West River Watershed Management Plan
Technical Memorandum #1:
State of the Watershed

February 2015

Prepared For:

Save the Sound &
West River Watershed Coalition

In Cooperation With:

Connecticut Department of
Energy & Environmental Protection

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1 Introduction

1.1 Background

The West River watershed is approximately 34 square miles and is located in the municipalities of New Haven, West Haven, Bethany, Hamden, Prospect, and Woodbridge, Connecticut (*Figure 1-1*). The 25-mile long river originates at Lake Bethany and continues south, eventually discharging into New Haven Harbor. Wintergreen Brook and Sargent River are the major tributaries to the West River. The West River, like many other urbanized rivers and streams in Connecticut, has been impacted by historical development and land use activities in its watershed. Water quality in the West River is degraded due to elevated bacteria levels resulting from stormwater runoff, agriculture, sanitary sewer overflows, illicit discharges, and other sources. This degradation has resulted in impaired conditions in the watershed, which means that the waterbodies cannot support certain types of uses, such as recreation or aquatic life habitat. In 2012, the Connecticut Department of Energy and Environmental Protection (CTDEEP) developed a Total Maximum Daily Load (TMDL) for bacteria-impacted waterbodies statewide, including the West River, to begin to address the bacteria impairments. The TMDL identified reductions in indicator bacteria loads to the West River that are necessary for the impaired segments to meet State water quality standards and once again support contact recreation.

Save the Sound (STS) is working with the West River Watershed Coalition, CTDEEP, municipalities in the watershed, and other groups, to develop a watershed based plan for the West River. The development of the watershed based plan is funded by the Nonpoint Source Grant program under Section 319 of the Clean Water Act and will be consistent with the CTDEEP and U. S. Environmental Protection Agency (EPA) "nine elements" watershed planning process. The plan will incorporate available water quality data and previous and ongoing studies to prioritize waterbodies and implementation projects to reduce pollutant loads in the watershed. The goal of the watershed based plan is to facilitate capacity building and engage the watershed municipalities and stakeholders to ultimately restore impaired segment of West River and Edgewood Park Pond to their designated uses. Fuss & O'Neill, Inc. was retained by STS to lead the development of the watershed based plan, working with a Project Steering Committee consisting of representatives from the watershed municipalities, government organizations, educational institutions, non-profit organizations, and others who live and work within the watershed.

1.2 The Watershed Planning Process

A watershed based plan is a comprehensive, science-based planning document for the protection and restoration of water resources. The watershed based planning process characterizes current and emerging issues facing the watershed, sets goals and objectives, and provides recommendations that have the clear potential to affect on-the-ground change within the watershed.

The watershed planning process includes the preparation of three related documents. This first document, the "State of the Watershed" report, summarizes existing water quality and land use conditions in the West River watershed. It also identifies the major water quality and related water resources issues to be addressed by the watershed based plan. The second report will document a site-

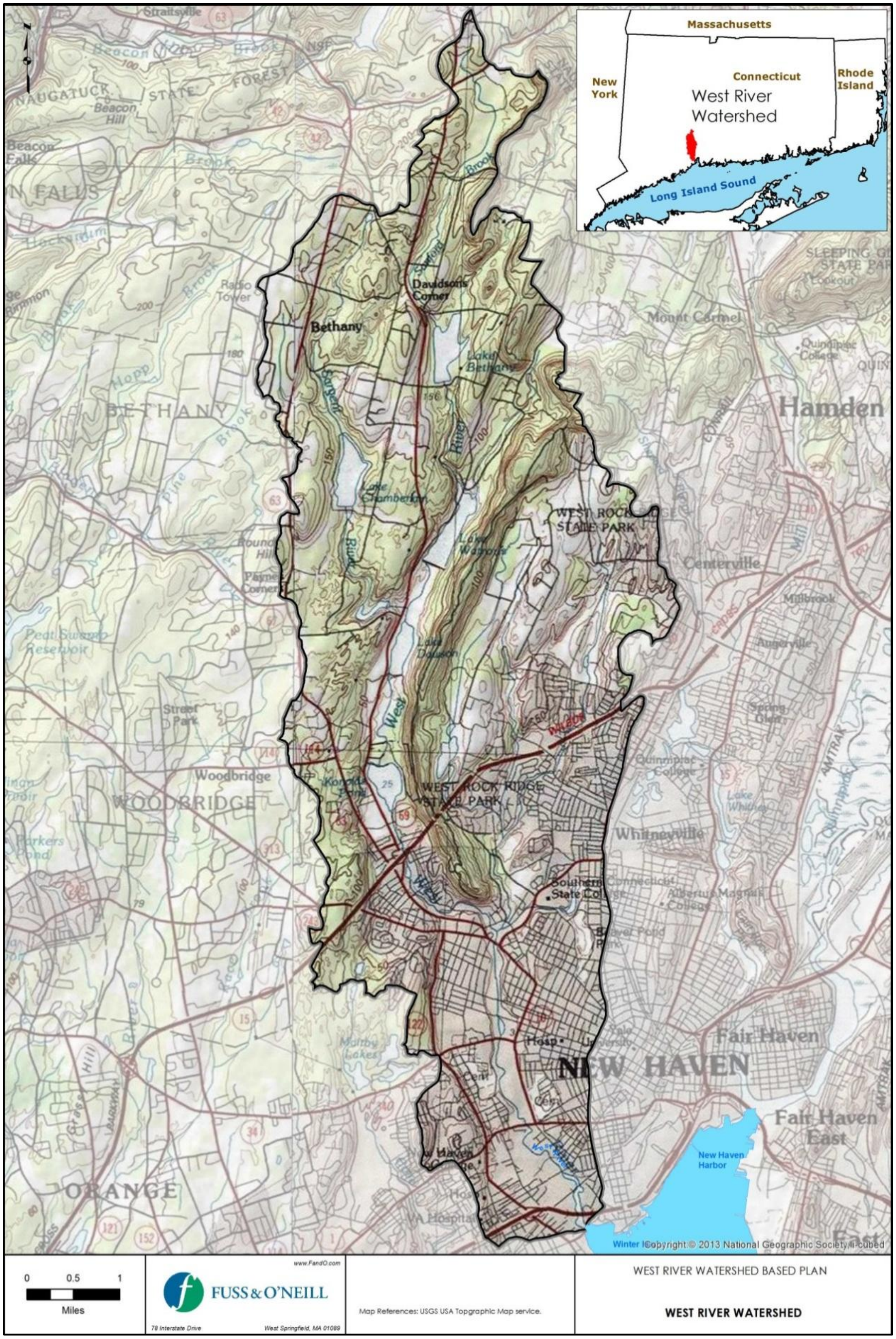

Figure 1-1. West River Watershed

specific stormwater retrofit assessment of the watershed. The "Low Impact Development and Green Infrastructure Assessment" report will identify retrofit concepts to serve as future implementation projects and examples of projects that could be implemented in the watershed. The final report, the Watershed Based Plan will identify prioritized action items to protect and improve water quality and water resource conditions in the West River and its watershed, guided by input from the Project Steering Committee.

This "State of the Watershed" report is the first phase of the process which informs the recommendations in the watershed based plan, which is being developed to be consistent with the EPA and CTDEEP guidance. The watershed based plan will incorporate the nine watershed management planning elements required by CTDEEP and EPA for future funding of plan recommendations through the Section 319 Nonpoint Source Grant program, as well as similar state and federal funding programs. The nine key elements (see box) establish the structure of the plan, including specific goals, objectives, and strategies to protect and restore water quality; methods to build and strengthen working partnerships; a dual focus on addressing existing problems and preventing new ones; a strategy for implementing the plan; and a feedback loop to evaluate progress and revise the plan as necessary.

EPA Nine-Elements of a Watershed Based Plan

a. Identify causes and sources of pollution
b. Estimate pollutant loading to the watershed and the expected load reductions
c. Describe management measures that will achieve load reductions and targeted critical areas
d. Estimated amount of technical and financial assistance and the relevant authorities needed to implement the plan
e. Develop and information/education component
f. Develop a project schedule
g. Describe the interim, measurable milestones
h. Identify indicators to measure progress
i. Develop a monitoring component

1.3 Previous Studies and Stewardship Activities

Areas of the West River watershed have been the subject of extensive study by various groups including CTDEEP, Yale University School of Forestry & Environmental Studies, City of New Haven, City of West Haven, Town of Woodbridge, Connecticut Fund for the Environment/Save the Sound (CFE/STS), Friends of Beaver Pond Park (through the Urban Resources Initiative (URI)), and other local schools and universities. Various water and natural resource planning and stewardship efforts within the West River watershed have included restoration projects for the West River Tidal Marsh, West River Memorial Park, and Edgewood Park. With the exception of the 2012 TMDL (see *Section 3.1*) and local land use planning, there have been no comprehensive watershed-based planning efforts to address the water quality impairments in the West River watershed. Notable restoration and management studies and projects that have been conducted within the watershed are described briefly below.

West River Memorial Park

West River Memorial Park is a former approximately 134-acre tidal marsh. It has been the subject of extensive study due to the historic degradation of this area and interest in its potential restoration. The following studies and projects have been completed; studies relevant to wetlands within the watershed are described further in *Section 4.2*:

- *Restoration of an Urban Salt Marsh: An Interdisciplinary Approach* (Miller, J. A., Coppock, J., and D. G. Casagrande, (Eds.)., 2007): This Yale University-produced bulletin is a collection of scientific research and articles drawing on the multi-disciplinary experience of restoration ecology using the West River Memorial Park as a case study (See *Section 4.2)*.

- *Conceptual Master Plan Report: West River Memorial Park* (Vollmer Associates, 1999): This master plan's goal is to provide an increase in active and passive recreation opportunities and habitat restoration in West River Memorial Park. This master plan forms the basis for the ongoing restoration efforts of the tidal marsh areas within the park.

- *Environmental Review: West River Memorial Park Restoration, New Haven, Connecticut* (Milone & MacBroom, 2002a): This environmental review evaluates several elements of the proposed *Conceptual Master Plan Report* (Vollmer Associates, 1999), including tidal marsh and river channel restoration, improvements to existing soccer fields, and construction of a playground.

- *Preliminary Engineering Study, West River Memorial Park Tidal Marsh Restoration* (Milone & MacBroom, 2002b): This preliminary engineering study investigated potential restoration activities for the West River Memorial Park Tidal Marsh. Discussion of completed activities and the current project status is included in *Section 4.2*.

- *West River Tide Gates and Edgewood Park Tidal Fluctuation and Salinity Migration Monitoring Study* (Milone & MacBroom, 2005): This tide gate study evaluated water level (i.e. flooding) and salinity impacts of the manually-operated sluice gate and port that was installed on one of the tide gates at the Orange Avenue Bridge (Route 1) and is discussed in *Section 4.2*.

Edgewood Park

Edgewood Park is located north of West River Memorial Park, and consists of approximately 113 acres including Edgewood Park Pond (also called Duck Pond), which is impaired for recreational uses due to elevated bacteria concentrations. In addition to the *West River Tide Gates and Edgewood Park Tidal Fluctuation and Salinity Migration Monitoring Study* (Milone & MacBroom, 2005) described above, a *Management Plan for Edgewood Park* was developed through the Yale School of Forestry and Environmental Studies (Brower et al., 1999), described further in *Section 6.4.*

Pond Lily Dam

Pond Lily Dam was constructed in 1780 and consists of an earthen berm and a 191-foot long, six-foot high spillway (Milone & MacBroom, 2011; Zaretsky, 2013). The dam is located in the City of New Haven and Lily Pond impoundment extends into the Town of Woodbridge. Dating back to 1978 and possibly earlier, Pond Lily Dam has been the subject of various studies regarding flooding issues, fish passage, dam stability, and has included at least one general environmental assessment of dam removal alternatives (Milone & MacBroom, 2011). The removal of the dam using Hurricane Sandy Recovery funding is planned for July 2015 (New Haven Independent, 2014). See *Sections 5.1 and 5.5*.

Beaver Pond Park

Beaver Pond Park is owned by the City of New Haven and is an approximately 107-acre park that includes athletic fields (including Bowen Field) and an approximately 86-acre wetland and pond system. Friends of Beaver Pond Park is a community group active in preserving and enhancing the pond areas for recreational uses. Several studies have been conducted on Beaver Pond Park, discussed in *Section 6.4.* The most recent studies include:

- A study entitled *Invasive Plants in Beaver Ponds Park* (Sullivan, et al., 2006) was conducted in 2006, which identified several invasive species in the park and provided management options for common reed *(Phragmites australis).*
- A *Management Plan for Beaver Pond Park* (Bates et al., 2007) developed recommendations for the park.
- A study entitled *Beaver Pond Trash Study* (DTC, 2009) was conducted in 2009.

Stormwater Management & CSO Abatement

The City of New Haven's storm drainage system is owned and maintained by the City of New Haven. A Stormwater Management Pilot Program Study (Malcolm Pirnie, 2010) was conducted in June 2010 to evaluate the possibility of creating a Stormwater Authority and suggest updates to the City's stormwater management plan at the time.

The City of New Haven has combined sanitary and storm sewer systems that discharge untreated sewage into the West River and New Haven Harbor during periods of heavy rain. These discharges are referred to as Combined Sewer Overflows (CSOs). The Greater New Haven Water Pollution Control Authority (GNHWPCA) has monitored flow at CSO locations since 2012, discussed in *Section 5.3.* CFE/STS completed a Green Infrastructure Feasibility Scan (Hazen & Sawyer, 2012) to assess the feasibility of green infrastructure[1] implementation in New Haven and Bridgeport, which included areas in the West River watershed. An overall CSO abatement plan for the West River and a more targeted green infrastructure suitability study for the sewersheds with the majority of the CSO discharges was developed this year and discussed in *Section 5.3* (CH2MHILL, 2014a and CH2MHILL, 2014b). In November 2014, New Haven Urban Resources Initiative was awarded a grant through the Long Island Sound Futures Fund (LISFF) to implement several green infrastructure projects within sewershed areas identified in the CH2MHILL study.

Water Quality Monitoring

Previous and ongoing water quality monitoring data has been collected and is summarized in *Section 3.2*, including data from the statewide bacteria TMDL (2012) and associated monitoring data for the West River watershed collected by CTDEEP, the CTDEEP ambient water quality and benthic monitoring data, and monitoring data collected by university research groups and local schools.

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[1] LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. The goal of LID is to mimic a site's pre-development hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Green infrastructure is similar to LID and refers to systems and practices that use or mimic natural processes to infiltrate, evapotranspire, or reuse stormwater. Green infrastructure and LID include stormwater management practices such as rain gardens, permeable pavement, green and blue roofs, green streets, infiltration planters, trees and tree boxes, and rainwater harvesting. These practices capture, manage, and/or reuse rainfall close to where it falls, thereby reducing stormwater runoff and keeping it out of receiving waters.

2 Watershed Description

2.1 West River and Its Watershed

The 34.5 square-mile West River watershed is located in New Haven County in the communities of New Haven, West Haven, Bethany, Hamden, Prospect, and Woodbridge, Connecticut. The southern portion of the watershed contains highly urbanized areas of New Haven and West Haven, while the watershed's northern portion is more sparsely populated and contains significant areas of protected water supply land.

The West River watershed is a north-south oriented watershed that extends from the headwaters of Sanford Brook, north of Lake Bethany near Route 42, south to New Haven Harbor and Long Island Sound. The main stem of the West River flows through Lake Bethany, Lake Watrous, Lake Dawson and Konolds Pond. The Sargent River and Wintergreen Brook (and the Wintergreen Brook tributaries, Wilmot Brook and Belden Brook) discharge to the West River. The tidally-influenced portion of the river, which contains the approximately 62-acre West River Tidal Marsh, extends from New Haven Harbor to approximately Edgewood Park Pond in New Haven (*Figure 2-1*).

The watershed is home to approximately 75,000 residents and a variety of other land uses. The density of development and the percentage of impervious cover increases from the north to south through the watershed, as can be seen in an aerial view in *Figure 2-2*. Similar to other coastal watersheds in south-central and southwestern Connecticut, the West River's water quality has been impacted by a history of industrial activity and urbanization. A 3.2-mile segment of the West River stretching from the outlet of Konolds Pond to Edgewood Park Pond has been identified as impaired for recreation due to bacteria and impaired for aquatic life due to unknown causes. The estuary portions of the West River south of Edgewood Park Pond are impaired for recreation due to bacteria; marine life due to dissolved oxygen saturation, nutrients, oils and grease, dissolved oxygen, and PCBs; and shellfish due to bacteria. Edgewood Park Pond is impaired for recreation due to bacteria. The southern portion of Wintergreen Brook where it joins the West River is also impaired for recreation due to bacteria (CTDEEP, 2012).

For the purposes of this watershed plan, the West River watershed has been divided into eight subwatersheds[2] (*Figure 2-1*). *Table 2-1* lists the land area and miles of streams within each subwatershed.

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[2] The Maltby Lakes and associated drainage area are considered part of the West River watershed. CTDEEP basin mapping incorrectly depicts the Maltby Lakes within the Cove River watershed and South Coastal basin. The outlet from Maltby Lake No. 1 flows easterly to Horseshoe Lagoon and eventually the West River. According to the South Central Connecticut Regional Water Authority (SCCRWA), the Cove River was diverted and is hydrologically separated from Maltby Lakes. The Trout Brook/Indian River watershed has the potential to be diverted to the Maltby Lakes. Since the Maltby Lakes are not currently used for water supply, the Trout Brook/Indian River watershed is not considered part of the West River watershed system. Approximately 70 percent of the Maltby Lakes subwatershed is owned and managed by SCCRWA, while the remainder is privately owned including a portion of the Golf Course at Yale. The Maltby Lakes subwatershed is 1.2 square miles in size and comprises roughly 3.5% of the overall West River watershed area. *Appendix B* of this document contains mapping of the Maltby Lakes subwatershed. Management recommendations for the West River watershed will also have applicability to land use activities within the Maltby Lakes subwatershed.

