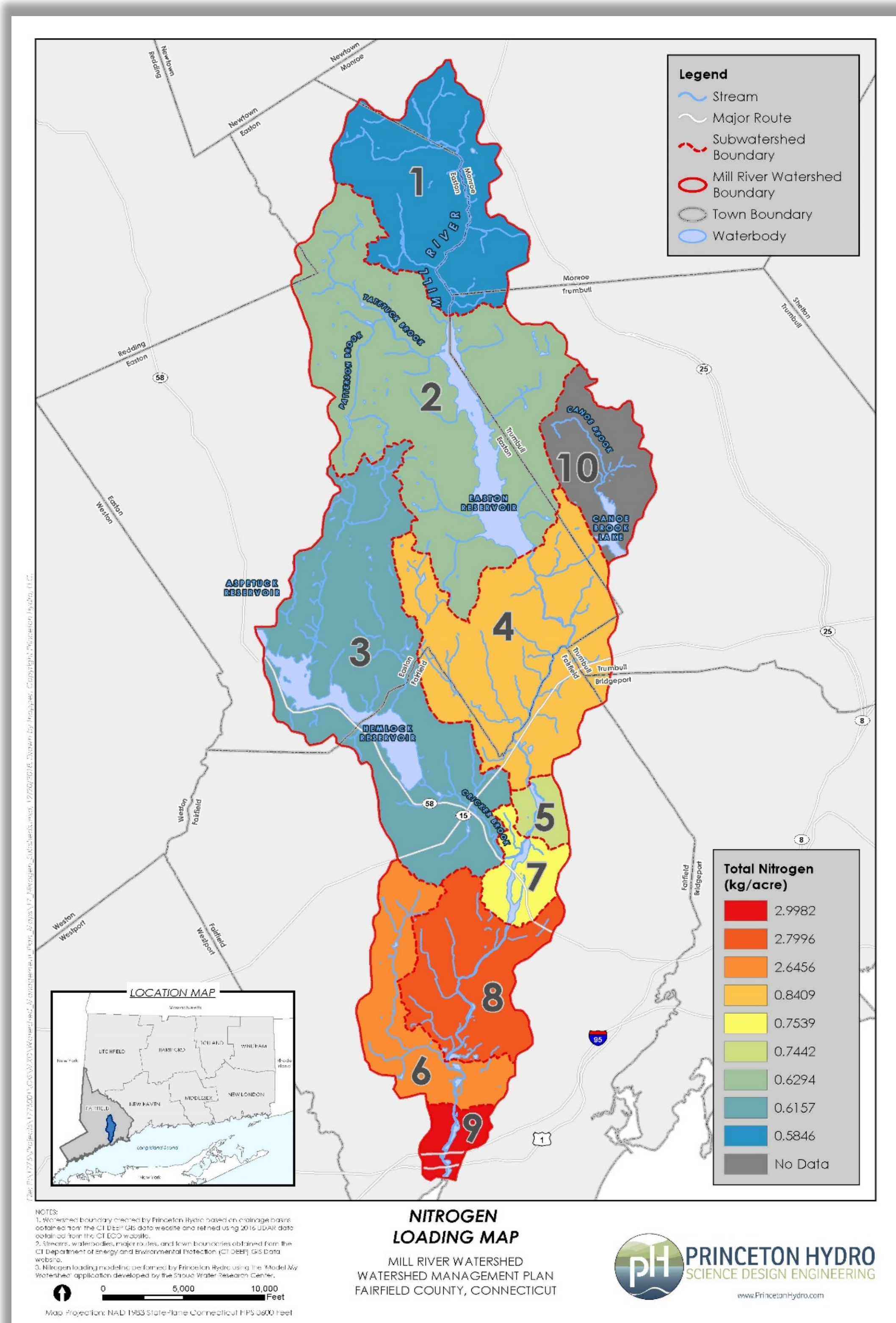


Figure 3.19: Nitrogen Loading Map

3.4.2 PHOSPHORUS

Phosphorus is another important nutrient pollutant. In freshwaters, it is often the limiting nutrient, the one that regulates total primary productivity due to relative scarcity relative to biological demand. Phosphorus is typically found in particulate forms and thus is usually bound to inorganic particulates that are often expressed as total suspended solids. While internal phosphorus loading is common in anoxic lakes releasing dissolved species of phosphorus in the hypolimnion or deep water, in the presence of sufficient dissolved oxygen concentrations it precipitates out of the water column and binds to iron. Erosion is often a major source of phosphorus, but organic forms can also be important including vegetation. Fertilizers, human and animal waste, and dryfall deposition can all be important sources. Groundwater can have elevated concentrations of dissolved phosphorus relative to surface waters, where dissolved forms are very rapidly assimilated, at least during the growing season, by photosynthesizing organisms.

Over 60% of phosphorus loading in the Mill River watershed is the result of streambank erosion, the mobilization of particles bearing phosphorus. Groundwater is the secondary loader, accounting for roughly 19% of the total load, expressed primarily in dissolved forms. Runoff from the various LU/LC types accounts for 13% of the phosphorus load, with Hay/Pasture contributing nearly 8%. Farm animals and septic systems both account for less than 5% of the total load. A summary table and two figures showing phosphorus loading by source throughout the Mill River watershed are provided below.

Table 3.18: Total Phosphorus Loads by Source

Category	Description	TP	
		kg	%
Runoff	Hay/Pasture	217.1	7.9
	Cropland	6.4	0.2
	Forest	23.0	0.8
	Wetland	9.2	0.3
	Open Land	2.0	0.1
	Low Density Mixed Developed	68.3	2.5
	Medium Density Mixed Developed	29.3	1.1
	High Density Mixed Developed	4.3	0.2
Other Sources	Farm Animals	122.0	4.5
	Stream Bank	1680.0	61.3
	Groundwater	514.5	18.8
	Septic Systems	65.9	2.4

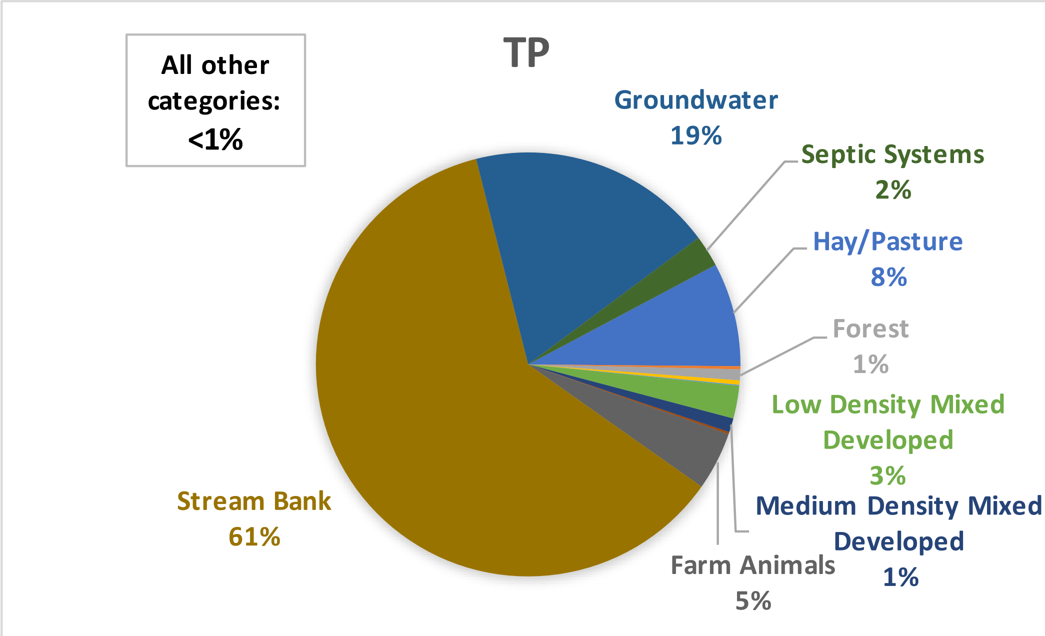


Figure 3.19: Total Phosphorus Loading by All Sources

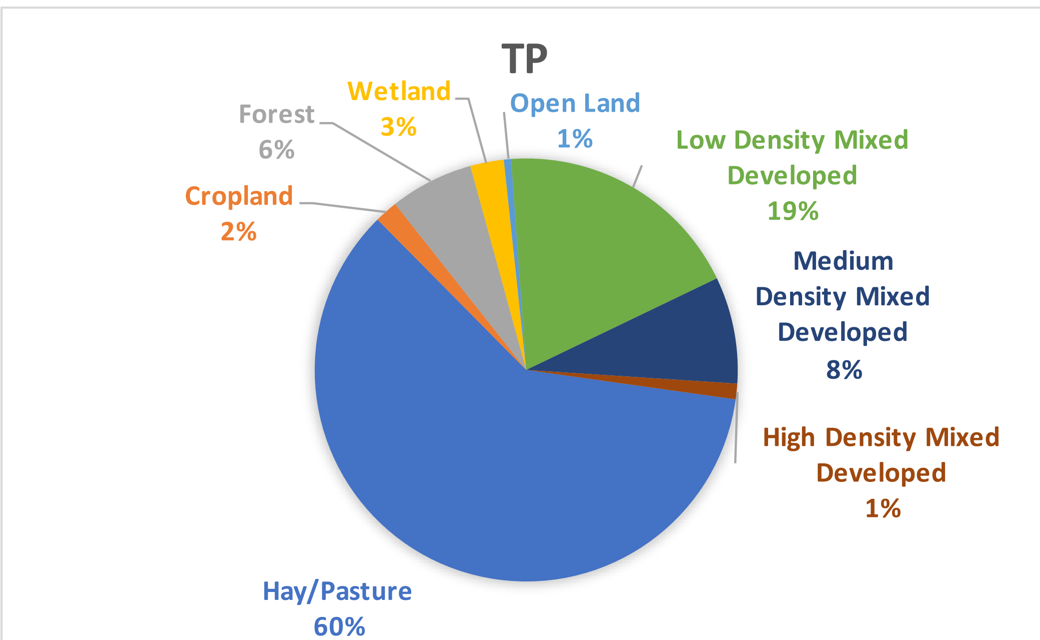


Figure 3.20: Total Phosphorus Loading in Runoff by LU/LC Types

The loading values were then examined on a subwatershed basis and summarized in Table 3.19 below. Each subwatershed was ranked by both total phosphorus load and specific phosphorus load, represented here as kg per acre. For the total load rank scheme, load is generally correlated with area, but this relationship is not perfect and is seen to be modified due to differential loading related to land use patterns identified in the specific load calculations. As with the examination of nitrogen loads, Subwatersheds 8, 4, 9 and 6 have substantially higher specific phosphorus loads than the other watersheds. Highlighting the variation is the difference between the highest and lowest ranked subwatersheds in which the unit area load for phosphorus in Subwatershed 8 is 308% of that calculated for Subwatershed 1.

Table 3.19: Subwatershed Total Phosphorus Loads Ranked

Rank	SubWS	Area acres	Total Load TP (kg)	Rank	SubWS	Area acres	Specific Load TP kg/acre
1	4	3432.3	366.8	1	8	1677.7	0.111
2	2	5655.4	312.2	2	4	3432.3	0.107
3	3	4582.7	247.6	3	9	348.2	0.095
4	8	1677.7	186.9	4	6	1357.6	0.092
5	6	1357.6	124.9	5	7	548.5	0.077
6	1	2611.4	94.4	6	2	5655.4	0.055
7	7	548.5	42.3	7	3	4582.7	0.054
8	9	348.2	33.1	8	5	273.9	0.053
9	5	273.9	14.5	9	1	2611.4	0.036

The subwatersheds with the highest specific loads tend to have higher relative contributions of phosphorus loading from both septic systems and stream bank erosion, indicators of both the need to treat sanitary sewage onsite and higher stormwater loads in these watersheds. The northerly subwatersheds, despite increased reliance on onsite septic systems without sanitary sewer service actually have decreased phosphorus loading from septics expressed as a percentage. Farm animal loading is higher in these areas, as well as phosphorus loading attributable to a specific LU/LC, in this case Hay/Pasture. Subwatershed 5, one of the middle subwatersheds, is intermediate between these two groupings in most respects. In general, lower subwatersheds should focus on septic management, stream bank restoration, and stormwater volume control, while the upper subwatersheds should target agricultural BMPs and manure management.

Table 3.20: Subwatershed Total Phosphorus Load Percentage by Source

Source	Subwatershed ID								
	1	2	3	4	5	6	7	8	9
Hay/Past	29.7%	29.4%	25.0%	13.1%	0.0%	1.0%	0.0%	0.0%	0.0%
Cropland	0.0%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Forest	5.0%	2.2%	3.3%	1.7%	3.0%	1.4%	0.5%	0.7%	0.3%
Wetland	1.9%	0.8%	0.7%	0.3%	0.5%	0.4%	0.0%	0.6%	0.3%
Open_Land	0.0%	0.2%	0.3%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%
Ld_Mixed	2.8%	3.1%	3.2%	5.6%	15.5%	8.3%	12.6%	6.9%	9.0%
Md_Mixed	0.4%	0.7%	0.9%	2.8%	6.2%	2.7%	3.6%	5.2%	9.6%
Hd_Mixed	0.1%	0.0%	0.2%	0.4%	0.6%	0.1%	0.4%	0.9%	1.7%
Farm Animals	14.0%	10.1%	10.0%	5.0%	7.4%	5.5%	5.5%	4.3%	3.3%
Stream Bank	15.2%	30.5%	35.3%	50.4%	27.5%	42.4%	49.8%	43.9%	24.1%
Groundwater	29.5%	19.3%	19.2%	14.3%	27.7%	31.4%	19.7%	25.8%	31.4%
Septic Systems	1.2%	1.7%	1.9%	6.2%	11.5%	6.7%	8.0%	11.7%	20.3%

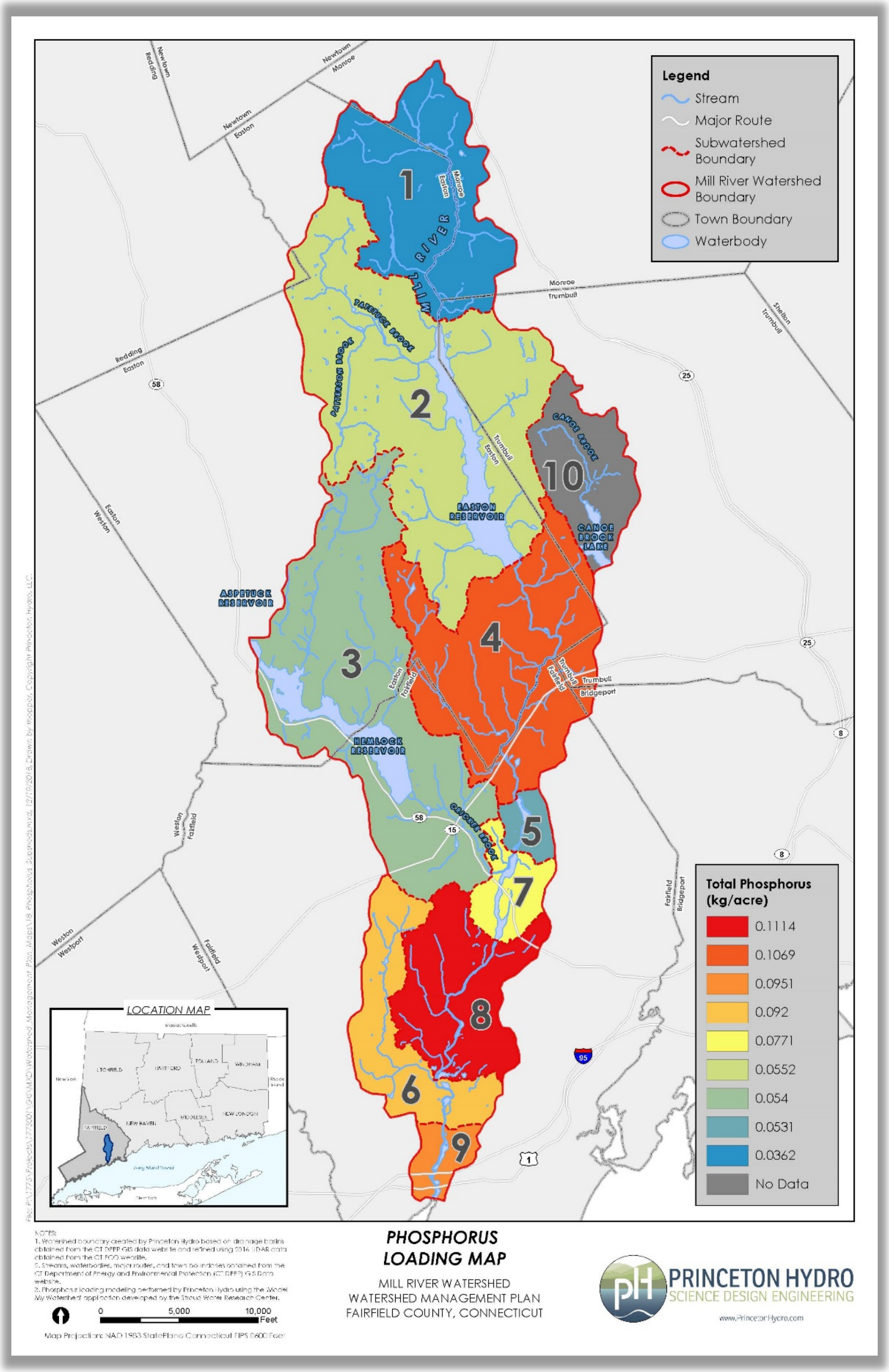


Figure 3.21: Phosphorous Loading Map

3.4.3 SEDIMENT

Sediment loading includes various fine to coarse particles generally called total suspended solids (TSS). These are primarily inorganic soil particles, but may also include organic particulates such as decomposed vegetal materials within the soil matrix and algal cells. Sediment impairments can manifest in a variety of ways, but increased turbidity and formation of sediment bars are some of the more common impacts which may lead to secondary impairments such as increased flooding, colonization of nutrient rich sediments by invasive plants, and a decline in substrate quality and macroinvertebrate community health. Sediment loading is tied strongly to LU/LC types and activities such as land clearing for development, surface mining, and tillage which contribute to erosion. Increasing impervious coverage increases stormwater runoff which results in changes to stream hydraulics and exacerbates instream erosion of the bed and bank. It is important to note that one of the primary functions of stream systems is the transport of sediment, and it is desirable to maintain a state of equilibrium where material eroded or mobilized at a specific site are replaced by those originating upstream. Stream systems that have many impoundments which efficiently capture TSS may actually lead to downstream sediment starvation where bed materials are not replaced.

The MapShed model simulates several different sediment loads, including erosion and sediment transport from the land surface, instream bank erosion, and overall sediment loads, which equate to the quantity of solids that are discharged through the watershed, which accounts for settling processes within the system. In the Mill River watershed, stream bank erosion accounts for nearly 98% of the total sediment load. Of the remaining load developed within the watershed Hay/Pasture accounts for 62% and the mixed developed land uses accounts for about 31% combined. Sediment is reported in tonnes, also known as the metric ton and is denoted herein as 1000 kg. Pie charts are also provided below.

Table 3.21: Sediment Loads by Source

Category	Description	Sediment	
		1000 kg	%
Runoff	Hay/Pasture	45.7	1.6
	Cropland	1.6	0.1
	Forest	3.1	0.1
	Wetland	0.1	0.0
	Open Land	0.7	0.0
	Low Density Mixed Developed	12.9	0.4
	Medium Density Mixed Developed	8.6	0.3
	High Density Mixed Developed	1.3	0.0
Other Sources	Farm Animals	0.0	0.0
	Stream Bank	2833.3	97.5
	Groundwater	0.0	0.0
	Septic Systems	0.0	0.0

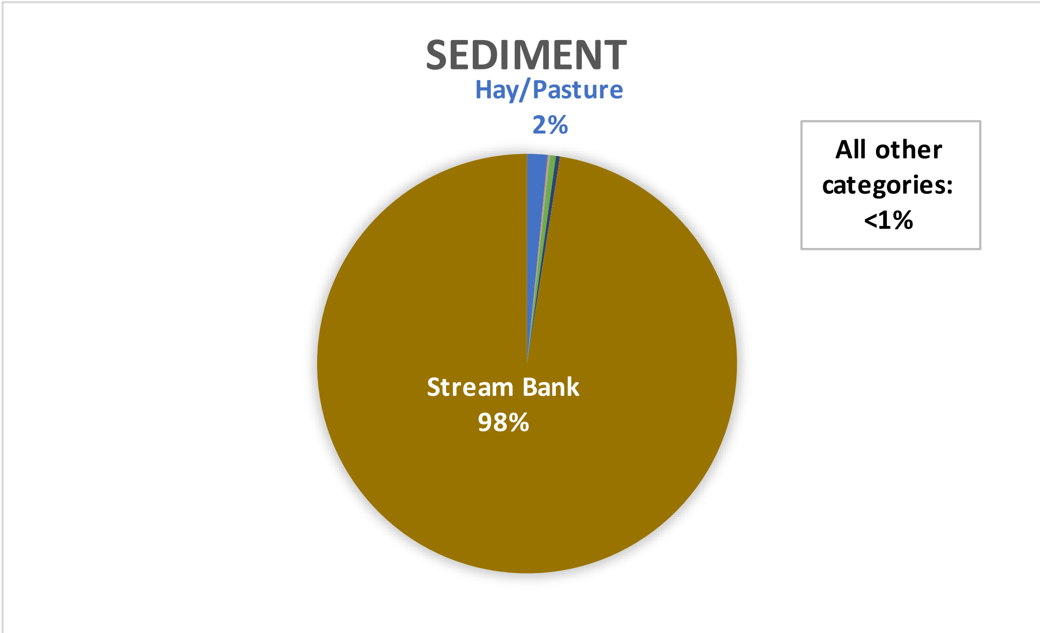


Figure 3.22: Sediment Loading by All Sources

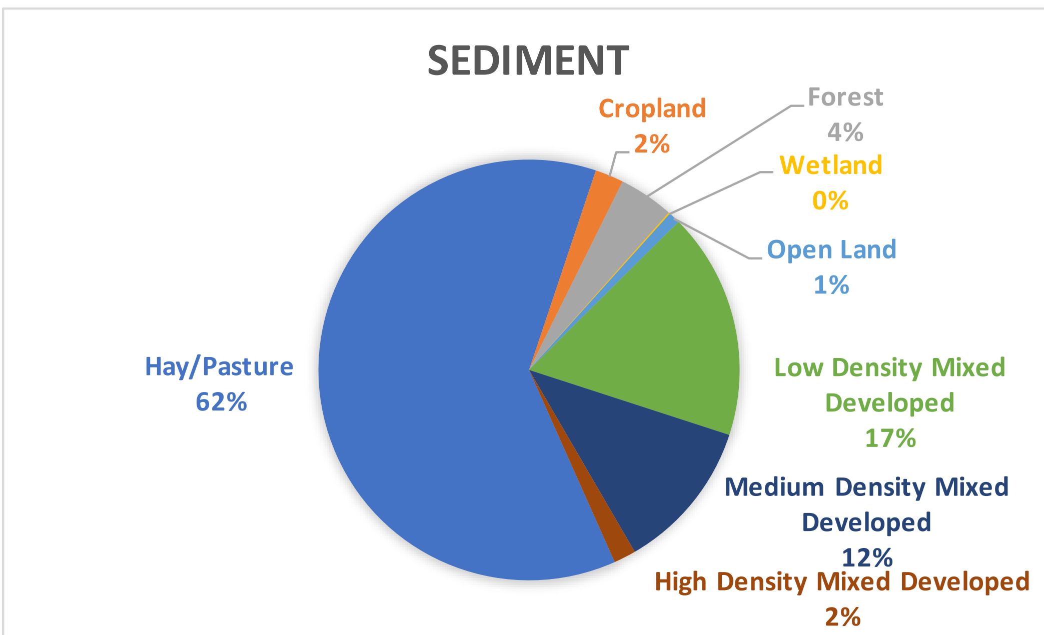


Figure 3.23: Sediment Loading in Runoff by LU/LC Types

Sediment loading was ranked for each subwatershed. Total sediments loads were highest in Subwatersheds 4, 8, and 6, all implicated as among the worst in the other examined pollutants. The correlation with area is surprisingly weaker for sediments than nitrogen or phosphorus. On a specific load basis, Subwatersheds 4, 8, 6, and 7 were ranked highest, and exhibited a significant increase on a per unit area basis than the other subwatersheds. Indeed, there is a nearly 30-fold difference between the Subwatershed 1 and Subwatershed 4. The ranking summary table is provided below.

Table 3.22: Subwatershed Sediment Loads Ranked

Rank	SubWS	Area acres	Total Load Sed (1000 kg)	Rank	SubWS	Area acres	Specific Load Sed 1000 kg/acre
1	4	3432.3	571.3	1	4	3432.3	0.166
2	8	1677.7	252.2	2	8	1677.7	0.150
3	6	1357.6	164.8	3	6	1357.6	0.121
4	2	5655.4	75.7	4	7	548.5	0.118
5	3	4582.7	67.9	5	9	348.2	0.078
6	7	548.5	64.8	6	5	273.9	0.051
7	9	348.2	27.2	7	3	4582.7	0.015
8	1	2611.4	14.6	8	2	5655.4	0.013
9	5	273.9	13.8	9	1	2611.4	0.006

The source of these loads is interesting. The highest specific loading was simulated in Subwatershed 4, 8, 6, and 7, all of which had a high percentage of their load attributed to instream erosion, indicating elevated development density and associated increases in stormwater. This again suggests management measures should focus on stormwater management, and potentially stream stabilization measures. Subwatersheds 1, 2, and 3 are either lightly developed headwaters or have large reservoirs that act as sinks for sediment capture. Agricultural uses are larger contributors in these watersheds, again suggesting the use of agricultural BMPs in this area. The loads by source expressed as percentages are summarized in Table 3.23.

Table 3.23: Subwatershed Sediment Load Percentage by Source

Source	Subwatershed ID								
	1	2	3	4	5	6	7	8	9
Hay/Past	25.2%	11.4%	9.8%	3.6%	0.0%	0.4%	0.0%	0.0%	0.0%
Cropland	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Forest	2.7%	0.6%	0.7%	0.3%	1.4%	0.2%	0.1%	0.2%	0.1%
Wetland	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Open_Land	0.0%	0.1%	0.2%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%
Ld_Mixed	1.4%	1.0%	0.9%	1.2%	5.3%	2.1%	2.7%	1.7%	3.6%
Md_Mixed	0.3%	0.4%	0.4%	0.9%	3.5%	1.1%	1.2%	1.9%	5.8%
Hd_Mixed	0.1%	0.0%	0.1%	0.1%	0.3%	0.0%	0.1%	0.3%	1.0%
Farm Animals	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stream Bank	70.0%	85.5%	87.9%	93.8%	89.4%	96.1%	95.9%	95.9%	89.5%
Groundwater	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Septic Systems	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

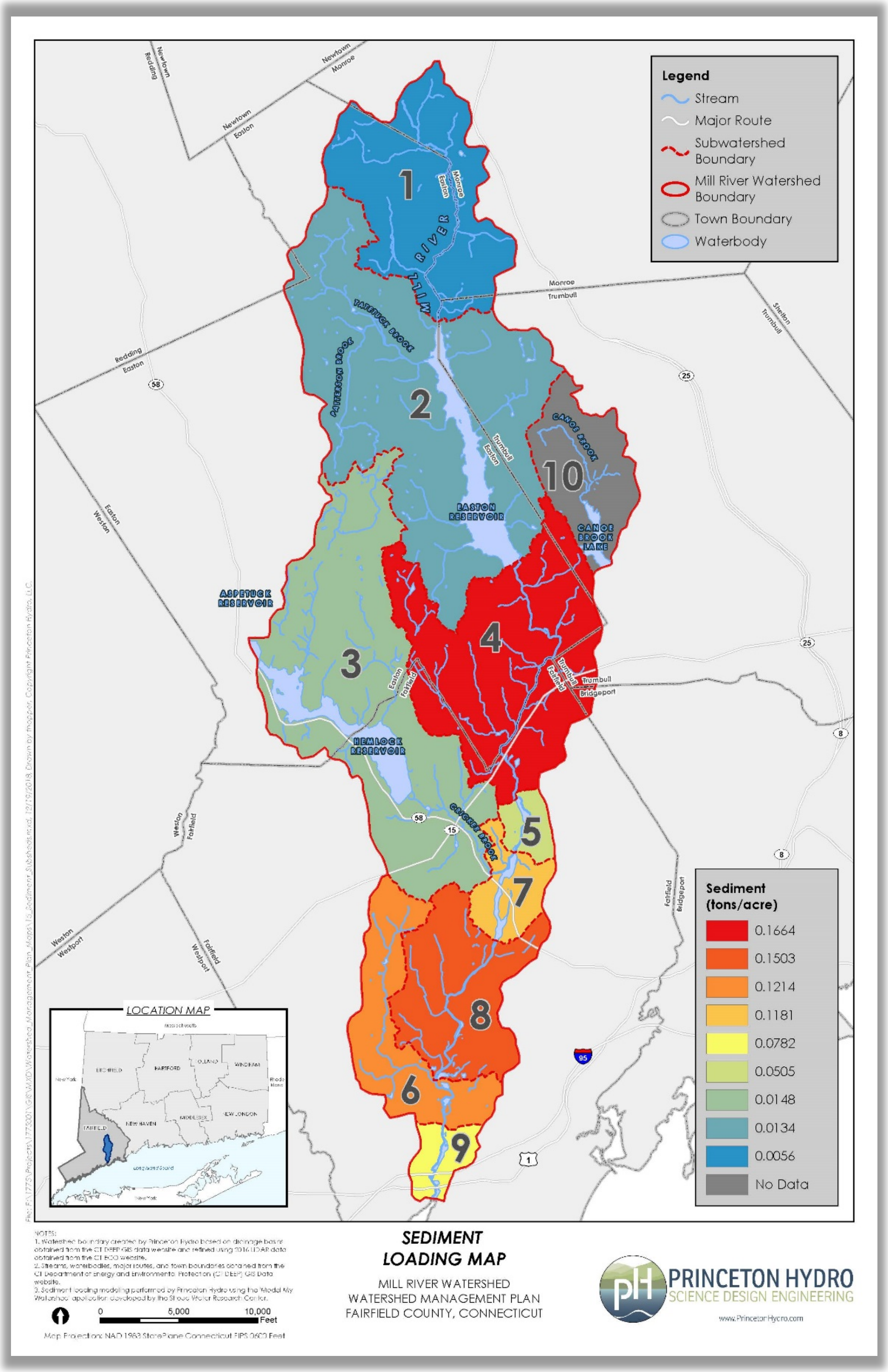


Figure 3.24: Sediment Loading Map

3.4.4 INDICATOR BACTERIA

The various indicator bacteria and relevant water quality standards have been discussed above. Two bacterial groups/species are of interest for this project, fecal coliform and *E. coli*. While these groups can be pathogenic, they are primarily viewed as indicators of other pathogens, such as viruses, associated with human and animal waste. Again, both fecal coliform and *E. coli* are well documented as problematic in the watershed and through ongoing sampling efforts continue to exceed water quality criteria. Each of these groups has an associated TMDL to address use impairments related to elevated concentrations of these bacteria. MapShed simulates fecal coliform loading in the watershed, both as loads of total organisms and as concentrations incorporating the hydrology data. As stated above, MapShed does not calculate *E. coli* loads or concentrations, but using a regression equation, fecal coliform data can be transformed to *E. coli*. For indicator bacteria, both fecal coliform and *E. coli* data will be used; fecal coliform will be used to estimate total loads and sources, while *E. coli* concentrations will be used as an analog to specific loads by utilizing concentrations. *E. coli* data will also be used to examine seasonality.

Table 3.24: Indicator Bacteria Loads by Source

Category	Description	Fecal Coliform	
		Organisms	%
Runoff	Farm Animals	2.46E+13	35.3
	WWTP	0.00E+00	0.0
	Septic Systems	3.50E+13	50.3
	Urban Areas	6.33E+12	9.1
	Wildlife	3.68E+12	5.3

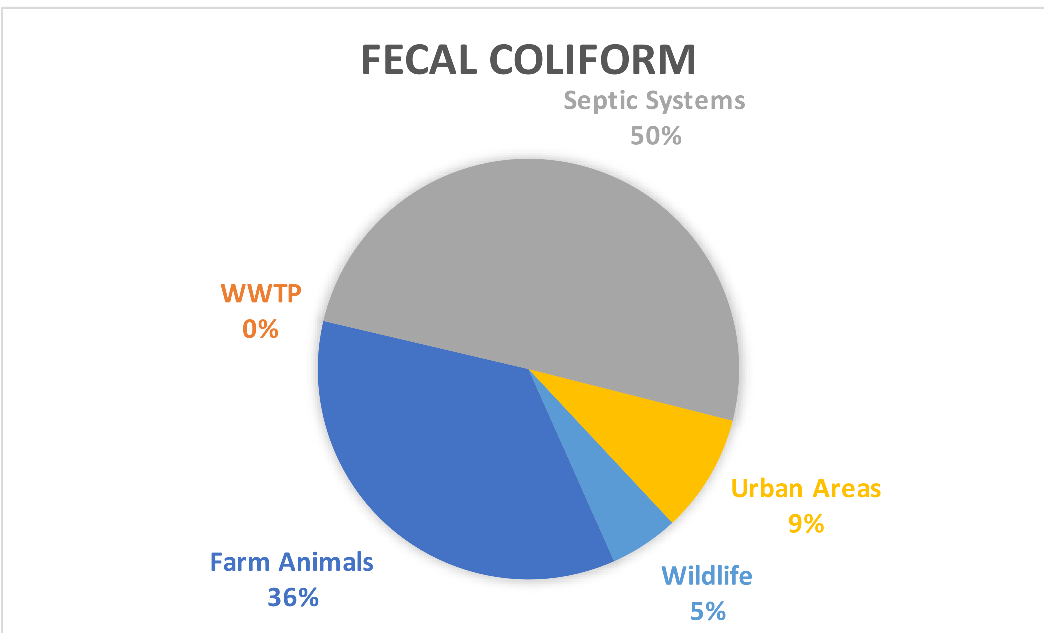


Figure 3.25: Indicator Bacteria Loading by Source

The model considers five different potential sources of indicator bacteria loading. In the Mill River watershed, the primary source of bacteria is septic systems, which account for over 50% of the load. This is followed by farm animals at over 35%. Urban areas, which accounts for wash off from impervious surfaces and wildlife together account for less than 15%. Wildlife loading is likely underrepresented in this analysis due to reported Canada goose (*Branta canadensis*) problems, as well as the numerous surface waters and park-like settings. However, in the absence of accurate counts model inputs were left at default values. WWTP (wastewater treatment plants) is 0%, reflecting that there are no treatment facilities discharging within the Mill River watershed.

At a subwatershed scale, indicator bacteria were ranked according to fecal coliform loads (organisms) and *E. coli* concentrations. On a load basis, Subwatersheds 4 and 8 were ranked highest, typical of other pollutants in these areas. Subwatersheds 2 and 3 were also ranked high, mainly as a consequence of total area. When ranked by concentrations, Subwatersheds 9, 8, 4 and 5 showed the greatest loading density. These subwatersheds, unsurprisingly, correspond to the areas of greatest development density. It is also worth noting that the subwatersheds exhibit a wide range of simulated loading concentrations, where Subwatershed 9 has calculated concentrations 523% of those calculated for the headwater Subwatershed 1.

An examination of the sources neatly compares to the known land use patterns. The three uppermost subwatersheds have high animal load contributions, from both farm animals and wildlife, ranging between 55 and 80% of the load. From Subwatershed 4 south through Subwatershed 9, animal loads decrease and both septic loads and urban area loads increase accordingly. In these six subwatersheds, septic systems account for at least 60% of the total fecal coliform load. As such, as before, agricultural BMP and manure management are the best solutions in the upper portions of the watershed, while the management of septic systems, stormwater runoff, and illicit storm sewer connections are better suited to manage these loads in the more developed subwatersheds.

Table 3.25: Subwatershed Indicator Bacteria Load Percentage by Source

Source	Subwatershed ID								
	1	2	3	4	5	6	7	8	9
Farm Animals	56.3%	51.5%	44.3%	12.7%	0.7%	2.1%	1.8%	1.2%	0.2%
WWTP	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Septic Systems	19.3%	31.5%	37.3%	68.0%	69.8%	69.9%	60.8%	78.1%	78.9%
Urban Areas	2.5%	5.4%	6.2%	15.8%	27.9%	24.9%	36.6%	19.6%	20.6%
Wildlife	21.8%	11.6%	12.2%	3.5%	1.6%	3.1%	0.9%	1.1%	0.3%

An examination of modeled *E. coli* concentrations by subwatershed is appropriate to gain further insight to loading. As mentioned above, bacteria concentrations have a strong seasonality component to them, which reflects the intersection of a living pollutant interacting with seasonal hydrology and climates. Concentrations are lowest in March and April, consistent with low temperatures which increase die-off rates, and higher flows. Concentrations tend to peak in late summer/early autumn around September, during periods of high water temperatures and low flows.

