Mianus River Watershed Based Plan

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COMMONLY USED ACRONYMS

BMP	Best Management Practice
CBP	Chesapeake Bay Program
CFU	Colony-Forming Units
CWA	Clean Water Act
CLEAR	Center for Land Use Education & Research
CTDEEP	CT Department of Energy and Environmental Protection
CWP	Center for Watershed Protection
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
HSG	Hydrologic Soil Group
ICM	Impervious Cover Model
IWL	Impaired Waters List
LID	Low Impact Development
LIS	Long Island Sound
MS4	Municipal Separate Storm Sewer System
N	Nitrogen
NEMO	Nonpoint Source Education for Municipal Officials
NH_4	Ammonium
NO_2	Nitrite
NO_3	Nitrate
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRWIC	Norwalk River Watershed Initiative Committee
NRCS	Natural Resources Conservation Service
NURP	National Urban Runoff Program
O&M	Operations and Maintenance
P	Phosphorous
RBV	Rapid Bioassessment by Volunteers
SSURGO	Soil Survey Geographic
SVA	Stream Visual Assessment
SWRPA	South Western Regional Planning Agency
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UConn	University of Connecticut

Commonly used terms are defined for the purposes of this document as follows:

Adaptive Management – A structured, iterative approach to the management of natural resources, where monitoring feedback is used to refine management activities.

Best Management Practice (BMP) – Methods, measures, or practices designed specifically for the control of nonpoint source pollution. BMPs include structural and nonstructural controls.

Bioretention – A practice to manage and treat stormwater runoff by using a specially designed planting soil bed and planting materials to filter runoff stored in a shallow depression. The areas consist of a mix of elements, each designed to perform different functions in the reduction of pollutants and attenuation of stormwater runoff (CTDEP 2004, *Stormwater Quality Manual*)

Impairment – Used here to refer to reaches of stream where aquatic conditions may fall below state water quality criteria. Reaches may be listed as impaired on the state Listing of Impaired Waters (303(d) list), or they may be considered likely targets for a future listing based on field assessments or review of data.

Impervious Cover – Hard surfaces that do not allow water to infiltrate (generally roofs and different types of pavement).

Infiltration – The process by which water passes into and through the ground.

Indicator Species – A species whose presence indicates human-created abiotic conditions such as air or water pollution (often called a pollution indicator species) (Lindenmayer et. al. 2000).

Low Impact Development (LID) – A planning-level approach to land development (or re-development) that seeks to minimize impacts to natural systems. With respect to streams, LID seeks to manage stormwater as close to its source as possible, with an emphasis on small-scale structural BMPs over traditional “gray” infrastructure methods of controlling stormwater (in the context of cities and streetscapes, this approach is often referred to as “green” infrastructure).

Naturalized Surface Storage Basin – Used to describe a range of large, vegetated depressions built for control of stormwater. Basins may be wet or dry, and may be designed to infiltrate any fraction of the stormwater captured. Based on these and other details, naturalized surface storage basins may be designed for flood control, water quality, channel protection, or a combination of all these functions as site constraints allow.

Nonpoint Source (NPS) Pollution – Pollution that originates from multiple sources over a relatively large area. NPS pollution can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forestry practices, and urban and rural runoff.

Point Source Pollution – Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities.

Pollutant Load – The quantity of material carried in a body of water which exerts a detrimental effect on some subsequent use of that water.

Restoration – The return of an ecosystem to a close approximation of its condition prior to disturbance (NRC 1992). Used most often in this document to refer to stream restoration and wetland restoration.

Retrofit – Structural alteration of an existing BMP, commonly performed to add water quality and/or channel protection functions to a basin or swale that was originally designed only for flood control.

Riparian Buffer – Used in this document to refer to any depth of forest or meadow-type vegetation planted or naturally occurring adjacent to the stream channel.

Stormwater Runoff – Rainwater which is not infiltrated into the ground and so flows directly over land, often entering structured drainage systems like gutters, storm drains, and roadside swales.

Subsurface Infiltration – The temporary storage and infiltration of stormwater in an engineered bed of partially void rock and soil built underneath gardens, lawns, or paved areas.

Subsurface Storage – The temporary storage and slow release of stormwater captured in a void subsurface chamber, often used to control stormwater runoff where space constraints prevent the use of other surface measures to control runoff.

Subwatershed – Used here to refer to smaller drainage areas within the larger watershed (see watershed definition below).

Swale – Referred to in the *Connecticut Stormwater Quality Manual* as a "water quality swale," a vegetated open channel designed to treat and attenuate the water quality volume and convey excess stormwater runoff. (*CTDEP 2004, Stormwater Quality Manual*)

Water Quality Criteria – Elements of state water quality standards expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use (EPA 1994).

Water Quality Standard – Provisions of state or federal law which consist of a designated use or uses for the waters of the United States, and water quality criteria for such waters based upon such uses. Water quality standards are meant to protect public health or welfare, enhance the quality of the water, and serve the purposes of the Clean Water Act (EPA 1994).

Watershed – A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Watershed Based Planning – Refers to a science- and community-driven approach to addressing long-term management of watershed impairment (EPA 2008).

The Mianus River is a small but important water resource and one of a number of coastal rivers that empty into Long Island Sound (LIS) in southwest Connecticut. Locally treasured for its hiking, fishing, and clear waters, the river has nevertheless experienced significant impacts from development and intensive recreational use. Its headwaters in North Castle and Bedford, New York, drain to the S.J. Bargh Reservoir, a drinking water source for the communities of Greenwich, Stamford, Port Chester, Rye, and Rye Brook. Thousands of local residents hike, fish, paddle, jog, and walk their dogs in the Mianus River Greenway, a string of protected parkland that includes the Mianus River Gorge Preserve and Mianus River Park. In the lower watershed, the river passes through residential neighborhoods and dense commercial centers before emptying into LIS near Route 1 in Greenwich.

An unusually well-protected waterbody in an otherwise developed region, the Mianus River has a long history of stewardship and conservation. Many active volunteer and nonprofit groups are currently working to better understand the river and balance the needs of the community with needs of the ecosystem. High-quality waters support a variety of uses, and the many natural areas along the stream add to the pastoral character of the landscape.

Nevertheless, urban development in some locations within the Mianus River Watershed has resulted in less-than-ideal water quality and degraded natural habitats. Future development threatens to further degrade the river's significant scenic, commercial, recreational, and ecological value. In order to maintain good conditions and restore impacted areas, individuals and organizations who value the watershed will need to ensure that new development in the watershed is built in an environmentally responsible and sustainable manner, and the restoration of river sections impacted by development.

The story of the Mianus River is one that is being repeated in urban rivers and streams throughout the world. It is a story of the powerful relationship between rivers and the land they flow through. In the Mianus River Watershed, watershed stakeholders are now working together to understand how land use changes have caused conditions in the Mianus River to deteriorate in some locations, and how better land management practices and policies can restore and preserve the Mianus River for future generations.

UNDERSTANDING THE LAND/WATER CONNECTION

Aquatic scientists now understand the critical link between the health and quality of rivers and the characteristics of the land through which they flow. Human impacts to land use through farming or urban development, result in predictable changes to rivers that lessen their value to society and decrease their ecological value. Fortunately, this understanding has led to the development of a set of strategies for better managing landscapes, strategies that can restore degraded rivers and prevent healthy rivers from becoming imperiled.

Many of the land areas draining to the Mianus River (known as the Mianus River Watershed), particularly near Route 1, along Strickland Brook, and in and around Bedford Town Center, have experienced significant residential development. Stream assessments and water quality data suggest that streams flowing through more developed areas have lower water and habitat quality than streams flowing through less developed areas. As in many other rivers, urban land use has affected the Mianus River by changing the amount and pattern of water flowing to the

Mianus River and creating new sources of pollution. Specifically, the introduction of impervious surfaces associated with urban development, such as rooftops, roads, driveways, and parking lots, have altered the flow of water through the watershed. Prior to urban development, much of the rain and snow falling into the watershed would have been absorbed into the ground or evaporated back into the atmosphere by the dense stands of forest that once covered the area. Today, however, much of that rain and snow instead falls onto hard surfaces, where it quickly flows into the Mianus River. This urban stormwater runoff carries an array of chemicals and pollutants including oils/grease, fertilizers and pesticides, dirt, bacteria, and trash into the river and the smaller streams that feed it. Many aquatic organisms are extremely sensitive to these increases in pollution.

As a result of the increase in impervious surfaces, the intensity and frequency of high flows in the Mianus River has also increased in some locations. At the same time, small dams and landscape features located in and adjacent to the stream have confined the river's flow path through residential neighborhoods in some headwater areas and areas within the lower watershed. These changes have altered the natural patterns of erosion and sediment deposition in some areas of the river, leading to eroded stream banks in some areas, and overly mucky stream beds in others. In these areas, habitat for fish and many other forms of aquatic life key to the stream's natural food chain have been damaged.

Harmful changes to water quality, habitats, or aquatic life that diminish the usability or value of a river are referred to as impairments, and states have in many cases developed specific criteria for identifying them. In the Mianus River, however, state sampling has been limited, and impairments have been largely anecdotal, or identified through studies external to state sampling programs. Nevertheless, a growing body of evidence suggests that urban development is slowly but steadily damaging the Mianus River.

REVERSING THE TREND

Even as scientists understand the progressive harm that rivers sustain when their watersheds become urbanized, the scientific community has also worked to develop ways of reversing these trends by better managing urbanizing landscapes. These methods range from relatively simple activities such as planting trees along stream banks, to structural stormwater best management practices (BMPs) such as wetlands, porous pavements, and underground gravel-filled chambers that help slow down, filter, and infiltrate (i.e., soak into the soil) urban stormwater runoff. Past studies have shown that these types of approaches can significantly improve the quality and health of urban streams and rivers.

A WATERSHED APPROACH

The process by which communities, scientists, municipal officials, and other groups together develop an action plan for protecting and restoring a resource like the Mianus River is called watershed planning. The watershed planning process focuses on identifying the specific set of actions that will result in a measurable and significant improvement of the health and quality of rivers and streams in a watershed. Another fundamental part of the watershed planning process is changing everyday perceptions, attitudes, and behaviors in ways that benefit rivers and streams. It is rooted in the belief that every person living in a watershed can make a positive difference to improve the health of their local waterways. The watershed planning process is also about celebrating and demonstrating the importance of healthy streams and rivers to local residents' quality of life, and highlighting the reduced quality of life that results from unhealthy streams and rivers. In short, watershed planning seeks to bring about social and cultural change that elevates healthy water resources from an ancillary issue to core moral value.

Most importantly, watershed planning is not an activity restricted to technical specialists. While professionals play a role in promoting the understanding of the subject, educating non-professionals about watershed science, and recommending solutions to problems, the heart of the watershed planning process involves the organizations, citizens, and community leaders who live in the watershed coming together to form an engaged community ready to lead a push for positive change.

The watershed planning process involves a number of diverse activities including:

- Reviewing existing reports and background data;
- Mapping the physical, political, economic, and environmental characteristics of the watershed;
- Using computer models to estimate the quantity of pollutants entering the stream and determine the amount by which they must be reduced;
- Assessing the existing condition of the water, aquatic life, and habitat in the streams and rivers;
- Meeting with community members, interested citizens, and municipal officials to understand how these diverse groups use and value the rivers and streams;
- Identifying specific areas of concern, and developing goals and strategies for improving the river in specific ways;
- Identifying and prioritizing the most beneficial and cost-effective pollution-reduction projects;
- Developing a plan for monitoring the streams and rivers to determine if their quality is improving or degrading over time;
- Developing recommendations for educating watershed residents about the importance of healthy streams and rivers and the specific steps they can take in their own homes and businesses to reduce pollution; and
- Developing an action plan for implementing all components: pollution-reduction initiatives, educational and outreach activities, and monitoring.

THE MIANUS RIVER WATERSHED BASED PLAN AND THE U.S. ENVIRONMENTAL PROTECTION AGENCY WATERSHED PLANNING PROCESS

Funding for the development of a Watershed Based Plan (“the Plan”) was obtained by the South Western Regional Planning Agency (SWRPA) through a grant from the Connecticut Department of Energy and Environmental Protection (CTDEEP). The source of funding for the grant comes from the Federal Section 319 program (referencing Section 319 of the Clean Water Act [CWA]), which provides federal funding to states to help implement the CWA. Specifically, the funding is provided to develop plans to restore waterbodies that have been impaired by nonpoint source (NPS) pollution. NPS refers to sources of pollution that originate from landscape sources, e.g., fertilizers and pesticides carried to streams from urban stormwater runoff, as opposed to pollutants delivered to streams from specific point source discharges, such as wastewater treatment plants.

To assist organizations conducting watershed based planning, the U.S. Environmental Protection Agency (EPA) has developed a nine-step watershed planning process. CTDEEP requires that all watershed based plans developing using Section 319 funding follow the EPA process. The watershed based planning process emphasizes measurable goals and strategies; community involvement; and adaptive management, the process of using monitoring to assess whether the Plan is working and making continual adjustments based on monitoring information. The steps outlined in the EPA watershed planning process and associated sections of this Plan that address each step are as follows:

- Identify potential causes and sources of pollution (Chapter 2);
- Formulate pollution load reduction estimates (Chapter 3);
- Identify management goals, strategies, and actions to address identified pollution sources (Chapters 5 and 6);
- Research sources of financial and technical assistance (Appendix B);
- Develop recommendations for education and outreach (Chapter 8);
- Plan implementation schedule (Chapter 6);
- Identify interim milestones (Chapter 6);
- Implement performance criteria (Chapter 6); and
- Make recommendations for monitoring and assessment (Chapter 9).

While the focus of the Plan and the EPA watershed planning process is to reduce sources of NPS pollution, many of the techniques available to accomplish this will also result in other watershed improvements. For instance, BMPs such as constructed wetlands that store and filter polluted urban stormwater runoff can also be used to reduce flooding and reduce rates of stream bank erosion.

A high level of public and stakeholder involvement was incorporated during all phases of the planning process. A volunteer steering committee was formed to support Plan development and review technical documents. Members provided feedback on interim drafts of the Plan and met at key points in the planning process to review the content and direction of the Plan. The steering committee was composed of state and municipal representatives, SWRPA, and local stakeholders who expressed an interest in taking an active role in shaping the Plan. Members of the following organizations contributed to the steering committee:

- Aquarion Water Company;
- City of Stamford, Connecticut;
- CTDEEP;
- Mianus River Gorge Preserve;
- Mianus River Watershed Council;
- Stamford Land Trust;
- Town of Bedford, New York;

- Town of Greenwich, Connecticut;
- Town of North Castle, New York; and
- Trout Unlimited, Mianus Chapter.

The public engagement process included the formation of a steering committee, and a series of three public meetings held on July 13, 2010; April 28, 2011; and November 30, 2011. The meetings were intended to collectively define the watershed's valuable uses, and to identify management goals and strategies aimed at protecting and restoring these uses. Strategies related to water quality, outreach, and managing development were identified to support the Plan goals. In addition, project consultants presented a working list of potential structural BMPs to begin implementing Plan goals and strategies. Stakeholders provided feedback on these BMPs and identified additional management actions to support goals and strategies.

WATERSHED BASED PLAN OVERVIEW

The following sections of the executive summary provide an overview of the primary components of the watershed planning process. Conclusions and recommendations that were developed during the process are summarized below. More extensive descriptions of the methods, results, conclusions, and recommendations associated with the Plan are presented in the full report and appendices.

Assessing Existing Conditions

Understanding the existing condition of streams and rivers, including the quality of habitats, the chemical composition of stream water, and the health and diversity of aquatic life is an important first step to developing a watershed based plan and to determining the specific actions that are recommended to improve stream conditions. Understanding the existing condition of streams and rivers within the Mianus River Watershed involved several steps, including looking at the overall level of development within the watershed as an indicator of the level of watershed stress; reviewing water quality and biological data collected by CTDEEP and others in past studies; and reviewing the designated uses and impairments that have been established by CTDEEP through its assessment programs. In addition, visual assessments of the stream channel were conducted in representative locations to assess the quality and diversity of aquatic habitats, and computer models were used to predict the quantity of key pollutants being carried into the stream in various locations.

Near-stream development is one of the many factors affecting water quality in the Mianus River

Overall, the existing conditions assessment reveals a river that has been visibly impacted by development, although not to an extent that clearly inhibits use for drinking water and recreational purposes. Bacteria were identified as a problem in Strickland Brook, and are thought to be elevated in other areas; however, data are limited. Impervious surfaces comprise over 12 percent of the watershed's total area. National studies have shown that rivers flowing through watersheds with this level of impervious surface often show signs of impact to aquatic habitat. As a result of development, stream life in many areas of the Mianus River may be less diverse than would be expected in undeveloped watersheds, and areas of the river may contain higher proportions of pollution-tolerant species. Species known to be sensitive to pollution may be less common in the Mianus River than in rivers that flow through less developed environments. Aquatic habitats are also significantly impacted in some parts of the Mianus River Watershed.

In general, habitat and aquatic communities are of higher quality in the central reaches of the watershed and preserved areas, a conclusion that reflects their generally less developed nature (some areas in the central watershed are significantly less impervious than the watershed average). Development-related impacts, however, are evident in the semi-rural headwater regions, illustrating just how sensitive streams can be to even modest changes in land use. In the lower river, particularly in Strickland Brook, many stream banks have been stabilized by small walls and stones and are often devoid of forested streamside vegetation. Historic mill dams and other smaller dams and structures are common throughout the stream channel. However, despite areas of poor conditions throughout the watershed, many good-quality resources persist. These include good water quality around the S.J. Bargh Reservoir; forested, stable stream banks in many locations; and spring runs of herring and other fish species. Though somewhat impacted by development, the Mianus River supports a wide range of uses and a variety of aquatic life.

Understanding Watershed Uses and Values

Every river or stream is used and valued in ways that are as diverse as the rivers themselves. In large rivers, hydropower and navigation are often key uses. In other rivers, the provision of water for drinking or irrigation is a key use, and for others, active recreation uses dominate—including swimming, boating, and fishing. Rivers often provide uses that are not often recognized, such as conveying treated sanitary waste away from communities and conveying flood waters. And some rivers are valued primarily for their scenic attributes and their contribution to landscape character and sense of place.

As watersheds urbanize and streams and rivers become degraded, the overall suite of uses and values provided by a river system declines. Specific uses such as swimming may become inappropriate, unhealthy, or even dangerous. Uses and values may be increasingly perceived to be at odds with each another, as pressures on water use increase due to urbanization. For instance, withdrawals of water for drinking or irrigation may be perceived as conflicting with recreational fishing as less water is available to support fish populations. Uses and values may also vary significantly among various stakeholder groups. Members of sport fishing associations may be primarily concerned with the ability of a particular stream to support populations of popular sport fish, for example, while streamside residents may be much more concerned about the stream's aesthetic value or the impacts of flooding.

The history of river management is full of examples of river resources that have been managed to provide for one use to the detriment of others. Today, watershed managers understand that rivers are increasingly diversely used and valued and should be managed accordingly. A commitment to managing rivers for a diverse set of uses is not always easy, but is another central tenet of good watershed planning. As such, the twin objectives of watershed planning are (1) to understand the full range of uses and values associated with a watershed's streams and rivers; and (2) to manage these resources to provide the full range of uses and values over time in a sustainable manner.

To understand how the Mianus River Watershed and its streams and rivers are used and valued, SWRPA convened a group of watershed stakeholders to participate in a workshop that focused on the issue of uses and values. The results of the workshop revealed that despite some water quality and habitat problems, stakeholders use and value the Mianus River and its smaller feeder streams in a number of important ways. Uses range from drinking water to fisheries to property value and scenic character. Some stakeholders expressed concern that recreational uses are having a detrimental effect on water quality and habitat in parts of the river, particularly in the lower watershed and Mianus River Park. Most agreed on the need for improved management of and dialogue among recreational user groups. The discussion of uses and values highlighted an almost universal sense that the Mianus River Watershed is a special place of great value to its community, but one that needs to be actively managed in order to support continued use.

The steering committee defined the following key uses through which the community values the river:

- Drinking water;
- High-quality aquatic habitat;
- Fisheries;
- Preserved greenway;
- Recreation;
- Education;
- Homes/property values/scenic beauty;
- Flood control/hydrologic response; and
- Historic/cultural value.

Management Goals and Strategies for Improving the Watershed

Watershed management goals express the broad ways that streams and rivers need to be improved or enhanced to better meet the range of uses and values held by various stakeholders. Management strategies outline the specific sets of actions required to achieve the goals. As with the uses and values, the development of watershed management goals and strategies for the Mianus River Watershed involved working with watershed stakeholders. SWRPA staff coordinated and led a workshop for watershed stakeholders that focused on developing goal statements and associated strategies. The workshop began with a review of the existing conditions assessment and the uses and values previously identified by the stakeholders. Table E1 summarizes management goals and strategies identified in this workshop.

Watershed Management Goals

Through the workshop process and follow up discussions with the stakeholder group, the following management goals were established for the Plan:

Table E1. Management Goals and Strategies

Management Goals	Management Strategies
Enhance stormwater runoff management	Promote the use of Best Management Practices to reduce nutrient and sediment loading
	Avoid future increases in stormwater-related impacts through low impact development based policies and stormwater ordinances
	Define and remediate potential bacterial impairments within the Mianus River Watershed and improve riparian habitat
	Establish a long-term water quality monitoring program
Protect and enhance drinking water quality	Maintain and improve in-stream flows
Restore impaired biological communities	Reduce the impact of small dams and impoundments through barrier mitigation
	Manage the impacts of recreational activity on natural lands and aquatic resources along the Mianus River Greenway and the Mianus River Gorge
Maintain and enhance recreational opportunities	Encourage better stewardship of public and private lands by implementing education and outreach programs for landowners and municipal officials
	Pursue strategic land acquisition to protect headwater streams and promote greenway expansion
	Implement the Plan and monitor outcomes

Enhance stormwater runoff management

Given the amount of residential development in the watershed, enhancing stormwater runoff management is important for improving water and habitat quality, and ultimately the health of aquatic life in the Mianus River Watershed. Enhanced stormwater runoff management will also significantly reduce the quantities of NPS pollution delivered to the Mianus River and its feeder streams. Improved stormwater management can help reduce some of the erosion and sediment problems that have degraded aquatic habitat along portions of the Mianus River.

Protect and enhance drinking water quality

In total, approximately 70 percent of the total watershed drains to a drinking water supply, with only Strickland Brook and the portion of the Main Stem below Aquarion's Mianus Mill Pond excluded from the drinking water area. Despite the presence of significant quantities of forested lands within the Mianus River Gorge Preserve, significant development has occurred within many of the source water areas to the reservoir. The existing conditions assessment showed that water quality in some areas has been impacted by elevated nutrients and bacteria concentrations. Improving water quality will result in a cleaner, more beautiful stream that can ensure the security of drinking water supplies and support a more diverse community of aquatic life. As water quality improves, residents' ability to use the Mianus River for non-contact and contact recreation will improve, as will the value of the river as a scenic and aesthetic resource.

Restore impaired biological communities

Monitoring reports and visual assessments suggest that biological communities within many areas of the watershed have become degraded due to a combination of factors that include heavy recreational use and urban development. Less than 40 miles from New York City, the

Mianus River and surrounding natural lands are subject to intense recreational use, an important value that has nevertheless reached levels that are in some cases resulting in negative impacts to resource quality. Development in the watershed has also reached levels in many areas that are typically associated with impacts to stream communities. Dams and private water supply wells in the watershed may also be adding to the problem by reducing the amount of flow in the river channel (and hence the available wetted area available to support aquatic life) and, in the case of dams, creating a physical barrier to fish migration.

Maintain and enhance recreational opportunities

With its network of trails and public access points, scenic quality, and proximity to large population centers, the Mianus River Watershed is a key recreational resource. The Mianus River Gorge Preserve, Mianus River Park, and all of the other linked open spaces that make up the Mianus River Greenway are important amenities for hikers, joggers, and other outdoor enthusiasts. While the level of recreational use poses challenges for maintaining natural features, it is equally important to manage the Mianus River for continued and sustainable recreational use.

Watershed Management Strategies

Management strategies support the achievement of watershed goals through sets of specific actions. Strategies identified by watershed stakeholders include the following:

Promote the use of Best Management Practices to reduce nutrient and sediment loading

The implementation of BMPs can result in significant decreases in nutrient and sediment loading, which can in turn improve the health of the waterways within the watershed. BMPs include both structural and non-structural practices. Structural BMPs refer to built projects at a particular location, and may include rain gardens, constructed wetlands, green roofs, and other techniques for capturing, filtering, and infiltrating urban stormwater runoff. Structural BMPs can be installed in a variety of locations throughout the watershed to reduce the impact of urban stormwater runoff in developed areas. Nonstructural BMPs involve methods for decreasing sources of pollution through changes in behavior or property management techniques, and include such activities as picking up pet waste, properly maintaining septic systems, and reducing the use of lawn fertilizers.

Avoid future increases in stormwater-related impacts through low impact development based policies and stormwater ordinances

Maintaining high-quality streams in the Mianus River Watershed will depend on preventing impacts from future development through the adoption of progressive, low impact development (LID) based stormwater, zoning, and development ordinances. These ordinances will help to ensure that new development is designed and built to preserve the natural environment and reduce increases in stormwater runoff and NPS pollution. This work is particularly important in the Towns of Bedford, Pound Ridge, and North Castle, New York, within which lies a majority of the source water for subwatersheds to the S. J. Bargh reservoir.

Define and remediate potential bacterial impairments within the Mianus River Watershed and improve riparian habitat

Stakeholders have suggested that sections of the Mianus River may be unsafe for recreation due to high levels of bacteria from pet and wildlife waste in recreational areas, particularly where dogs, geese, and livestock have unrestricted access to the river. Failed or leaking septic systems can often be a significant contributor to bacteria loading. Although a large-scale, publically-available study of septic system impacts has not been conducted in the Mianus River Watershed, results of an in-house sanitary inspection program conducted by Aquarion Water Company over the past ten years suggest that septic systems in the watershed have a low overall failure rate. Addressing potential bacterial sources will involve stepping up efforts to identify and document reaches where bacterial impairments exist, identifying the causes of documented impairments, and eliminating the impairments through a combination of structural and non structural BMPs.

In addition, the restoration of riparian zones, the areas immediately adjacent to the stream channel, can play a central role in reducing bacterial impairments while providing a number of other benefits. Riparian areas provide important habitats for a variety of birds, mammals, reptiles, and amphibians; shade stream channels to keep stream water cool; provide important inputs of food (in the form of leaves, sticks, and other tree parts) on which macroinvertebrates and other aquatic life feed; and remove pollutants from stormwater runoff. In many places in the Mianus River Watershed, riparian areas have been altered by urban development. Reforesting these areas will help to improve water quality within the Mianus River and its feeder streams. The Plan identifies several site-specific riparian buffer BMPs that will improve streamside infiltration and prevent large amounts of bacteria from washing into the river. In addition to the specific BMPs outlined in the Plan, watershed groups are strongly encouraged to work with property owners to install additional buffers throughout the watershed, particularly on properties where lawn is currently mowed up to the stream edge.

Establish a long-term water quality monitoring program

The Plan outlines specific steps that, based on prior experience and best science, are likely to result in significant stream and watershed improvements (see Chapter 9). As stakeholders work to implement the Plan, feedback on whether it is working is critical. Using a process termed "adaptive management," water quality monitoring provides critical information about which management actions are working, and allows for adjustments to the Plan in ways that improve outcomes. Monitoring data can also be effectively used as an outreach tool for attracting additional funding.

Maintain and improve in-stream flows

In many instances, reservoirs can change the amount and timing of flow to downstream areas in ways that are detrimental to aquatic life. The exact effects depend on the size and configuration of the reservoir (e.g., whether water is released from the top or the bottom of the reservoir), the type of river channels that exist downstream, and the pattern of water releases.

In the Mianus River Watershed, reservoir management operations have altered the natural flow pattern of the river, and may be negatively impacting downstream aquatic life and habitats. Additionally, stakeholders have suggested that private wells in the upper watershed have reduced the amount of streamflow. Given the lack of river-specific flow data, the Plan recommends a comprehensive in-stream flow study as the next step in managing this important issue. The study will give stakeholders a better understanding of how and whether water withdrawals are affecting aquatic life and habitat within the watershed, to what extent stream flow standards set by CTDEEP are being achieved, and, if they are not being met, what modifications to the reservoir management regime could be implemented to achieve in-stream flow standards. At a minimum, reservoir management operation should be in compliance with CTDEEP in-stream flow standards. However, the Plan also recommends an adaptive management framework for evaluating the ecological response of the downstream river segments to reservoir operation modifications, and if needed, additional modifications until site specific ecological/biological targets have been achieved.

Reduce the impact of small dams and impoundments through barrier mitigation

As described earlier, numerous small dams and weirs cross the Mianus River and its tributaries, many of which no longer serve their original function. These structures, while small, can have significant cumulative effect, most notably in blocking the migration of fish populations. Methods for reducing the negative effects of small dams include the installation of fish ladders and natural fishways, partial dam removal, and full dam removal. Given the large number of barriers in the watershed, the Plan first recommends the development of a comprehensive fish passage and barrier mitigation plan to prioritize management actions.

Manage the impacts of recreational activity on natural lands and aquatic resources along the Mianus River Greenway and the Mianus River Gorge

Two recent reports, the 2006 *Managing Natural Resources & Recreation: An Action Plan* and the 2012 *Mianus River Park Management Plan* developed by stakeholders and the National Park Service outline the management actions needed to maintain and restore recreational resources in Mianus River Park. This Plan supports the recommendations of both documents, and seeks to use similar approaches to manage recreational areas throughout the Mianus River Greenway. Recommendations for these areas may include trail stabilization, rerouting, or elimination, drainage and remediation work, bank stabilization, temporary trail closures, and increased stewardship activities. Because recreational activity in these areas has been historically controversial, collective planning that involves all user groups will be important to long-term success.

Encourage better stewardship of public and private lands by implementing education and outreach programs for landowners and municipal officials

Promoting healthy attitudes toward stewardship and general property management is an essential way of improving overall watershed health. Effective educational materials focus on helping both private citizens and public officials become more aware of the relationship between NPS pollution and local-scale actions, such as lawn care practices and pet waste management, and provide practical, easy-to-implement actions that reduce such pollution. Education and outreach efforts will make use of the full range of media outlets and presentation possibilities available.

Pursue strategic land acquisition to protect headwater streams and promote greenway expansion

Several partners, including the The Mianus River Watershed Council, The Mianus River Gorge Preserve, Aquarion Water Company, local land trusts, and the Towns of Bedford, Pound Ridge, and North Castle, New York may be well-suited to collaboratively identify and prioritize conservation acquisition targets within headwater stream drainages upstream of the S.J. Bargh Reservoir, particularly in areas with significant undeveloped, unprotected, private lands. Many priority parcels have already been identified, as noted in the 2011 *Mianus River Greenway Priority Properties to Protect* report. The Plan supports the prior efforts to identify and preserve properties, and recommends the extension of existing efforts into additional areas of the watershed.

Implement the Plan and monitor outcomes

The Plan outlines long-term strategies for achieving each of the watershed based planning goals. Implementing the Plan will require the collective efforts of many partners to attract funding; work with private and public landowners to design, implement, and maintain BMPs; coordinate and implement outreach campaigns; and collect monitoring data. While volunteerism is critical to successful Plan implementation, hiring a full-time, paid program coordinator to lead fundraising, act as a liaison between partner groups, and coordinate individual initiatives and management actions will greatly improve the prospect for long term success.

Plan implementation works best when it is an iterative process that is constantly honed and changed according to evaluations of monitoring data. While the strategies outlined in the Plan are based in the best and current science and have, in most instances, been successfully applied in other watersheds, collecting data about how and if the Plan is achieving its intended effects is critical. Monitoring data will provide hard evidence on whether the Plan is working as planned and if not, provide the opportunity to change the approach.

HOW MUCH IS ENOUGH?

N and P, common in lawn fertilizers, can be partially responsible for poor water quality conditions.

Key NPS pollutants include bacteria, nitrogen (N), phosphorus (P), and sediment. Each pollutant degrades waterways in unique but significant ways. Computer modeling can be used to develop numerical targets for the specific amount of each pollutant that should be reduced to restore high-quality conditions.

As part of the Plan, the computer model WinSLAMM was used to estimate the current quantity of each pollutant entering the Mianus River and its feeder streams. The model uses the characteristics of the watershed, including land use, soil types, and the specific type and arrangement of impervious surfaces (rooftops, parking lots, and roadways). A separate model was developed for each of 22 subwatersheds (smaller drainage areas within the larger watershed). The modeling process was then repeated as if the watershed were undeveloped, estimating the quantity of pollutants delivered to the stream in the absence of human settlement. The difference between the pollutant quantities predicted in the developed and undeveloped models represents the reduction in pollution required to fully eliminate human sources of common NPS pollutants in the watershed.

Given the fact that reducing pollutant loads to predevelopment conditions is an ambitious goal, an interim target of eliminating 60 percent of the development-related pollutant load was established. Sixty percent represents a commonly accepted efficiency rate for NPS pollution-reduction BMPs. The full (100 percent) load reduction targets call for reductions of 0.1, 1.7, 81.7, and 59.6 percent in sediment (expressed as Total Suspended Solids [TSS]), P expressed as particulate P, N expressed as nitrate (NO_3), and indicator bacteria, respectively. Interim load reduction targets call for TSS, particulate P, and NO_3, and indicator bacteria reductions of 0.06, 1.0, 49.0, and 35.8 percent, respectively.

Table E2. Summary of Pollutant Load Reduction Targets

	Interim Target	Full Target
TSS	0.06	0.1
Particulate P	1.0	1.7
NO_3	49.0	81.7
Indicator Bacteria	35.8	59.6

IMPLEMENTING THE PLAN

Management goals and strategies define the overall aims of the Plan and the types of activities that will help achieve the improvements articulated by the Plan's goals. But goals and strategies alone do not result in an actionable Plan for improving the Mianus River Watershed. Building on the goals and strategies, SWRPA staff with the project consultant and steering committee developed lists of specific management actions needed for Plan implementation.

Management actions were developed for each management strategy based on observations made during field assessments. Recommendations from stakeholders, technical reports and guidance, and best professional judgment were also taken into account. Recommended management actions include structural BMPs such as rain gardens and stormwater basins; non-structural BMPs such as policy initiatives; educational and outreach programs to promote the adoption of watershed-friendly behaviors across the watershed; and monitoring activities.

An implementation schedule was developed to achieve the goals outlined in the Plan. Management actions were recommended for short-term (one to five years/pilot phase), mid-term (five to 10 years), and long-term (10 to 20 years) implementation. It is recommended that successes and lessons learned be evaluated every five years and the Plan updated or revised as necessary.

Potential sources of funding for recommended management actions are presented in Appendix B. A number of grant programs are available through state and federal agencies, nonprofits, and corporate partnerships. Minimum and maximum dollar amounts for identified funding programs are presented, as are application deadlines and any required match money. Other financial opportunities including use of impact fees, taxes, utility districts, and membership drives, are described briefly.

STRUCTURAL BEST MANAGEMENT PRACTICE IDENTIFICATION

Structural BMPs such as rain gardens, basins, and swales are particularly useful for the reduction of NPS pollution because they are tangible, one-time construction projects that are relatively uncomplicated to model, design, construct, and monitor. In addition, structural BMPs are often associated with ancillary benefits; these include improved aesthetics and landscaping and education and demonstration potential. Structural BMPs often are associated with significant reductions in pollution, although efficiencies vary by BMP type and pollutant.

For these reasons, structural BMPs were identified as a first step toward addressing the NPS pollution reduction targets in the watershed. The BMPs were identified through a combination of feasibility analysis, field inspection, and stakeholder recommendations. Planning-level costs and load reduction estimates were developed for each structural BMP and can be found in Appendix A.

An existing swale identified for potential retrofit to improve stormwater management capability and reduce erosion.

Target Areas

In even a relatively small watershed such as the Mianus, hundreds of potential structural BMP opportunities exist. To target structural and non-structural BMPs where they will be most useful, the project team used a desktop analysis to select 13 target subwatersheds. These were identified based on location in sensitive areas (i.e., draining directly to drinking water sources or contained, small headwater streams), modeled amounts of NPS pollutants, and/or identification by watershed stakeholders.

Within each target area, the team then conducted an analysis to identify potential structural BMP locations. The process involved identifying unused green spaces using aerial photographs to which runoff from large developed areas could be routed. Subsequently, project engineers visited each site to further assess its feasibility and develop a more precise estimate of how much stormwater could be conveyed to and managed within each structural BMP. Using this approach, 11 structural BMPs were identified, with planning-level costs ranging from $7,000 to $633,000. Total cost of all structural BMPs identified through this process would be approximately $2,484,500. Two additional sites for potential structural BMPs were identified by stakeholders.

Pollution-load reduction estimates were modeled for each structural BMP identified through the targeting process. Reductions associated with the structural BMPs represent less than one (1) percent of the total target load reduction NO_3, just over one (1) percent for bacteria, and approximately 37 percent and 800 percent of the total targets for particulate P and TSS, respectively. These represent 0.5, 2.0, 62.0, and 1,370 percent of the interim targets, respectively, for NO_3, bacteria, particulate P, and TSS. Although these structural BMPs will not by themselves achieve the full load reduction targets for NO_3, bacteria, and particulate P, they present potentially feasible, vetted first steps. These identified structural BMPs will be more than sufficient to manage the total TSS target.

REACHING OUT TO CHANGE BEHAVIORS

Many sources of NPS pollution come from relatively small but widely practiced behaviors such as over fertilization of lawns, poor inspection of septic systems, and failure to pick up pet waste. Education and outreach activities are particularly focused on helping watershed residents understand the connection between their actions and the health of the Mianus River and giving home and business owners inexpensive, easy-to-implement actions that can, en masse, result in significant reductions in NPS pollution. Since so much NPS pollution originates on private property, outreach to homeowners and municipal officials is critical to the implementation of long-term management goals and strategies. Outreach to owners of property directly adjacent to streams, and to municipalities located in the Mianus River's headwaters may be particularly useful.

The outreach and education component of the Plan recommends a combination of media and education formats to educate residents and local businesses about the need for pollution prevention and stewardship in the Mianus River Watershed. Proposed outreach campaigns relate to LID approaches, buffer establishment, landscape and pet waste management, use of rain barrels, open space preservation, and septic maintenance and repair.

MONITORING OUTCOMES

Monitoring ensures that the groups who implement the Plan understand how their collective efforts impact the health and quality of the watershed. Monitoring data can also be used to adjust and adapt the Plan to increase the effectiveness of watershed management efforts.

The Plan outlines a detailed approach for measuring success through a monitoring program that includes the following components:

- **Routine in-stream monitoring,** conducted at fixed stations throughout the watershed on an annual or biannual basis. The primary purpose of routine monitoring is to detect changes in in-stream conditions over time during Plan implementation. Routine monitoring includes habitat, water quality, and biological data collection.

- **Early-warning monitoring,** a more specialized type of monitoring that helps detect emerging threats through more intensive monitoring of conditions within sensitive headwater areas. Early warning monitoring focuses on physical changes to the shape and size of stream channels and easy-to-measure characteristics such as water temperature.

- **Structural BMP monitoring,** conducted to identify performance and maintenance issues associated with structural BMPs and assessing the downstream effect of structural BMPs on streams. The routine monitoring plan for structural BMPs includes the assessment of vegetation, structures, downstream water quality, downstream outfalls, and sediment and debris accumulation.

One of a number of coastal rivers that empty into Long Island Sound (LIS) in southwestern Connecticut, the Mianus River is an important water resource that is well loved by its community, yet increasingly threatened by patterns of recreational and consumptive water use and urban development. The river flows north from its headwaters in North Castle and Bedford, New York, then arches east and eventually south as it passes through Bedford Town Center and suburban and rural residential neighborhoods. The river enters the S.J. Bargh Reservoir in the Mianus River Gorge Preserve. Below the reservoir the river passes through low- to medium-density residential neighborhoods in Stamford and Greenwich, Connecticut, and eventually crosses the developed corridor along Route 1 and I-95 where it mixes with tidal salt water from LIS. Major tributaries include the East Branch and Piping Brook, which join the Main Stem midway through the river's course, and Strickland Brook, which joins the river at its outlet to LIS in Greenwich, Connecticut.

Located in an otherwise developed region, the Mianus River Watershed has been well preserved by a historically conservation-minded community. The Mianus River Gorge Preserve, one of the first projects of the newly formed Nature Conservancy in the 1950s, was created at the request of a group of concerned citizens. Since then, many additional areas along the river have been permanently protected as a string of open spaces now known as the Mianus River Greenway. Yet, even with these protections in place, residential development and a multitude of small dams have impacted the quality of habitat and the river's natural flow pattern. In the lower watershed, conflicts have arisen over intense recreational use of the river. These issues illustrate the need for long-term management that treats the resources and problems of the watershed as a whole, rather than as a collection of disparate sites and user groups.

WATERSHED SETTING

The Mianus River Watershed has a drainage area of approximately 35 square miles, located in Fairfield County in the southwestern coastal region of Connecticut, and Westchester County in southeastern New York. The watershed boundary includes portions of the Town of Greenwich and City of Stamford, Connecticut and the Towns of Bedford, North Castle, and Pound Ridge, New York (Figure 1). Regionally, the watershed is located in an area where dense commercial development and suburban and rural areas commonly exist next to each other. Its historic and scenic character has typically been valued by residents of Fairfield and Westchester Counties, and many forested areas and open spaces have been permanently preserved in the greater region.

In a region that has seen extensive development in the later half of the twentieth century, the Mianus River Watershed has been remarkably well protected. The Mianus River Gorge Preserve, which surrounds a large portion of the river's central Main Stem, contains over 700 acres of forested land that is managed for conservation by the Mianus River Gorge Preserve, Inc. Below the gorge, a string of parks and forest parcels buffer the river's banks and offer the community a peaceful respite from the bustle of the New York Metropolitan Area.