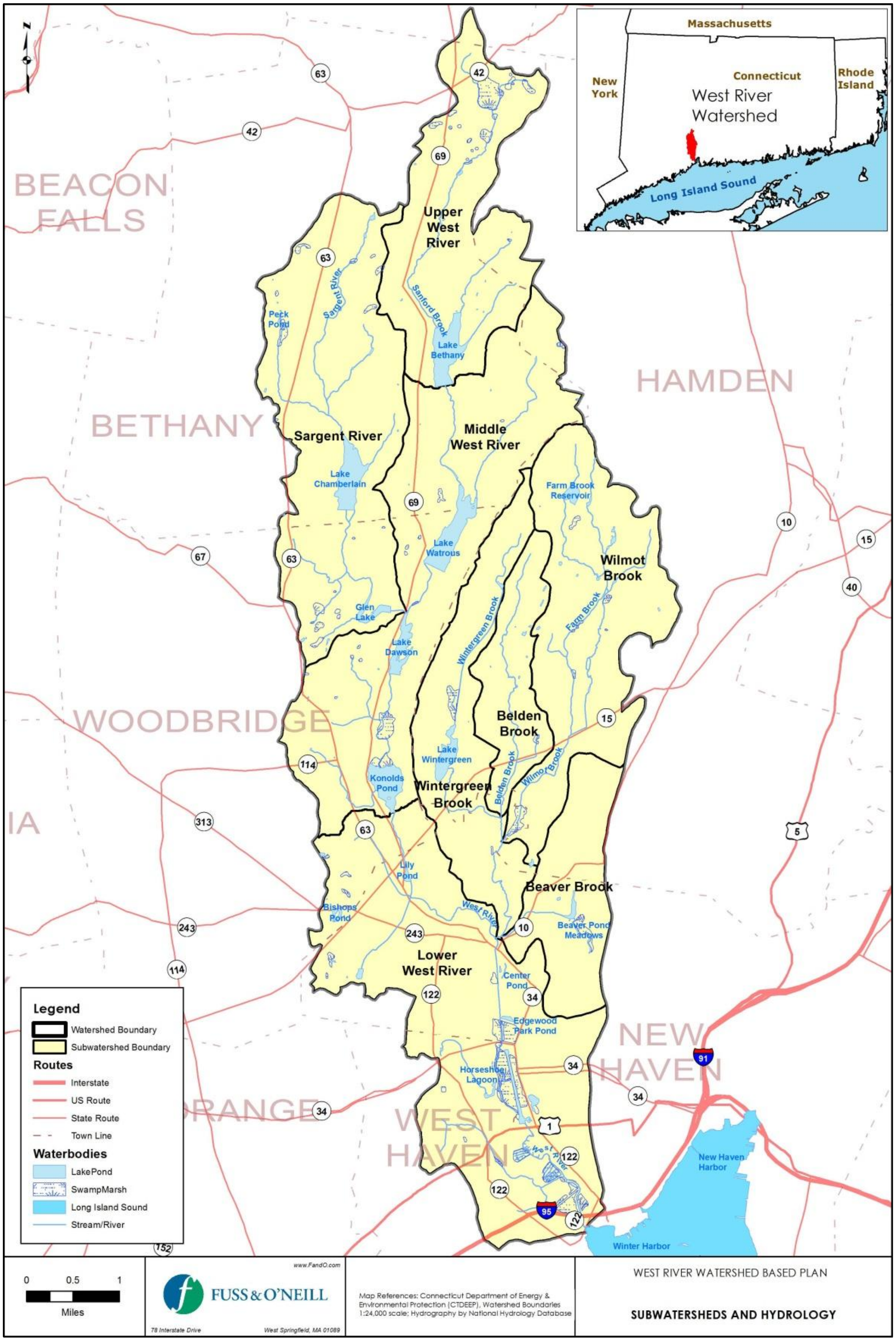

Figure 2-1. Subwatersheds and Hydrology

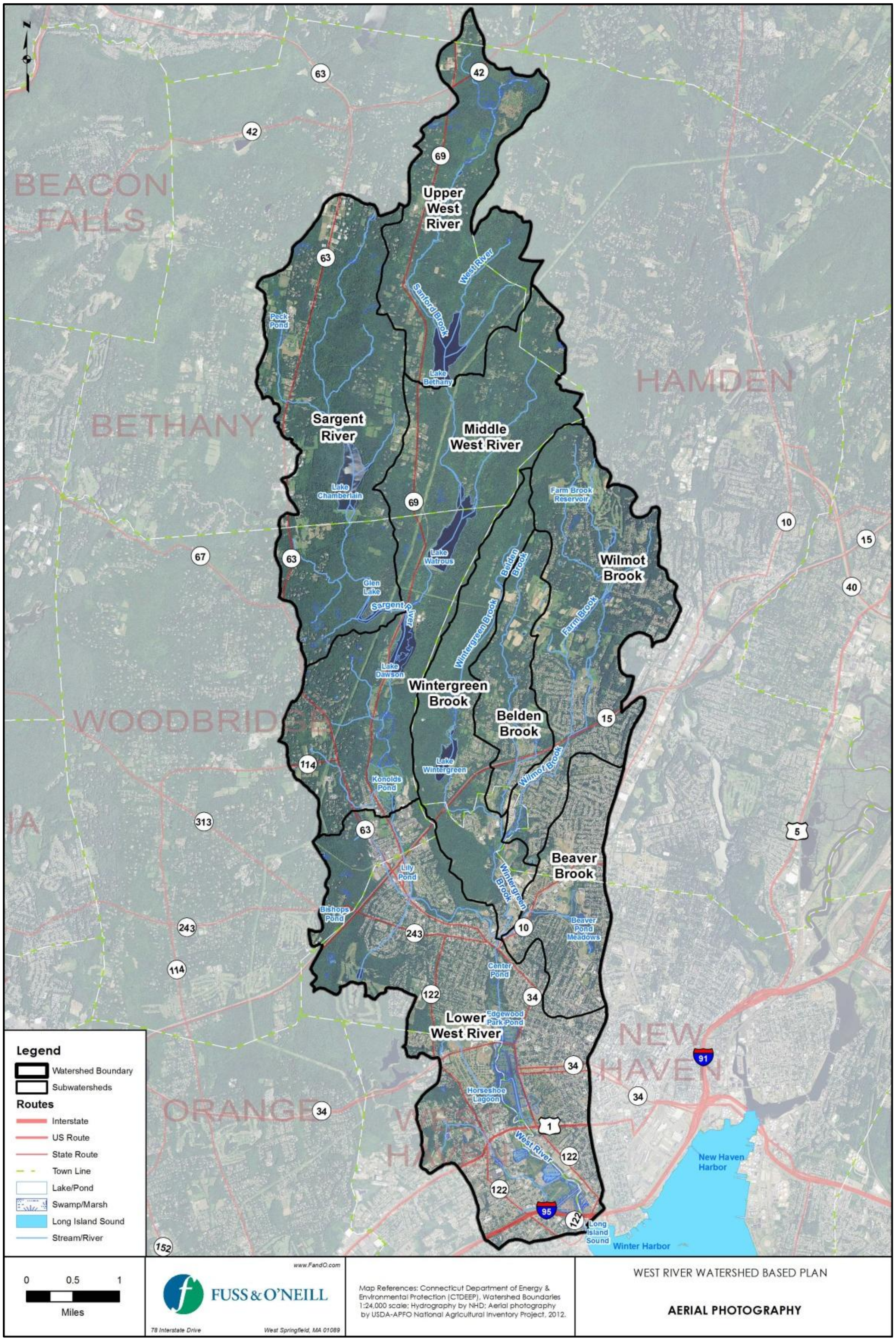

Figure 2-2. Aerial Photography

Table 2-1. Subwatersheds

Subwatershed	Abbreviation	Area (Acres)	Area (Square Miles)	Stream Length (Miles)
Upper West River	UWR	2,579	4.03	7.7
Middle West River	MWR	4,118	6.43	10.4
Lower West River	LWR	4,993	7.80	15.4
Sargent River	SGR	3,656	5.71	11.6
Wintergreen brook	WGB	1,795	2.80	6.2
Belden Brook	BLB	950	1.49	3.8
Wilmot Brook	WMB	2,724	4.26	10.6
Beaver Brook	BVB	1,261	1.97	1.5
Watershed Total		22,076	34.49	67.3

The main stem West River flows through the Upper West River, Middle West River, and Lower West River subwatersheds. The tributary subwatersheds are the Sargent River, Wintergreen Brook, Belden Brook, Wilmot Brook, and Beaver Brook.

- Upper West River Subwatershed: The Upper West River subwatershed contains the headwaters stream, Sanford Brook, which flows to Lake Bethany, a public water supply reservoir. Its northernmost point is in Prospect, but the majority of the subwatershed is in Bethany, with a small portion located in Hamden. It contains a substantial amount of undeveloped area since 1,223 acres (47%) of the land area within the subwatershed is owned by the South Central Connecticut Regional Water Authority (SCCRWA). Route 69 runs along its western side, just to the east of Sanford Brook and Lake Bethany, and Route 42 crosses the northern part of the subwatershed. Lake Bethany's outlet is the southern end of the Upper West River subwatershed.

- Middle West River Subwatershed: The Middle West River subwatershed contains the middle segment of the main stem West River and two public water supply reservoirs – Lake Watrous and Lake Dawson – and also contains the recreational waterbody Konolds Pond. The northern half of the subwatershed is located in Bethany and the southern half is in Woodbridge. The level of development in the subwatershed increases from north to south. Approximately 36% of the subwatershed is owned by SCCRWA.

- Lower West River Subwatershed: The Lower West River subwatershed is the southernmost subwatershed and is located primarily in West Haven and New Haven. The subwatershed is highly urbanized and contains dense residential neighborhoods. Several notable recreational and open space areas are located within the subwatershed, including the Yale Bowl, the Saint Lawrence, Evergreen, and Saint Bernards cemeteries, West River Memorial Park and a portion of the Golf Course at Yale. Pond Lily and Bishops Pond are in the northern portion of the subwatershed. Center Pond, Edgewood Park Pond and Horseshoe Lagoon and its associated wetlands are located in the southern portion of this subwatershed. Interstate 95 runs approximately through the southern portion of the subwatershed. The West River transitions from a freshwater river to an estuary near Edgewood Park Pond, and eventually discharges to Long Island Sound.

- Sargent River Subwatershed: The Sargent River subwatershed has lower development than many of the other subwatersheds, with the exception of residential and institutional uses along Route 63. A large portion of the subwatershed is a public water supply watershed with 1,519 acres (42%) owned by SCCRWA. The northern two-thirds of the subwatershed are located in Bethany, and the southern portion is in Woodbridge. The Sargent River subwatershed contains Peck Pond and a small wetland just west of Route 64. Lake Chamberlain is located in the center of this subwatershed, and Glen Lake is in the southern portion. Both are public water supply reservoirs managed by SCCRWA.

- Wintergreen Brook Subwatershed: The Wintergreen Brook subwatershed is located in the center of the West River watershed within Hamden and New Haven and consists of land within the West Rock Ridge State Park, including Lake Wintergreen on the northern and western sides of the subwatershed. The eastern portion of the subwatershed contains a magnet school in Hamden, and a portion of the New Haven Housing Authority-owned West Rock housing development.

- Belden Brook Subwatershed: The Belden Brook subwatershed is located in the center of the West River watershed, primarily in the town of Hamden. The southern portion of the watershed is located in New Haven, and includes the New Haven Housing Authority-owned West Rock housing development. The Belden Brook subwatershed does not contain any named lakes, but contains a few wetland areas throughout the watershed. Belden Brook is a tributary to Wintergreen Brook.

- Wilmot Brook Subwatershed: Wilmot Brook subwatershed is a moderately populated watershed located almost entirely within Hamden, and is more densely populated near the Wilbur Cross Parkway (State Route 15), south of Benham Street. The northern portion of the subwatershed contains Farm Brook Reservoir, Laurel View Country Club, and a Town-owned open space area.

- Beaver Brook Subwatershed: The Beaver Brook subwatershed is located in the eastern portion of the watershed in New Haven and Hamden. It is highly urbanized, consisting of dense residential neighborhoods in New Haven and a portion of Southern Connecticut State University (SCSU), as well as a magnet and technical school. The subwatershed also contains wetland areas and Beaver Ponds within Beaver Pond Park.

2.2 Watershed Municipalities and Demographics

The West River watershed is located in six municipalities: Prospect, Bethany, Hamden, Woodbridge, New Haven, and West Haven within New Haven County (*Table 2-2*). The population density is greatest in West Haven and New Haven with an estimated 5,057 and 6,766 people per square mile, respectively (CERC, 2014). For comparison, Bethany, in the north of the watershed, has a population density of 258 people per square mile (CERC, 2014). This is reflective of the overall land use character of the watershed, with densely developed urban centers in the south and less densely developed suburban communities in the north.

The watershed population in 2010 was estimated at 75,000 people in 29,000 households (U.S. Census Bureau, 2010). The Connecticut Economic Resource Center (CERC) predicts populations in the watershed municipalities will increase in all towns except Woodbridge, with the population estimate for 2020 for all watershed municipalities increasing 6.6% to 287,763 from 2012 population levels (CERC, 2014). This increase is slightly greater than the projected population increases of 3.3% for the State of Connecticut and 4.4% for New Haven County over the same time period (CERC, 2014).

Table 2-2. Distribution of Municipalities in the West River Watershed

Municipality	Total Acreage of Municipality	Acreage in Watershed	% of Municipality in Watershed	% of Watershed
Bethany	13,690	6,574	48.0%	29.8%
Hamden	21,278	5,899	27.7%	26.7%
New Haven	12,288	4,354	35.4%	19.7%
Woodbridge	12,284	3,762	30.6%	17.0%
West Haven	7,007	1,443	20.6%	6.6%
Prospect	9,238	44	0.5%	0.2%
Watershed (Total)	75,786	22,076	N/A	100%

3 Water Quality

Water quality is a primary indicator of the ecological health of a river and its ability to support specific uses such as drinking water supply, recreation, habitat, and industrial uses. Water quality is also inherently linked to the activities that take place in a watershed. Water quality in the West River (including the estuary portions), Sargent River, Belden Brook, Sanford Brook, Wilmot Brook, Farm Brook, Wintergreen Brook, and Edgewood Park Pond has been monitored by CTDEEP, Yale University School of Forestry & Environmental Studies, and other groups including the Foote School and Edgewood School. The monitoring data are reviewed in this section with respect to the Connecticut Water Quality Standards and the CTDEEP Draft 2014 Integrated Water Quality Report to assess current water quality conditions in the watershed (CTDEEP, 2014a).

3.1 Water Quality Classification, Standards, and Impairments

The Federal Clean Water Act (CWA) was established to protect the nation's surface waters. Through authorization of the CWA, the United States Congress declared as a national goal "water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and recreation in and on the water wherever attainable." The CWA requires states to:

1. Adopt Water Quality Standards,
2. Assess surface waters to evaluate compliance with Water Quality Standards,
3. Identify those waters not currently meeting Water Quality Standards, and
4. Develop Total Maximum Daily Loads (TMDL) and other management plans to bring waterbodies into compliance with Water Quality Standards.

Connecticut Water Quality Standards (CWQS) are established in accordance with Section 22a-426 of the Connecticut General Statutes and Section 303 of the CWA. The CWQS are used to identify priorities for pollution abatement efforts by establishing designated uses for surface, coastal and marine and ground waters and identify the criteria necessary to support these uses. The system classifies inland surface waters into three different categories, Class AA, Class A and Class B and coastal and marine surface waters into two categories, Class SA and SB (*Table 3-1*). The CWQS designates four classes for groundwater: GAA, GA, GB, and GC.

Figure 3-1 depicts the Water Quality Classifications of surface water and groundwater in the West River watershed. There are several water supply subwatersheds designated as Class AA waters in the West River watershed, including the Upper West River subwatershed, the Sargent River subwatershed, and the Middle West River subwatershed to the outlet of Lake Dawson. The remaining main stem sections of the West River below Lake Dawson and the tributaries to the West River, including Beldon Brook, Wilmot Brook, Wintergreen Brook, and Beaver Brook, are designated as Class A surface waterbodies with the following designated uses: potential drinking water supply; fish and wildlife habitat; recreational use; agricultural and/or industrial supply; and other uses, including navigation. There are no Class B surface waters within the watershed. The tidally-influenced sections of the West River are considered estuaries and begin downstream of Edgewood Park Pond (south of Edgewood Avenue) and end at the mouth of the West River in New Haven Harbor, downstream of Interstate 95. The upper portion of the

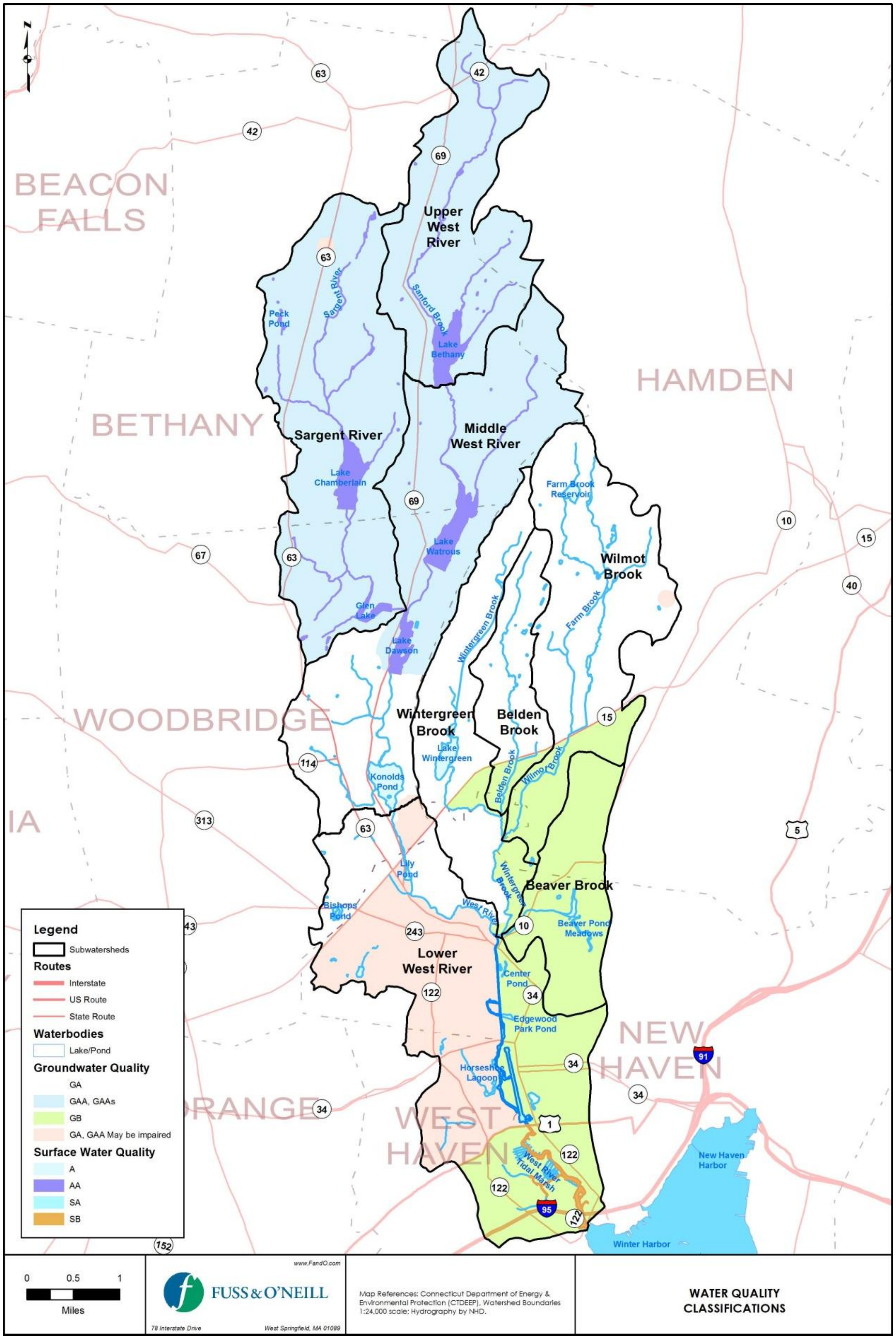

Figure 3-1. Water Quality Classifications

estuary, ending at the Route 1 road crossing, is Class SA, with designated uses including habitat for fish, other aquatic life, and wildlife habitat; shellfish harvesting for direct human consumption; recreation; industrial and/or agricultural supply; and navigation. The lower portion is Class SB with designated uses including commercial shellfish harvesting; recreation; industrial and/or agricultural supply; and navigation.