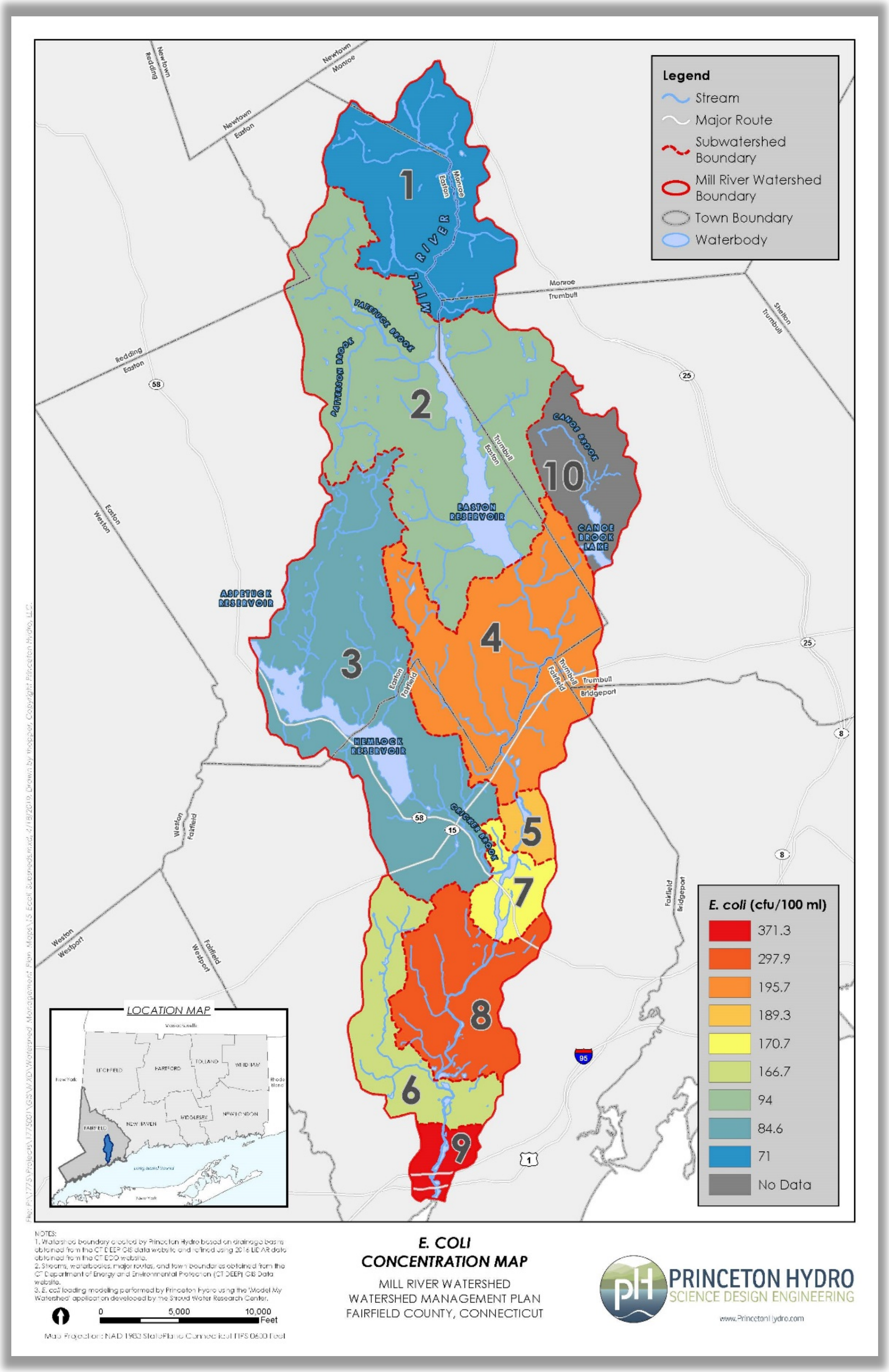


Figure 3.26: E. coli Concentration Map

Lastly, modeled concentrations, in aggregate for the watershed, show relatively good agreement with sampling data in the watershed. Unfortunately, they also indicate routine contravention of applicable water quality standards. *E. coli* concentrations by subwatershed (including the entire Mill River watershed) and month are summarized in the table below. Please note that individual subwatershed concentrations do not represent concentrations in the Mill River at the corresponding subwatershed, but average concentrations of the projected load.

Table 3.26: Subwatershed *E. coli* Concentrations by Month

Source	Subwatershed ID									
	Mill River	1	2	3	4	5	6	7	8	9
Jan	54.7	17.4	26.9	27.0	71.2	86.9	73.8	88.9	132.5	192.4
Feb	49.0	14.7	24.3	24.4	64.3	82.9	65.0	89.6	117.0	182.2
Mar	47.9	15.6	25.6	25.0	57.1	70.0	53.8	75.7	99.7	161.1
Apr	43.1	13.9	22.6	22.4	52.6	59.3	46.0	58.8	91.7	150.1
May	69.2	25.1	38.2	36.2	78.3	77.5	61.2	72.8	124.3	194.3
Jun	76.4	25.5	39.7	38.1	96.5	109.7	85.1	112.8	160.0	243.9
Jul	148.9	54.1	79.3	73.3	181.9	190.3	148.8	186.0	277.8	389.4
Aug	283.7	110.9	147.3	138.6	363.2	330.7	285.8	268.0	537.1	634.9
Sep	586.1	270.6	343.8	290.4	601.5	515.6	437.3	441.5	787.4	910.2
Oct	469.7	212.0	264.1	228.4	504.3	453.7	439.7	382.3	736.8	788.0
Nov	181.9	78.7	95.5	87.8	209.4	208.1	219.1	186.0	362.1	408.7
Dec	72.1	25.9	35.3	34.6	92.0	103.7	101.3	99.4	176.4	224.9
Total	171.6	71.0	94.0	84.6	195.7	189.3	166.7	170.7	297.9	371.3

4.0 ESTIMATE OF LOAD REDUCTIONS

This section corresponds to the second EPA element, an estimate of load reductions expected from management measures. As per EPA guidance, this section will focus strongly on presenting the required load reductions outlined in the applicable TMDLs. Several other reasons support this approach. First, this WMP is a successor to the TMDLs, particularly the *E. coli* TMDL, and a primary goal is to develop implementable management measures to address pollutant loading in the watershed. Second, while various pollutants were examined in detail at the subwatershed scale in the pollutant load section above (including nitrogen, phosphorus, sediment, and various indicator bacteria), there are few guiding numerical State water quality standards against which to compute load reductions. Indeed, for most of the relevant parameters narrative water quality standards essentially state that pollutants not exceed a level that would impair designated uses, and determining those impacts would require a much-expanded study, intensive in both sampling and analysis. Finally, the TMDL incorporates sophisticated modeling elements for indicator bacteria that not only address the appropriate water quality criteria, but address the distribution of concentrations represented by having adopted both geometric means and single sample maxima criteria.

In addition to focusing primarily on the load reductions outlined in the TMDLs, the MS4 permit requirements will also be examined. This will be examined because the TMDLs and MS4 program requirement largely overlap in many respects. Additionally, management of pollutant loads in the watershed will focus strongly on managing stormwater for both quantity and quality, and complying with MS4 requirements will address a large portion of the load management required by the TMDLs.

4.1 E. COLI *LOAD REDUCTIONS*

The TMDL Analysis for Mill River utilized the cumulative distribution function method to calculate the necessary load reductions. The required load reductions consisted of several components: the Wasteload Allocation (WLA) reduction, calculated using wet event data and considered to be point source loading from urban runoff; a Load Allocation (LA) reduction calculated using dry condition data correlated to baseflow and nonpoint source loading; an overall TMDL reduction that pools the data; and a margin of safety (MOS), which is implicit in the calculation. Indicator bacteria sampling was conducted at two sampling stations within the reach of concern and as a result, TMDL reductions were calculated for each of those sampling stations. As noted above, each of the two stations exceeded *E. coli* criteria, although the distribution of sample results was quite different between the two. One of the stations, M2S, was located immediately downstream of Lake Mohegan and concentrations were much lower and in fact met the geomean standard, but exceeded the maximum concentration on several occasions. The interpretation of the measured lower concentrations from M2S relative to the other station (M3) is that Lake Mohegan was acting as a regional detention basin providing bacteria removal services.

As mentioned above, the TMDL analysis utilized a cumulative distribution function to assess necessary reductions. This is most easily represented graphically, with the plotting of a cumulative distribution curve, with concentrations on the x-axis and cumulative proportion of samples on the y-axis. In order to meet the water quality standards, the samples must fall to left of the curve. The benefit of this approach is that it allows individual samples to exceed the geomean standard of 126 cfu/100 mL, as long as cumulatively the geomean is met. It also draws a hardline at the maximum value, in this 576 cfu/100 mL. In order to calculate the necessary reduction a criteria value for the proportion is calculated and compared to the measured concentration to calculate the necessary reduction expressed as a percentage. The individual percent reductions are then averaged. The results of the loading/concentration reduction analysis are provided below.

Table 4.1: *E. coli* TMDL Analysis Summary

	Samples				Average % Reduction		
ID	Dry	Wet	Total	Geomean cfu/100 mL	Wet (WLA)	Dry (LA)	Total (TMDL)
M2S	16	10	26	105	31%	11%	19%
M3	20	11	31	299	52%	57%	55%

The necessary reductions are variable, as are the measured concentrations at each of the sampling stations. This reflects the differences not only in potential loading according to land use differences, but also flow and natural attenuation of pollutants throughout a complex watershed. As the TMDL represents a relatively small segment of Mill River (according to the Integrated Water Quality Report (IWQR, including 303(d) and 305(b) lists, about 4.1 river miles) and its watershed, additional exploration of required *E. coli* reductions was warranted. This included an analysis of the 2016 and 2017 Harbor Watch data, as well as the modeled concentrations developed using MapShed. Load reductions were calculated using a simplified method that CT DEEP adopted for *A Statewide Total Maximum Daily Load Analysis for Bacteria Impaired Waters* (2012), which is different than the method utilized for the Mill River TMDL. In this method, the percent reductions required are simple comparisons of calculated geomeans and single sample maxima to the relevant water quality standard, rather than accounting for cumulative distributions. While simpler, this method yields similar results that are therefore assumed to be of equal utility.

Table 4.2: Harbor Watch *E. coli* Reduction Summary

Sampling Station	Subwatershed	Geomean Reductions		Max. Reductions	
		2016	2017	2016	2017
Mill A	Southport Harbor	NA	54.5%	NA	54.5%
Mill 1	9	69.0%	57.7%	80.1%	52.0%
Mill 2	9	57.0%	67.0%	80.8%	69.4%
Mill 3	6	0.0%	0.0%	84.0%	0.0%
Mill 3.5	8	44.7%	31.1%	55.7%	43.5%
Mill 4	8	51.2%	14.3%	29.8%	0.0%
Mill 5	8	0.0%	0.0%	0.0%	50.3%
Mill 6	8	0.0%	0.0%	0.0%	20.0%
Mill 6.5	8	0.0%	0.0%	0.0%	7.1%
Mill 7	5	0.0%	0.0%	72.6%	0.0%
Mill 8	4	26.7%	0.0%	90.1%	75.0%
Mill 10	4	0.0%	0.0%	47.6%	28.0%
Mill 11	4	0.0%	0.0%	8.6%	0.0%
Mill 12	4	0.0%	0.0%	0.0%	0.0%
Mill 13	1	0.0%	0.0%	0.0%	0.0%

Reductions using the Harbor Watch data necessary to satisfy the geomean criteria varied widely throughout the watershed. In 2016, nine of the fourteen stations met the standard, but at the five remaining subwatersheds necessary reductions ranged from 27% to 69%. 2017, a wetter year, showed only four stations (excluding the newly added at that time Mill A in Southport Harbor) needed reductions ranging from 14% to 58%. Utilizing empiric data, rather than calculated loads, introduces inherent variability in these calculations which will change on an annual basis. In total, the required average reduction between the stations was 15%. In the interest of providing analysis on a subwatershed scale, the Harbor Watch stations were tied to the subwatershed delineations. Not surprisingly, the areas identified as the highest loaders in the MapShed model, were confirmed in the review of the empiric data. Indeed, Subwatersheds 4, 8, and 9, among the largest modeled concentrations, all required significant load reductions. The same analysis was conducted looking at the maximum criteria (576 cfu/100 mL). Required reductions to meet the maximum standard, in subwatersheds which exceeded the standards, ranged from 9% to 90%, but this is somewhat more nebulous than the stronger geomean data. A table summarizing these analyses is included below.

The same analysis was conducted utilizing the modeled concentration data on a subwatershed basis. The findings again corresponded with both the TMDL and the Harbor Watch data analyses. The headwater subwatersheds, 1, 2, and 3, required no reductions to meet the geomean standards, while the other subwatersheds required reductions of 24% to 66%. It is worth noting again that the subwatershed concentration data is based off the hydrology and loading potential of that individual subwatershed, that lacking the cumulative inputs of both bacteria and stream flow would not reflect observed concentrations in the stream per se, but the required reductions still provide a useful metric of the magnitude of the problem and the corrective actions needed. In addition, as with the load analysis, the Mill River watershed was modeled in total, and would require a roughly 27% reduction in *E. coli* concentrations to meet the geomean standards.

To recap, the required reductions are not easily distilled to a single number which is reflective of the variability of the system on a spatial, seasonal, and annual basis. According to the *E. coli* TMDL, average required reductions, as based on the cumulative distribution function method, will range between 19% and 55%. Other methods calculated herein and based on more recent Harbor Watch sampling data and modeling shows required reductions for the geomean standard between 14% and 69%, and reductions of up to 90% to meet the single sample maximum standard. In any case, the water quality criteria themselves will be the benchmark to ascertain compliance, but a significant effort to reduce bacteria loading or concentrations by around half will drive the selection and implementation of management measures.

Table 4.3: Modeled *E. coli* Reduction Summary

Subwatershed	*E. coli* (cfu/100mL)	Mean Reduction
Mill River	171.6	26.6%
1	71.0	0.0%
2	94.0	0.0%
3	84.6	0.0%
4	195.7	35.6%
5	189.3	33.4%
6	166.7	24.4%
7	170.7	26.2%
8	297.9	57.7%
9	371.3	66.1%

4.2 MS4 *PERMIT REQUIREMENTS*

The constituent municipalities within the Mill River watershed are all participants in the MS4 Program, subject to the MS4 General Permit. 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. The *E. coli* TMDL is also inextricably tied to the MS4, and it is stated that the MS4 is the basis of the TMDL implementation effort. 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 WMP, and progress in meeting the requirements.

4.2.1 GENERAL PERMIT CONDITIONS

Section 5 of the MS4 General Permit identifies several permit conditions. The principal, guiding conditions though 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 Mill River watershed is subject to several TMDLs. The Long Island Sound TMDL for Dissolved Oxygen, which governs the entirety of the State, the pollutant of concern is nitrogen. Mercury is another pollutant of concern covered by the Northeast Regional TMDL for mercury, which is also statewide but actually includes all of New England plus New York. As there are no explicit sources of mercury in this watershed, sources of known mercury contamination excluding atmospheric deposition, minimal management would be expected. Finally, the watershed is subject to three indicator bacteria TMDLs. The primary bacteria would be *E. coli* within the Mill River watershed which contravenes recreational uses. Fecal coliform is related to impairment of Direct Shellfish Harvesting within the estuarine portions of the lower Mill River and downstream in Southport Harbor.

4.2.2 STORMWATER MANAGEMENT PLANS

One of the permit conditions is the development of a stormwater management plan or similar document, including this WMP. 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 in turn including recent reporting on these measures from the Towns of Fairfield and Easton, the two largest contributing municipalities by area (respectively 33.9% and 52.9% of the watershed).

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. Both 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 WMP, 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 WMP, 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 two towns, but some elements are in progress as work continues or as refinements suggest themselves. In Fairfield, all mapping tasks are completed as is prioritization of sites, as well as record keeping, and reporting. Maps are being used to drive maintenance of BMPs. Refinements to legal authority are proposed under a single ordinance, whereas current ordinances are being used to enforce activities. Refinement of record keeping is also expected. The Town continues to work on addressing all IDDE-Appendix B technical requirements.

Easton is working on a written IDDE program, and continues to develop individual elements of the program. Aspects of outfall mapping is completed, and as of 2017 efforts to digitize the data to GIS formats and continue other mapping requirements is ongoing. Employees have received training in detecting illicit discharges during other maintenance activities. One illicit discharge was identified and corrected, as well as a failing septic system. The Town has drafted an illicit discharge ordinance that is expected to be adopted by 2019. Identification of priority areas for IDDE is ongoing.

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. Both towns have satisfied all conditions with the exception of updating land use ordinances. Specifically, the 2017 MS4 General Permit requires developers to comply with the 2002 *Guidelines for Soil Erosion and Sedimentation Control* as amended, the *Connecticut Stormwater Quality Manual*, and all stormwater discharge permits issued by CT DEEP, and any other additional measures as deemed necessary by the municipality. Both Fairfield and Easton are in the process of memorializing these updates. Otherwise both towns have updated interdepartmental site plan review processes, continue to review site plans for stormwater quality concerns, conduct site inspections on an as-needed basis to ensure compliance, maintain public comment through hearings and public alert systems, and require developers and consulting engineers to satisfy all permitting requirements and potential obligation to obtaining additional authorization from CT DEEP.

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 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

In Fairfield, updating land use regulations is pending, but most of these requirements have already been in use on the order of decades and enforcement is already in place for most projects. The other conditions are ongoing, consistent with newly released requirements, and are expected to be completed over the course of several years. Easton has drafted land use regulation updates and continues to work on implementing notification and public notice recording. They continue to conduct site inspections, have interdepartmental review coordination, and review site stormwater plans.

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. Fairfield largely relies on the Harbor Watch sampling efforts to meet this requirement. Easton has conducted extensive monitoring.

5.0 MANAGEMENT MEASURES

This section corresponds to the third of the EPA 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 WMP, 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 WMP 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. The specific implementation projects are the first located, sited, and conceptually designed projects related to the pollutant reduction measures discussed in the TMDLs. In addition to being constructed at identified locations, 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, is a trove of valuable information and will be a primary source for much of this information. Lastly, the pollutant removal efficacy and the field methodology for assessing candidate implementation sites will also be discussed.

5.1 REVIEW OF IDENTIFIED PROBLEMS AND MANAGEMENT MEASURES

This section will provide a brief review of identified pollutant loading issues and sources throughout the watershed at a subwatershed scale. A basic description of management measures and opportunities to correct the identified problems will be provided.

5.1.1 SUBWATERSHED 1 MILL RIVER HEADWATERS

This subwatershed, located in the headwaters of Mill River, according to measured water quality data, modelled pollutant loading, and the inventory of the natural resources, indicate that this subwatershed has the highest ecological quality in the Mill River watershed. In particular, the specific loads (load normalized for area or expressed as pollutants per unit area) of nutrient pollutants, solids, and bacteria are the lowest in the watershed.

Despite the high quality of this subwatershed, there are elements of the loading regime that provide targets for load reductions. There are several important high level considerations that bear remembering when identifying potential management measures for a watershed plan. First, is that pollutant loading is cumulative, and even in defined areas that have generally low loading and no contravention of applicable water quality criteria or impairment of designated uses, as the loads are transported through the watershed, they may manifest in a problem area downstream. From a mitigation perspective, removing an equal portion of the load whether at the point of impact or upstream is functionally identical. Second, even in rural areas, wherever there is a deviation in LU/LC or land use practices from a natural state (which in this watershed would be forested lands or wetlands predominantly) there is an opportunity to change those practices or implement in-situ controls (structures, plantings, etc.) to reduce loads. Last, management measures must address loads that are manageable. For instance, groundwater is often a major source of nitrogen loading, yet there are few practical means of directly addressing this loading. Instead efforts are best spent focusing on alternative, easily manageable loads, like fertilizers or septic management, that are both distinct from the groundwater load yet also indirectly control it. Of course, there are issues of prioritization and generally targeting loading where it is highest and most concentrated provides the greatest cost-benefit and total removal capacity, but there are also inexpensive BMPs for diffuse areas that may provide removal efficacies of similar cost-benefit.

This watershed has the greatest forest coverage of any subwatershed, and the second highest amount of agricultural lands at 4.7% of the subwatershed. While a modest amount, some elevation of the loads is attributable to agricultural uses in the watershed. Loading attributable to livestock is amongst the highest in the watershed and leads to increased nitrogen, phosphorus, and bacterial loading in the subwatershed. As such, manure management and stream buffers would be effective in managing these loads. This is the only subwatershed in which soil erosion or surface runoff accounts for more than 15% of the total solids load; indeed, hay and pasture lands alone account for 25% of the solids loading here. Therefore, agricultural BMPs focusing on preserving top soil, such as the use of cover crops and modifying haying practices, could be effective in reducing the solids load.

Overall, this is a low priority watershed, but relatively modest measures geared mostly towards agricultural practices could help reduce the loading of the pollutants of concern. Large portions of this subwatershed are already protected open space, but there are large undeveloped parcels that may be candidates for protection. In areas where environmental quality is high, land preservation is probably the best management strategy to prevent degradation.

5.1.2 SUBWATERSHED 2 EASTON RESERVOIR

Subwatershed 2 encompasses Easton Reservoir and adjacent areas. It is the largest subwatershed by area, and as a result it can generate large loads of some pollutants, for example it is the second largest contributor of phosphorus, yet the specific loads tend to be low to moderate indicating fewer manageable or concentrated loads. In many respects it is similar in land use, general loading scheme, and subwatershed load ranking to Subwatershed 1 although it is marked by increased development and open waters. There is only one documented use impairment in this subwatershed in which an unnamed tributary to Easton Reservoir originating at the Snow Farm Pond is not supporting aquatic life uses. Generally, there seems to be little significant water quality degradation in this subwatershed.

Once again, livestock contributes elevated loading of both nitrogen and phosphorus to the system, although both account for 10% or less of those loads respectively. Livestock is also the primary loader of indicator bacteria, accounting for over 50% of the total load. Manure management and stream buffers again are likely the best solutions to reduce these loads. Streambank erosion accounts for 85% of the sediment load, and the total nitrogen and total phosphorus loading attributable to eroded streambed material is somewhat elevated indicating that bank stabilization could be useful in reducing these loads. Soil erosion attributable to agricultural lands is also elevated, and BMPs designed to manage soil erosion would be important in reducing these loads. While a good portion of the subwatershed is State forest, and thus protected, additional opportunities for open space acquisition are available and should be investigated.

As with Subwatershed 1, this watershed provides relatively few opportunities for major load reductions. Agricultural BMPs, targeting the maintenance of top soil, reducing erosion, and managing manure, will be the primary method to target manageable loads in the watershed, but open space preservation and streambank stabilization may also play a part. This is a low priority subwatershed because of the low specific loading, which in turn, is function of relatively low development levels.

5.1.3 SUBWATERSHED 3 CRICKER BROOK

This area is a very close analog to Subwatershed 2. Hydrographically, this subwatershed is centered on Hemlock Reservoir. It is the second largest subwatershed, relatively lightly developed with forested lands covering nearly 60% of the watershed. This is the only subwatershed that does not intersect Mill River and is hydrologically connected to the system through Cricker Brook which discharges to Samp Mortar Reservoir, an impoundment of Mill River. Cricker Brook has been identified on the 303(d) list as not attaining for recreation for exceedance of *E. coli* and has been prioritized for inclusion in the Statewide Bacteria TMDL; according to the available data no source of *E. coli* has been identified. Watershed modelling indicates that bacterial concentrations and loading are higher than Subwatershed 1.

Utilizing pollutant load rankings for specific loads, this subwatershed is ranked 7th or 8th for the examined pollutants of concern, indicating low pollutant loading in general. Livestock again is implicated as a significant source of both TN and TP in the subwatershed. Similarly, farm animals account for nearly half the bacterial loading, but this is first examined watershed in which septic systems contribute more than 35% of the total bacterial load. Manure management should be a major consideration for the management of both nutrients and bacteria in the watershed. Expanding or repairing stream buffers can also aid in the management of these loads. Generalized septic system management is also recommended, but this is a general measure that will be encouraged system wide. Roughly 10% of the sediment load is attributable to soil erosion from hay/pasture lands and agricultural BMPs to limit soil erosion should be implemented where appropriate. There is significant protected open space in the watershed, primarily State forest, but some municipal properties are also preserved including the Richardson Golf Course Areas. Where possible, open spaces should be preserved. Streambank erosion accounts for nearly 88% of the solids loading in the subwatershed and 35% of the phosphorus load. Streambank stabilization measures, in selected locations, could help manage this load.

Subwatershed 3 does not rank as a high priority area for the control of nutrients, solids, or bacteria according to the pollutant load modelling, but recent prioritization for the control of *E. coli* in Cricker Brook in the downstream portions of the subwatershed indicate the need to manage for bacteria. This is most ably accomplished through manure management in agricultural lands, as well as through an increasing focus on limiting septic system loading. Controlling soil erosion and stabilizing streambanks is important in managing the sediment load.

5.1.4 SUBWATERSHED 4 CANOE BROOK

Subwatershed 4 represents a major shift in development pattern and water quality relative to the three previous watersheds. This subwatershed is sited in the eastern central portion of the watershed and is bisected by Mill River and bound by Easton Reservoir at its upstream extent and Lake Mohegan downstream. This is the largest of the more urbanized subwatersheds at over 5.3 mi^2. Developed lands account for over 50% of the area, although forested cover accounts for 40%. This is the last subwatershed with any significant agricultural land at just 3.2%.

In addition to the changes described, the waters within this subwatershed are designated Class A; there are no large surface waters in this watershed. This is one of the most intensely studied and sampled portions of the Mill River watershed. This watershed contains the segments of Mill River that are identified within the TMDL for *E. coli*, and field sampling for that effort showed routine contravention of both the geomean and single sample maximum standards. Harbor Watch sampling confirmed high *E. coli* concentrations in this watershed and reach more recently. Utilizing the pollutant loading data, it ranked first or second highest for most of the total loads and specific loads of nitrogen, phosphorus, and sediment. It was also the highest loader for fecal coliform overall and had the third highest modeled *E. coli* load by concentration. This type of loading is spurred of course by increased development density as well as a reliance on onsite septic systems, although a portion of the subwatershed is sewered, primarily to the east of Mill River. The storm sewer network, which is built to service these types of residential areas and the supporting infrastructure, also leads to increased conveyance of the loads commensurate with increasing impervious coverage and base load generation rather than natural or engineered stormwater treatment. There is little preserved open space in this subwatershed, much of what does exist is developed in some fashion, and relatively little opportunity to affect major protection efforts.

Because of the scale of pollutant loading a more detailed examination is required. TN loading is high in this watershed. Approximately 10% of the nitrogen load is attributable to septic systems, nearly 17% from generalized runoff processes, and 9% from streambank erosion. The effective management of these loads will focus most strongly therefore on septic management and generalized stormwater quality treatments. Since streambank erosion is also a major source of nitrogen streambank stabilization efforts and stormwater volume reductions, met through increasing perviousness, infiltration, or detention, are also important means to manage loads. Despite a reduction in agricultural lands, TP loads attributable to livestock and runoff from hay/pasture should be controlled through manure management and other agricultural BMPs. Loads attributable to streambank erosion and septic systems are also high and would be treated concurrently through the same means suggested to manage those components of the nitrogen load. The sediment load from this subwatershed is almost entirely driven by streambank erosion and stabilization efforts should be considered, although runoff still accounts for about 6% of that load.

Bacterial loads, as evidenced through sampling, modeling, and targeted control efforts through inclusion in a TMDL, are elevated and require significant attention. Septic systems account for nearly 70% of the bacterial load and septic management will be the primary method to manage this load. Despite that, both farm animals and runoff from urban areas account for 12-16% each, addressing these items through manure management and various urban stormwater BMPs is crucial for reducing the bacterial loads. In addition, those measures identified in the MS4 permit requirements, such as Illicit Discharge Detection and Elimination (IDDE) will also be important in affecting load reductions.

Subwatershed 4 is of highest priority for the control of all examined pollutants of concern. This watershed is large, relatively densely developed, but largely lacks sanitary sewer service that could offset some of the loading. It is also a target rich for implementation projects. One of the benefits of focusing on this watershed is that the functionality of BMPs largely overlaps. For instance, BMPs meant to treat stormwater quality will generally have a positive impact on both nutrient pollutants, solids, and bacteria, although the various designs and techniques will vary in removal efficacy.

5.1.5 SUBWATERSHED 5 LAKE MOHEGAN

Subwatershed 5 is located to the south of Subwatershed 4. Mill River bisects the subwatershed, but hydrographically, it is dominated by Lake Mohegan and extends to Samp Mortar Reservoir downstream. This is the smallest of the subwatersheds at just 274 acres. In keeping with the general pattern of increasing development moving south within the watershed, developed lands account for 68% of this subwatershed. Most of the developed areas within the subwatershed have sanitary sewer service.

This subwatershed is also included in the *E. coli* TMDL, but unlike the next subwatershed, concentrations were somewhat lower with lower required TMDL reductions. Mill River sampling stations in this stretch continue to show exceedances of the *E. coli* maximum water quality standard as reported by Harbor Watch.

Overall, this subwatershed has low nitrogen loading as both a total load and specific load. Despite the sewer service in the area, septic systems account for the highest percentage of loading of any of the subwatersheds at 12.5%, but the total load is only 25 kg, less than 0.1% of the total nitrogen load in the watershed. TP loads, both total and specific are similarly low. Regarding sediment loading, the specific load is ranked 6th. Of the developed or urbanized subwatersheds this is the only one in which streambank erosion accounts for less than 90% of the total load. The indicator bacteria are the one area where this subwatershed has a high concentration, ranking 4th overall. The primary source is septic systems at nearly 70%, but runoff, a highly manageable load, is high at nearly 28%. Stormwater managements and septic management, as well as IDDE will be important measures to combat bacterial loading.

Subwatershed 5 is ranked as medium priority, because it has known and continuing exceedances for *E. coli* and includes segments of Mill River with a bacteria TMDL. Otherwise, pollutant loading is low in both a relative and absolute sense, but indicator bacteria, particularly *E. coli*, is the primary pollutant of concern.

5.1.6 SUBWATERSHED 6 BROWNS BROOK

This arced subwatershed forms much of the southwestern watershed boundary before curving to the east and crossing Mill River; it terminates at the head of tide. It is well developed throughout and dominated by developed, open space and low intensity development indicating relatively large lot size. The southeastern portion is sewered. This subwatershed is not included in the *E. coli* TMDL, although Harbor Watch data indicates ongoing exceedance of the single sample maximum criterion. Sampling conducted by Harbor Watch also shows contravention of the fecal coliform standards at the head of tide station at the bottom of the subwatershed.

Within the larger Mill River watershed, TN and TP specific loads rank moderate to high, with high sediment loads on both a total and specific load basis. Interestingly, nitrogen loading is driven by groundwater inputs, at over 90%, the highest within the watershed. While the septic load is low when expressed as a percentage, overall it has the third highest nitrogen load attributable to septic systems, thus indicating septic management as important for the control of nitrogen loading. Groundwater is also a major loader of TP, tied for the highest. TP from streambank erosion is relatively high. Sediment loading is almost wholly driven by streambank erosion, and stabilization efforts including buffer repair is important.

Bacterial loading is modest in this subwatershed, with total load ranked 5^{th} and *E. coli* concentration ranked 6^{th}. Septic systems are the primary loader at nearly 70% of the bacterial load, but runoff from urban areas accounts for 25% of the load. As such, septic management and stormwater quality management for bacteria will be import in reducing bacterial loads.

This subwatershed is considered a high priority watershed because of its moderate to high loads across the examined pollutants of concern and because of its urbanized nature. Additionally, continued monitoring of Mill River shows exceedance of indicator bacteria water quality standards. Last, because of the source and general nature of pollutant loading, there are opportunities to effectively manage the loads in this subwatershed.

5.1.7 SUBWATERSHED 7 SAMP MORTAR RESERVOIR

Subwatershed 7 encompasses a small area, 0.85 mi^2, in the southeastern portion of the watershed. It is dominated by Samp Mortar Reservoir, an impoundment of Mill River. The entire portion of the subwatershed east of Mill River is sewered as well as the northwestern quadrant upstream of Cricker Brook with plans to expand the area. This section is just downstream of the TMDL segments on Mill River in Subwatersheds 5 and 4 and along the TMDL-prioritized Cricker Brook in Subwatershed 3. As a percentage, developed lands account for nearly 80% of the watershed area, with 10% as open water, and just 11% forested. This is actually the second most highly developed subwatershed, but much of the development is of low intensity and overall imperviousness is lower than other subwatersheds downstream. There are several open space areas, aside from the reservoir, some of them privately held, others as parks including recreational fields. This subwatershed, surprisingly, is poorly documented likely because there are no free-flowing sections of Mill River, but as a result there are no described water quality impairments. This watershed is bound upstream and downstream by two of the most impaired watersheds and thus many of these problems likely manifest through here as well. To some degree however, the reservoir itself likely acts as large, regional BMP helping to lower bacteria concentrations downstream, as well as assimilating solids and pollutants loads. To some extent, this is already documented at Lake Mohegan, upstream of this area, where bacteria concentrations remain high but are much reduced relative to points upstream.

Total loads generally are ranked as medium to low, while specific loading rates tend to be moderate in the subwatershed. Nitrogen loading has a strong septic component. While most of the subwatershed is sewered, proximity to the river/reservoir may play a part in the loading. Additionally, groundwater loading is paradoxically low because of the reservoir and some of that load could manifest as higher septic loading. Surficial runoff as a vector represents 16% of the TN load, second only to Subwatershed 4 in the urban subwatersheds. As such, septic management and stormwater management controls will be important in reducing this load. The same patterns hold true for phosphorus loads, and thus the same management measures would be used. Sediment delivery is almost wholly a function of streambank erosion, but given that Mill River is impounded here and there is essentially no mapped tributary network, no specific efforts to manage sediment is required here, although other management measures will result in reducing sediment loads. Modeled bacteria concentrations are ranked fifth, right in the middle for the entire watershed. While septic systems again are identified as greatest contributors, runoff accounts for nearly 37% of the load, about 50% greater than the next subwatershed. As a result, this indicates that besides generalized septic management practices, the focus should be on the capture and treatment of stormwater for the mitigation of bacteria.

Overall, managing loads in this subwatershed is of medium priority. Certainly, management efforts here should focus most highly on controlling runoff of *E. coli* from urbanized areas by improving stormwater treatment capacity.

5.1.8 SUBWATERSHED 8 GREENFIELD HILL/RIVERFIELD

This is a moderate sized watershed located in the southeastern portion of the watershed. Mill River bisects the subwatershed. There are no regulated dam features, however there are a number of small offline impoundments and a variety of constrictions and other structures that cause backwatering and overwidening of the river. This is a highly developed watershed, at over 70% development, although 23% of the watershed is classified as forest. There are a number of preserved open spaces, including a large cemetery, an elementary school, and several natural areas. The eastern half of the watershed is sewered. This subwatershed has a large and well mapped tributary network.

There are a variety of documented water quality impairments in this section. Harbor Watch monitoring data indicates systemic contravention of *E. coli* water quality criteria for geomean and single sample maxima. It also contravenes dissolved oxygen standards, which is not surprising given the evident reduction in flow velocities and numerous small impoundments. In terms of pollutant loading, this watershed is probably the worst. It has the highest total and specific nitrogen loads, the highest specific phosphorus load, and is ranked second highest in total solids and specific solids loading and bacterial load and concentration.

TN loading is driven primarily by groundwater, and septic loading is moderate at approximately 6% of the TN load. The prominence of groundwater as a source of loading is probably driven by its position low in the watershed, with a relative lack of surface waters by area. As usual, streambank erosion is the major contributor to phosphorus loading, but septic systems are also large contributors at roughly 12%. TP from surface runoff is tied to medium and high density mixed development in the watershed. Nutrient pollutants are best managed through stormwater management and septic management practices. Over 95% of the sediment load originates within the stream, indicating that streambank stabilization and buffer enhancements are the best methods to reduce these loads.

Modeled *E. coli* concentrations show that the loads exceed the geomean standard throughout most of the year. Septic systems account for 78% of the loads, but urban runoff also accounts for nearly 20%. Wildlife is a small contributor as modeled, but realistically given reports and the park like settings of the river in this area, waterfowl loading is probably much higher. Septic management, stormwater management including management of domestic animal waste, and likely waterfowl management will all be required to reduce bacteria loading here.