In spite of these protections, the river has nevertheless been impacted by human activity. Early mill dams are found throughout the watershed, blocking the movement of fish and the river's natural flow pattern. Residential land along the river is in high demand, and many homeowners

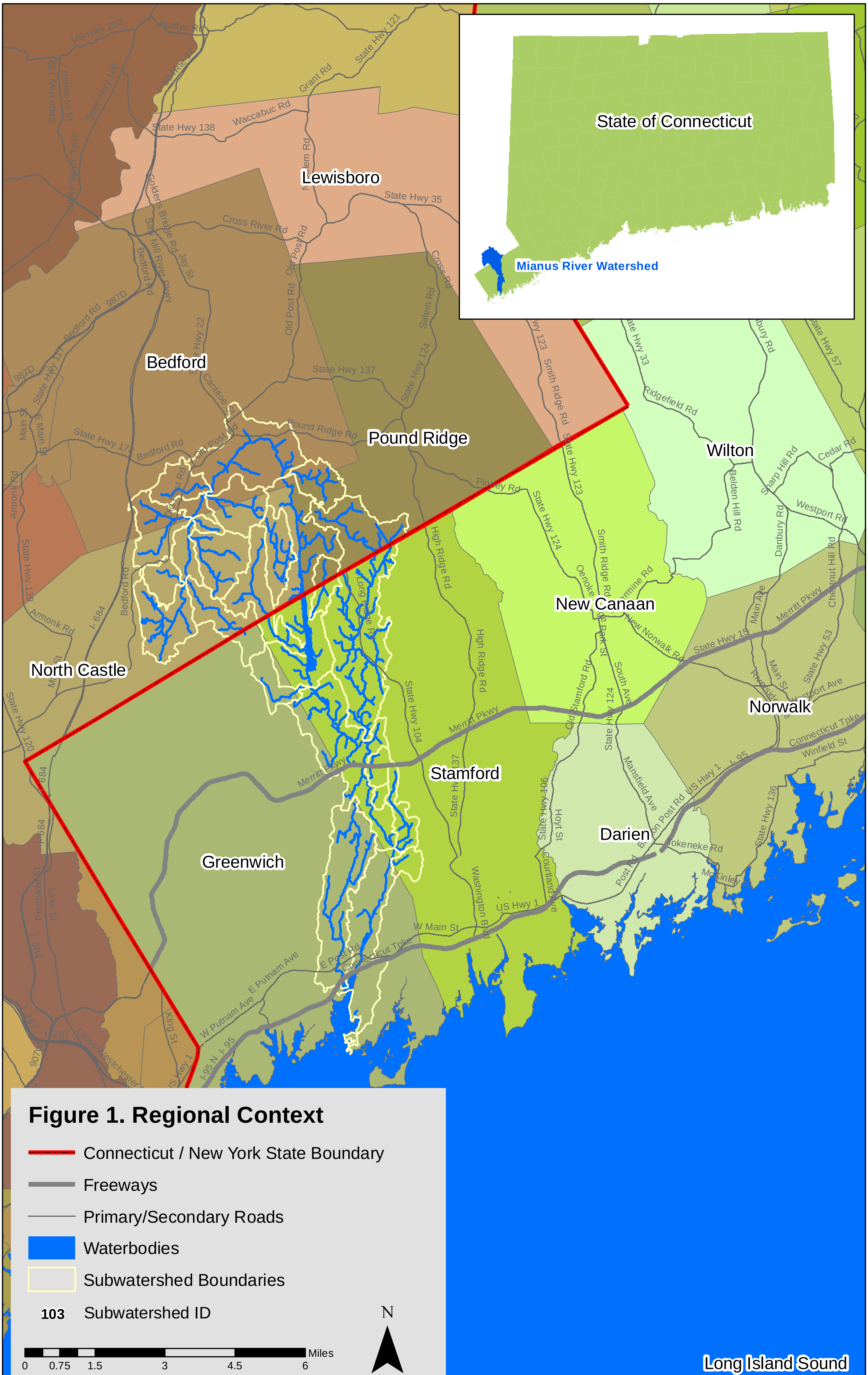


Figure 1. Regional Context

have modified the channel and riparian zone with small walls, dams, bridges, and landscaping. In the lower watershed, intense recreation in park areas has led to disputes over the need for better stewardship and responsible use. In some areas, urban development has reached levels that often result in water and habitat quality impacts. These patterns have imperiled many of the resources that make the Mianus River Watershed a desirable place to live and play.

THE URBAN STREAM SYNDROME

When watersheds become urbanized, changes in the physical and chemical stream characteristics cause a systematic and predicable decline in the health and diversity of aquatic species. Nonpoint source (NPS) pollutants, such as bacteria, sediment, nitrogen (N), and phosphorus (P) are delivered to streams in increasing quantities. And increased rates of stormwater runoff scour high-quality habitats and stress aquatic life. Riffles (rocky, fast-moving areas of the stream that support fish-spawning and provide habitat for many aquatic insects known as macroinvertebrates) become filled with sediment. Physically, stream channels become simplified and no longer contain the complex maze of deep pools, woody debris piles, backwater areas, and rocky areas that provide habitats for a diverse community of aquatic life. Rates of bank erosion increase, further increasing pollutant loading and sedimentation of key habitats, and in many cases threatening streamside properties. Rates of flooding and associated flood damage also increase. Odor issues and dangerous levels of bacteria eliminate or significantly reduce the ability to swim, fish, and otherwise recreate in urban streams.

The Mianus River lies somewhere in the middle on the spectrum of effects of urbanization. Aquatic monitoring and stream assessments reveal a patchwork of conditions, in some cases quite healthy and in others partially degraded. Regionally, the river has fared better than many of its neighbors, due mainly to land protection in the headwaters and a strong local community committed to protecting this resource.

The Mianus River Watershed Based Plan ("the Plan") outlines a targeted, science-based, and community-led effort to improve and protect conditions in the Mianus River Watershed through on-the-ground restoration and stormwater management, watershed monitoring, and education and outreach. The Plan focuses on reducing NPS pollution, the diffuse sources of which are pet waste, lawn fertilizers, and pesticides. These sources, unlike end-of-pipe pollution sources such as those generated from wastewater treatment facilities, have traditionally been difficult to identify and control.

NEED FOR A WATERSHED BASED PLAN

NPS pollution, that is, the nutrients, bacteria, sediment, and other pollutants carried by rain water over land is more and more a major problem for watershed managers across the country. Historically, pollution to waterbodies has been regulated through the National Pollution Discharge Elimination System (NPDES) program, which is geared toward large commercial, industrial, or public sites that discharge water to streams. Over the past several decades, this program has reduced levels of pollution and improved water quality throughout the country. NPDES has however been less effective at managing NPS pollution.

Runoff from the municipal drainage network—mostly via roads, sewers, and swales—is partially regulated under NPDES Municipal Separate Storm Sewer System (MS4) permits. This program requires general outreach and maintenance activities to improve awareness and management of stormwater, but it does not currently set any specific pollutant loading limits. In most suburban areas, stormwater runoff comes from private, often residential properties, the individual impacts of which are minimal. Taken together, these small roofs and driveways can generate a significant amount of largely unregulated runoff and NPS pollution.

In the Mianus River Watershed, development in some areas is approaching threshold levels that are commonly associated with mild to moderate water quality and aquatic habitat degradation (see Chapter 2). Although sampling by the Connecticut Department of Energy and Environmental Protection (CTDEEP) has been very limited, the existing conditions assessment conducted in support of this Plan (Chapter 2) identifies multiple areas where water quality and habitat problems exist. Many of these problem areas are related to stormwater runoff from roads and parking lots, or residential landscaping and construction along the stream banks. If current land use practices are continued, stream conditions may worsen to a point where aquatic habitat is significantly impacted. In the absence of strong regulation to deal with this problem, and since the watershed spans municipal and land use boundaries, watershed based planning is a particularly important approach to dealing with these NPS pollution-related problems.

Watershed based planning uses a science-based and community-driven approach to assess existing conditions; set goals for watershed improvements; outline strategies through which these goals will be achieved; identify water quality and habitat problems and the causal factors responsible for these problems; develop feasible, cost-effective solutions; and provide a framework for revising the Plan during the implementation process in response to monitoring data, a process called adaptive management. Throughout the planning process, watershed stakeholders provide critical information and feedback. A plan developed with the full participation of the community will enjoy better support and in the long run will be more effectively implemented than one that developed using a top-down, regulatory-driven approach.

The Plan was developed in response to water quality and habitat problems associated with NPS pollution. The core purpose of the Plan is to develop an actionable framework for reducing NPS pollution, and to consider other ways that the water resources within the watershed can be improved (including improving habitat and reducing flooding). Funded by CTDEEP, the Plan was developed in accordance with the Nine Steps of Watershed Planning recommended by the U.S. Environmental Protection Agency (EPA) (EPA 2008). The planning process was administered by the South Western Regional Planning Agency (SWRPA), with technical support from project consultant AKRF, Inc.

The Plan is intended to provide a long-term guide for watershed protection and restoration. Central to its approach is the idea that the Plan will be most effectively implemented when municipalities and partner organizations work together to achieve pollution reduction targets and minimize future impacts. Management actions outlined in the Plan require varying degrees of technical and communications expertise, and as such are geared toward a variety of stakeholders, organizations, and agencies. Implementation is expected to be incremental, and identified management actions may take 20 years or more to be fully effective. At the end of this period, water quality and habitat within each stream reach is expected to meet criteria established by CTDEEP.

HISTORY OF PLANNING FOR THE MIANUS RIVER

The Plan builds on the Mianus River Watershed's long history of community involvement. The river has benefited from strong municipal support coupled with significant research and conservation activities by scientists at the Mianus River Gorge Preserve, and planning and outreach by the Mianus River Watershed Council. Many other organizations and agencies have contributed to protection efforts, beginning in the later half of the 20th century and continuing to the present day. The following is a list of major technical and planning publications relating to assessment and management of the Mianus River Watershed:

- *Mianus River Greenway Priority Parcels to Protect*, Mianus River Watershed Council, 2011;
- *Managing Natural Resources & Recreation: An Action Plan* (Mianus River Park), National Park Service Rivers, Trails & Conservation Assistance Program, 2006;
- *Town of Greenwich Water Quality Study*, Milone & MacBroom, 2004;
- *Biotic Survey and Water Analysis of the Mianus River*, Aquatic Resource Consulting, 2000;
- *Mianus River Study*, Marine & Freshwater Research Service, Delta Environmental Services, Inc., 1997;
- *A Report on the Condition of the Mianus River and Mianus Pond in Greenwich, Connecticut*, Caroline C. Baisley, Greenwich Department of Health, and Thomas Baptist, Greenwich Conservation Commission, 1993;
- *Mianus River Watershed Project Report, A Bioregional Approach to Watershed Protection*, The Westchester Land Trust, 1992;
- *Guide to Watershed Protection for Those Living and Working in the Mianus River Watershed*, The Westchester Land Trust, 1992;
- *Biological Stream Assessment, Mianus River*, Bode, Novak, and Abele, 1991;
- *Surface Water Quality Assessment Program, Phase I&II—Mianus and Stone Hill Rivers*, Safewater Consultants, 1988; and
- *Stream Survey of the Mianus River*, Baily and Lagler, 1936.

The Mianus River Watershed Council was founded in 1989 as a partnership of environmentalists, town officials, and water company representatives who recognized the need for a watershed approach to protection of the region's water resources. Since its inception, the Council has been active in numerous planning and technical initiatives to understand and preserve the watershed. The Council aims to initiate and coordinate efforts for land and water protection in the Mianus River Watershed; act as land managers and stewards of the lower watershed; and educate the public.

While early watershed studies focused on characterizing the river's water quality, recent planning efforts have aimed to resolve the recreational conflicts within the Mianus River Park, a large block of forested land that bounds the eastern and western banks of the Main Stem just below the Merritt Parkway. A 2.6-mile nature trail connects a trailhead at Cognewaugh Road in Greenwich with the Merriebrook Lane trailhead across the river in Stamford. The area is heavily used for jogging and dog walking. Beginning in 2003, the City of Stamford and the National Parks Service Rivers & Trails Program led stream assessments and eight facilitated public workshops to define key problems and possible solutions (National Park Service 2006). This process resulted in a series of targeted recommendations to protect the park while providing for continued recreation. At this time a group of concerned citizens joined to form the Friends of Mianus River Park, with a mission "to sustain and protect the Mianus River Park for all users and future generations."

Building on the National Park Service study, recent planning has continued to emphasize land preservation planning in the lower watershed. In 2011 the Mianus River Watershed Council published the report, *Mianus River Greenway Priority Parcels to Protect*, an analysis of unprotected open space parcels located within or adjacent to protected lands. The report identifies 10 target parcels located in the City of Stamford adjacent to or below the S.J. Bargh Reservoir, which together total an additional 324 acres of connected forest. This publication is intended to aid decision-making by land trusts and municipalities.

The Plan is intended to consolidate, synthesize, and build on the varied assessments, planning studies, and management recommendations conducted to date. Although primarily focused on NPS pollution reduction, the goals and strategies outlined in the Plan fit well with the recreation-focused planning that has recently been emphasized in the Mianus River Watershed.

PUBLIC ENGAGEMENT & STEERING COMMITTEE

A central intent of the watershed based planning process is to provide a framework through which members of the watershed community may shape future management activities and influence decision-making. The individuals and organizations living and working in the watershed know it best, and are uniquely suited to guide goal-setting and long-term implementation. With this goal, stakeholders from the municipal, conservation, and business communities were invited to provide input from the earliest stages of Plan development through revision and publication of the final document.

The public engagement process included a series of three public meetings held on July 13, 2010; April 28, 2011; and November 30, 2011. During the first meeting, project consultants presented initial findings of the existing conditions assessment while stakeholders defined the watershed's important uses and values, discussed the measurable attributes of the watershed and river system that provide for key uses and values, and discussed the existing impacts and emerging threats to these uses and values. Uses and values defined during the meeting included drinking water, recreation, wildlife, and many other environmental and cultural attributes.

At the second meeting, the group discussed management goals that, if achieved, would preserve high-quality resources while addressing existing impacts and emerging threats. Management strategies defining specific steps required to achieve the management goals were also discussed. Following this discussion of management goals and strategies, project consultants presented a working list of potential stormwater best management practices (BMPs) to begin to implement the management goals and strategies. Stakeholders provided feedback on these BMPs, and identified additional management actions to support goals and strategies. The third meeting was presented as a kickoff to final Plan development and implementation, and additional comments were provided by stakeholders.

In conjunction with the public engagement process, a volunteer steering committee was formed to support Plan development and review technical documents. The steering committee was composed of state and municipal representatives, and local stakeholders who expressed an interest in taking an active role in shaping the Plan. Members of the following organizations contributed to the steering committee:

- Aquarion Water Company;
- City of Stamford;
- CTDEEP;
- Mianus River Gorge Preserve;
- Mianus River Watershed Council;
- Stamford Land Trust;
- Town of Bedford;
- Town of Greenwich;
- Town of North Castle; and
- Trout Unlimited, Mianus Chapter.

To facilitate public input across a broad demographic, a blog and interactive online map were created. Stakeholders were provided an opportunity to publish blog posts about watershed topics of their choosing. An interactive map was designed to allow users to create points of interest for potential management activities, areas of concern, or any other relevant information. Project consultants shared progress updates and other relevant news and information on a weekly basis.

The draft Plan was released for public review, giving stakeholders an opportunity to review the Plan and provide feedback before the Plan was completed. The draft Plan was made available from October 3, 2012 – November 3, 2012. An open house was held October 25, 2012 where the Plan was presented to the community.

PLAN OVERVIEW AND ORGANIZATION

At its core, the Plan establishes a framework for identifying and responding to watershed problems. In accordance with EPA guidance (EPA 2008), the Plan was developed to include the following nine (9) elements:

Identify potential causes and sources of pollution (Chapter 2)

Chapter 2 characterizes existing conditions within the watershed. The chapter provides a basic description of the physical, political, and environmental characteristics of the watershed, and characterizes the quality of aquatic resources in the watershed through a review of existing data and a stream assessment data collected during Plan development. Finally, the chapter provides estimates of NPS pollutants developed using the computer model WinSLAMM.

Pollution load reduction estimates (Chapter 3)

Chapter 3 of the Plan estimates the NPS pollutant reductions that would be required to restore pollutant loading levels to pre-development conditions. WinSLAMM was the primary means used to develop estimates and predict the pollutant loading rates associated with an undeveloped (i.e., fully forested) watershed condition. The difference between the undeveloped loads and the actual loads presented in Chapter 2 was established as the total load reduction target. Because a 100 percent reduction in pollutant loading due to development is not feasible for all pollutants, an interim goal of 60 percent of the calculated pollution load reduction target was established.

Management recommendations to address identified pollution sources (Chapters 5, 6, and 7)

Specific management recommendations required to achieve the pollutant load reductions estimated in Chapter 3 are presented in Chapters 5 and 6. Specifically, Chapter 5 outlines broad goals for the Plan and discusses management strategies for achieving these goals, which include:

- Enhancing stormwater management;
- Protecting and enhancing drinking water quality;
- Restoring impaired biological communities; and
- Maintaining and enhancing recreational opportunities.

Chapter 6 expands on the management strategies described in Chapter 5 by outlining specific management actions and their associated costs. Management actions include structural and non-structural BMPs as well as broader programs geared toward managing pollution across the watershed.

Chapter 7 discusses the identification and assessment of individual structural BMPs meant to reduce NPS pollution. Individual structural BMP descriptions and estimated costs and pollutant load reductions associated with each BMP are presented in Appendix A and Chapter 7.

Sources of financial and technical assistance (Appendix B)

Sources of financial and technical assistance are provided in Appendix B of the Plan. Sources include grant funding, foundation support, and other forms of funding.

Plan implementation schedule (Chapter 6)

Chapter 6 provides an implementation schedule for each identified management action.

Interim milestones (Chapter 6)

Chapter 6 provides interim milestones required for the implementation of each identified management action.

Implementation performance criteria (Chapter 6)

Chapter 6 outlines performance criteria for each identified management action.

Education and outreach (Chapter 8)

Chapter 8 speaks specifically to education and outreach activities that support Plan implementation. The education and outreach approach emphasizes reaching out to homeowners and commercial property owners to educate them about the relationship between property management and watershed health, and to offer practical suggestions for simple, inexpensive actions that can be taken to reduce NPS pollution.

Monitoring and assessment (Chapter 9)

Chapter 9 outlines recommended steps for monitoring and assessment. Monitoring recommendations include routine monitoring of water quality, macroinvertebrates, and habitat at fixed monitoring stations; early-warning monitoring to identify emerging threats in small headwater subwatersheds; and monitoring for structural BMPs.

A watershed based plan relies on a thorough and science-based understanding of the existing conditions of streams and rivers throughout the watershed. This chapter provides a basic description of the physical, political, and environmental characteristics of the watershed, and characterizes the quality of aquatic resources in the watershed through a review of existing stream assessment data collected during Plan development. It also provides estimates of NPS pollution developed using the computer model WinSLAMM. Finally, the chapter presents the use designations established by CTDEEP for various stretches of the Mianus River and its tributary streams.

Overall, the existing conditions assessment reveals a river that has been somewhat impacted by development. Impervious cover—the hard surfaces such as paving and rooftops that prevent water from soaking into the soil—comprises approximately 12 percent of the watershed's total area. National studies have shown that rivers flowing through watersheds with this level of impervious cover will exhibit impacts to habitat and water quality, although these impacts may not be severe or highly visible. A review of limited CTDEEP bio-monitoring data indicate generally good water quality on the Main Stem below the reservoir, as did previous sampling of the Upper Main Stem (Aquatic Resources Consulting 2000). However, visual assessments conducted by AKRF in the summer of 2011 and prior studies indicate possible habitat or water quality problems in Strickland Brook, the East Branch, and the Upper Main Stem above the S.J. Bargh Reservoir. Furthermore, the *Biotic Survey and Water Analysis of the Mianus River* cites older documents that have indicated sediment from surface runoff as a main source of habitat degradation in the Mianus River (Aquatic Resources Consulting, 2000).

Impacts of development are evident in the upper reaches of the watershed, on tributary streams as well as the Upper Main Stem, emphasizing how sensitive streams can be to even modest changes in land use. The large, forested areas adjacent to and just below the reservoir do somewhat successfully preserve good quality stream conditions, as evidenced by visual assessments and CTDEEP bio-monitoring. Below the reservoir, erosion and sediment problems associated with banks along River Road and the Mianus Mill Pond have been identified by stakeholders.

Despite degraded conditions at multiple sites throughout the watershed, many good-quality resources do exist. For example, healthy aquatic macroinvertebrate and fish communities were found on the Main Stem. Forested banks and good-quality habitat are found in the large preserved areas surrounding the Mianus River Gorge Preserve. Understood as a whole, the watershed remains a place characterized in many locations by abundant and vibrant natural resources and high quality streams as well as a place where the effects of modest urban development are also evident. Because impacts to the river have not yet been severe on a broad scale, the Plan must effectively balance the need to protect existing high-quality resources with the need to improve conditions in degraded areas.

WATERSHED CHARACTERIZATION

The approximately 22,169-acre Mianus River Watershed is located in southwestern Connecticut and southeastern New York, in the coastal slope and lowlands of Fairfield and

Westchester Counties. The river flows north from its headwaters in North Castle, New York, then curves east and south through the municipalities of Bedford and Pound Ridge before crossing the state boundary and flowing south through Stamford and Greenwich, Connecticut where it outlets to LIS. The watershed is bisected by the Metro-North Railroad and by two major highways, I-95 and the Merritt Parkway (CT-15). For the purposes of this Plan, the study area ends just below the confluence with Strickland Brook, at the point where the Metro-North Railroad crosses the estuary.

The Mianus River Watershed contains approximately 106 miles of stream, including tributaries. Major tributaries include the East Branch (seven miles long), Piping Brook (three miles long), and Strickland Brook (five miles long), and several smaller unnamed streams. The Main Stem of the Mianus River from below the S.J. Bargh Reservoir to the downstream extent of the study area is approximately nine miles long.

In its headwaters, the river is a relatively slow-moving lowland stream with a silty bottom; as it moves into the Mianus River Gorge, the stream speeds up through a series of pools and rocky outcrops (Aquatic Resources Consulting 2000). Multiple small dams and channel modifications are found throughout the watershed. Major dams are located at the S.J. Bargh Reservoir, Mianus Mill Pond, and Mianus Pond near the Route 1 crossing. Despite these modifications, the banks have not been extensively channelized, and most of the channel maintains a meandering pattern.

Water Quality

High-quality water resources are important to support the recreational and drinking water needs of the local community. Many residents get their drinking water from private wells, which depend on clean groundwater with good rates of recharge. The upper watershed drains to the S.J. Bargh Reservoir, which provides drinking water to many residents living within and outside of the watershed. In addition to providing a source of drinking water, the Mianus River is also used for recreational fishing (bank fishing and fly fishing). Boaters row and paddle the multiple small ponds along the lower reaches of the Mianus River.

Given the diversity of uses that depend on high-quality water, water quality is a serious concern. There has been limited sampling within the watershed, so it is unclear to what extent water quality meets or fails to meet requirements. State sampling programs (discussed in more detail later in this chapter) have not been sufficient to indicate that any portion of the river fails to meet minimum standards; however studies have indicated problems related to bacteria in Strickland Brook (Milone & MacBroom 2004) and on the Main Stem (Aquatic Resources Consulting 2000). Since 2004, sewers have been installed in parts of Greenwich in the lower portion of the watershed, which may invalidate earlier bacteria data. Prior to development of the Plan it has been generally presumed that some reaches may fail to meet state standards for recreation or habitat, based on the assessments described above.

Stakeholders have suggested that bacterial problems within the watershed may be related to numerous malfunctioning or under-performing septic systems located on private property, but results of Aquarion Water Company's sanitary monitoring program suggest that failure rates of septic systems within the watershed are very low (B. Roach, pers. comm., 8.20.12). Aquarion conducts annual visual sanitary inspections at approximately 240 sites within the Mianus River Watershed in the communities of Bedford, Pound Ridge, North Castle, Greenwich, and Stamford (B. Roach, pers. comm., 8.20.12). During the past five years of monitoring, Aquarion performed over 1,000 sanitary inspections within the Mianus River Watershed and found no reportable septic system failures (B. Roach, pers. comm., 8.20.12). However, it should be noted that the Aquarion study was based on a visual inspection of septic system condition and did not include advanced techniques for identifying septic plumes.

Land Use

Land use is one of the most important variables in understanding watershed condition. As development increases, stream conditions worsen due to changes in the hydrologic cycle. Many factors influence how a watershed responds to development. These include physical characteristics of the river and how and when the development takes place. Total impervious cover is generally accepted as an indicator of overall watershed health (Center for Watershed Protection [CWP] 2003). An in-depth discussion of the impacts of impervious cover is presented later in this chapter.

Prior to 1900, early land uses in the Mianus River Watershed were largely related to farming, although parts of the Gorge were never farmed due to steep slopes and rocky soil. In the estuary, oyster farming was a major industry, peaking in the early 20th century. Since then, the land has been largely cleared and developed for suburban neighborhoods. Commercial corridors are found near the coast and in Bedford Town Center. The region has experienced rapid residential and commercial development over the past 50 years, and is characterized by a robust local economy as well as a large residential population.

Land use within the Mianus River Watershed is primarily residential (76 percent of the watershed area) (Table 1). The watershed assumes a more rural character in the upper watershed, while suburban residential communities dominate land use in the lower watershed (Figure 2). Approximately 22 percent of the watershed is preserved as open space. The remaining three percent of land use is designated for commercial, industrial, and institutional uses. Impervious cover is estimated to be 12 percent.

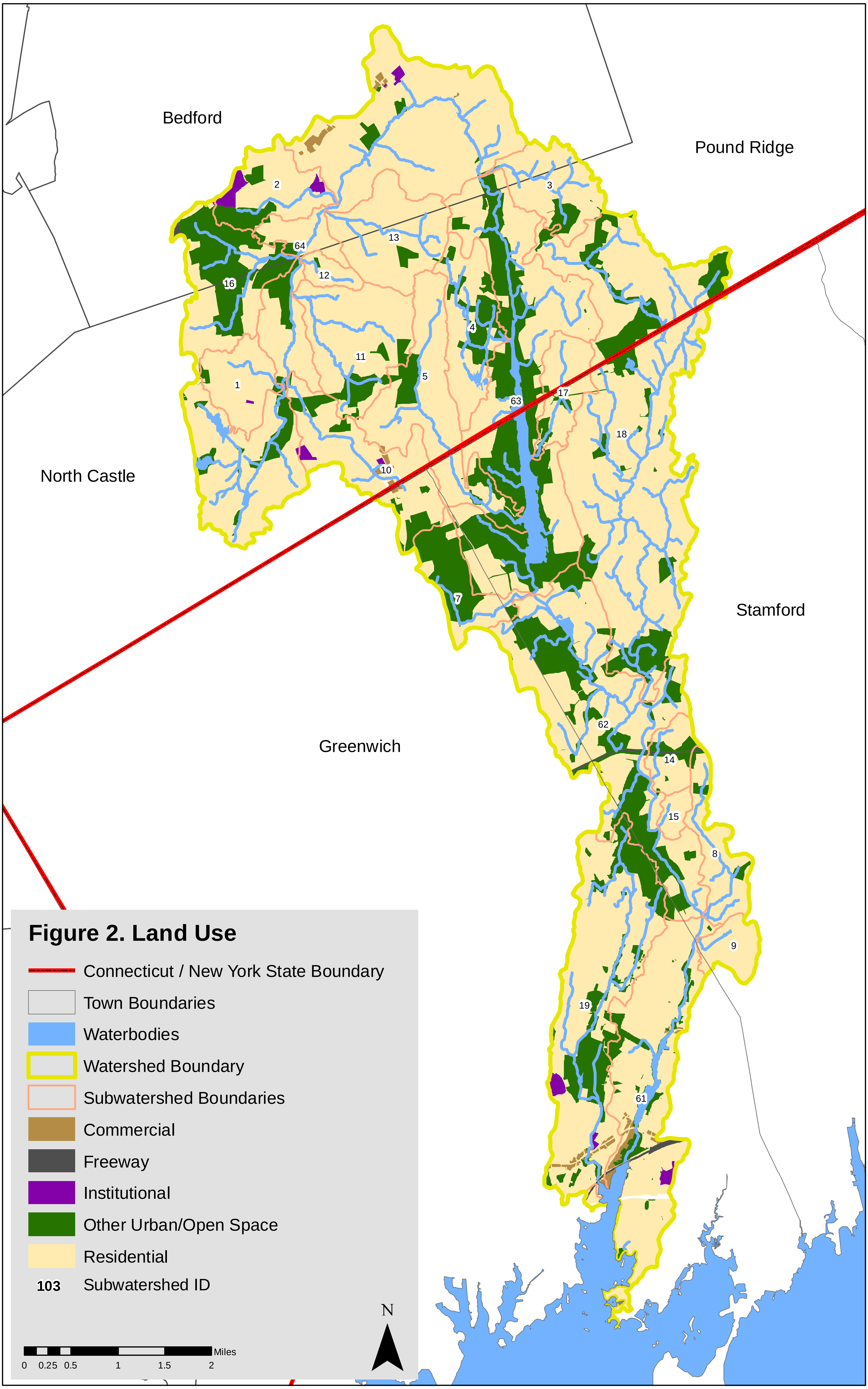
Table 1. Watershed Land Use

Land use	Percent of Watershed Area
Commercial	1
Freeway	<1
Industrial	<1
Institutional	1
Other Urban/Open Space	22
Residential	76

Vegetation and Wildlife

Vegetation and wildlife are closely tied to land use and soil type characteristics. In the Mianus River Watershed, plant and animal species found are generally typical of the region. Forest composition, which in most areas contains a mix of native and non-native species, is generally consistent with the level of anthropogenic modification.

The upper portion of the watershed is characterized by low, rolling hills where successional oak and oak-pine forests once covered the landscape (Griffith et. al. 2009). The lower portion of the watershed is characterized as LIS Coastal Lowland, where hills give way to low-elevation coastal plain. Native forest vegetation includes oaks (*Quercus sp.*), hickories (*Carya sp.*), and dense



Land use data provided by SWRPA as a composite of local land use, zoning, and open space data, and the Uconn CLEAR 2006 Connecticut Land Cover Data.

brier thickets (Griffith et. al. 2009). The lower portion of the watershed represents the northernmost reach of some Piedmont-type vegetation species including holly (*Ilex sp.*), sweetgum (*Liquidambar sp.*), and post oak (*Quercus stellata*) (Griffith et. al. 2009).

The Mianus River Gorge, located at the heart of the watershed, contains some of the last stands of old-growth forest left in the region. Steep slopes and poor logging potential made this area unappealing to settlers, while much of the adjacent forest was cleared for pasture land in the 18th and 19th centuries. Today the Gorge is home to coyote, deer, bobcat, and a variety of birds, reptiles, and amphibians.

Below the gorge, most of the remaining forested land within the watershed has some history of disturbance, whether related to land development or farming. As is typical in the region, native forest species have given way in many areas to large stands of invasive species, including bamboo (*Bambusa vulgaris*), Japanese barberry (*Berberis thunbergii*), Norway maple (*Acer platanoides*), and others. An overabundance of white-tailed deer has led to increasing pressure to hunt these animals as a forest management measure.

Soils and Geology

Soils and geology play an important role in stream processes. For instance, sedimentation and P cycling, two processes that strongly influence stream chemistry and habitats, are dependent on soil characteristics such as erodability and organic material content. Regional geology influences the shape and gradient of the stream channel, which in turn influences how the river flows and changes shape over time.

The watershed is underlain by metamorphosed sedimentary and igneous schist and gneiss formations of the Hartland and Gneiss Dome belts, both relatively erosion-resistant formations (Griffith et. al. 2009). Regionally the formations are located within the Connecticut Valley Synclinorium (Griffith et. al. 2009). Soils within the watershed are classified as Hydrologic Soil Group (HSG) A-B, C, or D which represent, in order, good, fair, and poor drainage conditions. The majority of soils are classified as A-B or C, with several areas of locally poor drainage (HSG D).

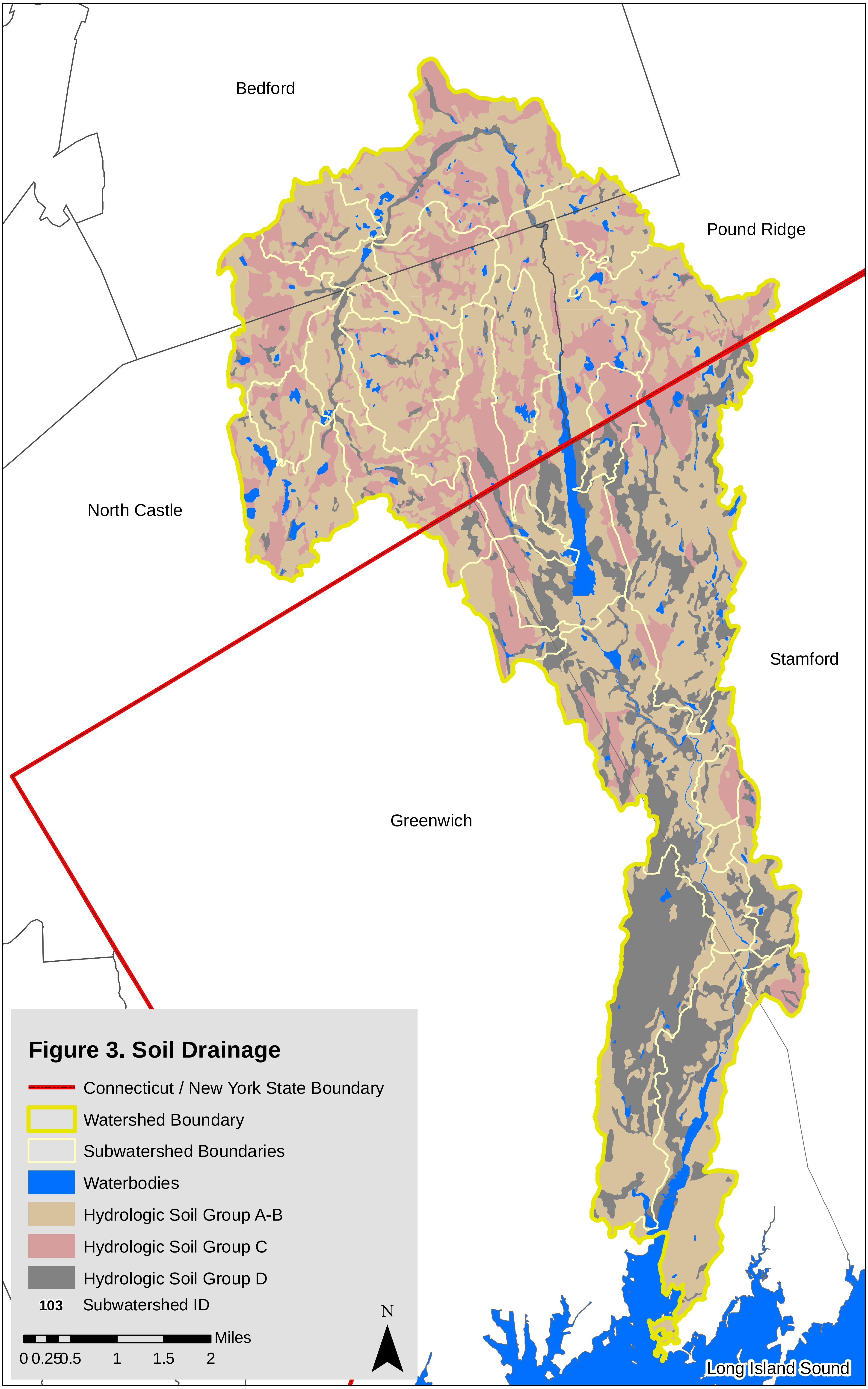
Located along the eastern coastal plain, soils and geology within the Mianus River Watershed are generally representative of the region. Well-drained soils predominate overall, although conditions vary throughout (Table 2, Figure 3). The river follows a fairly low gradient from the low hills of North Castle, then steepens significantly through the Mianus Gorge, a periglacial feature created by blockage and rerouting of streams below the glacial front (USGS Geology of National Parks, 3D and Photographic Tours: accessed 5/23/12).

Table 2. Hydrologic Soil Group Percent of Total Area

Hydrologic Soil Group	Percent of Watershed Area
Groups A and B	55
Group C	22
Group D	19
Water	3

STREAM CONDITION ASSESSMENT

A stream condition assessment was conducted to understand how water quality, habitat quality, and the diversity and composition of aquatic communities vary throughout the



Manipulated soil data provided by SWRPA; Original data obtained from the SSURGO database for the States of Connecticut and New York.

watershed. Understanding the existing condition of streams and rivers within the Mianus River Watershed involved several steps including looking at the overall level of development within the watershed as an indicator of the level of watershed stress, reviewing water quality and biological data from past studies, reviewing the designated uses and problem areas that have been established by CTDEEP through their assessment programs, and conducting visual assessments of the stream channel in representative locations to assess the quality and diversity of aquatic habitats.

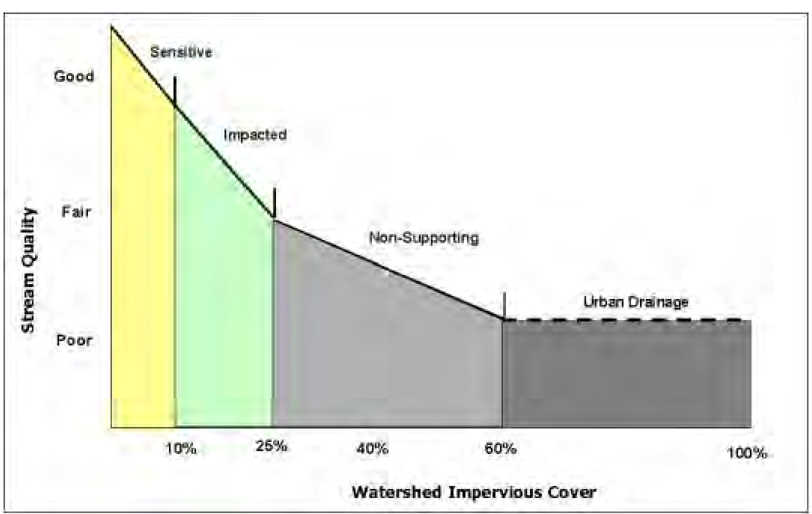
Based on the assessment, most portions of the watershed appear to be in fair to good condition for the support of recreation and aquatic life. Fair stream conditions were generally associated with areas of dense residential and commercial development, while good conditions were associated with reaches draining small, forested areas. Isolated poor conditions were found in Strickland Brook and the Upper Main Stem, and were mainly associated with channel modification and areas of more intense development.

Impervious Cover Analysis

Impervious cover refers to land cover that does not infiltrate rainfall. Parking lots, roads, driveways, roofs, sidewalks, and other impervious areas speed the rate at which water travels over land. This ultimately leads to higher peak flows during storms, and lower rates of groundwater recharge. Stormwater from impervious surfaces tends to carry high concentrations of pollutants, particularly bacteria, nutrients, and sediment.

In mixed-use watersheds, stream condition is often correlated with total impervious cover, which serves as an index of watershed modification and urbanization. Figure 4 describes the Impervious Cover Model (ICM) (CWP 2003), a useful tool for understanding the level of stream impacts associated with development. The ICM establishes "thresholds" of watershed imperviousness beyond which aquatic life is increasingly impacted. At approximately 10 percent impervious, signs of impact are seen in habitat and aquatic communities. At approximately 25 percent impervious, habitat degrades below the minimum needed to support aquatic life. With impervious cover estimated at approximately 12 percent in the Mianus River Watershed, the river is expected to show signs of anthropogenic impacts, while also supporting aquatic life.