Table 3-1. Connecticut Surface Water Quality Classifications

Designated Use	Inland Surface Waters			Coastal and Marine Surface Waters	
	Class AA	Class A	Class B	Class SA	Class SB
Existing or proposed drinking water supply	•				
Potential drinking water supply		•			
Habitat for fish, other aquatic life, and wildlife habitat	•	•	•	•	
Shellfish harvesting for direct human consumption				•	
Commercial shellfish harvesting					•
Recreation	•	•	•	•	•
Industrial and/or agricultural supply	•	•	•	•	•
Navigation	•	•	•	•	•

The groundwater quality classification in areas that contribute to the drinking water reservoirs is GAA. The groundwater in the middle portion of the watershed is Class GA and the lower portion of the watershed west of the West River is GA, "may be impaired.[3]" The groundwater primarily east of the West River in New Haven is Class GB. The designated uses for the classes of groundwater under the CWQS are:

- Class GAA: Existing or potential public supply of water suitable for drinking without treatment; baseflow for hydraulically connected surface waterbodies.
- Class GA: Existing private and potential public or private supplies of water suitable for drinking without treatment; baseflow for hydraulically connected surface waterbodies.
- Class GB: Industrial process water and cooling waters; baseflow for hydraulically connected surface waterbodies; presumed not suitable for human consumption without treatment.
- Class GC: Assimilation of discharge authorized by the Commissioner pursuant to Section 22a-430 of the General Statutes. As an example a lined landfill for disposal of ash residue from a resource recovery facility. The GC hydrogeology and hydrologic setting provides the best safeguard to adjacent resources.

The CWA requires each state to monitor, assess and report on the quality of its waters relative to attainment of designated uses established by the State's Water Quality Standards. When waters are not suitable for their designated use, they are identified as "impaired." Every two years, the State of

[3] A groundwater class that "may be impaired" means that the groundwater quality goal and designated use is Class GA or GAA, however there may be a known or potential impairment sources.

Connecticut assesses watercourses and waterbodies in the state and provides to EPA a list of impaired waters. *Table 3-2* summarizes the impaired designated uses for waterbodies in the West River watershed from the Draft 2014 Integrated Water Quality Report (CTDEEP, 2014a), including the causes and potential sources of the impairments. *Table 3-2* summarizes the water quality classifications of various segments, or reaches, and tributaries of the West River that do not meet their Water Quality Criteria designated uses. *Figure 3-2* depicts the locations of the impaired waterbodies.

Several streams are impaired for habitat for fish, other aquatic life, and wildlife, as determined by a combination of information on the existing benthic macroinvertebrate community, fish community, physical/chemical data, toxicity, and stream flow records. The suitability of surface waters for recreation is determined using the *Enterococci* group bacteria in salt (estuarine) water, and *Escherichia coli (E. coli)* in fresh water as indicators of fecal pollution.

The rivers, lake, and estuary segments included in the Draft 2014 Integrated Water Quality Report and listed in *Table 3-1* and *Figure 2-3* described from downstream to upstream are:

- West River: The river segment "West River (New Haven/Woodbridge)-01" extends from just downstream of Edgewood Park Pond to the Konolds Pond outlet dam and is not supporting for aquatic life or recreation. The river segment "West River (Woodbridge/Bethany)-02" extends from the inlet of Konolds Pond to the outlet of Lake Bethany, including Lake Dawson and Lake Watrous. The segment is not assessed for recreation or aquatic life.

- Sargent River: The river segment "Sargent River-01" extends from the confluence with West River at the Route 69 crossing to Munson Road Pond dam, but does not include Lake Glen and Lake Chamberlain. The segment is fully supporting for aquatic life and not assessed for recreation.

- Wintergreen Brook: The segment "Wintergreen Brook (New Haven)-01" extends from the confluence with the West River near the Blake Street road crossing to the confluence with Wilmot Brook near the Wilmot Road crossing and is not assessed for aquatic life and not supporting for recreation. Segments "Wintergreen Brook (New Haven)-02" and "Wintergreen Brook (New Haven)-03" extend from the upstream limit of "Wintergreen Brook (New Haven)-01" to the Lake Wintergreen outlet near the Wintergreen Avenue crossing. The segments are not assessed or have insufficient information for recreation and aquatic life.

- Edgewood Park Pond: Edgewood Park Pond is 2.72 acres and is located along the eastern bank of West River, just upstream of Chapel Street in New Haven. The pond is fully supporting for aquatic life but not supporting for recreation.

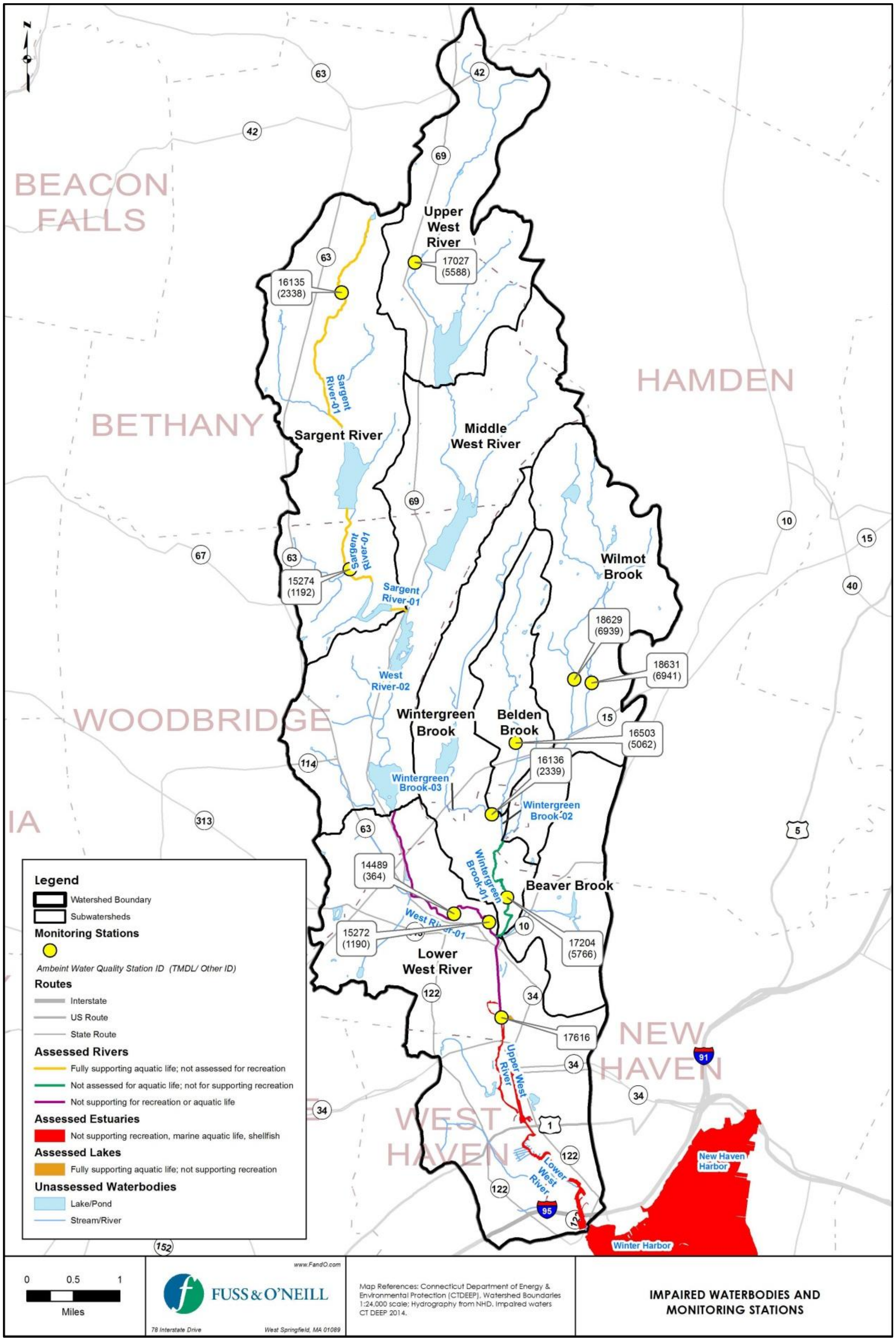

Figure 3-2. Impaired Waters

- Estuaries: Estuary segment "LIS CB Inner - West River (Lower), West Haven" extends from the mouth of the West River near the Interstate 95 crossing to the SA/SB water quality line at Route 1 crossing. Estuary segment "LIS CB Inner - West River (Upper), West Haven" extends from the Lower segment to the south side of Edgewood Avenue near Edgewood Park Pond. The lower segment is not supporting for aquatic life and recreation and not assessed for shellfish (commercial harvesting) and the upper segment is not supporting for aquatic life, recreation, and direct consumption of shellfish.

A Total Maximum Daily Load (TMDL) is a target pollutant level that must be met to restore the quality of the water and meet designated uses. It is a "pollution budget" that identifies the reductions in point and nonpoint source pollution that are needed to meet Connecticut water quality standards for a particular waterbody and a strategy to implement those reductions to restore water quality. TMDLs therefore provide the framework for restoring impaired waters. *Table 3-2* lists the priority year for TMDL development for some of the Category 5 waters in the West River watershed, which are waters where available data and/or information indicate that one or more designated uses are not being supported and a TMDL is needed.

Several of the waterbodies that are impaired for bacteria are Category 4A, meaning they have an approved TMDL. CTDEEP completed a "Statewide Bacteria TMDL" for 176 impaired waterbody segments that were listed on the 2010 Impaired Waters List (CTDEEP, 2012). The West River (Segment CT5305-00_01) and Edgewood Park Pond (CT5305-00-3-L1_01) are the two waterbodies within the West River watershed that are impaired for bacteria. The designated impairment is based on water quality data collected from two monitoring locations (Stations 1190 and 364) on the impaired segment of the West River, and at one sampling location (Station 17616) on Edgewood Park Pond. The TMDL and water quality data are discussed in *Sections 3.1 and 3.2*, respectively.

Table 3-2. Water Quality Classifications and Impaired Waters

Waterbody Name/ Segment ID	Water Quality Classification	Impaired Designated Use	Cause	TMDL Category/ Priority Year	Potential Sources
Rivers					
West River (New Haven/Woodbridge)-01 / CT5305-00_01	A	Habitat for Fish, Other Aquatic Life and Wildlife	Unknown	5 / None	Industrial point source discharges, landfills, illicit discharges, CSOs
		Recreation	Escherichia coli	4A / 2012 (Statewide Bacteria TMDL)	Industrial point source discharges, illicit discharges, CSOs, failing septic systems, agricultural activity, stormwater runoff, nuisance wildlife/ pets, and others
West River (Woodbridge/Bethany)-02 / CT5305-00_02	A/AA	None	N/A	N/A	N/A
Sargent River-01 / CT5303-00_01	A	None	N/A	N/A	N/A
Wintergreen Brook (New Haven)-01 / CT5304-00_01	A	Recreation	Escherichia coli	5 / 2016 (To be included in Statewide Bacteria TMDL)	None Listed
Wintergreen Brook (New Haven)-02 / CT5304-00_02	A	None	N/A	N/A	N/A
Wintergreen Brook (New Haven)-03 / CT5304-00_03	A	None	N/A	N/A	N/A
Lake					
Edgewood Park Pond (New Haven) / CT5305-00-3-L1_01	A	Recreation	Escherichia coli	4A / Statewide Bacteria TMDL (2012)	Industrial point source discharges, illicit discharges, CSOs, failing septic systems, agricultural activity, stormwater runoff, nuisance wildlife/ pets, and others
Estuary					
LIS CB Inner - West River (Lower), West Haven / CT-C1_015-SB	SB	Habitat for Marine Fish, Other Aquatic Life and Wildlife	Dissolved oxygen saturation	5 / None	Landfills, municipal discharges, illicit discharges, remediation sites, groundwater contamination, CSOs
			Nutrient/ Eutrophication Biological Indicators	5 / None	

Table 3-2. Water Quality Classifications and Impaired Waters

Waterbody Name/ Segment ID	Water Quality Classification	Impaired Designated Use	Cause	TMDL Category/ Priority Year	Potential Sources
			Oil and Grease	5 / None	
			Dissolved Oxygen	5 / 2014 to 2017[4]	
			Polychlorinated biphenyls	5 / None	
		Recreation	Enterococcus	5 / None	None Listed
		Commercial Shellfish Harvesting Where Authorized[5]	Fecal Coliform	5 / None	None Listed

[4] CTDEEP has an ongoing program to coordinate interstate efforts to implement and enhance the 2001 Long Island Sound Dissolved Oxygen TMDL. CTDEEP identified the excessive discharge of nitrogen from human activities as the primary pollutant causing hypoxia. Nitrogen fuels the growth of algae in the Sound, which eventually decays, consuming oxygen in the process.

[5] The shellfish growing area is classified as prohibited (administrative closure) due to CSO discharges, even though the segment is Not Assessed (i.e., there are no monitoring data). (Katie O'Brien-Clayton, CTDEEP, personal communication, December 4, 2014).

Table 3-2. Water Quality Classifications and Impaired Waters

Waterbody Name/ Segment ID	Water Quality Classification	Impaired Designated Use	Cause	TMDL Category/ Priority Year	Potential Sources
LIS CB Inner - West River (Upper), West Haven / CT-C1_022	SA	Habitat for Marine Fish, Other Aquatic Life and Wildlife	Dissolved oxygen saturation	5 / None	Potential sources include non-permitted stormwater, industrial point source discharge, landfills
			Nutrient/ Eutrophication Biological Indicators	5 / None	
			Oil and Grease	5 / None	
			Dissolved Oxygen	5 / 2014 to 2017[6]	
			Polychlorinated biphenyls	5 / None	
		Recreation	Enterococcus	5 / None	None Listed
		Shellfish Harvesting for Direct Consumption	Fecal Coliform	5 / None	None Listed

[6] CTDEEP has an ongoing program to coordinate interstate efforts to implement and enhance the 2001 Long Island Sound Dissolved Oxygen TMDL. CTDEEP identified the excessive discharge of nitrogen from human activities as the primary pollutant causing hypoxia. Nitrogen fuels the growth of algae in the Sound, which eventually decays, consuming oxygen in the process.

According to the Statewide Bacteria TMDL, the potential sources of indicator bacteria in the West River watershed include point and non-point sources, such as permitted point discharges, illicit discharges, Combined Sewer Overflows (CSOs), failing septic systems, agricultural activity, stormwater runoff, nuisance wildlife/pets, and possibly others (CTDEEP, 2012). These potential sources are discussed in *Sections 5, 6, and 7* of this document.

3.2 Water Quality Monitoring

Inland Surface Waters

Inland surface water quality monitoring data has been collected in the West River watershed at the locations listed in *Table 3-3* by the CTDEEP Ambient Monitoring and Assessment Program[7]. Sampling and testing for the water quality parameters shown in *Table 3-4* has been conducted since the mid-1990s. However, few parameters have been consistently sampled throughout the period of record. Given that, and the identified impairments due to bacteria, this section focuses on water quality monitoring for bacteria. The bacteria TMDL for the West River was developed using *Escherichia coli* (*E. coli*) data collected by CTDEEP.

Table 3-3. CTDEEP Water Quality Monitoring Stations

Ambient Water Quality Station ID	TMDL/Other Station ID	Waterbody	Location
14489	364	West River	Upstream of Valley Rd
15272	1190	West River	Upstream of Blake St
15274	1192	Sargent River	At Sperry Rd
16135	2338	Sargent River	At Hilldale Rd
16136	2339	Wintergreen Brook	At Wilmot Rd and Wayfarer St
16503	5062	Belden Brook	First left past farm off Wintergreen Ave
17027	5588	Sanford Brook	Downstream of 2nd Crossing US Lake Bethany
17204	5766	Wintergreen Brook	Below Wintergreen Ave
18629	6939	Wilmot Brook	Upstream Benham St
18631	6941	Farm Brook	Upstream Benham St
17616	17616	Edgewood Pond	Pond Outfall

[7] Although data was reportedly collected through an educational program by the Foote School at a location near Amrhyn Field, it was unavailable at the time this report was prepared. Additional monitoring data provided by the Edgewood School was also not available at the time this report was prepared.

Table 3-4. Summary of Available Water Quality Monitoring Data

CTDEEP Monitoring Program	Parameter(s)	Ambient Water Quality Data Station	Monitoring Years (Number of Samples Collected)
Volunteer Monitoring for the Ambient Monitoring and Assessment Program	Alkalinity, Ammonia, Biological Oxygen Demand (BOD), Calcium, Chloride, Dissolved Oxygen, *Enterococci*, *Escherichia coli,* Hardness, Metals, Nitrogen, Oxygen Saturation, pH, Phosphorus, Solids, Specific Conductance, Turbidity	14489	2001 – 2007 (13)
		15272	1996 – 2010 (12)
		15274	1996 – 2001 (10)
		16135	2007 – 2013 (2)
		16136	2007 – 2013 (4)
		17204	2010 (9)
		17616	2011 (9)
Continuous Water Temperature Monitoring	Water Temperature	16315	June – October 2013 (Hourly)
		16136	
		16503	
		18629	
		18631	

Stations 364 (14489) and 1190 (15272) on the West River in 1998 and 2010 and at Station 17616 at Edgewood Park Pond in 2011 *(Table 3-5)*. Single sample values at these stations also exceeded the WQS for *E. coli* multiple times. CTDEEP (2012) also found that both wet-weather and dry-weather samples exceeded the WQS for *E. coli* at Station 1190[8] on the West River. At Edgewood Park Pond (Station 17616), both the wet-weather and dry-weather samples exceeded the WQS, but the geometric mean during wet-weather was 18 times greater than the dry-weather geometric mean. Bacteria data has not been collected at any sampling stations after 2010 by the CTDEEP.