This area is of highest priority due to its status as a major loader of all the pollutants of concern. Because of the development density, there are many opportunities to implement the various proffered management measures, and these will have to be constructed or adopted on a widescale to affect necessary load reductions.

5.1.9 SUBWATERSHED 9 MILL RIVER UPPER ESTUARY

This unique subwatershed is situated at the lower terminus of the Mill River watershed where it discharges to Southport Harbor. Unlike the remainder of the watershed, this subwatershed is estuarine as it is tidal throughout to the head of tide marking the upper bound of the subwatershed, and the water is brackish, at least in the lower reaches. Mill River is designated a Class SA water in this subwatershed. This is the most highly developed subwatershed, with nearly 85% of the land built out. As a percentage of land mass, it has the highest relative concentration of low, medium, and high intensity development. Most of the watershed is sewered, with the exception of the northwestern quadrant.

Harbor Watch monitoring data indicates nearly perpetual exceedance of water quality standards for *E. coli*, as well as major problems for dissolved oxygen and fecal coliform. In effect, all the water quality impairments of the watershed are manifested in a cumulative way here in the lowest reaches of Mill River. Loading is also problematic. As a small subwatershed, the total loads originating within this subwatershed are actually small.

Specific loads for TN and TP are ranked 3rd, while the specific sediment load is 5th which may be lower than expected because so much of the land is already impervious and thus somewhat resistant to surficial erosion.

TN loading is driven by groundwater, but the manageable loads, including surface runoff and septics, accounts for about 15% which should be addressed through stormwater and septic management schemes. TP loading is different than the other urbanized areas; streambank erosion accounts for just 24% of the TP load, but septic systems and urban runoff, both manageable loads, account for over 40% of the load. The same measures used to control nitrogen will be effective in phosphorus management. Solids loading is again dominated by streambank erosion, and it should be noted that the finer grained materials in this subwatershed are more mobile than the watershed at large, but surficial loads account for over 10%. Stormwater management as well as streambank stabilization and buffer enhancements are key for managing solids loads. Septic systems are the main source of *E. coli* loading, but runoff from urban areas is also important and accounts for nearly 21% of the load. Wildlife is clearly underrepresented, and thus requires management as well. Stormwater, septic, and wildlife and pet waste management will be necessary to affect load reductions.

Overall this is a high, but not highest priority watershed. Water quality is probably the worst in this subwatershed, and yet loads are not, although certainly bacterial loading is high. As mentioned above, the poor water quality is reflective of the cumulative loading throughout the watershed that manifests at the terminus of the stream. While it is important to address the loads in this subwatershed, it is more important to manage the loads where they are highest, contribute disproportionally relative to area, or where they are most highly concentrated and easily tackled. In utilizing a holistic watershed approach relative improvement in water quality affected through load management should be greatest here, although this subwatershed will always be, as a consequence of its position at the end of the watershed, most susceptible to impairments.

5.1.10 SUMMARY OF PROPOSED GENERALIZED MANAGEMENT MEASURES

The following table briefly summarizes the proposed general management measures in the watershed, as well as the priority rating for each subwatershed. Not surprisingly, a few general measures are consistently identified throughout the watershed, which is simply a function of development patterns and the overall similarity of the subwatersheds to each other. At a high level, the subwatersheds can be split into the rural north, including Subwatershed 1, 2, and 3, and the urbanized watersheds south of the major reservoirs including Subwatersheds 4, 5, 6, 7, 8, and 9. Despite this split, septic management and streambank erosion controls are identified throughout simply as watershed-wide sources of pollutant loading. In the following sections of the WMP a more detailed discussion of these measures will be provided which will explore the various management measures under each umbrella.

Table 5.1: Generalized Management Measure Summary and Prioritization

SubWS ID	SubWS Name	Management Measures	Priority
1	Mill River Headwaters	Manure management and livestock-centric stream buffer enhancement; agricultural BMPs for soil preservation; open space preservation.	Low
2	Easton Reservoir	Manure management and livestock-centric stream buffer enhancement; agricultural BMPs for soil preservation; streambank stabilization; open space preservation.	Low
3	Cricker Brook	Manure management and livestock-centric stream buffer enhancement; agricultural BMPs for soil preservation; streambank stabilization; open space preservation; septic management.	Low
4	Canoe Brook	Septic management; streambank stablilization; stormwater management for quality and volume; manure management; agricultural BMPs.	Highest
5	Lake Mohegan	Stormwater management; septic management; IDDE.	Medium
6	Browns Brook	Septic management; streambank stabilization, buffer enhancements; stormwater management for bacteria.	High
7	Samp Mortar Reservoir	Stormwater management; septic management.	Medium
8	Greenfield Hill/Riverfield	Stormwater management; septic management; streambank stabilization, buffer enhancement; waterfowl/pet waste management.	Highest
9	Mill River Upper Estuary	Stormwater management; septic management; streambank stabilization, buffer enhancement; waterfowl/pet waste management.	High

5.2 GENERAL MANAGEMENT MEASURES

This section will provide information on the various management measures described above. Some of these management measures may be thought of as at-large measures, those designed to treat especially diffuse loading with implementation undertaken at the property owner level, while others are more complex or structural solutions that may be the responsibility of the homeowner or sponsored by the towns or other stakeholder.

5.2.1 SEPTIC MANAGEMENT

Septic management has been offered as one of the primary managements measures to address bacterial loading in the Mill River watershed, as well as to reduce nitrogen and phosphorus loads. Septic systems are known by a variety names, and are officially recognized as Subsurface Sewage Disposal Systems (SSDS) by the Fairfield Health Department. Septic systems are designed to treat and dispose septic wastewaters. Traditional systems consist of a septic tank that receives wastewater, that is then discharged to a distribution box and thence through perforated conveyance lines into the drainage field. The tanks provide primary treatment that includes the separation of solids that sink from the wastewater and subsequent bacterial decomposition of those precipitates. Secondary treatment is provided as the wastewater infiltrates the subsurface soils, through adsorption, filtration, oxidation, and other means. In addition to these traditional designs, there are older cesspools, generally simple masonry tanks with no drain field, mound-type or select fill systems in which the drain field is constructed of sand above grade where the depth to the limiting zone is insufficient to ensure proper function, and a host of new alternative designs. A schematic of a traditional system is provided below.

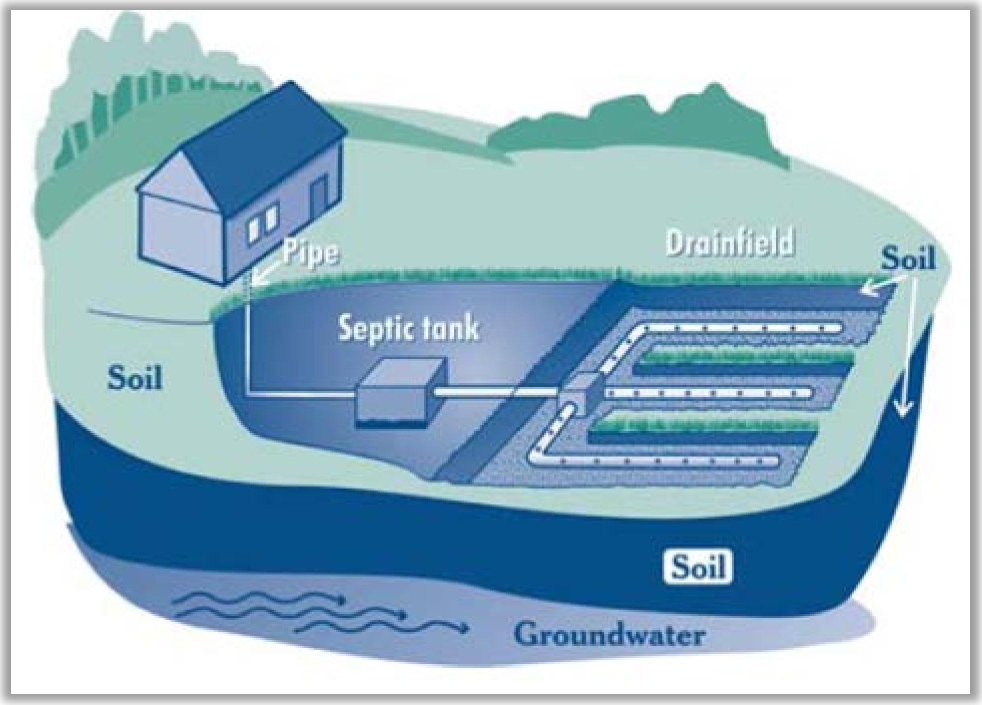


Figure 5.1: Traditional septic system schematic. Source: USEPA

Septic systems are an important component of managing wastewater, especially in rural communities and even in older urbanized areas where treatment and conveyance infrastructure does not exist. Treatment capacity of these systems can be high, especially as it pertains to bacteria and phosphorus, although nitrogen, as discussed above, is highly soluble and does not readily bind to soil particulates so these loads are harder to manage. The biggest problem from a loading perspective is septic system failure. This is a somewhat nebulous term and definitions vary. Some failures are very obvious, others less so. Failures can result from design, performance, or age, but these intersect and overlap. Common failure types according to the EPA are:

- Hydraulic – Excessive hydraulic loading to undersized systems, low soil permeability, ponding, poor maintenance, or increasing water use over the design capacity.
- Organic – Excessive organic loading from unpumped, sludge-filled tanks results in biomat loss of permeability (a stratum of anaerobic bacteria lining the trenches in the drain field).
- Depth to Limiting Zone – Insufficient soil depths, high water tables, and impermeable layers can all diminish pathogen removal and hydraulic performance.
- System Age – Systems more than 25 to 30 years old. Failure rates in older systems triple. Regular maintenance, e.g. tank pumping and alternating leach fields, can prolong system life indefinitely.
- Design Failure – Inappropriate system design for site characteristics including hydraulic load or restrictions.
- System Density – Cumulative effluent load from all systems in watershed or groundwater recharge area exceeds the capacity of the area to accept or properly treat effluent.

In the Mill River watershed, only 12% of the area is sewered, while the remaining 88% of the watershed is service by onsite septic systems; in Fairfield (including portions of the town outside of the watershed) 15% of the population rely on septic systems for wastewater treatment. In six of the modeled subwatersheds, septic systems are identified as the primary loader of bacteria, as well as a major source of both nitrogen and phosphorus. Several of these common failures are especially concerning in this watershed, including system age and system density.

According to the Fairfield Town Sanitarian, the average age of septic systems in the town is 31 years. This is above the age of concern cited above and indicates the potential for a trebling of failures in the years ahead. A study published by the Connecticut Agricultural Experiment Station showed a half-life of traditional septic system designs as 26.7 years; stated differently the cumulative failure rate is 50% at 26.7 years (Hill, D.E. and C.R. Frink, 1974). In addition to the increased risk of failure with the aging systems, there is also concern regarding system design, siting, and construction. The *Connecticut Regulations and Technical Standards for Subsurface Sewage Disposal Systems* were updated in 2000 and revised again in 2018 and include a variety of measures meant to reduce failure rates and increase system performance. Failed systems under the technical regulations define a failed system as "effluent surfacing to the ground, backing up into building plumbing, and/or identified as causing pollution to State groundwaters. Age and improper installation are cited as the most common reasons for system failure." Failure rates are seemingly low in Fairfield, cited as approximately 0.6% annually. Looking at the system, with glacial till dominated geology, relatively good infiltration would be expected in the watershed, which could minimize the obvious failures stated above, ponding on the leach field and sewage backup. The third component of the failure triad, pollution to State groundwaters, is much harder to detect. This study, using both available and modeled data, as well as a general assessment of septic system density, shows that this septic system loading is problematic. First, field measurements throughout the watershed indicate frequent, distributed, and sometimes severe contraventions of indicator bacteria criteria. Modeling of the system confirms this, although caveats are warranted. The model used a failure rate of 15%, much higher than reported by Fairfield but consistent with EPA estimates of failures rates between 5 to 25%. This failure rate aligns though with the age of the systems and the measured values. The EPA has also stated that septic systems within 100 yards of surface waters will influence water quality and due to the density of the tributary network within the watershed this highlights the vector between septic systems and water quality.

Managing septic loads and improving septic system performance to reduce pollution of surface and groundwaters will require participation of both the government and regulating agencies and departments as well as the system operator, typically a homeowner or other controlling authority in commercial or public setting. At its most basic, septic management for existing systems must incorporate actions for the following elements:

1. Inspection
2. Maintenance
3. Repair
4. Replacement

For the most part, these items will be the responsibility of the system owner. Economics are an important consideration because there are costs associated with each of these steps, yet there are also cost savings involved in minimizing repairs or replacement through spending on inspection and maintenance. Adherence to the State technical regulations and the oversight of the approval process for new development and system replacement performed by the local health department are important in ensuring proper performance and most importantly decreasing health impacts. As with any program that needs to reach a wide audience, outreach and education are ultimately the key to success. Fortunately, there are a variety of existing brochures, handouts, and other similar materials that can easily be adopted, as well as materials the towns already utilize.

INSPECTION

In order to avoid septic system failure, systems need to be inspected by trained professionals regularly. Inspections often include, but are not limited to the following elements:

- Check accumulation of sludge, scum, or trash
- Identify previous inspections and maintenance
- Piping to and from the box should be assessed for clogs, cracks, and failures
- Assess tank condition for cracks, rust, baffle integrity, misalignment, and malfunction

- Assess leach field conditions, which may require digging a cross-section

In addition to these elements, homeowners should be aware of potential performance issues. This would include: surface ponding at the drainfield; lush, green grass growth at the drainfield; slow-draining of toilets and sinks; and sewer odors, both internally and externally.

State regulations require that inspections only be performed by licensed or certified onsite wastewater professionals. Inspections are required during real estate transactions.

MAINTENANCE AND BEST MANAGEMENT PRACTICES

Maintenance is one of the most important factors in the management of septic systems. Without proper periodic maintenance performance suffers and they may not properly treat the effluent leading to excessive nutrient and bacteria loading that could manifest as both human health problems and impairments to surface and groundwater quality. The following maintenance tasks and BMPs should be part of the routine operation of onsite wastewater treatment systems:

- Septic tanks should be pumped out and inspected every 2 to 5 years; for systems installed post-2000 filters at the outflow baffle should need to be serviced at the same time. For systems that are undersized, experience heavy use, have exhibited performance problems, are subject to non-flushable wastes, or are nearing the end of their life cycle, pumping frequency may need to be increased.
- Maintain inspection records and know the location of the access manhole, inspection ports, and drainfield.
- Practice water conservation and limit, where possible, excessive wastewater generation.
- Do not drive or park on the septic as this has the potential to damage septic components and compact soils.
- Divert runoff from impervious areas including roofs and driveways away from the system.
- Limit vegetation on the systems to grass; woody vegetation can damage pipes and tanks.
- Use low-phosphorus or no-phosphorus detergents
- Septic system additives are not effective and may compound problems or leach organic solvents.
- Do not dispose of non-degradable material such as grease, cigarette butts, or personal hygiene items, do not use garbage disposals as these can overload the system with organic materials, and do not dispose of medicines, solvents, paints, poisons, or excessive household cleaning chemicals.

While many of these BMPs are common sense measures, they can significantly add to system life and the reduction of pollutants if faithfully observed. From an operational perspective, maintenance pumping is the most important action. If a system is not properly cleaned, sludge will buildup in the system and could either clog pipes and the outlet, or foul the drainfield which could cause flooding of untreated effluent or backup into the structure. Pumping removes the settled phosphorus, solids, and other nutrients before it reaches system capacity. A properly maintained septic system will cost far less over the long run.

REPAIRS, REPLACEMENTS, AND NEW CONSTRUCTION

Professional inspections, inspections during pump outs, and general operator awareness may necessitate system repairs to maintain system efficacy or correct deficiencies. These repairs can be minor or major, and given the severity of the impairment could require outright system replacement. Major repairs and other alterations could require town approval, as would replacements. As mentioned above, obvious and catastrophic failures occur at a low rate in Fairfield, however given the age of the systems it is expected that the failure rate will increase in the coming years. Replacements in particular may make a major difference in pollutant loading in the watershed as replacements systems will adhere to current technical regulations that ensure better treatment of effluent.

New systems will similarly provide enhanced treatment and will ensure better siting relative to existing and limiting conditions at the site and may preclude certain areas for onsite wastewater treatment. One of the recent changes is requiring two-chamber tanks to better segregate solids (Figure 5.2). Connecticut does not currently permit advanced alternative systems. In any case, adherence to current CT DEEP, CT Department of Public Health, and local ordinances will ensure proper disposal of onsite wastewater. This is accomplished through the permitting and review process and design guidelines.

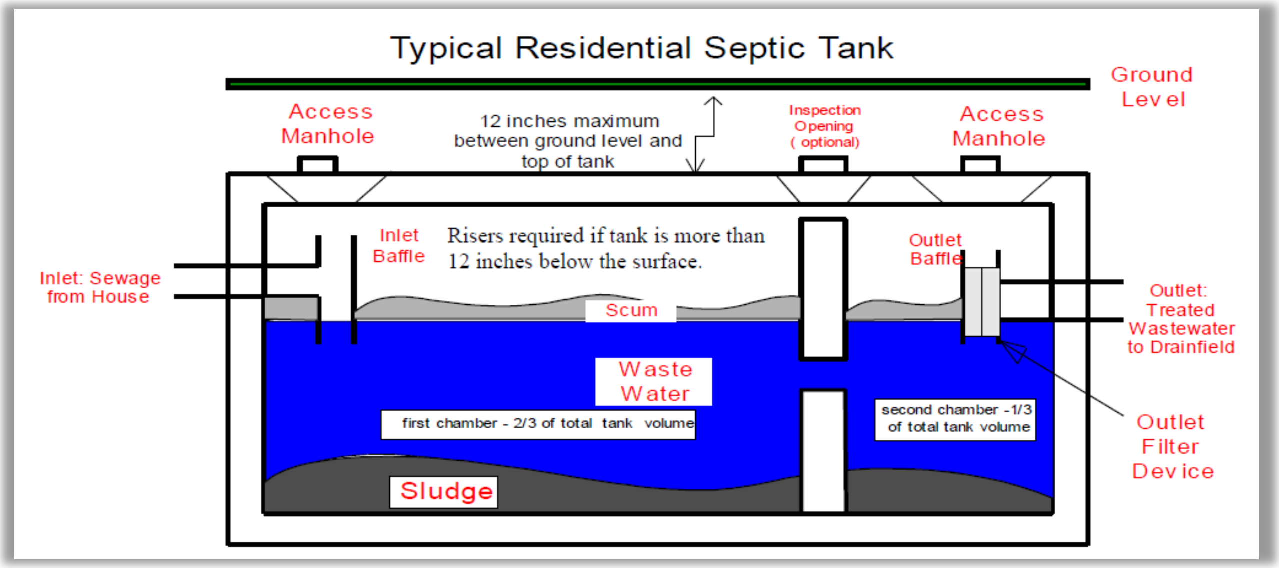


Figure 5.2: Two-chamber tank. Source: CT Southwest Conservation District

EDUCATION, OUTREACH, AND RESOURCES

Public participation is key in ensuring septic management efforts are successful. This requires outreach efforts to educate homeowners about the need to implement an inspection and pumpout regime and to incorporate the suggested BMPs. These types of efforts are already underway and should be expanded where possible. Educational materials, brochures, handouts, public meetings, newspapers, and websites are all effective teaching tools. Where possible the link between septic maintenance and achieving water quality goals in the community and the improvement of impaired recreational uses needs to be made. Municipalities also need to be seen as partners in these endeavors and community resources. The WMP includes a section on these various elements which will point to a variety of educational resources, technical information, costing, and economic assistance.

5.1.2 STORMWATER MANAGEMENT

Stormwater Management is another primary management measure that must be employed to affect load reductions in the Mill River watershed. For this WMP, stormwater management measures will focus on the retrofit of existing stormwater management features or installing stormwater management measures in areas where it is lacking, either wholly or in part. It will not focus on stormwater management measures for new development or redevelopment projects because those measures are already required under the MS4 program and enshrined in town ordinances. In particular, the use of Low Impact Development (LID) is encouraged to the Maximum Extent Practical (MEP) and performance standards should meet or exceed those of the *Connecticut Stormwater*

Quality Manual. There are standards for both redevelopment and new development with separate criteria for each based on the Directly Connected Impervious Area (DCIA). The MS4 permit states:

1. For redevelopment of sites that are currently developed with Directly Connected Impervious Area (DCIA) of forty percent or more, retain on-site half the water quality volume (the runoff from a precipitation event of 1 inch) for the site
2. For new development and redevelopment of sites with less than forty percent DCIA, retain the water quality volume for the site

There are a number of conditions regarding these projects that have been outlined in the MS4 section above, but as part of existing land use regulations proper stormwater management for new development and redevelopment is adequately covered. The focus on retrofitting existing stormwater management practices or implementing stormwater management where none exists is important in the context of this watershed, in which there is a high level of existing development that is serviced by an aging infrastructure that is failing to a certain degree to protect water quality in the watershed as documented by the 303(d) list, inclusion in various TMDL analyses, continued monitoring efforts, and modeling conducted herein. Measures to be implemented will largely draw upon the Stormwater Quality Manual, both as an exhaustive source of these measures and as the resource identified by the MS4 program.

STORMWATER MANAGEMENT MEASURE SELECTION

This WMP has shown through characterization efforts discussed above that the primary pollutant of concern in the watershed is *E. coli*, one of the indicator bacteria. It also has elevated loading of the nutrient pollutants nitrogen and phosphorus, excessive solids loads, and elevated stormflow/runoff volumes as a consequence of imperviousness. The following figure demonstrates the effectiveness of various stormwater management measures for different pollutants of concern.

Category	Practice	Pollutant Reduction: Sediment	Total P	Total N	Metals	Hydro Carbons	Bacteria	Ground Water Recharge/ Runoff Volumn Reduction	Stream Channel Protection	Peak Flow Control
Stormwater Ponds	Wet pond	●	●	●	●	●	◐	○	●	●
	Micropool ED pond							◐	●	●
	Wet ED pond							◐	●	●
	Multiple pond system							○	●	●
Stormwater Wetlands	Shallow wetland	●	●	●	◐	●	●	○	●	◐
	ED wetland							○	●	●
	Pond/wetland system							○	●	●
Infiltration Practices	Infiltration trench	●	●	●	●	◐	●	●	◐	○
	Infiltration basin							●	●	◐
Filtering Practices	Surface sand filter	●	●	●	●	●	◐	◐[1]	◐	○
	Underground sand filter							○	○	○
	Perimeter sand filter							○	○	○
	Bioretention							◐[1]	◐	○
Water Quality Swales	Dry swale	●	◐	◐	●	◐	○	◐[1]	○	○
	Wet swale							○	○	○

Notes: ● Effective
◐ Somewhat effective
○ Least effective

[1]If designed as exfilter
ED – Extended Detention

Figure 5.3: Stormwater Management Effectiveness Criteria. Source: CT Stormwater Quality Manual

Unfortunately, as the primary pollutant of concern bacteria are among the hardest to treat. Various stormwater wetland and infiltration practice designs offer the best control for bacteria. Stormwater ponds and various filtering practices offer some treatment but of reduced efficacy relative to other designs. One benefit of any of these designs is that they are also effective in the treatment of stormwater for solids and nutrients, and may also offer channel protection and flow control benefits. Water quality swales offer little in the way of bacteria removal although they can be effective for the removal of both solids and metals. In some cases, particularly in maintained lawn space they may be the most appropriate BMP.

In addition to selecting BMPs for a target pollutant, site constraints are also important. For instance, in residential areas there are often space constraints and concerns regarding nuisance insects and safety such that features with open water may be undesirable. Physical characteristics such as slope and infiltration capacity must also be considered. A figure showing some of the pertinent criteria is provided below.

Category	Practice	Soil Infiltration Capacity	Seasonally High Water Table	Drainage Area (acres)	Slope	Required Head
Stormwater Ponds	Micropool ED pond	USDA Hydrologic Soil Group A and B soils may require pond liner unless groundwater intercepted	Construct below water table. Construct liner for sites with higher potential pollutant loads or water supply aquifers.	10 min[1]	15% max	4 to 8 ft
	Wet Pond			25 min[1] 1-5 max[2] (pocket pond)		
	Wet ED pond					
	Multiple pond system					
Stormwater Wetlands	Shallow wetland	USDA Hydrologic Soil Group A and B soils may require pond liner unless groundwater intercepted	Construct below water table. Use liner for sites with higher potential pollutant loads or water supply aquifers	10 min	8% max	2 to 5 ft
	ED wetland			5 max[2] (pocket wetland)		
	Pond/wetland system					
Infiltration Practices	Infiltration trench	Min field measured infiltration rate 0.3 in/hr Max infiltration rate 5.0 in/hr Pretreatment required over 3.0 in/hr	Bottom of facility 3 feet above seasonally high water table	2 max[2]	15% max	1 ft
	Infiltration basin			10 max[2]		3 ft
Filtering Practices	Surface sand filter	Unrestricted	Underdrain for unlined system 2 feet above seasonally high water table	25 max[2]	6% max	5 ft
	Underground sand filter			10 max[2]		5 to 7 ft
	Perimeter sand filter			2 max[2]		2 to 3 ft
	Bioretention			5 max[2]		2 to 5 ft
Water Quality Swales	Dry Swale	Unrestricted	Swale bottom 2 to 4 feet above seasonally high water table	5 max[2]	5% max	3 to 5 ft
	Wet Swale	Unrestricted	At or below seasonally high water table	5 max[2]		<1 ft

Notes: [1]Unless adequate water balance
[2]Drainage area can be larger if appropriately designed
ED – Extended Detention

Figure 5.4: Physical Feasibility Criteria. Source: CT Stormwater Quality Manual

The following sections will discuss these various treatment designs, especially as they pertain to the management of bacteria. In addition to the primary treatment practices discussed above, secondary treatment practices will also be explored including catch basin inserts and media filters.

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; and biological uptake. 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 primary 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

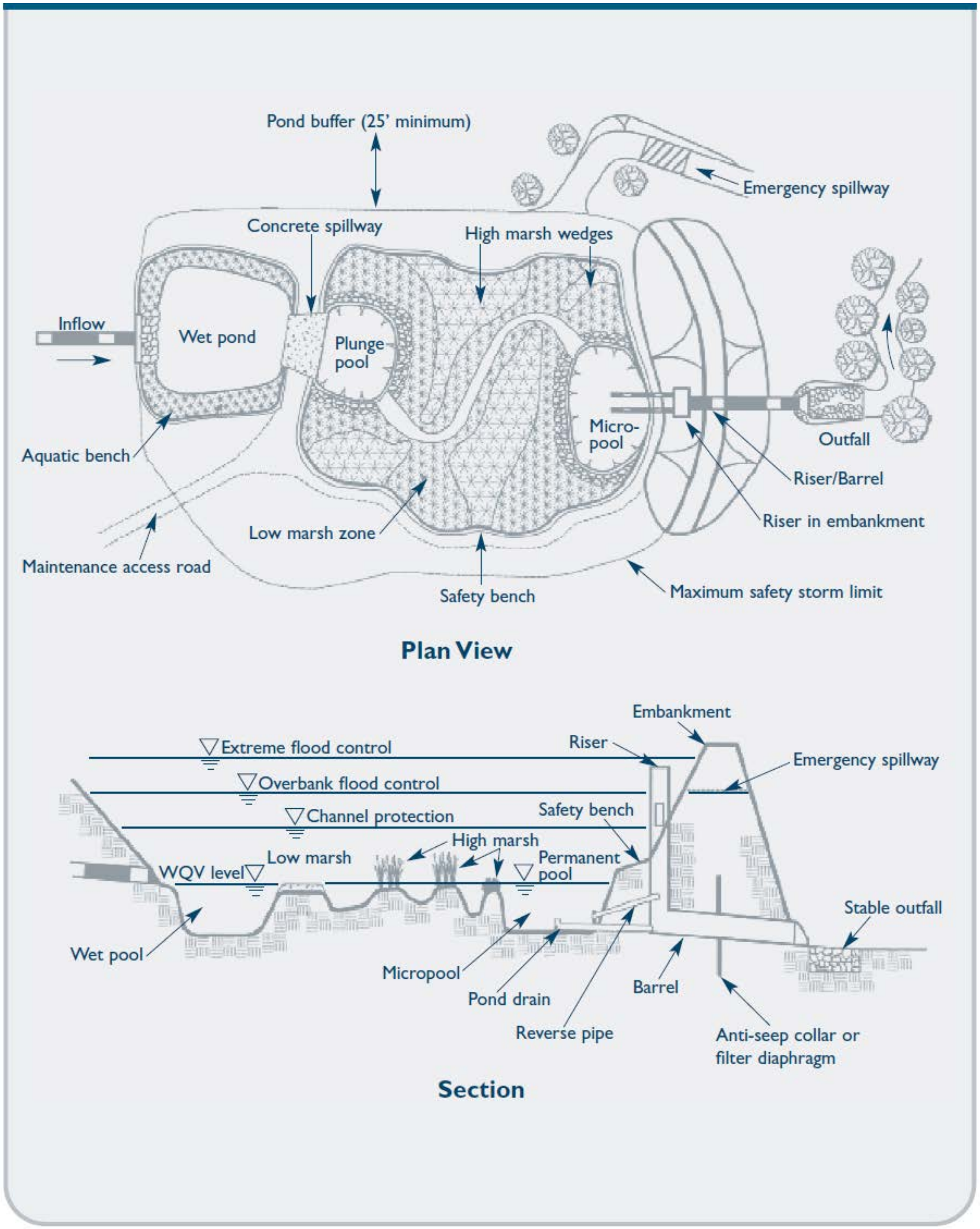


Figure 5.5: Pond/Wetland System. Source: CT Stormwater Quality Manual

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. Again, these are one of only two primary treatment types considered effective for the treatment of bacteria. Because of their mode of action, infiltration of captured runoff, they are effective in 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, and the infiltration basin. 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 drainage basin and they require frequent maintenance.

Costs for these systems are highly variable, but so are the designs and they may be useful in areas where there is limited space and structures need to be shoehorned. As such, they are useful for locations such as parking lot medians. This may be especially useful in the Mill River watershed where there are many DCIAs and little space. They are also useful for areas where there are no existing stormwater management features. Depth to the water table however, will always be a major constraining factor in site selection.

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	Significant Benefit
Phosphorus	Significant Benefit
Nitrogen	Significant Benefit
Metals	Significant Benefit
Pathogens	Partial Benefit
Floatables*	Partial Benefit
Oil and Grease*	Partial Benefit
Dissolved Pollutants	Partial 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

*Only if a skimmer is incorporated

Implementation Requirements

Cost ....Moderate
Maintenance..High

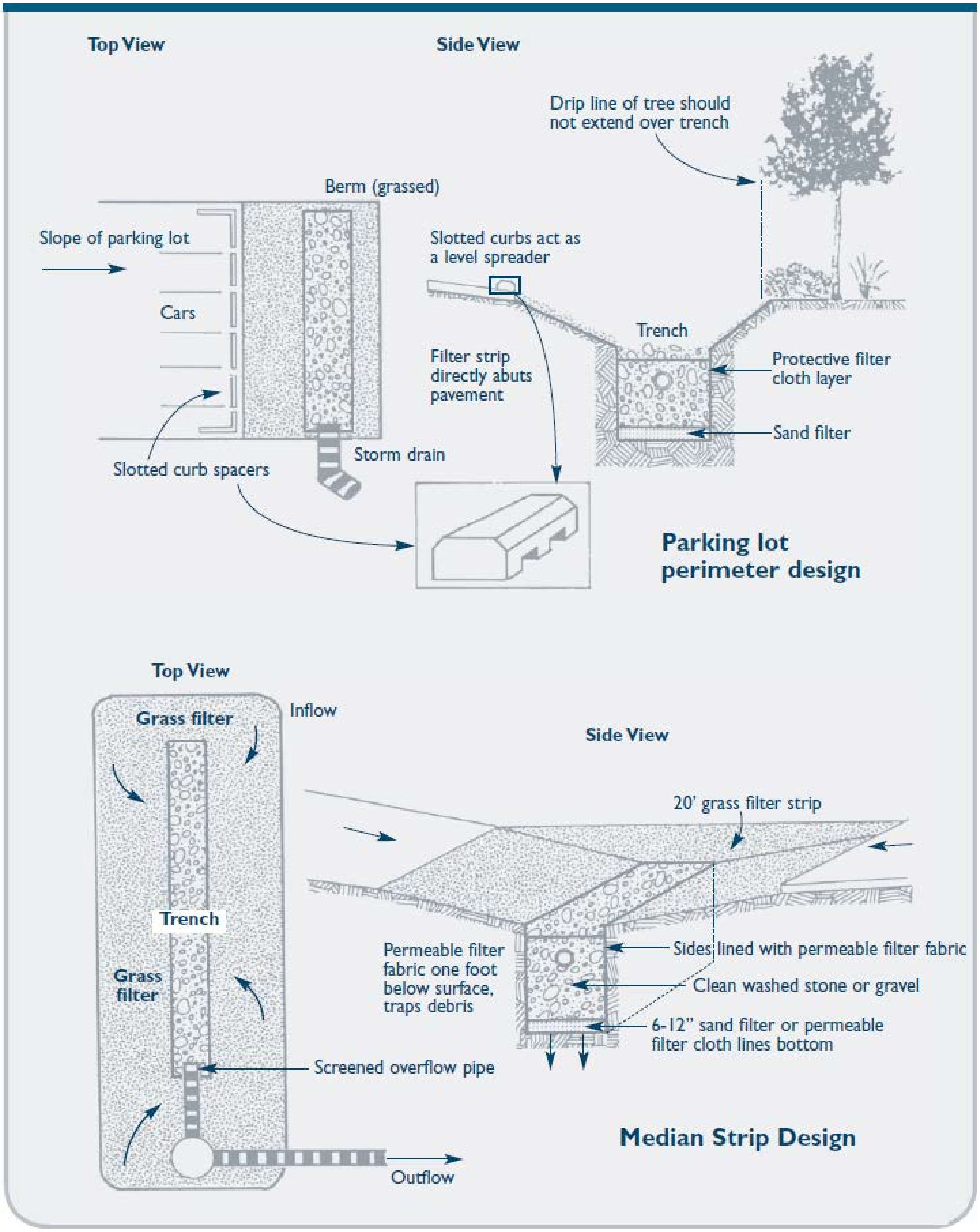


Figure 5.6: Infiltration Trench Design for Parking Lots. Source: CT Stormwater Quality Manual

STORMWATER PONDS

Stormwater pond designs use a large permanent pool design to affect pollutant removal. Planted wetland or aquatic benches are incorporated in the designs, but are not the primary treatment element as in stormwater wetlands, although these do offer critical nutrient uptake and mechanical filtering. There are four basic designs, although each can offer a number of layouts to suit site requirements. These designs include wet ponds, a base design, micropool extended detention pond for peak runoff control, wet extended detention pond similar to wet ponds with a focus on peak control, and multiple pond systems that can improve removal performance. These systems work primarily by sedimentation/precipitation processes. Soluble pollutants may be controlled through adsorption and bacterial decomposition/cycling.

The benefits of these systems include the ability to treat both particulate and soluble nutrients, provide an aesthetic benefit, may act as wildlife habitat, and are easily adaptable. If these intercept groundwater they may act as a pollution vector, in smaller designs may have trouble maintaining pool volume, require a large footprint, can cause thermal impairments, require large storage volumes to attenuate peak flows, and may be a safety issue due to pool features and the potential to attract mosquitoes.

A wet pond design concept is provided below. One of the key features of these systems is a forebay meant to capture the bulk of the coarse particulate load and designed for frequent maintenance dredging, which limits gross accumulations in the primary pool. These systems could be of some utility in the watershed, especially in areas where it is important to control solids loading and attenuate peak flow volumes to limit in-channel erosion in the receiving tributary.