Figure 4. Impervious Cover Model



To relate impervious cover to stream conditions, the stream network was divided into a series of 22 second-order reaches, each draining a smaller basin area (referred to here as a "subwatershed"), with the Main Stem confluence serving as the downstream extent (Figure 5). Direct drainage areas to the Main Stem were delineated as one subwatershed, which was then split into segments (subwatersheds 64, 63, 62 and 61). Percent impervious cover was estimated for each subwatershed. Percent impervious cover was also estimated for a 200-foot buffer area surrounding each stream reach. The expected condition of each reach was predicted using an impervious cover score based on the ICM discussed above (

Table 3, Figures 4 and 6). The percent impervious cover for both total subwatershed area and adjacent buffer area for each stream reach were assigned a score based on the following rubric:

- IC < 10 percent = 0
- IC 10–25 percent = 1
- IC > 25 percent = 2

The score for the subwatershed area and adjacent buffer area were summed and categorized according to the following rubric:

- Total score 0 = good
- Total score 1–2 = fair
- Total score 3–4 = poor

Table 3. Impervious Cover Score

	Land cover within subwatershed					Land cover within riparian buffer					
	Land Area (acres)			Land Area Percent		Land Area (acres)			Land Area Percent		
Subwatershed	Total Area	Impervious	Pervious	% IA	%PA	Total Area	Impervious	Pervious	% IA	%PA	Impervious Cover Score
1	364.35	38.51	325.84	11	89	38.77	3.78	34.98	10	90	2
2	472.16	44.02	428.15	9	91	67.37	5.93	61.44	9	91	0
10	778.94	85.71	693.23	11	89	120.61	17.06	103.56	14	86	2
11	818.80	78.05	740.74	10	90	174.63	15.67	158.96	9	91	1
12	109.48	11.97	97.51	11	89	34.68	3.76	30.91	11	89	2
13	680.45	72.52	607.92	11	89	124.20	13.62	110.58	11	89	2
16	796.27	40.56	755.70	5	95	149.85	4.61	145.25	3	97	0
64 (Upper Main Stem)	3167.89	347.08	2820.81	11	89	609.56	59.33	550.22	10	90	2
64 and tributaries	7188.34	718.43	6469.91	10	90	1319.66	123.76	1195.90	9	91	1
3	493.93	34.51	459.42	7	93	121.99	8.24	113.74	7	93	0
4	582.92	32.56	550.36	6	94	180.74	7.52	173.22	4	96	0
5 (Piping Brook)	980.72	75.92	904.80	8	92	202.06	13.89	188.17	7	93	0
17	337.81	32.27	305.54	10	90	77.31	5.76	71.55	7	93	1
63 (Main Stem/Bargh Reservoir)	2357.88	144.70	2213.18	6	94	541.13	20.06	521.07	4	96	0
63 and tributaries	11941.61	1038.40	10903.21	9	91	2442.88	179.23	2263.65	7	93	0
7	408.95	29.24	379.71	7	93	72.90	6.06	66.84	8	92	0
14	215.14	20.45	194.69	10	90	35.86	3.50	32.35	10	90	2
15	87.52	9.63	77.89	11	89	15.29	1.68	13.61	11	89	2
18 (East Branch)	3466.06	392.83	3073.23	11	89	1036.09	108.59	927.50	10	90	2
62 (Below Bargh Reservoir)	2074.01	262.60	1811.41	13	87	581.09	63.97	517.12	11	89	2
62 and tributaries	18193.28	1753.14	16440.13	10	90	4184.11	363.03	3821.07	9	91	1
8	385.76	40.72	345.04	11	89	139.35	14.31	125.04	10	90	2
9	206.32	22.70	183.63	11	89	25.41	2.79	22.61	11	89	2
61 (Lower Main Stem)	1576.58	518.26	1058.33	33	67	185.80	32.83	152.97	18	82	3
61 and tributaries	20361.94	2334.82	18027.12	11	89	4534.67	412.97	4121.70	9	91	1
19 (Strickland Brook)	1807.87	400.61	1407.26	22	78	437.71	67.63	370.08	15	85	2

IA is impervious area
PA is pervious area
Impervious cover scores equate to the following expected stream conditions:
Poor (impervious cover score = 3 or 4)
Fair (impervious cover score = 1 or 2)
Good (impervious cover score = 0)

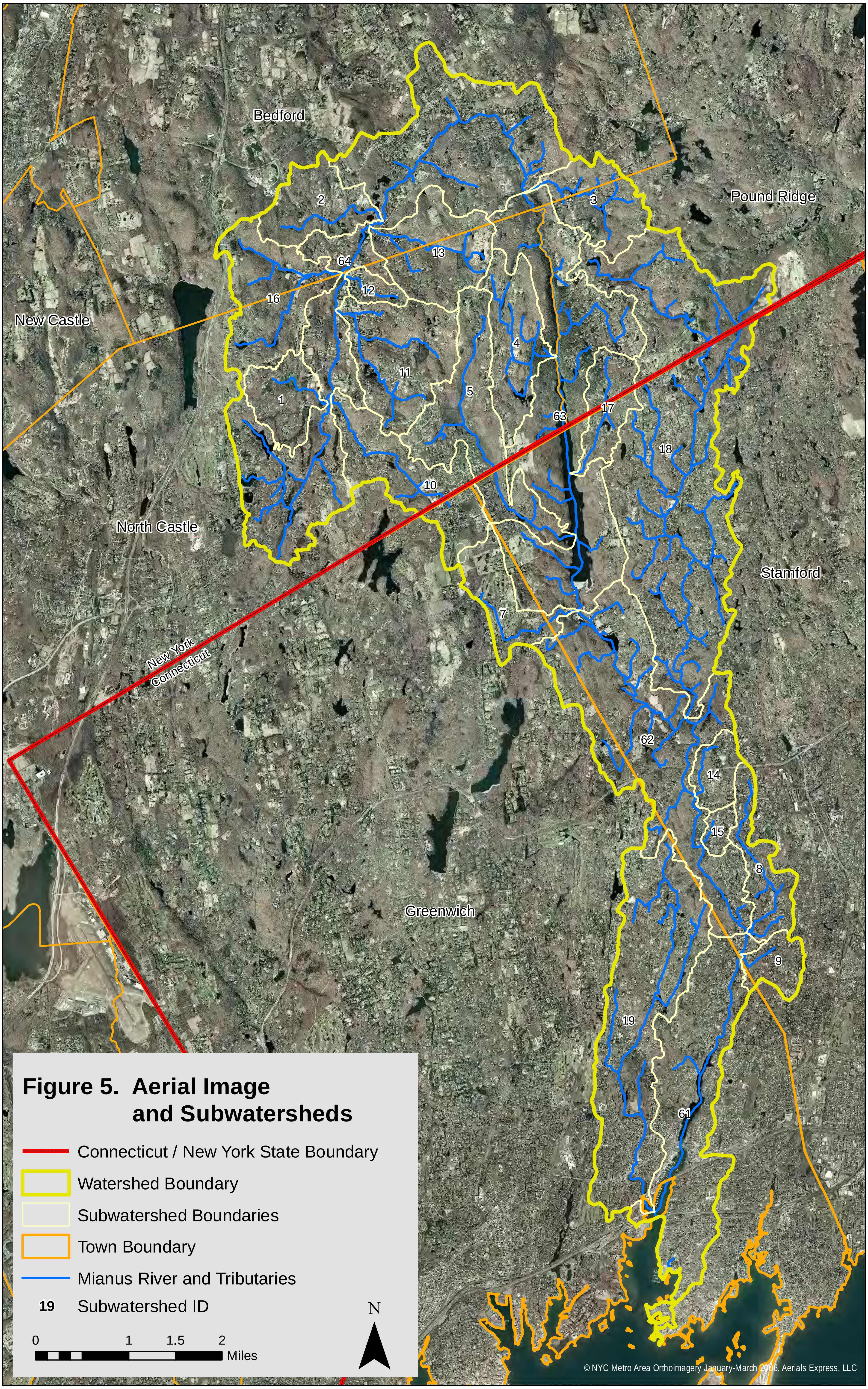


Figure 5. Aerial Image and Subwatersheds

Connecticut / New York State Boundary
Watershed Boundary
Subwatershed Boundaries
Town Boundary
Mianus River and Tributaries
19 Subwatershed ID

0 1 1.5 2 Miles

N

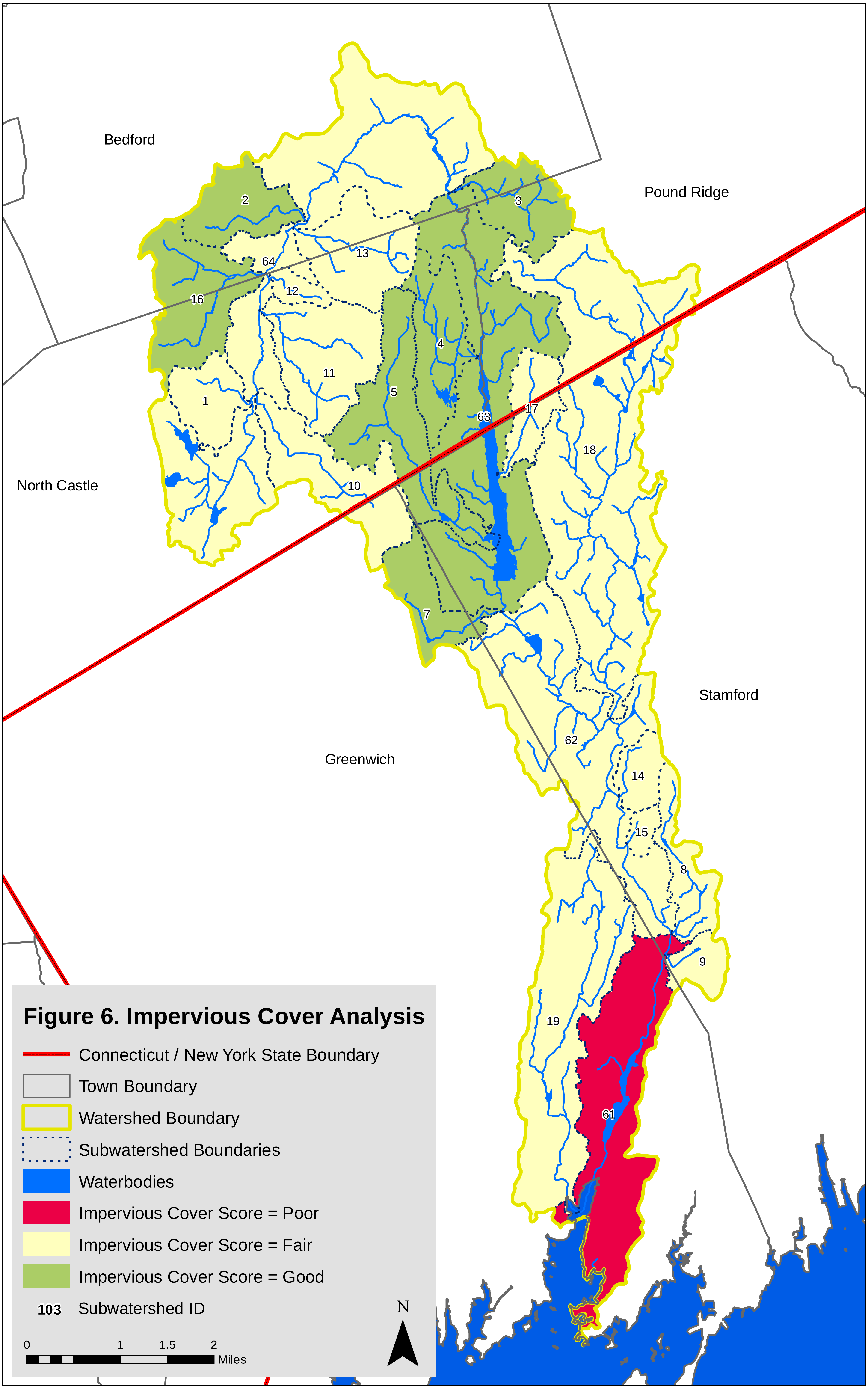


Figure 6. Impervious Cover Analysis

Visual Assessment

Visual assessments were conducted to check the conditions predicted by the ICM against actual conditions. The intention was to observe "areas of friction" where the ICM predictions did not accurately predict the observed condition, and to further investigate these areas to learn more about conditions specific to the Mianus River Watershed. Conditions not addressed by the ICM but which may have influenced the visual assessment include time period since most recent land disturbance, quality of riparian vegetation, and condition and type of pervious surfaces.

On April 15 and 16, 2011 visual assessments were conducted at nine representative locations (Table 4, Figure 7) along the Mianus River to evaluate the quality of in-stream and riparian habitats over a land use gradient (Appendix C). These sample sites were selected based on expected condition following the impervious cover analysis, independent of previous water quality monitoring or assessment locations. Sample locations were selected to include a range of impervious cover score levels, position within the watershed and geographic breadth. Assessments were performed using the Natural Resources Conservation Service (NRCS) Stream Visual Assessment (SVA) Protocol (NRCS 1998). This protocol integrates stream stability, water quality, and habitat into a single numeric score from 1 to 10, where 10 represents the best condition (see Appendix C for scoring criteria and results). The score for each attribute was averaged to generate the reach SVA score.

Table 4. Stream Visual Assessment Score

Sample Location ID	Subwatershed (Headwaters to outlet)	SVA Category*	Impervious Cover Score** in Same Reach as Sample
15	64 (Upper Main Stem)	poor	fair
18	64 (Upper Main Stem)	poor	fair
20	64 (Upper Main Stem)	fair	fair
19	10	fair	fair
14	3	good	good
16	4	fair	good
17	4	good	good
11	62 (Below Bargh Reservoir)	good	fair
12	18 (East Branch)	poor	fair
13	18 (East Branch)	fair	fair
10	19 (Strickland Brook)	poor	fair

***SVA categories equate to the following SVA scores:**
≤6.0 = Poor
6.1-7.4 = Fair
7.5-8.9 = Good
≥9.0 = Excellent
****Impervious cover scores equate to the following expected stream conditions:**
Poor (impervious cover score = 3 or 4)
Fair (impervious cover score = 1 or 2)
Good (impervious cover score = 0)

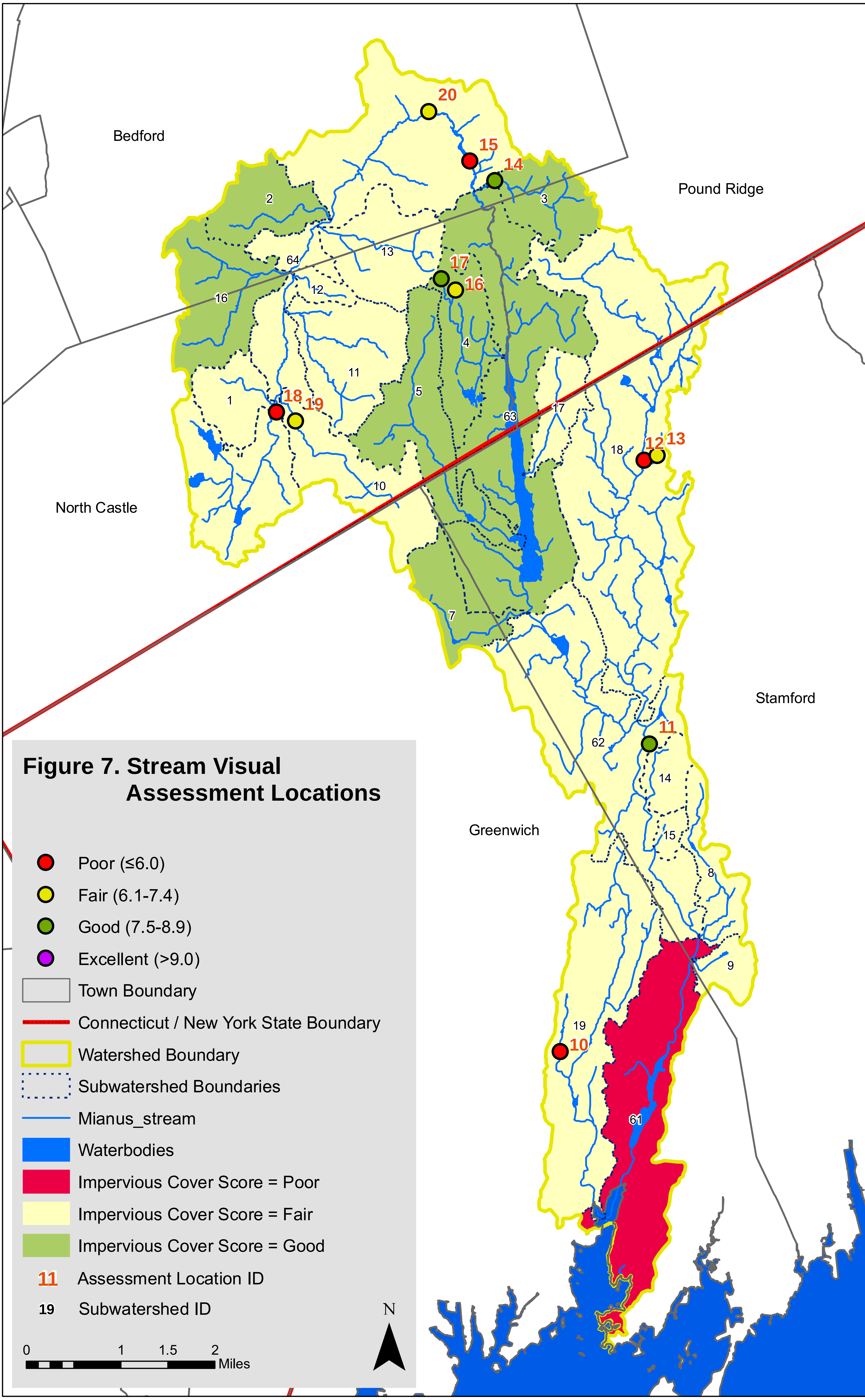


Figure 7. Stream Visual Assessment Locations
Poor (≤6.0)
Fair (6.1-7.4)
Good (7.5-8.9)
Excellent (>9.0)
Town Boundary
Connecticut / New York State Boundary
Watershed Boundary
Subwatershed Boundaries
Mianus_stream
Waterbodies
Impervious Cover Score = Poor
Impervious Cover Score = Fair
Impervious Cover Score = Good
11 Assessment Location ID
19 Subwatershed ID
0 1 1.5 2 Miles
N
Bedford
Pound Ridge
North Castle
Stamford
Greenwich

Aquatic Biota Analysis

Aquatic species exhibit a range of tolerance to pollution. Species with the lowest tolerance tend to be found only in the highest-quality streams, while species with higher tolerance are more widespread across a varied range of stream conditions. Typically, macroinvertebrates and fish are used as indicator species to predict water quality and habitat condition.

For the purpose of this analysis, sampling data for fish and macroinvertebrate species were provided by CTDEEP. Simple metrics of pollution tolerance were applied to generate an expected aquatic biota support score for each sample location (Roth et Al., 2000; Barbour et al., 1999; Hilsenhoff 1982). For fish and macroinvertebrate metrics, categories were assigned as "supporting," "impaired," or "severely impaired" (Table 5, Figure 8):

- Score 0.0–5.0 = supporting
- Score 5.1–6.9 = impaired
- Score 7.0–10.0 = severely impaired

Table 5. Stream Capacity to Support Biota

Sample Location ID*	Subwatershed	Fish Score**	Biotic Support Category	Macroinvertebrate Score**	Biotic Support Category
5181	18 (East Branch)	5.0	**Supporting**	-	-
168	62 (Below Bargh Rerervoir)	3.5	**Supporting**	3.0	**Supporting**

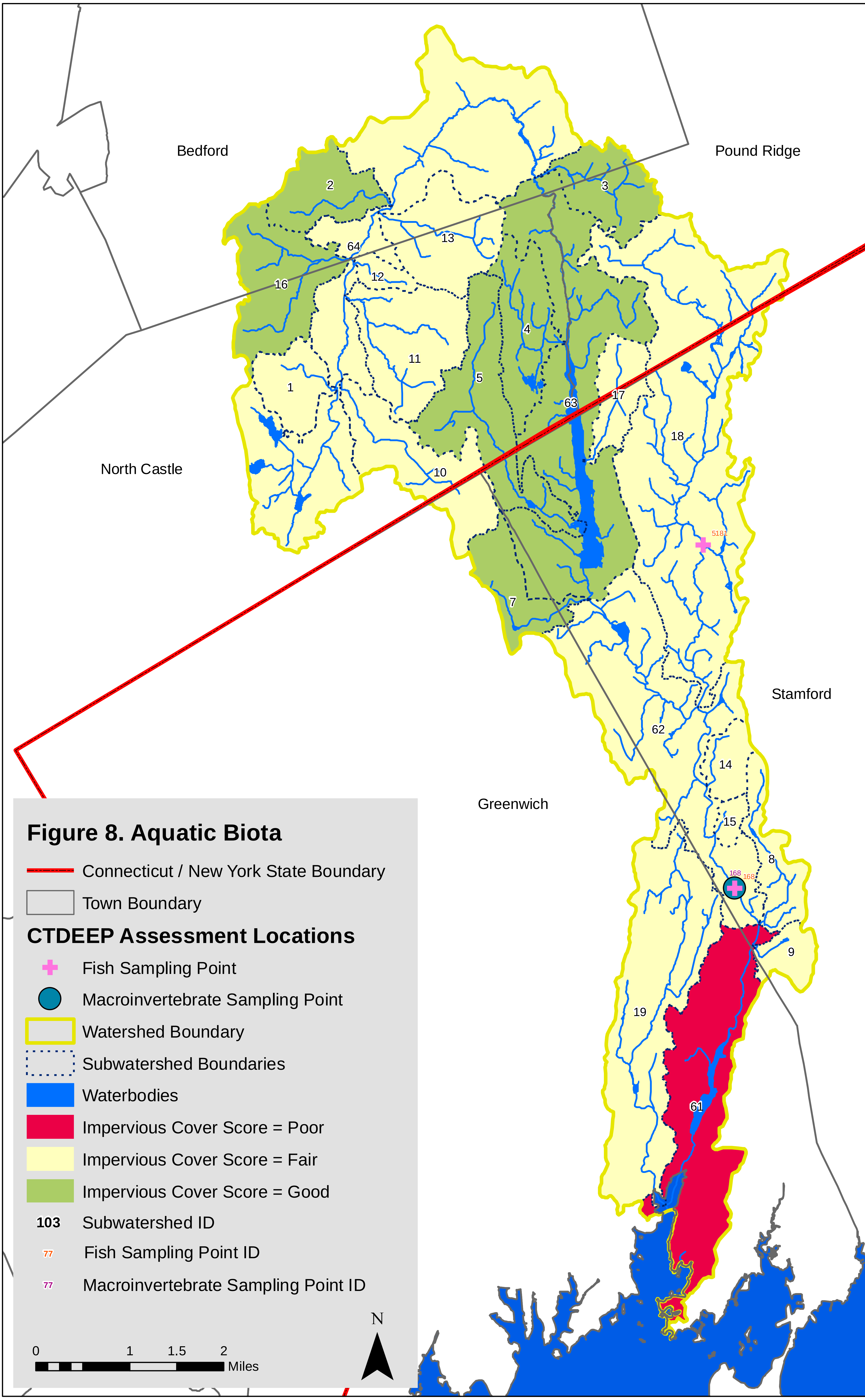
The fish and invertebrate scores equate to the following biotic support categories:
Score 7.0 - 10.0 = severely impaired
Score 5.1 - 6.9 = impaired
Score 0.0 - 5.0 = supporting
***CTDEEP biotic assessment sample locations**
****Scores were derived from CTDEEP biotic assessments**

STREAM CONDITION ASSESSMENT SUMMARY

The stream condition assessment included analyses of impervious cover, assessment of biological monitoring data, and field reconnaissance of aquatic habitat conditions. Results of this analysis reveal a river that has been somewhat impacted by urbanization but where high-quality habitat and reasonably healthy aquatic communities persist in many areas. Conditions in the watershed generally range from good to poor across a land-use gradient, with areas in good condition generally associated with well-established riparian buffers and undeveloped floodplains.

Based on the impervious cover analysis, Mianus River conditions were predicted to range from good to fair, with the majority of good conditions predicted in the reaches draining parts of the Mianus River Gorge Preserve (Table 3, Figure 6). Strickland Brook, the East Branch, and the Upper and Main Stem were predicted to have fair conditions based on the impervious cover analysis. The Lower Main Stem was the only subwatershed predicted to be in poor condition.

Visual assessment generally corroborated predictions of the impervious cover analysis, although some reaches were found to be in better or worse condition than expected (Table 4, Figure 7). As predicted, good conditions were observed in the reaches adjacent to and directly


Bedford
Pound Ridge
North Castle
Stamford
Greenwich
2
3
64
13
16
12
4
11
5
1
63
17
18
10
5181
7
62
14
15
8
168
168
9
19
61
Figure 8. Aquatic Biota
Connecticut / New York State Boundary
Town Boundary
CTDEEP Assessment Locations
Fish Sampling Point
Macroinvertebrate Sampling Point
Watershed Boundary
Subwatershed Boundaries
Waterbodies
Impervious Cover Score = Poor
Impervious Cover Score = Fair
Impervious Cover Score = Good
103 Subwatershed ID
77 Fish Sampling Point ID
77 Macroinvertebrate Sampling Point ID
0
1
1.5
2
Miles
N

north of the Mianus River Gorge Preserve. Observed conditions were better than predicted by the impervious cover analysis in subwatershed 62 (site 11) along the Main Stem. Channel characteristics may make the river more resistant to instability at this location.

Reaches in Strickland Brook, the East Branch, and the Upper Main Stem were in worse condition than predicted. The comparison of visual assessment and impervious cover analysis results in these locations suggest that in-stream conditions in the Mianus River Watershed are strongly influenced by both watershed-scale conditions (i.e., levels of overall imperviousness) and local-scale conditions such as poor riparian buffers and dams. In particular, large tracts of open space within these subwatersheds may have slightly improved the overall impervious cover score, although levels of development might be quite high in some areas. These local-scale conditions often resulted in stream conditions that were in worse condition than predicted by the ICM.

Local conditions responsible for poorer-than-expected conditions included dams, poor riparian buffers, channelization, and streamside development. Dams were often associated with shallow, stagnant pools, and were observed in all locations where conditions were more impaired than expected (visual assessment sites 10, 12, 15, 16, and 18). Also, recent ridge-crest developments coupled with steep valley walls likely contributed to the formation of gullies within some protected areas (e.g., Mianus River Gorge Preserve, etc.). Downstream of the Mianus River Gorge Preserve, multiple areas of channelization were observed on residential properties where the stream flowed through private backyards. In subwatershed 19, sample site 10 is located on an unstable reach of a small tributary to Strickland Brook where the stream is abutted by residential lawns and flows in culverts under driveways. In subwatershed 18, site 12 is located downstream of the Rockrimmon Golf Course, where an algae-rich pond and unstable banks were observed. In subwatershed 64, site 15 is located along the Main Stem just downstream of Miller's Mill. Degradation of this reach is likely due to the presence of a large dam; conditions within the upstream impoundment; and sediment delivery from adjacent roads and gullied tributaries. In subwatershed 4, conditions at site 16 were likely due to its location directly downstream of a low-head dam, in contrast to nearby site 17 which was not impounded and was in good condition. In subwatershed 64, site 18 is located below the Windmill Lakes development, where multiple instances of serious erosion in drainage ditches and first-order streams were observed.

POLLUTANT LOADING ANALYSIS

The reduction of NPS pollutants is a central aspect of the watershed based planning process. Before pollution reduction strategies can be considered, however, an understanding of the quantity of NPS pollutants entering various steams within the watershed is needed. It is important to distinguish loading, which is a quantity of pollutant transported per unit time, from concentration, which is a quantity of pollutant per volume of water.

There are a few methods for estimating pollutant loading (i.e., the amount of pollutants entering the stream). Generally, these methods fall into two categories, computer simulation and direct measurements. Given the difficulty and expense of directly measuring pollutants, the Plan team decided to use computer simulation to estimate the quality of pollutants being introduced to the Mianus River and its tributaries. Direct measurements of pollutant loading may be conducted later in the implementation process to verify the loading estimates developed here (see the discussion of wet-weather monitoring in Chapter 9).

A number of computer models have been developed to predict pollutant loading from urban watersheds. These models range from very simple spreadsheet models to very complex, physically based models that require extensive data collection and calibration. For this project, WinSLAMM was chosen. It is a model that has been specifically developed to predict NPS pollutant loading from urban areas. WinSLAMM provides a good balance between ease-of-use and technical complexity. It is not a physically based model in that it does not directly simulate the processes that generate and transport pollution through landscapes. Rather, WinSLAMM bases its estimates of pollutant loading on estimates of pollutant concentrations (the quantity of pollution in a given volume of water) associated with urban stormwater runoff from various types of common urban surfaces including rooftops, various types of roadways, parking areas, and open spaces as well as various soil types. The source of these estimates comes from a series of nationwide studies of urban runoff.

In Chapter 3, the existing pollutant load estimate will be compared with pollutant load estimates for the Mianus River Watershed assuming urban development had not occurred (i.e., the entire watershed was forested). This comparison will be used to develop estimates of the required reductions in pollutant loads required to fully restore the watershed to pre-developed conditions. The remainder of this section provides an overview of the common NPS pollutants for which load estimates were developed, provides details on the development of the pollutant load model, and summarizes the results of the pollutant load analysis.

Common Types of Nonpoint Source Pollution

NPS pollution is a general term that includes a wide variety of substances such as sediment, nutrients such as N and P, pesticides, heavy metals, oils and grease, trash, and bacteria. Of these, sediment, N, P, and bacteria are considered the most important NPS pollution parameters. WinSLAMM can simulate loading for each of these pollutants by estimating N modeling as nitrate (NO_3), P as particulate P (the portion of P that is associated with sediment particles), and using Total Suspended Solids (TSS) as an indicator of sediment loading. Finally, WinSLAMM uses fecal coliform as an indicator of pathogenic bacteria loading. The following sections provide a general overview of common NPS pollutants and their sources.

Nitrogen

N is found in streams in several forms and is essential for the growth of aquatic plant life such as algae. N is present in a variety of forms. Inorganic forms of N are those forms of N not incorporated into living or once living materials, such as leaves. Most inorganic forms of N are readily dissolved in the water column and are taken up by aquatic plants to support their growth. When plants and animals die and decompose, organic forms of N are eventually reconverted back into inorganic forms.

While N is vital to stream life, elevated levels can cause an overabundance of aquatic vegetation. As this vegetation decomposes, oxygen dissolved in the stream water is rapidly used. In severe conditions, the process of decomposition can completely use up the dissolved oxygen, resulting in fish kills. Human sources of N include urban stormwater runoff, where animal waste and fertilizers are washed into the stream; septic systems; wastewater treatment facilities; and industrial facilities.

Phosphorus

Like N, P is essential for the growth of aquatic plants and is present in streams in a variety of forms. However, unlike N, P is strongly bound to sediment particles. While the majority of P is "stuck" to sediment particles, some of it is also dissolved in the water column. This form of P is the most easily used by aquatic plants. In certain situations, aquatic plants can also directly use P that is bound to sediment particles.

P is the factor that most commonly limits the growth of aquatic plants, such as algae, in streams. In undeveloped areas, levels of P in streams are very low, as any P delivered to the stream is quickly taken up by aquatic plants. Therefore, increases in P loading to streams can result in rapid increases in plant growth. As these plants decompose, oxygen dissolved in the stream water is rapidly used. In severe conditions, the process of decomposition can completely use up the dissolved oxygen, resulting in fish kills. Human sources of P include overland flow from urban and suburban areas where animal waste and fertilizers are washed into the stream as well as inputs from wastewater treatment and industrial facilities. Channel erosion and loose soil washed from disturbed area can also be a major source of P within streams.

Total Suspended Solids

Sediment particles, measured as TSS, wash into streams through surface and channel erosion, road runoff, and stormwater carrying loose soil from disturbed sites. Fine particles of organic material, including soil, partially decomposed plant matter, algae and other bits of debris become suspended in the water column along with fine sediment. High levels of TSS can cloud the water column, clog fish gills, cover spawning habitat, and decrease light available for photosynthesis. Particles may retain heat, leading to elevated water temperature and lowered levels of dissolved oxygen. Human sources of sediment include erosion from construction activities, wastewater and industrial effluent, tilled agricultural soils, sand spread on roadways, and sediment carried in stormwater runoff.

Bacteria

Many different species of bacteria are carried into surface waters from developed and undeveloped areas. Most inputs are carried by overland flow during storm events, which wash bacteria off the land area and into the stream. Waste from pets and resident geese populations, local wildlife, and improperly functioning septic systems are all potential sources of bacteria. Concentrations of bacteria in the waterway may vary dramatically, but are usually highest after a rain event. Elevated levels of bacteria are often related to wet-weather runoff from developed areas.

Fecal coliform was used as the modeling parameter to indicate total levels of bacteria based on constraints of the WinSLAMM model. However, in Connecticut *Escherichia coli* (*E. coli*) is used as the indicator species for pathogenic bacteria, viruses, and protozoans in freshwater streams, and as criteria for state water quality standards for fresh water. *E. coli* is a type of fecal coliform bacteria commonly found in the digestive tracts of warm-blooded animals. *E. coli* and fecal coliform levels are very closely correlated, with *E. coli* generally following the same concentration patterns as fecal coliform, but at slightly lower levels.

Modeling Methods

Pollutant loading was modeled for the Mianus River Watershed using WinSLAMM, which estimates pollutant loading from urban lands using an extensive database of field data collected during the National Urban Runoff Program (NURP) study, a nationwide study that measured the pollutant concentrations in stormwater runoff from various types of common urban surfaces across a number of U.S. cities. Briefly, WinSLAMM models pollutant loads for individual stormwater events for specific source areas (areas that have similar soil types and land cover), applying NURP pollutant concentrations to different types of land cover based on the NURP study results. The pollutant concentrations are multiplied by the total volume of runoff, which WinSLAMM estimates based on precipitation data to calculate the total quantity, or load, of each modeled pollutant. Loads from individual storm events are then summed to compute annual loads.

It is important to note that WinSLAMM does not model sediment and nutrient loading from stream banks and septic systems; hence, loading from these features is not included in results. Ideally, simulation models are calibrated using field data. However, for this study locally collected hydrology or pollutant data were not available for calibration.

Data Acquisition and Processing

The following data sources were obtained and used in the WinSLAMM model to estimate pollutant loading:

- Rainfall dates, duration, and accumulation—these data were obtained for the years 2002 to 2010 from the Bridgeport Sikorsky Station, located in Fairfield County Connecticut (41.15833, -73.12889), provided through the National Oceanic and Atmospheric Administration (NOAA);
- Soil data—these data were obtained from the Soil Survey Geographic (SSURGO) database for the State of Connecticut);
- Land use data—these data were provided by SWRPA based on a composite of local land use, zoning, and opens space data and the University of Connecticut (UConn) Center for Land Use Education & Research (CLEAR) 2006 Connecticut Land Cover Data;
- Runoff coefficients for source areas—provided through WinSLAMM;
- Particle sizes—provided through WinSLAMM;
- Particulate solids concentrations for source areas and land uses—provided through WinSLAMM;
- Particulate residue reduction for curb and gutter delivery systems—provided through WinSLAMM; and
- Pollutant probability distribution data for source areas and land uses—provided through WinSLAMM.

In many cases the raw data obtained for the study had to be modified before it could be used in the WinSLAMM model. Generally, this involved regrouping or reclassifying land use and soils data to conform to the land use and soil categories used by WinSLAMM.

Soil Data Processing

The SSURGO data set used for the study is a digital soil survey and is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. WinSLAMM cannot use these data directly. Instead, the soil data obtained from the SSURGO database was reclassified to match the input categories used by WinSLAMM based on the soil texture field in the SSURGO dataset.

WinSLAMM requires that soils be assigned to one of the four HSGs, which reference the ease with which water infiltrates a particular soil type:

- HSG A: Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist of deep, well drained to excessively drained sands or gravelly sands.

These soils have a high rate of water transmission, and are composed of less than 10 percent clays and more than 90 percent sand or gravel.

- HSG B: Soils having a moderate infiltration rate when thoroughly wet. These consist of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission and are composed of 10–20 percent clay and 50–90 percent sand.
- HSG C: Soils having a slow infiltration rate when thoroughly wet. These consist of soils with a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission, and are composed of 20–40 percent clay and less than 50 percent sand.
- HSG D: Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, hydric soils, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission and are composed of at least 40 percent clay and less than 50 percent sand.

Land Use Data Processing

As with soil data, the land use data obtained for the modeling effort had to be reclassified to match the input categories used by WinSLAMM. Land use data were assigned WinSLAMM input categories (residential, other urban, commercial, industrial, highway, and institutional). The residential, other urban, and highway categories were found to oversimplify land use within each subwatershed, and were broken out into additional subcategories. For open space, subcategories included undeveloped open space, parks and other "moderately" developed open space, and "fully developed open space" characterized by large areas of managed turf. Residential areas were divided into subcategories for rural, large-lot suburban, small-lot suburban, and urban development patterns. Highway areas were distinguished by characteristic features for either the Merritt Parkway or I-95.

WinSLAMM requires the land use sub-categories to be further broken down into source areas. To determine the percent of different runoff and pollutant source areas (e.g., roof, landscaped, street, undeveloped, etc.) for each land use sub-category, representative samples (0.25-mile area) within each land use sub-category were measured using aerial imagery obtained from Microsoft Bing Maps Aerial (ca. 2007). WinSLAMM also requires the user to specify certain land use characteristics. Land use characteristics (e.g., disconnection of roof leaders, density of housing, roadside swale frequency, etc.) were assigned by examining the aerial imagery and Google Maps street view (photo years vary, typically 2007–2010). A drive-through survey of the watershed was conducted April 15 and 16, 2011 to verify existing conditions and collect data on roadside conveyance systems and local storm sewer drainage.

POLLUTION LOADING MODELING RESULTS

The WinSLAMM model computed average annual loading for each of the four pollutants chosen for the study. The model results are provided in Table 6 and are presented as average annual loads and average unit area annual loads for each subwatershed (lb/yr and lb/ac/yr for particulate P, NO_3, and TSS; billion colony-forming units (cfu)/yr and billion cfu/ac/yr for indicator bacteria). Annual loads represent the total amount of pollution per year at the outlet of the subwatershed. Unit area loads represent the total annual output divided by the total acreage of the subwatershed, which allows easier comparison among subwatersheds of varying size.

Annual TSS, particulate P, and NO_3 loading in the Mianus River Watershed averaged approximately 12 million, 57,000, and 124,000 lb/yr, respectively. TSS unit area loading varied considerably among subwatersheds, ranging from 235 lb/ac/yr in subwatershed 4 to 967 lb/ac/yr in subwatershed 19 (Strickland Brook). Unit area loading for particulate P also varied significantly among subwatersheds, ranging from a minimum of 0.8 lb/ac/yr in subwatershed 4 to a maximum of 4.6 lb/ac/yr in subwatersheds 9 and 19 (Strickland Brook). NO_3 unit area loads were more variable among subwatersheds than either particulate P or TSS, ranging from 0.6 lb/ac/yr in subwatersheds 3 and 4 to 17.5 lb/ac/yr in subwatershed 19. The river generated an average annual loading of approximately 5,954,000 billion cfu of indicator bacteria. Unit area loading ranged significantly among subwatersheds, from 99 billion cfu in subwatershed 4 to 681 billion cfu in subwatershed 19.

The wide variations in unit area loading among subwatersheds are due to several factors internal to the WinSLAMM modeling process, including land use and soil type. For instance, poorly drained soils are often associated with higher particulate P and TSS loading, and areas with a high percentage of impervious cover are associated with high levels of bacteria, NO_3, particulate P, and TSS. Other factors which contribute to the variance in pollutant loading include how stormwater is handled or treated, the number and size of ditches and swales, if houses and buildings are directly connected to storm sewers, and the presence and condition of riparian buffers.

USE DESIGNATIONS AND IMPAIRMENTS

Use designations are used by CTDEEP to classify streams according to their highest function within the community. Depending on their size, condition, and location, streams may be designated for fish or shellfish consumption, recreation, drinking water, habitat, or agriculture, among other uses. Section 303(d) of the Clean Water Act (CWA) requires states to compile an Impaired Waters List (IWL) to direct management actions toward waters not meeting their designated use.

To understand the river from a regulatory perspective, state water quality designations and sampling were reviewed as part of the existing conditions assessment. Uses designated for the Mianus River are presented in Figure 9. Use designations for freshwater streams in Connecticut are listed below. Only classes AA, A, and SA are found in the Mianus River system:

- AA: Existing or proposed drinking water supplies; habitat for fish and other aquatic life and wildlife; recreation; and water supply for industry and agriculture.
- A: Habitat for fish and other aquatic life and wildlife; potential drinking water supplies; recreation; navigation; and water supply for industry and agriculture.
- B: Habitat for fish and other aquatic life and wildlife; recreation; navigation; and industrial and agricultural water supply.

- SA: Habitat for marine fish, other aquatic life and wildlife; shellfish harvesting for direct human consumption; recreation; industrial water supply; and navigation.
- SB: Habitat for marine fish, other aquatic life and wildlife; commercial shellfish harvesting; recreation; industrial water supply; and navigation.

Table 6. Pollutant Loading Analysis Results

Subwatershed (Headwaters to outlet)	Area (ac)	Avg TSS Load (lb/yr)	Avg TSS Load (lb/ac/yr)	Avg Particulate P Load (lb/yr)	Avg Particulate P Load (lb/ac/yr)	Avg NO_3 Load (lb/yr)	Avg NO_3 Load (lb/ac/yr)	Avg Indicator Bacteria Load (billion cfu/yr)	Avg Indicator Bacteria Load (billion cfu/ac/yr)
64 (Upper Main Stem)	2363.4	1,817,638	769	9,632	4.1	5,346	2.3	536,038	227
1	364.4	107,891	296	635	1.7	462	1.3	39,547	109
10	778.9	422,097	542	2,003	2.6	1,546	2.0	131,384	169
11	818.8	287,357	351	1,210	1.5	972	1.2	90,334	110
12	109.5	33,970	310	185	1.7	129	1.2	14,582	133
16	796.3	482,943	606	930	1.2	1,074	1.3	113,138	142
13	680.4	228,971	337	1,300	1.9	907	1.3	78,699	116
2	472.2	185,908	394	671	1.4	543	1.1	55,442	117
3	493.9	116,990	237	491	1.0	314	0.6	54,893	111
63 (Main Stem/Bargh Reservoir)	2074	989,600	477	4,494	2.2	2,804	1.4	254,415	123
4	582.9	137,268	235	484	0.8	355	0.6	57,780	99
17	337.8	229,833	680	1,322	3.9	755	2.2	61,492	182
5 (Piping Brook)	980.7	703,860	718	2,926	3.0	1,492	1.5	178,759	182
7	409	344,515	842	1,297	3.2	750	1.8	79,248	194
62 (Below Bargh Reservoir)	1576.6	1,479,094	938	6,237	4.0	22,908	14.5	838,305	532
18 (East Branch)	3466.1	1,255,906	362	6,899	2.0	13,005	3.8	636,277	184
14	215.1	145,416	676	618	2.9	442	2.1	40,358	188
15	87.5	23,168	265	136	1.6	94	1.1	9,190	105
8	385.8	307,209	796	1,614	4.2	940	2.4	78,568	204
61 (Lower Main Stem)	3162.4	909,405	288	4,866	1.5	36,479	11.5	1,332,936	421
9	206.3	159,344	772	947	4.6	527	2.6	42,053	204
19 (Strickland Brook)	1807.9	1,749,012	967	8,328	4.6	31,700	17.5	1,230,310	681
Mianus Watershed:	**22,169**	**12,117,395**	**547**	**57,225**	**2.6**	**123,544**	**5.6**	**5,953,748**	**269**

Most reaches in the Mianus River Watershed are designated Class AA streams (Figure 9), and as such are held to the strictest water quality standards. Strickland Brook is designated as a Class A stream. The Mianus River estuary is designated a Class SA waterbody, which means that human consumption of shellfish is permitted.

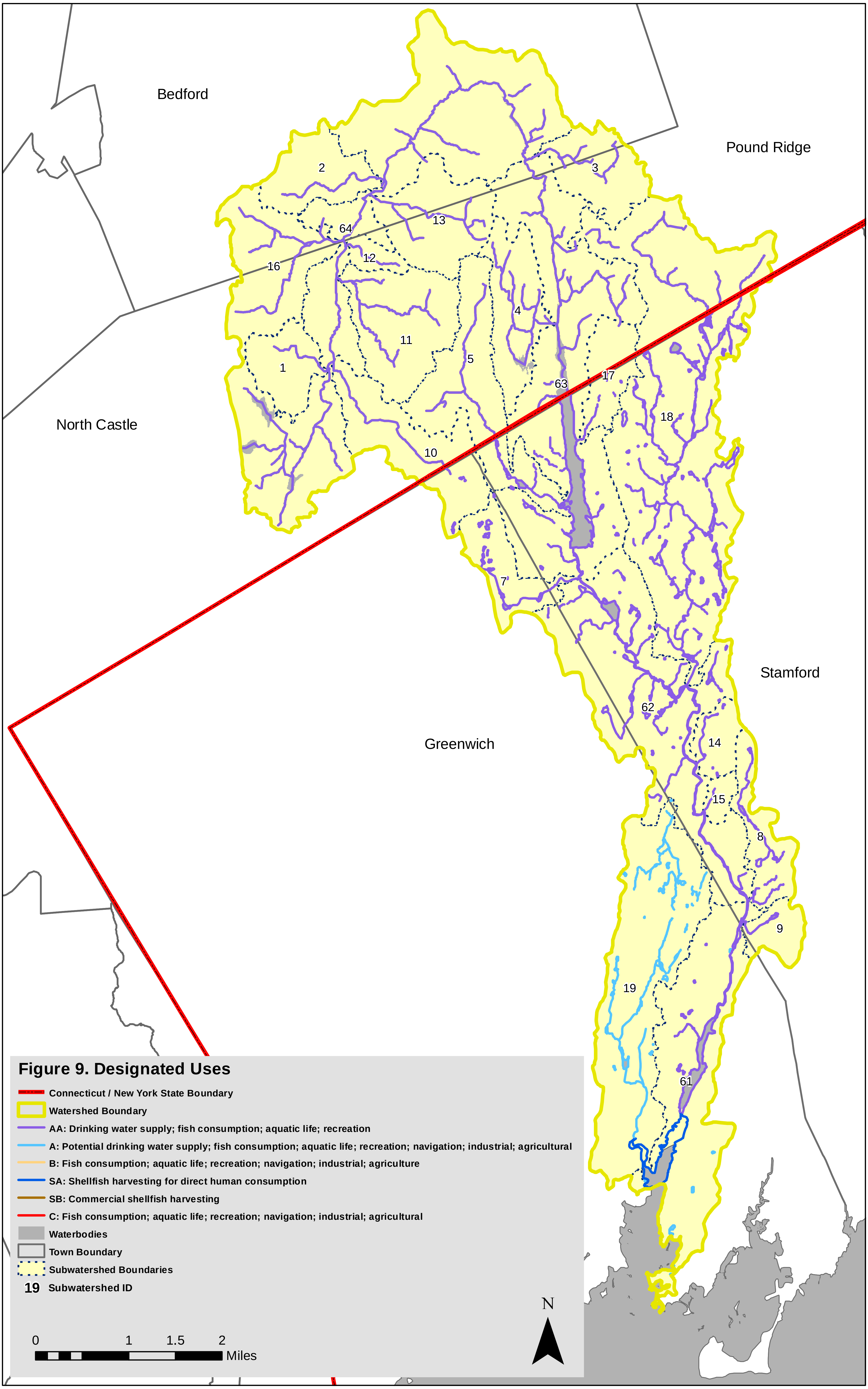
These use designations are associated with a series of quantitative and qualitative standards that define maximum concentrations for various pollutants above which a waterbody is no longer considered to meet its designated use. A waterbody that is found to fail minimum quality standards for its designated use is placed on the Connecticut IWL. In the Mianus River Watershed, no segments have been identified as failing water quality standards.

Use Attainment/Need for Further Investigation

Per CTDEEP policy, a stream reach is assumed to “attain” its designated use until sampling proves otherwise. A portion of a stream cannot be listed as “impaired” for its designated use until sufficient data have been collected to support this conclusion. Since sampling in the Mianus River Watershed has been limited, it is impossible to know with certainty where additional state-defined water quality impairments may exist. However, based on the existing conditions assessment presented in this chapter, it is possible to suggest problem areas where impairments are likely to be found. Throughout this document, the term “impairment” is used generally to refer to areas expected not to meet state standards.

During field reconnaissance, several sampling locations were found where conditions would likely support a 303(d) listing. For instance, the SVA analysis indicated poor or fair conditions in seven locations on Class AA designated streams, and in one location on the Class A designated Strickland Brook. Assessments in these areas indicate that habitat and water quality may be impaired for aquatic life and recreation and warrant further investigation.

As noted in the impervious cover analysis, SVA scores were commonly associated with predicted impervious cover scores based on existing land use conditions. Since field observations of tributary streams were similar to or worse than the predicted conditions based on impervious score, all tributary streams located in subwatersheds with fair impervious cover scores (subwatersheds 1, 8, 9, 10,11, 12, 13, 14, 15, 17) warrant further investigation to determine if impairments are present.