Table 3-5. TMDL Bacteria Data Summary

TMDL Station ID	Geometric Mean (colonies/100 mL)	Maximum Single Sample (colonies/100 mL)
WQS	*126*	*410*
364	869	1,350
1190	597	3,300
17616	334	4,100

Coastal and Marine Surface Waters

Coastal and marine surface water quality monitoring data has been collected in the West River watershed by the CTDEEP, CFE/STS, and the Yale University School of Forestry & Environmental Studies, discussed in *Section 4.2.2*. The impairments of the estuary segments of the West River are based on various data sources. The segment "LIS CB Inner - West River (Lower), West Haven / CT-C1_015-SB" was historically impaired for habitat for fish, other aquatic life and wildlife due to the tidal gates, which

[8] Insufficient data was available to calculate wet weather geometric mean *E. coli* concentration at Station 364.

have since been retrofitted to allow for 2-way flow (See *Section 4.2.2)*. However, low dissolved oxygen and super-saturation of oxygen were measured in 2008 and 2012 by a joint research project with CFE/STS and the Yale University School of Forestry & Environmental Studies (CFE/STS, 2013). Additionally, the 2006 Integrated Water Quality Report reports the presence of historical sediment contamination (from scrap metal yard, creosote and lime pits) and urban nonpoint source pollution. The segment is impaired for recreation due to CSO discharges. The shellfish growing areas classified as prohibited for harvesting (administrative closure) also due to CSO discharges. (Katie O'Brien-Clayton, CTDEEP, personal communication, December 4, 2014). The segment "LIS CB Inner - West River (Upper), West Haven / CT-C1_022" has many of the same data sources informing the impaired segments listing as segment CT-C1_015-SB, including data collected by CFE/STS (Katie O'Brien-Clayton, CTDEEP, personal communication, December 4, 2014).

4 Natural Resources

4.1 Topography, Geology, and Soils

Connecticut can be divided into three major physiographic provinces—the Western Uplands, the Central Valley, and the Eastern Uplands. These meet the Coastal Slope on the southern edge of the state, along Long Island Sound. The geology of the uplands consists primarily of metamorphic rocks, while sedimentary rocks dominate the bedrock geology of the Central Valley (Bell, 1985). The eastern and southern portions of the West River watershed are part of the Central Valley, and the northern and western portions of the watershed are part of the Western Uplands.

Typical of other coastal watersheds in Connecticut, the topography of the West River watershed varies from steep slopes to rolling hills and shallow sloping areas. A topographic map of the watershed is shown in *Figure 1-1,* showing the variation in topography across the watershed. While the southern section tends to be flatter, the northern portion of the watershed has a more varied topography. The area surrounding the estuary portion of the West River is topographically flat and provides flood and erosion protection to nearby upland areas, as well as important habitat, which is discussed in *Section 4.5.4.*

The West Rock Ridge is the most prominent topographic feature in the watershed, at an elevation of approximately 600 feet above the surrounding valley and extending for approximately 15 miles along the eastern side of the Central Valley. A six-mile portion of the Ridge is protected in West Rock State Park (USGS, 2014). The West Rock Ridge divides the Wintergreen Brook subwatershed from the Middle and Lower West River subwatersheds and is comprised of West Rock Dolerite. The majority of the Central Valley portion of the watershed is New Haven Arkose, a sedimentary rock colloquially known as "brownstone," and a popular building material due to its color (Bates, 2007). Bedrock geology in the portion of the watershed within the Western Uplands is dominated by metamorphic schists and gneisses.

The surficial glacial deposits are a major factor in determining the soil and drainage characteristics because they form the parent material for soil development and influence the rate of water infiltration and subsurface flow (NRCS, 1993). The parent material in the southern portion of the watershed, including the majority of the Lower West River and Beaver Brook subwatersheds, is classified by the Natural Resources Conservation Service (NRCS) as urban influenced, which means it is comprised of urban land and urban land complex soils *(Figure 4-1)*. These soils are typically a mix of native and urban materials, which have resulted from soil disturbance by humans and various filling activities. Melt-out till is common in the central portion of the watershed, and lodgement till is found in the northern parts (NRCS, 2007). Till is unsorted material that was deposited by glacial ice.

Soils are classified by the NRCS into Hydrologic Soil Groups (HSG) to indicate the minimum rate of infiltration obtained for bare soil after prolonged wetting *(Figure 4-2)*. NRCS Hydrologic Soil Groups provide an indicator of the infiltration potential within an area. Group A soils consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission. Group B soils consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures with a moderate rate of water transmission. Group C soils consist of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture with a low rate of water transmission. Group D consists chiefly of clay soils with a high swelling

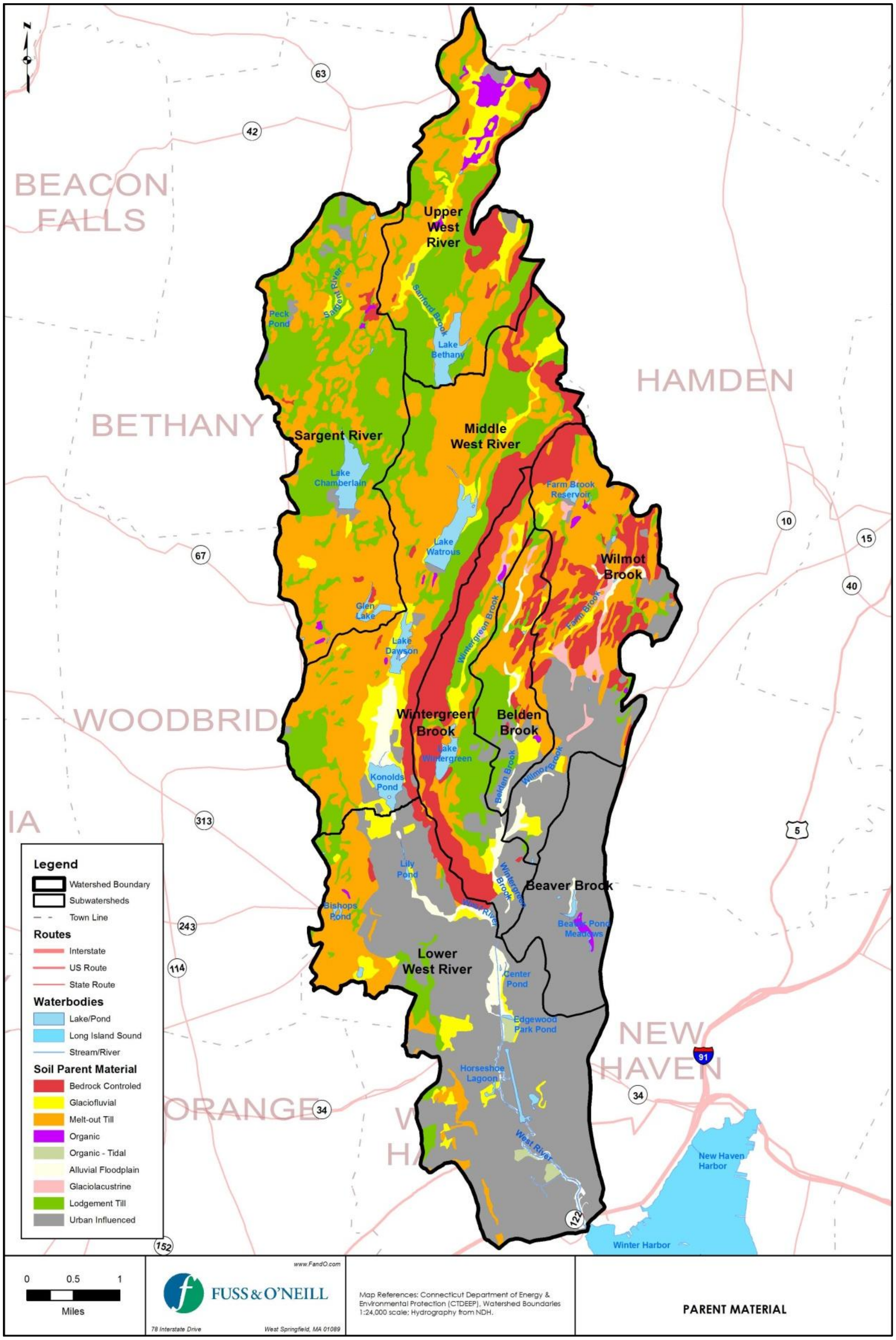

Figure 4-1. Soil Parent Material

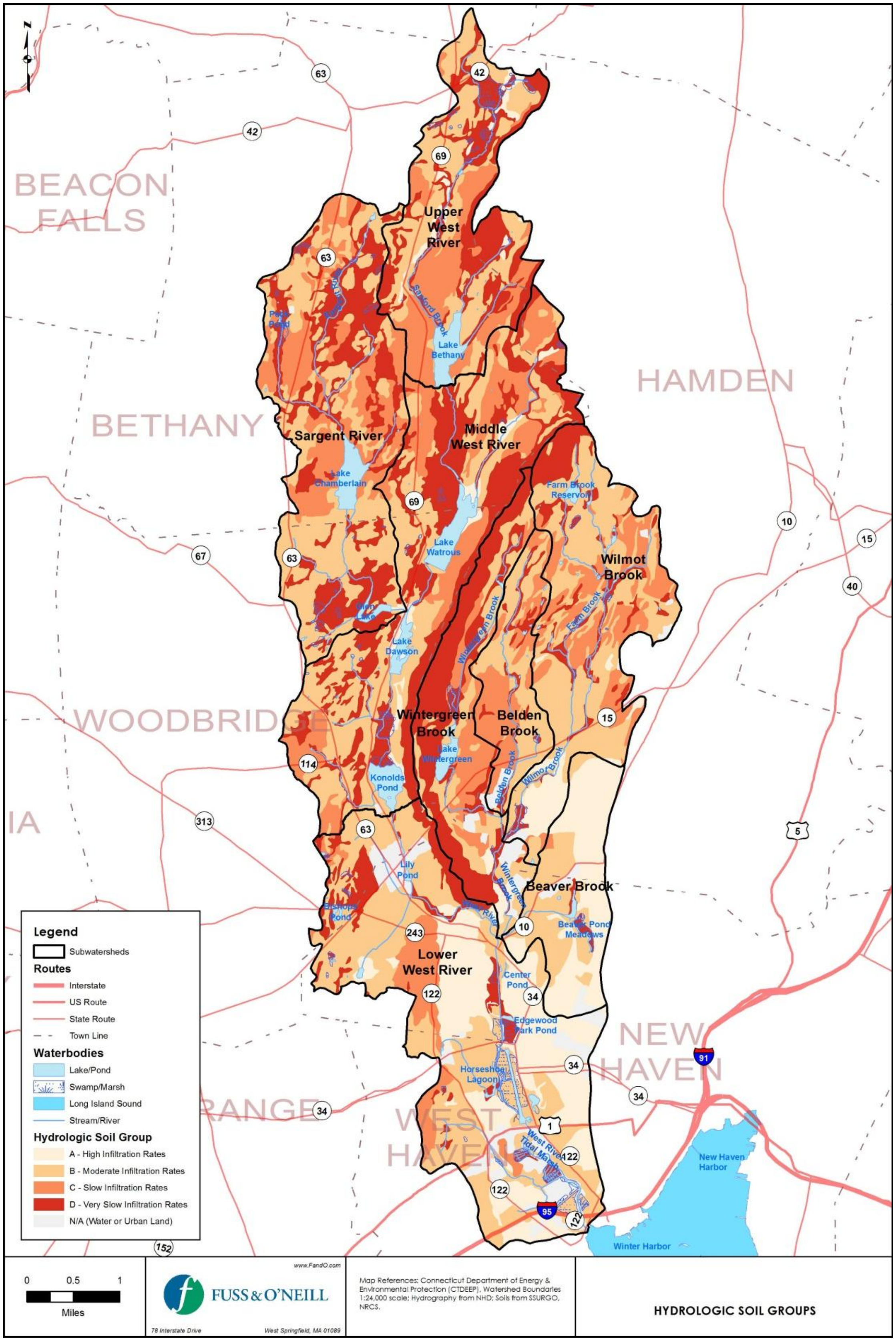

Figure 4-2. Hydrologic Soil Groups

potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material with a very low rate of water transmission.

4.2 Wetlands

Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. Wetlands include marshes, swamps, bogs, and fens. Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance (EPA, 2013). Wetlands are an important hydrologic feature of a watershed and provide water quality benefits by removing pollutants and mitigating flood flows. Properly functioning wetlands remove significant amounts of nutrients during the growing seasons when the wetland plants are flourishing. The following sections describe the inland and tidal wetlands within the West River watershed.

4.2.1 Inland Wetlands

The State of Connecticut designates wetlands by soil classification since certain soils can cause groundwater to remain near the ground surface, which can transform soil characteristics. Wetland soils can also be defined by landscape position.

In 1972, Connecticut enacted the Inland Wetlands and Watercourses Act (IWWA), which regulates activities affecting wetlands and watercourses. This act is implemented through municipal inland wetlands and watercourses commissions, as well as the CTDEEP. Local commissions have adopted regulations governing activities affecting inland wetlands and watercourses, including land adjacent to inland wetlands and watercourses, which is referred to as upland review area. The upland review area defines the extent of regulated activities in non-wetland or non-watercourse upland areas. The following classes of wetland soils are defined by the IWWA:

- Poorly drained soils – These soils occur in places where the groundwater level is near or at the ground surface during at least part of most years. These soils generally occur in areas that are flat or gently sloping.
- Very poorly drained soils – These soils are typically characterized by groundwater levels at or above the ground surface during the majority of most years, especially during the spring and summer months. These areas are generally located on flat land and in depressions.
- Alluvial and floodplain soils – These soils form where sediments are deposited by flowing water, and thus typically occur along rivers and streams that are flooded periodically. The drainage characteristics of these soils vary significantly based on the characteristics of the flowing water, ranging from excessively drained where a stream tends to deposit sands and gravel to very poorly drained where a stream deposits silts or clays.

The Federal Clean Water Act definition for wetlands is based on soil characteristics, vegetation, and hydrology. The Federal designation defines wetlands as (Cowardin et al., 1979):

> "Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominately hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water as some time during the growing season of each year."

Figure 4-3 shows the extent and distribution of wetlands in the West River watershed based on NRCS soil classifications, following the State of Connecticut definition. *Figure 4-3* also shows wetland classifications available from the U.S. Fish & Wildlife Service National Wetlands Inventory. State-designated wetlands and surface waters make up 13% of the overall watershed (approximately 2,950 acres), while approximately 6% of the watershed area (approximately 1,256 acres) is mapped as Federally-designated wetlands and surface waters.

4.2.2 Tidal Wetlands

Tidal marshes are a type of tidal wetland occurring at the interface of the land and ocean. Tidal marshes support a diverse ecosystem of vegetation and wildlife. They serve as nursery grounds for many fish species; waterfowl and many aquatic animals use them for homes, food, and resting areas. Tidal marshes also play a role in improving water quality and protecting shore areas from flooding. The tidally-influenced portion of the West River contains the approximately 62-acre West River Tidal Marsh.

As of 1995, the total loss of tidal wetlands in the West River watershed was estimated at 90%: only 74 acres of nearly 800 acres remain unfilled (Kenny, 1995). Of these, 20 acres are considered highly disturbed salt marsh. A 17-acre, relatively undisturbed salt marsh is located near Spring Street in West Haven (Orson et al., 1997; Casagrande, 1997).

West River Memorial Park is a linear recreation park that contains approximately 167 acres of undeveloped parkland, water, and wetland located on the western side of New Haven between Columbus Avenue and Derby Avenue. Less than a century ago the park was a tidal marsh that once covered approximately 130 acres of land but has since been disturbed by dredging, filling, and the installation of tide gates (Barten & Kenny, 1997; Milone & MacBroom, 2002). Tide gates were installed at the southern end of Congress Avenue prior to 1910 to control mosquitos and utilize the land for development (Casagrande, 1997). A long straight channel was dredged through the park to create a reflecting pool in the late 1800s. The dredged material was used to fill the wetlands and create an upland recreation area. Although the tidal gates served to restrict salt water flow, the amount of fill did not completely eradicate the freshwater wetlands, and the site became dominated by common reed *(Phagmites australis)* (Casagrande, 1997).

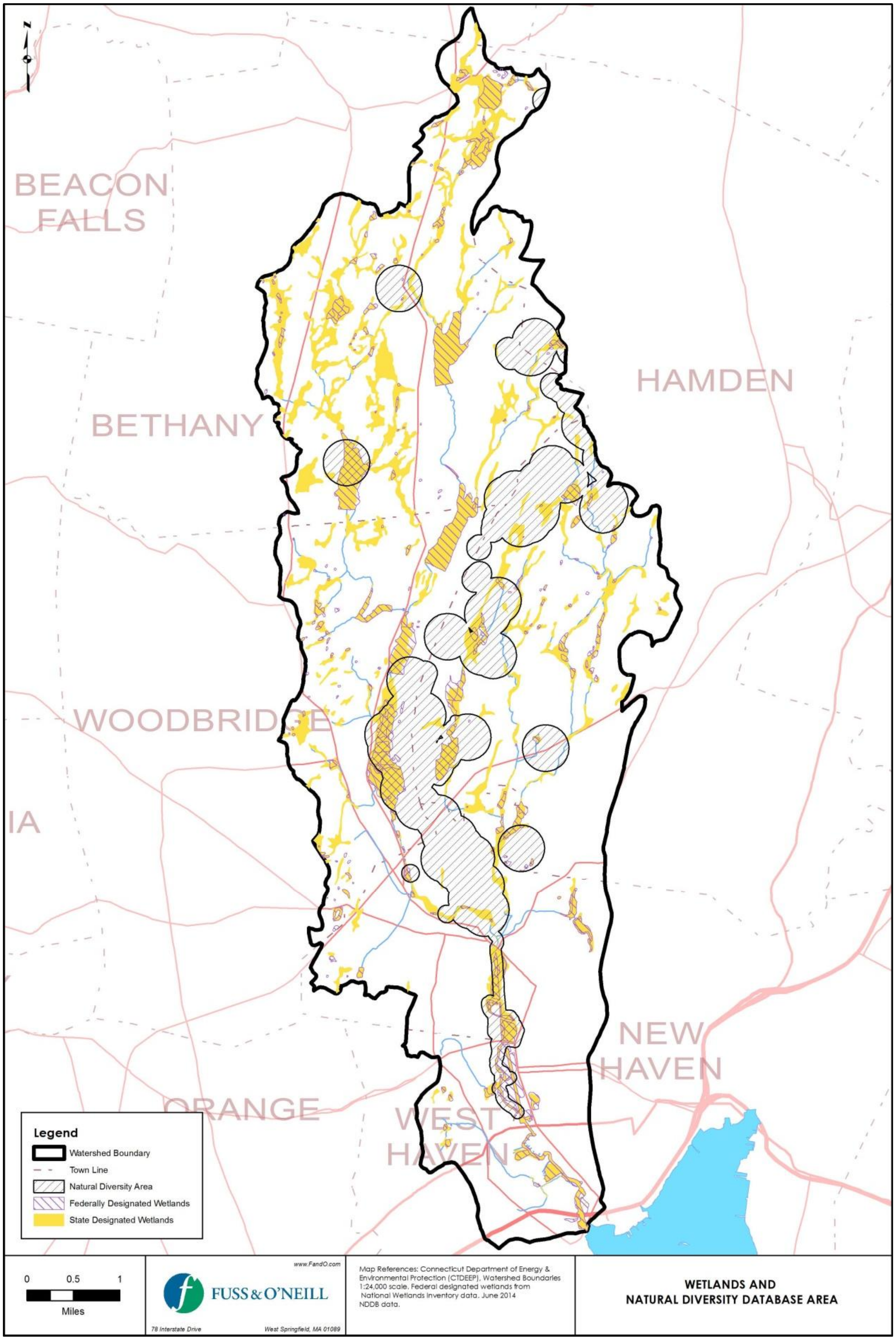

Figure 4-3. Inland Wetlands and Endangered and Threatened Species Habitat

In 1994, the West River Memorial Park was listed by the CTDEEP as a potential salt marsh restoration site. A preliminary engineering study was conducted for the restoration of West River Memorial Park Potential restoration activities that were investigated include expanding an existing pond area in the southeastern section of the park; dredging an existing sediment bar in the reflecting pool; connecting the West River with the head of the reflecting pool; constructing a bridge at the connection between the West River and Horseshoe Lagoon; expanding the southern confluence of the West River and reflecting pool; opening one or two tide gate flaps; and excavating the existing marsh along Ella Grasso Boulevard to encourage tidal flooding (Milone & MacBroom, 2002b).