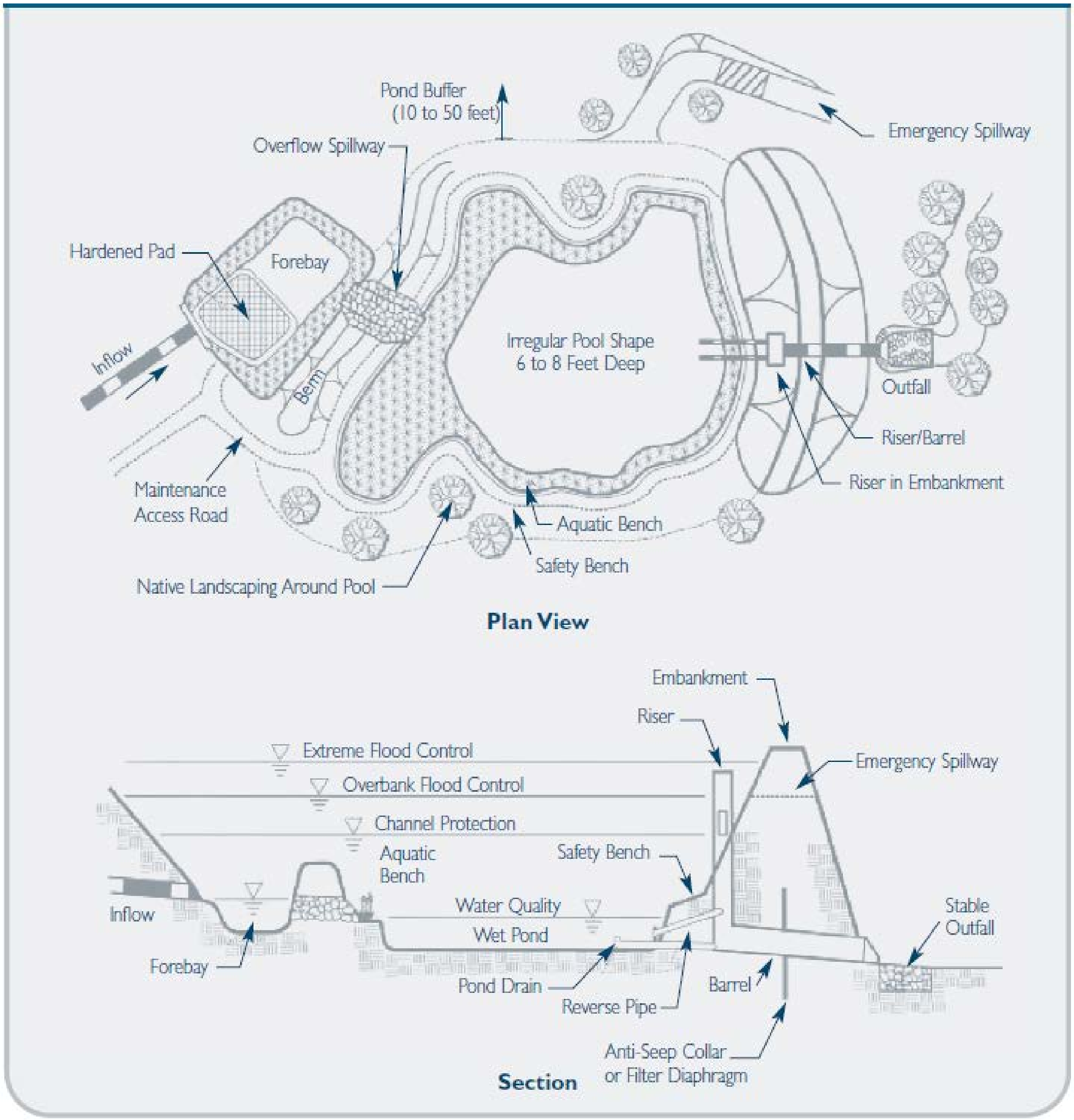


Figure 5.7: Wet Pond Design. Source: CT Stormwater Quality Manual

FILTERING PRACTICES

These BMPs involve the capture of stormwater that is then passed through a filter media, typically sand, organic materials, or soil, to remove pollutants. While primary treatment is similar to infiltration designs, these systems then discharge, at least a portion, of the treated stormwater to some type of conveyance either surficial or subsurface. There are two basic design types, surface filters and underground filters, but this project will primarily examine surface filters including surface sand filters, organic filters, and bioretention systems. Most designs include inflow regulating features to intercept the water quality volume, pretreatment for coarse solids removal, filter media, and outlet to surface or soil. These systems are especially effective in small catchments.

These systems have few siting limitations, small footprints, easily installed as retrofits, high bacterial removal efficiency, extended operational life, and can provide groundwater recharge. There are limitations including the need for pretreatment to prevent media clogging, expense, require a large head, provide little quantity control, and may be overwhelmed with heavy sediment loads.

Bioretention systems are of special interest in this watershed and include planted soil as a filter media to garner pollutant removal associated with filtration as well as biological uptake. In addition to larger designs, rain gardens are a variant of bioretention systems that are sometimes considered pocket BMPs, that is small structures that treat very small catchments, such as runoff from a single roof. These systems are also noted for their aesthetic value with the use of hardy native plants.

A bioretention schematic design is provided below.

Treatment Practice Type

Primary Treatment Practice	●
Secondary Treatment Practice	

Stormwater Management Benefits

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

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

*Only if a skimmer is incorporated

Implementation Requirements

Capital Cost....................................High

Maintenance Burden..................High

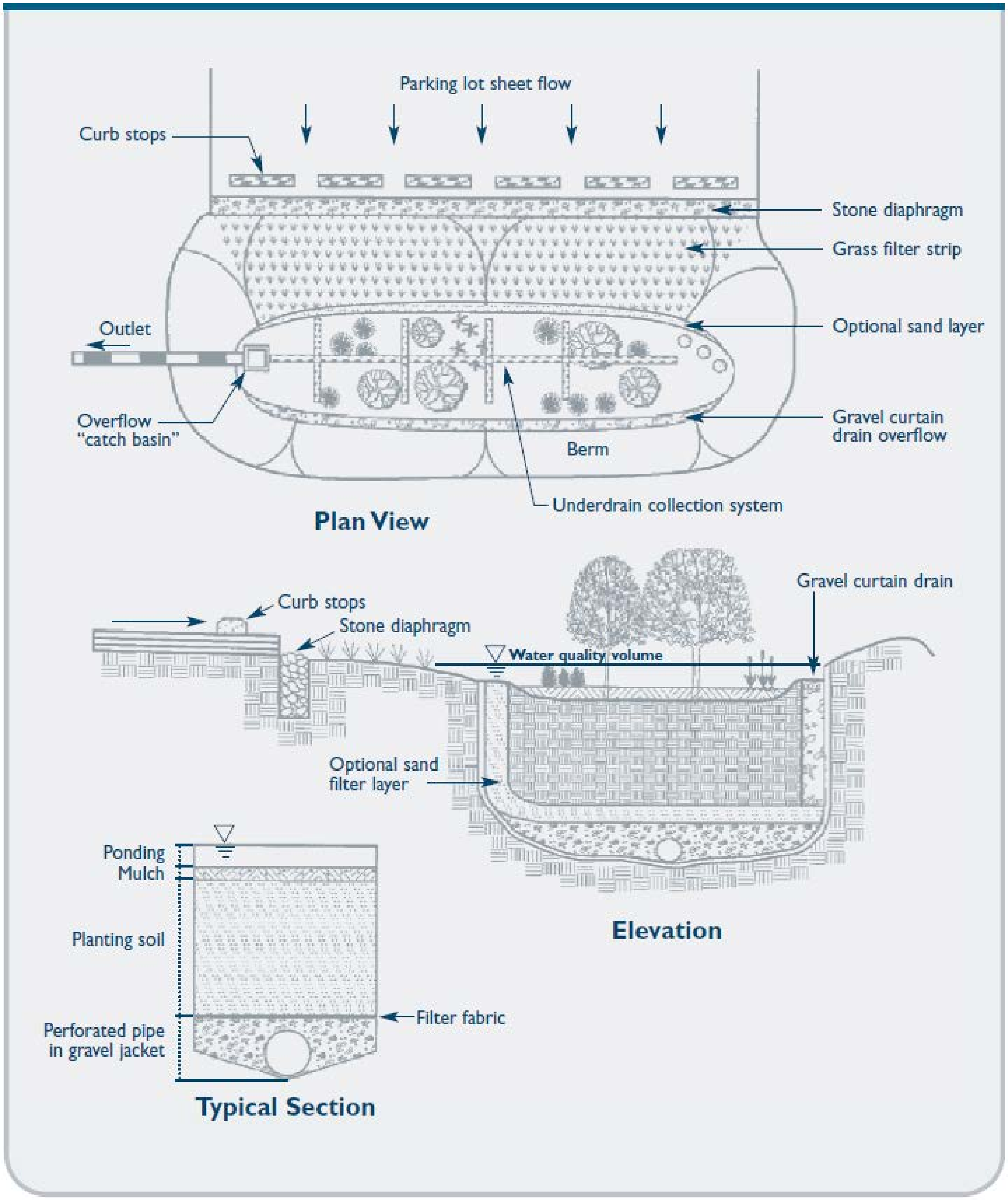


Figure 5.8: Bioretention Basin Design. Source: CT Stormwater Quality Manual

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 more generally, but are beneficial as pre-treatment devices. 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, to reduce directly connected impervious areas, as retrofits or receiving treated runoff from other BMPs, in conjunction with stream buffer systems, and on 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, and 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	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	Partial Benefit
Groundwater Recharge	Partial Benefit
Stream Channel Protection	Partial Benefit
Peak Flow Control	Low or Unknown Benefit

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

Suitable Applications

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

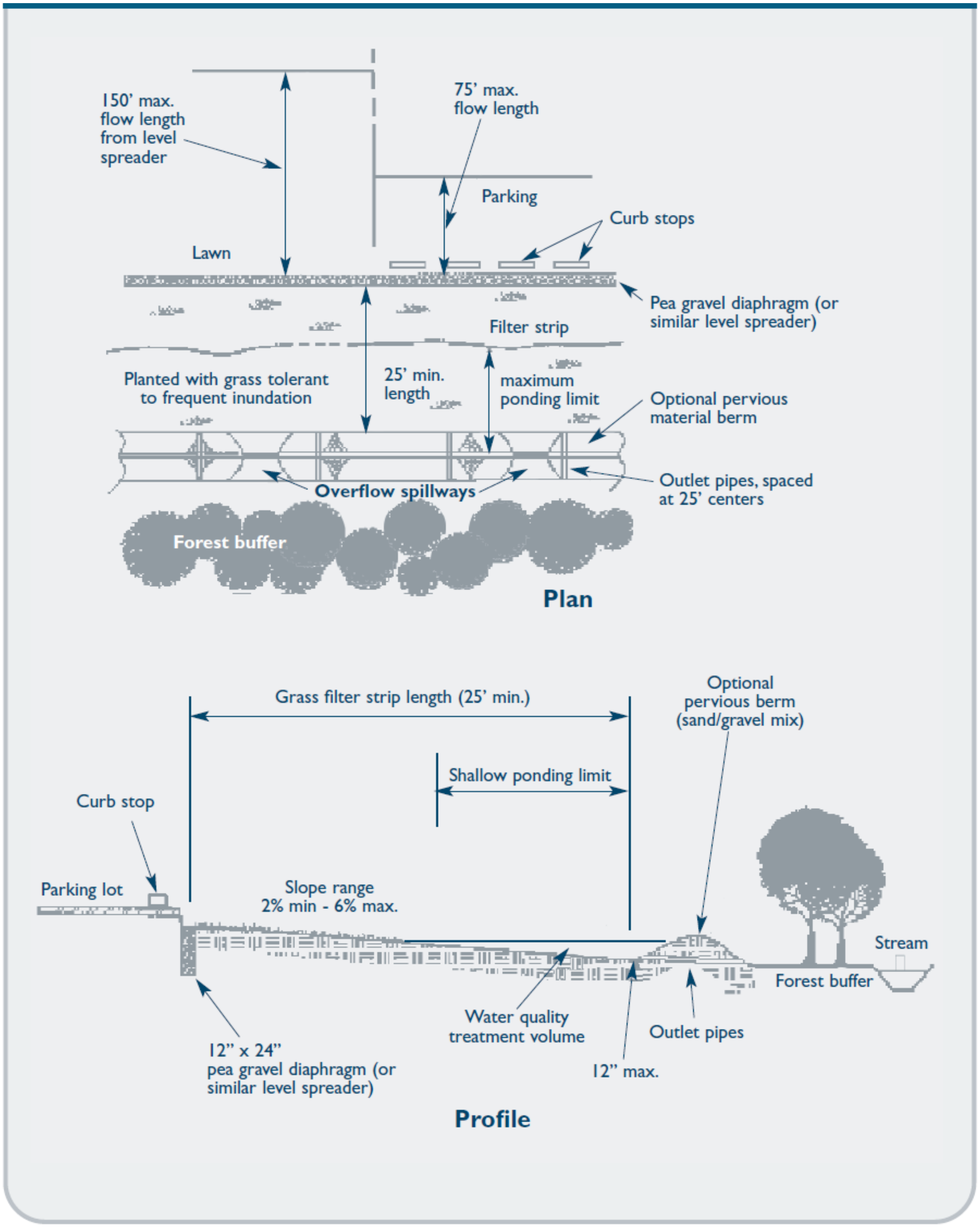


Figure 5.9: Vegetated Filter Strip Schematic. Source: CT Stormwater Quality Manual

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 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.

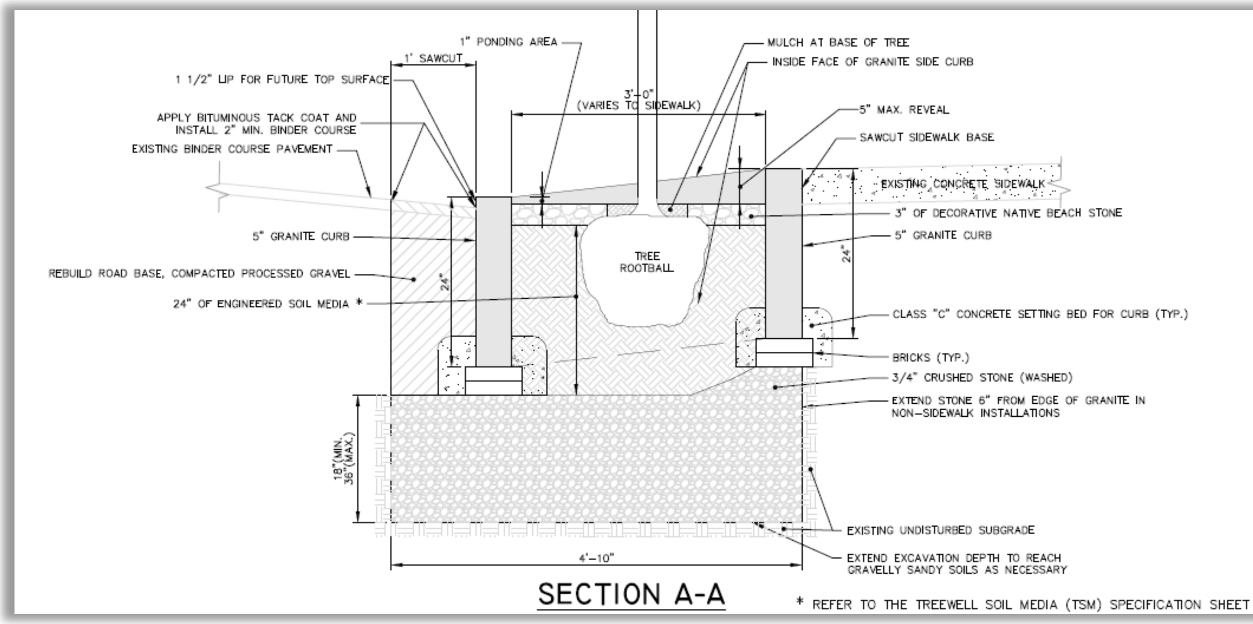


Figure 5.10: Tree Well Schematic. Source: Eastern Connecticut Conservation District

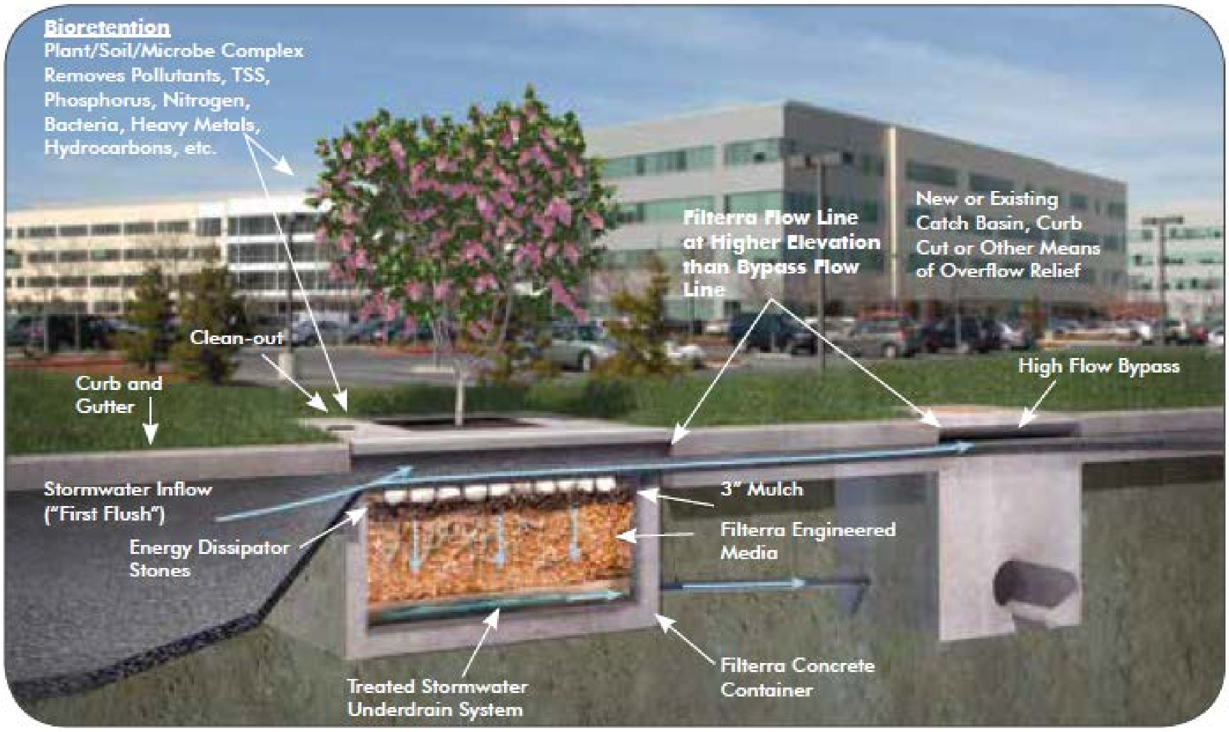


Figure 5.11: Tree Well Schematic. Source: Contech Engineered Solutions

POLLUTANT REMOVAL RATES

As this WMP is focused on meeting 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 distributed process impedes development and population of a centralized database.

Some of the difficulty in ascertaining these values 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 WMP, 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 *New Jersey 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 5.2: Pollutant Removal Efficiency

Management Measure	Removal Efficiency			
	Solids	Nitrogen	Phosphorus	Bacteria
Stormwater Wetlands	90%	50%	30%	70%
Infiltration Practices	80%	50%	60%	70%
Stormwater Ponds	80%	30%	60%	40%
Filtering Practices	80%	35%	50%	40%
Vegetated Filter Strips	80%	30%	30%	10%
Tree Well/ Tree Filter	83%	50%	60%	85%

In addition to the values above, researchers examined paired influent (untreated stormwater) and effluent (treated stormwater) concentration data from the International Stormwater BMP Database which showed retention ponds, media filters, and wetlands among the most efficacious designs for bacterial abatement.

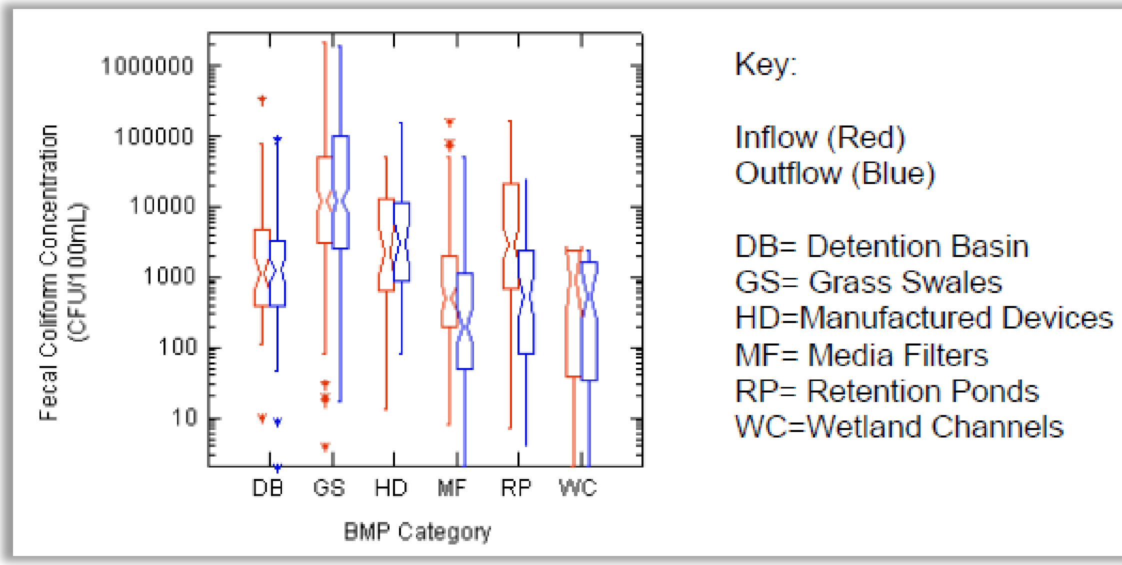


Figure 5.13: Bacterial Removal by BMP. Source: Stormwater Magazine

5.2.3 AGRICULTURAL BEST MANAGEMENT PRACTICES

Overall, agricultural lands comprise just over 4% of the total land mass, yet they have an outsized impact on certain aspects of pollutant loading. In particular this is true for sediment loading and bacteria. Runoff from agricultural lands accounts for just 1.7% of the total solids loading, but 64% of all surface erosion, which excludes in-stream erosion. This presents an opportunity for the control of that load through relatively simple practices. The bacterial load related to farm animals is over 35% of the estimated total load. While this may appear to be unnaturally high, it conforms to the characteristics of the watershed. While relatively few animals were populated in the models, primarily in the rural subwatersheds in the north near the two main reservoirs (Subwatershed 1, 2, and 3), even small farms with few animals would be enough to generate these types of loads. Second, large animals produce an incredibly high bacterial loads that are deposited in the open that are directly and easily mobilized in stormwater runoff. Finally, because the rural subwatersheds have low impervious coverage and low development densities there are fewer obvious targets to manage stormwater. A focus on agricultural lands in these areas identifies a target and ensures the types of cumulative load reductions that will be needed to achieve watershed water quality improvements. While there are a number of agricultural BMPs that can be implemented, many are variations on a theme, and the WMP 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

As stated above, agricultural lands comprise about 4% of the Mill River watershed, and the vast majority of these are pasture/hay lands with few row crops. As such, the bulk of the effort to control agricultural erosion should focus on hay crop and pasture management practices. Farmers that gain significant income from their farms are typically engaged in best practices as a result of outreach efforts and education (often in conjunction with local conservation districts and UConn Extension), but also through a sense of environmental stewardship and the economics of maintaining top soil and other resources. For hobbyist farms or residents with several animals raising awareness of these issues and implementing recommendations is important.

Pasture and hay land 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 1000 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 flow concentrations.

- 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. These techniques will be discussed in full in subsequent sections of this document.
- 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 Mill 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 other 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.

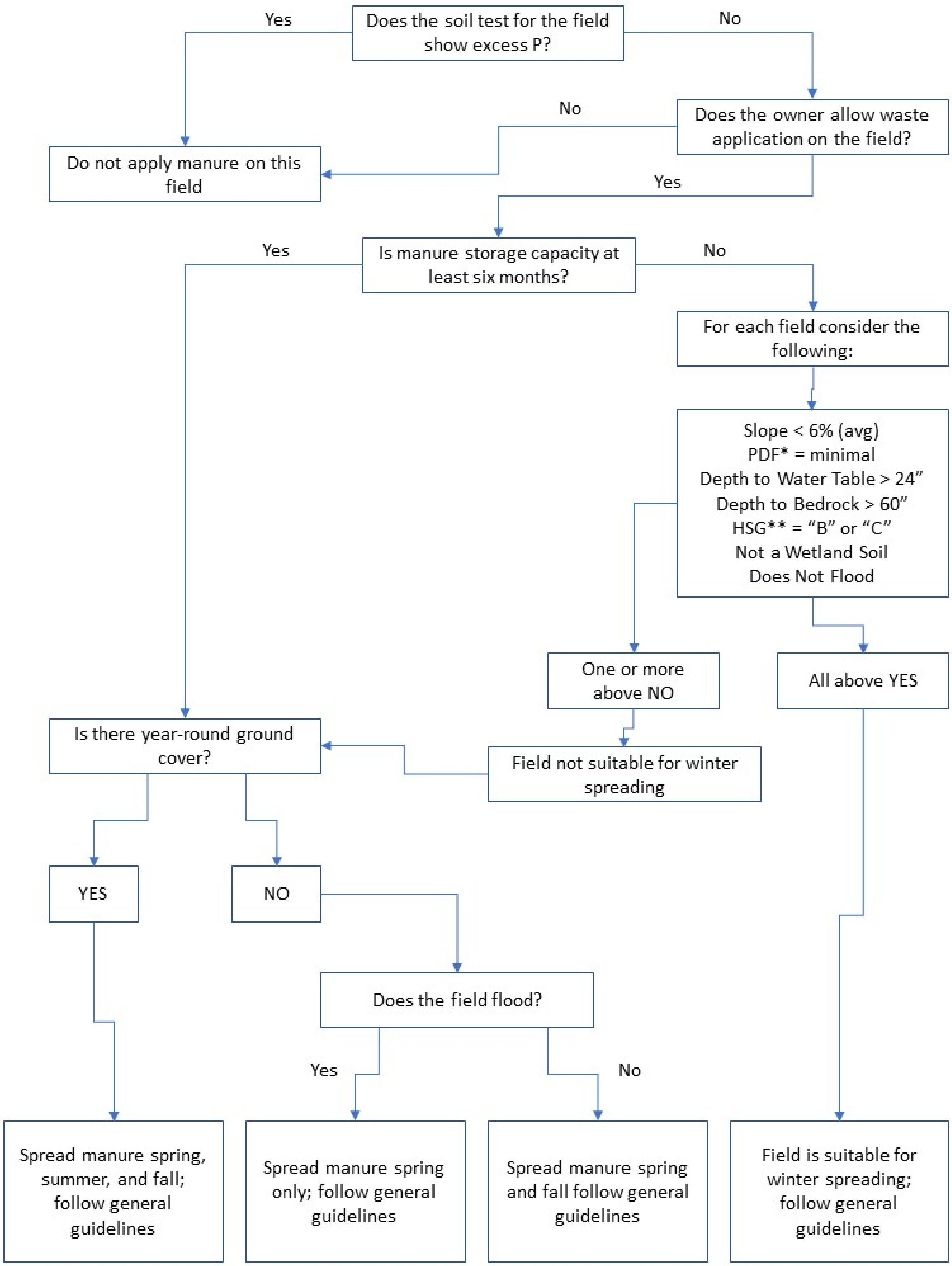
A field stacking area is used to temporarily stockpile manure for up to six months where groundwater and surface water contamination is least at risk and at time when daily spreading is not feasible. These areas should be located: near the receiving field, on minimal slopes with small or no catchment, 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.



*PDF – Pollutant Delivery Factor **HSG – Hydrologic Soil Group

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.

5.2.4 STREAM BANK STABILIZATION AND RIPARIAN BUFFER ENHANCEMENTS

Another important set of NPS management measures in the Mill River watershed will focus on streambank stabilization and riparian buffer enhancements. Streambank erosion accounts for approximately 97.5% 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 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 5.12), 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.

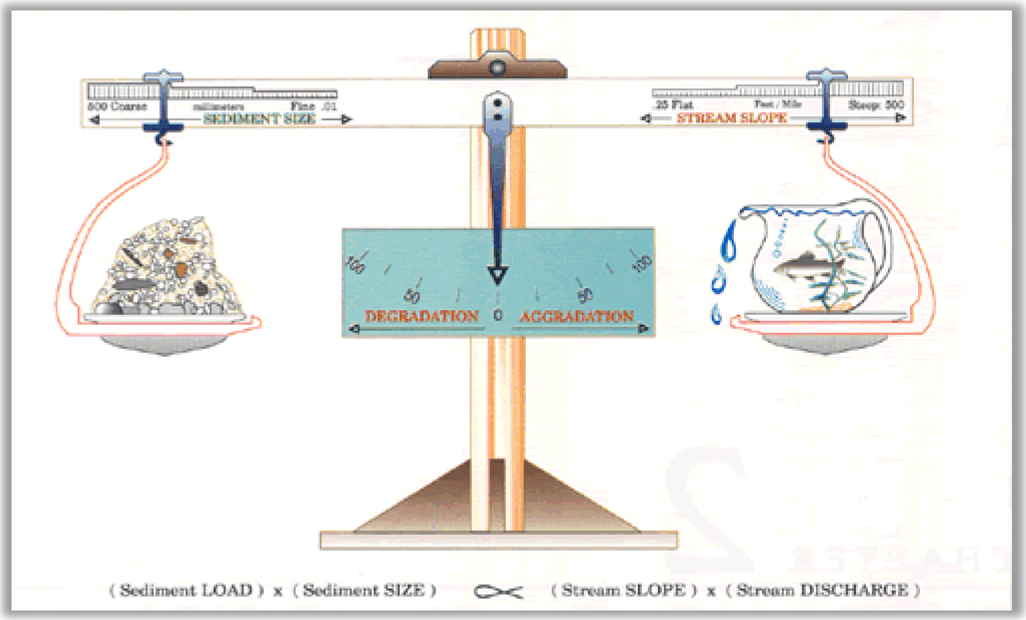


Figure 5.12: Lane's Balance. Source: Fluvial Geomorphology, SUNY

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.

While modeled bed and bank erosion was quite high, a very cursory examination of some potential candidate sites did not suggest any areas of immediate high concern for stabilization efforts, although riparian buffer enhancement is incorporated into several of the site specific BMP concepts. This demonstrates that bed load transport is perfectly normal, in fact essential, although impairments related to excessive stormwater loading are also recognized. From a more practical perspective, Mill River itself has a length of 38 stream miles, and much more in the tributary network, meaning that candidate project areas will be identified over time and stabilization efforts can be incorporated at that point. This is in keeping with the goals of the WMP, which includes iterative works towards reducing loads.

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 de-facto protection and thus are rated lower. It should be noted though that these types of projects offer ideal opportunities for expanding public access 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. 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.
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 Mill 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.

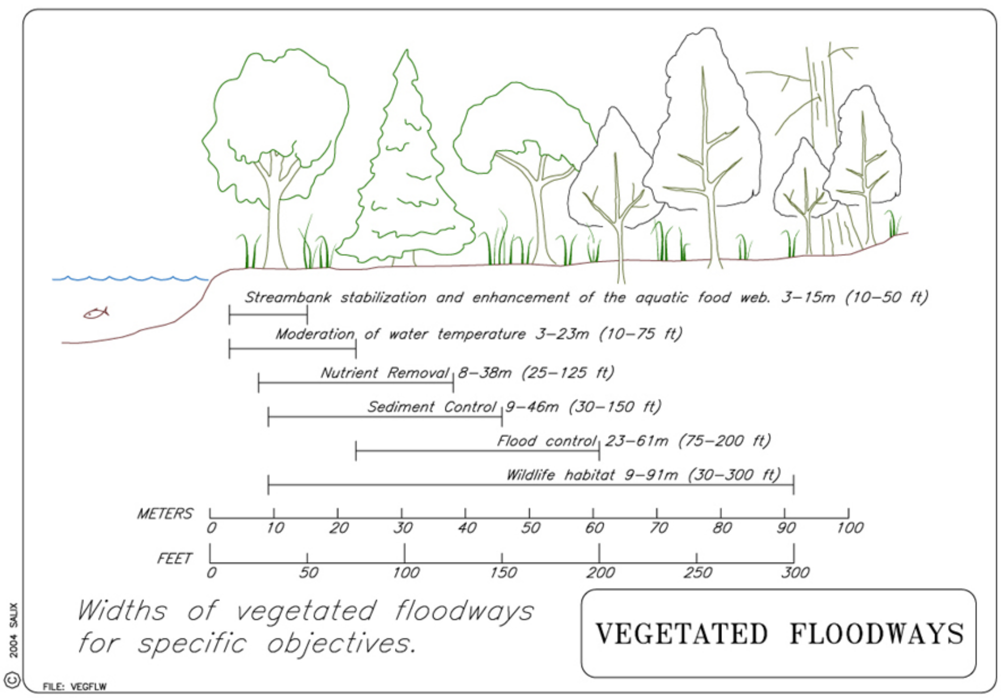


Figure 5.13: Riparian Buffer Zones and Functional Value Widths

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 begins 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. A more comprehensive list of native plantings for varying zones including herbaceous, shrub, and tree components can be found in Appendix A of the Stormwater Quality Manual; those planting recommendations would also be used in the stormwater management measures described above.

Figure 5. Sample Planting Recommendations According to Moisture Conditions

TREES

Silver Maple
Box Elder
Persimmon →
Black Ash
Red Ash
Pawpaw →
Sweet-bay Magnolia
Sycamore →
Cottonwood
Swamp White Oak
Oak,Willow →
Willow, Sandbar & Black

SMALL TREES/SHRUBS

River Birch
Smooth Alder
Chokeberry, Red
Chokeberry, Black →
Groundselbush
Dogwood, Red Osier & Silky
Summersweet →
Winterberry →
Inkberry →
Swamp Rose
Swamp Azalea
Meadowsweet →
Highbush Blueberry →
Witherod →
N. Arrowwood

TREES

← Maple, Red →
Bitternut Hickory →
← Redbud →
Hackberry →
American Beech →
← Ash, White →
← Honey Locust →
Kentucky Coffee Tree →
← Sweet-gum
Tuliptree →
Black-gum →
← Large-toothed Aspen →
← Oak, Pin →

SMALL TREES/SHRUBS

← Black/Sweet Birch →
Mountain Laurel →
← Hornbeam →
Yellow Birch →
← Shadbush (A.arborea & canadensis) →
← Dogwood, Gray & Flowering →
Fringe Tree →
American Hazelnut →
← Black Huckleberry
← Common Spicebush →
← Rosebay Rhododendron
← Southern Arrowwood
← Ninebark
← American Elder →
Bayberry →
← Highbush Cranberry →
Red Elm

TREES

White Pine
Black Cherry
Sassafras
Canada Hemlock
Oak, White
← Oak, Red
Oak, Chestnut
Hickory, Shagbark
Maple, Sugar
Black Walnut

SMALL TREES/ SHRUBS

Hop-hornbeam
Witchhazel
Staghorn Sumac
Nannyberry
Blackhaw

Arrows denote that certain species can tolerate either a wetter or drier environment.

Figure 5.14: Trees and Shrubs for Planting Zones

BED AND BANK STABILIZATION BMPS

Bed and bank stabilization is the keystone of most current stream restoration projects. These projects usually revolve around the maintenance of bed and bank stability, prevention of erosion, limiting excessive or accelerated sedimentation, restoring floodplain connectivity, improving fish passage, maintaining natural hydraulic and hydrologic conditions, and protecting at-risk infrastructure. The focus of bed and bank stabilization implementation efforts should focus on areas where accessibility is relatively high and where erosion is a clear result of anthropogenic causes, such as the removal of all riparian vegetation or other buffer encroachments. The following section will discuss some of the varied streambank stabilization projects that may be applicable in the watershed. The table below shows most of the major stabilization methods currently employed (utilizing commonly accepted terminology), as well as their primary function, best uses, and implementation complexity. These various methods will be discussed below as separate functional groups.

Table 5.3: Bed and Bank Stabilization Measures

Method	Primary Functions	Best Use	Implementation Complexity
Bank Grading	Floodplain Connnection, Bank Stabilization	Long Runs, Bends	Moderate
Bendway Weir	Flow Deflection	Outer Bend	High
Boulder Placement	Flow Deflection	Habitat Creation	Low
Boulder Toe	Toe Protection	Outer Bend	Moderate
Brush Mattress	Bank Stabilization	Innner and Outer Bend, Habitat Creation	Low
Cross Vane	Grade Control, Flow Alignment	Prevent Head Cuts, Habitat Creation	High
Engineered Rock Riffl	Grade Control, Flow Alignment	Prevent Head Cuts, Habitat Creation	High
Gabion Baskets	Toe and Bank Protection	Limited Space	High
J-Hook Vane	Flow Deflection	Outer Bend, Habitat Creation	High
Live Fascines	Bank Stabilization	Innner and Outer Bend, Habitat Creation	Low
Longitudinal Peaked Stone Toe Protection	Toe Protection	Long Runs, Outer Bend	Moderate
Riprap	Toe and Bank Protection	Outer Bend, Long Runs	Moderate
Rock Vane	Flow Deflection	Outside Bend	HIgh
Rootwad Revetment	Toe Protection	Outer Bend, Habitat Creation	Moderate
Soil Lifts and Soil Wraps	Bank Stabilization	Long Runs, Bends	Moderate
Step Pool	Grade Control	Flow Alignment Prevent Head Cuts, Limited Space	High
Vegetation Planting	Bank Stabilization	Inner and Outer Bend, Habitat Creation	Low

BANK STABILIZATION

A variety of methods are used to stabilize streambanks ranging from fairly simple projects such as planting to more complex methods such as grading and eventually the placement of gabions and riprap (discussed under toe protection strategies). The choice of method depends on a variety of factors including site hydraulics, stream order, erosion severity, channel incision, floodplain connectivity, and proximity to structures.