Bedford
Pound Ridge
North Castle
Stamford
Greenwich
2
3
64
13
12
16
4
11
5
1
63
17
18
10
7
62
14
15
8
9
19
61
Figure 9. Designated Uses
Connecticut / New York State Boundary
Watershed Boundary
AA: Drinking water supply; fish consumption; aquatic life; recreation
A: Potential drinking water supply; fish consumption; aquatic life; recreation; navigation; industrial; agricultural
B: Fish consumption; aquatic life; recreation; navigation; industrial; agriculture
SA: Shellfish harvesting for direct human consumption
SB: Commercial shellfish harvesting
C: Fish consumption; aquatic life; recreation; navigation; industrial; agricultural
Waterbodies
Town Boundary
Subwatershed Boundaries
19 Subwatershed ID
0
1
1.5
2
Miles
N

As discussed in Chapter 1, the intent of the watershed based planning process is to reduce NPS pollution. In Chapter 2, results of computer simulations estimating the average annual loads of four key NPS pollutants were presented. These loads represent a best estimate of the current pollutant delivery to the Mianus River and its tributaries. A key question moving forward is "how much do pollutant loads need to be reduced?"

There are many ways to approach the issue of pollutant load reduction. Ideally, the question of load reduction would be answered by first determining the maximum in-stream concentrations of various pollutants that would allow the stream system to provide the full spectrum of uses and values articulated in Chapter 4. The required load reduction would then be the one that lowers the pollutant concentrations from their current levels to acceptable levels. Using this approach, however, requires in-stream monitoring data that currently do not exist for the Mianus River. In addition, this approach requires the use of a standard for the acceptable maximum pollutant concentrations for each segment of the Mianus River and its tributaries. State numeric standards have not yet been established for N, P, or TSS concentrations. And although numeric standards exist for indicator bacteria, sampling data is insufficient to characterize in-stream concentrations of indicator bacteria throughout the Mianus River and its tributaries.

An alternative and more feasible method to determine pollutant load reduction targets is to estimate the pollutant loading in the Mianus River for its undeveloped condition. This method assumes that the entire watershed consists of forest cover, and computes the load reduction targets as the difference between the current loading and the loading associated with an undeveloped condition. With this information, it is possible to determine the amount of total pollutant load that is the result of human activity in the watershed.

The following section establishes pollution reduction targets for the Mianus River using the reference condition approach described above. It is useful to think of these estimates as maximum load reduction targets. In reality, it will not be possible to eliminate all pollutant sources that derive from human activity. Given that streams can absorb some level of additional pollutant loading and still provide the full spectrum of uses and values articulated in the Plan, a 100 percent reduction in development-related pollutant loads is most likely not needed to fully restore the Mianus River and meet the Plan's goals. Therefore, the Plan establishes an interim, working goal of eliminating 60 percent of the development-related pollutant load.

MODELING METHODS

Pollutant load reduction targets were developed for TSS, particulate P, NO_3, and indicator bacteria using WinSLAMM. Predevelopment conditions were modeled using a method similar to that used to develop existing conditions models (methods and results described in Chapter 2); here, however, the models assume that land use within the watershed is 100 percent forested. As described in the introduction to this chapter, the predevelopment load was subtracted from the existing conditions load to determine the total target pollutant load reduction for each subwatershed for each pollutant. The target was set to zero if the predevelopment load was greater than the existing conditions load (discussion of results follows). In the following tables, total and interim targets are presented.

Model inputs

Inputs to the predevelopment model were similar to those used to model existing conditions, and included rainfall, soils, land use, and subwatershed delineation data. The predevelopment model differed from the existing conditions model only in that land use for each subwatershed in the predevelopment model was defined entirely as "undeveloped land." Because land use in each predevelopment model was designated 100 percent "undeveloped," the model contained up to three source areas corresponding to three soil texture types classified according to the HSG.

As noted above, the Plan acknowledges that total targets, which reduce pollutant loads to undeveloped conditions, may not be feasible in the short term. Interim pollutant load reduction targets of 60 percent of the total target were calculated to provide a realistic milestone. This number represents a typical load reduction rate for management measures as accepted by CTDEEP.

MODEL RESULTS

Total annual pollutant load reduction targets for the watershed call for a 9,304 lb/yr reduction in TSS (Table 7), a 998 lb/yr reduction in particulate P (Table 8), a 100,931 lb/yr reduction in NO_3 (Table 9), and a 3,550,136 billion cfu/yr reduction in indicator bacteria (Table 10). Since the load reductions reflect a return to baseline pollutant loading, achievement of these targets is expected to meet and exceed state standards for in-stream habitat and pollutant concentrations. Interim targets representing 60 percent of the total target are presented alongside total targets in Tables 7, 8, 9, 10, and 11.

All subwatersheds contribute NO_3 and indicator bacteria loads in excess of predevelopment conditions, but the magnitudes vary greatly (Tables 9 and 10). NO_3 load reduction targets range from 48 lb/yr to 34,721 lb/yr and the indicator bacteria reduction targets range from 4,243 billion cfu/yr to 1,146,062 billion cfu/yr for all subwatersheds (this represents a total rather than per unit area target). Conversely, not all subwatersheds contribute TSS and particulate P above predevelopment conditions (Tables 7 and 8). Load reduction targets were developed only for those subwatersheds with development-derived TSS and particulate P loads in excess of predevelopment estimates. Particulate P load reduction targets were as large as 424 lb/yr in the eight subwatersheds where particulate P increased from predevelopment conditions. TSS load reduction targets were as large as 4,201 lb/yr in the three subwatersheds where TSS increased from predevelopment conditions.

As noted above, TSS and particulate P loads decreased from the predevelopment scenario to existing conditions scenario for several subwatersheds. This result was typically associated with poorly drained soils (HSG D), which naturally generate higher levels of TSS and P than other soil types. In these instances, increased impervious cover in the existing conditions model may have eliminated substantial sources of TSS and particulate P, thus reducing load estimates from the predevelopment to existing conditions scenario. For subwatersheds where TSS and/or particulate P loads decreased from existing conditions, no load reduction targets were developed for the respective constituent. For TSS, this fact may appear to contradict visual assessments, which have indicated that fine sediment is overabundant in the upper watershed and in Strickland Brook. These results do not imply that sediment is not a concern in the watershed; rather they indicate that TSS related to land use changes external to the stream channel may not be the primary cause of sedimentation. It is likely that a combination of channel modification (dams, culverts, etc.) and other characteristics such as steepness and soils within the greater watershed are the source of the observed sedimentation.

For the Mianus River Watershed, total pollution reduction targets require annual decreases of 0.1 (Table 7), 1.7 (Table 8), 81.7 (Table 9), and 59.6 percent (Table 10) for TSS, particulate P, NO_3, and indicator bacteria loads, respectively. Interim (60 percent) targets require decreases of 0.06, 1.0, 49.0, and 35.8 percent, for TSS, particulate P, and NO_3, and indicator bacteria, respectively. All pollutants are summarized in Table 11. Typical load reductions and efficiencies for the management actions recommended in the Plan are presented in Chapter 6.

Table 7. Total Suspended Solids Load Reduction Targets

Subwatershed (headwaters to outlet)	Existing Load (lb/yr)	Predevelopment Load (lb/yr)	Total Load Reduction Target (lb/yr)	Percent Reduction (%)	Interim Load Reduction Target (lb/yr)
64 (Upper Main Stem)	1,817,638	1,889,796	0	0.0%	0
1	107,891	113,591	0	0.0%	0
10	422,097	429,703	0	0.0%	0
11	287,357	294,043	0	0.0%	0
12	33,970	32,426	1,544	4.5%	926
16	482,943	488,538	0	0.0%	0
13	228,971	238,830	0	0.0%	0
2	185,908	190,901	0	0.0%	0
3	116,990	112,789	4,201	3.6%	2,521
63 (Main Stem/Bargh Reservoir)	989,600	1,029,198	0	0.0%	0
4	137,268	133,709	3,559	2.6%	2,135
17	229,833	246,895	0	0.0%	0
5 (Piping Brook)	703,860	704,562	0	0.0%	0
7	344,515	351,644	0	0.0%	0
62 (Below Bargh Reservoir)	1,479,094	1,570,325	0	0.0%	0
18 (East Branch)	1,255,906	1,295,101	0	0.0%	0
14	145,416	152,536	0	0.0%	0
15	23,168	23,837	0	0.0%	0
8	307,209	326,054	0	0.0%	0
61 (Lower Main Stem)	909,405	1,012,182	0	0.0%	0
9	159,344	171,105	0	0.0%	0
19 (Strickland Brook)	1,749,012	1,992,828	0	0.0%	0
Watershed Total:	**12,117,395**	**12,800,593**	**9,304**	**0.1%**	**5,582**

[1] Sum of watershed load reduction targets ≠ predevelopment – existing load because negative targets are not represented.

Table 8. Particulate Phosphorus Load Reduction Targets

Sub-watershed (headwaters to outlet)	Existing Load (lb/yr)	Predevelopment Load (lb/yr)	Total Load Reduction Target (lb/yr)	Percent Reduction (%)	Interim Load Reduction Target (lb/yr)
64 (Upper Main Stem)	9,632	9,449	183	1.9%	110
1	635	568	67	10.6%	40
10	2,003	2,148	0	0.0%	0
11	1,210	1,470	0	0.0%	0
12	185	162	23	12.4%	14
16	930	2,443	0	0.0%	0
13	1,300	1,194	106	8.2%	64
2	671	955	0	0.0%	0
3	491	564	0	0.0%	0
63 (Main Stem/Bargh Reservoir)	4,494	5,146	0	0.0%	0
4	484	669	0	0.0%	0
17	1,322	1,234	87	6.6%	52
5 (Piping Brook)	2,926	3,523	0	0.0%	0
7	1,297	1,758	0	0.0%	0
62 (Below Bargh Reservoir)	6,237	7,852	0	0.0%	0
18 (East Branch)	6,899	6,476	424	6.1%	254
14	618	763	0	0.0%	0
15	136	119	17	12.5%	10
8	1,614	1,626	0	0.0%	0
61 (Lower Main Stem)	4,866	5,061	0	0.0%	0
9	947	855	92	9.7%	55
19 (Strickland Brook)	8,328	9,964	0	0.0%	0
Watershed Total:	**57,225**	**63,998**	**998**	**1.7%**	**599**

[1] Sum of watershed load reduction targets ≠ predevelopment – existing load because negative targets are not represented.

Table 9. Nitrate Load Reduction Targets

Subwatershed (Headwaters to outlet)	Existing Load (lb/yr)	Predevelopment Load (lb/yr)	Total Load Reduction Target (lb/yr)	Percent Reduction (%)	Interim Load Reduction Target (lb/yr)
64 (Upper Main Stem)	5,346	3,333	2,013	37.7%	1,208
1	462	216	246	53.2%	148
10	1,546	765	781	50.5%	469
11	972	549	423	43.5%	254
12	129	62	66	51.2%	40
16	1,074	861	213	19.8%	128
13	907	448	459	50.6%	275
2	543	351	192	35.4%	115
3	314	226	88	28.0%	53
63 (Main Stem/Bargh Reservoir)	2,804	1,857	947	33.8%	568
4	355	268	87	24.5%	52
17	755	429	326	43.2%	196
5 (Piping Brook)	1,492	1,226	266	17.8%	160
7	750	605	146	19.5%	88
62 (Below Bargh Reservoir)	22,908	2,717	20,191	88.1%	12,115
18 (East Branch)	13,005	2,400	10,605	81.5%	6,363
14	442	266	176	39.8%	106
15	94	47	48	51.1%	29
8	940	561	379	40.3%	227
61 (Lower Main Stem)	36,479	1,758	34,721	95.2%	20,833
9	527	295	232	44.0%	139
19 (Strickland Brook)	31,700	3,372	28,328	89.4%	16,997
Watershed Total:	**123,544**	**22,613**	**100,931**	**81.7%**	**60,559**

Table 10. Indicator Bacteria Load Reduction Targets

Subwatershed (Headwaters to outlet)	Existing Load (billion cfu/yr)	Predevelopment Load (billion cfu/yr)	Total Load Reduction Target (billion cfu/yr)	Percent Reduction (%)	Interim Load Reduction Target (billion cfu/yr)
64 (Upper Main Stem)	536,038	354,296	181,742	33.9%	109,045
1	39,547	22,947	16,599	42.0%	9,959
10	131,384	81,325	50,060	38.1%	30,036
11	90,334	58,341	31,993	35.4%	19,196
12	14,582	6,613	7,969	54.6%	4,781
16	113,138	91,539	21,599	19.1%	12,959
13	78,699	47,613	31,086	39.5%	18,652
2	55,442	37,327	18,115	32.7%	10,869
3	54,893	24,021	30,871	56.2%	18,523
63 (Main Stem/Bargh Reservoir)	254,415	197,375	57,041	22.4%	34,225
4	57,780	28,484	29,296	50.7%	17,578
17	61,492	45,597	15,895	25.8%	9,537
5 (Piping Brook)	178,759	130,310	48,449	27.1%	29,069
7	79,248	64,284	14,964	18.9%	8,978
62 (Below Bargh Reservoir)	838,305	288,783	549,523	65.6%	329,714
18 (East Branch)	636,277	255,131	381,146	59.9%	228,688
14	40,358	28,294	12,064	29.9%	7,238
15	9,190	4,946	4,243	46.2%	2,546
8	78,568	59,654	18,914	24.1%	11,348
61 (Lower Main Stem)	1,332,936	186,874	1,146,062	86.0%	687,637
9	42,053	31,384	10,668	25.4%	6,401
19 (Strickland Brook)	1,230,310	358,473	871,838	70.9%	523,103
Watershed Total:	**5,953,748**	**2,403,612**	**3,550,136**	**59.6%**	**2,130,082**

Table 11. Pollutant Load Reduction Targets and Percent Reductions

Subwatershed (Headwaters to outlet)	NO₃ Total Target (lb/yr)	NO₃ Interim Target (lb/yr)	NO₃ Target as Percent of Total Watershed Target	Particulate P Total Target (lb/yr)	Particulate P Interim Target (lb/yr)	Particulate P Total Target as Percent of Total Watershed Target	TSS Total Target (lb/yr)	TSS Interim Target (lb/yr)	TSS Total Target as Percent of Total Watershed Target	Indicator Bacteria Total Target (billion cfu/yr)	Indicator Bacteria Interim Target (billion cfu/yr)	Indicator Bacteria Total Target as Percent of Total Watershed Target
64 (Upper Main Stem)	2,013	1,208	2.0%	183	110	18.3%	0	0	0.0%	181,742	109,045	5.1%
1	246	148	0.2%	67	40	6.7%	0	0	0.0%	16,599	9,959	0.5%
10	781	469	0.8%	0	0	0.0%	0	0	0.0%	50,060	30,036	1.4%
11	423	254	0.4%	0	0	0.0%	0	0	0.0%	31,993	19,196	0.9%
12	66	40	0.1%	23	14	2.3%	1,544	926	16.6%	7,969	4,781	0.2%
16	213	128	0.2%	0	0	0.0%	0	0	0.0%	21,599	12,959	0.6%
13	459	275	0.5%	106	64	10.6%	0	0	0.0%	31,086	18,652	0.9%
2	192	115	0.2%	0	0	0.0%	0	0	0.0%	18,115	10,869	0.5%
3	88	53	0.1%	0	0	0.0%	4,201	2,521	45.2%	30,871	18,523	0.9%
63 (Main Stem/Bargh Reservoir)	947	568	0.9%	0	0	0.0%	0	0	0.0%	57,041	34,225	1.6%
4	87	52	0.1%	0	0	0.0%	3,559	2,135	38.3%	29,296	17,578	0.8%
17	326	196	0.3%	87	52	8.8%	0	0	0.0%	15,895	9,537	0.5%
5 (Piping Brook)	266	160	0.3%	0	0	0.0%	0	0	0.0%	48,449	29,069	1.4%
7	146	88	0.1%	0	0	0.0%	0	0	0.0%	14,964	8,978	0.4%
62 (Below Bargh Reservoir)	20,191	12,115	20.0%	0	0	0.0%	0	0	0.0%	549,523	329,714	15.5%
18 (East Branch)	10,605	6,363	10.5%	424	254	42.5%	0	0	0.0%	381,146	228,688	10.7%
14	176	106	0.2%	0	0	0.0%	0	0	0.0%	12,064	7,238	0.3%
15	48	29	0.1%	17	10	1.7%	0	0	0.0%	4,243	2,546	0.1%
8	379	227	0.4%	0	0	0.0%	0	0	0.0%	18,914	11,348	0.5%
61 (Lower Main Stem)	34,721	20,833	34.4%	0	0	0.0%	0	0	0.0%	1,146,062	687,637	32.3%
9	232	139	0.2%	92	55	9.2%	0	0	0.0%	10,668	6,401	0.3%
19 (Strickland Brook)	28,328	16,997	28.1%	0	0	0.0%	0	0	0.0%	871,838	523,103	24.6%
Total:	**100,931**	60,559	**100.0%**	**998**	599	**100.0%**	**9,304**	5,582	**100.0%**	**3,550,136**	2,130,082	**100.0%**

The Mianus River Watershed means different things to different people. Some value its many utilitarian purposes, such as drinking water drawn from the S.J. Bargh Reservoir and Mianus Mill Pond, and the flood control benefits of large tracts of forested land. Others value it for reasons that are harder to quantify or put into monetary terms—for example, the environmental diversity the river supports, or the aesthetic character it lends to the region. Understanding how a river is used is a crucial piece of the watershed based planning process because it allows managers to set goals tailored to the values of the community.

During a public meeting, stakeholders articulated the ways that the watershed is used and valued. This chapter discusses the uses and values identified by the stakeholder group during this meeting as well as the comments offered by stakeholders on the physical attributes required to provide for these uses and values.

DRINKING WATER

The Mianus River Watershed is a major source of drinking water. Aquarion Water Company supplies water from it to approximately 100,000 people in the communities of Greenwich and Stamford, Connecticut, and Port Chester, Rye, and Rye Brook, New York. Within the watershed, many residences are served by private wells, making the protection of good groundwater resources a top priority.

Providing for drinking water uses requires not only a sufficient source of high-quality water, but also the infrastructure necessary to treat, store, and distribute it to customers. Stakeholders perceived drinking water as a potentially conflicting use that could deplete water sources for other downstream uses, such as fisheries and aquatic habitat. Yet drinking water can be perceived as a high-priority use, and one that many residents can relate to, creating the potential for it to act as a driver for resource protection and conservation efforts.

Stakeholders identified several ways to measure the watershed’s ability to provide sufficient drinking water resources, including measuring water quantity, particularly during low-flow and drought conditions; identifying recharge areas; quantifying forest cover; and monitoring changes in aquifer depths. Stakeholders recognized the importance of open space in protecting drinking water source areas and expressed the need to clearly designate and define open space areas and enforce use restrictions over time.

The principal threat to the drinking water supply is from urbanization of watershed areas above drinking water intakes. Urbanization has increased rates of sedimentation and eutrophication within the S.J. Bargh Reservoir and Mianus Mill Pond. In addition, unregulated water withdrawals in the upper watershed are also a concern.

HIGH-QUALITY AQUATIC HABITAT

Stakeholders identified high-quality aquatic habitat as a valuable resource within the Mianus River Watershed. Habitats include the physical environments, both in and adjacent to stream channels, that support various forms of wildlife. Existing aquatic and riparian habitats within the Mianus River Watershed support diverse aquatic life including fish, macroinvertabrates, wetland/riparian plant communities, amphibians, reptiles, and various terrestrial birds and mammals. Preserved riparian lands in the central portion of the watershed and relatively low levels of impervious cover in many sections of the watershed play a key role in preserving high quality habitats. Additionally, forested wetlands are frequently the source of headwater streams throughout the watershed, and provide it with critical ecosystem services: nutrient retention and processing, storm attenuation, and plant and wildlife habitat.

Stakeholders expressed concern about the impact of sediment deposition on aquatic habitats, citing increasing rates of sediment accumulation in some areas. Stakeholders felt that localized increases in erosion rates due to heavy recreational use may be contributing to increases in sedimentation along the Main Stem. The cumulative impact of water withdrawals and small impoundments may also be adversely impacting habitat quality, although these effects are poorly understood at present.

Stakeholders suggested a number of metrics for measuring the quality and extent of existing habitats. These include measuring key water quality parameters, mapping preserved buffers, and direct measurement of wildlife biodiversity.

FISHERIES

Stakeholders viewed fisheries as another significant watershed resource. In its lower reaches, the Mianus River supports a managed brown trout fishery and is home to several species of warm water sport fish. Stakeholders reported that historically, naturally reproducing brook trout populations were present in tributaries to the Main Stem upstream of the S.J. Bargh Reservoir. Portions of the River are managed as trout streams and stocked by the CTDEEP. Diadromous fish species including herring (*Alosa sp.*) and American eel (*Anguilla rostrata*) also migrate up portions the Mianus River, making use of a fish ladder near Route 1. The river also supports one of the largest herring runs in Connecticut. The watershed's fisheries offer a food source for otter, osprey, and other foraging birds.

Stakeholders discussed the impact of the many small dams and impoundments throughout the watershed, expressing that these features improve some types of fish habitat (e.g., warm water pond species) while restricting other species (e.g., cold water, or anadromous species). Stakeholders identified a number of attributes that support fisheries resources including baseflow, dissolved oxygen, low turbidity, water depth, temperature, and sediment accumulation.

PRESERVED GREENWAY

Stakeholders viewed the preserved greenway along portions of the Mianus River as a valuable watershed asset. The Mianus River Greenway is made up of open, protected lands owned by the State of Connecticut, Aquarion Water Company, the Town of Greenwich, the City of Stamford, the Greenwich Land Trust, the Stamford Land Trust, the Mianus River Gorge Preserve, and other private owners. The preserved greenway lands support aquatic and terrestrial plant and animal communities, add to the scenic beauty of the area, and provide diverse recreational opportunities. Stakeholders expressed concern about the management of designated open space areas, citing a need to better designate and define these areas and enforce regulations to ensure the greenway remains a viable resource over time.

RECREATION

The Mianus River Watershed, particularly within the Mianus River Greenway, supports a wide variety of recreational uses including birding, ice fishing, fishing, shellfishing, hiking, swimming, horseback riding, mountain biking (in Mianus River Park only), dog walking, cross-country skiing, and snow shoeing (it should be noted that parks within the Greenway maintain separate use regulations, and the above activities are not all permitted in all portions of the Greenway). Recreation was viewed both negatively and positively by watershed stakeholders. While recreational use of the watershed creates opportunities for residents and economic benefits by attracting visitors, some stakeholders view recreational activities as a source of watershed degradation. The stakeholders strongly expressed the view that recreational activity has reached levels that are negatively affecting the river and that recreational activity needs to be better managed to ameliorate these impacts.

Stakeholders cited the need to better identify and protect sensitive or critical habitats and the lack of effective management plans as barriers to accommodating recreation within the wider context of other watershed uses and values. Other suggestions for improving recreational uses within the Mianus River Park can be found in *Managing Natural Resources & Recreation: An Action Plan* (National Parks Service 2006); examples include developing a more cohesive signage system and installing trailheads and gateways. Increasing concern over bacteria levels in the Mianus River suggest that the river's use for contact recreation may be compromised, although a more comprehensive study of the scope and extent of the problem is needed.

EDUCATION

Watershed stakeholders viewed education as a potentially significant use and value associated with the watershed, focusing on the direct use of streams and rivers as learning experiences and "outdoor classrooms." The Mianus River Gorge Preserve has an active wildlife conservation research program for high school, college and graduate students. Eastern Middle School in Greenwich has historically used the Mianus River Park to access the river for water quality sampling and analysis with data analysis as part of science classes. The Mianus fishway near Route 1 is used routinely by environmental science instructors at Greenwich High School to illustrate and reinforce concepts about migratory fish species. In 2011 the Mianus River Watershed Council initiated a volunteer streamwalk assessment program with the Byram River Watershed Coalition and the NRCS. Stakeholders have suggested that it may be useful to inventory current uses and expand the environmental education potential of the Mianus River.

HOMES/PROPERTY VALUES/SCENIC BEAUTY

Watershed stakeholders perceived the Mianus River to be a source of scenic beauty that enriches the quality of life for watershed residents and also may result in increased property values. While it is clear that the rural character and open space associated with the Mianus River are important to local residents, these values may not be clearly understood by the public as linked to good water quality and the need for stewardship. Stakeholders questioned how these values could be more emphatically communicated to watershed residents.

FLOOD CONTROL/HYDROLOGIC RESPONSE

Watershed stakeholders valued the Mianus River Watershed's function in providing flood control and felt that this benefit could be quantified in terms of avoided flooding costs. Forested and otherwise undeveloped lands within the Mianus River play a critical role in infiltrating precipitation and, in so doing, reduce flood peaks to downstream communities. Finding ways to quantify and value this ecosystem service could help advance forest conservation efforts in the watershed.

HISTORIC/CULTURAL VALUE

Stakeholders identified the watershed and its water resources as having significant historic and cultural value. Like many rivers in the Northeast U.S., the Mianus River was once heavily used to power grist, saw, and textile mills along its shores. Although milling has long since ceased in the watershed, its legacy—both positive and negative—remains. These remnants of former milling operations provide an opportunity to understand and interpret the area's industrial past.

As discussed in earlier chapters, the Mianus River Watershed has been stressed by multiple factors relating to residential development and human use. In some areas, improvements in water and habitat quality, and biological community health are required to fully realize the great potential of the Mianus River as a natural, economic, cultural, and recreational resource. In other parts of the watershed, existing high-quality resources must be preserved and managed to maintain existing uses.

Management goals define the specific long-term outcomes that will lead to a healthy, high-quality river system that meets the needs of its diverse stakeholders. Goals were developed by the steering committee, taking into consideration the existing conditions analysis presented in Chapter 3 and the uses and values defined in Chapter 4. The management goals defined for the Plan are as follows:

- Enhance stormwater runoff management;
- Protect and enhance drinking water quality;
- Restore impaired biological communities; and
- Maintain and enhance recreational opportunities.

Management strategies outline sets of activities that, when implemented, will result in the outcomes defined by the goals. As with goals, the strategies were developed with important input from the steering committee through a series of public workshops. The following management strategies were identified:

- Promote the use of BMPs to reduce nutrient and sediment loading;
- Avoid future increases in stormwater-related impacts through low impact development (LID) based policies and stormwater ordinances;
- Define and remediate potential bacterial impairments within the Mianus River Watershed and improve riparian habitat;
- Establish a long-term water quality monitoring program;
- Maintain and improve in-stream flows;
- Reduce the impact of small dams and impoundments through barrier mitigation;
- Manage the impacts of recreational activity on natural lands and aquatic resources along the Mianus River Greenway and the Mianus River Gorge;
- Encourage better stewardship of public and private lands by implementing education and outreach programs for landowners and municipal officials;
- Pursue strategic land acquisition to protect headwater streams and promote greenway expansion; and
- Implement the Plan and monitor outcomes.

Each goal and strategy is discussed in detail in the sections below.

MANAGEMENT GOALS

Building on the uses and values defined in Chapter 4, the Plan establishes primary management goals focused on enhancing stormwater management, protecting and improving water quality, restoring impaired biological communities, and maintaining and enhancing recreational opportunities in the watershed. Goals were established by watershed stakeholders through a public meeting format following identification of watershed uses and values. While there are other goals that could be developed, it is important to focus management efforts primarily on these high-priority goals.

Enhance stormwater runoff management

Biological function, and aesthetic and recreational value are all collectively undermined by the impacts of unmanaged stormwater. Unmanaged stormwater disrupts local habitats, creates high-flow conditions that stress aquatic organisms, conveys pollutants that negatively affect aquatic life, and increases bank erosion rates, which in turn leads to higher nutrient loading, algae blooms, and sedimentation. Unmanaged stormwater also undermines recreational and aesthetic value by creating unsightly conditions (trash, eroding banks, gully-like channels) and carrying bacteria, which impairs safe contact activities such as swimming and fishing. Review of existing reports and field assessment suggests that stormwater-related impacts have impaired areas of the Mianus River and its tributaries. A coordinated effort to better manage stormwater will result in improvements to biological conditions as well as a more beautiful river with enhanced recreational opportunities.

Protect and enhance drinking water quality

Home to the S. J. Bargh Reservoir, the Mianus River Watershed supplies drinking water to over 100,000 people; as such, protecting and enhancing water quality within drinking water source areas is a key management goal. Raw water is also diverted from the Mianus River at the Mianus Mill Pond, which is located in the downstream portion of the watershed. In total, approximately 70 percent of the total watershed drains to a drinking water supply, with only Strickland Brook and the portion of the Main Stem below Aquarion's Mianus Mill Pond excluded from the drinking water area. Despite the presence of significant quantities of forested lands within the Mianus River Gorge Preserve, extensive development has occurred within many of the source water areas to the reservoir. The extent of development suggests that somewhat elevated nutrient and sediment loads are being delivered to the reservoir and may, over time, significantly impair raw water quality. Future growth, if not managed properly, will likely lead to further increases in nutrient and sediment loading. Significant sedimentation has also occurred within the impoundment associated the Mianus Mill Pond on Valley Road in Cos Cob.

Restore impaired biological communities

Monitoring reports and visual assessments suggest that biological communities within many areas of the Mianus River Watershed have become somewhat degraded. Analysis suggests that this degradation is likely the result of several interacting stressors. Situated less than 40 miles away from New York City, the Mianus River and surrounding natural lands are subject to intense recreational use, including fishing, horseback riding, mountain biking, hiking, and dog walking. While recreational use is an important value in the watershed, it has reached levels that are in some cases resulting in negative impacts to resource quality. Development in the watershed has also reached levels in many areas that are typically associated with impacts to stream communities. Numerous private wells may be diminishing baseflow in the headwaters.

Unmanaged stormwater from developed areas delivers pollutants that degrade water quality, increase hydraulic stress on organisms, and degrade in-stream habitats. Networks of small dams and impoundments create thermal pollution and block fish passage. The effects of under-performing or malfunctioning septic systems may also be degrading biological communities.

Maintain and enhance recreational opportunities

With its network of trails and public access points, scenic quality, and proximity to large population centers, the Mianus River Watershed is a key recreational resource. The Mianus River Gorge Preserve, Mianus River Park, and all of the other linked open spaces that make up the Mianus River Greenway are important amenities for hikers, joggers, and other outdoor enthusiasts. While the level of recreational use poses challenges for maintaining natural features, it is equally important to manage the Mianus River for continued and sustainable recreational use.

MANAGEMENT STRATEGIES

Management strategies define specific sets of management actions required to achieve the broad outcomes outlined in the preceding goals section. Strategies were developed taking into account the constraints and assets of the watershed, and are by design integrative; that is, they often address multiple goals simultaneously. The following section discusses the 10 management strategies that form the basis for Plan implementation. A list of management actions that support each of the strategies presented below can be found in Chapter 6, Table 14.

1. Promote the use of best management practices to reduce nutrient and sediment loading

Reducing nutrient and sediment loading will be important to enhancing the Mianus River's recreational and drinking water uses and ecological value. Although not severe in most cases, levels of development within several subwatersheds, some of which drain to the S.J. Bargh Reservoir, are suggestive of moderately increased levels of pollutant loading. And given the area's high watershed-to-reservoir area (about 100:1), the reservoir may be particularly susceptible to the effects of increased pollutant loading. Reducing sediment and nutrients in subwatersheds draining to the reservoir, particularly in Banksville and the Windmill Lakes area, will be important to maintaining a sustainable supply of drinking water. In addition to protecting drinking water supplies, reductions in nutrient and sediment loading will also be a critical aspect of maintaining the recreational and scenic uses associated with the Mianus River Greenway.

Key management actions for reducing sediment and nutrient loading will include:

- Implementing structural BMPs within sensitive headwater streams that are showing signs of instability and erosion. Structural BMPs should be concentrated in relatively small drainage areas (i.e., 2–5 square miles or less). Highly urban stormwater BMPs that are more expensive but offer a wider suite of ancillary aesthetic, economic, and social benefits (e.g., green streets, etc.) may help to attract a broader constituency and open more diverse funding sources.

- Avoiding impacts to roadside wetlands by limiting additional inputs of stormwater. Roadside wetlands in various conditions were observed throughout the watershed; some appeared to be handling stormwater inputs, but many appeared to be overwhelmed. New impervious area in a drainage system should seek to capture and infiltrate stormwater onsite using swales and bioretention (vegetated BMPs designed to infiltrate water; usually fairly small) rather than piping it into existing wetlands and wooded areas. Where this is not possible, stormwater should be managed upstream at its source. In addition, points of direct outfall to the river or to wetlands, for example where I-95 runoff discharges into Strickland Brook, should be addressed using structural BMPs such as roadside bioretention cells.

- Implementing non-structural BMPs. Non-structural BMPs such as “good housekeeping” at construction yards, nutrient management programs, or rain barrel incentive programs are important to manage nutrient and sediment loading, particularly for residential homeowners and business owners. Best management techniques for lawn care and roof runoff are difficult to implement on a large scale, but have the potential for widespread benefit.

- Municipalities leading by example. Publicly owned properties can be ideal sites for demonstration BMPs, which reduce overall pollution loading while providing an important education tool. Concurrently, municipal policies and maintenance practices (see Strategy 2) can help to set the tone for local residents and encourage good practices going forward.

Synergy: BMPs can offer a suite of related benefits for businesses and property owners. These include enhanced site aesthetics, educational opportunities, reduced maintenance costs, and rainwater harvesting.

Approach: Mixed-use watersheds provide a range of structural and non-structural BMP opportunities that can vary significantly in terms of implementation cost and downstream benefits (typical costs and load reductions associated with common BMPs are discussed in greater detail in Chapter 6). Structural BMPs tend to offer the greatest certainty in terms of pollution-reduction but can be expensive to implement. When planning for structural BMPs, it is important to first look for the “low-hanging fruit” (i.e., low cost/high benefit BMPs), which often involve the following types of opportunities (see Chapter 7 for opportunities identified in the watershed):

- Regional management opportunities to treat large, impervious areas within existing open space or parkland, (e.g., schools and parks where street runoff can be diverted and managed in unused open spaces, etc.);

- Small bioretention areas within unconstrained institutional and commercial properties (e.g., schools, universities, corporate campuses etc.).

Focusing implementation on target subwatersheds (as opposed to a scattershot approach involving implementation throughout the entire watershed) can help to create more momentum and demonstrate results in a shorter time frame.

Next steps: Review low-cost structural BMPs identified in Chapter 7 and select several manageable BMPs for early implementation.

2. Avoid future increases in stormwater-related impacts through low impact development based policies and stormwater ordinances

LID policies decrease the impacts of development on natural systems by requiring or incentivizing the use of an LID design approach for new and redevelopment projects. Adopting LID policies involves strengthening municipalities’ existing stormwater, subdivision, and zoning and land development ordinances, particularly in highly sensitive areas. These policies help ensure that new and redevelopment projects in the watershed are constructed so as to minimize impacts on local waterways. LID techniques include reducing impervious surfaces associated with development by the use of narrower roads or elimination of cul-du-sacs, and avoiding soil compaction and large scale regrading of development sites. An LID approach would require developers to locate buildings, roadways, and parking lots away from streams, wetlands, floodplains, high-quality forests, and other sensitive natural resources. It would also involve the use of small-scale structural BMPs such as rain gardens to soak stormwater into the ground at its source. These techniques mimic the way stormwater flows through undeveloped lands such as forests.

Although LID approaches are important throughout the watershed, the strongest development controls are meant to be implemented in headwater subwatersheds, where unmanaged stormwater can quickly lead to increased rates of stream channel and bank erosion. In particular, the Upper Mianus River Watershed in the towns of Bedford and North Castle has seen significant residential and some commercial development with limited stormwater controls. Requiring an LID approach for future development will ensure that development does not result in an increase in stormwater runoff and NPS pollution.

LID policies involve a number of specific requirements that encourage a more watershed-friendly approach to development:

- Municipal stormwater regulations that require volume-based management of smaller storms for water quality protection (typical requirements include the infiltration of at least the first inch of runoff from impervious surfaces); peak-rate control for moderate storms to protect channels from eroding (moderate-sized storms tend to inflict the most stream erosion over time); and management of larger storms for flood control are all useful methods to reduce impacts associated with development.

- Progressive planning and zoning provisions, such as cluster development and transit-oriented development, can limit sprawl. These approaches cluster development in a smaller area, leaving more open space, or locate development close to existing transportation and transit resources to limit the need for additional transportation infrastructure.

- Development ordinances may include mandatory tree mitigation requirements (i.e., programs that require trees to be replaced if they are removed); limit road widths and parking space size; allow flexibility in setback requirements (requirements for building setbacks from roadways or property boundaries sometimes limit the ability to cluster housing to protect open space and increase minimum lot sizes); strongly limit development on steep slopes; and require a conservation-oriented design approach that seeks to minimize large scale grading, engineered fills, whole-scale vegetation removal, and soil compaction (these practices are commonly associated with large-scale commercial developments). Incentives for BMPs that allow for infiltration into the ground, such as use of pervious pavements, depressed islands, and vegetated swales along roadways and parking lots should also be encouraged.

To set an example for the development community, LID practices may also be used in new municipal construction and long-term planning. For example, LID approaches that incorporate such BMPs as bioretention systems and rain gardens can be incorporated into streetscaping or repaving projects to create "green streets" that add visual interest to street corridors.

In some instances, municipal code may actually discourage LID (by requiring large minimum lots sizes or significant setbacks). A full review of existing land use regulations is recommended to identify barriers to LID implementation and to identify opportunities for incorporating LID into existing municipal regulations. Additionally, retraining and education programs for municipal officials and staff, construction inspectors, consulting engineers, contractors, and developers will ensure that LID regulations are properly implemented. **Synergy**: The watershed based approach provides a great opportunity to engage in multi-municipal planning so that development requirements are consistent throughout the watershed.

Challenge: Uniform guidelines among watershed municipalities will help to ensure that development is not simply pushed from town to town as individual towns strengthen their ordinances.

Existing resources: Many existing resources are available that provide model stormwater management resources including the CTDEEP's website www.ct.gov/dep, the CWP's web site (www.cwp.org), the Low Impact Development Center (www.lowimpactdevelopment.org), and the Nonpoint Source Education for Municipal Officials (NEMO) program (nemo.uconn.edu).

Approach:

- Key aspects of an effective and far reaching stormwater ordinance include providing standards for water quality protection (typically managing the first inch of runoff through infiltration), channel protection (typically managing 1–2-year storms), and flood control (peak rate control for larger storms, such as the 25-, 50-, and 100-year storms) for all new development and major redevelopment.
- A model LID ordinance may be useful to establish minimum stormwater criteria and promote LID approaches throughout the watershed.
- Municipal improvement projects may choose to utilize LID techniques wherever possible, in order to present an example for business and residential communities. Demonstration sites in particular may be useful for promoting LID practices while providing water quality benefit.

Next steps:

Form a multi-municipal planning group to review existing ordinances and work towards enabling LID.

3. Define and remediate potential bacterial impairments within the Mianus River Watershed and improve riparian habitat

Stakeholders have suggested that sections of the Mianus River may be impaired for recreational use by high levels of bacteria due to pet and wildlife waste in recreational areas, and perhaps leaking septic systems in the upper watershed. The latter, in particular, is the source of some debate within the watershed community (see discussion in Chapter 2). In addition, stakeholders have questioned to what degree indicator bacteria is a naturally-occurring pollutant stemming from wildlife sources, and as such may be beyond the reach of most management activities.

Based on an unpublished, in-house study of fecal coliform bacteria levels of streams within areas draining to reservoirs in the nearby Saugatuck River Watershed, environmental analysts at Aquarion Water Company have suggested that significant fecal coliform bacterial loading (including fecal coliform bacteria level "spikes" associated with storm events) is very likely generated by wildlife, and is not necessarily indicative of pollution (B. Roach; pers. comm.). Further study in both developed and undeveloped areas would be useful to isolate what portion of the bacterial load is coming from wildlife, versus from pet waste, leaking septic systems, urban runoff, or other factors.

A water quality assessment and long-term monitoring to identify and map bacterial impairments within the Mianus River Watershed would be a logical next step to better understanding the extent of bacterial impairments. Collected data will be important to help managers determine whether septic systems, recreation, wildlife, or a combination of factors is the major source of impairment. The study could be implemented by the Mianus River Watershed Council in concert with local municipalities. Harbor Watch/River Watch Program staff have experience with bacterial sampling and source tracking in nearby watersheds, and could provide an important source of technical assistance in conducting this type of study.

Once bacterial impairments are defined and sources identified, management actions can address limiting bacteria sources and adding riparian buffers wherever possible. This combined approach could include a variety of activities depending on the outcome of the initial study, but will most likely employ some or all of the following:

- *Prevent septic system failures*. Private septic systems, widespread throughout the watershed, are difficult for municipalities to monitor. In older developments and on properties adjacent to the stream, leaking septic systems may be a significant source of bacteria, although their level of contribution to the overall bacteria load is a topic of some dispute. Following an assessment of problem areas, properties with failing septic systems can be targeted through outreach to current homeowners, and through mandatory inspections at every deed transfer. As a preventative measure, Connecticut municipalities may choose to adopt more stringent separating distances of septic systems from streams, which would also address the related problem of nutrient contamination.

- *Manage pet waste*. Fecal bacteria from pet waste is easy and inexpensive to manage. Cleaning up after pets is important, especially at recreational areas along the river. Outreach including media campaigns and training can all be helpful to change pet owner behavior (see Strategy 8 and Chapter 8). Placing signs, free baggies, and trash cans at public recreation sites can get the message across and make it easy for pet owners to change their habits.

- *Create riparian buffers*. Riparian buffers can help to filter bacteria from stormwater runoff while providing a range of other benefits for streams. The several riparian buffer BMPs identified in Chapter 7 (at the Pine Ridge and Riverbank Road neighborhoods) can be important first steps toward reducing bacteria loads in key areas. Additional buffers can be implemented on private properties, particularly where lawn is currently mowed up to the stream edge. A variety of outreach approaches (see strategy 8) can be used to encourage buffer plantings on private property, including design guidance and workshops, and targeted education campaigns.

- *Reduce nesting populations of non-migratory geese*. Colonies of geese favor open areas adjacent to streams and ponds, especially where low grass allows a clear view of the water. At parks and golf courses, large colonies can become a significant water quality problem as well as a nuisance. Simply allowing grass to grow tall along the stream bank can discourage the geese from nesting in that location, and increasing the buffer with taller shrub plantings can be especially helpful. Where buffers are not an option, other methods of goose control may include harassment by dogs or limiting the viability of eggs.

Synergy: State water quality programs require monitoring in order to formally list streams for impairments. Once listed, additional funding may be available to de-list impaired segments.

Challenge: Monitoring for indicator bacteria requires training and access to laboratory facilities; sample results can vary widely with storm events.

Existing resources: Aquarion Water Company is already conducting monthly monitoring of indicator bacteria at Old Mill Lane in Stamford, and Bob Hill Road in Pound Ridge; Aquarion also conducts annual sanitary inspections of representative septic sites within the watershed.

Approach & next steps: Convene stakeholders to establish available knowledge base, availability of volunteers, select monitoring locations, and identify lab/equipment resources; reach out to Harbor Watch/River Watch to discuss extending other local bacterial impairment mapping programs to the Mianus River (see Chapter 9 for a detailed monitoring outline).

4. Establish a long-term water quality monitoring program

The Plan outlines specific steps that, based on prior experience and best science, are likely to result in significant stream and watershed improvements (see Chapter 9). As stakeholders work to implement the Plan, feedback on whether the Plan is working is critical. Using a process termed "adaptive management," water quality monitoring provides critical information concerning what management actions are working, and allows for adjustments to the Plan in ways that improve outcomes. Monitoring data can also be effectively used as an outreach tool for attracting additional funding.

Synergy: Aquarion Water Company engages in regular monitoring, although not for all parameters identified in Chapter 9. Graduate students have occasionally conducted additional monitoring. In addition, visual assessments and water quality sample collection are excellent opportunities to involve volunteers and streamside residents. As volunteers take an active role in stewardship, their awareness of watershed-related issues will increase.

Challenge: Monitoring programs can be time-intensive, and may require extensive training, expensive equipment or technical expertise. Sharing monitoring equipment with other nearby watershed programs may help to reduce costs.