A 2005 study evaluated impacts to the newly renovated soccer fields, tennis center, and Edgewood Park Pond of the manually-operated sluice gate and port that was installed on one tide gate in 2004 to increase tidal flushing. Water levels recorded during the study period did not rise above the elevation of the infrastructure of concern and the study concluded that precipitation events likely have more influence on flooding than the tidal fluctuations. Salinity data was also collect from November 2004 through January 2005. Salinity levels are generally between 20 and 32 parts per thousand (ppt) in healthy salt marshes. Under normal operation of the sluice gate, salinity results upstream of the Orange Avenue Bridge (Route 1) indicate that there is significant salinity stratification and poor mixing due to the variable water densities of fresh and saltwater. Since the surface fresh water will tend to dominate the shallow rooted plant zone of the marsh, establishment of a tidal marsh will be difficult in this area. Fresh water conditions were found throughout the water column upstream of Derby Avenue Bridge (Milone & MacBroom, 2005).

West River Tide Gates Closed

West River Tide Gates Open

The tidal marsh and channel restoration completed in 2012 involved replacing three of the old timber tide gates with self-regulating gates to enable better exchange of tidal waters with the lower portion of West River and provide flushing of currently stagnant portions of the dredged channel. The alteration was found to improve water quality in the river and restore portions of the tidal marsh. As part of the restoration project, invasive species were removed from Edgewood Park and a public access was improved with a raised walkway (Milone & MacBroom, 2012)

4.3 Fish and Wildlife

Endangered, Threatened, and Special Concern Species

The CTDEEP Natural Diversity Data Base (NDDB) maintains information on the location and status of endangered, threatened, and special concern species in Connecticut. The Connecticut Endangered Species Act defines "Endangered" as any native species documented by biological research and inventory to be in danger of extirpation (local extinction) throughout all or a significant portion of its range within Connecticut and to have no more than five occurrences in the state. The Act defines "Threatened Species" as any native species documented by biological research and inventory to be likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range within Connecticut and to have no more than nine occurrences in the state. "Species of Special Concern" means any native plant or any native non-harvested wildlife species documented to have a naturally restricted range or habitat in the state, to be at a low population level, to be in such high economic demand that its unregulated taking would be detrimental to the conservation of its population, or has become locally extinct in Connecticut.

Figure 4-3 depicts the generalized areas of endangered, threatened, and special concern species in the West River watershed. These areas represent a buffered zone around known species or community locations. *Table 4-1* lists species known to exist within the watershed (CTDEEP, 2014b).

Table 4-1. Endangered, Threatened, and Special Concern Animals

Common Name	Scientific Name	Status[1]
Coastal/Marine Communities *(Invertebrate Animals)*		
Silvery checkerspot	*Chlosyne nycteis*	SC*
Columbine duskywing	*Erynnis lucilius*	E
Pitcher plant moth	*Exyra fax*	SC
Noctuid moth	*Lepipolys perscripta*	SC
Bog copper	*Lycaena epixanthe*	SC
Aureolaria seed borer	*Rhodoecia aurantiago*	SC
Terrestrial Communities (*Vertebrate Animals)*		
Whip-poor-will	*Caprimulgus vociferus*	SC
Five-lined skink	*Eumeces fasciatus*	T
Peregrine falcon	*Falco peregrinus*	T
Wood turtle	*Glyptemys insculpta*	SC
Eastern hognose snake	*Heterodon platirhinos*	SC
Smooth green snake	*Liochlorophis vernalis*	SC
Northern leopard frog	*Rana pipiens*	SC
Carolina Eastern box turtle	*Terrapene carolina*	SC

(1) E = Endangered, T = Threatened, SC = Special Concern, * Extirpated (locally extinct)

Benthic Invertebrates

Sampling of macroinvertebrates via kick-net collection methods was performed by CTDEEP from 1990 to 2011. *Table 4-2* shows the multi-metric index (MMI) score calculated for the sampling events. The MMI is an index that combines indicators, or metrics, into a single value. Each metric is tested and calibrated to a scale and transformed into a unitless score prior to being aggregated into a multi-metric index. Both the index and metrics are useful in assessing ecological conditions. The basis of the aquatic life impairment designations for stream segment West River-01 (CT5305-00_01) is the calculated MMI consistently below the target value of 50.

Table 4-2. Macroinvertebrate Multi-metric Index (MMI) Summary

Waterbody	Stream Segment	TMDL/Other Station ID (See *Table 3-4*)	Sample Date	Multi-metric Index (MMI)[1]
West River-01	CT5305-00_01	364	8/13/1990	16.1
West River-01	CT5305-00_01	364	10/17/1997	10.8
West River-01	CT5305-00_01	364	10/3/2007	27.0
West River-01	CT5305-00_01	364	11/15/2011	30.1
West River-01	CT5305-00_01	1190	11/15/2011	29.2
Sargent River-01	CT5303-00_01	1192	6/20/1990	38.6
Sargent River-01	CT5303-00_01	2338	11/28/2007	85.4
Wintergreen Brook (New Haven)-03	CT5304-00_03	2339	10/9/2007	50.9
Belden Brook	N/A	5062	9/4/1990	54.5
Sanford Brook	N/A	5588	6/21/1990	43.5
Wintergreen Brook-01	CT5304-00_01	5766	9/4/1990	24.1

[1] Bold and highlighted values are below the target value of 50.

No benthic macroinvertebrate data have been collected under the CTDEEP River Bioassessment by Volunteers (RBV) Program within the West River watershed (Meghan Lally, CTDEEP, personal communication, December 2, 2014).

A study by Cuomo & Zinn (1997) documents existing benthic organisms of the lower West River as part of the marsh restoration efforts. Sites were sampled between the Chapel Street Bridge and the mouth of the West River during July 1995. All sites contained polychaete worms and other organisms typical of estuarine systems. The northernmost sites also contained some freshwater organisms, including chironomids and freshwater snails.

Fish

The West River and its tributaries were once important habitat for anadromous fish species. Anadromous fish begin life in freshwater, migrate to the sea to reach maturity, and return to freshwater to spawn. Existing fish passage and the potential for fish passage restoration within the watershed is presented in *Section 5.1*. A limited number of fish counts were conducted by the CTDEEP in 1990, 2007 and 2013 in the West River (Station 364), Wintergreen Brook (Stations 2339 & 5766), Belden Brook (Station 5062), Sargent River (Station 1192), and Sanford Brook (Station 5588). Blacknose dace *(Rhinichthys atratulus)*, white sucker *(Catostomus commersonii)*, wild brook trout *(Salvelinus fontinalis)*, American eel *(Anguilla rostrata)*, and various species of sunfish were the most common fish species found in the watershed during these limited surveys.

4.4 Vegetation

Endangered, Threatened, and Special Concern Species

As discussed in *Section 4.3*, the CTDEEP NDDB maintains information on the location and status of endangered, threatened, and special concern species in Connecticut. Endangered, threatened, and/or special concern species of terrestrial communities of vascular plants are listed in *Table 4-4*.

Table 4-3. Endangered, Threatened, and Special Concern Plants

Common Name	Scientific Name	Status[1]
Hairy angelica	*Angelica venenosa*	SC*
Puttyroot	*Aplectrum hyemale*	SC*
Arethusa	*Arethusa bulbosa*	SC*
Needlegrass	*Aristida longespica*	SC
Virginia snakeroot	*Aristolochia serpentaria*	SC
Sedge	*Carex magellanica*	E
Willdenow's sedge	*Carex willdenowii*	E
Eastern redbud	*Cercis canadensis*	SC*
Hairy lip-fern	*Cheilanthes lanosa*	E
Long-bracted green orchid	*Coeloglossum viride*	E
Yellow lady's-slipper	*Cypripedium parviflorum*	SC
Whitlow-grass	*Draba reptans*	SC
Goldie's fern	*Dryopteris goldiana*	SC
Fir clubmoss	*Huperzia selago*	SC*
Water pennywort	*Hydrocotyle umbellata*	E
Creeping bush-clover	*Lespedeza repens*	SC
Green adder's-mouth	*Malaxis unifolia*	E
Long-awn hairgrass	*Muhlenbergia capillaris*	E
Eastern prickly pear	*Opuntia humifusa*	SC
American ginseng	*Panax quinquefolius*	SC
Warty panic grass	*Panicum verrucosum*	SC*
Swamp lousewort	*Pedicularis lanceolata*	T
Hoary plantain	*Plantago virginica*	SC
Hooker's orchid	*Platanthera hookeri*	SC*

Table 4-3. Endangered, Threatened, and Special Concern Plants

Common Name	Scientific Name	Status[1]
Vasey's pondweed	*Potamogeton vaseyi*	T
Tall cinquefoil	*Potentilla arguta*	SC
Basil mountain-mint	*Pycnanthemum clinopodioides*	E
Sand bramble	*Rubus cuneifolius*	SC
Waputo	*Sagittaria cuneata*	E
Rough dropseed	*Sporobolus clandestinus*	E
Northern dropseed	*Sporobolus heterolepis*	E
Small dropseed	*Sporobolus neglectus*	E
Nodding pogonia	*Triphora trianthophora*	E
Narrow-leaved vervain	*Verbena simplex*	SC*
Possum haw	*Viburnum nudum*	SC*

(1) E = Endangered, T = Threatened, SC = Special Concern, * Extirpated (locally extinct)

Riparian Buffers

Riparian buffers are naturally vegetated areas adjacent to streams, ponds, and wetlands. Vegetative buffers help encourage infiltration of rainfall and runoff, and provide absorption for high stream flows, which helps reduce flooding and drought. The buffer area provides a living "cushion" between upland land use and water, protecting water quality, the hydrologic regime of the waterway and stream structure. Naturally vegetated buffers filter out pollutants, capture sediment, regulate stream water temperature and process many contaminants through vegetative uptake. The vegetative community of riparian buffers provides habitat for plants and animals, many of which are dependent on riparian habitat features for survival. Changes to the natural riparian buffer zone can reduce the effectiveness of the buffer and contribute to water quality impairment.

Development along the stream corridors in the lower portion of the watershed, primarily south of the Wilbur Cross Parkway (Route15), has resulted in substantial loss of riparian vegetation. The majority of the riparian zone for the impaired segments of the West River, Edgewood Park Pond, and Wintergreen Brook is characterized by developed land, turf grass, and deciduous forest. Developed areas are also a potential source of bacteria and other pollutants. The high degree of stream buffer encroachment along the lower main stem West River, Beaver Brook, Belden Brook, Wilmot Brook, and Wintergreen Brook has a significant impact on overall stream and habitat conditions.

The University of Connecticut Center for Land Use Education and Research (CLEAR) characterized Connecticut's watersheds and their riparian areas through the use of remotely-sensed land cover during the 1985 to 2006 time period (CLEAR, 2011). Results of this study indicate that the West River watershed experienced a 35% loss of forested land within the 300-foot riparian corridor (i.e., within 300 feet on either side of the streams and rivers in the watershed) prior to 1985, although the additional loss of forest between 1985 and 2006 has been relatively minor, with an additional 2% loss *(Figure 4-4)*. The impaired segments of the West River and Edgewood Park Pond have riparian areas dominated by developed, turf grass, and deciduous forest land uses (CTDEEP, 2012).

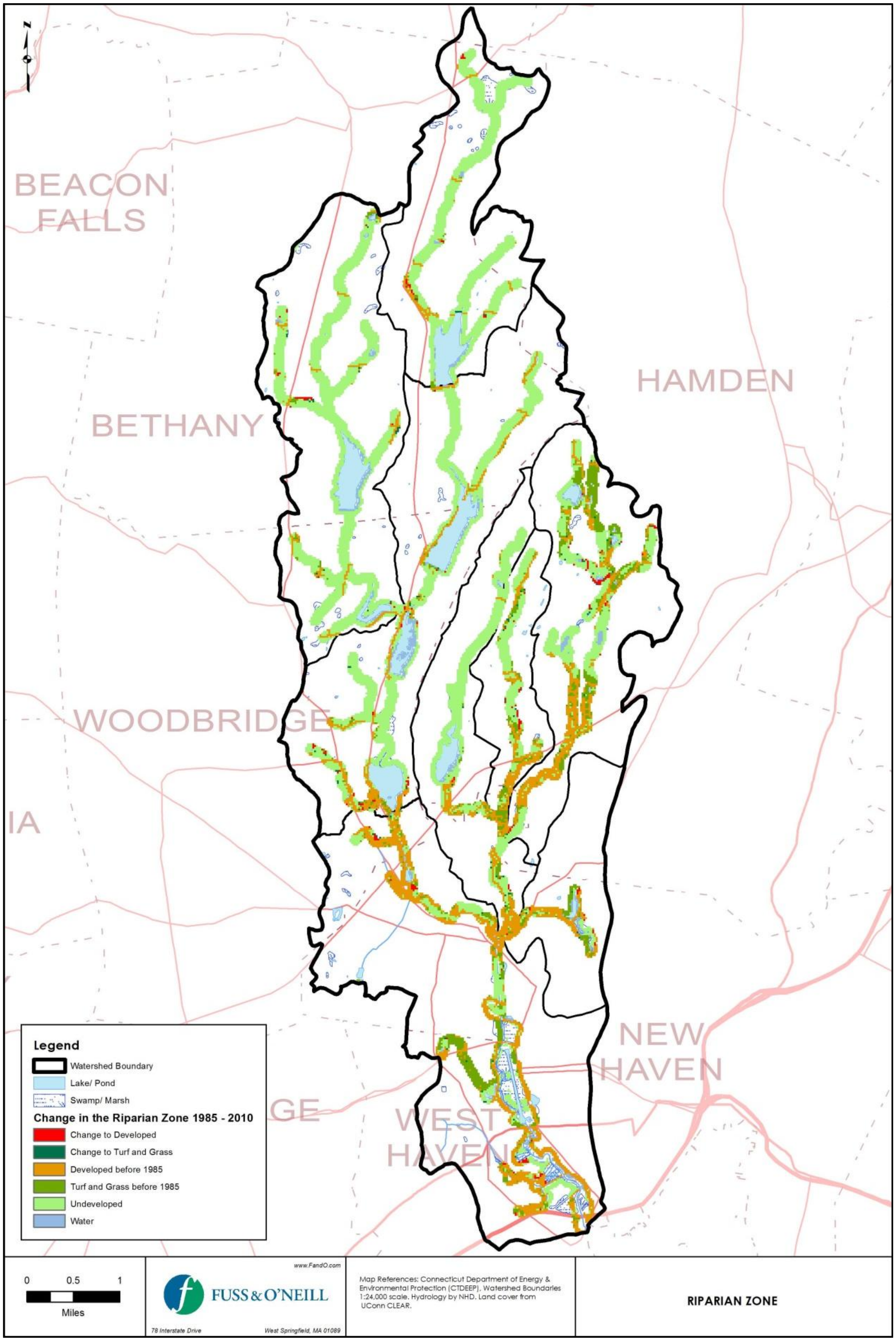

Figure 4-4. Riparian Buffer Land Cover Change (1985 to 2006)

Invasive Species

Invasive plant species, which are mostly non-native plant species that successfully out-compete native plants, are also prevalent throughout the watershed. A *Management Plan for Edgewood Park* was developed through the Yale School of Forestry and Environmental Studies (Brower et al., 1999). The study identified several invasive species, including oriental bittersweet, poison ivy, and wild grape, which are climbing vines and threaten the health of the native trees in the area. Phragmites *(Phragmites australis)* was also identified as a species to be monitored, particularly in the Edgewood Avenue Pond, which is critical bird habitat. Other invasive species noted in this study include:

- Multiflora rose (*Rosa multiflora*)
- Japanese knotweed (*Polygonum cuspidatum*)
- Norway maple (*Acer platanoides*)
- Purple loosestrife (*Lythrum salicara*)
- Greenbrier (*Smilax rotundifolia*)

STS/CFE received a grant in 2012 to remove phragmites at Edgewood Park Pond, which was conducted by the CTDEEP Wetlands Habitat and Mosquito Management Program (WHAMM).

A study called *Invasive Plants in Beaver Ponds Park* (Sullivan, et al., 2006) was conducted in 2006 and identified several common invasive species in the park and provided management options for common reed *(Phragmites australis).* Other invasive species in Beaver Ponds Park include:

- Giant or common reed *(Phragmites australis)*
- Oriental or ornamental bittersweet *(Celastrus orbiculatus)*
- Tree of heaven (*Ailanthus altissima*)
- Multiflora rose (Rosa multiflora)
- Japanese Knotweed *(Fallopia japonica)*
- Burning bush *(Euonymus alatus)*
- Japanese barberry(*Berberis thunbergii*)
- Norway maple *(Acer platanoides)*
- Purple loosestrife *(Lythrum salicaria)*

The Friends of Beaver Ponds Park has been involved in efforts to remove invasive species, including eradication efforts on the south side of the south pond where it borders Crescent Street between Munson and Fournier. The invasive species have either diminished or been mostly eradicated in this area. Invasive species are still located on the northern (Sherman Parkway) side of the south pond and around the north pond. In addition, porcelain berry and swallowwort were identified as an emergent invasive species of concern in the park. The Friends have been working with URI and the Yale University School of Forestry & Environmental Studies incoming students to assist in the control of these species (Nan Bartow, Friends of Beaver Ponds Park, President, personal communication, November 19, 2014).