Most modern stream stabilization and restoration projects rely heavily on a vegetative component. As with riparian buffer enhancement vegetation serves a variety of functions the most important of which is the stabilization of the bank through the rooting. While some projects may begin and end with bank plantings where hydraulics permit and erosion is relatively mild almost all other projects, especially those involving grading and excavation, utilize bank plantings as the final component of the project.

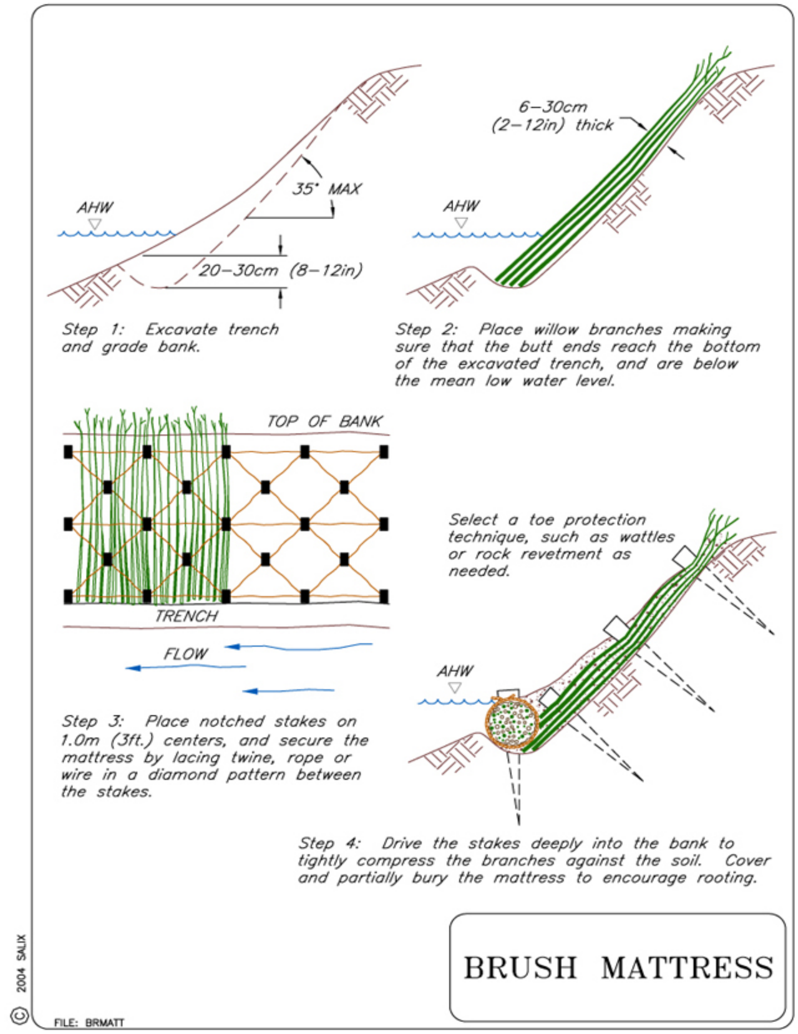


Figure 5.15: Brush Mattress

There are also more highly engineered approaches to vegetative planting, including the use of brush mattresses and live fascines as well as vegetated riprap designs. Brush mattresses, live fascines, and vegetated riprap solutions usually follow more extensive work, particularly bank grading, but take advantage of willows (*Salix* spp.) and red-osier dogwood (*Cornus sericea*) to stabilize banks and to reduce velocity and bank shear stress. Brush mattresses are simply willow or dogwood cuttings placed perpendicular to the channel lining the bank and anchored in place with stakes and ropes. The roots are placed in a trench below the normal water line and the toe protected with wattles or riprap.

Live fascines serve a similar purpose but are bundles of willow cuttings 6 to 12 inches in diameter stacked parallel up the face of the bank. They also promote the growth of willows along the banks but may serve an additional purpose as bank armoring materials until normal growth and colonization occurs. Riprap may also be placed over fascines with a reorientation of the bundles or live stakes may be inserted in the voids in the riprap. Gabions can be treated similarly but generally use a larger tree as opposed to the cuttings described above.

Bank grading is also useful for stabilizing banks especially when paired with plantings and toe protections, and is often seen on outside bends or along long eroded runs. More complex bank grading, including major excavation in channels that are extremely incised, may be performed to create a new floodplain. More generally though, bank grading is used to reduce the hydraulic angle of incidence thus decreasing erosive forces along the outside bend, allowing excessive flows to reach the floodplain, and providing stable substrate for planting using brush mattresses and fascines, or armoring with riprap which significantly increases the roughness coefficient. The slope of the grade varies with the desired outcome, but a 3:1 slope is often desired for most planting exercises or other bioengineering. A grading or slope flattening detail is provided below.

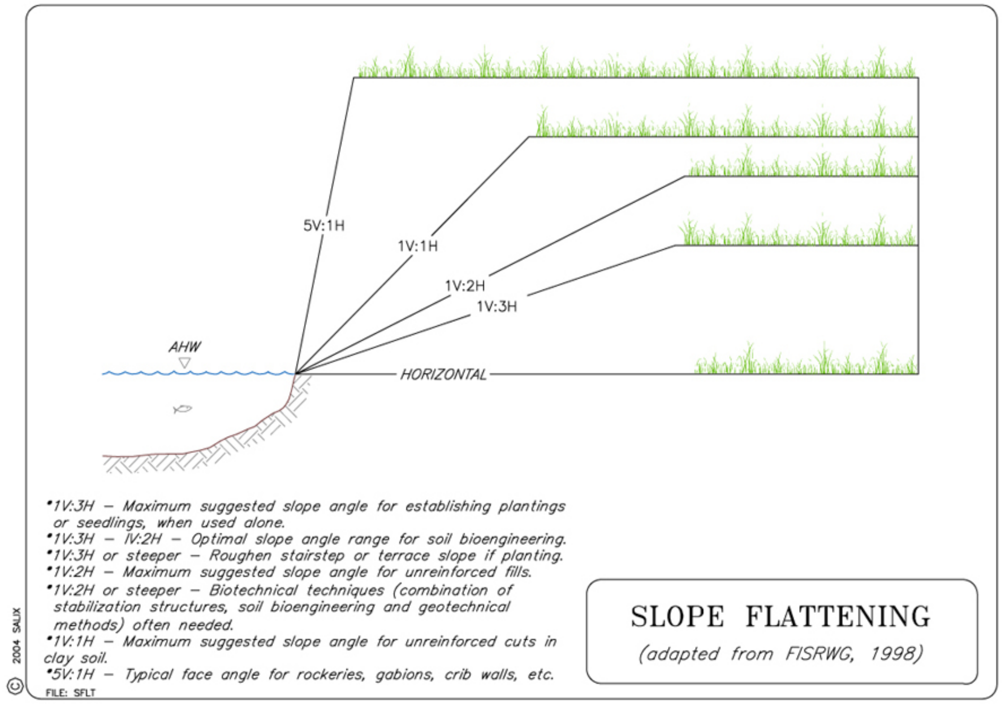


Figure 5.16: Grading Detail

TOE PROTECTION

Toe protection measures serve a slightly different purpose than the bank stabilization measures discussed above and are designed primarily to absorb hydraulic forces and sheer stresses that cause excessive erosion, mass wasting, and endanger nearby infrastructure. More specifically, these measures involve the placement of heavy materials, usually stone, along the toe of the bank, sometimes extending up the bank, to limit erosive effects. These types of strategies may be considered bank armoring, a practice that is gradually losing favor in stabilization projects because these types of systems can be unattractive, may be subject to failure and “overkill” (excessively engineered), and are largely artificial. However, the limitations of many project sites, including the required protection of structures and roadways or a simple lack of space to implement preferred design elements means that these protective measures are still important for bank and bed stabilization projects. Indeed, the judicious use of toe protections is absolutely critical to the success of many projects.

One of the best toe protection measures involves the use rootwads or rootwad revetments. The rootwad describes the lower portion of a tree trunk with limbs removed but the major portion of the root ball retained. These are usually placed in the toe of the bank on an outside bend with the trunk angled slightly back and keyed in deeply to the bank so that the anterior section of the root ball is flush with the bank, seated on a footer log, and oriented perpendicular to the main flow vector. The rootwad is then able to absorb most of the hydraulic impact to decrease erosion, but unlike some of the other toe protection measures serves other functions in the stream. The roots themselves can significantly increase local roughness in the stream thus slowing flow velocities. These rootwads are also outstanding fishery habitat and offer refugia from predation and flow, provide ambush points for predators, and foster abundant forage as the organic roots become well colonized by benthic macroinvertebrates.

Rootwads have several additional benefits to consider. Availability of the raw material tends to be high as they can be collected from construction sites where large trees have been removed or even onsite at restoration projects as some trees may have fallen into the river due to excessive or erosion or are removed during grading processes. Additionally, larger materials are generally more efficacious and implementation is limited only by the size of rootwad available; it is interesting to note that there are anecdotes of redwoods being utilized in Pacific coast projects.

Figure 5.17: Rootwad Placement. Source: Princeton Hydro

Boulder toe protection designs function similarly to rootwads to provide bank stability and prevent erosion along outside bends utilizing large boulders instead of trees. In addition to protecting the toe of the bank the boulders may be stacked as necessary to provide additional armoring higher up the bank. Design specifications are generally mutable but the resistive boulders should be placed to achieve approximately 50% embedment. Bank grading and the placement of fill material behind the boulders are usually encouraged. The material behind the boulders is usually planted with woody vegetation.

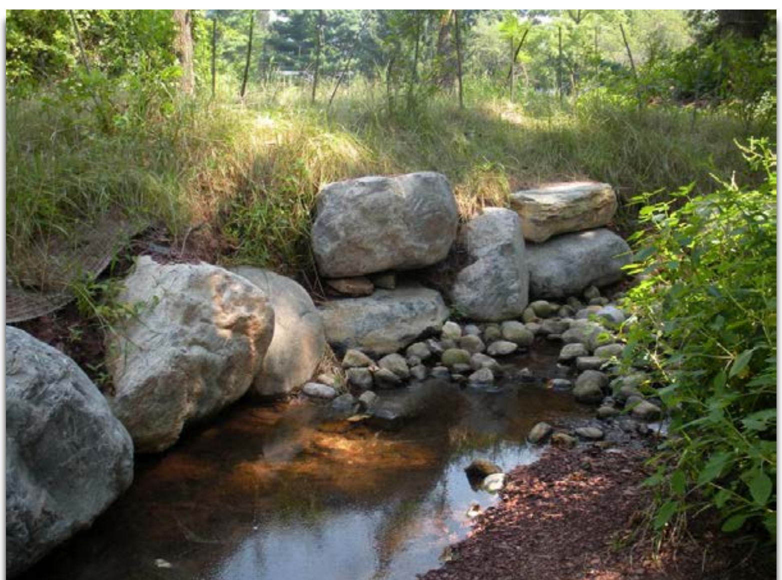


Figure 5.18: Boulder Toe Protection. Source: Princeton Hydro

The placement of riprap and gabion baskets is among the most familiar bank stabilization and bank protection measures. Riprap is coarse rock, relatively well graded (non-uniform or well distributed) and angular placed along outside bends or longer runs where erosion is observed. Most designs feature a trench or other retaining feature at the toe of the bank to help maintain the rock in place. Grading is usually extensive in these projects as a uniform surface and grade is required to maintain the rock in place with a final slope of 1:1 or 2:1. Geotextiles or other bedding materials may be necessary to ensure proper drainage and seating of the riprap, which must be carefully sized to handle hydraulic conditions during stormflow events to maintain bank stability. Newer designs may incorporate vegetation planted either in the void spaces between the riprap or planted in amended fill materials on the face of the riprap, the rock serving as an underlying layer. This type of approach is now considered somewhat excessive and unnecessary unless there is a need to absolutely lock the channel and bank in place.

Gabions are large wire cages filled with coarse rock, similar to the material used in riprap applications. Gabions have several advantages over riprap related to the cages which provide increased structural integrity and thus allow smaller rock to function as a single unit or be placed where larger rock would be required in a riprap placement. For this reason, gabion baskets can be used in much steeper applications, and may be placed almost vertically without concern for the angle of repose (the angular limit at which loose materials can be stacked), which is an important consideration where space is a defining limitation. There are several other gabion designs including gabion mattresses, which are much shallower than baskets with a larger footprint and gabion sacks which is mesh sack filled with rock. Both of these designs must be placed on flatter slopes than baskets. Gabions are almost always filled in place which aids greatly in their installation. Gabions are often required to withstand high shear forces in order to protect the infrastructure situated at the top of bank.

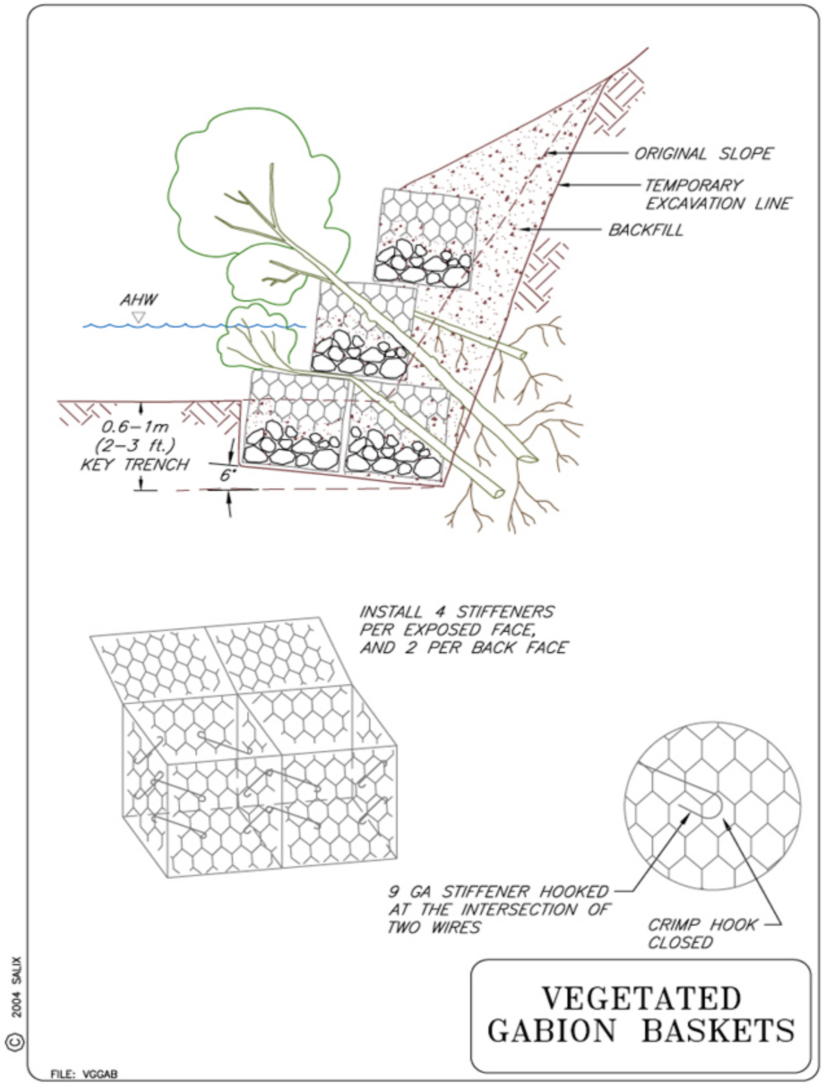


Figure 5.19: Gabion Detail

FLOW DEFLECTION

Another series of structural bank stabilization methods include the use of flow deflection devices. Unlike toe and bank protection measures which are designed to absorb the impact of accelerated flows to prevent erosion, flow deflection devices alter the hydraulics of the system and divert the majority of the discharge away from the bank and towards the center of the channel. Another major difference of this type of device is that they extend into the channel from the bank. A variety of flow deflection devices are currently utilized including bendway weirs, J-hook vanes, rock vanes, and rock spurs, but most are simple variations on a similar design.

Rock spurs are the simplest flow deflection devices, but utilize the same design strategies to limit erosion. At their simplest, rock spurs are merely rock piles abutting the bank and extending into the channel. The primary function is to reduce near bank velocity, shift the thalweg towards the center of the channel and minimize the potential for erosion.

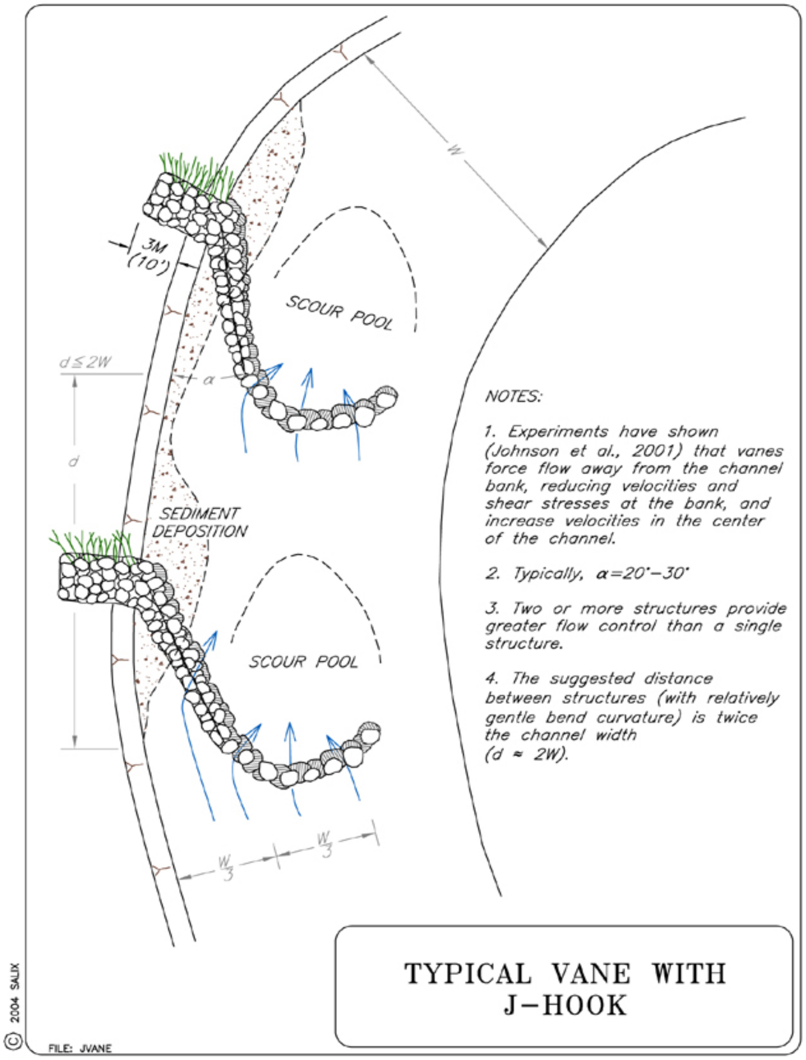


Figure 5.20: J-Hook Detail

J-hooks and rock vanes or vane arms are more highly engineered designs that are longer linear features that extend from the bank upstream at approximately 20 to 30° off the streambank with a gentle slope down the face of the vane. The main difference between the designs is that the J-hook has a curve at the end contributing to a scour pool and habitat creation, a feature missing in normal vane arms. Placement is critical to these devices and a common design flaw is not locating the vane far enough upstream. This is exhibited in the detail to the side which should probably have shifted the placement slightly upstream to initiate flow realignment sooner. The second common mistake is that too few features are installed to adequately maintain the desired flow path including at the egress of the curve. Finally, the third error is a tendency to expand the angle such that the main arm is installed at a 45° angle or larger. This type of installation minimizes the velocity gradient across the face of the vane thus decreasing the potential to redirect flow. However, good designs are proven to be effective at limiting erosion and show even higher efficacy when paired with other bank stabilization methods. As with other complex designs, good engineering is the key to the success of these solutions.

GRADE CONTROL

In-stream grade control is also another important component of bed and bank stabilization. While erosion is mostly thought of as a problem with the banks, channel incision includes both horizontal (bank) and vertical (bed) erosion. The erosion of bed materials results in entrenchment or a hydraulic disconnect of the channel with the floodplain. Since the stream no longer is able to flood the adjacent plain all the flow is forced through the incised channel resulting in even greater erosion. Under these conditions a typical type of erosional process that develops is the head cut, an erosional feature in the bed that migrates upstream. Grade controls therefore mitigate these processes and include several structures such as engineered rock riffles, step pools, and cross vanes or V-weirs. Other grade controls used historically such as dams will not be discussed here as they exacerbate erosion and sedimentation processes and represent other risks such as stream warming, altered hydraulics, and fish passage barriers. Grade control measures are also frequently used when stream channels have been extensively reshaped or when impoundments have been removed to prevent the formation of head cuts and to align flows in the center of the channel. Another use of grade control structures is to elevate the entire channel of severely incised streams to restore floodplain connectivity.

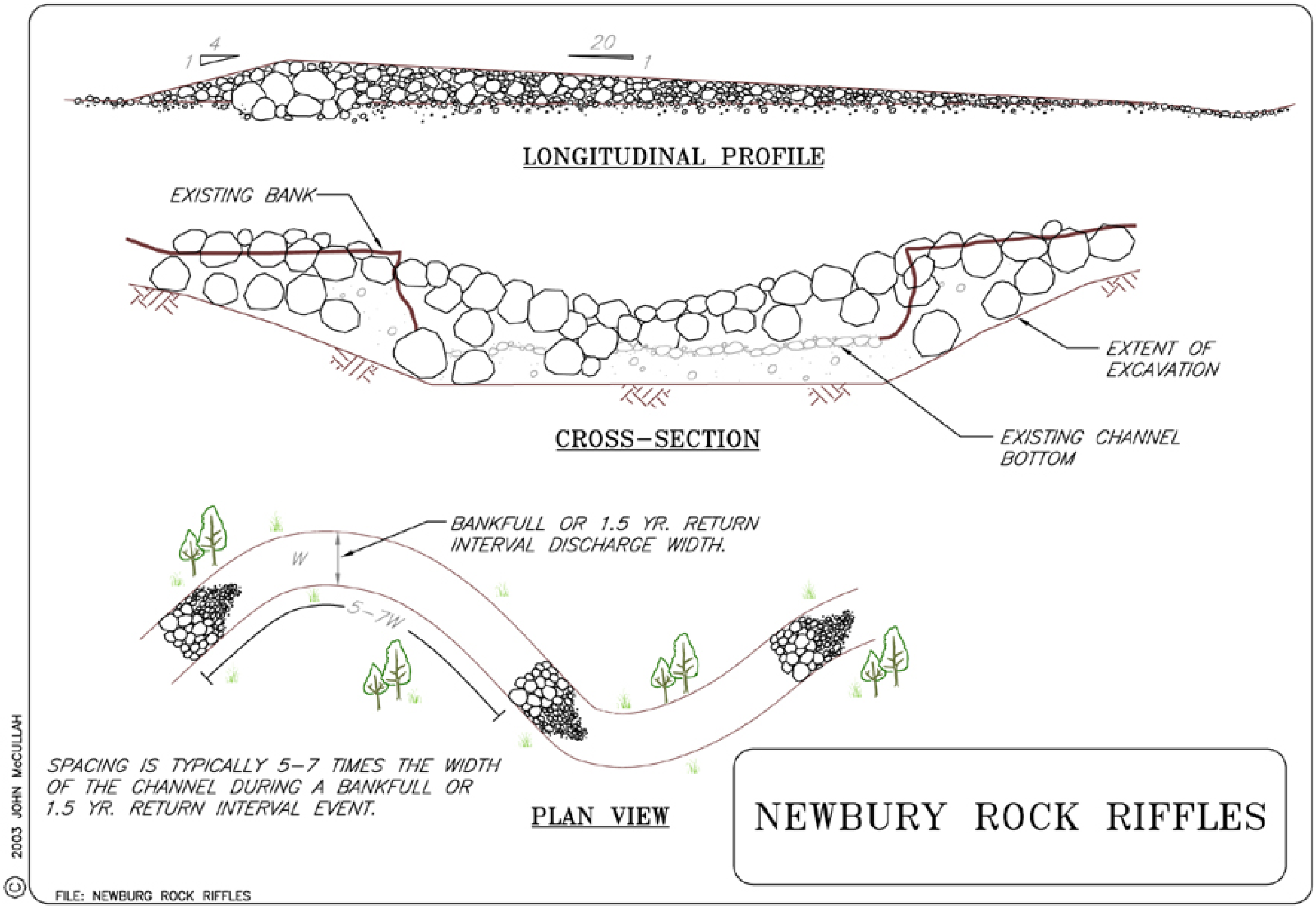


Figure 5.21: Engineered Rock Riffle Detail

Engineered rock riffles replicate naturally occurring riffles in streams (shown above). Besides providing grade control and preventing erosion, rock riffles are also important habitat features. Riffles are generally characterized by high grades relative to other stream segments and coarser sediments or substrate. This combination of factors introduces turbulent streamflow through these areas which creates highly oxygenated water. High DO levels and coarse substrates are critical to maintaining healthy macroinvertebrate populations in streams, particularly the EPT taxa which are among the primary macroinvertebrate indicator groups of stream health.

The cross vane or V-weir is similar to rock vane designs described in the previous section but extend completely across the stream and when seen in plan view look like a normal rock vane connected to a J-hook vane. Their primary function is grade control, but they also direct alignment of flow in a channel. Like other vane designs they work by lowering flow velocity along the bank, but also structurally shape channel morphology. Cross vanes have the added benefit of limiting downstream sediment deposition and creating a scour feature at the toe of the vane. Combined these features and functions can help improve DO concentrations, limit bed and bank erosion, and provide habitat complexity.

A final grade control measure is the step pool. Step pools are similar to cross vanes, but are linked in series and utilized in higher gradient streams. While the angularity of the vane would be reduced other details remain essentially unchanged. An important consideration that must be accounted for in this type of design is the relative difference between pool elevations which must be maintained at an acceptable height to allow fish passage; this height would vary based on targeted species. Step pools may also be used to realign water in tight, steep bends where the use of flow deflection techniques such as J-hooks would be impractical because of space limitations.

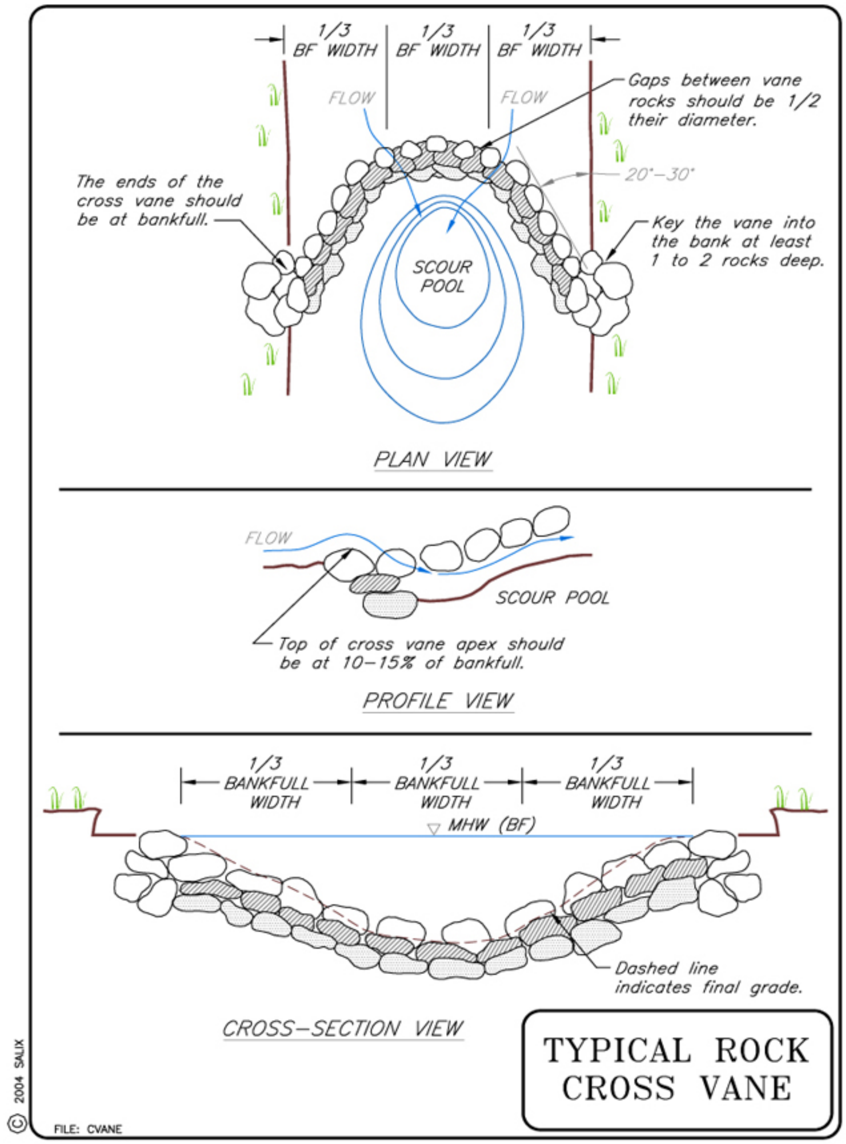


Figure 5.22: Cross Vane Detail

5.2.5 PET WASTE 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. In Fairfield, a pet waste community outreach program is already implemented, as are informational signs at parks, the provision of pet waste bags, and a longstanding dog waste ordinance. Monroe is developing outreach materials and has a policy of excluding dogs from public parks and has installed pet waste receptacles. Easton continues to work on implement pet waste BMPs. Because the WMP 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, but since the control of bacteria is the primary goal of this WMP 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 enforcement thereafter. As such, the towns will be best served by continuing their current programs. That said, it is important in 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 Mill River watershed, wildlife has been modeled as a relatively small contributor to the overall loading of nutrients and bacteria, but Canada goose has been noted as a nuisance species, particularly in the park settings with water features. Loading associated with geese can be particularly problematic as they defecate directly in or near waterbodies and thus represent a direct loading vector. 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.

5.2.6 FLOW MANAGEMENT AND AQUATIC ORGANISM PASSAGE

While the management measures discussed above target NPS loading and the control of *E. coli* in particular consistent with the management objectives of the TMDLs, it is also appropriate to consider the management of Mill River and its tributary network as fishery and wildlife habitat. This is especially true in light of new information in which Mill River and Cricker Brook have been identified on the List of Waters for Action Plan Development by 2022 to meet designated uses as habitat for fish, other aquatic life, and wildlife as specified for Class AA and A fresh waters. Maintenance or improving fisheries is also important for meeting recreational uses such as fishing. Therefore, it is important to manage flow in the Mill River and promote aquatic organism passage (AOP).

Unlike many of the management measures discussed above, which focus on addressing watershed processes with distinct sources or causes of impairments, such as impervious surfaces or illicit wastewater disposal that contribute to pollutant loading, or correction of problems with steam channels or the adjacent riparian corridors, such as arresting headcut erosion, flow management necessary to sustain stream conditions amenable for fish and other aquatic organisms will be primarily operational in nature and implemented by water managers that control reservoirs, dams, and other structures that dictate flow rates. Proper flow management is also critical in maintaining water quality. In particular, uninterrupted release of cold water from the two large reservoirs is necessary to support the high quality coldwater fishery in Mill River. The release of cold water offers several advantages. First, it maintains the proper temperature for species that are especially susceptible to warming, such as the salmonids. Cold water also maintains higher DO concentrations required to support cold water species, and additional flow can also increase turbulence, another important process in naturally oxygenating water. Macroinvertebrates, particularly the EPT taxa including mayflies, stoneflies, and caddisflies also benefit from these conditions.

Maintaining proper flows is also important for migratory species including the river herrings (*Alosa* spp.) and eels among others. For these species it is particularly important to maintain sufficient flows during the migratory periods to promote passage. While eels are less sensitive to flows, herring in particular need elevated flows in the spring to allow them to traverse upstream, while juveniles require steady flows in the late summer and early fall as they pass back downstream.

AOP is also important in promoting high habitat quality and focuses on maintaining connectivity of the system to promote migration, in-stream movements, and full utilization of the available stream network. There are a variety of barriers to fish passage prominent among them dams, culverts, and road crossings. These structures may be perched (elevated above flow), have excessive flow velocity, insufficient depth, be closed (many species will only pass through open channels), or are simply too high to surmount. In many cases, these barriers are a failure of design, being too small to pass required flows or have excessive slope, but others are exacerbated by problems such as erosion that forms scour pools or decreases bed grade, or contributes to siltation and capture of debris. Many of the bed and bank protection measures discussed above are incorporated in successful passage projects and may utilize grade control structures to reduce erosion and address excessive slopes, and use bank stabilization techniques to reduce erosion and improve habitat quality. In other cases, replacement of existing structures, like culverts and pipes, may be necessary. Dam removals also provide many benefits including free-flow and reductions in warming. In areas where dam removal is not feasible, fish ladders or other nature-like fishways may provide a suitable alternative.

5.3 IMPLEMENTATION PROJECT CONCEPTS

A major objective of the WMP was to develop specific design concepts for project implementation. These concepts are identified and prioritized locations, field assessed, and selected for suitability. Recommended management measures are based on site conditions and pollutant load. In addition to providing site specific stormwater management and pollution reduction goals, these projects are meant to be demonstration projects, highlighting the methods, structures, and practices that can be employed throughout the watershed. These are not completed engineering designs, an exhaustive list of all potential project sites, or able to meet all loading reduction goals. Instead, they are part of the iterative process of tackling NPS loading. Additional technical work and funding will be needed to bring these to fruition, part of which is addressed later in the WMP, and additional project sites will be identified over time and the methods demonstrated can be transferred. Each of the project sites will be discussed below, including specific recommended management measures, as well as an estimate of pollutant load reduction achieved by each measure.

5.3.1 SITE SELECTION AND FIELD ASSESSMENT

The development of implementation projects drew upon a number of project elements. First, a review of existing water quality data, water quality classifications, and other watershed-based documentation, including the TMDLs and MS4 permit, were reviewed to identify known designated use and water quality impairments. Next, pollutant loading and hydrology modeling was performed to characterize and rank pollutant loading by contributing source on a subwatershed scale. This ranking, in conjunction with the other watershed data, was used to prioritize management measures throughout the Mill River which varied by the pollutant loading scheme, a consequence of watershed characteristics and land use patterns. Following the synthesis of these elements, the project partners, most prominently the Fairfield Conservation Commission and Trout Unlimited provided a list of potential candidate sites based on known or suspected problem areas. Using GIS coverages and aerial photographs Princeton Hydro also developed a list of potential candidate sites.

Field assessments were then conducted to determine project viability through ground truthing. This involved general assessments of all the sites, identification of possible site constraints, and photo documentation. In some cases, some of the existing GIS data did not capture recent changes in site use. In others, stormwater retrofits had already been installed or stormwater management or land use differed from an initial understanding. Overall, the field assessments were used to confirm the viability of a project site and concept, affect a modification to initial management measure concept based on site conditions, or caused the site to be rejected and the list winnowed.

In general, the examined list of candidate project sites focused on not only the subwatersheds of priority, but the land uses of particular interest, such as impervious areas like parking lots, were considered a priority as were areas with existing stormwater infrastructure. The sites must also have clear and obvious impairments, identifiable source loads, or deficiencies regarding stormwater management. The feasibility of each site or project was considered in light of site constraints and whether garnering necessary permits was deemed likely. Lastly, where possible, the selected sites were to be either publicly-owned or publicly accessible, which included area like parks, easements, and campuses. Where possible, there was an attempt to select sites that would require different management measures in order to maximize their value as demonstration projects. The following sections of the WMP describe each of the implementation project concepts including a concept layout, a narrative of the site and the selected management measure, an estimate of the pollutant load and achievable load reduction, and any information that aids in the successful implementation of the project. In total, nine sites were selected for project implementation. They are presented in numeric order from north to south.