Existing resources: There may be opportunities for volunteer monitoring groups to train with scientists from Aquarion, Mianus Watershed Council, or graduate students working in the watershed.

Approach and next steps: A detailed monitoring and maintenance plan is provided in Chapter 9 of the Plan. This section of the Plan details three related monitoring programs. First, a routine monitoring program is proposed to evaluate in-stream conditions through water quality and aquatic macroinvertebrate sampling and habitat assessments. Routine monitoring is conducted at a fixed station throughout the watershed on an annual or biannual basis. In addition to routine monitoring, an early warning monitoring program is proposed to detect changes in sensitive high-quality streams. The early warning monitoring program primarily involves looking for small, headwater changes such as increases in bank erosion and stream temperature, which may indicate that urban development is affecting these sensitive areas. Chapter 9 also includes recommendations for monitoring structural BMPs to ensure their continued function.

5. Maintain and improve in-stream flows

Given the magnitude of water withdrawals from the S.J. Bargh Reservoir and Mianus Mill Pond, some level of impact to streamflow and habitat below the reservoirs is likely. Additionally, stakeholders have suggested that baseflow, the portion of flow that is not the result of rain events, in streams within the upper portions of the watershed has been reduced by private well use.

Aquarion Water Company and CTDEEP have studied how reservoir management and releases affect downstream ecological conditions throughout Connecticut (B. Roach, pers. comm. 8.20.12), which aided in the establishment of CT streamflow standards in 2011. As a first step toward maintaining and improving stream flows below the S.J. Bargh Reservoir, watershed partners may work with Aquarion to ensure that reservoir release rates are meeting CT streamflow standards.

However, compliance with streamflow standards does not ensure that all streamflow related impacts will be addressed. After CT streamflow standards have been fully implemented, an additional monitoring and adaptive management program is recommended to further characterize the stream system and determine if the adoption of release rates stipulated by the CTEEP standards have been sufficient to restore in-stream habitat conditions supportive of a diverse, healthy, and locally appropriate biological community.

If in-stream habitat is not sufficient after the implementation of CTEEP-stipulated release rates, watershed partners may consider conducting a comprehensive in-stream flow study both above and below the S.J. Bargh Reservoir to identify and evaluate additional measures for restoring an appropriate in-stream flow regime and maximize habitat benefits. The comprehensive study would explore how a combination of additional modifications to the current withdrawal/release regime from the reservoir, enhanced source water protection, groundwater recharge projects, and water conservation measures could satisfy long-term consumptive needs while providing the appropriate flow to support aquatic communities.

In addition, the Mianus Mill Pond has been identified by stakeholders as a problem area where increased sediment and algae have been observed. The flow and withdrawal schedule should not be eliminated as possible causes of impairment. An in-stream flow assessment for the lower half of the watershed should highlight this area and address the impact of possible changes in withdrawal schedule both above and within the Mianus Mill Pond.

Synergy: Releases from the reservoir may not necessarily have to be greater in volume to improve downstream conditions; changes in the timing of releases could potentially offer downstream benefits without adversely affecting the availability of drinking water.

Challenge: A comprehensive study will likely be expensive and requires extensive hydraulic and groundwater modeling and field data collection.

Existing resources: A summary and introduction to Connecticut streamflow standards is available at www.ct.gov/dep/streamflow.

Approach & next steps: Following the work of The Nature Conservancy and Aquarion Water Company in the Saugatuck River watershed, the Mianus River Watershed Council could partner with Aquarion Water Company to extend the same approach to managing releases from the S.J. Bargh Reservoir.

6. Reduce the impact of small dams and impoundments through barrier mitigation

The Mianus River and its tributaries are impounded by numerous small structures, many of which no longer serve their original function. Options for mitigating the negative effects of the small dams that block fish migration and can increase water temperature include fish ladders, natural fishways, partial dam removal, and full dam removal. A fish passage project is already underway at Mianus River Pond; additional work should build on this success.

Given the number of barriers, a comprehensive fish passage and barrier mitigation plan should be developed to prioritize management actions and assist in attracting funding. The plan should assess each significant existing fish barrier, including dams and culvert/bridge crossings, in terms of miles of habitat "opened," historical significance, presence of accumulated sediment, barrier height, the potential for any damaging changes post-removal, options for local material disposal, extent and magnitude of thermal pollution, existing constraints such as the presence of subsurface utilities, extent of required post-removal restoration work, existing ownership and usage, structural condition, landowner cooperation, potential for impacts to regulated resources (e.g., jurisdictional wetlands, etc.), presence of threatened and endangered species, existing safety and liability issues, and other factors that would affect project feasibility and trajectory (e.g., removal vs. fish passage only, etc.).

Once barriers have been assessed, mitigation may include retrofitting raised culverts, installing fish passage structures, and removing small dams where feasible. These measures will be most effective if implemented where significant new habitat can be opened. Culverts and dams are widespread throughout the watershed, and any efforts to restore fish passage to these areas will require coordination with private landowners as well as municipal or state officials.

Synergy: Improved fish habitat in the river may improve opportunities for recreational fishing.

Challenge: Barriers are small and numerous. Therefore, a single project may not open a significant reach of habitat.

Existing resources: Findings/successes of the Greenwich Conservation Commission's Mianus River Pond fish passage project should be used as a starting point.

Approach & next steps: Assess each significant barrier on the stream and develop a prioritized list of removal candidates.

7. Manage the impacts of recreational activity on natural lands and aquatic resources along the Mianus River Greenway and the Mianus River Gorge

Management of recreational impacts should support priorities of the 2006 *Managing Natural Resources & Recreation: An Action Plan* and the 2012 *Mianus River Park Management Plan*. These documents, which describe a specific location within the watershed, should ideally be extended as a master plan to include all portions of the Mianus River Greenway. The master plan should:

- Identify key ecological resources (e.g., high-quality habitats, sensitive areas including wetlands and steep slopes) that should be restricted for recreational access;
- Clearly define existing and future recreational demand;
- Provide a strategic plan for trail upkeep and maintenance by volunteer crews;

- Develop a plan for better management of public access points such as the Merriebrook Lane trail head (see Appendix A) and River Road parking lot (see Chapter 7); and
- Assess opportunities for trail modification to maximize habitat and recreational value, particularly in the northern section of Mianus State Park.

Management actions may involve trail stabilization, drainage and remediation work, bank stabilization, temporary trail closures, and increased stewardship and management activities. In addition, land use designations may need to be changed in some areas to minimize recreational uses of sensitive habitats. Stakeholders have identified three (3) parcels in the northern part of Mianus State Park where a change in designation might be appropriate (known as the Blake Coleman, Upper Mianus, and Lower Mianus parcels).

Synergy: Reductions in sediment loading associated with recreational enhancements will help to reduce rates of sediment loading to downstream sections of the river including the Mianus Mill Pond impoundment.

Challenge: This issue is controversial among user groups. There are strong proponents of unrestricted recreation in some areas. A strong engagement process with a certified mediator may be required to achieve consensus on some issues.

Existing resources: The Mianus River Watershed Council's *Mianus River Greenway Priority Parcels to Protect* report identifies high-priority parcels for acquisition. This could provide a starting point for further analysis and master plan development.

Approach & next steps: Prior to or concurrent with the development of the master plan, implement target management actions to reduce erosion from trail overuse and public access locations; develop work plan and funding options for master plan development.

8. Encourage better stewardship of public and private lands by implementing education and outreach programs for landowners and municipal officials

Promoting healthy attitudes toward stewardship and general property management is a critical step toward improving overall watershed health. Educational materials can focus on helping both private citizens and public officials become more aware of the connections between NPS pollution and local-scale actions such as lawn care practices and pet waste management and can provide practical, easy-to-implement actions for reducing NPS pollution. Educational initiatives can make use of the full range of media outlets and presentation mediums. The following methods may be useful for engaging and educating community members to take more active roles in management of their watershed:

- Workshops geared toward homeowners, developers, engineers, land use attorneys, and golf course managers, presented by municipal conservation boards or local naturalists (topics may include lawn maintenance and landscaping; stormwater management; riparian buffers; management of small ponds and impoundments; and proper septic care);
- Targeted e-mail and social media campaigns to direct community members to a website/online resource center with downloadable information, interactive maps, blog, and RSS feeds to news outlets for watershed professionals (state and local news sites, stakeholder pages, etc.);

- Courses and outreach for municipal officials (particularly Public Works, Parks, and Education Departments) geared toward LID practices, MS4 compliance and good housekeeping, and case studies of LID initiatives across the country;
- Courses for municipal officials geared toward open space protection and policy options for encouraging LID;
- Streamwalks, cleanups, enhanced river access points, and volunteer monitoring events geared toward developing active volunteer task forces and getting people out into the river; and
- Public service announcements for local radio and television stations, which may include messaging for landowners related to pet waste management, rainwater re-use, and septic system maintenance.

Outreach may also be targeted toward the owners and managers of properties that typically generate significant NPS pollution:

- *Municipal facilities and golf courses.* Working with municipal facilities and golf courses to develop nutrient management plans helps managers target fertilizers where they are needed most, avoid over-fertilizing areas that have adequate soil nutrients, time fertilizer treatments when they are less likely to run off into streams, and select fertilizers that are less prone to washing off into streams. The practices can also result in cost savings for managers. Nutrient management planning also looks at opportunities to add shoreline and riparian vegetation, which can reduce bacteria as well as nutrients, and may limit colonization by non-migratory geese. When meeting with golf course managers, the need for sustainable irrigation may also be emphasized.
- *Equestrian facilities and small farms*. Owners of hobby farms may be eager to learn about alternative methods of waste management to reduce inputs to the stream. Simply limiting livestock access to streams is an excellent way to reduce erosion and limit direct inputs of nutrients and bacteria. Other source controls can include manure storage facilities and reducing fertilizer use.
- *Garden centers and nurseries*. Garden centers and nurseries are often heavy users of fertilizers, which may be used outdoors in non-contained areas and may be spilled or left out in the rain, etc. Like farms and golf course owners, these facilities may be taught to use less fertilizer as needed, which can save them cost and reduce nutrient pollution to the stream.
- *Small private ponds.* Flocks of geese around small ponds can be locally significant sources of nutrients and bacteria. Working with property owners, plant buffers along ponds to deter geese while filtering polluted runoff.

Synergy: A "neighborhood-by-neighborhood" approach to stewardship may be helpful to create localized improvement and spur a sense of participation and civic engagement. Education and outreach programs can be combined with nearby demonstration projects involving, for instance, the installation of structural BMPs at community centers, municipal resource recovery and recycling facilities, schools, and churches.

Challenge: Some watershed residents and officials are likely to be highly educated and motivated to implement watershed-friendly practices. Although general awareness of watershed issues has increased in recent years, for the majority of residents and municipal officials, watershed issues still lag behind other "quality of life" issues including education, crime, and health care. Linking watershed issues with quality of life issues like drinking water can help to get these issues "on the radar screen."

Existing resources: The Mianus River Watershed benefits from a range of qualified stakeholder groups with good standing in the community. These organizations, as well as local conservation boards, will be a key resource for developing educational materials and connecting the materials with the necessary audience.

Approach and next Steps: Detailed recommendations for incorporating education and outreach activities into Plan implementation is provided in Chapter 8. This chapter emphasizes proven approaches such as targeting early adopters who can set a positive example for others to follow, combining education and outreach events with existing events (e.g., community fairs) to maximize participation, and emphasizing simple messages that stress changing one or two behaviors. Chapter 8 also stresses the use of multiple media forms to multiple audiences and creating a brand image using logos and consistent graphic styles.

9. Pursue strategic land acquisition to protect headwater streams and promote greenway expansion

Land acquisition for conservation purposes is beneficial both to preserve water quality and improve recreational resources in the Mianus River Greenway. By buffering streams and absorbing runoff, conservation land helps limit pollutant loading and attenuates heavy storm flows. By providing open space protected from development, conserved land ensures the long-term availability of recreational areas for local residents.

The Mianus River Watershed Council may work with municipalities, particularly the Towns of Bedford, Pound Ridge, and North Castle; local land trusts; and Aquarion Water Company to identify and prioritize conservation acquisition targets within drainages to headwater streams upstream of the S.J. Bargh Reservoir, particularly in areas with significant availability of undeveloped, unprotected, private lands. Additionally, work to acquire or preserve priority parcels identified as part the *Mianus River Greenway Priority Properties to Protect* report should continue. Support of opportunities to further enhance and expand the greenway should also be pursued. In the long term, a "conservation bank" implemented by all watershed municipalities may be useful to offset new development and add to permanently protected open space.

Synergy: Protecting open space increases opportunities for recreation, protects water quality, and may increase property values in the local vicinity.

Challenge: Due to generally high property values, remaining available land may be expensive.

Existing resources: Parcels have already been prioritized for inclusion in the Mianus River Greenway (Mianus River Watershed Council 2011). The Greenwich Land Trust, Stamford Land Conservation Trust, Westchester Land Trust, Mianus River Gorge Preserve, and municipal open space committees may also provide support.

Approach & next steps: Compile conservation targets already identified by the municipalities and the Mianus River Watershed Council; identify additional areas in target subwatersheds where parcel research has not been conducted.

10. Implement the Plan and monitor outcomes

Achieving the management goals outlined in the Plan will require a sustained effort among multiple partners. While there are many active groups and volunteers working to protect the watershed, effectively coordinating the efforts of all involved parties will be a significant challenge. Ideally, a paid program coordinator could be hired to oversee day-to-day implementation of the Plan, drive fund raising efforts, ensure coordination among partner groups, and lead the implementation of management actions. Securing funding to hire a coordinator through one of the active stakeholder groups (e.g., the Mianus River Watershed Council or the Mianus River Gorge Preserve, etc.) should be a first priority in implementing the Plan.

In addition to hiring a coordinator, Plan implementation will benefit greatly from a commitment to measuring and monitoring outcomes, and subsequent adaptation based on monitoring data. This type of adaptive management approach will be crucial to the Plan's success. Periodic evaluation and refinement of management actions throughout the Plan's implementation will help to ensure that resources are used in the most effective manner possible. For a detailed discussion of monitoring/maintenance, see Chapter 9.

Challenge: Implementing the Plan will require significant, long-term oversight by a committed individual; however, funds are limited to support a paid, dedicated position.

Existing resources: Many different groups are working within the watershed on a range of diverse priorities; Table 14 in Chapter 6 identifies organizations that may be well-suited to implement each management action based on the groups' mission, capacity, and prior experience.

Approach & next steps: Obtain funding for a program coordinator to oversee implementation of the Plan. Review the Plan every 5 years, evaluating successes and lessons learned, and revise and update the Plan as necessary.

The watershed based planning process involves a series of consecutive steps, from assessment of existing conditions through community engagement and goal setting that result in an actionable Plan. This chapter outlines the detailed steps, termed "management actions," to implementing the Plan. The first section of the chapter discusses how subwatersheds have been targeted for implementation, stressing the need to focus management actions in particular areas of the watershed, rather than randomly implementing projects throughout the watershed. Focusing implementation in specific areas is central to demonstrating early success, building momentum, and attracting new sources of funding. The remainder of the chapter presents recommended management actions and further elaborates on the broad groups of implementation activities outlined in the management strategies discussed in the previous chapter. Table 14 lists the management actions associated with each management strategy and suggests parties responsible for implementing the management actions. It also defines short-, medium-, and long-term interim milestones for management actions and provides performance criteria through which the implementation of specific management actions can be measured.

SUBWATERSHED TARGETING

Subwatershed targeting focuses implementation efforts in sensitive areas and those that generate significant NPS pollution based on modeling results. Of the 22 subwatersheds delineated in conjunction with this study within the greater Mianus River Watershed, 12 were targeted for implementation efforts based on the ranking method described below. These 12 subwatersheds included areas that drain to small headwaters, drinking water source areas, and portions of the Main Stem.

The targeting method incorporated two factors to identify target areas for implementation: sensitivity and impairment. The sensitivity score measures the degree to which streams within and immediately downstream of a particular subwatershed are likely to be sensitive to changes in land use such as urban development. The sensitivity rating consisted of two measures of sensitivity: (1) stream order, which is a measure of the location of a particular stream within the overall stream network (small feeder streams have a low stream order, while large rivers have a high stream order); and (2) whether a subwatershed is a source area for a drinking water reservoir (Strickland Brook is in fact the only subwatershed that does not drain either directly or indirectly to a drinking water source). In short, the sensitivity rating favored small, sensitive streams draining directly to drinking water sources.

The impairment score reflected the existing condition of streams within or immediately downstream of a particular subwatershed. Higher impairment scores reflected streams in more developed areas as measured by the percentage of the watershed with impervious cover and streams where computer modeling indicated high rates of pollutant loading.

A total score for each of the 22 subwatersheds was calculated by combining the sensitivity and impairment scores. In determining the final scores, the sensitivity score was weighted more highly than the impairment score. A detailed description of the subwatershed targeting metrics is provided in Table 12. Table 13 presents scores for each subwatershed.

Table 12. Subwatershed Targeting Metrics

Targeting Score	1	2	3
Drinking Water Source	Does not drain to a drinking water source	Drains indirectly to a drinking water source	Drains directly to a drinking water source
Stream Order	Less than 50 percent of the stream length is 1st order	50 to 99 percent of the stream length is 1st order	100 percent of the stream length is 1st order
Impervious Cover Score	Good	Fair	Poor
NO_3 Loading	Less than 1.3 lb/ac/yr	1.3 to 10.0 lb/ac/yr	Greater than 10.0 lb/ac/yr
Particulate P Loading	Less than 1.5 lb/ac/yr	1.5 to 3.0 lb/ac/yr	Greater than 3.0 lb/ac/yr
TSS Loading	Less than 300 lb/ac/yr	300 to 550 lb/ac/yr	Greater than 550 lb/ac/yr
Indicator Bacteria Loading	Less than 120 billion cfu/ac/yr	120 to 200 billion cfu/ac/yr	Greater than 200 billion cfu/ac/yr

IDENTIFIED TARGET SUBWATERSHEDS

The thirteen identified target subwatershed are depicted in Figure 10. These represent the subwatersheds with the highest combined sensitivity and impairment scores (1, 5, 7, 8, 10, 12, 14, 17, 19 [Strickland Brook], and the Main Stem [61, 62, 63, and 64]). The headwaters of subwatershed 18 were also included based on visual assessment results and stakeholder input.

IDENTIFIED MANAGEMENT ACTIONS

The Plan proposes a series of management actions, which include the development of structural and non-structural BMPs (discussed in the following pages), implemented through a variety of monitoring and education/outreach programs, as well as broader policy initiatives. Management actions (Table 14) are associated with each management strategy proposed in Chapter 5. In some cases, similar management actions apply to multiple strategies; these instances are cross-referenced in the table text. Many management actions identified by the Plan support multiple goals. This integrated approach acknowledges that the management goals identified in the Plan are related to one another and that implementation actions often have multiple benefits. In addition to providing a brief description of the management action, Table 14 provides a suggested schedule, implementation milestones, and quantitative or qualitative performance criteria for each management action.

Successful implementation will rely on a collaborative effort that brings together the shared knowledge and experience of the participating organizations. Accordingly, Table 14 also recommends organizations that would be well suited to implement each of the management actions, including a range of state, municipal, and nonprofit partners. Organizations were identified for implementation activities based on their legal authority, mission, and/or prior work in similar areas.

Table 13. Subwatershed Targeting Scores

Metric Ranking								
Importance rank*	1	2	3	5.5	5.5	5.5	5.5	
Normalized rank**	0.25	0.21	0.18	0.09	0.09	0.09	0.09	
Subwatershed Scoring								
Subwatershed	**Drinking Water Source**	**Stream Order**	**Impervious Cover Score**	**NO_3 Contribution**	**Particulate P Contribution**	**TSS Contribution**	**Indicator Bacteria Contribution**	**Overall Score**
17	0.75	0.428	0.358	0.178	0.267	0.267	0.178	2.426
62 (Below Bargh Reservoir)	0.5	0.428	0.358	0.267	0.267	0.267	0.267	2.354
14	0.5	0.642	0.358	0.178	0.178	0.267	0.178	2.301
8	0.5	0.428	0.358	0.178	0.267	0.267	0.267	2.265
64 (Upper Main Stem)	0.5	0.428	0.358	0.178	0.267	0.267	0.267	2.265
61 (Lower Main Stem)	0.75	0.214	0.537	0.267	0.089	0.089	0.267	2.213
7	0.5	0.642	0.179	0.178	0.267	0.267	0.178	2.211
5 (Piping Brook)	0.75	0.428	0.179	0.178	0.178	0.267	0.178	2.158
12	0.5	0.642	0.358	0.089	0.178	0.178	0.178	2.123
19 (Strickland Brook)	0.25	0.428	0.358	0.267	0.267	0.267	0.267	2.104
63 (Main Stem/Bargh Reservoir)	0.75	0.428	0.179	0.178	0.178	0.178	0.178	2.069
1	0.5	0.642	0.358	0.178	0.178	0.089	0.089	2.034
10	0.5	0.428	0.358	0.178	0.178	0.178	0.178	1.998
18 (East Branch)	0.5	0.428	0.358	0.178	0.178	0.178	0.178	1.998
9	0.5	0.214	0.358	0.178	0.267	0.178	0.267	1.962
15	0.5	0.642	0.358	0.089	0.178	0.089	0.089	1.945
13	0.5	0.428	0.358	0.178	0.178	0.178	0.089	1.909
16	0.5	0.428	0.179	0.178	0.089	0.267	0.178	1.819
2	0.5	0.642	0.179	0.089	0.089	0.178	0.089	1.766
11	0.5	0.428	0.358	0.089	0.089	0.178	0.089	1.731
4	0.75	0.428	0.179	0.089	0.089	0.089	0.089	1.713
3	0.5	0.428	0.179	0.089	0.089	0.089	0.089	1.463

*IR of 1 is highest priority and the IR for metrics of equal priority are averaged; metrics with equivalent importance are assigned an average importance rank

**Normalized rank = (7 - IR + 1) / 28

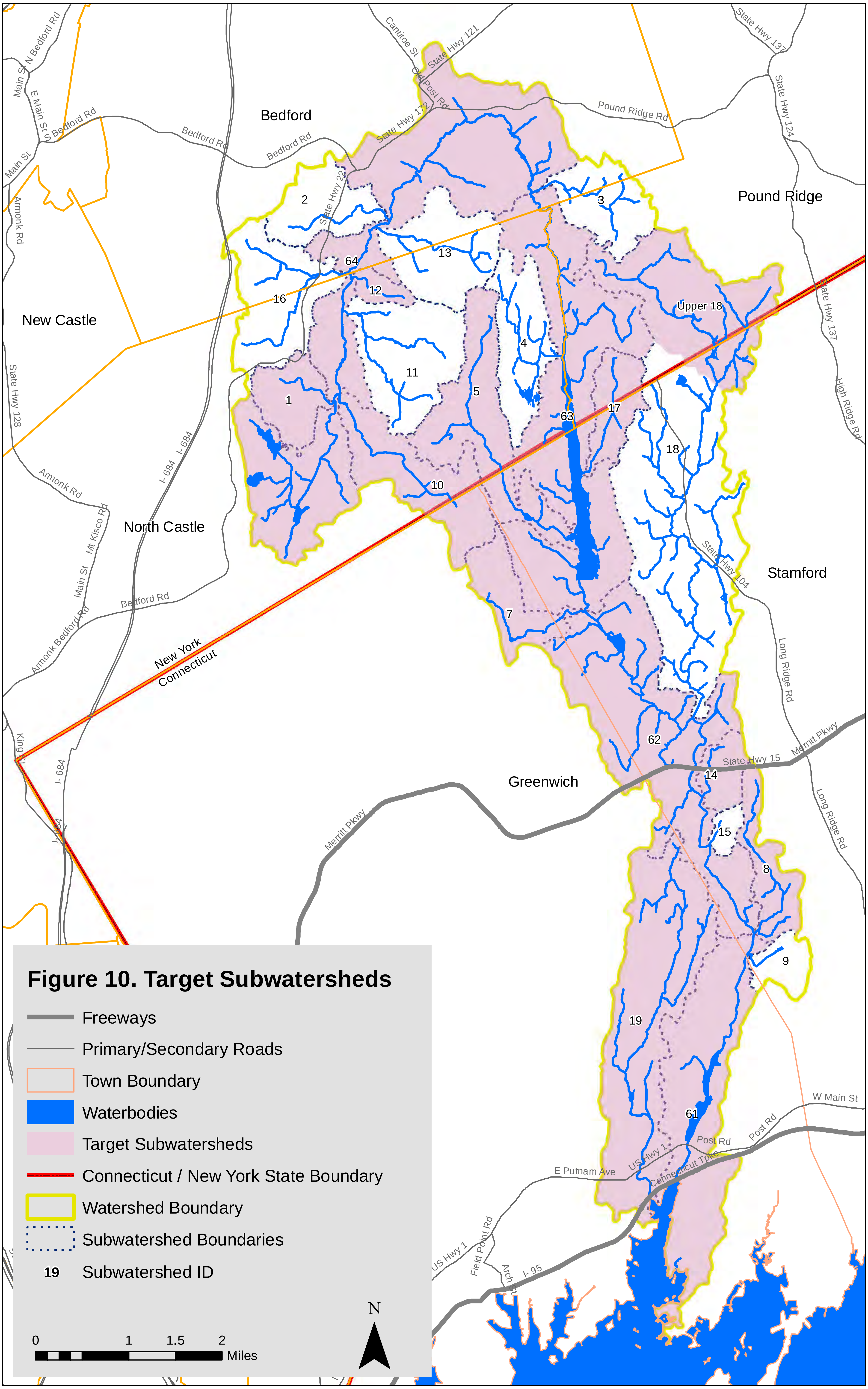


Figure 10. Target Subwatersheds

Table 14. Implementation of Management Goals, Strategies, and Actions

	STRATEGIES	GOALS: Enhance stormwater runoff management	GOALS: Protect and enhance drinking water quality	GOALS: Restore impaired biological communities	GOALS: Maintain and enhance recreational opportunities	PARTICIPATING ORGANIZATIONS: Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company	SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
1.	**Promote the use of BMPs to reduce nutrient and sediment loading**																				
1.1	Implement identified structural BMPs in the Windmill Lakes neighborhood (subwatersheds 64 and 1)	x	x	x	x	x			x				x						Pilot (1-5 yrs)	Year 1: Define goals and obtain letters of support from private landowners and NYSDOT where applicable; obtain funding; Year 2: Select consultant and complete detailed design; Year 3: Complete construction; Year 4-5: Conduct monitoring at basin inflow and outflow points, and evaluate functionality.	Modeled N, P, TSS, and bacteria load reductions; Treated impervious acres
1.2	Implement identified structural BMPs in Banksville Center	x	x	x	x	x	x		x				x						Pilot (1-5 yrs)	Year 1: Define goals and obtain letters of support from private landowners, public agencies, and CTDOT where applicable; obtain funding; Year 2: Select consultant and complete detailed design; Year 3: Complete construction; Year 4-5: Conduct monitoring at basin inflow and outflow points, and evaluate functionality.	Modeled N, P, TSS, and bacteria load reductions; Treated impervious acres
1.3	Develop rain barrel/rain garden incentive program for homeowners and commercial properties	x	x	x	x	x						x	x	x					Pilot (1-5 yrs)	Year 1: Define goals and strategies of rain barrel program, and obtain funding; Year 2: Purchase pilot rain barrels, and initiate outreach; Year 2-4: Create incentive program and expand outreach to homeowners and commercial properties within target subwatersheds; Year 5: Install 50 or more rain barrels or similar devices for rainwater harvesting watershed-wide.	Numbers of residential rain barrels installed; Treated impervious acres
1.4	Develop nutrient management incentive program for homeowners		x	x	x	x						x	x	x			x		Pilot (1-5 yrs)	Year 1: Define goals and strategies of nutrient management program; Year 2: Initiate outreach to streamside homeowners; Year 2-4: Create incentive program and expand outreach to all homeowners in pilot area; Year 5: Recruit 50 or more homeowners to commit to sustainable nutrient management practices.	Number of homeowners committed to sustainable nutrient management; Estimated N, P, TSS, and bacteria load reductions
1.5	Support the installation of structural BMPs to mitigate runoff, erosion and sedimentation from the Mianus River Park Parking Lot	x	x			x							x						Pilot (1-5 yrs)	Year 1: Define project scope and identify funding; Year 2-4: Project design and installation; Year 5: evaluate successes related to reduced sedimentation and erosion adjacent to the parking lot.	Modeled TSS load reductions; Treated impervious acres

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1.6	Develop an inventory of publicly owned lands suitable for implementation of specific structural BMPs	x	x			x							x						Pilot (1-5 yrs)	Year 1: Obtain property records and conduct desktop assessments of all public properties within the watershed for drainage direction and available open space; Year 2: Prioritize sites based on feasibility, and conduct field assessments to determine drainage areas and need for additional piping; Year 3: Develop costs for each proposed BMP, and prioritize by cost per square foot of impervious managed.	Number of properties assessed; feasibility of proposed BMPs
1.7	Implement approriate structural BMPs to treat stormwater unoff from I-95 prior to discharge into Strictland Brook	x		x	x	x				x	x		x						Pilot (1-5 yrs)	Year 1: Identify appropriate structural BMP based on site contrainsts and potential costs; Year 2: Define goals and obtain letters of support from private landowner and public agencies where applicable; obtain funding; Year 3: Select consultant and complete detailed design; Year 4: Complete construction; Year 5: Conduct monitoring at basin inflow and outflow points, and evaluate functionality.	Modeled N, P, TSS, and bacteria load reductions; Treated impervious acres
1.8	Work with municipalities and local business owners to address problem areas associated with construction yards adjacent to the river, particularly in the Banksville area		x	x	x	x	x	x					x		x				Mid-term (5-10 yrs)	Using aerial imagery, identify all barren parcels adjacent to the river; Obtain contact information for property owners and reach out via local community members and business leaders; Develop non-regulatory solution to manage erosion and pollution sources.	Parcels identified; Property owners contacted; Number of owners committed to sustainable land management
1.9	Promote the use of bioretention along state and local roads	x	x						x	x	x		x						Mid-term (5-10 yrs)	Create an inventory of degraded roadside wetlands in the watershed, and present to DOTs and municipalities; Conduct a drive-through assessment of roadside sites for proposed bioretention (aerials may not be useful); Partner with DOTs and municipalities to establish guidelines for new roads and maintenance/repair of existing roads.	Acres of the watershed assessed for new bioretention; Number of roadside wetlands surveyed.
1.10	Implement remaining identified structural BMPs (Appendix A), and identify additional sites for BMPs	x	x	x	x	x	x						x	x					Long term (5-20 yrs)	Obtain additional funding; Implement BMPs sequentially in subwatershed 19, subwatershed 62, subwatershed 7, and subwatershed 18; Conduct survey for additional BMPs and continue to implement as funding allows.	Modeled N, P, TSS, and bacteria load reductions; Treated impervious acres

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2. Avoid future increases in stormwater-related impacts through LID based policies and stormwater ordinances																					
2.1	Conduct a conservation audit of existing municipal regulations and standards to identify barriers to implementation of LID elements (Bedford, North Castle, Pound Ridge, Stamford, Greenwich)	x	x			x	x	x					x	x	x				Pilot (1-5 yrs)	Year 1: Determine code sections for comparison (setbacks, buffers, lot size/density, street width, parking, stormwater management, LID provisions, etc.; Year 2: Review code; Year 3-5: Complete evaluation.	Number of watershed municipalities evaluated (target = 5)
2.2	Work with headwater municipalities (Bedford, Pound Ridge, and North Castle) to develop and adopt progressive LID based land use, stormwater and zoning regulations as identified in the conservation audit (see 2.1)	x	x			x	x						x						Pilot (1-5 yrs)	Year 1: Establish minimum stormwater controls, including controls for water quality and channel protection for new development and redevelopment (see 2.6); Year 2: Develop planning-level LID guidelines for new development, to include incentives for clustered development and limiting sprawl, narrower road widths, and smaller parking spaces; Year 3: Strengthen residential regulations/incentives related to riparian buffers and setbacks, and near-stream construction; Year 4-5: Enforce ordinances as needed.	Number of watershed municipalities implementing controls (target = 5)
2.3	Promote reduction of rooftop runoff with residential LID program	x	x			x	x			x		x	x			x	x		Pilot (1-5 yrs)	Year 1: Define goals and strategies of residential LID program and secure funding; Year 2: Purchase pilot rain barrels, or other simple BMP tools, and initiate outreach to owners of the 100 largest homes (by footprint); Year 2-4: Create incentive program and expand outreach to all homeowners in a single subwatershed; Year 5: Establish 50 or more LID sites within a target subwatershed, and begin to expand the program to additional target subwatersheds.	Numbers of residential sites committed to an LID approach to managing rooftops
2.4	Incorporate LID approaches into municipal improvement projects/construction	x	x								x	x	x						Mid-term (5-10 yrs)	Where pavement improvements are needed in low-traffic areas, replace traditional pavement with a porous alternative; Encourage external roof leaders for new buildings; Redirect pipes/outfall structures to bioretention areas.	Number of maintenance/construction projects incorporating LID techniques
2.5	Encourage LID approaches for all new development initiatives and major renovations to ensure no net increase in runoff	x	x	x	x						x		x				x		Mid-term (5-10 yrs)	Establish volume and minimum disturbance criteria for residential and non-residential projects; Establish design criteria water quality and channel protection using CTDEEP's Stormwater Design Manual as a starting point; Build support for increased regulations at the municipal level.	Number of watershed municipalities implementing controls (target = 4)

Table 14. Implementation of Management Goals, Strategies, and Actions

STRATEGIES		GOALS: Enhance stormwater runoff management	GOALS: Protect and enhance drinking water quality	GOALS: Restore impaired biological communities	GOALS: Maintain and enhance recreational opportunities	PARTICIPATING ORGANIZATIONS: Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company	SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
2.6	Create watershed overlay district with consistent regulations and guidelines among the watershed municipalities	x	x	x	x	x	x						x	x					Long term (5-20 yrs)	Outline consistent approach to MS4 compliance for watershed municipalities; Establish minimum stormwater and LID controls, and achieve consensus among municipalities.	% MS4 compliance; % adoption of overlay
3. Define and remediate potential bacterial impairments within the Mianus River Watershed and improve riparian habitat																					
3.1	Identify and map the sources of potential bacterial impairments in the watershed.		x		x	x							x	x					Pilot (1-5 yrs)	Year 1-3: Beginning in subwatersheds with high bacteria load reduction targets (particularly 18, 19, 61, and 62), conduct detailed water quality sampling; Year 4-5: Evaluate potential remediation measures and develop an implementation plan.	Total area assessed; number of sites samples; number of impairments identified
3.2	Establish identified buffers in the Pine Ridge neighborhood in Greenwich (subwatershed 19), and at Riverbank Road in Stamford (subwatershed 62)	x	x	x	x	x		x					x						Pilot (1-5 yrs)	Year 1: Obtain letters of support from landowners, and establish permitting/design needs; Sample downstream water quality for bacteria; Year 2: Select consultant, as necessary, and complete design; Year 3: Complete construction; Year 4-5: Monitor water quality and goose populations, and complete analysis.	Total area of buffers established; before and after monitoring; Treated impervious acres; Estimated bacteria load reduction
3.3	Assess contribution, if any, of leaking septics to overall bacteria load, and develop a mitigation plan as needed		x		x	x	x					x	x						Pilot (1-5 yrs)	Year 1: Target properties for assessment based on spatial analysis of sewer type, soil type, depth to bedrock, proximity to stream, age of development, and additional municipal records as applicable; Year 2-3: Conduct visual assessment during stream walks; Year 4-5: Conduct targeted water quality monitoring based on visual/spatial assessment results, and develop a mitigation plan based on results.	Number of parcels assessed
3.4	Significantly reduce nesting populations of non-migratory geese		x		x				x	x		x	x					x	Pilot (1-5 yrs)	Year 1: Implement stream buffers wherever possible to limit access to open water habitat; Year 2: Define additional acceptable strategies for management as needed (controversial options include hunting, harassment by dogs, and limiting the viability of eggs);	number of sites addressed; estimated number of geese

Table 14. Implementation of Management Goals, Strategies, and Actions

	STRATEGIES	GOALS				PARTICIPATING ORGANIZATIONS													SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
		Enhance stormwater runoff management	Protect and enhance drinking water quality	Restore impaired biological communities	Maintain and enhance recreational opportunities	Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company			
3.5	Conduct a detailed riparian buffer assessment and prioritize additional areas for restoration	x	x	x		x		x					x		x				Pilot (1-5 yrs)	Year 1: Create GIS database with all known unbuffered segments; Year 2: Prioritize buffers based on potential indicator bacteria load reductions; Year 3-5: Implement outreach campaign for streamside homeowners to encourage volunteer work and identify potential buffer areas on private land.	Square feet of additional unbuffered areas identified; Square feet of buffers constructed; Estimated bacteria load reduction
3.6	Update mandatory minimum setback requirements for septic systems in the Town of Greenwich and the City of Stamford		x		x								x						Pilot (1-5 yrs)	Year 1: Review applicable state health code and other county or municipal regulations for septic system setbacks from streams; Year 2: Update regulations as needed to establish stringent minimum separating distances of septic systems from streams	Regulations updated (yes/no)
3.7	Evaluate results of task 3.1 and, as needed, prevent or reduce incidence of leaking septics on private property		x		x							x	x						Mid term (5-10 yrs)	Implement leaking septic mitigation plan established during pilot phase through outreach, enhanced inspections, and/or incentive/cost share programs; Establish a municipal monitoring program for residential and commercial properties.	Number of failing systems identified and replaced
3.8	Maximize adoption of minimum buffers on remaining private properties (see task 8.1)		x		x		x						x	x			x		Mid term (5-10 yrs)	Create GIS database with all known unbuffered segments and prioritize buffers based on indicator bacteria load reductions; Implement outreach campaign for streamside homeowners to encourage volunteer work; Modify development code if necessary, to create minimum buffer requirements, and create incentive/stewardship program to encourage buffers.	Square feet of additional unbuffered areas identified; Square feet of buffers constructed
3.9	Develop pet waste management program for public recreation sites		x		x	x		x				x	x		x				Mid term (5-10 yrs)	Outline goals and strategies of program, and inventory existing outreach/incentives; Select public sites, and define solutions (signage, baggies, etc.); Deploy outreach/incentive strategies at selected sites, and establish enforcement measures.	Estimated number of dog owners reached; Number of sites selected for management; Estimated bacteria load reduction
3.10	Conduct long-term monitoring for indicator bacteria below the S.J. Bargh Reservoir (see also 4.3)		x		x	x		x		x					x			x	Long term (5-20 yrs)	Establish methodology and select additional parameters if necessary; Select monitoring sites and schedule; Establish partnership to conduct data collection	Number of sites monitored; Consistency of method

Table 14. Implementation of Management Goals, Strategies, and Actions

	STRATEGIES	GOALS: Enhance stormwater runoff management	GOALS: Protect and enhance drinking water quality	GOALS: Restore impaired biological communities	GOALS: Maintain and enhance recreational opportunities	PARTICIPATING ORGANIZATIONS: Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company	SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
4.	**Establish a long term water quality monitoring program**																				
4.1	Develop a monitoring program for select headwater streams, and identify funding (see also 8.9 and Chapter 9)		x			x	x		x					x	x			x	Pilot (1-5 yrs)	Year 1: Develop a 5-year plan for monitoring, and work with municipalities and NGOs to incorporate funding for water quality monitoring into annual budgets; Year 2: Select sites and constituents; Years 3-5: Engage laboratory, consultants, and volunteer groups and establish monitoring for selected headwater streams; Year 5: Analyze program results and determine further needs.	Number of sites monitored for bacteria, N, P, TSS, and additional constituents if necessary; Consistency of method.
4.2	Work with municipalities and NGOs to incorporate funding for water quality monitoring into annual budgets		x			x	x	x					x	x	x				Mid-term (5-10 yrs)	Review available funding sources and apply for grants (see appendix B); consider allocating an annual sum as part of general municipal operations	Amount of funding secured
4.3	Expand monitoring to include additional sites as needed; maintain data online via a live-streaming map application (see also 3.10 and Chapter 9)		x			x	x	x						x	x			x	Long term (5-20 yrs)	Select additional headwater streams and segments lower in the watershed for monitoring, as needed; Extend headwater monitoring program to incorporate additional segments; Provide data online using interactive mapping tools.	Number of sites monitored for bacteria, N, P, TSS, and additional constituents if necessary; Consistency of method; Numbers of volunteers engaged.
5.	**Maintain & improve in-stream flows**																				
5.1	Adopt and implement CT streamflow standards			x	x		x			x			x		x			x	Pilot (1-5 yrs)	Year 1: Classify the river per CT streamflow standards and establish baseline habitat conditions below the S.J. Bargh Reservoir; Year 2: Adopt standards through a public participation process; Year 3: Implement standards and update reservoir release schedule as needed; Year 4-5: Monitor downstream habitat and record changes from baseline (see 5.4 and 5.5).	Standards are adopted and implemented (yes/no)
5.2	Conduct an in-stream flow assessment above the S.J. Bargh Reservoir to better understand impacts related to private well withdrawals, and establish consumptive use targets as necessary			x	x		x						x		x			x	Pilot (1-5 yrs)	Year 1-2: Review withdrawal permits, and estimate private well consumption; Year 3: Install stream gages; Year 4: Model system to determine extent of habitat impairment and flow required to improve conditions; Year 5: Establish flow criteria and develop plan for meeting future goals.	Acres of watershed area modeled; Miles of infrastructure assessed.