A plant inventory within the West River Tidal Marsh was conducted in the 1990s to assess the potential for salt marsh plants to thrive. The study found that the natural salt marsh community was gradually replaced by a community dominated by common reed with mixes of woody vegetation, cattail, and a variety of herbaceous dicots such as goldenrod and smartweed (Orson et al., 1997).

5 Water Infrastructure

This section describes the water infrastructure within the West River watershed including dams, water supply, wastewater collection and treatment, stormwater, and flood management, as it relates to water quality and quantity issues.

5.1 Dams

As with other similar coastal streams in Connecticut, a number of dams have been constructed along the West River and its tributaries. Approximately 31 dams are located within the West River watershed, and some of the more notable dams are listed in *Table 5.1*. Bethany Lake Dam, Lake Dawson Dam, Lake Watrous Dam, Lake Chamberlain Dam, and Glen Lake Dam are associated with public water supplies. The remaining dams and their associated impoundments may provide recreational opportunities, water supplies (agriculture), flood protection, and/or aquatic and wildlife habitat. Although dams provide significant benefits, they can also serve as barriers to fish migration and alter the hydrologic characteristics of a watershed.

Table 5-1. Notable Dams within the West River Watershed

Dam Name	Waterbody/Stream	Town
Bethany Lake Dam	Bethany Lake/ West River	Bethany
Lake Dawson Dam	Lake Dawson/ West River	Woodbridge
Lake Watrous Dam	Lake Watrous/ West River	Woodbridge
Lake Chamberlain Dam	Lake Chamberlain/ Sargent River	Bethany
Glen Lake Dam	Glen Lake/ Sargent River	Woodbridge
Farm Brook Project Site #1	Farm Brook Reservoir/ Farm Brook	Hamden
Lake Wintergreen Dam	Lake Wintergreen/ Wintergreen Brook	Hamden
Konolds Pond Dam	Konolds Pond/ West River	Woodbridge
Aversa Pond Dam	Bishops Pond/ Unnamed Tributary	Woodbridge
Pond Lily Dam	Pond Lily/ West River	New Haven
Beaver Pond Dam	Beaver Pond/ Beaver Brook	New Haven

Pond Lily Dam was constructed in 1780 and consists of an earthen berm and a 191-foot long, six-foot high spillway (Milone & MacBroom, 2011; Zaretsky, 2013). The dam is located in the City of New Haven, and the Lily Pond impoundment extends into the town of Woodbridge. A fishway was installed in the early 2000s to aid fish passage of anadromous and resident fish species. Hurricane Sandy Recovery funding has been received for the removal of Lily Pond Dam, which is scheduled to begin in July 2015 (New Haven Independent, 2014). The goals of the dam removal are improved fish passage and ecological function of the area near the Pond Lily Dam as well as channel and floodplain restoration through the riparian corridor (Milone & MacBroom, 2011). Removal of the dam will restore about 2.6 miles of stream to migratory fish including herring, eel and shad (FWS, 2014).

According to the Inland Fisheries Division of CTDEEP (Steve Gephard, CTDEEP, personal communication, November 17, 2014), the main stem of the West River is the only viable fishway in the watershed. Since the installation of the self-regulating tide gates at the Route 1 bridge in 2012, both spawning and nursery fish can migrate through the West River Tidal Marsh and up to Pond Lily Dam and potentially over the fishway at the dam. There are no other existing fishways in the West River system. CTDEEP has identified Konolds Pond as critical habitat for spawning and nursery river herring. The spillway is very low and gently sloped, and CTDEEP believes that some fish can enter Konolds Pond at certain flow levels. Following the removal of the Pond Lily Dam, CTDEEP intends to initiate a community-based effort to add a fishway to the Konolds Pond Dam to increase fish migration into Konolds Pond. There are no other significant opportunities for fisheries restoration upstream of Konolds Pond since the upstream dams on the main stem West River are associated with water supplies and have fluctuating water levels that are not conducive to fishways.

The Wintergreen Brook tributary system also has little potential for fish passage restoration since the downstream portion of Wintergreen Brook flows through an underground conduit. Further upstream there are barriers on Wintergreen Brook and the Beaver Pond system near SCSU that do not lend themselves to fish passage (Steve Gephard, CTDEEP, personal communication, November 17, 2014).

5.2 Water Supply

The South Central Connecticut Regional Water Authority (SCCRWA) supplies water to approximately 430,000 persons in the greater New Haven area, including residents within the West River watershed. Public water is supplied to the majority of the residents, businesses, and institutions within the watershed, with the exception of the western portion of Hamden near Mountain Road, the northern portion of Woodbridge west of Route 69, and almost all of Bethany (CTDPH, 2014).

Lake Chamberlain, Glen Lake, Lake Dawson, Lake Watrous, and Lake Bethany are managed by the SCCRWA for public water supply (SCCRWA, 2014). SCCRWA owns approximately 4,211 acres within the West River watershed. The West River Water Treatment Plant is located in Woodbridge.

There are no Aquifer Protection Areas (APAs) (also referred to as "wellhead protection areas") located within the watershed. APAs are designated around active well fields in sand and gravel aquifers that serve more than 1,000 people to protect major public water supply wells in sand and gravel aquifers.

5.3 Wastewater

Sanitary Sewer

Approximately 47% of the watershed area, containing 96% of the total households in the watershed, is serviced by sanitary sewer (*Figure 5-1)*. There are no Water Pollution Control Facilities (WPCFs) located within the West River watershed. The Greater New Haven Water Pollution Control Authority (GNHWPCA) is a regional sewer authority that provides sewer service to New Haven, Hamden, East Haven, and Woodbridge. The GNHWPCA owns and operates sewer mains and pump stations that convey sewer flow to the East Shore Water Pollution Abatement Facility located on the shore of New Haven Harbor, outside of the West River watershed. The City of West Haven also owns and operates a WPCF located outside of the watershed that discharges directly to New Haven Harbor. The WPCF collects wastewater from areas within West Haven shown in *Figure 5-1.* Woodbridge has only limited sewer service provided by GNHWPCA, primarily in commercial or higher density residential areas, and Bethany currently has no sewer service (SCRCOG, 2009).

Combined Sewer Overflows

The City of New Haven has combined sanitary and storm sewer systems that discharge untreated sewage into New Haven Harbor during periods of heavy rain. These discharges are referred to as Combined Sewer Overflows (CSOs). The City of New Haven owns and maintains the stormwater collection system (i.e., the storm sewer) and the GNHWPCA maintains the wastewater infrastructure, requiring cooperation to solve CSO issues.

During rainfall events, flow that cannot be diverted to the WPCF is diverted into the Truman Storage Tank, located under the parking lot for the Truman School, where it is held until flows to the WPCF subside. Excess flows may also discharge into New Haven Harbor if they exceed the capacity of the Boulevard Pump Station. If the flows continue to rise, regulators[9] along the Boulevard Trunk Sewer (BTS) will discharge through the CSO outfalls to the West River (CH2MHILL, 2014b). There are four CSO outfalls along the West River: CSO 003 (Ella T. Grasso Boulevard at Orange Avenue), CSO 004 (Ella T. Grasso Boulevard at Legion Avenue), CSO 005 (Ella T. Grasso Boulevard @ Derby Avenue), and CSO 006 (Whalley Avenue at Fitch Street) *(Figure 5-1)*.

The former CSO 002, located at the approximate location of the Truman Storage Tank, was closed prior to 2006. The former CSO 008, which was located at Sherman Parkway and discharged into Beaver Ponds, was closed in 2014 (although the outfall continues to convey stormwater discharges).

The GNHWPCA has installed several meters in the BTS and at CSO 003, 004, 005, and 006 to monitor flows since June 2012. Data collected between June 2012 and April 2014 indicate that between 12 and 42 CSO discharge events occur each year to the West River, with measured total CSO discharge volumes of 43.9 million gallons (MG) between June 2012 and May 2013 and 43.9 MG between April 2013 and May 2014 *(Table 5-2;* GNHWPCA, 2013 & 2014).

Table 5-2. CSO Discharges to the West River

CSO Number	Measured CSO Events		Measured CSO Volume (million gallons)	
	June 2012 to May 2013	April 2013 to May 2014	June 2012 to May 2013	April 2013 to May 2014
CSO 003	25	38	13.7	17.8
CSO 004	38	42	20.6	18.8
CSO 005	31	29	4.4	3.6
CSO 006	12	16	5.2	3.7
Total	--	--	43.9	43.9

[9] A "regulator" is a relief structure in a combined sanitary and stormwater collection system where the combined sanitary and stormwater flows are diverted to a WPCF during low flows and discharged into a surface waterbody during large storm events when the capacity of the WPCF is exceeded.

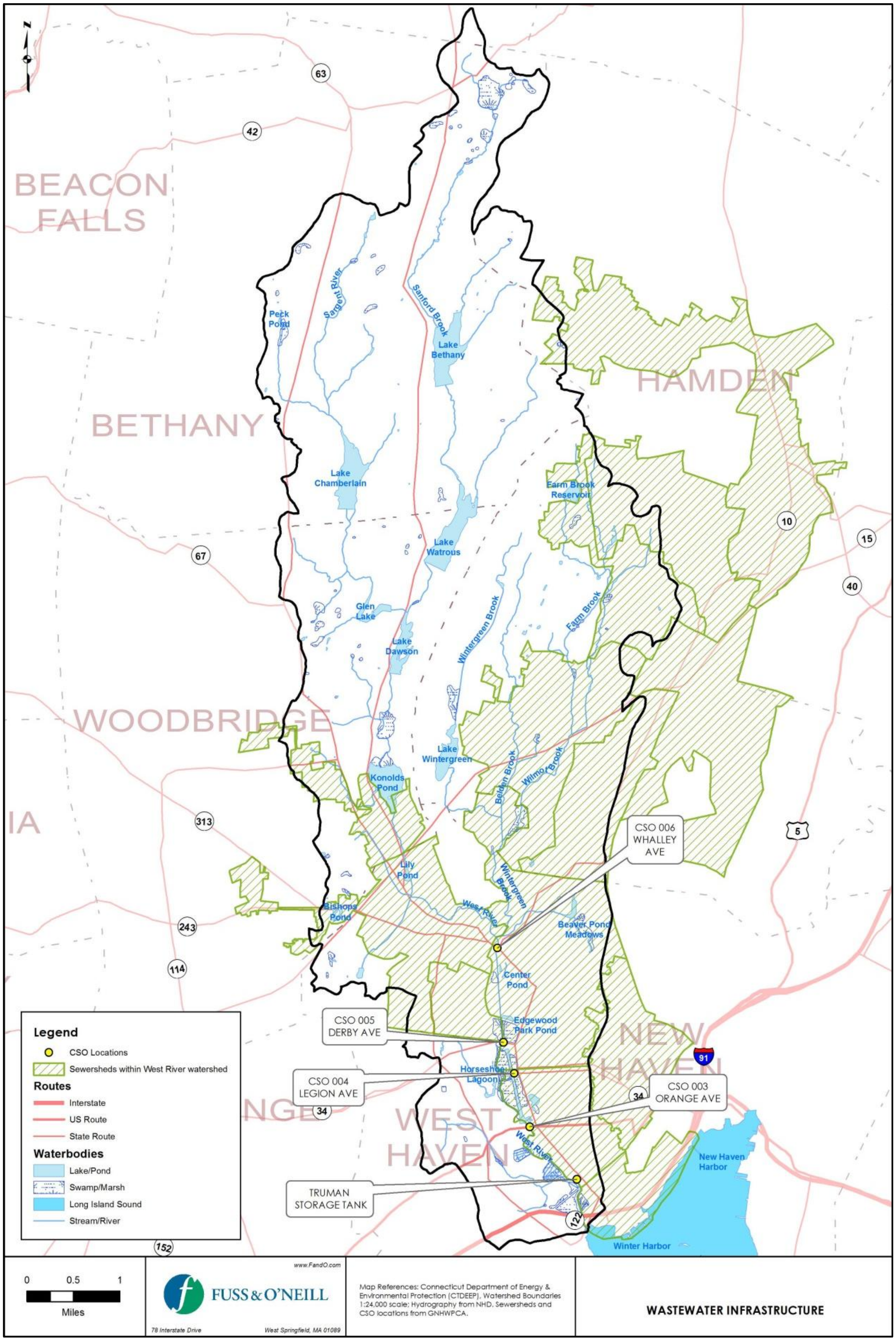

Figure 5-1. Wastewater Infrastructure

The City of New Haven has been working to address CSOs since the early 1980s. Several major CSO abatement projects were completed in New Haven prior to regionalization of the GNHWPCA in the mid-2000s. These projects focused on sewer separation of the sanitary and storm sewers. More recent projects that have been completed since the current Long Term Control Plan (LTCP)[10] was prepared including CSO flow monitoring (started in 2012), additional sewer separation, and the installation of the Truman Storage Tank (GNHWPCA, 2013 & 2014).

A recent study, "West River Combined Sewer Overflow Abatement Preliminary Design Memorandum," (CH2MHIL, 2014a) recommends several updates to the existing system, including reducing CSOs to the West River by modifying or constructing new regulators, maximizing the use of the Truman Storage Tank, maximizing pumping from the Boulevard Pump Station, maximizing conveyance and storage in the BTS, and evaluating green infrastructure (GI) alternatives within the BTS tributary areas (CH2MHILL, 2014a).

GNHWPCA also recently completed an update to the hydraulic model for the City's combined sewer system and continues to gather monitoring data on CSO discharge volumes. The model includes system improvements completed since the previous model and proposed improvements cited in the Preliminary Design Memorandum, including modifications to the Truman Storage Tank. The proposed modifications will improve the flow and storage within the tank, which will ultimately reduce backups and overflows. According to the GNHWPCA, the updated hydraulic model shows significant reductions in CSO discharge volumes since the original LTCP in 2001. Annual CSO discharge volumes to the West River are predicted to be approximately 14.65 MG, which translates to a significant reduction in loadings of indicator bacteria, nitrogen, and other pollutants to the West River. GNHWPCA will continue to implement CSO abatement measures to further reduce CSO discharges to the West River consistent with its LTCP.

In the past few years, the City of New Haven has adopted new regulatory requirements to reduce stormwater runoff contributing to the City's combined sewer system from development projects. New Haven is also in the process of establishing a stormwater authority and fee system, based on impervious cover, to provide a dedicated funding source for its stormwater management program and to provide further incentive for the use of GI and Low Impact Development (LID) approaches. GI/LID studies and projects in the watershed are described in *Section 5.4*.

5.4 Stormwater

Urban stormwater runoff generated in developed areas from buildings, pavement, and other compacted or impervious surfaces is a significant source of pollutants to the West River and its tributaries. In certain areas, urbanization within the West River watershed has altered the natural hydrology, these include the West River Tidal Marsh, SCSU property, and densely developed neighborhoods in New Haven.

[10] A Long Term Control Plan (LTCP) is required under the Environmental Protection Agency's and CTDEEP's CSO Control Policy to reduce the frequency, duration, and intensity of CSO events. The LTCP is a planning document for implementation of best management practices (BMPs) to reduce and control overflows.

Impervious surfaces prevent infiltration of rainfall and runoff into the ground. Stormwater generated from impervious surfaces typically contains increased pollutants from the atmosphere, vehicles, industry, lawns, construction sites, humans and animals. Without treatment, these pollutants are conveyed from the impervious surfaces to storm drainage systems and eventually to the receiving waterbodies during storms. Impervious surfaces and traditional piped storm drainage systems increase the volume, peak flow rates, and velocity of stormwater runoff to receiving waters. This can contribute to channel erosion, sedimentation, and reduced stream baseflow during dry periods. The amount of impervious cover in the West River watershed and the implications for water quality and overall stream health is discussed in *Section 6.3*.

The CTDEEP regulates stormwater discharges from municipalities in designated urbanized areas under the General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems (MS4). All of the municipalities in the West River watershed are regulated under the MS4 General Permit. The MS4 General Permit requires these municipalities to register with CTDEEP, develop and implement a Stormwater Management Plan that addresses six minimum control measures, and collect stormwater samples for representative land uses. The six minimum control measures include public education and outreach, public participation, illicit discharge detection/elimination, construction stormwater management, post-construction stormwater management, and pollution prevention/good housekeeping. The CTDEEP issued a proposed Draft MS4 General Permit in July 2014. The final permit is anticipated to be issued in 2015 or 2016 following completion of the ongoing permit hearing process. In addition to the watershed municipalities, state and federal institutions, including SCSU and potentially other institutional facilities, would be subject to the new MS4 General Permit.

Recent and ongoing efforts to incorporate green infrastructure (GI) and low impact development (LID) within the watershed have been initiated by various agencies and groups including GNHWPCA, City of New Haven, SCSU, and Save the Sound/Connecticut Fund for the Environment.

GNHWPCA

GNHWPCA identified potential GI/LID opportunities to reduce runoff into the combined sewer system for CSO sewersheds 003 and 004 since these account for 85% of the annual CSO volume to the West River (See *Section 5.3;* CH2MHILL, 2014b). The study area for the CSO drainage to Outfalls 003 and 004 is generally bounded by Orange Avenue to the south, West River Memorial Park to the west, George Street to the north, and Howard Avenue to the east. In the GI/LID study, sites or parcels for potential GI/LID opportunities were ranked and prioritized using the likelihood of implementation and suitability results. The top 20 parcels are ranked with highest suitability and current active development along with cost/benefit analysis (*Figure 5-2*; CH2MHILL, 2014b).

City of New Haven

The City of New Haven commissioned a feasibility study on creating a stormwater authority to establish a funding mechanism for stormwater services (MP, 2010). However, a stormwater authority has not yet been established.