MR-2

Mill River Stormwater Wetlands (MR-2)	
Subwatershed 4, Highest Priority	
Town of Easton	
N 41.2381°, W 73.2556 °	
Catchment ~70.4 acres	
Management Measures	
Stormwater Wetland	
Riparian Buffer Plantings	
Infiltration Basin	
Estimated Load Reductions	
Nitrogen (kg)	23.4
Phosphorus (kg)	0.5
Solids (kg)	295.0
Bacteria (%)	70%
Other Benefits	
Runoff Volume Reduction	P
Runoff Capture	S
Groundwater Recharge	P
Stream Channel Protection	S
Peak Flow Control	S
S - Significant	
P - Partial	
L - Low or Unknown	

MR-2 is located in Subwatershed 4, the highest priority subwatershed in the Mill River system. The approximately 70 acre catchment drains a portion of the residential neighborhood to the southwest of Easton Reservoir. Stormwater is released in an uncontrolled manner from the cul-de-sac at the end of Sturbridge Road down a steep slope. This results in erosion of the hill side, bank instability where the sheet flows and rills confluence with Mill River, and the formation of a sand bar near the shoreline as those materials are deposited. The banks are fairly well vegetated, especially with trees, although both herbaceous and understory shrubs and small trees are underrepresented. As with almost any developed area, invasive vegetation is present along the banks. Mill River crosses under South Park Avenue immediately downstream of the site.

Several management measures are suggested for this location. The primary one is the creation of a stormwater wetland near the toe of the slope. There are a variety of benefits to this type of system. First, stormwater wetlands, unlike some other management measures, require a large catchment, at a minimum around 25 acres, in order to maintain the proper hydrology, i.e. enough water moving through the system to maintain wetted conditions for the wetland plants to properly grow, which is crucial for the function of these designs. Besides good nutrient and pathogen removal capacity, these are also effective at mitigating peak flow and channel protection, both of which are necessary to help limit continued erosion in the area.

Some secondary measures are also identified as having value for this site. First, a small infiltration basin or infiltration trench could be installed immediately adjacent to the cul-de-sac to provide both some pre-treatment during larger storm events for downslope measures as well as infiltration of small events. Infiltration measures usually work best in small catchments, but could be useful here for managing small events. These systems also require deep soils and sometimes several feet of head, both of which could be satisfied at this site. Finally, some simple invasive species management and replanting of the riparian buffer is recommended to improve bank stability and habitat quality.

A site map is provided below, as well as several photographs that document stormwater management impairments at the site.

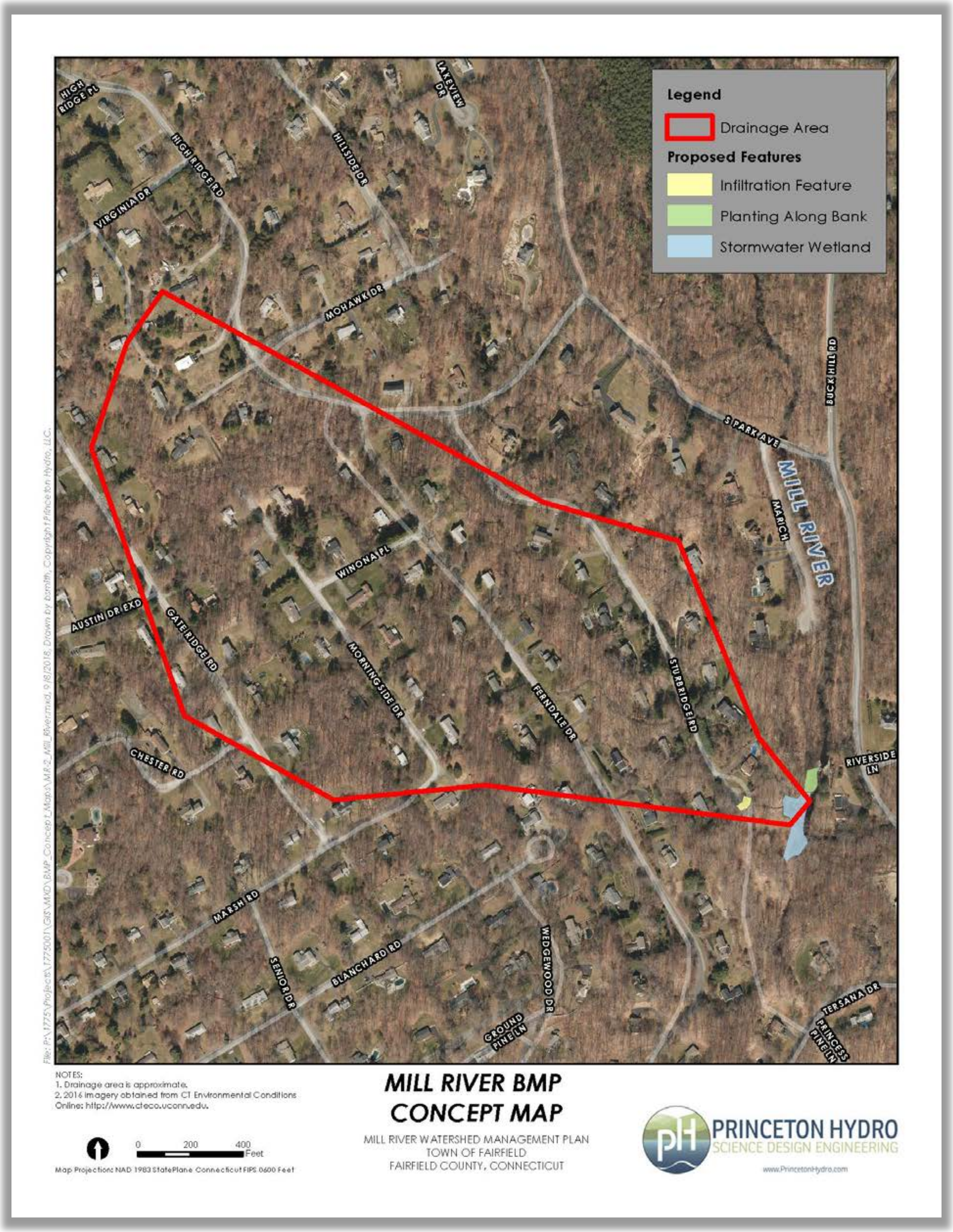


Figure 5.23: Mill River Stormwater Wetland Map

Figure 5.24: Unmanaged stormwater flow from Sturbridge Road

Figure 5.25: Here the bank of Mill River is being eroded and fresh material deposited in the channel

MR-3

Covenant Church BMPs (MR3)	
Subwatershed 4, Highest Priority	
Town of Easton	
N 41.2216°, W 73.2565 °	
Catchment ~2.64 acres	
Management Measures	
Tree Filters	
Step Bioretention Basin	
Riparian Buffer Restoration	
Estimated Load Reductions	
Nitrogen (kg)	1.0
Phosphorus (kg)	0.1
Solids (kg)	35.8
Bacteria (%)	40%-80%
Other Benefits	
Runoff Volume Reduction	P
Runoff Capture	S
Groundwater Recharge	P
Stream Channel Protection	S
Peak Flow Control	P
S - Significant	
P - Partial	
L - Low or Unknown	

The MR-3 site encompasses the Covenant Church site in Easton. The site is located along the western bank of Mill River, just west of Sport Hill Road. This is a small catchment at only 2.6 acres, but it is defined by what could be considered the most problematic elements of watershed development patterns in Mill River, high imperviousness, unmanaged stormwater discharging directly to Mill River, and buffer encroachment. While the watershed or catchment here is small as are the loads of nutrients and solids, these are the types of area that cumulatively impact water quality in the watershed. Certainly, loads of solids and nutrients are minimal here since the bulk of the property is paved, but fecal loading from pets and wildlife are discharged untreated and rapidly to Mill River. At the same time, this rapid runoff contributes to higher peak flows that exacerbate in-stream solids loading.

Three distinct BMP approaches will be used here. For the parking lots, which can be considered the central focus, it is recommended that four tree well or tree filter units be installed. Besides the various nutrient removal capacities these offer within a small footprint, these units will also help to minimize stormwater runoff by infiltrating and transpiring some of the intercepted runoff. Please note too that the estimated bacteria removal efficiency can vary significantly by design, especially regarding the soil or filter media composition.

The second phase is the installation of step bioretention cells, essentially as small multipond wet pool system. In essence, this would be a series of linked raingardens constructed in a step system in the existing conveyance along Sport Hill Road. The step system not only overcomes the grade limitations, but increases treatment efficacy, which is already good in these systems, and better simulates plug flow where retained water is treated over time and replaced by a new plug migrating through the system.

The last component is riparian buffer enhancement along Mill River. It is obvious that the buffer is severely encroached and virtually non-existent throughout, and due to these factors is exhibiting in turns erosion, sedimentation, and more generally instability. A program of planting riparian vegetation can help stabilize the banks, increase floodway roughness, and help mitigate stormwater inputs.

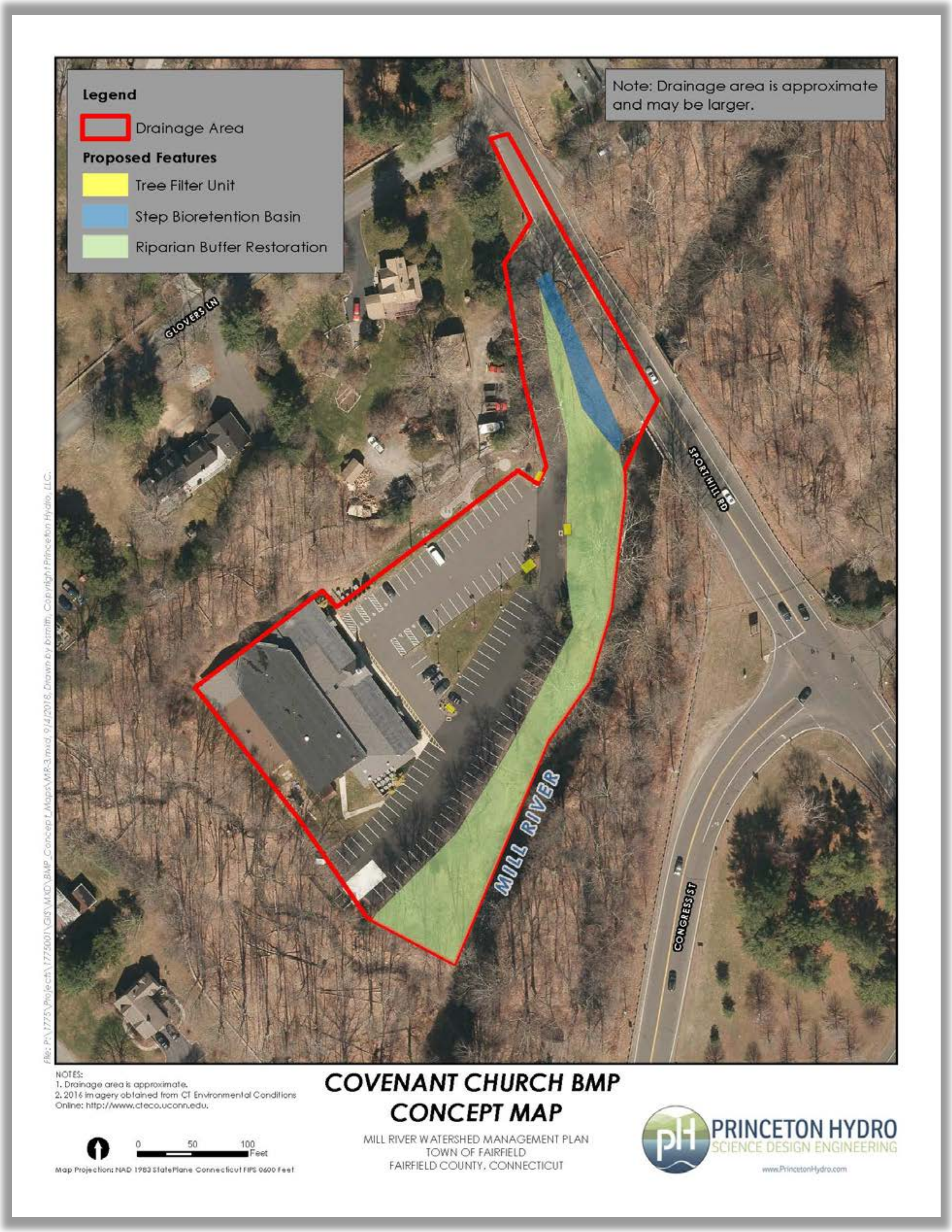


Figure 5.26: Covenant Church BMPs

Figure 5.27: Candidate site for step bioretention system to manage stormwater conveyance and improve channel stability; geotextiles from previous stabilization exposed

Figure 5.28: Riparian buffer enhancement target in encroached channel lacking brush layer

Figure 5.29: Target area for tree well unit; existing catch basin offers no stormwater treatment

MR-4

Rt. 15 Service Plaza BMPs (MR4)	
Subwatershed 4, Highest Priority	
Town of Fairfield	
N 41.2178°, W 73.2574 °	
Catchment ~2.12 acres	
Management Measures	
Stormwater Pond	
Tree Filter Units	
Riparian Buffer Enhancements	
Estimated Load Reductions	
Nitrogen (kg)	0.7
Phosphorus (kg)	0.1
Solids (kg)	32.6
Bacteria (%)	40%-85%
Other Benefits	
Runoff Volume Reduction	P
Runoff Capture	S
Groundwater Recharge	P
Stream Channel Protection	S
Peak Flow Control	S
S - Significant	
P - Partial	
L - Low or Unknown	

The MR4 site is a service plaza of Merritt Parkway. It is located within Fairfield, nestled between the highway and Congress Street, which in turn abuts the eastern bank of Mill River. Like many areas that service infrastructure demands, this area is almost entirely defined by high imperviousness, not only of the parking lot, but also the roadways. Numerous major transportation corridors traverse the watershed, and thus the management template of this site will be transferrable to other areas. Overall, loads of nutrients and solids are solids are quite low here simply because the ground is impervious, but as a result this area generates high volumes of stormwater. In addition, this area is also used as a pet walking area for travelers with attendant bacterial loads easily mobilized and discharged offsite. In addition, the riparian area is also extremely encroached, with Congress Street offset just 35 feet from the top of bank.

To address these issues three BMPs are recommended for the site. The first is the installation of a stormwater pond to the south of the connector road to manage stormwater flows from paved areas; due to the small catchment a liner will likely be needed to maintain a wetted pool. This area is currently impacted by sheet flow with bare soil exposed throughout. Within the service plaza area proper, up to five tree filter units are recommended. Not only will these provide good stormwater treatment in confined footprints, depending on the filter media selected they can provide a very high degree of bacteria removal capacity, especially important for pet walking areas. Lastly, riparian buffer plantings, up to 1000 linear feet, should be considered for the Mill River. Site assessment showed this area to be lacking an herbaceous plant component. The banks through here also exhibits signs of both erosion and sedimentation.

In addition to the primary BMPs, this site provides an opportunity to erect educational signage with the ability to reach a broad array of users. It may also be used directly as an educational tool through a stewardship program with nearby Sacred Heart University.

The site concept map and several photographs of the site are provided below.

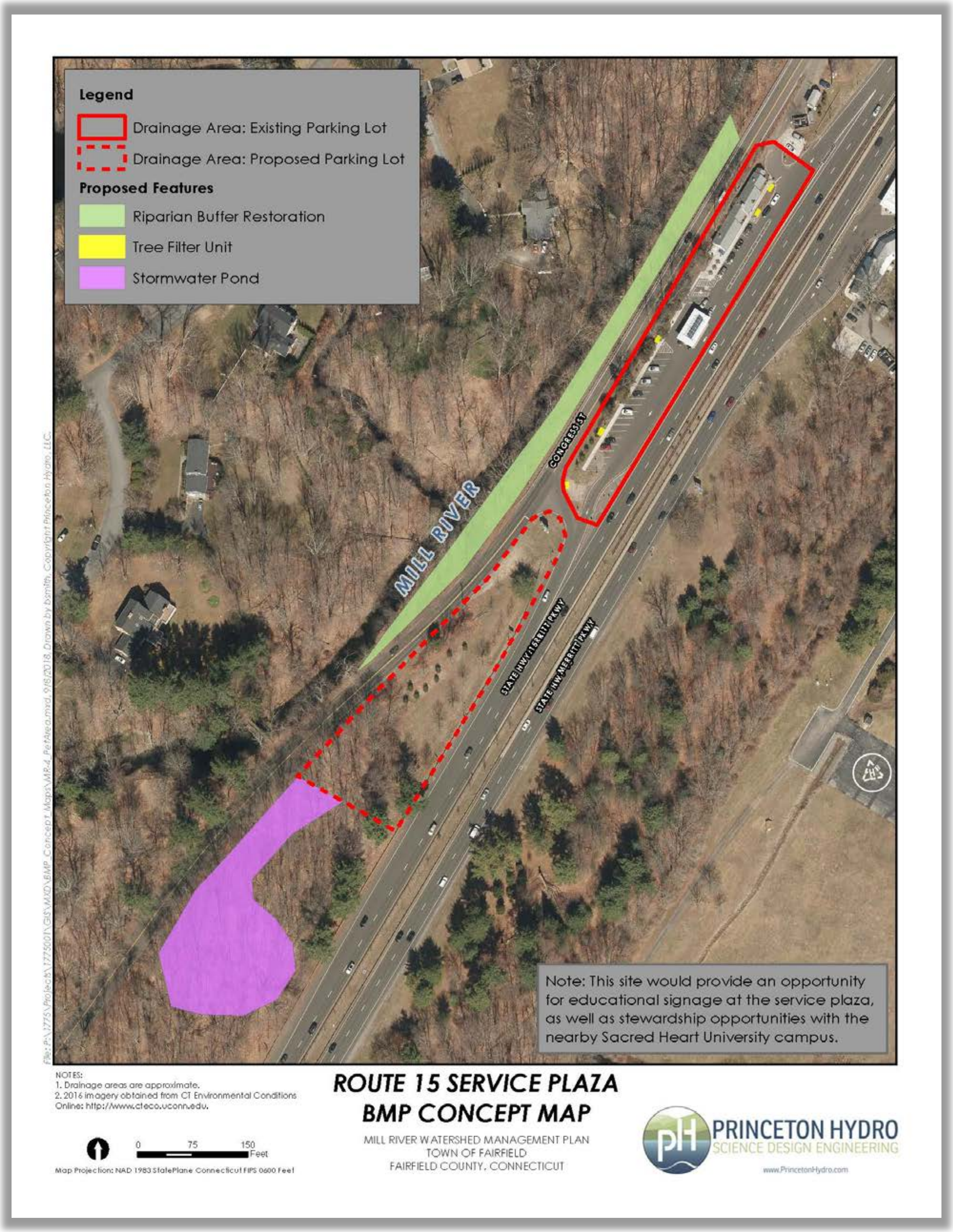


Figure 5.30: Route 15 Service Plaza BMPs

Figure 5.31: Candidate site for tree filter install to improve interception of stormflow, reduce delivery of solids such as mulch to catch basins, and remove bacteria

Figure 5.32: Candidate site stormwater pond to capture and treat sheet flow

MR-5

This is a dual purpose site, encompassing the Park and Ride on Jefferson Street as well as a Connecticut Department of Transportation (CTDOT) storage yard. The site lies between Merritt Parkway and the Jefferson Street ramps. Once again, this site is large impervious surface, but also incorporates bulk storage areas. As such, the typical stormwater problems, such as the generation of excessive stormwater and high peak flows, exist as does the potential for enhanced solids loading due to CTDOT storage at the site. Stormwater infrastructure does exist at the site in the form of catch basins in the parking lot, various roadside swales, and a detention basin in poor repair. Detention basins offer little stormwater treatment capacity, although do provide peak flow reductions.

In order to improve stormwater management at the site it is recommended that conveyance and capture of stormwater first be improved at the parking lot. While a variety of LID BMPs could be installed (such as those shown in Figure 5.29), the simple installation of water bars or small dykes to direct sheetflow to the catch basins is sufficient because of the downstream treatment capacity offered by the existing basin. For the basin the main aspect would be a conversion to stormwater pond design, meant to dramatically increase stormwater quality treatment, including soluble materials and other parking lot pollutants not discussed including metals and hydrocarbons. Such a design would continue to provide the capture of solids and significantly lower peak flow volumes.

The site concept layout is provided below, as are photographs of the basin and a detail of an alternative LID parking lot layout with various BMPs.

Jefferson St. Parking BMPs (MR5) Subwatershed 4, Highest Priority Town of Fairfield N 41.221178°, W 73.2526 ° Catchment ~4.27 acres	
Management Measures	
Stormwater Pond Retrofit	
Parking Lot Diversion/Water Bars	
Estimated Load Reductions	
Nitrogen (kg)	2.4
Phosphorus (kg)	0.2
Solids (kg)	112.1
Bacteria (%)	40%
Other Benefits	
Runoff Volume Reduction	S
Runoff Capture	S
Groundwater Recharge	L
Stream Channel Protection	L
Peak Flow Control	S
S - Significant	
P - Partial	
L - Low or Unknown	

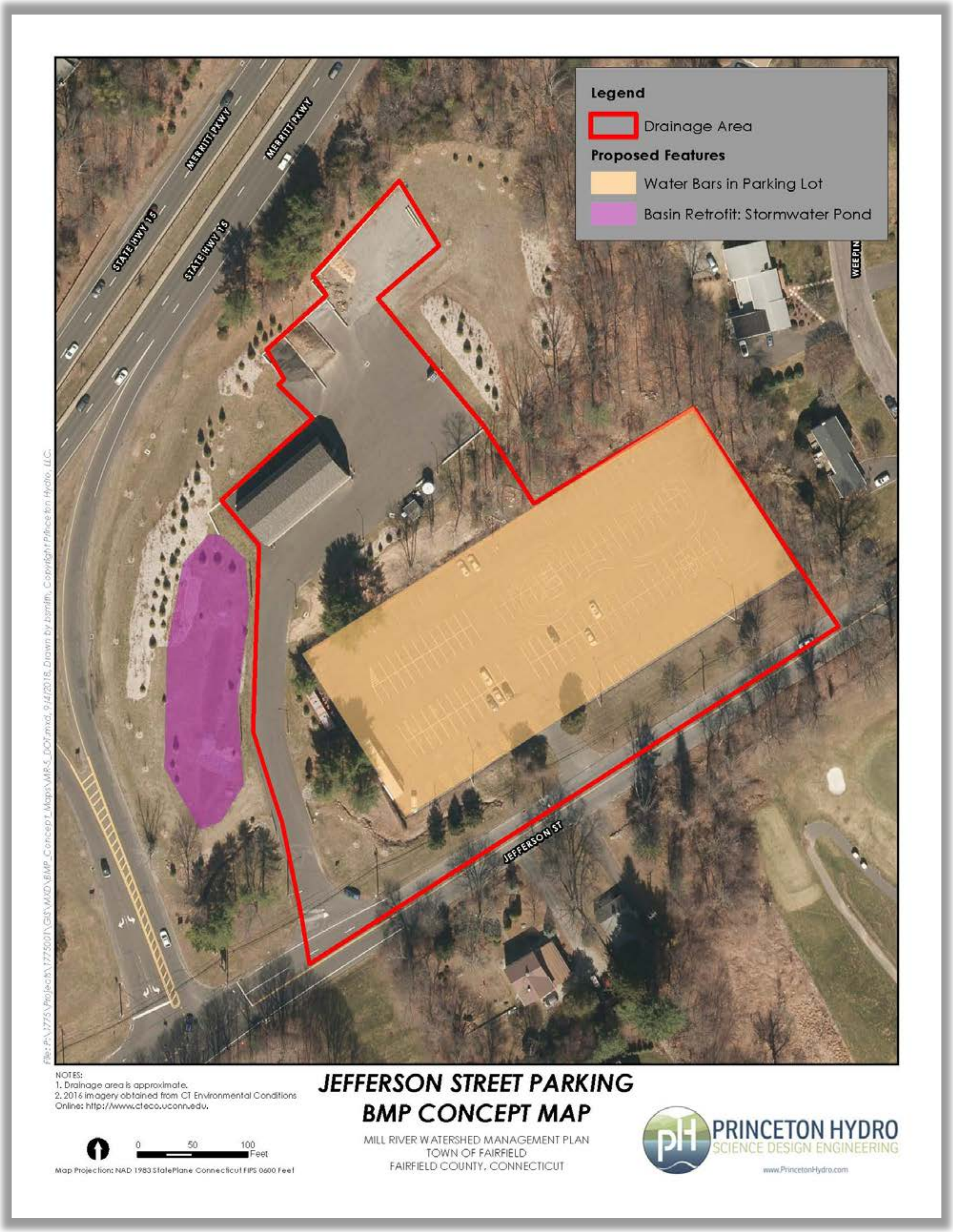


Figure 5.33: Jefferson Street Parking BMPs

Figure 5.34: Existing detention basin is a candidate for conversion to a stormwater pond design

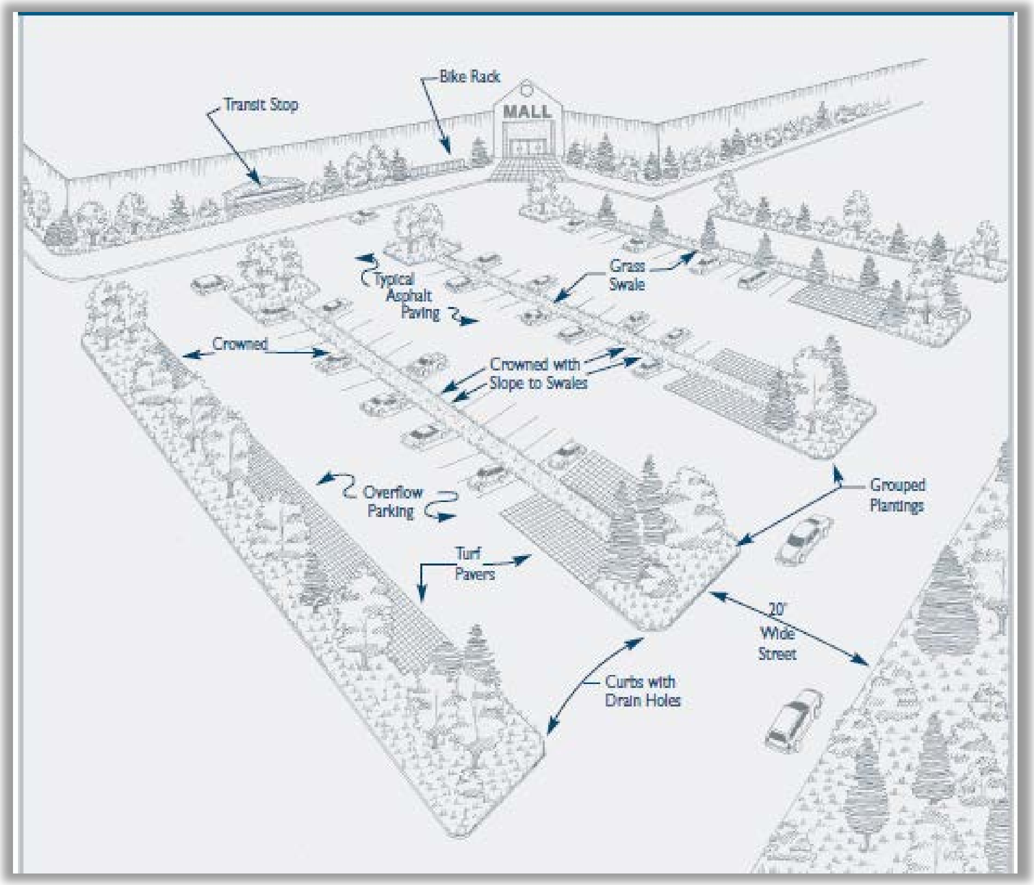


Figure 5.35: Detail of various LID parking lot BMPs; for this site simple water bars are likely sufficient: CT Stormwater Quality Manual

MR-7

Sacred Heart University represents a campus setting; while this is an educational facility, similar layouts may be found for commercial, industrial, institutional, or governmental uses. The campus is located along the eastern boundary of Fairfield near the intersection of Bridgeport and Trumbull. Like many campuses, there are a mix of smaller uses within the larger landscape including large institutional buildings, maintained lawn, recreational areas, and supporting transportation network of roads and parking lots. While nutrients, solids, and even bacterial loads are anticipated to be small (given a proper fertilizing regime and no obvious uses related to animal husbandry) these facilities generate high amounts of stormwater from paved areas, compacted soils, and roofs. Management often tends towards reducing flooding, by, where possible or as older management structures dictate, rapidly shunting the water away from buildings and parking lots.

A number of areas and stormwater strategies were considered for the campus, but continued site development/redevelopment and upgrades to modern stormwater designs around the facility meant that some original concepts were not necessary. Efforts should therefore focus on improving management of parking lot runoff through the use of tree filters or tree wells. This provides a number of benefits including volume reductions, groundwater recharge, and peak flow control, as well as high removal rates for nutrients, solids, and bacteria. These units will also correct erosion where existing infrastructure is overwhelmed. In total, ten areas were identified within three parking lots in the portion of campus lying between Park Avenue and Jefferson Street. Opportunities for signage and stewardship exist at the campus.

The drainage areas and BMP locations are shown on the concept map. Photographs depicting existing stormwater infrastructure are also provided.

Sacred Heart University BMPs (MR7)	
Subwatershed 4, Highest Priority	
Town of Fairfield	
N 41.2231°, W 73.2423 °	
Catchment ~3.03 acres	
Management Measures	
Tree Filters	
Estimated Load Reductions	
Nitrogen (kg)	1.4
Phosphorus (kg)	0.1
Solids (kg)	55.7
Bacteria (%)	85%
Other Benefits	
Runoff Volume Reduction	P
Runoff Capture	S
Groundwater Recharge	P
Stream Channel Protection	L
Peak Flow Control	P
S - Significant	
P - Partial	
L - Low or Unknown	

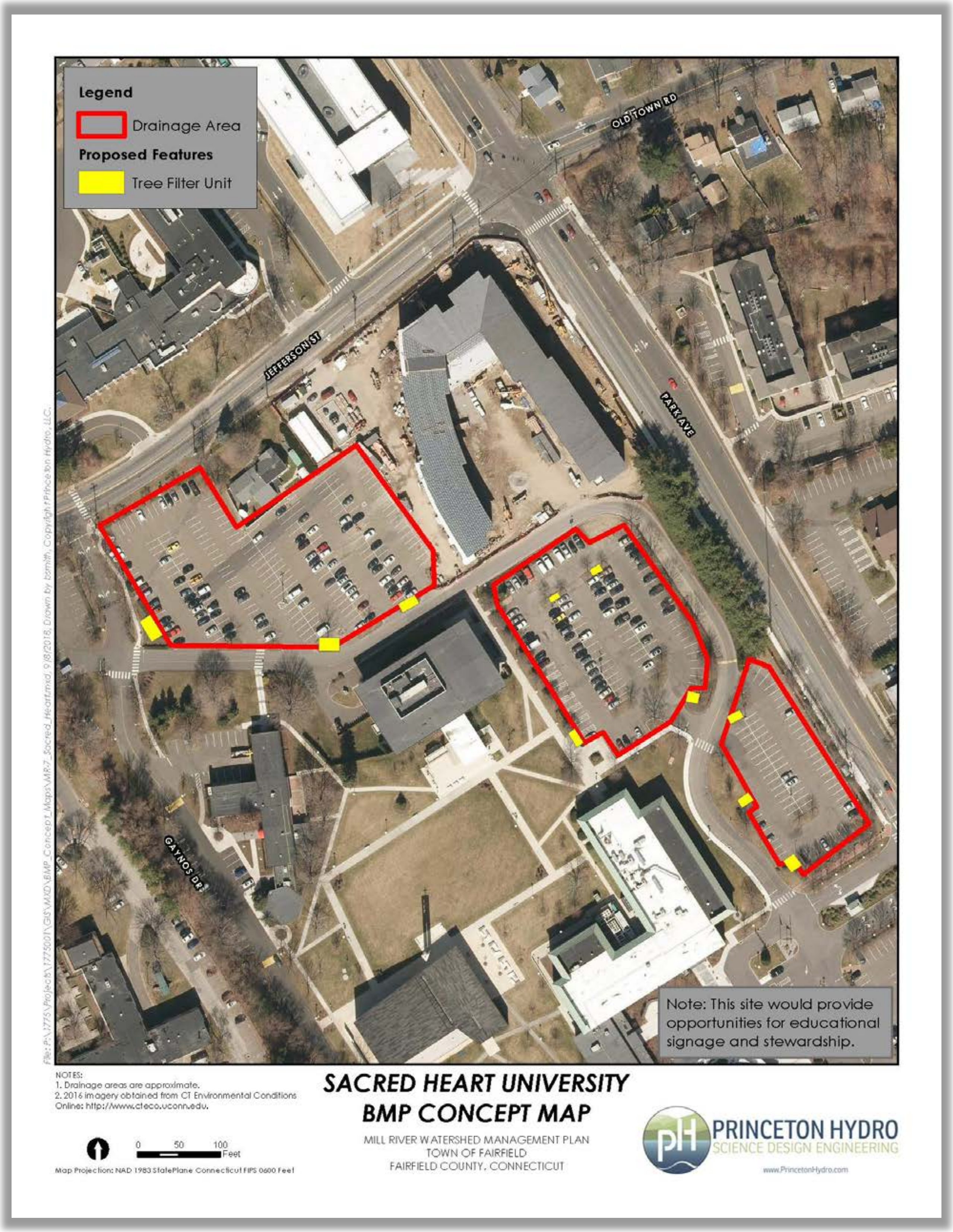


Figure 5.36: Sacred Heart University BMPs

Figure 5.37: Parking lot runoff not adequately intercepted, leading to erosion

Figure 5.38: Poor stormwater management leads to ponding and generation of solids

MR-8

The Mill River Shoreline project is located within Fairfield, across from the Duck Farm Road Open Space Area, a part of the Mill River Greenbelt. The small catchment of 3.7 acres is situated between Mill River and Alma Drive to west, and bound downstream by Duck Farm Road. This is a residential neighborhood with maintained lawn to the water's edge. Mill River is over widened in this reach as a result of constriction at Duck Farm Road. In its current configuration there is essentially no functional value to the riparian area.

This is a candidate site for riparian restoration activities, although this will require buy-in from homeowners to implement the project. The primary goal is to restore at least a partial buffer in this section to capture runoff and stabilize the bank providing channel protection. It will enhance habitat quality in the reach. While nutrient and solids treatment will be low, due to the small available footprint, it can provide secondary pollution abatement value. If designed properly it will limit waterfowl access and site use thus limiting bacteria loading. The key to a successful design will be maintaining both access to the shoreline and a view of the water. This can be accomplished by using low vegetation, with a heavy reliance on herbaceous plants, preferably flowering varieties, and orienting footpaths on a bias or zig-zag pattern such that a view of grassed areas is blocked from the river which discourages waterfowl movements.

A site map is provided below as well as a photograph of existing site conditions.

Mill River Shoreline BMP (MR8)	
Subwatershed 8, Highest Priority	
Town of Fairfield	
N 41.1668°, W 73.2698 °	
Catchment ~3.74 acres	
Management Measures	
Riparian Buffer Restoration	
Estimated Load Reductions	
Nitrogen (kg)	3.0
Phosphorus (kg)	0.1
Solids (kg)	74.2
Bacteria (%)	10%
Other Benefits	
Runoff Volume Reduction	L
Runoff Capture	S
Groundwater Recharge	L
Stream Channel Protection	S
Peak Flow Control	L
S - Significant	
P - Partial	
L - Low or Unknown	

Figure 5.39: Mill River Shoreline concept

Figure 5.40: West bank of Mill River (left) contains no riparian vegetation in this residential setting

MR-9

The Carolton Chronic Convalescent BMP site is an assisted living facility. Located within Fairfield, it lies on the eastern watershed boundary and abuts Roger Ludlowe Middle School and Sturges Park just north of I-95 (Connecticut Turnpike). As with other campus-type facilities discussed in the WMP, the site is highly impervious as a result of a large building nestled among servicing parking lots. Overall, projected loading of pollutants is low, but excessive runoff and inadequate treatment are issues. As with all such surfaces, any pollutants that do exist, including fecal bacteria from wildlife, are easily transported into receiving waterways.

Tree filters are recommended at this site to provide stormwater interception and treatment. Tree filters will likely be used as the stormwater system does discharge to an existing basin. As such, these units would provide a function that might be described as pre-treatment. Portions of the parking lots and drainage areas are in poor repair, and these areas generate significant solids loads that could more easily be maintained in discrete units. A primary benefit to these systems is that they can easily be installed within a small footprint. In total, four tree filter units are recommended for this site.

A concept map is provided, as well as images of existing conditions.