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5.3	Conduct a feasibility study to quantify the degree and causes of impairments to the Mianus Mill Pond and evaluate restoration and mitigation options		x	x	x					x			x					x	Pilot (1-5 yrs)	Year 1: Convene stakeholders and technical experts, including Aquarion Water Company, CT Department of Public Health, CTDEEP, the Town of Greenwich, the U.S. Army Corps of Engineers, and adjoining property owners; Year 2: Collect water quality samples under wet-weather and dry-weather conditions, and evaluate bacteria and dissolved oxygen constituents against state standards; Year 3: Conduct a biotic assessment of indicator species to determine the effect of sediment and nutrient loading on aquatic life; evaluate cost/feasibility of potential management actions.	Water quality parameters sampled; Number and variety of management options assessed
5.4	Conduct an in-stream flow assessment below the S.J. Bargh Reservoir to determine if adoption of CT streamflow standards has improved in-stream habitat conditions (see 5.1)			x	x		x						x		x			x	Mid term (5-10 yrs)	Assess habitat below the S.J. Bargh Reservoir both before and after CT streamflow standards have been implemented; Complete hydraulic and hydrologic study of the reservoir system, and install stream gages.	Acres of watershed area modeled; Miles of infrastructure assessed.
5.5	Address in-stream flow conditions through adaptive management of drinking water resources			x	x	x	x	x		x			x		x			x	Mid term (5-10 yrs)	Tie withdrawal permits to consumptive use limits; Implement changes to the reservoir release program in accordance with in-stream flow targets; Monitor downstream habitat features and target species populations and continue to revise/refine release regime and withdrawal limits accordingly.	Flow (cfs) and timing of release schedule; miles of in-stream habitat improved; number of target individuals counted

6. Reduce the impact of small dams and impoundments through barrier mitigation

STRATEGIES		GOALS: Enhance stormwater runoff management	GOALS: Protect and enhance drinking water quality	GOALS: Restore impaired biological communities	GOALS: Maintain and enhance recreational opportunities	PARTICIPATING ORGANIZATIONS: Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company	SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
6.1	Develop barrier mitigation master plan to evaluate and prioritize barrier removals/retrofits in terms of migration barriers, river flow/flooding, and impacts to water quality			x	x	x	x		x	x					x				Pilot (1-5 yrs)	Year 1: Enter known culvert and dam locations into GIS, and establish further needs; Year 2: Collect remaining data through streamwalk assessments; Year 3: Develop mitigation plan and establish monitoring program/criteria; Year 4-5: Remove or retrofit 1-2 high priority structures (i.e. fishways and other bypass structures).	Number of barrier sites assessed; number of removals or retrofits conducted
6.2	Retrofit raised culverts, install fish passage structures, and remove small dams where feasible			x	x	x	x		x	x	x		x		x			x	Mid term (5-10 yrs)	Obtain additional funding; Conduct owner outreach to residential and commercial properties adjacent to target barriers identified in the mitigation plan; Obtain fish ladders/counters; Partner with CTDOT to address eventual replacement of culverts and small dams under their control.	Fish counted on an annual basis; Miles of potential connected habitat

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7. Manage the impacts of recreational activity on natural lands and aquatic resources along the Mianus River Greenway and the Mianus River Gorge																					
7.1	Create a monitoring-driven adaptive management plan for all parks, conservation areas, and preserved open spaces, to include trail master planning		x	x	x	x	x	x		x				x		x			Pilot (1-5 yrs)	Year 1: Convene task force to include recreational users, pet owners, and environmental advocates and identify a phased approach to address all potential lands; Year 2: Develop monitoring plan to quantify how recreational use is impacting environmental resources; Year 3: Establish multi-use goals and strategies for implementation, building on the 2006 *Mianus River Park Action Plan* ; Year 4-5: Implement preliminary management actions and initiate follow-on monitoring.	Variety of interests represented by task force; Number and specificity of monitoring criteria; consistency of monitoring methodology
7.2	Work to have the designations of the three northern parcels of Mianus State Park (Blake Coleman, Upper Mianus, Lower Mianus) changed to implement conservation efforts and minimize recreational uses in sensitive habitats		x		x	x	x			x									Pilot (1-5 yrs)	Year 1-3: Build residential and municipal support via education and outreach campaigns geared toward communicating the non-recreational value of sensitive areas.	Number of parcels re-designated (target = 3)
7.3	Modify trail system to maximize habitat and recreational value using a regenerative design approach		x	x	x	x	x	x						x					Pilot (1-5 yrs)	Year 1: Identify ecological and recreational resources, and define design agenda to allow for multiple uses; Year 2: Select landscape architect to mediate a community-driven design process; Year 3-4: Complete design and build structural features; Year 5: Establish plan for volunteer maintenance and monitoring.	Number of stakeholders supporting plan; Number of attendees at community meetings; Multiple uses addressed by design
7.4	Address problem areas at the River Road parking lot, including bank erosion, loss of riparian vegetation, and sedimentation	x	x	x		x		x											Pilot (1-5 yrs)	Year 1: Evaluate options to stabilize riparian zone; Year 2: Select measures and complete design/engineering plan, if necessary; Year 3-5: Install stabilization measures.	Length of bank protected/stabilized
7.5	Continue to support implementation activities identified in the 2006 *Mianus River Park Action Plan* ; in the *Mianus River Park Management Plan* (under development 2012); and additional targeted restoration throughout the watershed		x		x			x				x			x				Mid-term (5-10 yrs)	Track status of recommendations and monitor outcomes; Recruit volunteers for management activities; Publicize activities via multiple media outlets (see Chapter 8).	Number of identified activities implemented/supported

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7.6	Establish long-term management policies, and implement additional structural features as needed to achieve identified goals for the greenway				x	x	x	x											Long term (5-20 yrs)	Continue and expand outreach activities such as stewardship events, ambassador program, and signage improvements (see *Mianus River Park Action Plan*); Enforce correct use policies.	Number of events and audience reached; number of complaints regarding improper use

8. Encourage better stewardship of public and private lands by implementing education and outreach programs for landowners and municipal officials

	STRATEGIES	Enhance stormwater runoff management	Protect and enhance drinking water quality	Restore impaired biological communities	Maintain and enhance recreational opportunities	Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company	SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
8.1	Develop a series of workshops for developers, engineers, land use attorneys and property owners to encourage watershed-friendly yard design and management		x			x	x					x	x		x	x	x		Pilot (1-5 yrs)	Year 1: Establish goals, target audience, content, and schedule; Year 2: Hold first workshop with attendance by 20-30 members of the target audience; Year 3-5: Reach additional audience through partnerships with local neighborhood organizations and civic groups (two workshops per year with similar attendance).	Number of events and audience reached
8.2	Develop a training series for municipal officials, boards, and commissions to encourage LID and other strategies facilitating MS4 compliance		x			x	x					x					x		Pilot (1-5 yrs)	Year 1: Establish goals, target audience, content, and schedule; Year 2: Hold first LID workshop with attendance by municipal officials (Stamford, Greenwich, North Castle, Pound Ridge, and Bedford municipalities represented); Year 3-5: Develop additional workshop content and continue to schedule events (2 per year).	Number of events and audience reached
8.3	Conduct email & social media campaigns to encourage stewardship of private property		x			x	x					x	x						Pilot (1-5 yrs)	Year 1: Define message and target audience/s and obtain contact information; Year 2: Obtain web/social marketing consultant to develop graphics, refine message, and deploy campaigns (may be useful to deploy in conjunction with public service announcements)	Number of watershed citizens reached
8.4	Promote roadway and parking lot "good housekeeping" practices to Public Works, Parks Departments, and Boards of Education to maintain watershed friendly operations and practices		x			x	x					x	x		x				Pilot (1-5 yrs)	Year 1: Establish interdepartmental municipal task force; Year 2: Develop employee training modules for fleet and building maintenance, sand usage and cleanup, catchbasin cleaning and retrofitting, landscape maintenance, and proper waste disposal; Year 3-5: Conduct training sessions.	Number and completeness of training modules (see EPA guidelines for Good Housekeeping); Number of events and audience reached

Table 14. Implementation of Management Goals, Strategies, and Actions

	STRATEGIES	GOALS: Enhance stormwater runoff management	GOALS: Protect and enhance drinking water quality	GOALS: Restore impaired biological communities	GOALS: Maintain and enhance recreational opportunities	PARTICIPATING ORGANIZATIONS: Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company	SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
8.5	Organize and promote priority stream-side clean up efforts			x	x	x	x	x						x	x				Pilot (1-5 yrs)	Year 1: Select cleanup sites in conjunction with multiple other activities (gateways, ribbon cuttings, demonstration sites); Year 2: Partner with corporate human resource departments to obtain volunteers, and schedule multiple events within a single subwatershed.	Number of events conducted; Number of volunteers recruited
8.6	Develop programs to encourage better management of small ponds and impoundments.		x	x		x							x		x				Mid-term (5-10 yrs)	Select target sites; Advocate for stream buffers, dam removal where appropriate, goose management, and reductions in fertilizer use; Offer training for property owners (see 8.1); Provide free labor in the form of volunteer work days/cleanups, etc.	Number of properties committed to improving management techniques; Number of dams removed; Estimated N, P, and bacteria load reductions.
8.7	Develop programs to promote sustainable management at golf courses, nurseries, and horse farms	x	x	x	x	x	x					x	x						Mid-term (5-10 yrs)	Select sites for outreach; Produce a brochure for golf course and nursery managers (information on stream buffers, soil testing, organic fertilizing practices, and goose management); Produce a brochure for managers of horse farms (information on stream buffers, grazing practices, manure removal/covering, and goose management); Partner with trusted community members to conduct personal outreach at select sites.	Number of properties committed to improving management techniques; Estimated N, P, and bacteria load reductions.
8.8	Implement a "neighborhood-by-neighborhood" approach for restoration of stream reaches	x	x	x	x								x						Mid-term (5-10 yrs)	Define target residential neighborhoods adjacent to the stream; Conduct outreach via social and recreational programs; Recruit homeowners to "sponsor" buffer restoration and plantings on their property; Schedule additional education and outreach events related to lawn care, pet waste, and septics.	Number of restorations implemented; Estimated N, P, and bacteria load reductions.
8.9	Engage volunteers in monitoring tasks (see also 4.1)		x			x	x			x			x		x				Long term (5-20 yrs)	Establish task force to oversee volunteer effort; Recruit volunteers for stream walks, septic monitoring, fish and benthic surveys, habitat assessment, and other tasks as appropriate.	Hours of volunteer service secured; Number of volunteers

Table 14. Implementation of Management Goals, Strategies, and Actions

	STRATEGIES	GOALS: Enhance stormwater runoff management	GOALS: Protect and enhance drinking water quality	GOALS: Restore impaired biological communities	GOALS: Maintain and enhance recreational opportunities	PARTICIPATING ORGANIZATIONS: Mianus River Watershed Council	Mianus River Gorge Preserve	Friends of Mianus River Park	NYSDEC	CTDEEP	NYSDOT/CTDOT	Southwest CT Conservation District	Mianus Municipalities	Mianus Land Trusts	Trout Unlimited	UConn Cooperative Forestry Extension	UConn CLEAR and NEMO	Aquarion Water Company	SCHEDULE	INTERIM MILESTONES	PERFORMANCE CRITERIA
9. Pursue strategic land acquisition to protect headwater streams and promote greenway expansion																					
9.1	Fund and support implementation of the Mianus River Greenway Priority Properties to Protect report		x		x	x	x	x					x	x					Pilot (1-5 yrs)	Year 1: Obtain funding; Year 2: Make contact with owners of all priority properties; Year 3: Further prioritize the list by feasibility/owner support; Year 4: Acquire properties where possible, and continue to monitor ownership.	Priority acres protected
9.2	Continue acquisition activities to support headwater and greenway protection		x		x	x	x	x					x	x				x	Mid-term (5-10 yrs)	Monitor sale properties, particularly those identified as conservation targets; Maintain contact with land owners; Continue to secure funding opportunities and acquire property as funding allows.	Priority acres protected
9.3	Building on existing regulation in several watershed municipalities (see also 2.2), develop a "conservation bank" program for new development in the watershed		x			x	x	x		x			x	x		x			Long term (5-20 yrs)	Create scoping document to assess financial feasibility and to define oversight and legal requirements; Modify code at the watershed scale to include bank offsets in permitting for new development; Establish incentives/assistance/recognition to encourage early adoption by developers.	Number of transactions conducted; Acres of land preserved
10. Implement the Plan and monitor outcomes																					
10.1	Identify funding for a program coordinator to aid in implementation of the Plan.	x	x	x	x	x	x			x			x						Pilot (1-5 yrs)	Year 1: Review available funding sources (Appendix B) and apply for grants; Year 2: Select coordinator and prioritize tasks; Year 3-4: implement programs and demonstrate successes; Year 5: obtain long-term financial support for the position from municipalities and NGOs.	Amount of funding awarded
10.2	Review the Plan every 5 years, evaluating successes and lessons learned. Revise and update the Plan as necessary	x	x	x	x	x	x			x			x						Long term (5-20 yrs)	Formally initiate a plan review and evaluation in year 4 of each 5-year cycle; At the end of the 5-year cycle, update and revise the Plan as necessary. If at any time based on monitoring data conditions of the watershed dramatically change the Plan should be adapted to current conditions.	All above

Emphasizing Best Management Practices

Whether it is building a stormwater rain garden that manages urban runoff, working with a hobby farm owner to install livestock fencing, or teaching a homeowner how to properly care for a septic system, the core approach to implementation involves putting in place BMPs that result in measurable reductions in or prevention of NPS pollution. BMPs include a range of project types that reduce NPS pollution and other negative effects of unmanaged stormwater runoff. For the purposes of this Plan, BMPs are categorized as either structural or non-structural BMPs. Structural BMPs refer to physical, site-specific pollution reduction projects that include rain gardens, porous pavement, livestock fencing, and constructed wetlands as well as stream restoration and riparian buffering. Equally important, non-structural BMPs are changes in behavior that result in NPS pollution reduction at its source, leading to protection and improvement of water resources. These include reductions in fertilizer use, proper septic system maintenance, and proper disposal of pet waste.

As part of an NPS reduction plan, the management actions presented in Table 14 rely heavily on a broad range of structural and non-structural BMPs. In addition, 13 site-specific structural BMPs are recommended and described in Chapter 7 (Table 19). Most of these BMPs were selected through a process of desktop identification and field vetting. Appendix A contains detailed site descriptions, costs, photos, and feasibility constraints associated with 11 of the identified site-specific structural BMPs. Two additional areas were identified by stakeholders for further analysis and potential structural BMPs (BMPs L and M in Table 19).

Plan Phasing

Although full Plan implementation will likely require 20 or more years, the Plan emphasizes the use of interim milestones, including an initial five year pilot phase, to ensure consistent progress. The first five year implementation period will lay the foundation for future success through a combination of strategic planning, outreach, and small-scale management actions designed to test and demonstrate a long-term approach. As early success is crucial, short-term programs with clearly defined objectives may have a higher likelihood of success. This pilot phase is intended to be a testing, incubation, and capacity-building period in which small, manageable activities are implemented. Such actions may be single structural BMPs, or outreach activities such as training events or marketing programs. Once these smaller actions have been completed, typically near the end of the five year term, monitoring and assessments will provide a better understanding of which approaches need to be repeated or expanded to achieve long-term goals, and which need to be refined.

Pilot phase implementation activities may focus on one of the target subwatersheds outlined earlier in this chapter. Implementation of multiple management actions in a single subwatershed during the pilot phase will likely yield the most measurable short-term resource improvements. Once opportunities in a particular subwatershed are exhausted and improvements have been documented, implementation activities can be replicated in other subwatersheds. This method is preferable to a more diffuse approach because it demonstrates a micro-scale version of the full implementation approach, allowing the approach to be tested and refined with limited funding. If a subwatershed-scale effort shows positive outcomes, it follows that similar methods will be successful at larger scales. In addition, this approach allows watershed partners to more powerfully demonstrate the early success that is so critical for building momentum and attracting long-term funding.

At the end of the pilot implementation period, watershed partners should engage in a brief, focused, strategic planning process to outline implementation for the next five-year period. During the 5-to-10-year, mid-term implementation period, successful management actions and approaches may be implemented on a broader scale, within other target subwatersheds. Major follow-on planning activities and pilot-scale implementation activities should be complete, and a clear path to achieving long-term goals may be established. Funding and monitoring goals should be clearly defined for the following 10 years, and refined metrics for measuring success should be put in place.

Long-term (10-to-20 years) planning incorporates the outcomes from the evaluation, planning, and preliminary implementation that occurs during the initial 10-year period. During the long-term implementation period, the pace of implementation is accelerated to reflect the gains in funding, capacity, technical "know how," and successful delivery during the first 10 years of implementation. Long-term management actions and strategies identified in the Plan are designed to be refined based on successes and lessons learned during the pilot and mid-term implementation periods. Accordingly, milestones and schedule are less precisely defined for the long-term implementation period.

Performance Criteria and Adaptive Management

Implementation of the Plan relies heavily on an adaptive management approach through which management actions are continuously refined and improved by evaluating past actions. In accordance with this approach, performance criteria were developed for each management action. In most cases, performance criteria do not represent prescriptive endpoints, but rather provide metrics with which to track outcomes over time. Water quality criteria are suggested generally for common NPS pollutant types (see Chapter 9 for a full discussion of water quality constituents and monitoring methods). In some cases, targets for performance criteria for the pilot phase have been defined (e.g., number of homes implementing rain barrels) though partners may feel free to adjust these targets based on their own resources and funding levels. Whether they adopt the targets set forth in the Plan or adjusted targets, during the pilot phase partners should set realistic goals that have a high likelihood of being achieved. Achieving even modest goals during the initial implementation phase will build momentum and enthusiasm, attract funding, and set the stage for wider implementation. At the end of the pilot phase, management actions implemented in the watershed may be evaluated and priorities for the mid-term phase should be established. Regular evaluations and updates of the Plan will focus efforts and encourage long-term success.

Cost-Effective Implementation

With limited funding available, it is important to select management actions that maximize pollution reduction and other desired benefits while minimizing cost. While simple in concept, cost/benefit analysis can be difficult because of the uncertainty in determining pollution reduction and other benefits, particularly broad initiatives such as outreach programs targeting widespread behavior changes. When selecting structural BMPs, an understanding of unit costs (that is, cost per unit of pollution or unit of stormwater managed) is useful for concept-level planning. Structural BMPs can vary widely in the cost per unit pollutant removed. For instance, highly engineered BMPs such as green roofs have extremely high unit pollutant reduction costs. On the other hand, simple BMPs such as riparian buffers, which require limited engineering and can be installed by volunteers without the use of heavy equipment, tend to have much lower unit costs. Appendix B presents a list of potential watershed funding sources.

Tables 15, 16, and 17 summarize pollutant load reductions associated with many of the management actions recommended in the Plan. Load reductions associated with management actions that remove pollutants at their source are typically presented as absolute values (amount of bacteria kept out of the stream per prevented septic failure, etc.) and are presented in Tables 15 and 16. Structural BMPs function by intercepting stormwater runoff and removing a percentage of pollution from the water captured. For these BMPs, pollution reduction potential is typically presented as a percent reduction, which represents the fraction of pollutants removed from the treated runoff. Pollutant reduction efficiencies for common structural BMP types are presented in Table 17. In addition, literature values are available for some source control activities, such as riparian access control for livestock, and are also presented as percent reductions in Table 17. General ranges for capital and operations and maintenance (O&M) costs for various BMP types are presented in Table 18.

Table 15. Unit Pollutant Load Reductions from Non-Structural Best Management Practices

	Annual Load Reduction[1]			
Pollution Source	**Total N (TN) (lb)**	**Total P (TP) (lb)**	**TSS (lb)**	**Indicator Bacteria (billion cfu)**
One (1) Canada goose	12.05	10.68	N/A	2,660
One (1) dog—	6.72	0.88	N/A	408,800
One (1) malfunctioning septic system—repaired or upgraded	7.48	0.58	23.03	2,611,000
One (1) acre lawn—fertilizer use reduced by 50 percent	18.80	0.38	N/A	N/A

[1]All reductions derived using methodology outlined in Caraco 2002

Table 16. Grouped Pollutant Load Reductions from Non-Structural Best Management Practices

	Annual Load Reduction[1]			
Pollution Source	**TN (lb)**	**TP (lb)**	**TSS (lb)**	**Indicator Bacteria (billion cfu)**
Small flock of geese (10 geese)	120.5	106.8	N/A	26,600
100 people cleaning up after their dogs	672	88	N/A	40,880,000
10 homes conducting annual septic maintenance and repair	74.8	5.8	230.3	26,110,000
10 homes using ½ their normal amount of lawn fertilizer	188	3.8	N/A	N/A

[1]All reductions derived using methodology outlined in Caraco 2002

Table 17. Pollutant Reduction Efficiencies of Structural Best Management Practices

(Norwalk River Watershed Initiative Committee [NRWIC] 2011; Table updated by AKRF in 2012)

		Water quality performance - Percent reductions			
BMP	**Source[2]**	**TSS**	**TN**	**TP**	**Bacteria**
Bioretention	CWP 2007	52	43	22	70
Constructed Wetland	CWP 2007	58	22	45	50
Dry Pond/Extended Detention	CWP 2007	61	25	17	30
Grassed Swale	CWP 2007	85	32	28	0
Riparian buffer	Modeled values (avg)	23	22[3]	23[4]	23
Infiltration	CWP 2007	89	42	65	not available
Livestock Riparian Access Control	Monaghan et al. (2007)	not available	not available	not available	22-35
Green Roof	CWP 2007	-	53	53	-
Porous Pavement	CWP 2007	90	70	48	70
Rain Barrel	CWP 2007	-	40	40	-
Wet Pond	CWP 2007	76	30	48	70

[1] Norwalk River Watershed Plan, 2011 (table 6-4)

[2]CWP (2007) National Pollutant Removal Performance Database (NRPRD): Version 3, 2007; median values. For permeable pavement, used infiltration practice data. Values are generally mass or load-based measurements of efficiency; NYSDEC Manual (2010): Just "phosphorus" and "nitrogen" are listed. Indicator bacteria is lumped; NYSDEC (2001) Table A.4 is from Appendix A of the 2001 manual. This appendix and table were removed in subsequent versions (2003 onward); CWP (2005) MD guide: A User's Guide to Watershed Planning in Maryland, CWP. Dry pond value assumes extended detention. For permeable pavement, used infiltration practice data; CWP (2008), Runoff Reduction Method (referred to as RR memo), CWP Runoff Reduction Method, 2008. Values are mean for Total Removal (considers change in concentration and volume).

[3]Values as NO_3, not TN

[4]Values as particulate P, not TP

Table 18. Capital and Operations and Maintenance Costs of Best Management Practices

(NRWIC 2011; Table updated by AKRF in 2012)

BMP	Unit	Capital Cost per unit ($)	O&M Cost per unit ($)
Wet Pond	Cubic Feet	5.1–8.5	0.9–1.5
Dry Pond	Cubic Feet	2.6–6.8	0.4–1.2
Bioretention	Cubic Feet	8–20	2–5
Riparian buffer[1] (grass)	Square Feet	0–.01	N/A
Infiltration[2]	Cubic Feet	5	2
Reforestation	Planted Tree	328	N/A
Rain Barrel	Gallon	7-8	-
Porous Pavement	Square Feet	6.2	0.8
Grassed Swale	Square Feet	0.56	0.2
Green Roof	Square Feet	20–28	5–7
Illicit Discharge Detection & Elimination	per program	$23,300-101,200 Initial Cost;	$43,000-126,500 Annual Cost;
Septic maintenance[3]	Per household	-	$1,500 to 4,000
Downspout disconnection[3]	Per household	$150 to 400	-
Livestock Riparian Access Control			
Education and outreach[3]	Per program	Cost will vary significantly--examples include: $2,000 for advertising campaigns to in excess of $500,000 for a full program involving brochures, advertising, surveys, etc.	-

All PlaNYC (2008)except where otherwise noted
[1]EPA 2004, Chapter 6
[2] Maryland Cooperative Extension, Fact Sheet 774
[3] NRWIC 2011

CHAPTER 7 STRUCTURAL BEST MANAGEMENT PRACTICES

The management actions presented in Chapter 6 describe discrete steps required to achieve the Plan's management goals. Several of these management actions involve the design and construction of structural BMPs. This chapter identifies 11 structural BMPs that were identified and field-vetted during Plan development as potential first steps toward meeting the Plan's pollution-reduction targets. Feasibility was evaluated for each BMP through a desktop and field assessment process, which is described later in the chapter. Estimated costs, load reductions, and engineering feasibility considerations associated with each BMP are presented in Appendix A. Two (2) additional sites were later identified by stakeholders for structural BMPs.

The structural BMPs described in this chapter do not represent an exhaustive list of opportunities in the watershed. In fact, they probably represent a fairly small percentage of the total number of opportunities in the Mianus River Watershed. The structural BMPs identified do, however, represent some of the most compelling and cost effective opportunities that were identified during a formal desktop and field assessment process, and through input of the watershed community. In many cases, the structural BMPs identified represent a prototypical project type that could be replicated in other similar sites throughout the watershed.

Structural BMPs identified in this chapter are primarily geared toward achieving measurable pollution reduction goals. However, most BMPs can be designed to provide for multiple benefits. Meadow plantings in large extended detention areas can improve habitat for birds and small mammals. Rain gardens in public spaces can improve site aesthetics and, with some signage, become highly visible demonstration sites. BMPs constructed at or near schools can be planted and maintained by students, providing a unique extension of typical earth sciences coursework. In this way, the BMPs proposed here can be implemented in conjunction with multiple other management actions related to education and citizen science, habitat, and promoting LID in the watershed.

Descriptions for each structural BMP are presented in Appendix A, and include:

- BMP type;
- Subwatershed;
- Order-of-magnitude cost estimate;
- Potential benefits;
- Probable permitting requirements;
- Site access;
- Ownership;
- Other constraints;
- Context and rationale;
- Existing conditions; and
- Design approach and feasibility.

STRUCTURAL BEST MANAGEMENT PRACTICE IDENTIFICATION

Structural BMPs (Table 19, Figure 11) were identified within target subwatersheds through a process of desktop reconnaissance, field investigations, and stakeholder input. The process of identifying target subwatersheds is described in detail in Chapter 6.

Desktop Analysis

A desktop analysis was used to identify feasible, low-cost and high-benefit pollutant reduction BMP opportunities located in target subwatersheds. Areas were flagged for further investigation if they exhibited any of the following characteristics:

- Large, unused open spaces adjacent to and downslope from developed areas;
- Existing stormwater management basins;
- Road crossings where, based on topographic contours and adjacent land use, road runoff appears to discharge into the stream;
- The potential for unstable stream reach locations based on land cover change over the past 26 years (based on data from the UConn CLEAR program);
- Denuded riparian buffers, particularly within high nutrient and sediment loading land uses such as golf courses and farms;
- Public lands such as schools, parks, and public golf courses with potentially available open space that could be used for stormwater treatment and demonstration BMPs; and
- Privately owned open spaces located downslope of significant developed areas.

Field Vetting

To further vet structural BMP opportunities, visual field assessments were conducted at areas identified during the desktop assessment. Investigations were conducted on June 8, 16, and 17, 2011. The primary purpose of the field assessment process was to refine the type, location, and extent of pollutant reduction measures and to collect site-specific data pertaining to constraints, feasibility, cost, and benefit. Information relating to the following features was collected at most sites:

- Existing infrastructure (conveyance, existing stormwater controls, presence of non-stormwater infrastructure, potential inflow and outflow locations);
- Site topography;
- Drainage characteristics;
- Land cover and use;
- Property ownership;
- Extent, nature, and location of pollutant sources or other issues;
- In-stream habitat and physical conditions;
- Existing uses and/or structural, regulatory, or infrastructural constraints; and
- Upstream/downstream conditions within the subwatershed.

Structural BMPs Identified by Stakeholders

In addition to the 11 structural BMPs identified through the process described above, two (2) BMPs were suggested by members of the steering committee. Described in detail below, these

BMPs respond to site-specific problems identified by members of the local community. Table 14 includes management actions associated with these BMPs; however, costs, load reductions, and detailed descriptions are not provided in Appendix A due to some uncertainty regarding scope of these BMPs.

River Road Pull-Offs

Several shoulders along River Road near Mianus River Park, used as pull-offs for fishing access, were identified by stakeholders as a source of NPS pollution. This section of River Road runs directly adjacent to the River with little or no buffer between the road and the river. Overuse along the river bank has led to erosion and loss of riparian vegetation, which in turn result in deposition of sediment and road gravel into the Main Stem of the Mianus River. The addition of new pull off areas and unrestricted vehicle access have led to concerns from the Mianus River Watershed Council that conditions may further deteriorate unless problem areas are addressed. Additionally, a culvert that connects an existing wetland to the river is clogged.

Stakeholders have been working with the Town of Greenwich to address this problem. Several potential solutions are possible. Simply closing the pull-off and redirecting parking to a more suitable parking area may help to alleviate problems at one location, while gravel migration from pull-offs should be stabilized by paving designated pull-off areas or installing structural gravel containment systems such as a Geoweb® system at other pull-off locations. Crib walls, which are log cabin-like structures filled with soil and stone, could be installed along the channel as designated fishing locations to isolate and stabilize use areas. Adjacent stream banks should be planted with riparian vegetation. Connectivity between the wetland and river should be restored by repairing and maintaining the impaired culvert.

The area is referred to as BMP L in Table 19, and recommendations are included in the management actions listed in Table 14.

Mianus Mill Pond

Sediment accumulation within the impounded Mill Pond reach of the Main Stem upstream of the Aquarion Mianus Mill Pond, off Valley Road in Cos Cob has reduced water depths, and the impoundment now routinely experiences significant algal blooms typical of eutrophic (nutrient enriched) conditions. This area was identified by stakeholders as a source of degradation. The reduction in water depth creates conditions that favor excessive plant growth by expanding the area of river bottom available for emergent plant colonization and increasing light available for plant growth.

More information is needed to determine the best course of remedial action. A diagnostic feasibility study should be performed to quantify the degree of and causes for impairment and evaluate restoration options. The study and recommendations should be carefully reviewed by stakeholders and technical experts, including Aquarion Water Company, the CT Department of Public Health, CTDEEP, the Town of Greenwich, the U.S. Army Corps of Engineers, the Mianus River Watershed Council, and adjoining property owners before any corrective steps are taken.

Possible management options could include the installation of a high-flow bypass to reduce sediment accumulation rates, aeration, or other pond management techniques. Given the impoundment's relatively small surface area and large drainage area, some level of in-pond treatment may be required to maintain water depth and prevent recurring algal blooms. Depth integrated water quality sampling may be useful to determine the impoundment's trophic status and seasonal dissolved oxygen and thermal profiles.

The area is listed as BMP M in Table 19. Load reductions (Table 20) were not modeled due to uncertainty of project scope. Recommendations to determine the exact cause of impairments and the best management approach are presented in Table 14. Although structural approaches are discussed above, the best management approach may also include non-structural or off-site BMPs to reduce sediment loading above the pond. While the pond is being studied, BMPs throughout the upper watershed that drains to Mianus Mill Pond will almost certainly be useful to improve water quality.

Structural Best Management Practice Costs

Order-of-magnitude cost estimates were developed for each field-vetted structural BMP and are presented in Appendix A. Estimates were developed based on unit costs derived from regional and nationwide studies, engineer's best estimate, and case studies. Unit costs are based on estimated impervious drainage area draining to each BMP or, in the case of stream restoration, on length of stream within the restoration area. The estimated planning-level cost to implement all of the 11 identified structural BMPs is estimated at approximately $2,484,000. Structural BMP cost is generally related to the size of the impervious drainage area and hence the amount of pollution managed by the practice; however, some practices tend to be more expensive to construct for the same pollutant reduction benefit. While costs and benefits of implementation may vary widely, the following structural BMPs represent relatively inexpensive opportunities based on planning-level cost estimates:

- Riverbank Road Buffers ($8,000)
- Pine Ridge Neighborhood Buffers ($7,000)

ESTIMATED POLLUTANT LOAD REDUCTIONS

Estimates of pollutant load reductions were developed for each of the 11 structural BMPs included in Appendix A (BMPs A-K). The following section summarizes the method and assumptions used to obtain load reduction values, and presents annual reductions in NO_3, particulate P, TSS, and indicator bacteria associated with each BMP.

The WinSLAMM model was used to develop pollutant load reduction estimates for structural BMPs. As discussed in Chapter 2, this approach applies empirically derived pollutant loading values to local rainfall, soil, and land use data to calculated NPS loads. Due to modeling constraints, unit pollutant reduction estimates derived from literature values were used to estimate pollutant load reductions for stream restoration BMPs.

Pollutant Load Reduction Estimates for Structural Best Management Practices

Field-vetted structural BMPs were modeled using WinSLAMM to determine estimated pollutant load reductions. A detailed description of the WinSLAMM model and the rationale for its use in this study is provided in Chapter 2. In addition to the capabilities discussed in Chapter 2, WinSLAMM also provides the capability to model pollutant reductions associated with structural BMPs. The following structural BMP types were modeled:

- Riparian buffer;
- Bioretention;
- Subsurface infiltration;
- Extended detention (referred to in Appendix A as "naturalized surface storage," since rates of infiltration may vary);

- Extended detention retrofit (referred to in Appendix A as "retrofit existing basin," since rates of infiltration may vary); and
- Grassed swale retrofit.

The first step in modeling pollutant load reductions was to develop concept-level designs for each structural BMP. Concept designs were developed based on the maximum structural BMP area available (as determined by site constraints), local soil conditions, and design guidance provided by the Connecticut Stormwater Quality Manual (CTDEP 2004). Drainage areas to each structural BMP were delineated based on a combination of contour data, field assessment, a review of aerial imagery and street view photography (www.googlemaps.com and www.bingmaps.com), and infrastructure mapping, where available. Drainage areas and BMP areas should be refined during the detailed design phase, and pollution loading values updated accordingly.

Source areas within each drainage area (areas with similar land use and soil characteristics) were also delineated. A delineation of source areas is required by WinSLAMM as a data input. The soil type and land use within each source area were defined based on the dominant soil type and land use within that area. Other inputs to the WinSLAMM model were developed according to the methods described in Chapter 2.

Using WinSLAMM, pollutant load estimates were determined for the drainage areas to each structural BMP. One model estimated the pollutant loading without the structural BMP, while a second model included the pollutant reduction effect of the structural BMP. The difference between the "with structural BMP" and "without structural BMP" models represented the estimated pollutant load reduction expected from implementing each structural BMP.

Pollutant Load Reduction Estimates for Stream Restoration Best Management Practices

Data from a stream restoration study of Spring Branch Stream in Baltimore County, MD (Chesapeake Bay Program [CBP] 2006), were used to obtain pollution reduction estimates for stream restoration BMPs. This study was selected for the following reasons:

- The study provided estimates of TN, TP, and TSS.
- Although conducted in the Chesapeake Bay drainage, the estimated pollutant reduction efficiencies for the Spring Branch Stream study may be applicable in suburban Piedmont watersheds underlain by crystalline bedrock. The Mianus River Watershed is in the coastal plain of Connecticut and is underlain by crystalline bedrock. These values have been applied to other coastal watersheds that are outside the Piedmont region (CBP 2006).
- Other studies and estimation methods have proposed larger reductions for TSS and TP (CBP 2006). For instance Evans et al., 2008, proposed reduction efficiencies of 36 and 95 percent for TSS and TP, respectively (Evans et al. 2008). Using the Spring Branch Stream values represents a conservative estimate for a metric that can be highly variable and lacks a large body of literature to develop more refined estimates.

The Spring Branch Stream Study found the following unit pollutant reductions for TSS, TP, and TN:

- TSS - 2.55 lb/linear foot(lf)/yr;
- TP - 0.0035 lb/lf/yr; and
- TN - 0.02 lb/lf/yr

For each stream restoration, the length of stream to be restored was measured using the software ArcGIS 10 and then multiplied by the load reduction rate for each pollutant. Indicator bacteria reductions are not typically associated with stream restoration.

Table 19.Identified Site-Specific Structural Best Management Practices

Subwatershed	Structural BMP Name	BMP ID	Structural BMP Type
19 (Strickland Brook)	Central Middle School	A	Bioretention & subsurface storage
62 (Below Bargh Reservoir)	Merriebrook Parking Lot & Trail	B	Bioretention
19 (Strickland Brook)	Old Post Rd. Median & Bus Stop	C	Bioretention
7	Cameron Drive Right-of-Way	D	Naturalized surface storage basin
7	Stanwich Country Club & Adjacent Residence	E	Stream restoration & riparian buffer
10	Banksville Town Center	F	Naturalized surface storage basin; level spreader; bioretention good housekeeping
18 (East Branch)	Rockrimmon Country Club	G	Naturalized surface storage basin and stream restoration
64 (Upper Main Stem)	Miller's Mill	H	Stream restoration
64 & 1	Windmill Lakes Neighborhood	I	Multiple small bioretention facilities
19	Pine Ridge Neighborhood	J	Riparian buffer
62 (Below Bargh Reservoir)	Riverbank Road Buffers	K	Riparian buffer
61 (Lower Main Stem)	River Road Pull-Offs	L	Bank stabilization and structural enhancement
61 (Lower Main Stem)	Mianus Mill Pond	M	High flow bypass or aerator (dependant on further analysis)

Total Pollutant Load Reduction Estimates for Structural Best Management Practices

The total modeled pollutant load reduction estimate for all 11 structural BMPs identified in Appendix A was 76,278 lb/yr of TSS, 373 lb/yr of particulate P, 317 lb/yr of NO_3, and 41,440 billion cfu/yr of indicator bacteria. Pollutant load reduction estimates varied widely by site and pollutant. BMP I, Windmill Lakes Neighborhood, is expected to produce the greatest decrease in TSS, particulate P, and NO_3 loads. Implementation of BMP A, Central Middle School, is expected to produce the greatest reduction in indicator bacteria. These sites provide a starting point for identification and implementation of similar structural BMPs throughout the watershed. Estimated pollutant load reductions for the 11 structural BMPs were lower than the total (100 percent) load reduction target or the interim (60 percent) targets defined in Chapter 3 for Particulate P, NO_3, and indicator bacteria. For TSS, however, the reduction associated with the 11 BMPs was greater than the total target. Additional nutrient reductions associated with stream restoration are presented as TN and TP for BMPs E, G, and H (Table 20).

Reductions associated with the structural BMPs represent less than one percent of the total target load reduction for $NO_{3,}$ just over one percent for bacteria, and approximately 37 percent and 800 percent of the total targets for particulate P and TSS, respectively (Table 20). These represent 0.5, 2.0, 62.0, and 1,370 percent of the interim targets, respectively, for NO_3, bacteria, particulate P, and TSS. Since the BMPs identified will not fully meet the interim or total load reduction targets for NO_3, particulate P, and bacteria, additional structural and non-structural BMPs will be needed in order to meet the goals of the Plan. For this reason, the Plan emphasizes an integrated approach to implementation using all of the varied management actions described in Table 14.

Table 20. Pollutant Reductions from Site-Specific Structural Best Management Practices

BMP	Runoff Volume (cf/yr)	TSS (lb/yr)	Particulate P (lb/yr)	NO_3 (lb/yr)	Indicator Bacteria (billion cfu/yr)
A. Central Middle School	588,247	5,227	22.48	23.84	10,010
B. Merriebrook Parking Lot and Trail	20,559	1,110	4.19	0.56	86
C. Old Post Rd. Median and Bus Stop	174,344	3,914	25.23	4.86	715
D. Cameron Drive Right-of-Way	60,501	11,147	75.76	6.8	656
E. Stanwich Country Club & Adjacent Residence	613,485	14,368	27.67[1]	27.73[1]	7,810
F. Banksville Town Center	109,881	2,814	12.95	4.32	1,059
G. Rockrimmon Country Club	143,346	2,782	3.68[2]	6.64[2]	3,425
H. Miller's Mill	N/A	255	[3]	[3]	N/A
I. Windmill Lakes Neighborhood	478,456	26,017	146.79	105.03	6,724
J. Pine Ridge Neighborhood Buffers	175,776	3,442	22.31	65.19	4,521
K. Riverbank Road Buffers	285,680	5,202	31.65	72.35	6,436
All Watershed Projects	**2,650,274**	**76,278**	**372.71**	**317.32**	**41,440**

[1]Nutrient load reduction due to stream restoration: TP (lb/yr) = 3.8; TN (lb/yr) = 22.0
[2]Nutrient load reduction due to stream restoration: TP (lb/yr) = 0.75; TN (lb/yr) = 4.3
[3]Nutrient load reduction due to stream restoration: TP (lb/yr) = 0.35; TN (lb/yr) = 2.0

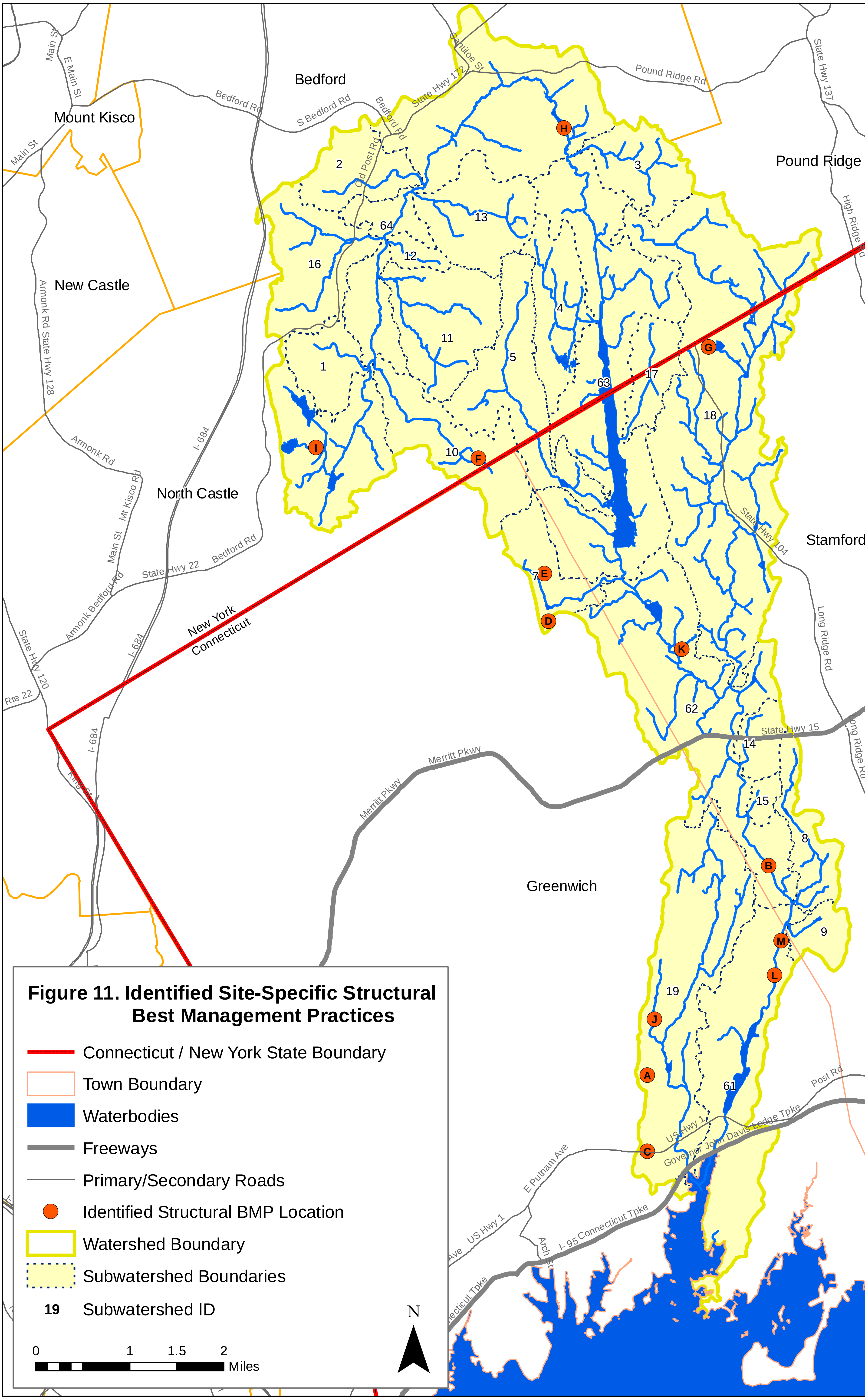

Figure 11. Identified Site-Specific Structural Best Management Practices

Community engagement, outreach, and education are essential components of Plan implementation. The diffuse nature of NPS pollution means that impacts are cumulative, and daily activities carried out on both private and public property—landscaping, recreation, property maintenance, and waste disposal—can have far-reaching effects downstream. Effective outreach and education can establish the connection between water quality issues and residents' quality of life. It can inform residents about the link between personal property care choices and the health of water sources, and provide easy-to-implement, practical steps to make homes and businesses watershed-friendly.

The sheer scale and cost of downstream management of NPS pollution can be prohibitive. Large structural BMPs, such as constructed wetlands, can be effective where space permits, but in many watersheds dominated by residential land use, opportunities to build large BMPs are limited. Under current law, municipalities and state agencies do not have statutory authority to mandate pollution reduction activities on privately owned properties. Thus, inspiring residents and municipal officials to voluntarily implement BMPs that improve water quality on their own properties is critical to meeting water quality goals.

DESIGNING AN EFFECTIVE CAMPAIGN

Effective education and outreach programs are targeted, succinct, and accessible to all members of the community. They are also fun, engaging, inspirational, interesting, and eye-catching. Watershed science principles can be difficult to communicate clearly and the connections between personal behaviors and large-scale water quality impacts are often not readily apparent. Clear, simple communication is critical. Whether outreach is conducted through large-scale media outlets like radio and television, or through stakeholder events and personal outreach, it is important to understand the values and preferences of the audience members and to emphasize easy-to-implement changes that have direct benefit for the audience as well as the environment. Programs should also emphasize both the financial and non-financial benefits to the audience.