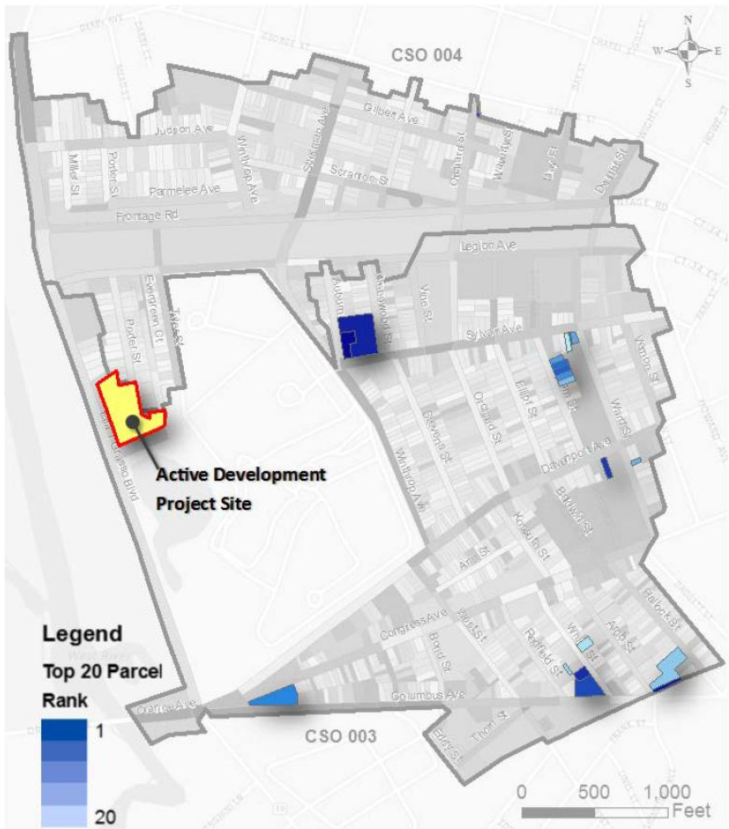

Figure 5-2. Top 20 Parcels with Highest Stormwater BMP Suitability (CH2MHILL, 2014b)

SCSU

A Stormwater Master Plan was prepared for SCSU as part of the Master Plan Update, 2009 Amendment (Fuss & O'Neill, 2012). Recommendations for stormwater improvements are provided for individual campus drainage areas based on the hydrologic analysis and drainage system evaluations. General recommendations included emphasizing the use of LID techniques to reduce peak flow rates, runoff volume, and pollutant loads. Specific campus projects are listed in the 2012 report.

Save the Sound/Connecticut Fund for the Environment

Connecticut Fund for the Environment and Save the Sound recently completed a project "Green Infrastructure Feasibility Scan" to assess the feasibility of green infrastructure implementation in New Haven and Bridgeport. A feasibility scan was conducted for both cities to evaluate opportunities to incorporate green infrastructure into ongoing wet weather management efforts. Results of the feasibility scan indicate that green infrastructure can serve as an effective approach to managing CSOs and other wet weather issues within Bridgeport and New Haven. The study is intended to serve as a foundation for future detailed planning and design efforts within these communities (Hazen & Sawyer, 2012).

In November 2014, New Haven Urban Resources Initiative was awarded a grant through the Long Island Sound Futures Fund (LISFF) to implement several green infrastructure projects within sewershed areas identified in the CH2MHILL study.

5.5 Flooding

Figure 5-3 depicts flood hazard areas within the West River watershed, including the 100-year and 500-year flood zones and the regulatory floodway. Flood zones are defined by the Federal Emergency Management Agency (FEMA) as the area below the high water level that occurs during a flood of a specified recurrence interval[11]. FEMA also defines a "floodway" as the stream channel and adjacent areas that carry the majority of the flood flow at a significant velocity, whereas "floodplain" also includes the flood fringe or areas that are flooded without a strong current.

Table 5-3 summarizes peak flow frequency estimates for given recurrence intervals for the West River and several of its tributaries (FEMA, 2013).

Table 5-3. Peak Flow Frequency Estimates (in cfs) of the West River

Location	Drainage Area (square miles)	Recurrence Interval			
		10 years	50 years	100 years	500 years
WEST RIVER NO. 2					
At Whalley Avenue	29.48	2,750	4,000	4,800	6,300
At Blake Street	18.59	1,500	2,150	2,550	3,500
At Lily Pond Avenue	16.38	1,150	1,750	2,250	3,200
At Lake Dawson	13.9	990	1,590	1,910	2,720
WINTERGREEN BROOK					
At Blake Street	10.88	1,600	2,300	2,750	3,550
At Wilmont Avenue	8.42	1,500	2,150	2,550	3,300
BEAVER BROOK NO. 3					
At Blake Street	2.03	150	230	280	370
At Crescent Street	1.77	80	100	110	130
FARM BROOK (ALSO CALLED WILMOT BROOK)					
At Woodin Street	3.99	700	1,050	1,250	1,900
At Wilbur Cross Parkway (State Route 15)	3.40	450	850	900	1,300

[11] The average number of years between floods of a certain size is the recurrence interval or return period. For example, there is a 1-in-100 chance that a 100-year flood will happen during any year. The actual number of years between floods of any given size varies because of the natural climate variability. (Source: http://pubs.usgs.gov/fs/FS-229-96/)

WEST BRANCH FARM BROOK (ALSO CALLED FARM BROOK)					
At Morgan Street	0.57	300	550	600	850

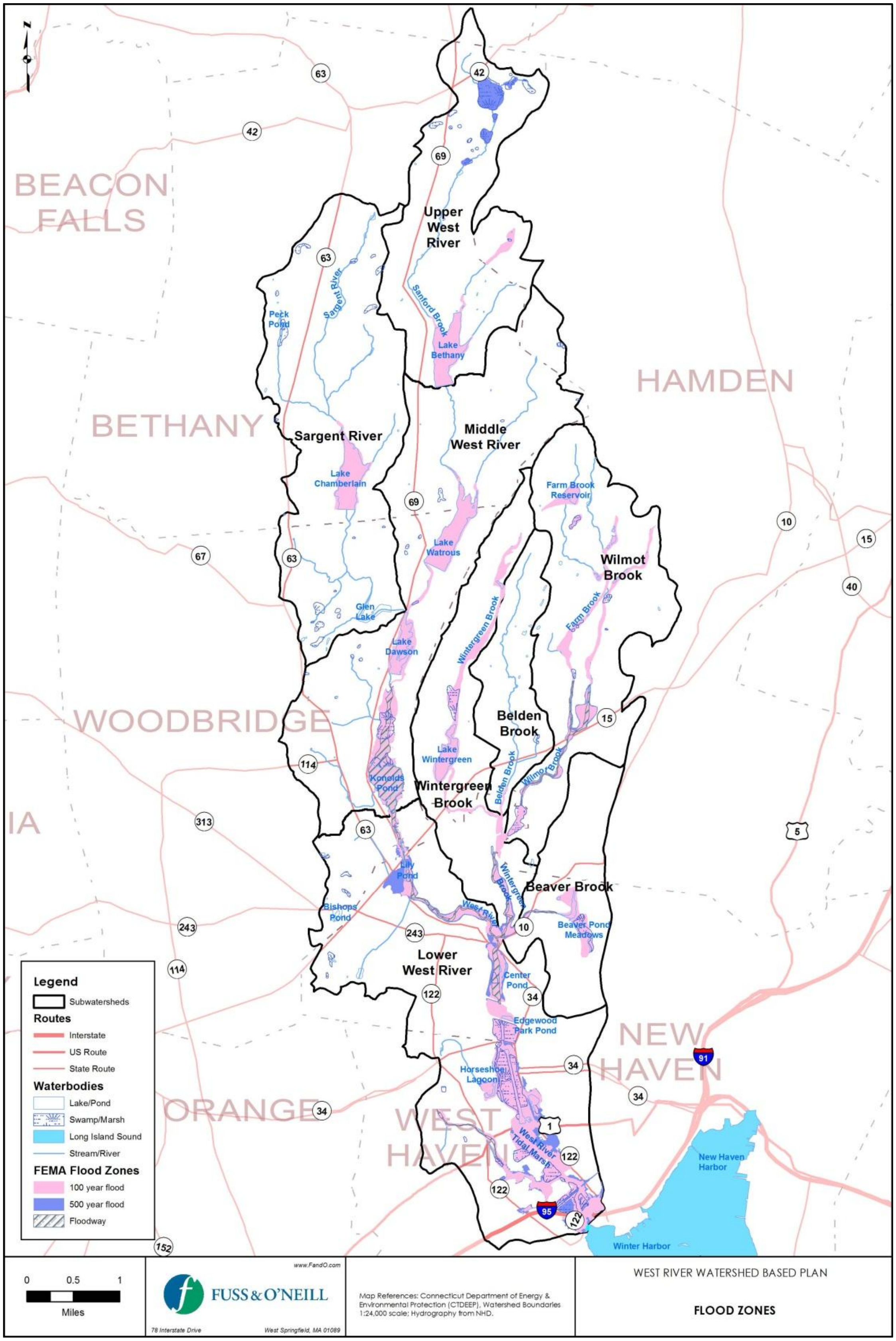

Figure 5-3. Flood Zones

The West River watershed has a history of flooding as a result of historical development of the watershed. The U.S. Army Corps of Engineers spent much of the 1900s redirecting the West River to suit industrial and flood control needs.

In 1982, New Haven experienced the worst flooding on record, which prompted construction of a completely channelized area around Blake Street (CT Rivers Community, 2014). This devastating flooding event caused many people, especially in the Woodbridge Flats area near Blake Street, to leave their homes. Businesses, such as, the Mite Corporation, Geometric Tools Company and 500 Blake Street closed due to the flood (Kinder, 2014).

The Woodbridge Flats area is located to the west of the West River in the Town of Woodbridge, which has had historic flooding issues. The area is a dense, low-lying urban neighborhood, with many hydraulic constraints upstream and downstream of Merritt Avenue. A *Study of Flooding Conditions in the Woodbridge Flats* (From Landin Street to Lawrence Street, between Litchfield Turnpike and Amity Road, Woodbridge, Connecticut) was published in April 1981. The Town of Woodbridge commissioned a report to analyze the Woodbridge Flats area of Woodbridge, Connecticut in 2007. This flood study analyzed the West River from Konolds Pond Dam in the Town of Woodbridge to the Lily Pond Dam, in the City of New Haven and the stream from Lawrence Street to the confluence with West River. The study recommends channel improvements with a 60-foot wide channel between Pond Lily Avenue and Merritt Avenue, and a 30-foot wide channel between Merritt Avenue and Bradley Road (Cardinal Engineering Associates, Inc., 2009).

Based on the New Haven County Flood Insurance Study (FEMA, 2013), Hamden and New Haven have historically experienced localized flooding from Wilmot Brook (also known as Farm Brook) and its tributaries. Therefore, flood control structures have been constructed for flood protection including Farm Brook Project Site #1, an earthen dam impounding Farm Brook Reservoir and two lower dams called Farm Brook Project Site #2A and #2B located on Farm Brook and West Branch Farm Brook (also called Farm Brook), respectively.

As discussed in *Section 4.2.2*, tide gates were installed at the Route 1 road crossing, primarily to reduce mosquito breeding. They only provide flood reduction from the normal daily tide cycle and small coastal events; they do not provide major flood protection (FEMA, 2013).

6 Watershed Land Use

The type and distribution of land use and land cover within a watershed has a direct impact on nonpoint sources of pollution and water quality. This section describes the current land use and land cover patterns in the watershed, and the implications for water quality and stream health.

6.1 Land Use

Figure 6-1 depicts generalized land use in the West River watershed, which was derived from 2008 GIS zoning and open space data provided by South Central Regional Council of Governments (SCRCOG). The “water” land use category was derived from the National Hydrography Dataset (NHD). Parcel information and roadways were derived from CTDEEP GIS data. Agricultural lands were identified using land cover data from UConn Center for Land Use Education and Research (CLEAR). The data set was verified using aerial photographs, and updates to land use were made to reflect current conditions.

The land use categories were consolidated into 12 generalized land use categories (*Table 6-1*). Land use affects the quality of stormwater and nonpoint source runoff that flows into the West River and its tributaries. Forested land and wetlands are generally beneficial to water quality. Residential, commercial, and industrial areas contribute greater amounts of runoff and associated pollutants, which can degrade water quality. *Table 6-1* identifies the land use composition of each subwatershed.

Table 6-1. Land Use (acres)

Land Use	Beaver Brook		Belden Brook						Percent of Watershed
	Beaver Brook	Belden Brook	Lower West River	Middle West River	Sargent River	Upper West River	Wilmot Brook	Wintergreen Brook	
Low Density Residential	110	433	0	536	402	592	171	0	7.7%
Medium Density Residential	468	142	601	905	711	225	313	137	15.6%
High Density Residential	57	0	1,072	5	0	0	1,026	64	12.6%
Commercial	214	21	355	25	142	48	0	3	2.9%
Institutional	6	0	290	61	119	0	138	138	4.5%
Industrial	149	63	343	28	0	17	15	50	4.0%
Open Space	229	110	998	21	15	2	336	81	7.5%
Roadway	0	108	762	156	118	84	298	83	8.3%
Agriculture	0	67	7	149	413	88	160	36	4.3%
Forest	15	3	279	1,942	1,565	1,338	209	1,137	27.7%
Wetland	13	3	185	52	45	79	31	19	1.1%
Water			101	238	126	106	27	47	3.0%

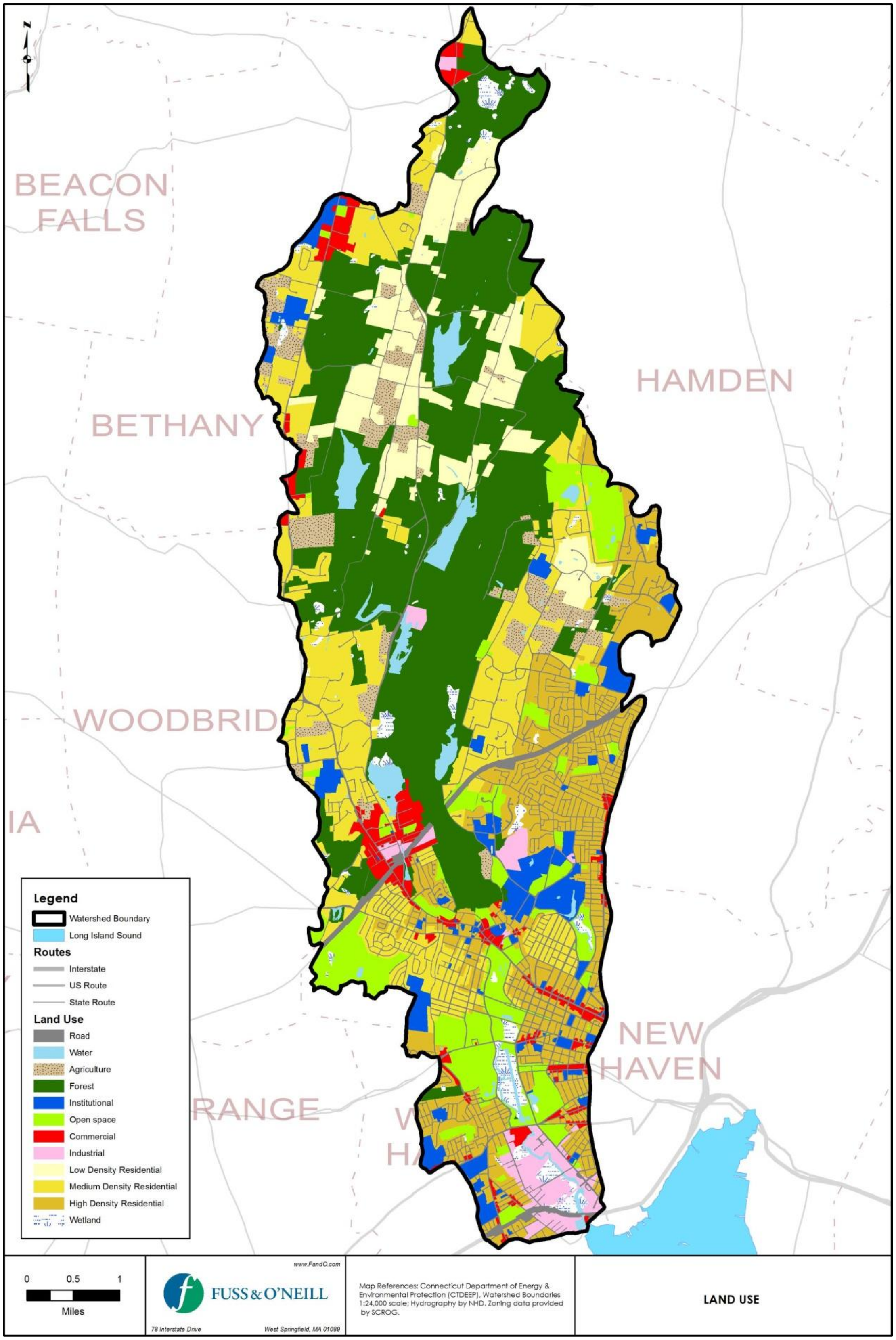

Figure 6-1. Land Use

The watershed is moderately developed overall with approximately 36% of the watershed consisting of residential areas, including low, medium, and high density residential land use. Approximately 20% of the watershed is made up of commercial, institutional, and industrial lands, and roadways. A substantial amount of green space exists in the central and northern parts of the watershed, with approximately 35% of the watershed as forested or open space. Forested areas include trails, protected space, and forest. The open space land use includes parks, playing fields, cemeteries, golf courses, and other turf and non-agricultural fields. Agricultural lands, which include agricultural fields, pasture land, and equestrian centers, make up 4.3% of the watershed. Another 5% of the watershed is comprised of lakes, estuaries, and wetlands. The density of development generally increases from north to south in the watershed, with the majority of the high-density residential, industrial, and commercial areas south of Route 15. Notable exceptions to this trend are the SCCRWA water treatment facility (industrial land use), which borders Lake Watrous and Lake Dawson in the center of the watershed, and the commercial area between Lily Pond and Konolds Pond.

6.2 Land Cover

Land cover differs from land use – it refers to what is present on the land surface, as opposed to what is permitted, practiced, or intended for a given area (University of Connecticut Center for Land Use Education and Research, 2012). *Figure 6-2* depicts land cover in the West River watershed, which was derived from 2010 Landsat satellite imagery with a ground resolution of 30 meters. The land cover data in the watershed are classified into eleven categories (*Table 6-2*), which are used in the Connecticut Land Cover Map Series and described following the table (University of Connecticut Center for Land Use Education and Research, 2012). *Table 6-2* shows that the distribution of land cover in the watershed has remained relatively consistent since 1985.

Table 6-2. Land Cover

Land Cover	1985		2001		Relative Change in Percent of Watershed	Change in Acres
	Percent of Watershed	Acres	Percent of Watershed	Acres		
Developed	29.3%	6,473	31.3%	6,907	2.0%	434
Turf & Grass	8.4%	1,857	9.3%	2,054	0.9%	197
Other Grasses	1.1%	241	1.0%	224	-0.1%	-17
Agricultural Field	4.0%	884	3.6%	784	-0.5%	-100
Deciduous Forest	45.8%	10,104	43.8%	9,676	-1.9%	-428
Coniferous Forest	4.3%	948	4.2%	929	-0.1%	-19
Water	3.2%	700	3.0%	654	-0.2%	-46
Non-forested Wetland	0.3%	60	0.3%	61	0.0%	1
Forested Wetland	2.0%	440	1.8%	405	-0.2%	-35
Tidal Wetland	0.5%	115	0.5%	110	0.0%	-6
Barren Land	0.6%	124	0.7%	146	0.1%	22
Utility Corridor	0.6%	130	0.6%	127	0.0%	-3

[1]Calculation = % land cover 2010 - % land cover 1985. Source: CLEAR, 2010.