Carolton Convalescent BMP (MR9)	
Subwatershed 9, High Priority	
Town of Fairfield	
N 41.1464°, W 73.2654°	
Catchment ~6.98 acres	
Management Measures	
Tree Filters	
Estimated Load Reductions	
Nitrogen (kg)	5.5
Phosphorus (kg)	0.2
Solids (kg)	105.1
Bacteria (%)	85%
Other Benefits	
Runoff Volume Reduction	P
Runoff Capture	S
Groundwater Recharge	P
Stream Channel Protection	L
Peak Flow Control	P
S - Significant	
P - Partial	
L - Low or Unknown	

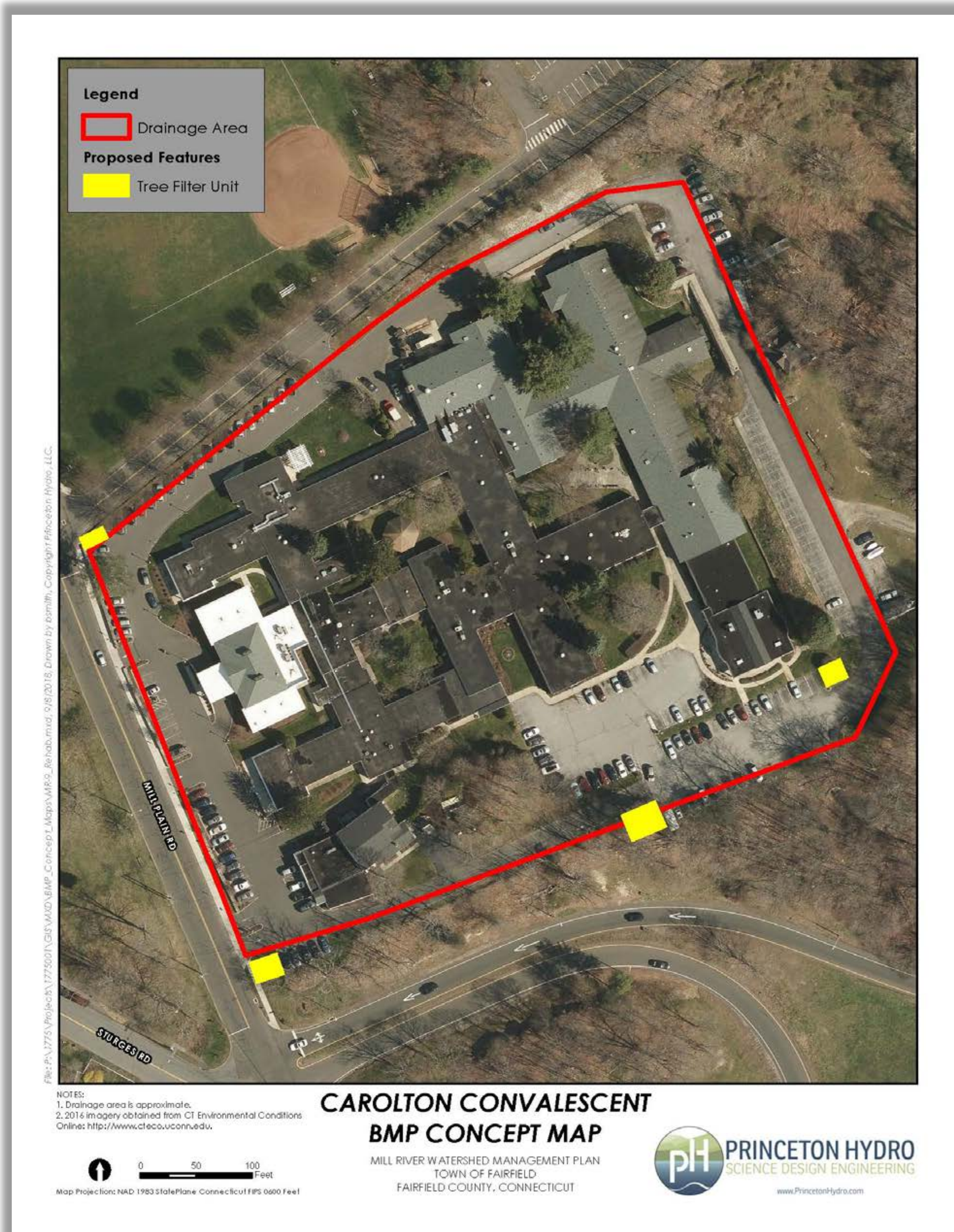


Figure 5.41: Carolton Chronic Convalescent BMPs

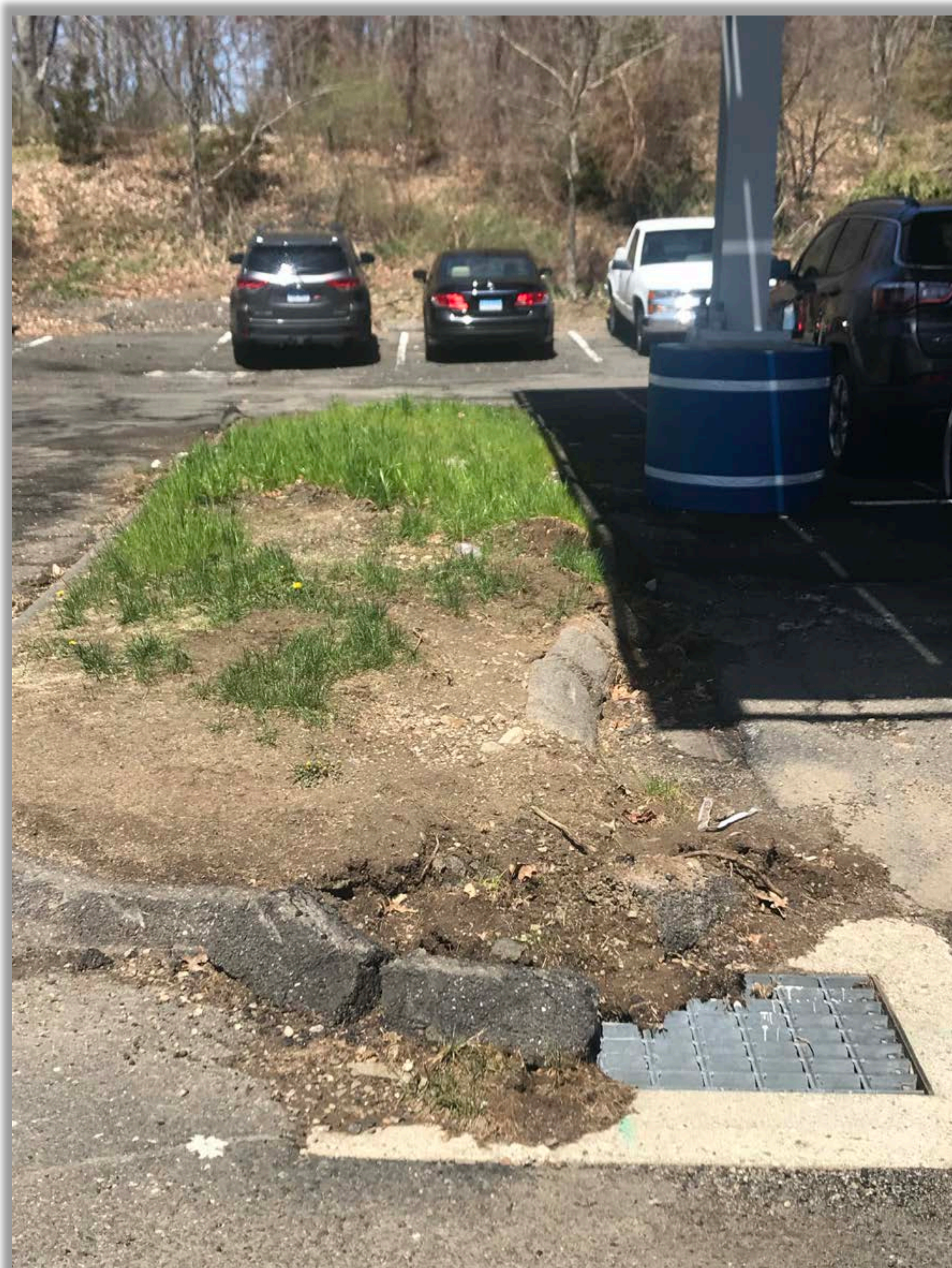


Figure 5.42: Parking lot catch basin inundated with eroding soils

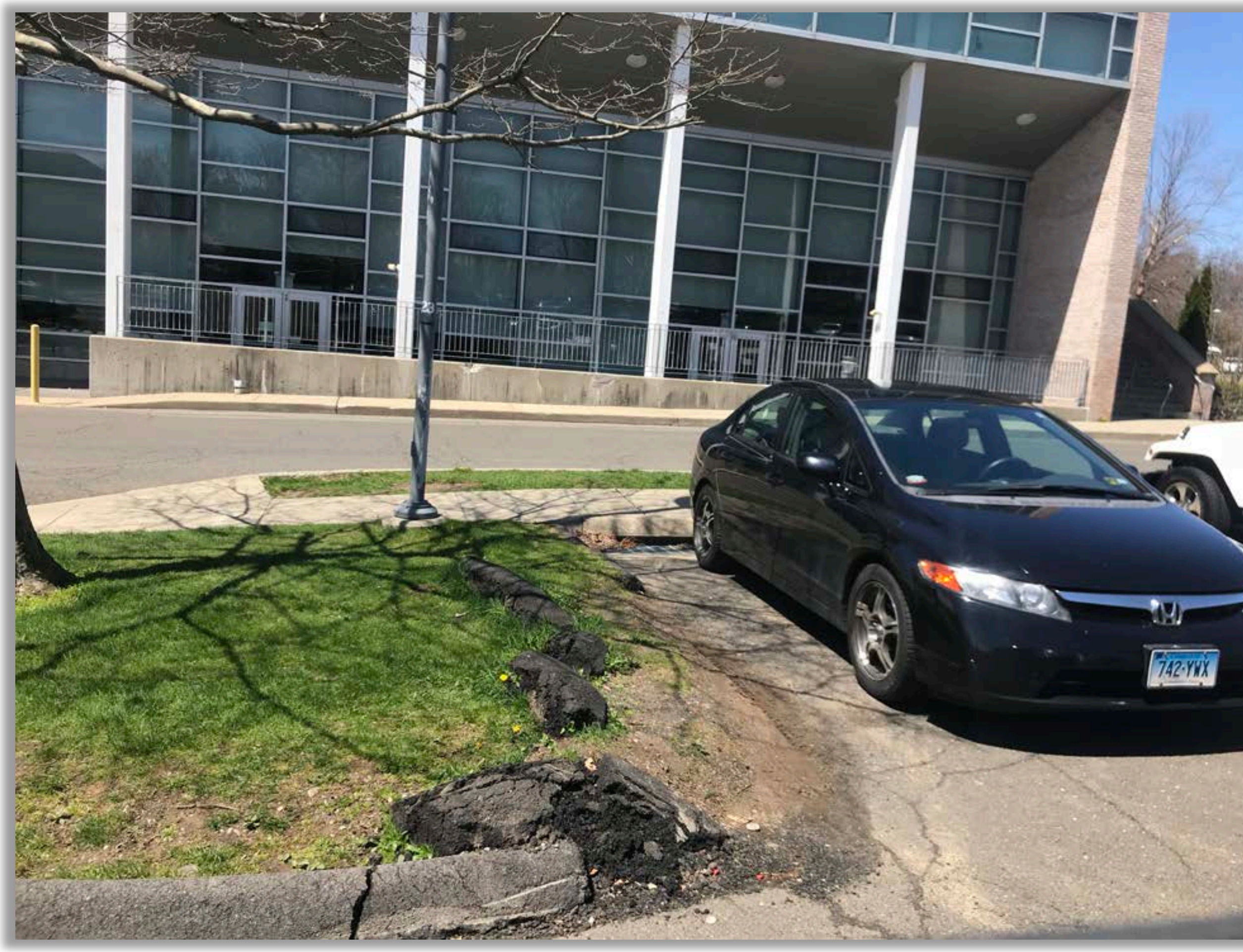


Figure 5.43: Another catch basin showing capture of leaf litter and solids from eroding lawn surface and poor state of repair for curbing

MR-10

Riverfield School is located in Fairfield on Mill Plain Road. Mill River lies approximately 0.35 miles to the west of the project site. This site is a school facility, and accordingly has large areas of impervious surfaces including the school roof and parking lots. Unlike some of the other institutional campuses, total imperviousness is somewhat lower due to increased coverage of recreational areas. The value of these athletics fields as it relates to infiltration is probably low, but the focus of this project, at least in an initial phase, will be management of stormwater associated with the parking areas and roadways.

These areas, having impervious surfaces, generate small pollutants loads, but large hydraulic loads. Tree filters have been selected as an appropriate means to intercept and treat runoff from paved areas. It is likely that the filters will be connected to the existing conveyance infrastructure, but where conditions permit tree well designs, which incorporate infiltration should be considered. The parking lots are in good shape yet bare soils and compaction in surrounding areas likely increase runoff and solids loading through the area. In total, five tree filter units are recommended for this site. As a publicly-owned entity, the necessary approvals to implement the recommended project scheme are considerably reduced.

A concept map is provided below. Existing conditions are depicted in a picture.

Riverfield School BMP (MR10)	
Subwatershed 8, Highest Priority	
Town of Fairfield	
N 41.1648°, W 73.2677°	
Catchment ~1.39 acres	
Management Measures	
Tree Filters	
Estimated Load Reductions	
Nitrogen (kg)	2.0
Phosphorus (kg)	0.1
Solids (kg)	20.7
Bacteria (%)	85%
Other Benefits	
Runoff Volume Reduction	P
Runoff Capture	S
Groundwater Recharge	P
Stream Channel Protection	L
Peak Flow Control	P
S - Significant	
P - Partial	
L - Low or Unknown	

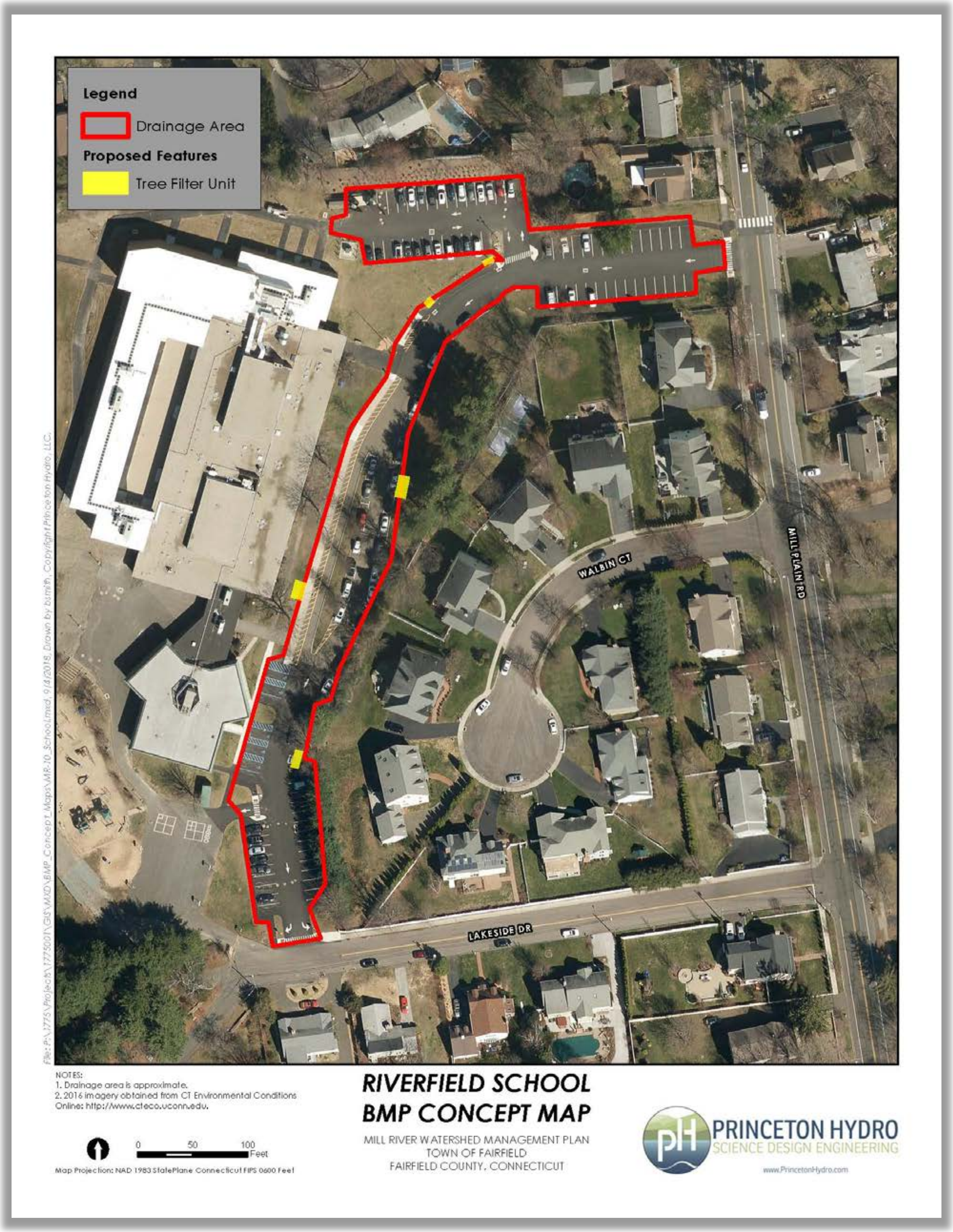


Figure 5.44: Riverfield School BMPs

Figure 5.45: Catch basin adjacent to roadway

MR-11

The Beers Road project site is located within Fairfield along the town boundary with Easton. The small catchment is just 0.5 acres, and includes the stormwater generated along Beers Road from Morehouse Road to Rolling Hills Drive. Beers Road spans the Morehouse Brook valley, includes portions of both towns, and the captured stormwater is discharged directly to the brook.

Several problems have been noted at the site, particularly infilling of the catch basin and destabilization of the streambank at the point of discharge, which is perched and lacks a headwall. In order to address these problems, the catch basin should be fitted with an insert to better capture sediments that are otherwise discharged to the brook. In order for it to function properly, to capture and discharge stormwater and prevent ponding on the road, regular maintenance will be required to empty accumulated sediment which is made easier with the insert.

In addition, the culvert needs to be removed and replaced with a proper design to minimize energy at the outlet and sited at the proper grade to prevent future bank instability.

The project site is depicted in the concept map and pictures of existing infrastructure.

Beers Road BMP (MR11) Subwatershed 4, Highest Priority Town of Fairfield N 41.2309°, W 73.2804° Catchment ~0.47 acres	
Management Measures	
Inlet Retrofit	
Estimated Load Reductions	
Nitrogen (kg)	0.0
Phosphorus (kg)	0.0
Solids (kg)	3.4
Bacteria (%)	10%
Other Benefits	
Runoff Volume Reduction	L
Runoff Capture	P
Groundwater Recharge	L
Stream Channel Protection	S
Peak Flow Control	L
S - Significant	
P - Partial	
L - Low or Unknown	

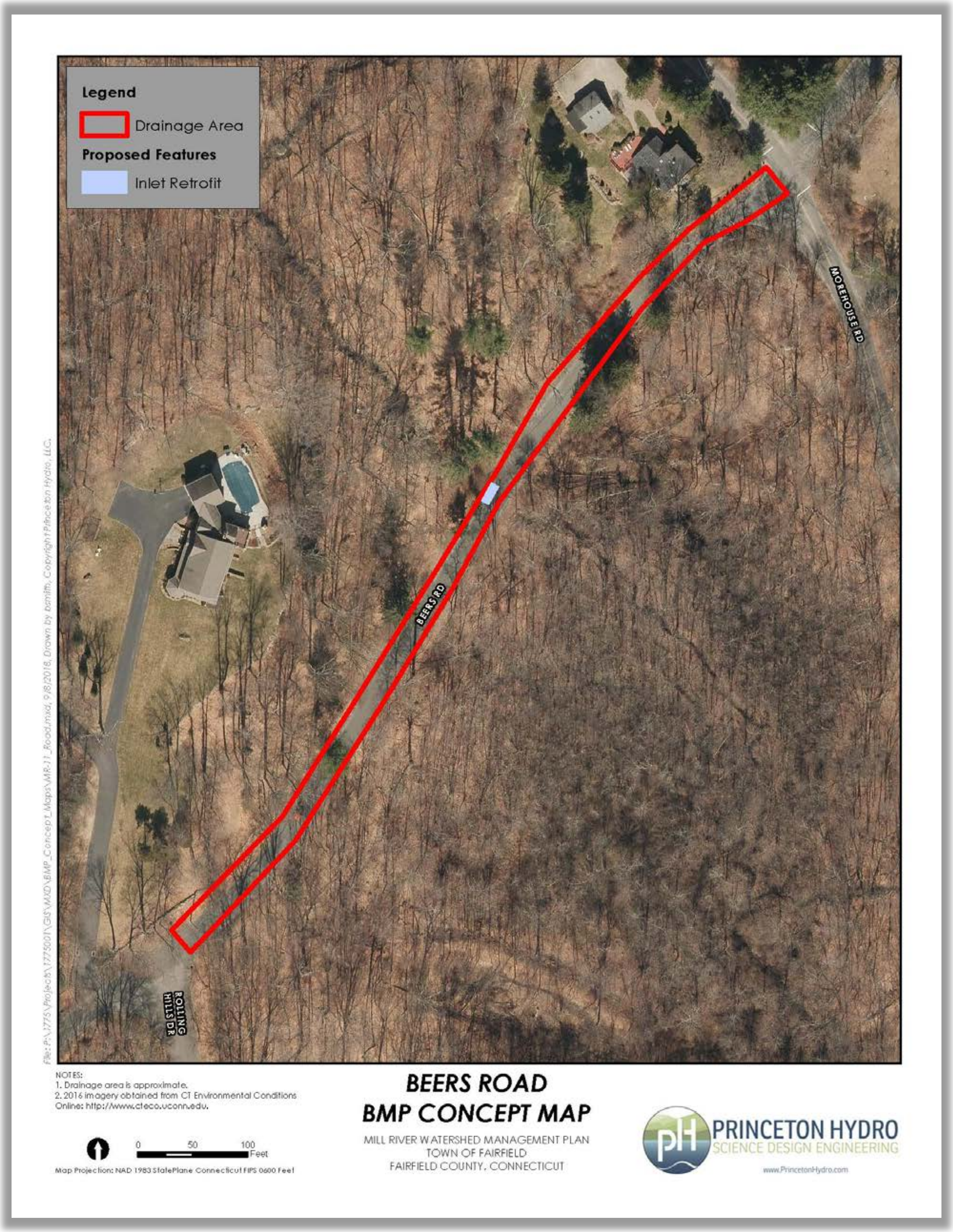


Figure 5.46: Beers Road Concept

Figure 5.47: Beer Road catch basin to be retrofitted with basin insert

Figure 5.48: Catch basin discharges to Morehouse Brook at the road culvert creating bank instability and downstream sedimentation

5.4 ADDITIONAL IMPLEMENTATION PROJECT SITES

In addition to the nine implementation project concepts described above additional project sites have been identified throughout the watershed. In order to seriously affect load reductions, especially for indicator bacteria, implementation of management measures will need to be taken on as broad a scale as possible within the watershed. There are several reasons requiring this type of approach, which are primarily related to the diffuse nature of loading in the watershed, large required reductions, on the order of 50% and higher, necessary to meet the TMDL, and the difficult of managing bacteria loads relative to some of the other NPS pollutants. Therefore, additional project sites have been selected representing two different subsets of candidate sites selected according to different criteria. The analysis also includes site prioritization, based on the subwatershed in which the site is located.

5.4.1 TOWN OF FAIRFIELD IMPLEMENTATION PROJECT SITES

The Town of Fairfield has identified 20 additional project sites. The selection of these sites represents an amalgam of different site types and required management measures, but all represent a known problem area documented by the Town. The identification of these sites has arisen in a variety of ways but include public comment, landowner complaints, and identification of sites through operational activities of the municipal government. While the management of bacterial loads is a primary benefit and objective for many of these sites, these sites are expected to address a wide array of NPS loading and will include a variety of measures designated in the following broad categories:

- Agricultural BMPs
- Pet Waste and Wildlife Management
- Stormwater Management
- Stream Bank and Riparian Enhancement

In combination, these management measures will seek to address the following pollutant loading and related issues:

- Agricultural nutrient loading and solids generation
- Streambank erosion
- Stormwater generation and runoff
- Pet waste
- Retrofits of underperforming BMPs
- Deferred BMP maintenance
- Riparian encroachment
- Wetland restoration
- Dam removal

A table is provided below which details a project identifier, suggested management measure, and management measure category. A project figure depicting these sites and additional sites may be found below.

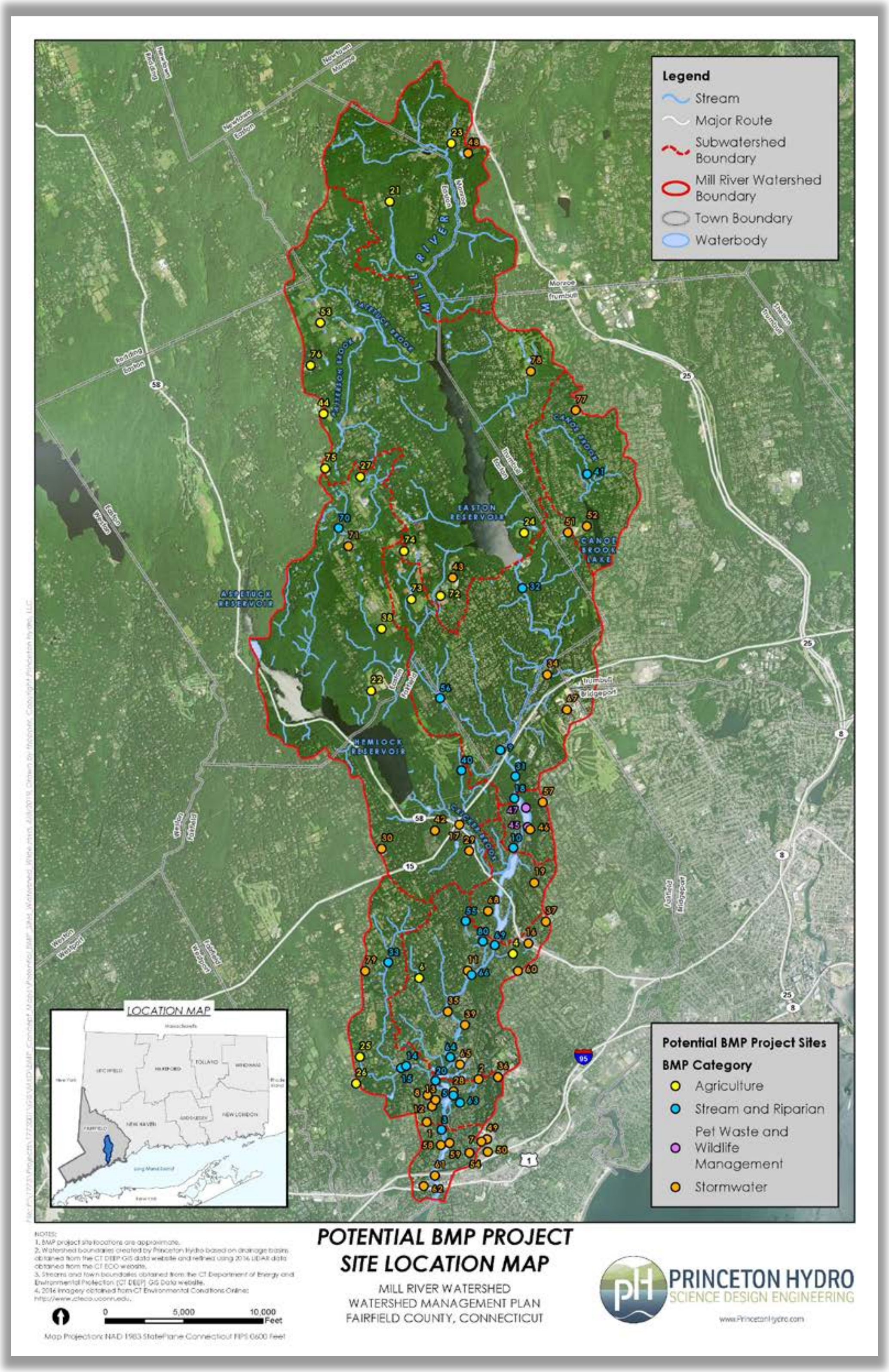


Figure 5.49: Additional Implementation Project Sites

Table 5.4: Fairfield Potential BMP Project Sites

BMP ID	NAME	CATEGORY	DESCRIPTION	SubWS ID	PRIORITY
4	220 Pansy Road	Agriculture	Stormwater and nutrient management	8	Highest
6	366 Mine Hill Road	Agriculture	Erosion and nutrient management along the stream	8	Highest
9	450 Congress Street	Bank and Riparian Enhancements	Repair stream bank erosion	4	Highest
11	834 Brookside Drive	Stormwater	Stormwater BMP for parking lot	8	Highest
16	2181 Black Rock Turnpike	Stormwater	Stormwater BMP for parking lot	8	Highest
18	Cascade Parking - 880 Morehouse Hwy	Bank and Riparian Enhancements	Repair stream bank erosion	4	Highest
20	Two Brooks Lane ROW	Bank and Riparian Enhancements	Repair stream bank erosion	8	Highest
1	40 Southport Terrace	Stormwater	Detention basin maintenance	6	High
2	55 Matilad Place	Stormwater	Detention basin maintenance	6	High
3	63 Mill Hill Terrace	Bank and Riparian Enhancements	Repair stream bank erosion from unimproved parking area	9	High
5	231 Doreen Drive	Bank and Riparian Enhancements	Repair stream bank erosion	6	High
7	400 Mill Plain Road	Stormwater	Detention basin maintenance	9	High
8	421 Fulling Mill Lane	Stormwater	Detention basin maintenance	6	High
12	1159 Bronson Road	Stormwater	Stormwater BMP for landscaping business property	6	High
13	1174 Bronson Road	Stormwater	Stormwater BMP for landscaping business property	6	High
14	1780 Bronson Road	Bank and Riparian Enhancements	Repair stream bank erosion	6	High
15	1845 Bronson Road	Bank and Riparian Enhancements	Repair stream bank erosion	6	High
10	607 Winnepoge Drive	Bank and Riparian Enhancements	Repair stream bank erosion from beaver damage	5	Medium
19	High Ridge Park - 33 Palamar Drive	Stormwater	Construct stormwater treatment BMP	7	Medium
17	4000 Black Rock Turnpike	Stormwater	Stormwater BMP for park and ride	3	Low

5.4.2 GIS-IDENTIFIED IMPLEMENTATION PROJECT SITES

Lastly, another suite of potential implementation project sites has been identified using geographic analysis. This analysis was predicated on first considering pollutants of concern and identifying the physical characteristics that contribute to load generation as well as the vectors of the loading. Using various GIS layers and analytical tools intersections of these contributing factors could be identified and then examined using aerial photographs and other tools. An effort was made to identify examples of each of the generalized management categories including stormwater management, agricultural BMPs, stream bank stabilization and riparian enhancement, and pet waste and wildlife management. No specific project sites were identified for septic management measures for several reasons. First, onsite septic management is primarily the responsibility of the owner/operator of the system, although the municipalities bear responsibility to ensure proper siting and design of the system, proper enforcement of the governing regulations, and working with the public when failures do occur. There of course is also a public outreach and educational duty to ensure proper function. Regarding the sewered areas, the operation and control of those duties is already highly regulated and actively maintained. The MS4 program requirements also address illicit discharges and other cross-contamination in a parallel program. Finally, the identification of failing or malfunctioning septic systems is not easily accomplished through GIS means, especially as operation and maintenance factor so heavily in their performance. In total, 60 additional project implementation candidates were mapped.

This analysis therefore focused on examining a number of key coverages including:

- Land Use/Land Cover – LU/LC is intimately linked with pollutant loading calculation and in particular this analysis focused on mixed and residential land uses secondarily on agricultural uses as loaders of nutrients, solids, and bacteria. Other types were also examined including transportation, institutional, and commercial. Open spaces also represent opportunities especially regarding control of pet waste and as publicly-owned sites where implementation may be easier.
- Streams, Waterbodies, and Wetlands – This WMP is focused on managing water resources and identifying traits and areas that are subject to excessive pollutant loading or show degradation. Where these features abutted areas with elevated loading or were otherwise hydraulically connected, this indicated a potential implementation site.
- Slopes and Topography – In conjunction with the streams layer, slopes could be used to infer areas of excessive erosion or solids loading.
- Impervious Cover – Imperviousness is related to LU/LC, but indicates a mechanism of higher loading through increased runoff which serves a vector of bacterial, nutrient, and solids pollutants from the land surface as well as increased risk of erosion within receiving channels.
- Stormwater Conveyance/Storm Sewers – Mapping of the storm sewer network is mandated by the MS4 permit and identifies basins and outfalls that are prime candidates for retrofits.
- Roads – Roads are stormwater vectors, highly impervious, interconnected, ubiquitous, and often encroach waterways and wetlands providing various opportunities for NPS management.

Table 5.5a: GIS-Identified Potential BMP Project Sites

BMP ID	NAME	CATEGORY	DESCRIPTION	SubWS ID	PRIORITY
31	Cascades-mohegan Trails Open Space	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 3,000 LF	4	Highest
32	Centennial Watershed State Forest	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 2,500 LF	4	Highest
34	Dover Park	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	4	Highest
51	Madison Middle School	Stormwater	Rain gardens for stormwater management and public education	4	Highest
56	Municipal Open Space (Blue Bell Lane)	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 1,500 LF	4	Highest
67	Sacred Heart University	Stormwater	Rain gardens for stormwater management and public education	4	Highest
73	Sherwood Farm	Agriculture	Erosion stabilization	4	Highest
74	Silverman's Farm	Agriculture	Stormwater and nutrient management	4	Highest
35	Drake Lane Public Open Space	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	8	Highest
36	Fairfield University	Stormwater	Rain gardens for stormwater management and public education	8	Highest
37	Fairfield Woods Junior High School	Stormwater	Rain gardens for stormwater management and public education	8	Highest
39	Flower House Drive park	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	8	Highest
55	Mt Laurel Park	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 1,500 LF	8	Highest

Table 5.5b: GIS-Identified Potential BMP Project Sites

BMP ID	NAME	CATEGORY	DESCRIPTION	SubWS ID	PRIORITY
60	Osborn Hill Elementary School	Stormwater	Rain gardens for stormwater management and public education	8	Highest
64	Riverfield	Bank and Riparian Enhancements	Riparian restoration/erosion control	8	Highest
65	Riverfield Elementary School	Stormwater	Rain gardens for stormwater management and public education	8	Highest
66	Riverside Park/Springer Glen Open Space	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 3,000 LF	8	Highest
69	Samp Motar Dam Open Space	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 600 LF	8	Highest
80	Trillium Road Open Space	Bank and Riparian Enhancements	Wetland restoration	8	Highest
25	300 Hulls Farm Rd	Agriculture	Stormwater, erosion, and nutrient management	6	High
26	361 Hulls Farm Rd	Agriculture	Stormwater and nutrient management	6	High
28	Birchbrook Park	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	6	High
33	Connecticut Audubon Society Open Space	Bank and Riparian Enhancements	Dam removal and wetland restoration	6	High
63	Perry's Mill Ponds Park	Bank and Riparian Enhancements	Wetland restoration	6	High
79	Timothy Dwight Park	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	6	High
49	Ludlowe Middle/Highschool	Stormwater	Rain gardens for stormwater management and public education	9	High
50	Ludlowe Middle/Highschool Basin	Stormwater	Detention basin maintenance	9	High
54	Mill Plain Green (Town Green)	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	9	High

Table 5.5c: GIS-Identified Potential BMP Project Sites

BMP ID	NAME	CATEGORY	DESCRIPTION	SubWS ID	PRIORITY
58	Old Fording Place Open Space (Bronson Road)	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	9	High
59	Old Fording Place Open Space (Somerset Avenue)	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	9	High
61	Outfall at I95 Crossing	Stormwater	Retrofit outfall structure and/or add water quality treatment measures	9	High
62	Palmers Neck Park	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	9	High
45	Lake Mohegan Beach	Pet Waste and Wildlife Management	Pet waste station	5	Medium
46	Lake Mohegan Beach Parking Lot	Stormwater	Rain gardens for stormwater management and public education	5	Medium
47	Lake Mohegan Dog Park	Pet Waste and Wildlife Management	Pet waste station	5	Medium
57	North Stratfield Elementary School	Stormwater	Rain gardens for stormwater management and public education	5	Medium
68	Samp Mortar Rock	Stormwater	Construct stormwater treatment BMP on public land and redirect local storm sewers	7	Medium
41	Great Oak Park	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 6,000 LF	10	Medium
52	Madison Middle School Fields	Stormwater	Stormwater BMP for sport field	10	Medium
77	Tashua Elementary School	Stormwater	Rain gardens for stormwater management and public education	10	Medium
21	45 Maple Rd	Agriculture	Erosion and nutrient management along the stream which bisects the property	1	Low

Table 5.5d: GIS-Identified Potential BMP Project Sites

BMP ID	NAME	CATEGORY	DESCRIPTION	SubWS ID	PRIORITY
23	85 Hattertown Rd	Agriculture	Stormwater and nutrient management	1	Low
48	Lakewood YMCA (Camp Tepee)	Stormwater	Rain gardens for stormwater management and public education	1	Low
24	99 Kachele St	Agriculture	Stormwater and nutrient management	2	Low
43	Helen Keller Middle School	Stormwater	Rain gardens for stormwater management and public education	2	Low
44	High Lonesome Stables	Agriculture	Stormwater and nutrient management	2	Low
53	Maple Row Farm	Agriculture	Stormwater, erosion, and nutrient management	2	Low
72	Sherwood Farm	Agriculture	Stormwater and nutrient management	2	Low
75	Slady's Tree Farm	Agriculture	Stormwater and nutrient management	2	Low
76	Sweetbrier Farm	Agriculture	Stormwater and nutrient management	2	Low
78	Tashua Recreation Area	Stormwater	Stormwater BMP for public golf courese	2	Low
22	73 Wilson Rd	Agriculture	Stormwater and nutrient management	3	Low
27	701 Sport Hill Rd	Agriculture	Stormwater, erosion, and nutrient management	3	Low
29	Black Rock Church	Stormwater	Stormwater BMP for parking lot	3	Low
30	Burr Elementary School	Stormwater	Rain gardens for stormwater management and public education	3	Low
38	Farm fields along Morehouse Rd	Agriculture	Stormwater and nutrient management	3	Low
40	Grace Richardson Conservation Area Open Space	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 3,000 LF	3	Low
42	Greenfield Hunt Development	Stormwater	Detention basin maintenance	3	Low
70	Samuel P. Senior Memorial Park	Bank and Riparian Enhancements	Stream/Riparian/Wetland restoration along publc open space, approx 1,500 LF	3	Low
71	Samuel Staples School	Stormwater	Rain gardens for stormwater management and public education	3	Low

6.0 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 WMP, this section addresses the fourth of the EPA nine elements.