The following guidelines are designed to help watershed stakeholders develop and implement an effective education and outreach plan:

- *Define the audience and customize the approach.* Location within the watershed, occupation, and access to resources can have a profound effect on how audience members interpret and react to the campaign. A variety of media types may be used wherever possible to create widespread recognition.
- *Craft a clear, actionable message.* It is important to target a single behavior or a pattern of behaviors that are impacting water quality. Once the activity is defined, leverage social factors and existing perceptions to create a sense of urgency. Create a simple message that motivates action, even if it is just one action at a time.
- *Don't "reinvent the wheel."* Partner with trusted business owners, municipal officials, and community groups to "piggyback" the message on other related programs. An understanding of which types of media have been used before, and in what way, can

guide a new campaign to either build on proven success, or branch out into fresh new territory.

- *Target early adopters.* Craft a message that encourages action among a receptive group. These can be homeowners with a demonstrated interest in environmental issues, sportsmen, or conservation advocates and commissioners. These early adopters will help redefine norms and expectations.
- *Evaluate success (and failure) and be open to change*. Metrics should relate not only to how many individuals were reached, but also to some defined measurement of what steps were taken in response (e.g., how many septic inspections were requested and how many rain barrels were purchased). These metrics may be difficult to measure and may require close partnership between advocates, local business, residents, and municipal officials.

Creating a Media Brand

Many times, small community organizations launch targeted campaigns without first developing a companion effort to brand their organization within the community. While targeted campaigns are important for communicating a single message, a more generalized media presence is important to establish an organization as legitimate and trustworthy and to establish a recognizable and exciting brand.

Branding can start with development of a professional, attractive, and recognizable logo and supporting graphic theme to help residents associate seemingly disparate occurrences together (a workshop advertisement with a sign recognizing a homeowner-built rain garden or a logo on a local web site, etc.) and suggest the presence of a coordinated campaign worthy of participation and attention. An effective logo uses simple colors and lines, limited text, and contains the organization's title or initials. Attention to graphic detail can signal a high level of professionalism. Logos that are pixelated, photo-based, or set on a colored background reflect poorly on the organization and may present a worse image to the pubic than no logo at all.

MEDIA FORMATS

Some media formats will be better suited to a certain message, and will depend on the audience, available funding, and desired time frame. In most cases, a combination of several media formats will be most effective.

Direct mail

E-mail and print campaigns are effective for communicating a general message to a broad audience. The format is useful when the message is simple enough to be contained in a few headline captions, and where graphics are important to highlight or communicate the message. However, direct mail, particularly print mail, can be expensive to produce and distribute.

Events

Educational events offer the experience of direct interaction with experts and/or hands-on participation and the opportunity to provide in-depth information on a particular topic. Service events such as monitoring programs, trail maintenance crews, and stream cleanups offer the opportunity to combine education and networking. Ideally these programs can be led and/or carried out by a local service organization, Boy or Girl Scouts, a church, or a group of corporate volunteers. Allowing volunteers to "get their hands dirty" may be the best way to get the message across.

In general, segmenting messages is considered a wise practice. Events may be the exception to this rule, however, since they require a certain level of commitment on the part of the organizer and the attendee. Booths at local fairs and school events can be a useful way of educating the public on multiple subjects through a variety of print handouts, posters, and giveaway items, such as bumper stickers. Events that attract local sponsorship, such as fundraising dinners, runs/walks, and benefit concerts, help raise a general awareness about watershed issues.

It should be noted that events tend to attract audience members who already have an interest in or affinity for the area. Where interest is limited, attendance can be poor, particularly among young people and parents with young children. Scheduling of events must be well in advance, using a variety of advertising methods. Linking events with existing or recurring events, offering food or giveaways (e.g., a free rain barrel), inviting well known speakers, scheduling events near public transportation routes and/or in locations with easy parking, and/or scheduling events around Earth Day celebrations and away from holiday or vacation periods, are all effective methods for increasing participation levels.

Websites

A web presence is important for any effective outreach campaign. At best, a well-designed website simultaneously serves as a source of information, enforces the “brand identity” of the given program, and incorporates social media components to engage site visitors. Website templates such as Blogger and Wordpress are simple to use and offer a free or almost free solution for program managers. Maps can easily be integrated using Google Maps functions. If additional functionality or graphics are required, a web designer may be needed to implement these features.

Websites serve as clearinghouses for information, and are an inexpensive way to house a “press kit” of documents, graphics, and text for media coverage. The press kit is usually a simple link that can be distributed with press releases or queries to television or radio stations. The press kit page may contain important news releases, high-resolution photos or a logo, contact information, mission statement, and promotional brochures or videos, as desired. This information can also be made available on disk.

Social Media

Social media sites like Facebook, Twitter, Google+, and blog and wiki sites offer a wide range of new opportunities for using electronic media for outreach and education. Social media offer unique opportunities to build relationships, interact with constituencies, solicit feedback and opinion, and collaborate across audience types. Social media also offer the opportunity to communicate rapidly and frequently with a large number of individuals interested in the message and are especially important for reaching young people. However, since users selectively filter content, creating interesting, humorous, or genuinely useful material is crucial to the success of this type of campaign. An effective social media campaign will (a) provide content that users choose to receive; and (b) publicize content by creating an active, reciprocal relationship with the audience.

Depending on the message, some sites may be more appropriate than others. Twitter is useful for publicizing links and very short content; it is open to all users and does not require permission to access content. Facebook, on the other hand, allows more personalization of messaging, but is geared toward a smaller social circle. Google+ represents a middle ground between the two, with fewer restrictions on length, images, and audience.

It is important to note that over-reliance on social media may exclude groups that do not actively use these media outlets for information. The impact of messaging with social media can also be difficult to predict since users "opt-in" to receive content and often selectively filter content due to the staggering volume and pace of communication on social media sites. Although social media can be an effective way to reach certain audiences, it is best used in conjunction with other media sources to reach a broader group of stakeholders.

As part of the watershed based planning process, a blog and interactive online map were created (www.mianusriverwatershedplanning.blogspot.com) so stakeholders might share comments and geographically locate problem areas. Project consultants updated the blog regularly through the planning process with relevant information, news, and work status updates. The blog was generally well received, although active participation was limited among stakeholders, possibly due to the small size of the audience.

Radio, Television, and Print News

Press releases, public service announcements, or guest appearances on local radio or TV programs are good options for raising the overall level of awareness about a specific issue, reaching a diverse and large audience, or to publicize events. Best options for TV coverage include interviews or spots on National Public Radio (NPR) member stations or other local non-commercial radio stations, public service announcements on public access channels, and television news coverage of major events. Press releases to local papers are a critical means of promoting events, and may also be used to link to websites for additional content. Editorials, feature articles, and news stories in newspapers are also important and potentially effective means for raising awareness about specific issues. In addition, featured articles in municipal and organization newsletters can help distribute the message to a new audience.

Personal Contact

Direct personal outreach by partners and prominent community members can be a particularly useful tool where the target audience is small, when the message requires background or explanation, or when the outreach goal requires extensive and sustained personal contact or relationship development. In these cases it is very important to select a trusted ambassador who understands and can speak to the concerns of the audience. This type of outreach works well as a means to influence owners of large properties (e.g., golf courses, municipal departments, industrial facilities, and tracts of open space, etc.). However, it is partially dependent on existing relationships within the community, and may be counterproductive if an appropriate spokesperson cannot be found.

Demonstration Best Management Practices

Visible public sites are often ideal settings for stream-friendly BMPs, such as riparian buffers, rain gardens, or rain barrels. These sites can provide a meeting space and educational opportunity for school groups, allow residents to directly participate in BMPs via volunteering, generate interest and excitement for watershed work, and provide a highly visible demonstration of techniques that could be used on a watershed wide basis. Demonstration sites can also help garner media attention for watershed efforts. Coverage of a watershed demonstration BMP by local TV, print, or radio media can be a huge help in raising the overall awareness of watershed issues and to create a sense of momentum.

OUTREACH AND EDUCATION GOALS

In the Mianus River Watershed, outreach and education activities should support the goals established in the Plan. Activities should be aimed at increasing awareness and stewardship of watershed issues, establishing the link between one's personal choices and water resource quality and encouraging easy-to-implement, low-cost watershed-friendly practices that benefit property owners and watershed residents. Outreach efforts may be tailored to the major audiences in the watershed, including: municipal officials, residents, and business owners.

The following activities were selected as "low-hanging fruit" for outreach based on their relative simplicity to implement, their importance to achieving watershed goals, and their cost effectiveness.

- **Municipal investment in LID** can help improve water quality and reduce flooding through improved infiltration in developed areas, pollutant control, and a decrease in erosive flows.
- **Riparian buffer establishment** and riparian zone maintenance can improve water quality, provide benefits to streamside homeowners, and are simple and inexpensive to implement.
- **Improved landscape management practices** reduce pollutant loads, improve habitat, and reduce property management costs.
- **Proper disposal of animal waste** is a relatively simple, inexpensive way to reduce bacterial loadings that can have sizeable impacts on water quality.
- **Rain barrels** on residential properties can prevent high flows of roof runoff that would otherwise carry lawn pollutants (nutrients, bacteria) into stream. Homeowners may use the collected rainwater for irrigation, outdoor washing, and other non-potable applications.
- **Inspection, maintenance, upgrade, and repair of residential septic systems** can significantly reduce bacterial and nutrient loading to streams.
- **Open space preservation** provides excellent habitat, recreational, and water quality benefits, but may be difficult to implement based on the high cost of land in the Mianus River Watershed.

STRATEGIES FOR IMPLEMENTATION

The following presents a discussion of strategies for each outreach goal. Appropriate audience, messaging, format, and useful existing programs are identified, along with potential challenges.

Municipal Investment in Low Impact Development

Targeted outreach efforts toward municipal officials and staff can help to encourage municipalities to voluntarily implement LID approaches, both as structural BMPs on public property and in the public right-of-way, and as non-structural BMPs and broader incentive and regulatory programs. Outreach and education efforts should focus on:

- Communicating the wide-ranging benefits (enhanced aesthetics, educational benefit, etc.) of LID through pilot demonstration BMPs conducted jointly with educational programming and materials;

- Encouraging the incorporation of LID aspects into planned capital projects such as streetscape enhancements or park renovations, and maximizing demonstration value of these sites through signage and volunteer involvement;
- Providing information concerning grant and low-interest loan programs that could help fund LID;
- Encouraging LID as a way for municipalities to demonstrate environmental leadership;
- Emphasizing that some structural BMPs can be low cost and easy-to-implement and can be installed using a combination of municipal staff and volunteers;
- Educating municipal officials about the need to reduce stormwater runoff to improve stream quality and reduce flooding; and
- Providing accurate information concerning project timelines, engineering requirements, and funding requirements.

Municipal governments may be wary of LID as a new concept, particularly when there are few local examples. Educational workshops can help officials overcome their initial concerns. Photos and “success” stories about other LID programs can help to ease the fear of early adoption. Demonstration BMPs may help to allay municipal concerns and provide a focal point for outreach related to specific LID practices. Several of the BMPs identified in Chapter 7 are located on public property, and could be designed with additional signage and viewing/seating areas for use as outdoor classroom areas. These BMPs may in turn lend themselves to additional publicity by offering a visual example of a technical concept.

Target Audience: Municipal officials; professional staff, particularly, engineers and public works directors; and board and commission members.

Message: A LID approach can help beautify and reduce maintenance needs on public properties and educate residents about the importance of protecting and enhancing local streams and LIS.

Existing Programs and Opportunities for Partnership: There are currently no LID outreach programs underway in the Mianus River Watershed; however, extensive training documentation and case studies are available through the CTDEEP website (ct.gov/dep) and NEMO (nemo.uconn.edu).

Media Format: Workshops and educational programming should be the focus of LID outreach and education efforts. Because the audience is relatively small, initial outreach can be conducted via phone, personal visits, or direct mailings.

LID workshops may include a heavy case study component and provide opportunities to connect with other municipalities that have been successful in incorporating LID into their planning process. Keeping in mind that municipal officials are busy, a series of short, evening programs scheduled to coincide with regular meetings may be ideal. Photos, video clips, and testimonials can teach municipal officials about LID practices. Educational materials may be selected and developed for distribution at each workshop, with special attention to tone (non-technical) and visual representation. Landscape renderings, concept plans, and photos of constructed BMPs are all extremely useful in communicating new concepts.

Riparian Buffer Establishment

In developing an outreach program for the Mianus River Watershed, significant attention should be given to streamside property owners, as their land has a direct connection to runoff and water quality. Property owners who take steps to establish and maintain riparian buffers can create a measureable improvement in local in-stream conditions.

Tall grass, shrubs, or forested riparian buffers along the stream corridor are a very efficient method of removing bacteria and to a lesser extent nutrients carried in overland flow. In addition, riparian buffers help stabilize the bank and deter geese from taking up permanent residence. Since the majority of the Mianus River is bounded by private residential property, outreach to streamside homeowners is the primary vehicle for implementing riparian buffers on a large scale.

Outreach efforts should focus on:

- Emphasizing the relationship between water quality and overall quality of life;
- Educating residents about the critical importance of riparian buffers, even relatively narrow buffers in improving water quality and preventing potentially damaging stream bank erosion;
- Emphasizing design details that can maintain views of and access to the stream;
- Providing tips and advice for self-installation of riparian buffers including planting tips, contact information for local nurseries, and plantings lists; and
- Emphasizing the benefits of riparian buffers in improving property values, property beautification, and reductions in property maintenance.

Select volunteer homeowners for a riparian buffer design charette working with partner organizations such as a well-known landscape contractor or landscape architect. These professionals can work with the volunteers to select plantings and accessibility options that mediate the owner's needs with the need for riparian buffer placement. Send out invitations to all streamside homeowners and present the results at a community meeting. Concurrently, it may be helpful to create a sense of community among streamside owners using online media and other social events. As a privileged group of individuals, these owners may also be more likely to share a sense of stewardship for their common resource.

Target Audience: Streamside property owners.

Message: Riparian buffers are easy-to-install, make your property more attractive, and help protect your local stream and LIS.

Existing Programs and Opportunities for Partnership: Recreationally oriented nonprofits such as Trout Unlimited may be well-suited to partner with interested homeowners. Partnership with local nurseries or home improvement stores can also be an effective means of targeting homeowners. UConn CLEAR, NEMO, and CTDEEP can offer a variety of technical guidance and are well-suited to support property owners and municipalities.

Media Format: Workshops and volunteer/recreational events may be a primary tool for outreach to streamside landowners. Local contractors may be willing to speak to groups of homeowners without direct compensation in exchange for publicity and local nurseries may be willing to offer free or reduced cost seedlings for workshop participants. Riparian buffer workshops can also be combined with other homeowner-targeted workshops (e.g., rain barrel or rain garden workshops).

Riparian buffer education materials can also be effectively integrated into a variety of online destinations including municipal and community web sites and social networking sites. Print or on-line articles in local newspapers, gardening magazines, and other publications can also be an effective means to educate streamside landowners about riparian buffer BMPs. Programs that reward or recognize homeowners that install riparian buffers can be particularly effective. These programs can often be sponsored by local landscape-related service providers and/or local non-profit groups.

Finally, working with local nurseries to set up displays at retail outlets can also be an effective means to educate homeowners about riparian buffers. Timing displays during spring and fall planting seasons can help to reach homeowners when they are actively planning for and funding landscape improvements.

Improved Landscape Management Practices on Residential and Commercial Property

Private residential and commercial properties make up a large portion of the total watershed area. Modifying landscape management practices such as mowing and fertilization can significantly limit pollution and improve water quality. Anecdotal evidence suggests that dumping of lawn clippings and leaves directly into streams, as well as over or improper fertilization, seem to be the most common landscaping issues affecting water quality. Since many homeowners and businesses hire landscaping companies to perform landscape care services, outreach to both property owners and landscape companies is important in driving wide-scale changes in practices.

Outreach to property owners and landscape professionals should:

- Emphasize the benefits of watershed-friendly landscaping practices in improving the health and quality of local streams and LIS,
- Encourage composting as a means to reuse lawn clippings rather than dumping them in the stream,
- Encourage the use of soil testing to calibrate fertilizing requirements and eliminate excessive or unneeded fertilizer,
- Encourage the use of slow-release fertilizers,
- Encourage application of fertilizers during dry weather periods,
- Encourage lawn aeration as a means to improve infiltration and improve turf health,
- Encourage appropriate mowing heights as a means to conserve water and improve turf health, and
- Encourage reductions in turf areas as a means to reduce property management costs.

Target Audience: Residents, landscape professionals, and commercial property and business owners.

Message: (to landowners) Watershed-friendly landscaping practices are easy to adopt and good for your lawn, good for local streams, and help protect LIS.

(to landscape contractors) Watershed-friendly landscaping practices can help reduce your operating costs and make you more competitive.

Messaging for individual campaigns is best when it is simple and compelling and focused on asking audience members to change one behavior (e.g., overfertilizing wastes your money and harms local streams; get a soil test before fertilizing your lawn this year). Messaging directed at landscape professionals may take the form of professional training and personal outreach (calls, e-mails, or visits by members of garden clubs or other community organizations). If possible, training sessions should leverage continuing education credits or offer some kind of alternate form of recognition for participants. Messaging may be timed to coincide with spring planting periods where homeowners and businesses typically make lawn care decisions and purchase lawn care products.

Existing Programs and Opportunities for Partnership: Local garden clubs may be ideal ambassadors for progressive property management practices. In addition, the UConn Cooperative Extension and the Connecticut Agriculture Experiment Stations offer soil testing as well as guidance and tools for sampling and amending soil. Municipalities, non-profits, landscaping companies, home improvement centers, and nurseries can also be effective partnerships.

Media Format: A wide variety of media formats and approaches can be used to advocate for watershed-friendly landscaping practices. Given the large number of audience members, mass media may be most useful where possible. For instance, newspaper articles and inserts in municipal newsletters are potentially effective approaches to print media. In addition, garden clubs and watershed nonprofits may be willing to hold property owner workshops. Giveaways, such as free soil test kits, may be useful to increase participation, while extending sponsorship opportunities to landscape service providers could help to fund the events. Booths and exhibits at local home improvement stores or nurseries, or at local fairs or community events, could also be effective in reaching landowners. River-friendly or watershed-friendly recognition or reward programs can be used to encourage participation. Sponsorship from local landscape companies, non-profits, and nurseries can fund these programs.

Proper Disposal of Animal Waste

Pet waste represents a small but manageable source of the overall bacterial load in the Mianus River Watershed. While solutions are simple and inexpensive—clean up after pets—the challenge for advocates lies in reaching the multitude of dog owners, and creating a message with enough social incentive to spur a change in behavior.

In public parks, trash cans and free baggies are a simple, inexpensive solution that can encourage pet owners to clean up after their pet. In addition, signage and print handouts placed near the baggies can be used to spread the message.

It may be more difficult to influence behavior on private property. In this case, a mass-media campaign using electronic and print media may be the most effective way to reach pet owners. In other watersheds, "spokesdogs" have been nominated from the canine community to attend outreach events promoting pet waste management. Emphasizing the health and hygiene benefits of cleaning up pet waste within private properties can be an effective route to encouraging behavior change.

Small hobby farms are another potential bacteria contributor, especially where manure is collected near the stream channel or in a direct flow path. Managers of these facilities may be encouraged to cover manure when possible, and either compost responsibly or have it hauled offsite. Since there are relatively few hobby farms in the watershed, outreach may take the form of site visits and letters.

Target Audience: Pet and property owners; farm managers.

Message: Cleaning up after pets and large animals is easy, inexpensive and helps keep bacteria out of local streams

Existing Programs and Opportunities for Partnership: Bacteria monitoring through the Harbor Watch/River Watch program may be helpful for both acquiring data and involving local community members in the monitoring process. Partnering with local dog parks and pet stores could also be beneficial.

Media Format: A comprehensive campaign may include multiple media formats to reach the widest audience possible. In addition to signage, baggies, and flyers at public sites, a large-scale postcard mailing from each municipality to its residents might employ humorous, eye-catching graphics to direct the reader to a web page outlining the problems and solutions. Newsletter or newspaper articles or editorials can also help to raise awareness and encourage simple behavior changes. Partnering with local pet stores to set up a booth or exhibit or to sponsor the distribution of informational materials with advertisements could also be an effective means of reaching pet owners.

A “spokesdog” may be nominated using social media and photos (i.e., allow community members to vote on a photo/description of each dog using Facebook to comment, “like,” etc.). The contest could be further publicized through other social media outlets and partner websites, and via local newspapers, television, and radio.

Residential Rain Barrels

Rain barrels are a simple, cost-effective way for homeowners to manage stormwater on their property before it enters the municipal drainage system. Homeowners can save money on lawn and garden watering by substituting harvested rainwater for potable water. Their savings may be increased through a partial municipal subsidy or a rain barrel giveaway program. Even then, the cost savings alone may not be enough to create an incentive. In conjunction with financial incentives, a strong outreach campaign may be necessary to “sell” the social and environmental benefits to the public.

Target Audience: Homeowners whose roof downspouts discharge to or near a stream or paved area, or are directly connected to the municipal storm sewer.

Message: Rain barrels provide a free source of water for your plants and help the environment by reducing water use and the amount of stormwater that flows into local streams.

Existing Programs and Opportunities for Partnership: There may be partnership opportunities for municipalities and water companies to offset an additional portion of the cost, and to offer technical assistance to homeowners.

Media Format: In order to reach the widest audience, an effective rain barrel campaign may employ a range of commercial media including local news and radio, promotional videos, a website, and extensive publicity via social media. One to two workshops should be offered for interested residents.

Inspection and Maintenance of Residential Septic Systems

Failing septic systems on residential property can cause significant loading of nutrients and bacteria, either as discharges when the system fails, or as slow leaching from old, inefficient systems. Adverse effects to water quality typically become more severe for properties that are located close to the stream. Since septic failure or potential failure rates can be difficult to quantify, preventative measures including homeowner education may be the best way to prevent this problem.

Outreach and education for septic system owners should focus on:

- Educating owners of septic systems about proper maintenance and care and the benefits of a properly functioning system,
- Encouraging homeowners to have periodic inspections of their septic system to ensure proper functioning,
- Common signs of malfunctioning septic systems,
- Proper steps to take if a malfunction is suspected, and
- Communicating the potential water quality issues associated with leaking or malfunctioning septic systems.

Ideally, educational materials would be distributed by the municipality or health districts to all new homeowners and at each deed transfer. These may include a maintenance schedule, a list of maintenance contractors, and simple graphics showing the extent and location of recreation and drinking water resources in the watershed. Outreach to homeowners may be more useful when linked with sampling programs targeted at residential properties located along the stream corridor. Volunteers trained to detect signs and impacts from leaking septic systems will be more likely to manage their own systems correctly, and will self-police among the community. In addition, neighborhoods draining to streams identified as having potential septic plumes should be targeted for outreach efforts.

Target Audience: Homeowners.

Message: Teach septic owners to recognize the most common signs of malfunctioning septic systems, to prevent system malfunctions through regular maintenance, and to take appropriate action if a leak or malfunction is suspected.

Existing Programs and Opportunities for Partnership: Scientists and interns at the Mianus River Gorge Preserve may be available to help train neighbors to sample for bacteria near their homes.

Media Format: Flyers and brochures may be distributed at community meetings, at property transfers/sales, and within municipal mailings or newsletters. Articles on septic care can be published within local newspapers or other print media and posted on municipal websites.

Targeted workshops may focus on older areas or where monitoring shows bacterial impairment or direct evidence of septic plumes. In smaller neighborhoods, flyers or direct mail can also be effective ways to publicize events.

Open Space Preservation

An effective method of preserving water quality, open space preservation can also be difficult to implement. In the Mianus River Watershed, undeveloped land is limited and extremely valuable. Although funding sources (e.g., easements, grants, etc.) may be available they will often not match the prices offered by development interests. In general, significant personal or social incentive is necessary to counterbalance market forces.

Before beginning a campaign, it will be important to identify parcels that have the highest conservation value, and to develop a strategic plan to prioritize protection efforts. Once a plan is in place, a twofold campaign may target owners of potential conservation properties as well as the general public. Respectively, these campaigns may address the personal benefit of preserving open space (e.g., creating a lasting legacy, maintaining a sense of place), and the public benefits of open space (e.g., recreation, healthy communities, livability).

Target Audience: Private owners of high-priority conservation sites, watershed residents, and business owners.

Message: Open space is a critical part of what makes a community a special and attractive place to live. Support open space preservation through donations to local land trusts, conservation easements, or by preserving your own property.

Existing Programs and Opportunities for Partnership: The Greenwich, Westchester, North Castle, and Stamford Land Trusts and Pound Ridge Land Conservancy are all organizations that acquire properties, facilitate easements, and in some cases host stewardship events.

Media Format: Outreach to target property owners should be personalized where possible. Letters, visits, and small social events may be particularly effective. Mass or digital media may be less emphasized, if used at all. Messaging can help property owners understand why their decision matters, and what non-financial and financial benefits a decision to preserve their land can yield. Personal connections are crucial to establishing a shared sense of purpose and trust; introductions may be made through civic groups, local government officials, clubs and leagues, etc. In contrast to outreach to landowners, outreach to the broader public may emphasize the use of electronic media. E-mail listservs may be useful if enough addresses can be collected to reach a broad audience; social media allows for a more open dialogue among users, but may not be as accessible to some audiences.

A well-designed monitoring program enables stakeholders to evaluate the results of management actions and assess progress towards meeting the management goals outlined in the Plan. Monitoring provides critical feedback through which adjustments to implementation efforts can be made through a process termed adaptive management. Monitoring also allows partners to assess the performance and condition of individual pollution reduction BMPs and to identify needed maintenance.

This section of the Plan:

- Outlines an effective approach to watershed monitoring;
- Reviews existing monitoring programs in place within the watershed;
- Reviews the important variables that should be monitored on a watershedwide basis;
- Provides in-depth guidance for conducting three types of critical monitoring activities: routine monitoring, early warning monitoring, and structural BMP monitoring; and
- Provides brief guidance on monitoring other aspects of the Plan that do not lend themselves to quantitative monitoring.

MONITORING APPROACH

Watershed monitoring can be tricky business. For example, variable weather and other environmental conditions can make it difficult to detect changes in in-stream conditions, while funding availability can stifle the most well intentioned monitoring program. The following sections provide a high-level review of some critical aspects of an effective monitoring program.

Subwatershed-Scale Monitoring

Watersheds can be slow to respond to landside pollution reduction measures, and year-to-year variability can further obscure results. Where possible, routine monitoring should be conducted at fixed stations at small (e.g., one (1) to five (5)-square-mile) subwatershed outlets rather than exclusively at the outlet to the Main Stem. Although more costly, this approach is more likely to detect change at acceptable timescales and provide the early evidence of success that is so critical to attracting continued funding for implementation efforts.

Using Reference Reaches

Habitat and in-stream conditions are constrained by the natural setting within which streams flow. For instance, low-gradient sand bed streams will not provide suitable habitat for trout spawning, even in the complete absence of watershed stressors. Using a reference reach is a good way to establish realistic and place-appropriate targets for in-stream habitat, water quality, and biological communities. Reference reaches need not be located in the target watershed but will be most useful within the same ecoregion and physiographic province as the target watershed.

Lowering Monitoring Costs

Funding for monitoring is limited, and activities should be carefully selected in order to maximize value and minimize cost. Several steps can be taken to manage and lower monitoring costs. For example, the use of bio-indicators and visual assessments as the primary tools for routine monitoring can avoid the costly laboratory fees and time-consuming travel costs associated with water quality monitoring. Using volunteers, where appropriate, can also help to lower costs and provide valuable educational opportunities.

Overcoming Environmental Variability with a Smart Sampling Plan

Seasonal and climatic variations have a strong influence on stream flow, pollutant concentrations, and biological communities. Consistent multi-year monitoring at fixed stations is critical so as to distinguish real change in conditions driven by implementation activities or land use change from those that are due to natural variation.

Involving Volunteers Wisely

Volunteers can play a valuable role in watershed monitoring programs, but it is important to choose their tasks carefully and provide adequate training. Ideally, monitoring should be carried out concurrently with related outreach programs so that the education components of each program inform shared goals. Appropriate volunteer tasks are simple and repeatable. If special skills are required, they should be easily taught and tested. For example, the CTDEEP's Rapid Bioassessment by Volunteers (RBV) program uses short training sessions, which cover collection techniques and context information for sampling stream macroinvertebrates, but stops short of teaching the volunteers the skills required to accurately identify the species. The following are some suggested tasks to be handled by volunteers:

- Collection of water quality grab samples;
- Kick-net sampling for macroinvertebrates;
- Operating a flow meter during storm events;
- Temperature monitoring;
- Partial visual assessments (water clarity, presence or absence of algae, presence or absence of barriers, etc.); and
- Structural condition and clogging of BMP features.

A Commitment to Quality Control

Regardless of the monitoring activity, quality control is a critical part of any monitoring plan. Field data collection tends to be most effective when volunteers and/or professionals are trained carefully. Monitoring equipment requires regular inspection, maintenance, and calibration. Proper chain-of-custody procedures are important when collecting and processing field samples. Following sample handling and holding time procedures and processing samples at accredited laboratories is also critical. Finally, data entry should be reviewed for accuracy.

Smart Data Management

Data management is a critical aspect of any monitoring plan. Ideally, monitoring data should be managed in a relational database, such as Microsoft Access, rather than managing data in individual spreadsheets. All data records should include the time and date of measurements and/or analysis, the site location, the person(s) and/or entities responsible for collecting, analyzing, and entering the data, and the field collection/laboratory method used. Any anomalies or irregularities in data collection or analysis procedures should also be noted. To maximize data security, a limited number of individuals should have read/write access to the database.

An Adaptive Management Approach

Adaptive management provides a framework within which monitoring is performed. At its core, an adaptive management approach suggests that implementation efforts be continually evaluated and, if needed, adjusted based on monitoring data. Routine monitoring within a particular subwatershed can be used to determine the efficacy of management actions implemented within that subwatershed. If subwatershed-scale sampling does not show anticipated improvements in in-stream conditions despite intensive implementation, for instance, this may point to problems with the design or suitability of the management actions, or suggest the presence of an alternative source of impairment that may have not been identified during the initial Plan development.

Sharing Results

Monitoring data are of interest to a number of end users including municipal officials, implementation partners, and the general public. An annual monitoring report should be prepared as the central means to communicate monitoring results. A non-technical, easy-to-read executive summary can be used to communicate monitoring results to non-technical audiences, while the body of the report can be used to communicate results to more technical audiences.

EXISTING AND PAST MONITORING PROGRAMS

Limited programs are in place within the Mianus River Watershed to monitor water quality and in-stream conditions. The following data have been collected:

- Fish and macroinvertebrates were sampled at the stream crossing with Merriebrook Lane in 1990 and in 2007; fish were sampled on the east branch of the Mianus River near the Wildwood Road bridge in 1990 only. At both locations, biota indicated good water quality conditions.
- According to a report by Milone & MacBroom (2004), Strickland Brook showed levels of fecal coliform in excess of state criteria during both dry and wet weather sampling events, which may be partially attributable to wildlife. However since the time of the study, sewers have been installed in the lower portion of the watershed, which may invalidate earlier data. Total orthophosphate, dissolved oxygen, TSS, temperature, pH, NO_3, Nitrite (NO_2), and specific conductivity were sampled at two locations in Strickland Brook: south of Cat Rock Road, and downstream at the end of Glenville Drive.
- Aquarion Water Company conducts regular monitoring for sodium and fecal coliform at Old Mill Lane in Stamford; and for pH, temperature, and conductivity at Mianus Mill Pond. An additional Aquarion sample site is located at Bob Hill Road in Pound Ridge, NY.
- Aquatic Resources Consulting collected water quality and macroinvertebrate samples at seven (7) sites in the Main Stem, the East Branch, and Pine Brook in May 1999; and at five (5) sites on the Main Stem and East Branch in September of 1999 (Aquatic Resource Consulting 2000).

MONITORING PARAMETERS

The following section provides an overview of key monitoring parameters typically used in routine watershed-scale monitoring efforts.

Water Quality

Water quality monitoring is used to characterize the chemical constituents, including several important NPS pollutants, present in stream water. Water quality monitoring is more expensive than visual assessment, but is essential for evaluating progress toward resolving listed water quality impairments and assessing reductions in total pollutant loading.

- **Nitrogen**: N is an essential and naturally-occurring macronutrient for stream plants, but in excessive quantities can lead to excessive plant growth and eutrophication. N is not typically the limiting nutrient in freshwaters, but is often the limiting nutrient in marine and estuarine systems. EPA offers reference concentrations of N for Total Kjeldahl Nitrogen (TKN) and TN (EPA 2000), but CTDEEP has not developed state-specific criteria for most NPS pollutants. Modeling results indicate “hotspots” in subwatersheds 19, 61, and 62.

- **Phosphorus:** P is an essential and naturally-occurring macronutrient for stream plants, but in excessive quantities can lead to excessive plant growth and eutrophication. P is most typically the limiting nutrient in most freshwater systems. EPA offers reference concentrations for TP (EPA 2000), but as with N, CTDEEP has not developed state-specific criteria for most NPS pollutants. Modeling results indicate “hotspots” in subwatersheds 18, 13, and 9.

- **Total Suspended Solids:** TSS is present in small quantities within pristine streams. Within degraded systems, however, TSS concentrations can increase by several orders of magnitude and can lead to sedimentation of benthic habitats and increases in nutrient loading, particularly P, which is strongly bound to sediment. Appropriate concentrations of TSS vary by location and natural patterns of erosion and sedimentation. CTDEEP has not developed state-specific criteria for most NPS pollutants. TSS sampling may include visual assessment of bed sediments and water clarity as well as grab samples to determine TSS concentrations. Modeling results indicate “hotspots” in subwatersheds 12, 3, and 4.

- **Bacteria:** As an indicator organism, *E. coli* is useful in predicting the level of fecal contamination in a water body. CTDEEP provides standards for *E. coli* and fecal coliform concentrations for class A and AA streams based on designated use for recreation or drinking water (CTDEP 2011, Water Quality Standards). Modeling results, which use fecal coliform rather than *E. coli* as the indicator of contamination, indicate “hotspots” in subwatersheds 19, 61 and 62. Fecal coliform and *E. coli* are typically very closely correlated. It is expected that fecal coliform “hotspots” will also demonstrate elevated levels of *E. coli* when sampled for that indicator.

- **Dissolved oxygen:** Dissolved oxygen is critical to the survival of all in-stream animals, but is particularly critical for cold water fish species such as trout. For Class A and B streams, CTDEEP maintains a standard of not less than 5mg/L of dissolved oxygen at any time (CTDEP 2011, Water Quality Standards). Dissolved oxygen impairments have not been identified in the Mianus River Watershed. Warm-weather, low-flow sampling is recommended in areas with suspected nutrient and temperature problems, as these will be the most likely reaches to be impaired.

Stream Biota

Fish and macroinvertebrates can serve as indicator species used to assess the overall health of the stream system, and to highlight needs for further monitoring. Sensitive fish and macroinvertebrate species will not survive where habitat or water quality is compromised, and so can provide an early indicator of potential impairment. Where habitat is good but macroinvertebrate populations have been impacted, water quality may be an issue. These variables are generally representative of the stream's ability to support aquatic life, and are commonly used by CTDEEP to assess watershed conditions and focus additional sampling.

Fish communities can represent quality as well as connectivity of habitat. Fish species are generally mobile. For example, resident fish may exist in stable populations in a reach enclosed at both ends by barriers, while the presence of anadromous individuals (that is, species which migrate between fresh and salt water) will indicate that some of the barriers are passable. In addition, the species composition of a sample population can be a good indicator of water temperature, dissolved oxygen, and viable habitat.

Macroinvertebrates are less mobile than fish, and as such are more representative of specific local conditions. Some species are particularly sensitive to sediment and substrate conditions. The healthiest communities are most often associated with shallow, fast moving, rocky sections of the stream called riffles, and piles of large woody material (e.g., sticks, logs) known as debris jams.

Habitat Quality and Channel Stability

Physical habitat refers to the combination of water flow, stream bottom material, vegetation, debris and other in-stream features that provide suitable environments for aquatic life to live, feed, and reproduce. Particular types of physical habitats such as deep pools, clean riffles composed of coarse gravel or fist-sized rock, and large piles of woody material such as sticks, twigs, and logs are particularly beneficial to a range of aquatic life. Several organizations have developed visual assessment methods through which both trained volunteers and professionals can assess the quality and diversity of habitat present in a particular reach of stream.

Channel stability refers to the degree to which the streams move and change over time. Streams can move from side to side, change in shape or size, or become steeper or flatter. All streams change over time, but in healthy streams these changes are often slow and gradual. When watersheds become developed, the changes in the amount of water and sediment carried to streams can cause rapid and unhealthy physical changes in streams that indicate an unstable condition.

The following types of information are often used to characterize habitat quality and channel stability.

- **Substrate** refers to the material (often mud, sand, gravel, cobble, or boulders) that rest at the bottom of the stream bed. Substrate is influenced by the type and quantity of leaf litter and natural debris; by the stream's shape and steepness; by the velocity of water moving through the system; and the type of material present in the soils surrounding the stream. Clean accumulations of rocky, fist, or gravel-sized substrate that are not packed with fine sand or mud are particularly important for many aquatic organisms including macroinvertebrates and many fish species. By contrast, sand or mud-bottomed channels typically support lower-quality and less diverse aquatic life.

- **Channel morphology** refers to the physical form of the stream channel including its size, shape, steepness, and meander pattern. Rapid changes in channel morphology can indicate unstable conditions which may in turn lead to worsening habitat quality and increased rates of erosion. Channel morphology is typically assessed using approaches such as stream channel surveys performed by professionals. The presence of large accumulations of sediment within the stream bed called channel bars, increases in stream width, buried or exposed infrastructure such as stormwater pipes or bridges, or the presence of sudden grade changes that may have the appearance of a small waterfall may indicate worrisome changes in stream morphology. Measuring the extent and location of bank erosion and the quality and abundance of habitat features is also an important aspect of characterizing channel morphology. Channel classification systems, such as the Rosgen Classification System, are also often useful in communicating information regarding channel morphology in a consistent manner.

- **Woody debris** is an important habitat feature that provides cover for fish species and macroinvertebrates. Heightened storm flows can flush woody debris out of the system, destroying habitat and destabilizing banks. In unforested reaches, woody debris may take years to re-accumulate.

- **Water temperature** is an important component of habitat for fish and benthic macroinvertebrates. Low temperatures tend to be richer in dissolved oxygen, while higher temperatures generally have less oxygen available. Temperature changes can be indicative of other habitat problems, including loss of over-shading vegetation and runoff from warm paved surfaces.

- **Type and density of in-stream vegetation** can be a good indicator of nutrient content. Thick, aquatic vegetation and dense algal blooms may be due to an overabundance of nutrients and are usually associated with anoxic or low oxygen conditions in the summer and poor habitat.

MONITORING PROGRAM

The monitoring program includes the following components (Table 21):

- **Routine in-stream monitoring.** Routine in-stream monitoring is conducted at fixed stations throughout the watershed. The primary purpose of this type of monitoring is to detect changes in in-stream conditions during implementation.

- **Early-warning monitoring.** Early-warning monitoring helps to detect emerging threats through more intensive monitoring of conditions within sensitive headwater areas, particularly those upstream of critical areas such as drinking water supplies.

- **Structural BMP monitoring.** Structural BMP monitoring allows watershed managers to evaluate the condition of structural pollution reduction measures, and to identify required maintenance of both new and existing BMPs.

Routine In-Stream Monitoring

Routine monitoring is the core of the watershed monitoring program. Monitoring is conducted for habitat and channel stability features, and for water quality and bio-indicators during both wet and dry weather. Frequency and duration of sampling varies depending on what type of data is collected (see Table 21).

Habitat and stream stability assessment

Building on the partial existing conditions assessment (Chapter 2) conducted in 2011 by AKRF, additional habitat assessments should be conducted within representative reaches using a similar scoring and rating approach (see Appendix C). Since conducting habitat assessments for every stream reach within the watershed will likely be costly, representative reaches should be selected within several subwatersheds (Table 21). Representative reaches should be free of major obstructions, barriers, or structures that could cause local-scale changes or impairments to habitat quality. Existing habitat protocols such as the NRCS SVA Protocol used in the existing conditions assessment can be used as a basis for monitoring. Habitat and stream condition assessment parameters should include:

- Channel width and depth;
- The presence of erosion or in-channel bars or other indicators of instability;
- Pool abundance and depth;
- Presence and abundance of large woody debris;
- Bank angle, height, and erosion severity;
- Riparian zone condition;
- Stream temperature; and
- Riffle embeddedness.

Bio-Monitoring

Macroinvertebrate communities should be collected and assessed via the CTDEEP's RBV program. Through this program, macroinvertebrates are collected and sent to CTDEEP staff for professional classification and data management. If possible, the current CTDEEP collection sites should be augmented with additional monitoring stations. Ideally, additional bio-monitoring sites will be located within representative reaches selected for habitat and channel stability assessment.

Dry Weather Water Quality Monitoring

With the exception of indicator bacteria, dry weather water quality monitoring should be conducted using grab samples taken quarterly at fixed stations in representative reaches within each recommended subwatershed (Table 21). Grab samples are recommended following at least 72 hours of dry weather after a significant rainfall event. Suggested parameters for dry weather monitoring are listed in Table 21, and include TP, orthophosphate, TSS, *E. coli*, TKN, NO_3, NO_2, and ammonium (NH_4). An initial baseline monitoring program during years one to five of the monitoring program implementation is recommended, consistent with the idea of a "pilot" phase of implementation.

Table 21. Monitoring Program Overview

Monitoring Type	Location	Frequency	Duration	Variables
Routine				
Habitat Quality and Channel Stability	Representative reaches within subwatersheds 1, 5, 7, 10, 14, the upper portion of 18, 19, 63, and 64	Semi-annually	Year 1: baseline conditions, Years 2-20: routine monitoring	Channel condition, hydrologic alteration, riparian zone, bank stability and stream cross-sectional area, water appearance, nutrient enrichment, barriers to fish movement, fish cover, pools, temperature, macroinvertebrate habitat (substrate), fish community
Wet Weather	Outlets of subwatersheds 19, 64, 63, 62, and 61 above the salt line	Once per 5 years	Periodically throughout implementation period.	TKN; NH_4; $NO_{2/3}$; TP; dissolved orthophosphate; TSS; *E. coli*
Bio-indicators	Representative reaches within subwatersheds 1, 5, 7, 10, 14, the upper portion of 18, 19, 63, and 64	Semi-annually	Year 1: baseline conditions, Years 2-20: routine monitoring	Macroinvertebrate communities
Dry Weather Water Quality	Representative reaches within subwatersheds 1, 5, 7, 10, 14, the upper portion of 18, 19, 63, and 64	Seasonally	Years 1-5: baseline conditions: Years 5-20: routine monitoring	TKN; NH_4; $NO_{2/3}$; TP; dissolved orthophosphate; TSS; *E. coli*
Early Warning	Representative reaches within subwatersheds 1, 5, 7, 10, 14, 17, and the upper portion of 18	Bi-annually	On-going through implementation period	Changes in grade or patterns of erosion, significant increases in bank height or channel width or depth, exposed infrastructure, steepened riffles, loss of depth in pool areas, severe or rapid bank erosion, large sediment bars, and embedded cobbles.
Structural BMPs	New and existing BMPs	Annually or bi-annually	On-going throughout implementation period	Vegetation type, structural condition, accumulation of sediment/debris, and condition of downstream outfalls; downstream water quality (TKN; NH_4; $NO_{2/3}$; TP; dissolved orthophosphate; TSS; *E. coli*)

Wet Weather Water Quality Monitoring

Characterization of wet weather pollutant loading would ideally be conducted at years five (5), 10, 15, and 20 of Plan implementation, funding permitting, in order to determine how much pollution is carried by stormwater runoff. Typically the overwhelming portion of total pollutant loading tends to occur during storm events. These events can be sampled using an automatic sampler at representative locations (Table 21). Trained volunteers can be helpful in performing a variety of tasks including monitoring weather conditions, turning on the autosampler prior to use, and collecting and transporting water samples.

Wet weather monitoring stations should be established at multiple representative locations (Table 21). Suggested parameters for wet weather monitoring include TP, orthophosphate, TSS, *E. coli*, TKN, $N0_3$, $N0_2$, and NH_4. Typically, flow-weighted composite water samples are collected using automated water samplers. Samplers are typically housed in wooden enclosures which can be locked between events. Prior to sample collection, a flow rating curve is established to relate stage to discharge. During sampling, water stage is measured continuously via pressure transduction and the stage/discharge relationship is used to allow the automated samplers to collect flow weighed samples. Typically five to seven storm events greater than 0.1 inch are sampled to generate event mean concentrations.

Early Warning Monitoring

The term "dynamic equilibrium" is used to describe how healthy streams shift and change shape while maintaining a characteristic form. This equilibrium exists in delicate balance with the regional hydrology. Where land cover has been modified, this dynamic equilibrium is disrupted and streams can undergo rapid and permanent changes that result in loss of habitat and increases in sediment and nutrient loading.

When channel adjustments intensify, corrective actions such as bank stabilization and channel redesign become extremely expensive and have high failure rates. Therefore, it is important to catch these changes while they are small and easy to repair. Early warning signs of changes in channel stability may include:

- Small areas of erosion or changes in stream grade;
- Significant increases in bank height or channel width or depth;
- Exposed infrastructure;
- Steepened riffles;
- Loss of depth in pool areas;
- Severe or rapid bank erosion; and
- Large sediment bars or embedded cobbles.

Early warning monitoring stations should be established within headwater (i.e., first order) drainages within subwatersheds 1, 5, 7, 10, 14, 17, and the upper portion of 18. Monitoring should be conducted at least semi-annually and the results communicated to municipal officials.

Structural Best Management Practice Monitoring

New and existing structural BMPs should be monitored and maintained to ensure proper function. For some municipalities, this will first require an inventory and assessment of existing BMPs within the watershed. Maintenance and monitoring falls into five (5) categories:

- Vegetation;
- Structures;
- Sediment/debris;
- Downstream outfalls; and
- Downstream water quality.

Vegetation

Vegetation is important because it reduces the volume of stormwater captured through infiltration and uptake while filtering out nutrients and creating an aesthetic amenity. Native plant species are typically more suited to respond to local weather patterns, require less water, and are more resistant to drought, thus creating lower-maintenance landscapes. Additionally, native plants minimize the need for fertilizer. Because these species are easily crowded out by non-native invasives, structural BMPs should be weeded at the beginning and end of the growing season to maintain a target vegetative community. This is particularly true for riparian buffers, which can pass non-native seeds into the river where they are easily exported downstream.

Structures

Headwalls, endwalls, outlets, and orifice pipes should be inspected on a regular basis to ensure that no structural damage is preventing proper function of the structural BMP. Clogging of the orifice or outlet pipes can flood the basin and cause nearby damage. Debris can accumulate in the control structure and at the inlet of the structural BMP, blocking flow in or out. Structures should be inspected twice per year.

Sediment/Debris

Depending in the total drainage area to the structural BMP and the nearby soil and development conditions, clogging may or may not be an issue. For structures managing runoff from roofs or other low-traffic areas, sediment clogging is not likely to be an issue. These BMPs should be inspected twice per year, and any visible accumulations of sediment should be removed. Basins with a large drainage, or any structural BMP managing runoff from streets, parking lots, or loose soil areas, can clog more quickly with sediment and other debris. Sediment most often accumulates heavily in forebay areas, over splash pads, at inflow points, and anywhere water tends to slow and settle. Appropriate removal schedules will vary by BMP, and should be established on a case-by-case basis.

Downstream Outfalls

Basin outfalls may simply tie into the storm sewer, in which case the only monitoring required is to assure that water is passing through as designed. However where basins outlet directly into wooded areas or streams, serious erosion can occur if the outlet is not designed correctly. Down-slope erosion is a common symptom of unprotected outfalls where water flows freely out of the pipe onto a natural surface. These can be prevented by stabilizing the outfall with stone and cobble for several feet along the flow path, and by avoiding areas with significant grade (CTDEP 2004).

Downstream Water Quality

Where funding permits, water quality should be monitored downstream of new structural BMPs and BMP retrofits to determine their effect on in-stream conditions. For this method to provide useful results, baseline conditions for that location need to be established before the BMP is constructed. Following construction, monitoring should be carried out regularly as load reduction function tends to vary with the age of the BMP and with maintenance techniques used. The sampling methodology and variables discussed above in the section “Routine In-Stream Monitoring” generally apply to sampling downstream of structural BMPs as well.

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[3]Observed areas where land cover within 300 feet of streams had changed to developed or turf and grass from 1985 to 2006, assuming these areas were likely sources of increased peak flows resulting in channel instability. These data were available for both Connecticut and New York.

APPENDIX A: SITE-SPECIFIC STRUCTURAL BEST MANAGEMENT PRACTICES

BMP A. Central Middle School

9 Indian Rock Ln., Greenwich, CT

Mianus River Watershed

BMP Type: Bioretention & subsurface storage
Subwatershed: 19
Construction Cost Estimate: $329,000
Potential Benefits: Water quality, flood control, channel protection
Permitting: Municipal Construction, 401 Water Quality Certification, and Water Diversion
Site Access: Road access
Other Constraints: Space and tree removal may be an issue for the bioretention practices

Existing Conditions

Central Middle School is located in the lower portion of subwatershed 19 near the far western drainage boundary. Pipes in the front parking lots along Indian Rock Ln. appear to drain to a central 18 in. pipe that drains toward Orchard St. The rear parking lot and roofs appear to drain toward a low point in the baseball fields at the rear of the property. An inlet and a large manhole were observed in the north section of the fields near Orchard St. (photo 1), and a large pipe was observed connecting into drains in Orchard St. and discharging into a stream across the street. Inlets observed in this area were sufficiently shallow for diversion to surface practices. A large field is located downhill of the school off Orchard Rd.

Proposed BMP

Stormwater management practices at Central Middle School should be divided between several small bioretention areas in the front of the property, and a single large subsurface storage unit in the rear. The subsurface unit should be designed to manage approximately 2.5 ac. of impervious area from the school roofs and rear parking lot, and to overflow into the manhole structure near Orchard St. The unit should be designed for channel protection, flood control, and water quality if possible.

The smaller front units should be designed to manage local drainage from the upper turn circle and driveway. The lower parking lot could be managed by a bioretention facility along Indian Rock Ln., but several mature trees would have to be removed (photo 2). Each of these smaller facilities should be designed to provide water quality benefits and as much flood control storage as possible to manage runoff.

This BMP would reduce peak flows and provide some uptake of nutrients by vegetation. Depending on infiltration rates, it could also reduce bacteria and provide some groundwater recharge. Before work proceeds, testing should be done to determine depth to water table and infiltration rates.

1: Baseball field northeast of proposed subsurface storage

2: Proposed bioretention area with mature trees

BMP B. Merriebrook Parking Lot & Trail

40-238 Merribrook Ln., Greenwich, CT

Mianus River Watershed

BMP Type: Bioretention
Subwatershed: 62
Construction Cost Estimate: $75,000
Potential Benefits: Water quality, channel protection, flood control
Permitting: Municipal Construction, Inland Wetlands and Watercourses, 401 Water Quality Certification, Stream Channel Encroachment, and Water Diversion; and USACOE Clean Water Act
Site Access: Road access
Ownership: Unknown
Other Constraints: Use conflicts at trail

Existing Conditions

Where Merriebrook Ln. crosses the Main Stem of the Mianus River, two (2) areas were identified as problems by stakeholders. The first is a gravel parking lot at the Red Barn facility, where a poorly installed parking lot is actively eroding and depositing gravel and sediment on the road near the edge of the stream. Several deep gullies were observed in the lower half of the lot, particularly around the roots of a tree (photo 1).

Just downhill, Merriebrook Ln. crosses the Mianus River. A popular trail is accessible from the west bank of the river. The trail is moderately eroded, and eroded channels drain through the forested riparian buffer between the river and the trail. The understory here is almost fully denuded, and tree roots are exposed. According to stakeholders, several attempts have been made to restore the buffer here, but conflicts between user groups have hindered progress.

Proposed BMP

The parking lot at the Red Barn should be paved to prevent further erosion. To offset the impervious area this will add, a small bioretention basin chould be installed on the other side of Merriebrook in a narrow stretch of roadside. This new facility would also be able to capture some of the runoff from the road. Several small trees and some brush would have to be removed. Overflow would have to discharge into the stream via the existing outfall. The basin should be sized to manage runoff from approximately 0.5 ac. of impervious area for water quality, flood control, and channel protection.

The problem of overuse on the trail is more complicated, as the obvious approach of adding riparian buffer plantings has been unsuccessful. A solution must allow some space for recreation in an area agreed upon by all users; the portion of riverfront not in that recreational area should be planted with robust woody understory species and fenced off to allow them to fully establish. Stakeholder meetings, design review, and good interpretive signage will be crucial management strategies at this site (not included in cost estimate).

1: Erosion at Red Barn parking lot

2: Poorly vegetated riparian buffer along river

BMP C. Old Post Rd. Median & Bus Stop

Old Post Rd. & Post Rd., Greenwich, CT

Mianus River Watershed

BMP Type: Bioretention & naturalized surface storage basin
Subwatershed: 19
Construction Cost Estimate: $178,000
Potential Benefits: Water quality
Permitting: Municipal Construction, 401 Water Quality Certification, and Water Diversion
Site Access: Road access
Other Constraints: Deep street inlets; limited space; some tree removal required; subsurface and overhead utilities

1: Proposed small bioretention location

2: Proposed basin location (far end of median)

Existing Conditions

The median area where Old Post Rd. diverges from Route 1 (Post Rd.) in downtown Greenwich is located at the west edge of the watershed. Deep pipes in Post Rd. carry runoff to the base of the median. The open area is mostly grass-covered, with several mature trees. Stanwich Rd. and Valleywood Rd. drain toward this area, and there are inlets at the base of both roads.

A sidewalk runs along old Post Rd. on the north side of the median strip. A bus stop that appears to be heavily used is located at the top of the hill on the west side of the median.

Proposed BMP

A series of small bioretention BMPs is recommended for the top portion of the site in order to manage runoff from the near sides of Post Rd. and Old Post Rd. without removing trees. Stormwater would be conveyed to and overflowed from the practices by curb cuts. At the downhill (east) side a grass-covered open area (photo 2) could be converted to a naturalized surface storage facility. This area should be designed to manage the impervious drainage from the far sides of both roads that could not be captured by sheet flow to the bioretention areas (approximately 0.5 ac.).

Increasing the treated area by diverting runoff from inlets at the base of Stanwich Rd. and Valleywood Rd. was determined infeasible due to inlet depth and cost.

Since the bus stop makes this area a fairly visible location, any stormwater facility built here should be carefully designed and planted to maximize aesthetic benefit. Care should be taken to ensure that clear signage is installed to maximize public exposure to the BMP.

BMP D. Cameron Drive Right-of-Way

Intersection of Cameron Drive & North Stanwich Rd., Greenwich, CT

Mianus River Watershed

BMP Type: Naturalized surface storage
Subwatershed: 7
Construction Cost Estimate: $176,000
Potential Benefits: Water quality, channel protection, habitat
Permitting: Municipal Construction, Inland Wetlands and Watercourses, 401 Water Quality Certification, Stream Channel Encroachment, and Water Diversion; and USACOE Clean Water Act
Site Access: Road access
Ownership: Private
Other Constraints: Impacts to wetlands

Existing Conditions

The Cameron Drive cul-de-sac neighborhood drains to a tributary stream which enters the Stanwich Golf Course from the south. The end cul-de-sac circle drains partially outside the Mianus River Watershed, and partially downhill with the rest of Cameron Drive. Seven (7) shallow inlets drain to a wooded wetland alongside the street where accumulated sediment and channel erosion were observed.

At the intersection of Cameron and North Stanwich, a large pipe discharges to the base of the wetland (photo 1). At the outlet point, banks of approximately two (2) ft. in height were observed. From that point, the wetland drains into a pipe under North Stanwich Rd.

Vegetation in the wetland is a mix of native and non-native floodplain and wetland species. Understory and herbaceous species dominate, with a few mature trees. An area of approximately 30 ft. by 60 ft., adjacent to Cameron Dr., contains an upland plant community.

Proposed BMP

A stormwater management approach to this neighborhood should seek to manage flows for flood control and channel protection as well as water quality. Because the BMP may impact an existing wetland, permitting could be difficult. However, given the poor quality of the existing wetland and its observed failure to manage current storm flows, a more engineered approach may be necessary to help manage downstream problems.

A constructed wetland could be installed adjacent to the existing wetland to manage runoff from approximately two (2) ac. of impervious area. Overflow should discharge into the pipe under North Stanwich Rd.

1: Wetland adjacent to proposed BMP

1: Drain and pipe to existing wetland

BMP E. Stanwich Country Club & Adjacent Residence

294 Taconic Rd. & 888 North St., Greenwich, CT

Mianus River Watershed

BMP Type: Stream restoration & riparian buffer
Subwatershed: 7
Construction Cost Estimate: $633,000
Potential Benefits: Water quality; channel protection
Permitting: Municipal Construction, Inland Wetlands and Watercourses, 401 Water Quality Certification, Stream Channel Encroachment, and Water Diversion; and USACOE Clean Water Act
Site Access: Access via driveway and lawn
Other Constraints: May interfere with lines of sight on golf course

Existing Conditions

The Stanwich Golf Club is located in the headwaters of subwatershed 7. The stream originates in three (3) large ponds which drain to a series of unbuffered channels and ponds in the golf course. Stagnant water and algae were observed in the stream crossed by the main driveway (photo 1).

Southeast of the golf course the stream passes through a forested area before entering a large property that appears to be residential. Ownership could not be determined. Here the stream banks have been stabilized, but ongoing channel instability including erosion (photo 2) was observed in areas. The channel drops along a steep gradient.

Proposed BMP

A combined stream restoration, riparian buffer planting, and nutrient management program are recommended to stabilize the stream and improve water quality. Approximately 1100 ft. of stream below the golf course should be restored with a combination of hard and soft stabilization. Because this area is located on private property, coordination with the homeowner would be required.

On the golf course the gradient is low and the stream appears fairly stable, but riparian buffers should be added on both sides of the stream and ponds for the length of the property (approximately 3500 ft. of stream). An eight (8) ft. wide buffer was estimated based on site constraints, but a wider buffer is recommend if more space is available and it will not interfere with golf course lines of sight. A meadow-type mix should be used to seed the banks, and once established, mowing should be restricted.

1: Stream at north end of golf course

2: Stream southeast of golf course

BMP F. Banksville Town Center

4-33 Bedford-Banksville Rd., Bedford, NY

Mianus River Watershed

BMP Type: Naturalized surface storage basins; level spreader; bioretention; good housekeeping
Subwatershed: 10
Construction Cost Estimate: $319,000
Potential Benefits: Water quality, flood control, channel protection, habitat
Permitting: Municipal Construction, USACOE Clean Water Act, Water Quality Certification, State Environmental Quality Review Act (SEQR)
Site Access: Access via road
Ownership: Private
Other Constraints: None

Existing Conditions

Banksville center, near the intersection of Banksville Ave. and Bedford-Banksville Rd., is located in the far headwaters of subwatershed 10. The stream originates on the east site of Bedford-Banksville Rd. across the state border in Connecticut. It crosses the road and passes through a low area where it receives storm flow via several outfalls from the uphill tennis club and shopping center on Bedford-Banksville Rd. The stream then passes through a forested wetland complex ranging from poor to good quality. Two (2) industrial facilities contribute runoff and possibly point source pollution to the stream/wetland complex. A significant amount of orange material was observed in the stream, as well as accumulated sediment and stagnant, cloudy water. Behind the Banksville fire station the stream is joined by a tributary that originates east of Bedford-Banksville Rd. The tributary flows west through a wetland/pond complex located behind an abandoned auto repair shop before entering a culvert under the road. The pond receives street runoff from multiple outfalls.

Proposed BMP

Dense development in the headwaters has had an effect in Banksville, evidenced by poor water quality and unstable channel conditions. Restoration here should take a holistic approach to managing stormwater, restoring function to existing wetlands, and limiting point-source pollution. Three (3) specific BMPs were identified:

- Construct a bioretention facility in the parking lot median at Saint Timothy's Chapel to manage runoff from approx. 0.5 ac. of parking lot and part of the road.
- Install a level spreader to dissipate storm flows from the outfalls behind the tennis club, where erosive flows are causing damage to an existing wetland. This should improve wetland hydrology and reduce erosion.
- Construct a naturalized surface storage basin in the open space across the street from the firehouse; divert stormwater from an existing inlet in Bedford-Banksville Rd.
- Recommend good housekeeping practices for streamside industrial facilities to reduce leaching of contaminants.

SEE FOLLOWING PAGE FOR PHOTOS


1: Proposed bioretention area, Saint Timothy's


2: Pond and open space across street from firehouse


3: Eroded wetland downstream from tennis club


4: Industrial facility adjacent to stream

BMP G. Rockrimmon Country Club

2949 Long Ridge Rd, Stamford, CT

Mianus River Watershed

BMP Type: Naturalized surface storage basin, stream restoration & riparian buffer
Subwatershed: 18
Construction Cost Estimate: $178,000
Potential Benefits: Water quality, flood control, channel protection, habitat
Permitting: Municipal Construction, Inland Wetlands and Watercourses, 401 Water Quality Certification, Stream Channel Encroachment, and Water Diversion; and USACOE Clean Water Act
Site Access: Access via road
Ownership: Private
Other Constraints: Golf course lines of sight

Existing Conditions

Rockrimmon Country Club is located in the headwaters of subwatershed 18. A first order stream originates in the pond at the southern end of the golf course (photo 2). Another larger stream passes through two (2) small ponds at the north end of the course. None of the ponds or streams that cross the course are well buffered. Significant algal growth was observed in the southern pond, which appears to be capturing stormwater from the entire site via a single pipe. Between the upper maintenance buildings and the main parking area, an asphalt-lined drainage channel is in poor condition and appears to be actively eroding (photo 1).

Proposed BMP

A restoration of this site should focus on riparian buffer establishment along the stream channel and ponds. The width of the buffer will depend on the available area and proximity to active driving lines where views are important to the function of the facility. For this assessment, an average buffer width of eight (8) ft. is assumed for a total length of 4,000 ft. of stream and pond bank.

To prevent further erosion, the undermined drainage channel should be addressed with a combination of soft and hard stabilization. The asphalt armor should be removed and replaced with a naturalized bed. This will require approximately 215 ft. of restoration work. The channel could be widened in less constrained sections to create storm storage.

Because unused open space is limited, there is little room to manage the site's stormwater. The wooded area below the main parking lot appears to offer the best opportunity to manage stormwater from the adjacent lot without extensive conveyance; however some tree removal would be required. A depression in the ground just beyond the parking lot could be expanded to manage approximately 0.5 ac. of impervious area, and an inlet near the southeast corner of the lot could be diverted into this area using approximately 100 ft. of additional pipe. It does not appear that the lower lot could feasibly be managed here due to the relative difference in elevation. Overflow could return to the existing infrastructure at the base of the parking lot.


1: Eroded drainage ditch


2: Southernmost pond

BMP H. Miller's Mill

2 Miller's Mill Rd., Bedford, NY

Mianus River Watershed

BMP Type: Stream restoration
Subwatershed: 64
Construction Cost Estimate: $171,000
Potential Benefits: Water quality, channel protection
Permitting: Municipal Construction, USACOE Clean Water Act, Water Quality Certification, Protection of Waters, State Environmental Quality Review Act (SEQR)
Site Access: Road access
Ownership: Private
Other Constraints: Historic site; tributary restoration will require removal of trees and good-quality meadow

Existing Conditions

Miller's Mill is located on the Upper Main Stem of the Mianus River, above the reservoir and Mianus Gorge Preserve. This site was identified by stakeholders as a problem area. Steep dirt roads are actively eroding and depositing large quantities of sediment on the upper banks and in inlets draining to the river. Sediment traps have been installed, but the regularity of maintenance appears insufficient to keep up with loads. A large amount of accumulated sediment was observed in all the inlets near the bridge and the intersection of Mianus River Rd. and Miller's Mill Rd. Erosion was observed near the outfall from the west sediment trap.

Immediately downstream of the dam, the river appears moderately incised and the floodplain somewhat disconnected. A gullied tributary draining a steep wetland on the other side of Mianus River Rd. enters the Main Stem from under the road. At the outlet of the culvert, clay-rich banks are four (4) ft. high and nearly vertical (photo 2).

Proposed BMP

Paving Miller's Mill Rd. would alleviate most of the sediment problems near the bridge, but this may be impossible due to historic designations. This possibility deserves further attention. Assuming paving is not an option, it is imperative that sediment traps and inlets be cleaned on a regular basin, and that the dirt road be regularly maintained. Alternatively, runoff from the Miller's Mill Rd. could be diverted to a naturalized surface storage basin with an easily accessible forebay to capture sediment and reduce erosion at the outfall (photo 1).

Erosion from the incoming tributary across Mianus River Rd. should be stabilized with a series of step pools to control grade from the culvert outlet approximately 100 ft. in to where the tributary enters the main river. Storage for flood control could be created adjacent to the eroded channel, with an easily accessible forebay for sediment removal.

There may be some potential for an upstream sediment forebay to help capture some of the sediment leaving the road. Approximately 200 ft. of bank along the west side of the stream could be lowered to reconnect the river with its floodplain. This would require the removal of approximately 15 mature trees as well as a good-quality meadow. Good housekeeping practices at the inlets and sediment traps would most likely eliminate the need for this sort of drastic control measure.


1: Erosion overflow from sediment trap to river


2: Gullied tributary to main stem

BMP I. Windmill Lakes Neighborhood

North Castle, NY

Mianus River Watershed

BMP Type: Multiple small bioretention facilities
Subwatershed: 64 & 1
Construction Cost Estimate: $410,500
Potential Benefits: Water quality, flood control, channel protection, habitat
Permitting: Municipal Construction, USACOE Clean Water Act, Water Quality Certification, Protection of Waters, State Environmental Quality Review Act (SEQR)
Site Access: Road access to most sites
Ownership: Public & private
Other Constraints: Space

Existing Conditions

The Windmill Lake neighborhood, just east of Brynwood Golf Club in North Castle, NY, is located in the far headwaters of the Main Stem Mianus River (subwatershed 64). The streams originate in a series of lakes (Windmill Lake, North Lake, Long Pond, and others) and then drain through a medium-density suburban neighborhood before joining the outlet of subwatershed 10 just below Middle Patent Cemetery.

Storm conveyance in the neighborhood uses a combination of short pipes and ditches, similar to other subdivisions in the watershed. Numerous small eutrophic ponds were observed in front yards and right-of-way open spaces. Accumulations of algae and sediment were present in every pond observed, and several were completely filled with sediment.

The gullied streams draining to and from the ponds were largely eroded with steep banks of one (1) to four (4) ft. In some areas the road and driveways adjacent to the storm conveyance system were undermined or fully washed away, indicating that the existing conveyance infrastructure is not fully equipped to manage current storm flows. Downstream from this neighborhood at the crossing with Middle Patent Rd. the stream was observed to be in "worse than expected" condition during the existing conditions analysis. In particular, large deposits of sand and sediment were observed in the stream bed and on the banks near the crossing with Middle Patent Rd., indicating that although base flow is limited in the summer months, sediment is moving downstream in large quantities during some storm events.

Proposed BMP

Dense development in the headwaters has had an effect in this neighborhood, evidenced by unstable channel conditions and erosion. Restoration here should focus on reducing peak flows and limiting erosion of fine sediment. Several potential BMPs sites were identified to manage erosive conditions:

- At Oak Ridge cul-de-sac, stabilize erosion and grade back channelized banks for a length of approx. 60 ft. to create storage; excavate around existing trees in the right-of-way; encourage road sheet-flow into this area.
- At Pond Ln., just downhill of the intersection with Mill Ln., create storage at the confluence of a ditch outlet and the stream channel; stabilize edge of road where stormwater is flowing overland across the road shoulder and undermining the asphalt.
- At Long Pond Rd.'s intersection with Pond Ln., restore eutrophic, one (1) ft. deep pond as a wetland; below the pond's outlet, restore wetland that has been overwhelmed by sediment.
- West of the Pond Ln. intersection on Long Pond Rd., ditches are eroding and headwall/endwall structures are in poor condition or collapsing. Manage storm flows here by directing road runoff from street inlets to a 20 ft. by 60 ft. open space that appears to be a right-of-way.
- At Fox Ridge Ct. and Elm Pl., a steep wetland is eroding. Downstream channel banks are 2-3 ft. high, and the stream eventually runs into a pipe. Create a series of pocket wetlands and restore existing wetland in the two (2) residential yards on the west side of Fox Ridge Ct. (located in subwatershed 1).

Windmill Lakes Neighborhood (cont.'d)

Bedford, NY

Mianus River Watershed


1. Oak Ridge cul-de-sac—erosion and exposed pipes


2. Pond Ln. & Long Pond Rd. – sediment in wetland


3. Pond Ln. & Long Pond Rd. – eutrophic pond


4: Pond Ln. – ditch outfall to stream


5. Fox Ridge Rd., downstream of Fox Ridge Ct.


6. Stream crossing at Middle Patent Rd. (not pictured on aerial

BMP J. Pine Ridge Neighborhood Buffers

Pine Ridge Lane to Castle Court, Greenwich, CT

Mianus River Watershed

BMP Type: Riparian buffer
Subwatershed: 19 (Strickland Brook)
Construction Cost Estimate: $7,000
Potential Benefits: Water quality
Permitting: None
Site Access: Access via private property
Ownership: Private (residential)
Other Constraints: Owner permission may be difficult

NO PHOTO AVAILABLE

Existing Conditions

The Pine Ridge neighborhood is located along the westernmost tributary draining into Strickland Brook. The residential homes here are all fairly large, and many lawns abut the stream directly with little or no riparian buffer. The stream crosses the road in several locations on Montgomery Ln., Pine Ridge Ln., Jeffrey Rd., and Castle Ct., and passes through approximately 11 unbuffered residential lawns between Montgomery Ln. and the tributary's outlet above Cos Cob Pond.

Proposed BMP

Approximately 26,000 ft.^{2} of meadow-type riparian buffer should be added along this portion of stream, assuming a buffer depth of approximately eight (8) ft. This may be achieved through planting, or may even be possible through establishment of a no-mow zone which would allow the existing grasses to grow thicker. Because this reach of stream is divided across multiple private properties, a coordinated effort will be required among all owners in order to achieve full continuity of the retrofit.

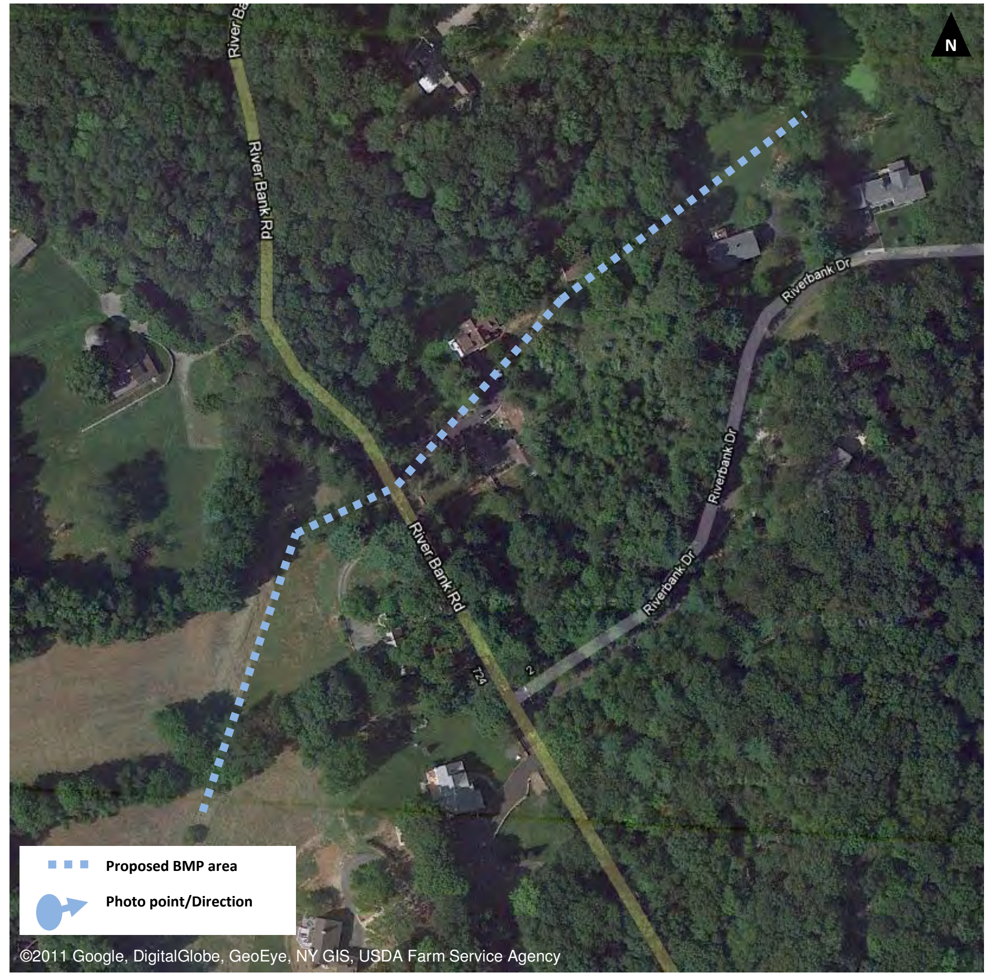
NOTE: Proposed BMP has not been field verified due to access constraints on private property.

BMP K. Riverbank Road Buffers

Riverbank Road and Riverbank Lane, Stamford, CT

Mianus River Watershed

BMP Type: Riparian buffer
Subwatershed: 62 (Main Stem)
Construction Cost Estimate: $8,000
Potential Benefits: Water quality
Permitting: None
Site Access: Access via private property
Ownership: Private (residential)
Other Constraints: Owner permission may be difficult



Existing Conditions

A small tributary crosses Riverbank Rd. near its intersection with Riverbank Dr. in Stamford. The tributary originates in a pond in a residential back yard on Riverbank Dr. The stream then passes through three (3) properties where the riparian buffer is limited or absent before crossing Riverbank Rd. and passing into an open field. The stream channel here appears to have been modified, and what buffer exists may not be adequate.

Proposed BMP

Approximately 28,000 $ft.^2$ of meadow-type riparian buffer should be added along this portion of stream, assuming a buffer depth of approximately 10 ft. This may be achieved through planting, or may even be possible through establishment of a no-mow zone which would allow the existing grasses to grow thicker. Because this reach of stream is divided across many private properties, a coordinated effort will be required among all owners in order to achieve full continuity of the retrofit.

NOTE: Proposed BMP has not been field verified due to access constraints on private property.

NO PHOTO AVAILABLE

APPENDIX B: FUNDING OPPORTUNITIES

Funding Source	Maximum Dollar amount	Minimum Dollar amount	Required match	Applications Open	Deadline
CTDEEP Watershed Funding Website					
http://www.ct.gov/dep/cwp/view.asp?a=2719&q=335494&depNav_GID=1654&pp=12&n=1 Index of many potential funding sources for funding watershed-based planning projects.					
CTDEEP Open Space and Watershed Land Acquisition	Up to 40-60%			Twice a year	
860-424-3016 david.stygar@ct.gov http://www.ct.gov/dep/cwp/view.asp?a=2706&q=323834&depNav_GID=1641					
CTDEEP Recreation & Natural Heritage Trust Program				Rolling	
http://www.ct.gov/dep/cwp/view.asp?a=2706&q=323840&depNav_GID=1641					
Eastman Kodak / Nat'l Geographic American Greenways Awards optional Program	$2,500	$500	Optional	April	June
kodakawards@conservationfund.org; jwhite@conservationfund.org (Jen White) http://www.conservationfund.org/kodak_awards					
EPA Healthy Communities Grant Program	$30,000	$5,000	Optional, non-federal up to 5%	March	April
617-918-1698 Padula.Jennifer@epa.gov					
Northeast Utilities Environmental Community Grant Program	$1,500				15-Sep
http://www.nu.com/environmental/grant.asp Cash incentives for non-profit organizations Patricia Baxa, baxapl@nu.com					
CTDEEP CWA Section 319 NPS			40% of total project costs (non-federal)		August
Non-point Source Management http://www.ct.gov/dep/nps Projects targeting both priority watersheds and statewide issues.					

Funding Source	Maximum Dollar amount	Minimum Dollar amount	Required match	Applications Open	Deadline
CTDEEP Section 6217 Coastal NPS			N/A		
http://www.ct.gov/dep/cwp/view.asp?a=2705&q=323554&depNav_GID=1709 Section 6217 of the CZARA of 1990 requires the State of Connecticut to implement specific management measures to control NPS pollution in coastal waters. Management measures are economically achievable measures that reflect the best available technology for reducing non-point source pollution.					
CTDEEP Hazard Mitigation Grant Program			75% Federal/25% Local		
http://www.ct.gov/dep/cwp/view.asp?a=2720&q=325654&depNav_GID=1654 Provides financial assistance to state and local governments for projects that reduce or eliminate the long-term risk to human life and property from the effects from natural hazards.					
American Rivers-NOAA Community-Based Restoration Program Partnership	Construction: $100,000 Design: $150,000				December
http://www.americanrivers.org/our-work/restoring-rivers/dams/background/noaa-grants-program.html These grants are designed to provide support for local communities that are utilizing dam removal or fish passage to restore and protect the ecological integrity of their rivers and improve freshwater habitats important to migratory fish.					
Fish America Foundation Conservation Grants	$75,000	$10,000	At least 75% (non - federal)		April
703-519-9691 x247 fishamerica@asafishing.org http://www.fishamerica.org/grants.html					
Municipal Flood & Erosion Control Board	1/3 project cost	2/3 project costs			
NFWF LIS Futures Fund Small Grants	$10,000	$3,000	optional (non- federal)	Fall/Winter	March
631-289-0150 Lynn Dwyer http://longislandsoundstudy.net/about/grants/lis-futures-fund					
NFWF Long Island Sound Futures Fund Large Grants	$150,000	$10,000	optional(non- federal)	Fall/Winter	April
631-289-0150 Lynn Dwyer http://longislandsoundstudy.net/about/grants/lis-futures-fund					

Funding Source	Maximum Dollar amount	Minimum Dollar amount	Required match	Applications Open	Deadline
NRCS Wildlife Habitat Incentives Program (WHIP)	$ 50,000/year	$1,000	25%	Rolling	May
Joyce Purcell, (860) 871-4028 For privately owned lands. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/whip					
NRCS Wetlands Reserve Program				Rolling	
Nels Barrett, (860) 871-4015 http://www.ct.nrcs.usda.gov					
USFS Watershed and Clean Water Action and Forestry Innovation Grants					
http://www.na.fs.fed.us/watershed/gp_innovation.shtm This effort between USDA FS-Northeastern Area and State Foresters to implement a challenge grant program to promote watershed health through support of state and local restoration and protection efforts.					
Corporate Wetlands Restoration Partnership (CWRP)	Typically $ 20,000	typically $5,000	3 to 1	April and August	
http://www.ctcwrp.org/9/ Can also apply for in-kind services, e.g. surveying, etc.					
River's Alliance Watershed Assistance Small Grants Program2	Typically $5,000, not to exceed $1,0000	$500	40% of total project costs		October
http://www.riversalliance.org/ 860-361-9349 rivers@riversalliance.org Funding passed through River's Alliance from CTDEEP's 319 NPS grant program for establishing new or emerging river – watershed organizations.					
USFWS National Coastal Wetlands Conservation Grant Program	$1 million		50%		
http://www.fws.gov/coastal/coastalgrants Ken Burton 703-358-2229. Only states can apply.					
EPA Green Infrastructure Funding Website					
http://water.epa.gov/infrastructure/greeninfrastructure/gi_funding.cfm Index to funding opportunities for LID practices and pollution reduction projects.					

Funding Source	Maximum Dollar amount	Minimum Dollar amount	Required match	Applications Open	Deadline
America the Beautiful Grant Program	$8,000		50%	May	June

USDA Forest Service funding through the CTDEEP Division of Forestry to support urban forestry efforts. www.ct.gov/dep/forestry

OTHER FINANCIAL OPPORTUNITIES

Private Foundation Grants and Awards

http://www.rivernetwork.org Private foundations are potential sources of funding to support watershed management activities. Many private foundations post grant guidelines on websites. Two online resources for researching sources of potential funding are provided in the contact information.

State Appropriations – Direct State Funding
http://www.cga.ct.gov/

Membership Drives
Membership drives can provide a stable source of income to support watershed management programs.

Donations
Donations can be a major source of revenue for supporting watershed activities, and can be received in a variety of ways.

User Fees, Taxes, and Assessments
Taxes are used to fund activities that do not provide a specific benefit, but provide a more general benefit to the community.

Stormwater Utility Districts
A stormwater utility district is a legal construction that allows municipalities to designated management districts where storm sewers are maintained in order to the quality of local waters. Once the district is established, the municipality may assess a fee to all property owners.

Impact Fees
Impact fees are also known as capital contribution, facilities fees, or system development charges, among other names.

Special Assessments
Special assessments are created for the specific purpose of financing capital improvements, such as provisions, to serve a specific area.

Sales Tax/Local Option Sales Tax
Local governments, both cities and counties, have the authority to add additional taxes. Local governments can use tax revenues to provide funding for a variety of projects and activities.

Property Tax
These taxes generally support a significant portion of a county's or municipality's non-public enterprise activities.

Excise Taxes
These taxes require special legislation, and the funds generated through the tax are limited to specific uses: lodging, food, etc.

Bonds and Loans
Bonds and loans can be used to finance capital improvements. These programs are appropriate for local governments and utilities to support capital projects.

Funding Source	Maximum Dollar amount	Minimum Dollar amount	Required match	Applications Open	Deadline
Investment Income Some organizations have elected to establish their own foundations or endowment funds to provide long-term funding stability. Endowment funds can be established and managed by a single organization-specific foundation or an organization may elect to have a community foundation to hold and administer its endowment. With an endowment fund, the principal or actual cash raised is invested. The organization may elect to tap into the principal under certain established circumstances.					
EMERGIN OPPORTUNITIES FOR PROGRAM SUPPERT					
Water Quality Trading Trading allows regulated entities to purchase credits for pollutant reductions in the watershed or a specified part of the watershed to meet or exceed regulatory or voluntary goals. There are a number of variations for water quality credit trading frameworks. Credits can be traded, or bought and sold, between point sources only, between NPSs only, or between point sources and NPSs.					
Mitigation and Conservation Banking Mitigation and Conservation banks are created by property owners who restore and/or preserve their land in its natural condition. Such banks have been developed by public, nonprofit, and private entities. In exchange for preserving the land, the “bankers” get permission from appropriate state and federal agencies to sell mitigation banking credits to developers wanting to mitigate the impacts of proposed development. By purchasing the mitigation bank credits, the developer avoids having to mitigate the impacts of their development on site. Public and nonprofit mitigation banks may use the funds generated from the sale of the credits to fund the purchase of additional land for preservation and/or for the restoration of the lands to a natural state.					

Source: Norwalk River Watershed Plan (NRWIC 2011); Web-links were verified for active status by AKRF in March 2012.

APPENDIX C: STREAM VISUAL ASSESSMENT FIELD SUMMARIES

Appendix A. Stream Visual Assessment Field Summaries

									Stream Visual Assessment Parameters														
Sample Location ID	Location	Subwatershed	ICScore*	Land use within Drainage	Approximate Active Channel Width	Gradient	Channel Form	Dominant Substrate	Channel Condition	Hydrologic Alteration	Riparian Zone	Bank Stability	Water Appearance	Nutrient Enrichment	Barriers to Fish Movement	Instream Fish Cover	Pools	Invertebrate Habitat	SVA Score**	SVA Category	Invertebrates Observed	Habitat Observed	Comments
10	Pine Ridge Road	19 (Strickland Brook)	fair	residential	2'	moderate	riffle-pool	cobble	8	8	7	9	10	8	1	3	1	5	**6.0**	**poor**	Chironomid; Gastropoda	riffles; boulders; leaf packs	
11	June Road and River Bank Road	62 (Below Bargh Reservoir)	fair	residential	25'	moderate	riffle-pool	cobble	7	7	9	8	10	9	10	6	7	8	**8.1**	**good**	not sampled	undercut banks; pools; wood; leaf packs	banks are steep (1-2 feet) but well armored with boulders and tree roots; minor/localized erosion downstream of bridge; road close to river
12	Mill Road and Old Long Ridge Road	18 (East Branch)	fair	residential; recreation	7'	moderate	riffle-pool	boulder	2	3	5	4	7	4	1	3	8	6	**4.3**	**poor**	not sampled	boulders; riffles; wood; pools	two dams within reach; riprap stabilization on one bank
13	Mohawk Trail	18 (East Branch)	fair	residential	7'	moderate	riffle-pool	cobble	5	7	8	5	9	9	5	4	4	6	**6.2**	**fair**	not sampled	leaf packs; undercut banks; riffles	adjacent forested wetlands; fine sediment accumulation
14	Downstream of Twin Lakes; off Long Ridge Road	3	good	residential, forested	5'	moderate	riffle-pool	cobble	9	10	10	10	10	10	5	7	5	8	**8.4**	**good**	Chironomid	riffles; wood; leaf packs; undercut banks	valley walls steep creating natural constriction
15	Miller's Mill Road-downstream of dam	64 (Upper main stem)	fair	residential, forested	25'	low	plane-bed	sand	5	5	9	3	9	9	1	5	7	7	**6.0**	**poor**	not sampled	undercut banks; overhanging vegetation; wood	channel historically incised and over widened; mid-channel accretion; incised 2-3 feet; feeder tribs with active incision/bank erosion
16	St. Mary's Church	4	good	residential, forested	2'	low	plane-bed	sand	9	10	10	10	10	10	7	3	1	3	**7.3**	**fair**	not sampled	undercut banks; root wads; submerged aquatic vegetation; leaf packs	downstream of a pond impounded by small 2' high wall; runs through wetland
17	St. Mary's Church	4	good	residential, forested	4'	moderate	riffle-pool	cobble	9	10	10	10	10	10	7	6	7	9	**8.8**	**good**	Tricoptera; Plecoptera; Oligochaeta	leaf packs; boulders; undercut banks; tree roots; submerged aquatic vegetation	filamentous algae abundant on rocks; stream flows from forested wetland
18	Middle Patent Road west of Bedford-Banksville Road	64 (Upper main stem)	fair	residential, forested	4'	moderate	riffle-pool	sand	1	7	10	6	10	10	7	2	1	2	**5.6**	**poor**	not sampled	undercut banks; riffles	evidence of recent or active erosion (bed and bank) and deposition of sand (channel and floodplain); appears highly disturbed
19	Middle Patent Road & Bedford-Banksville Rd.	10	fair	residential, forested	7'	high	step-pool	boulder	1	4	10	3	10	10	7	6	5	8	**6.5**	**fair**	not sampled	boulders; pools; undercut banks; riffles	past and active bank erosion and channel widening; braiding; some armoring
20	Middle Patent Road & Pound Ridge Road	64 (Upper main stem)	fair	residential, forested	25'	low	plane-bed	sand	7	8	5	5	8	10	10	4	6	4	**6.7**	**fair**	not sampled	undercut banks; overhanging vegetation; wood	flows through wetlands

***Impervious Cover (IC) Scores equate to the following expected stream condition:**
Poor (IC score = 3 or 4)
Fair (IC score = 1 or 2)
Good (IC score = 0)
****Stream Visual Assessment (SVA) Scores are the average of the parameter scores and equate to the following observed stream conditions (SVA Category):**
≤6.0 = Poor
6.1-7.4 = Fair
7.5-8.9 = Good
≥9.0 = Excellent