6.1 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 strict 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 a TMDL. Often, these grants operate on all three levels. In addition, many of the programs provide not only financial assistance, but technical assistance. The following sections will explore some of the available funding opportunities.

6.1.1 SECTION 319 NONPOINT SOURCE MANAGEMENT PROGRAM

One of the best known, widely utilized, and powerful 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 annually. While this funding covers an array of activities, the 319 grants are recognized by the EPA as particularly important in implementing TMDLs.

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, this WMP 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 aegis of the Connecticut Nonpoint Source 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 – here the focus is on funding projects identified in approved WBP including projects such as targeted load reductions, habitat improvements, and dam removal. As part of an approved plan these types of projects have already been identified and have undergone a rigorous characterization process with the crucial links to NPS control well established.
- Implementation Projects Not Associated with WBPs – Projects that target impaired waters, particularly those identified on the Integrated List, will be considered if they focus on pollution control and attainment of designated uses.
- Watershed Based Plan Development – The focus on the continued development of WBPs correlates to continued focus on implementing the projects contained therein, but also demonstrates that these grants need not be applied strictly to BMP construction, but also planning, monitoring, and research elements that form a part of cohesive effort to manage NPS loading.

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 – These elements are important in describing the focal points for implementation projects using a targeted approach.
- Watershed or Statewide Education and Outreach Projects – These types of projects are focused on increasing awareness, educating the public about the needs for these types of actions, and developing the base support and political will to implement pollutant control strategies. Some of the topics to be addressed would include pet waste, lawncare, and runoff management.
- Land Use Management Projects – These types of projects would support municipal or governmental management efforts and would include items such as land use evaluations, modification of regulatory programs to support green infrastructure and low impact development (LID), educating public officials, incorporating integrated pest management (IPM) and nutrient management, and other similar activities.

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 no longer required, but are encouraged and help to expand the scope of a work plan. One of the benefits of preparing a WMP 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 major role in meeting the funding requirements for this WMP.

6.1.2 OTHER FEDERAL FUNDING SOURCES

In addition to the 319 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 actors. 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 6.1: Federal Programs and Grants

United States Environmental Protection Agency (EPA)	
Urban Waters Small Grants	http://www2.epa.gov/urbanwaters/urban-waters-small-grants
Water quality improvements that support community revitalization in Eligible Geographic Areas	
Healthy Watersheds Consortioum Grants (HWCG)	https://www.epa.gov/hwp/healthy-watersheds-consortium-grants-hwcg
Protecting aquatic systems via landscape approaches	
Healthy Communities Grant Progran	http://www.epa.gov/region1/eco/uep/hcgp.html
New England-centric grant to reduce environmental risks and protect and improve human health and quality of life	
Environmental Education Grants	http://www.epa.gov/enviroed/grants.html
Environmental education projects that promote awareness, stewardship, and skills to protection the environment	
Five Star Restoration Grant Program	http://www.epa.gov/owow/wetlands/restore/5star/
Community-based restoration projects with many stakeholder partners providing education and training experience	
United States Fish and Wildlife Service (USFWS)	
North American Wetlands Conservation Act (NAWCA)	https://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php
Matching grants provided for wetlands protection and restoration activities for enhancement of bird habitat	
Partners for Fish and Wildlife Program	http://www.fws.gov/partners/
Technical and financial assistance program for private landowners to restore, enhance, and manage wildlife habitats	
National Coastal Wetlands Conservation Grant Program	http://www.fws.gov/coastal/coastalgrants/
Protection, restoration, and enhancement of coastal wetland ecosystems and associated uplands	
United States Forest Service	
Watershed and Clean Water Action and Forestry Innovation Grants	https://www.fs.usda.gov/naspf/index.php?q=programs/watershed
Landscape and watershed scale projects are supported through funding and technical assistance	
Natural Resources Conservation Service (NRCS)	
Conservation Stewardship Program	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/csp/
The largest US conservation program for agricultural and forest land management to benefit yields and habitats	
Conservation Reserve Program	http://www.nrcs.usda.gov/programs/crp/
For agricultural lands focused on reducing erosion, preserving and restoring forests and weltands, and other activities	
Emergency Watershed Protection Program (EWP)	http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ct/home/?cid=stelprdb1143958
Conserving natural resoruces by relieving immiminent hazards caused by repeated flooding and other issues	
Wildlife Habitat Incentives Program (WHIP)	http://www.nrcs.usda.gov/programs/whip/
Providing funding to eligible landowners to provide financial and technical assistance for sustainable management	
Environmental Quality Program (EQIP)	http://www.ct.nrcs.usda.gov/programs/eqip/eqip.html
For implementation of conservation measures on agricultural lands	
Healthy Forest Reserve Program	http://www.nrcs.usda.gov/programs/hfrp/proginfo/index.html
Helps private landowners restore, enhance, and protect forest resources and recovery of T&E species and biodiversity	

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.

6.1.3 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 6.2: CT DEEP Programs and Grants

Connecticut Department of Energy & Environmental Protection (CT DEEP)	
Connecticut Clean Water Fund	http://www.ct.gov/deep/cwp/view.asp?a=2719&q=325578&depnav_gid=1654
Environmental infrastructure assistance program focused on wastewater collection and treatment	
Connecticut Lakes Grant Program	http://www.ct.gov/deep/cwp/view.asp?a=2719&q=332726&depnav_gid=1654
A match program for lake restoration projects open to the general public	
Hazard Mitigation Grant	http://www.ct.gov/dep/cwp/view.asp?a=2720&q=325654&depNav_GID=1654
Funds projects that reduce or eliminate long-term risk to human life and property from natural hazards	
Landowner Incentive Program	http://www.ct.gov/dep/cwp/view.asp?a=2723&q=325734&depNav_GID=1655
Technical and funding assistance to landowners for habitat management projects; this in turn uses USFWS monies	
Open Space and Watershed Land Acquistion	http://www.ct.gov/dep/cwp/view.asp?a=2706&q=323834&depNav_GID=1641
Fund made available to muncipalities, conservation groups, and water suppliers for land acquisitions	
Recreation and Natural Heritage Trust Program	http://www.ct.gov/dep/cwp/view.asp?a=2706&q=323840&depNav_GID=1641
CT DEEP utilizes these funds to acquire land and expand natural open space holdings	
Urban Forestry Grant	http://www.ct.gov/dep/cwp/view.asp?a=2697&q=322872&depNav_GID=1631&depNav=|
An outreach program for non-profits servicing urbanized areas	

6.1.4 OTHER FUNDING SOURCES

Other funding sources exist outside of the government. These are usually non-profit environmental conservation and advocacy organizations, although quasi-governmental regional and interstate commissions are also included here. The base funding source for these groups varies, but charitable giving is often an important component. The missions of these groups tend to be more focused; Trout Unlimited is an example of a group dedicated to conservation, protection, and restoration of coldwater fisheries and watersheds. While the mission is narrow, this is a multi-faceted mission and can include fisheries management, water management, and watershed restoration with concerns including pollution, deforestation, stormwater, erosion, and other related topics. A summary of some of the larger and better known groups is provided in Table 6.3 below.

Table 6.3: Other Funding Sources

American Rivers - NOAA	
Community-Based Restoration Program Partnership	http://www.americanrivers.org/initiative/grants/projects/american-rivers-and-noaa-community-based-restoration-program-river-grants-2/
Grants for communities for removing dam and improving fish passage to restore riverine habitats	
Fish America Foundation - NOAA	
Conservation Grants	http://www.fishamerica.org/grants/
Partnership program for communities and agencies to restore habitat for marine and anadromous fishes	
National Fish and Wildlife Foundation (NFWF)	
NFWF Five Star and Urban Waters Restoration Grant Program	http://www.nfwf.org/fivestar/Pages/home.aspx
Community stewardship program to enhance wildlife habitat in priority watersheds	
NFWF Long Island Sound Futures Fund	http://longislandsoundstudy.net/about/grants/lis-futures-fund/
Supports projects that seek to protect and restore Long Island Sound	
Trout Unlimited	
Embrace A Stream	http://www.tu.org/conservation/watershed-restoration-home-rivers-initiative/embrace-a-stream
A matching grant program for coldwwater fisheries conservation	
New England Interstate Water Pollution Control Commission (NEIWPCC)	
Various Programs	http://http://neiwpcc.org/
An interstate partnership that provides training, hosts forums, and operates many programs to manage water pollution	

6.2 COST ESTIMATES

6.2.1 IMPLEMENTATION PROJECT CONCEPT COST ESTIMATES

Cost estimates have been prepared for each of the project concepts. These estimates have been prepared using several sources of guidance including the engineering estimating tool RSMeans and Princeton Hydro project experience. The estimates are based on real take off quantities from the developed catchments and include as appropriate material costs, excavation, planting, construction labor and other related items for the construction subtotal. Perhaps more importantly, professional services subtotals have been estimated and these can account for a significant portion of the budget. Those line items include:

- Engineering and Permitting – a flat 15% estimate relative to construction cost
- Construction Management/Oversight and Project Administration – assumed at 8%
- Surveying – Professional land surveys are necessary with many projects and a flat rate of $15,000 was assumed based on project experience

- Overhead
- Construction Phase Services – continued consulting
- Site Access and Maintenance – almost all projects with heavy machinery have special access requirements and site maintenance
- Profit – professional consultants account for profit
- A standard 35% contingency is also applied to account for unforeseen circumstances, changes in scope, or increases in materials costs

A summary table for the nine project concepts is provided below.

Table 6.4: Implementation Project Cost Estimates

BMP Concept Location	Construction	Professional Services	Contingency	Total
MR-2 Mill River BMP	251,013.46	158,077.67	143,181.90	552,273.03
MR-3 Covenant Church BMP	258,600.00	188,262.00	156,401.70	603,263.70
MR-4 Route 15 Service Plaza BMP	441,252.67	310,639.29	263,162.18	1,015,054.14
MR-5 Jefferson Street Parking BMP	71,911.67	63,180.82	47,282.37	182,374.85
MR-7 Sacred Heart University BMP	290,000.00	209,300.00	174,755.00	674,055.00
MR-8 Mill River Shorline BMP	196,068.00	146,365.56	119,851.75	462,285.31
MR-9 Carolton Convalescent BMP	116,000.00	92,720.00	73,052.00	281,772.00
MR-10 Riverfield School BMP	145,000.00	112,150.00	90,002.50	347,152.50
MR-11 Beers Road BMP	15,000.00	25,050.00	14,017.50	54,067.50
Total Cost Estimate				**4,172,298.02**

6.2.2 GENERAL MANAGEMENT MEASURE COST ESTIMATES

Some costs have also been prepared supporting the general management measures. Developing these costs is extremely difficult because the scale and scope of projects is so variable. As such, the amount of information provided is limited. When costs are provided, especially at the federal level, they fail to account for the State regulatory permitting process or assume projects are otherwise shepherded by the sponsor. The costs provided below therefore represent rough estimates, but they at least provide a frame of reference. Where possible, per unit costs are shown, whether it is catchment area, stream miles, or similar measure.

SEPTIC MANAGEMENT

While septic management is an important management measure in the watershed there are a limited number of management measures available including inspection, maintenance, repair, replacement, or new construction, and outreach. Additionally, conversion to sanitary sewer service and decommissioning of onsite septic systems is also important in limiting septic impacts, and aligns with the goals of Fairfield to expand the sanitary sewer service area. Using numbers published by the Delaware Division of Natural Resources and Environmental Control (DNREC) Division of Watershed Stewardship, some basic cost estimates are provided.

- Pump Out and Tank Inspection - $250 per event
- New Construction/Replacement - $15,000
- Operation and Maintenance (20 year life span) - $4,000
- Connection to Sanitary Sewer System - $8,500

Since outreach is an important component of this plan, specifically promoting BMPs for these systems, direct outreach programs are given a basic cost of $15 per household.

STORMWATER MANAGEMENT

Stormwater management has been widely implemented and as such cost estimates have been refined as there are a large number of projects that can be referenced. The Maryland Department of the Environment has prepared the excellent *Costs of Stormwater Management Practices in Maryland Counties* that provide these costs. The approach is comprehensive because it accounts for site discovery, design, planning, permitting, as well as base construction costs and annualized maintenance. Table 6.6 is an adaption of those costs projected for acre of treatment in the catchment.

Table 6.5: MD Unit Cost for Stormwater BMPs

Stormwater BMP	Initial Project Costs			
	Pre-Construction Costs[2]	Construction Costs[3]	Total Initial Costs	Total Annual Maintenance Costs
Impervious Urban Surface Reduction	$ 8,750	$ 87,500	$ 96,250	$ 875
Urban Forest Buffers	$ 3,000	$ 30,000	$ 33,000	$ 1,200
Urban Grass Buffers	$ 2,150	$ 21,500	$ 23,650	$ 860
Urban Tree Planting	$ 3,000	$ 30,000	$ 33,000	$ 1,200
Wet Ponds and Wetlands (New)	$ 5,565	$ 18,550	$ 24,115	$ 742
Wet Ponds and Wetlands (Retrofit)	$ 21,333	$ 42,665	$ 63,998	$ 742
Dry Detention Ponds (New)	$ 9,000	$ 30,000	$ 39,000	$ 1,200
Hydrodynamic Structures (New)	$ 7,000	$ 35,000	$ 42,000	$ 3,500
Dry Extended Detention Ponds (New)	$ 9,000	$ 30,000	$ 39,000	$ 1,200
Dry Extended Detention Ponds (Retrofit)	$ 22,500	$ 45,000	$ 67,500	$ 1,200
Infiltration Practices w/o Sand, Veg. (New)	$ 16,700	$ 41,750	$ 58,450	$ 835
Infiltration Practices w/ Sand, Veg. (New)	$ 17,500	$ 43,750	$ 61,250	$ 875
Filtering Practices (Sand, above ground)	$ 14,000	$ 35,000	$ 49,000	$ 1,400
Filtering Practices (Sand, below ground)	$ 16,000	$ 40,000	$ 56,000	$ 1,600
Erosion and Sediment Control	$ 6,000	$ 20,000	$ 26,000	$ -
Urban Nutrient Management[6]	$ -	$ 61,000	$ 61,000	$ -
Street Sweeping[7]	$ -	$ 6,049	$ 6,049	$ 431
Urban Stream Restoration	$ 21,500	$ 43,000	$ 64,500	$ 860
Bioretention (New - Suburban)	$ 9,375	$ 37,500	$ 46,875	$ 1,500
Bioretention (Retrofit - Highly Urban)	$ 52,500	$ 131,250	$ 183,750	$ 1,500
Vegetated Open Channels	$ 4,000	$ 20,000	$ 24,000	$ 600
Bioswale (New)	$ 12,000	$ 30,000	$ 42,000	$ 900
Permeable Pavement w/o Sand, Veg. (New)	$ 21,780	$ 217,800	$ 239,580	$ 2,178
Permeable Pavement w/ Sand, Veg. (New)	$ 30,492	$ 304,920	$ 335,412	$ 3,049

AGRICULTURAL BEST MANAGEMENT PRACTICES

Agricultural BMPs are also difficult to price because definitions of management, State and local regulatory context, and even age of the recommendations are so variable. Additionally, there may be many hidden opportunity costs associated with various actions that are not well explained. Scale is also a tremendous factor and thus unit costs are hard to calculate, as is price of seed and other basic costs. Using the DNRC estimates, a table of some agricultural BMPs is provided below.

Table 6.6: MD Unit Cost for Agricultural BMPs

Agricultural BMP	Unit Price	Unit
Cover Crops	$ 50.00	acre
Grassed Waterways	$ 16,500.00	acre
Grassed Filter Strips	$ 500.00	acre
Riparian Buffer Installation	$ 500.00	acre
Wetland Restoration	$ 4,400.00	acre
Field Border	$ 550.00	acre
Critical Area Planting	$ 7,300.00	acre
Conservation Tillage	$ 18.00	acre
Annual Maintenance	$ 5.00	acre
Nutrient Management Plan	$ 5.70	acre

STREAM BANK STABILIZATION AND RIPARIAN BUFFER ENHANCEMENTS

More than any other management measure, each project is so unique that generalizing costs is almost impossible. While all the cost components remain in effect, like surveying, design, permitting, construction, oversight, access, contingencies, overhead, etc. there are a number of additional elements that may need to be addressed. This could include hydraulic modeling, sediment contaminant testing, sediment management and disposal, land purchases and easement acquisition, specialized biological surveys, and a host of other factors. Scope and design goals also have a huge bearing on these projects. Light touch restoration, those that seek to manage areas with a minimum of excavation and the use of plants for stabilization are much different than projects that actively modify the entire cross-sectional geometry of a channel and require tons of rock and other materials. Under Table 6.6 provided above, some of the channel restoration techniques are described with a prescribed unit area cost.

PET WASTE AND WILDLIFE MANAGEMENT

These programs will primarily hinge on outreach efforts, and thus the $15 estimate per household or person reached can be assumed for these projects. Other actionable items, such as modifying ordinances do not have direct material costs. Material costs would be limited in most cases to the creation and installation of signage and the provision of waste bags and receptacles. Program costs for goose programs would be managed through the service provider and include number of repellant applications, egg addling events, or similar tasks.

6.4 TECHNICAL ASSISTANCE

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.

6.4.1 PROJECT ROLES

Project implementation is a complex process and requires team work to successfully complete. There are a number of amorphous roles that will develop, often with overlapping responsibilities, depending on the scale of the project. Below a review of these roles is provided including responsibilities and technical contributions.

- Project Sponsor – The project sponsor serves as the hub of project implementation. For many of the projects identified, the Town of Fairfield will likely 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, 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 their holding to have some significance.
- Stakeholders – Stakeholders consist of many people, but a large component would include the community that are directly or indirectly affected by the project, but regulators, public officials, and others may all have real interests. 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 those located downstream and therefore stand to gain the most by its success. While technical contributions may be limited, this is not always the case, and stakeholders and residents often have the best understanding of system deficiencies, a resource that needs to 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 strict reporting requirements as a condition of the grant award that would include technical reporting, design, and financial management.
- Regulators – A major function of regulatory agencies is to ensure that projects, whether implementation projects, planning, or other, 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 of demands 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.

6.4.2 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. In Fairfield, this is managed through the Health Department Environmental Health Program. Easton and the other municipalities also maintain a Health Department with similar responsibilities.
- Fairfield also maintains a Sewer Department (WPCA) that manages the sanitary sewer system.
- Departments of Engineering, Conservation, Building, and Town Plan & Zoning, also are involved with various elements related to septics.
- 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:

- Engineering Departments
- Building Departments
- Conservation Commissions
- Public Works
- Connecticut Southwest Conservation District: https://www.conservect.org/southwest/
- MS4 Program
- CT DEEP Stormwater General Permits: http://www.ct.gov/deep/stormwater
- Connecticut Inland Wetlands and Watercourses Act
- Connecticut Soil Erosion and Sediment Control Act
- Coastal Site Plan Review

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 43
- 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
- CT DEEP Coastal Management Manual: http://www.ct.gov/deep/cwp/view.asp?a=2705&q=323814&deepNav_GID=1622
- CT DEEP Coastal Nonpoint Source Pollution Control Program http://www.ct.gov/deep/cwp/view.asp?a=2705&q=323554&deepNav_GID=1709
- 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. Some of the 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, although both the federal government and a host of non-profit groups are important actors including USFWS, USGS, and American Rivers among them.

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 Tidal Wetlands Buffers Guidance: http://www.ct.gov/deep/lib/deep/long_island_sound/coastal_management/twbufferguidance.pdf
- 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 lower intensity management solutions than some of the other areas, 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. Both Fairfield and Monroe have or are developing pet waste outreach program and have implemented some management in their park systems. 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
- Fairfield County Deer Management Alliance: http://www.deeralliance.com/
- Connecticut River Coastal Conservation District Pet Waste Outreach: http://conservect.org/ctrivercoastal/PetWaste/tabid/317/Default.aspx

7.0 INFORMATION AND EDUCATION

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.

7.1 OUTREACH DEVELOPMENT

The protection and preservation of water quality and the ability to address the TMDL in the Mill River watershed is contingent upon the education of the target audience including public officials, residents, landowners, farmers, and business 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.
- Celebrate successes to recognize continuing and noteworthy efforts, encourage participation, and continue the implementation of the WMP.

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 groups identified in the financial and technical assistance section should be consulted. 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 to include property owners or managers that contain or are adjacent to waterways, ponds, wetlands, and floodplains. These are the areas most susceptible to degradation of aquatic ecosystems, but also in the best position to implement projects that can mitigate these problems.

7.2 ONGOING OUTREACH EFFORTS

Through this project there are current and active outreach programs. The WMP 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 primary grantee and project sponsor, the Town of Fairfield and the Fairfield Conservation Commission, the following project partners have been identified:

- CT DEEP
- Harbor Watch
- Trout Unlimited
- Fairfield Shellfish Commission
- FairPLAN
- Mill River Wetland Committee
- Lake Hills Association

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

- Kickoff Meeting November 2017 – Included the formation of Steering Committee, presentation of the project vision, and expression of areas, sites, and objectives that should be addressed.
- Plan Meeting April 12, 2018 – Discussion about preliminary work including document review, maps, and conceptual designs with provided feedback regarding design concepts and locations.
- Plan Meeting October 11, 2018 – Further progress updates and presentation of revised management concepts.
- Initial Draft Submission November 20, 2018 – An initial in-progress draft WMP was submitted to Fairfield and CT DEEP for review and comment.
- Draft WMP Presentation – Completed draft of the WMP is to be presented on May 2, 2019 for review and comment; upon reception of written commentary the required changes will be incorporated into a final document.

8.0 IMPLEMENTATION SCHEDULE

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.

From a practical perspective, one of the major limiters on successfully managing NPS pollution, meeting water quality standards and designated uses, and simply implementing a comprehensive watershed management plan is funding. Without question, project implementation is not an inexpensive proposition, especially where watershed-wide implementation is necessary to meet pollution reduction goals and align with the TMDL as in the Mill River watershed. As such, there will likely be a heavy reliance on grants and other financial vehicles. In turn, securing such funding is difficult 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 change over time.

The remainder of this section will explore the implementation schedule.

8.1 YEARS 1 TO 2

In the short term, approximately Years 1 and 2, the focus should be on addressing the nine concept implementation projects. These projects represent locations and sites that merit special attention, are known problem areas, and lie within the highest priority subwatersheds. The focus, especially in the early going, is to research grant availability, prepare grant submissions, and initiate the projects when funding becomes available. Realistically, all grant applications will not be awarded and therefore it is recommended that multiple applications are submitted. If a grant application is denied a different source of funding should be investigated or the project should be resubmitted in the next funding cycle. When possible and capacity allows, it is recommended that multiple projects be worked on concurrently. The life cycle of each project will naturally vary, but the cradle to grave duration of each individual project is likely to span two to three years from grant award to post-construction monitoring, even if the construction phase is brief.

In addition to the nine concept sites discussed in this section, some of the lower priority items should also be initiated at this time. This would include measures that include low-cost solutions like community outreach efforts and promotion of projects, procedures, and BMPs that should be adopted by homeowners and land managers. These are the types of projects that have lower technical requirements, but also keep the community engaged and harness their efforts to meet pollution abatement goals. The short term implementation schedule is provided below.

Table 8.1: Years 1 to 2 Implementation Schedule

BMP ID	Name	SubWS ID	Priority
MR2	Mill River Stormwater Wetlands	4	Highest
MR3	Covenant Church BMPs	4	Highest
MR4	Rt. 15 Service Plaza BMPs	4	Highest
MR5	Jefferson St. Parking BMPs	4	Highest
MR7	Sacred Heart University BMPs	4	Highest
MR8	Mill River Shoreline BMP	8	Highest
MR10	Riverfield School BMP	8	Highest
MR11	Beers Road BMP	4	Highest
MR9	Carolton Convalescent BMPs	9	High
Ongoing Tasks			
Grant Submissions			
Outreach Efforts			

8.2 YEARS 3 TO 5

This phase of project implementation is primarily focused on the development of projects that have been identified as being of highest priority because they are located in the Canoe Brook and Greenfield Hill/Riverfield subwatersheds (4 and 8). These areas have been identified as the most problematic sources of bacteria and other NPS pollutants by virtue of load or concentration, size, and development characteristics. They are also associated with measured impairments in water quality. The focus on implementing in these subwatersheds should provide the greatest benefit in meeting reduction goals.

There is an expectation that project implementation rates should accelerate in this phase of the project, in part building off the project experience gained in the first phase. As such, much of the focus will be on initiating the remaining highest priority sites. At the same time, many of the projects initiated in years 1 and 2 are anticipated to be nearing completion, or have been completed or constructed but have continuing monitoring and reporting requirements. Realistically, some of the initial projects forwarded, those with conceptual designs, likely have not been started and these will continue to hold priority in this phase of the project. As always, funding will be a major control in the execution of these projects.

In addition to the specific projects, a major effort should be made to promote septic management efforts. These efforts are less easily defined or locate, but this will be a major component in addressing bacterial pollution in the watershed.

Table 8.2 details the medium term implementation schedule.

Table 8.2: Years 3 to 5 Implementation Schedule

BMP ID	Name	SubWS ID	Priority
4	220 Pansy Road	8	Highest
6	366 Mine Hill Road	8	Highest
9	450 Congress Street	4	Highest
11	834 Brookside Drive	8	Highest
16	2181 Black Rock Turnpike	8	Highest
18	Cascade Parking - 880 Morehouse Hwy	4	Highest
20	Two Brooks Lane ROW	8	Highest
31	Cascades-mohegan Trails Open Space	4	Highest
32	Centennial Watershed State Forest	4	Highest
34	Dover Park	4	Highest
51	Madison Middle School	4	Highest
56	Municipal Open Space (Blue Bell Lane)	4	Highest
67	Sacred Heart University	4	Highest
73	Sherwood Farm	4	Highest
74	Silverman's Farm	4	Highest
35	Drake Lane Public Open Space	8	Highest
36	Fairfield University	8	Highest
37	Fairfield Woods Junior High School	8	Highest
39	Flower House Drive park	8	Highest
55	Mt Laurel Park	8	Highest
60	Osborn Hill Elementary School	8	Highest
64	Riverfield	8	Highest
65	Riverfield Elementary School	8	Highest
66	Riverside Park/Springer Glen Open Space	8	Highest
69	Samp Motar Dam Open Space	8	Highest
80	Trillium Road Open Space	8	Highest
	Ongoing Tasks		
Grant Submissions			
Outreach Efforts			
Septic Management Efforts			
Completion of Projects Started in Previous Cycle			
Initiation of Projects Identified in Previous Cycle			

8.3 YEARS 6 TO 10

This is the phase of the project where some of the lower priority items finally begin to be addressed. Specifically, this will include those projects within the Browns Brook and Mill River Upper Estuary subwatersheds (6 and 9). These are the two lowest subwatersheds, and as such have the most impaired water quality as a result of the cumulative impacts of the remaining watershed. They are also high loaders in their own right and projects located in these areas are still regarded as high priority.

Years 1 through 10 have a total of 58 projects identified, a major undertaking by any accounting. Much of this time is expected to be continued clearing of the project backlog, and there will likely be a number of active implementation projects at any time.

Table 8.3: Years 6 to 10 Implementation Schedule

BMP ID	Name	SubWS ID	Priority
1	40 Southport Terrace	6	High
2	55 Matilad Place	6	High
3	63 Mill Hill Terrace	9	High
5	231 Doreen Drive	6	High
7	400 Mill Plain Road	9	High
8	421 Fulling Mill Lane	6	High
12	1159 Bronson Road	6	High
13	1174 Bronson Road	6	High
14	1780 Bronson Road	6	High
15	1845 Bronson Road	6	High
25	300 Hulls Farm Rd	6	High
26	361 Hulls Farm Rd	6	High
28	Birchbrook Park	6	High
33	Connecticut Audubon Society Open Space	6	High
63	Perry's Mill Ponds Park	6	High
79	Timothy Dwight Park	6	High
49	Ludlowe Middle/Highschool	9	High
50	Ludlowe Middle/Highschool Basin	9	High
54	Mill Plain Green (Town Green)	9	High
58	Old Fording Place Open Space (Bronson Road)	9	High
59	Old Fording Place Open Space (Somerset Ave	9	High
61	Outfall at I95 Crossing	9	High
62	Palmers Neck Park	9	High
Ongoing Tasks			
Grant Submissions			
Outreach Efforts			
Completion of Projects Started in Previous Cycle			
Initiation of Projects Identified in Previous Cycle			

8.4 POST-YEAR 10

At this juncture, the medium and low priority projects should be initiated throughout the remainder of the watershed. The project types will shift, as the less developed areas, which have lower loading rates, are finally addressed. In particular, this phase will see a rise in the number of agricultural BMPs and a reduction in some of the strict stormwater management associated with high impervious surface coverage.

At this point, it may be beneficial to update the WMP and this plan should be considered a living document. Specifically, this would include assessing progress and removing project sites that have been completed. It may necessitate a shift in focus or strategy to combat continued loading at this point. It is also the proper time to identify new project sites.

Through this cycle, where possible, up to 89 identified projects have been initiated, completed, in-progress, or attempted to have been started. New projects will have suggested themselves in the interim, and there will need to be a concerted effort to identify the technical and financial assistance needed at this time.

The benefits of the work to date should be obvious at this point, reflected in the number of implemented projects, load reductions, and improvements in measured water quality.

Table 8.4: Years 10+ Implementation Schedule

BMP ID	Name	SubWS ID	Priority
45	Lake Mohegan Beach	5	Medium
46	Lake Mohegan Beach Parking Lot	5	Medium
47	Lake Mohegan Dog Park	5	Medium
57	North Stratfield Elementary School	5	Medium
68	Samp Mortar Rock	7	Medium
41	Great Oak Park	10	Medium
52	Madison Middle School Fields	10	Medium
77	Tashua Elementary School	10	Medium
10	607 Winnepoge Drive	5	Medium
19	High Ridge Park - 33 Palamar Drive	7	Medium
21	45 Maple Rd	1	Low
23	85 Hattertown Rd	1	Low
48	Lakewood YMCA (Camp Tepee)	1	Low
24	99 Kachele St	2	Low
43	Helen Keller Middle School	2	Low
44	High Lonesome Stables	2	Low
53	Maple Row Farm	2	Low
72	Sherwood Farm	2	Low
75	Slady's Tree Farm	2	Low
76	Sweetbrier Farm	2	Low
78	Tashua Recreation Area	2	Low
22	73 Wilson Rd	3	Low
27	701 Sport Hill Rd	3	Low
29	Black Rock Church	3	Low
30	Burr Elementary School	3	Low
38	Farm fields along Morehouse Rd	3	Low
40	Grace Richardson Conservation Area Open Spa	3	Low
42	Greenfield Hunt Development	3	Low
70	Samuel P. Senior Memorial Park	3	Low
71	Samuel Staples School	3	Low
17	4000 Black Rock Turnpike	3	Low

Ongoing Tasks
Update WMP and Assess Progress
Identify New Project Sites
Grant Submissions
Outreach Efforts
Completion of Projects Started in Previous Cycle
Initiation of Projects Identified in Previous Cycle

9.0 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.

9.1 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 WMP 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, event attendees, volunteers, trainees and related
- 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, geese managed, 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 local government initiatives enacted
- Attainment of designated uses, de-listing of impaired waters, and similar compliance with environmental quality standards

10.0 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.

10.1 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.

10.1.1 SEPTIC MANAGEMENT CRITERIA

The evaluation criteria for many of the septic management projects tends to be more categorical or conditional than many of the other projects. For instance, repairs may be simply noted as properly functioning, i.e. no backups and no ponding. Similarly, goals to convert to sanitary sewer service may denote the conversion in a database and perhaps estimated gallons of wastewater or nutrient loads treated. In some respects, these would function similarly to some of the measurable milestones, and proper function, observance of best management practices, regular maintenance, and other such actions would be noted.

Some technical water quality, infiltration, or hydraulic metrics may be employed with septic management projects. Infiltration rates determined by percolation tests may be a performance standard and even surface flow rates in severely malfunctioning systems. Additionally, illicit discharge detection and elimination (ILDE) and pollution track-down studies investigate the discharge of wastewater to storm sewer systems and can at least be considered site-specific investigations. As such, the following wastewater related criteria may be employed:

- Total nitrogen, ammonia, nitrate + nitrite (NO_x)
- Total phosphorus and soluble reactive phosphorus
- *E. coli* or other bacterial measures
- Specific conductance
- Total dissolved solids

10.1.2 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.

10.1.3 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

10.1.4 STREAM BANK STABILIZATION AND RIPARIAN BUFFER ENHANCEMENTS CRITERIA

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

10.1.5 PET WASTE 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

10.2 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. This watershed management plan is particularly focused on the management of indicator bacteria in the Mill River watershed, with a secondary focus on associated NPS pollution, particularly the nutrient pollutants and solids.

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 at Mill River, 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
- Fecal coliform in Class SA 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. Additionally, large reservoirs in the watershed and the manipulation of water from adjacent waterbodies can have an important influence on the flow regime. In Mill River there is an additional concern because the lower reaches are tidal. 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

10.3 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. These include classifications of surface and groundwaters with accompanying designated uses. There are also assigned water quality standards, both numerical and narrative. For Mill River 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, *A TMDL Analysis for the Mill River, Rooster River, and Sasco Brook* also specifies the total maximum daily load for *E. coli* in the river, and an estimate of the required reduction to achieve compliance with the *E. coli* standard.

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.

11.0 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.

11.1 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.

11.1.1 INFLUENT AND EFFLUENT

The most basic site monitoring program, particularly those for stormwater management designs, consists of monitoring the influent and effluent streams. 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.

11.1.2 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.

11.1.3 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. 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.

11.1.4 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 BACI, before, after, control, impact, and is especially powerful from a statistical perspective in determining project efficacy.

11.1.5 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.

11.2 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 to maintain the Harbor Watch monitoring of the Mill River that is already in place, and has provided several years' worth of data. This program is particularly strong because: it covers a variety of pollutants of concern including various indicator bacteria and nutrient pollutants; monitors standard limnological criteria; includes over 15 established sampling stations from the estuarine mouth to the headwaters; includes sampling under baseflow and stormflow conditions; includes several years of consecutive data; and is operated under a CT DEEP approved QAPP. Together, these features lend great strength to the program, but more importantly address elements that can be used to determine current water quality conditions and how water quality changes over time.

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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