The land cover types in *Table 6-2* have the following characteristics:

- Developed: High density built-up areas typically associated with commercial, industrial and residential activities and transportation routes. These areas contain a significant amount of impervious surfaces, roofs, roads, and other concrete and asphalt surfaces.
- Turf & Grass: A compound category of undifferentiated maintained grasses associated mostly with developed areas. This class contains cultivated lawns typical of residential neighborhoods, parks, cemeteries, golf courses, turf farms, and other maintained grassy areas. Also includes some agricultural fields due to similar spectral reflectance properties.
- Other Grasses: Includes non-maintained grassy areas commonly found along transportation routes and other developed areas, and within and surrounding airport properties. Also likely to include forested clear-cut areas, and some abandoned agricultural areas that appear to be undergoing conversion to woody scrub and shrub cover.
- Agriculture: Includes areas that are under agricultural uses such as crop production and/or active pasture. Also likely to include some abandoned agricultural areas that have not undergone conversion to woody vegetation.
- Deciduous Forest: Includes Southern New England mixed hardwood forests. Also includes scrub areas characterized by patches of dense woody vegetation. May include isolated low density residential areas.
- Coniferous Forest: Includes Southern New England mixed softwood forests. May include isolated low density residential areas.
- Water: Open waterbodies and watercourses with relatively deep water.
- Non-forested Wetland: Includes areas that predominantly are wet throughout most of the year and that have a detectable vegetative cover (therefore not open water). Also includes some small watercourses due to spectral characteristics of mixed pixels that include water and vegetation.
- Forested Wetland: Includes areas depicted as wetland, but with forested cover. Also includes some small watercourses due to spectral characteristics of mixed pixels that include both water and vegetation.
- Tidal Wetland: Emergent wetlands, wet throughout most of the year, with distinctive marsh vegetation and located in areas influenced by tidal change.
- Barren Land: Mostly non-agricultural areas free from vegetation, such as sand, sand and gravel operations, bare exposed rock, mines, and quarries. Also includes some urban areas where the composition of construction materials spectrally resembles more natural materials. Also includes some bare soil agricultural fields.
- Utility Corridor: Includes utility rights-of-way. This category was manually digitized on-screen from rights-of-way visible in the Landsat satellite imagery. The class was digitized within the deciduous and coniferous categories only.

Review of the earliest available aerial photography (1934) and more recent aerial photography (2012) (*Figure 6-3*) shows that the southern portion of the watershed (south of what is now Route 10) was heavily developed even by 1934. Densely populated residential areas are seen in the photograph, with increasing density approaching New Haven. The estuary channel had already been modified by 1934 and has the same straightened geometry seen today. Since 1934, there has been a significant decrease in farmland and an increase in forested areas. Much of the central and northern portion of the watershed consisted of agriculture land use in the 1930s, whereas today there are fewer farms, more residential and commercial development, and more forested land.

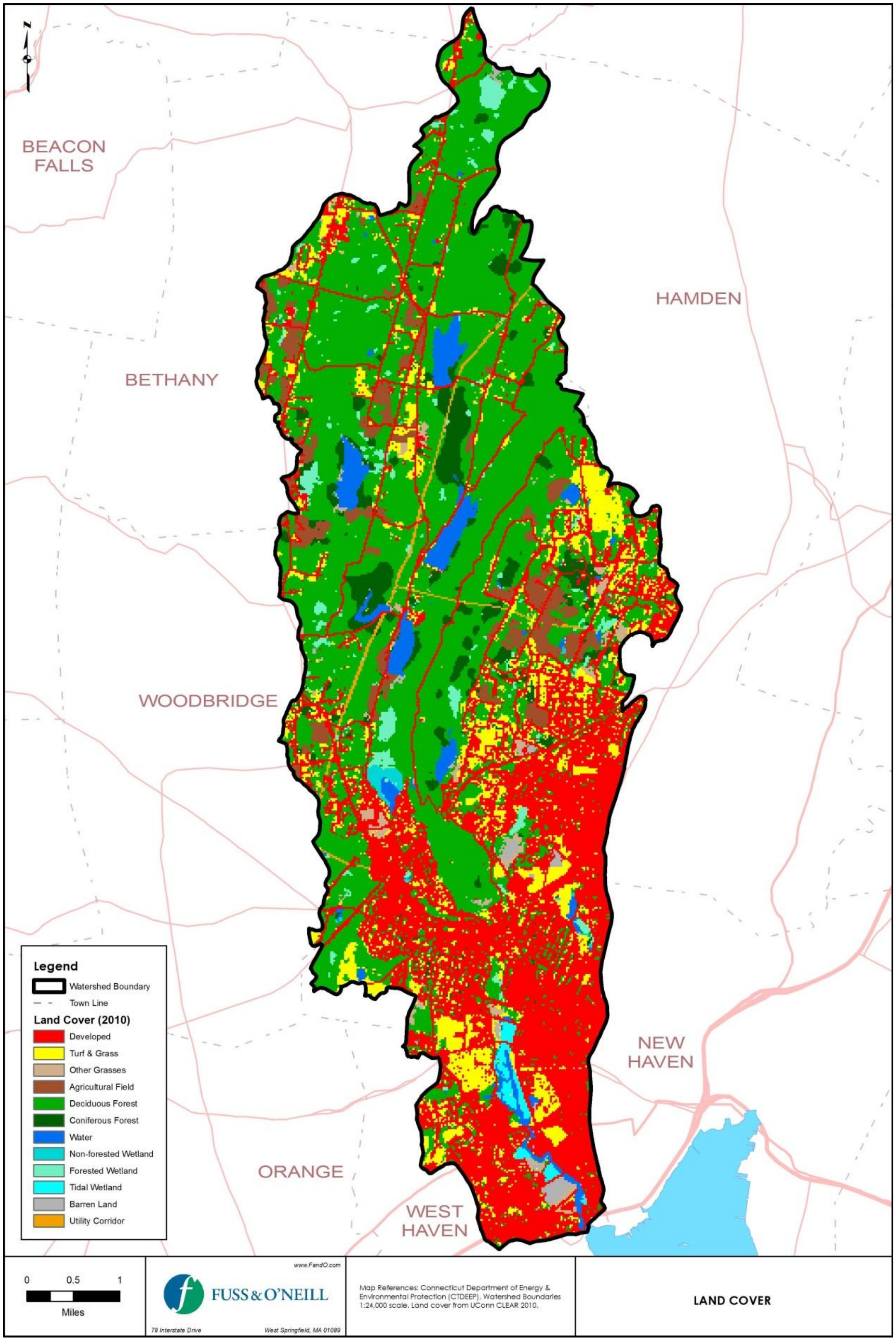

Figure 6-2. Land Cover

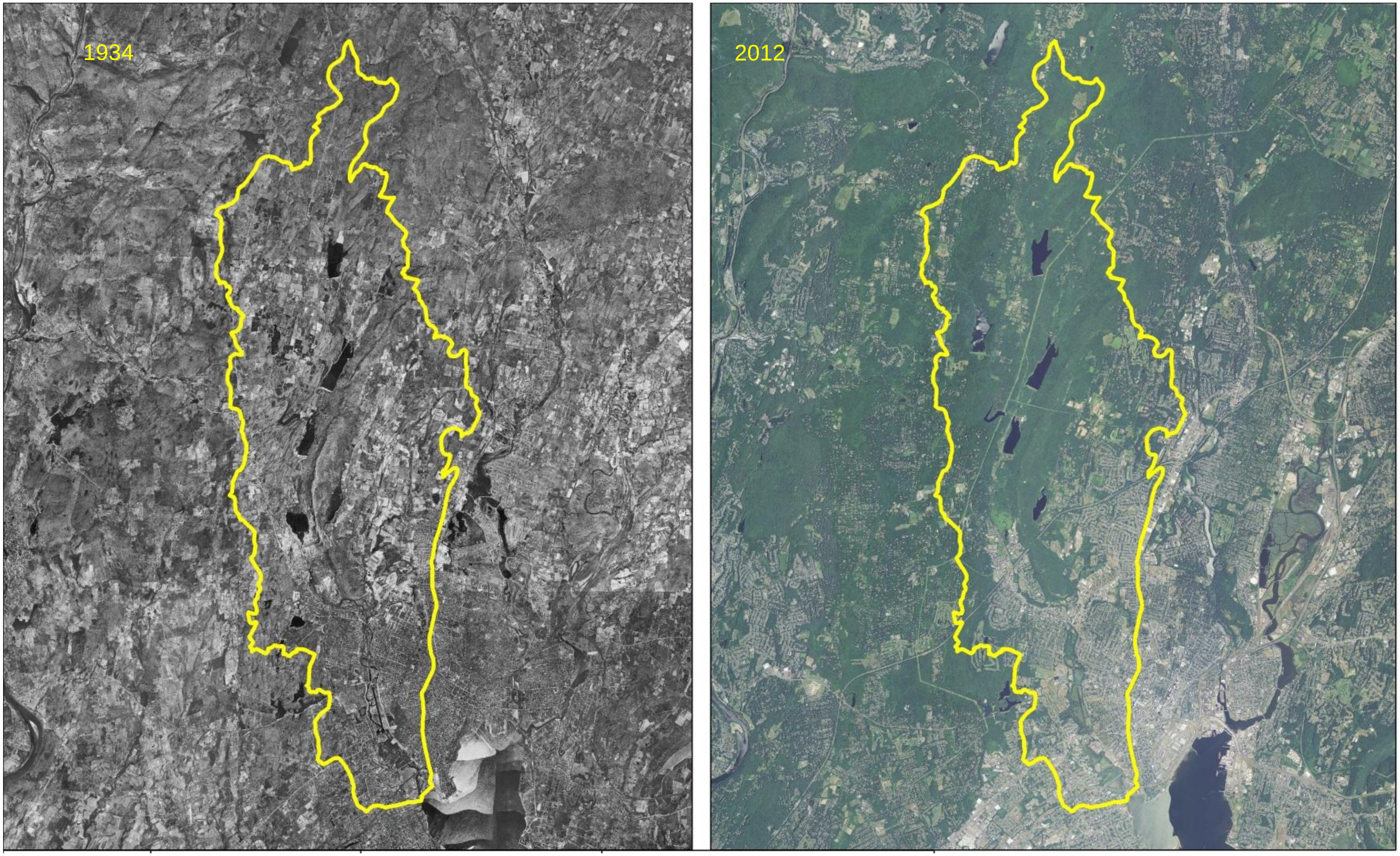

Figure 6-3. Aerial Photography Comparison (1934-2012)

6.3 Impervious Cover

Conversion of undeveloped land to impervious surfaces prevents precipitation from naturally soaking into the ground and introduce new pollutant sources, resulting in a variety of hydrologic and water quality changes in a watershed. Impervious cover is a measure of the amount of impervious surfaces covering the landscape and can be used to assess the ecological condition of a watershed. Numerous national studies have documented the cumulative effects of urbanization on stream and watershed ecology (Center for Watershed Protection, 2003; Schueler et al., 1992; Schueler, 1994; Schueler, 1995; Booth and Reinelt, 1993; Brant, 1999; Shaver and Maxted, 1996). Research has also demonstrated similar effects of urbanization and watershed impervious cover on downstream receiving waters such as lakes, reservoirs, estuaries, and coastal areas.

The link between land use, landscape alteration, and water quality in Connecticut has also been documented by CTDEEP, as measured by watershed impervious cover and biological assessments of streams across the state (Bellucci, 2007). In general, the higher the percentage of impervious cover within a watershed, the lower the water quality. Watersheds tend to exhibit evidence of ecological stress and water quality impacts when watershed impervious cover reaches between 10% and 25%. In Connecticut, this lower threshold has been estimated at around 12% impervious cover. Impervious cover between 25% and 60% reduces stream stability and leads to habitat loss, water quality degradation, and decreased biological diversity (NRDC, 1999). Watershed imperviousness in excess of 60% is generally indicative of watersheds with significant urban development.

The University of Connecticut Center for Land Use Education and Research (CLEAR) analyzed land 2010 cover data within the West River watershed to estimate the amount of impervious cover in local drainage areas in the basin. The results of this analysis are shown in *Figure 6-4*. The Lower West River subwatershed and the Beaver Brook subwatershed have high percentages of impervious cover (greater than 25%), as do the southern and eastern portions of the Wilmot Brook subwatershed. The Sargent River, Upper West River, Middle West River, and upper portion of the Wintergreen Brook subwatershed have the lowest percentages of impervious cover (less than 10%). All other areas have 10% to 20% impervious cover. All subwatersheds except Sargent River, Upper West River, and Middle West River have at least a portion of their area with a percentage of impervious cover that is indicative of ecological stress and water quality impacts. Based on 2010 land cover data, overall impervious cover in the West River watershed is estimated at 12%, which is at or near the typical threshold above which ecological impacts are typically observed.

The entire length of the impaired segment of the West River is surrounded by areas with over 15% impervious cover, and by some areas in the lower reaches of the impaired segment with over 25% impervious cover. The impaired lower segment of Wintergreen Brook also flows through areas with between 10 and 20% impervious cover and is located just downstream of Beaver Brook, which drains an area with impervious cover exceeding 25%.

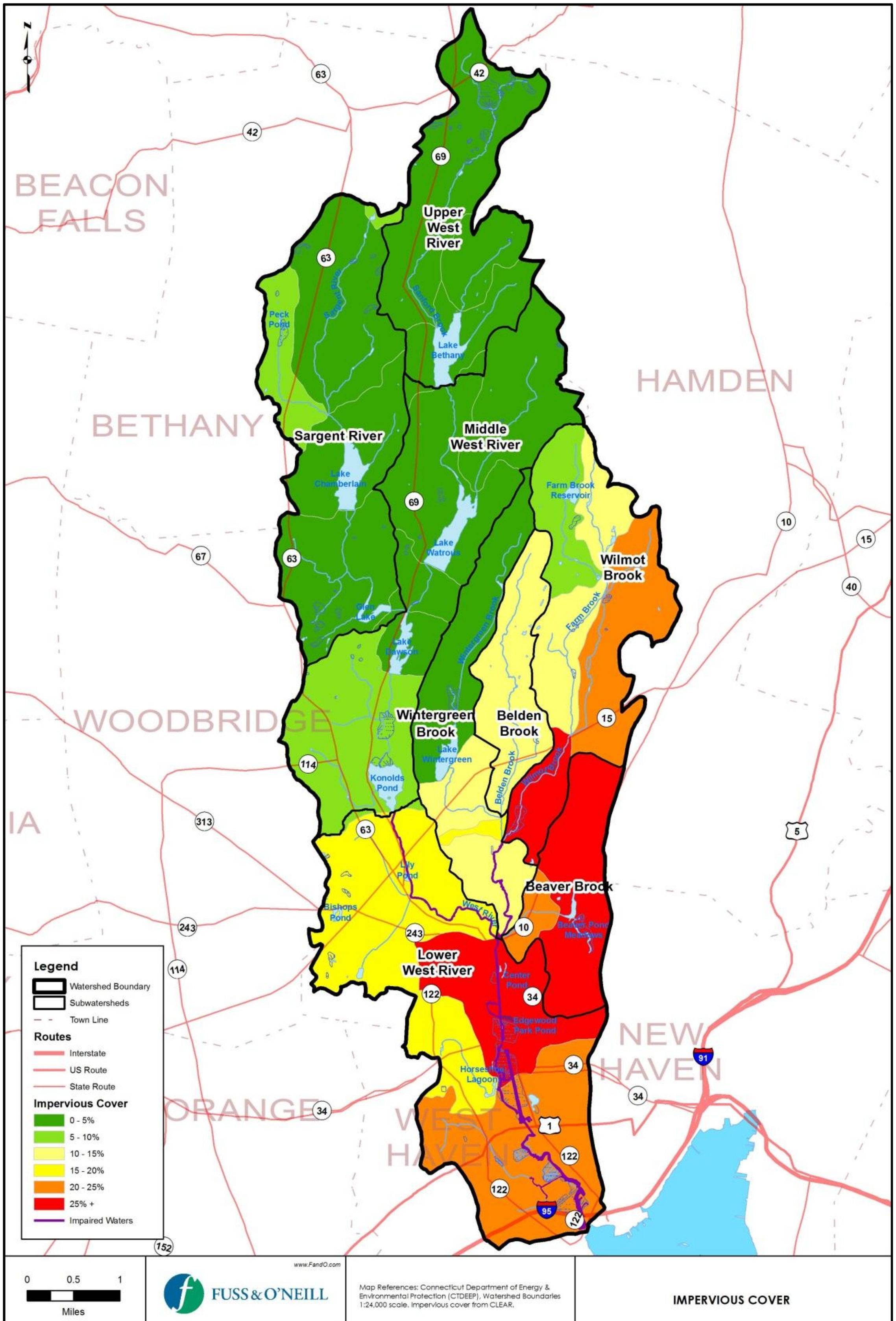

Figure 6-4. Watershed Impervious Cover

6.4 Open Space

Open space plays a critical role in protecting and preserving the health of a watershed by limiting development and impervious coverage, preserving natural pollutant attenuation characteristics, and supporting other planning objectives such as farmland preservation, community preservation, and passive recreation. Open space is also important as habitat for native and migratory species and protection of public water supply, both significant uses of open space in the West River watershed. Open space includes preserved natural areas as well as lightly developed parks, playgrounds, and cemeteries.

Active and passive open space areas in the West River watershed were identified based on GIS information provided by SCROG in addition to data compiled and published by CTDEEP, including federal land, state-owned property, and other municipal and privately-owned open space. *Figure 6-5* shows open space land in the West River watershed and identifies major open space parcels. The largest open space land includes:

- SCCRWA (4,211 acres)
- West Rock State Park (1,691 acres)
- The Course at Yale (700 acres, 272 in the watershed)
- West River Memorial Park (167 acres)
- Laurel View Country Club (162 acres)
- Edgewood Park (113 acres)
- Beaver Pond Park (107 acres)
- St. Lawrence Cemetery (94 acres)
- Evergreen Cemetery (86 acres)
- Yale Upper Playing Fields (71 acres)
- Beaverdale Memorial Park (43 acres)

Open space areas that have been the subject of study or the location of previous restoration efforts are described below.

West River Memorial Park

The approximately 167-acre West River Memorial Park is located near the West River in West Haven and New Haven. It connects to Edgewood Park to the north. It contains park land, an estuary, marshes, trails, sports fields and the Barnard Nature Center. The Nature Center holds educational programs and houses the park ranger office. The park is partnered with the nearby Barnard Environmental Magnet School. Three osprey platforms are located in the park, and all are active nesting sites (Barnard Nature Center, 2014). Other bird species that have been observed in West River Memorial Park include Great Egret, Black Crowned Night Heron, Great Blue Heron, King Fishers, wild turkeys, and osprey. White Tail Deer and muskrat can also be found in the park (SCROG, 2014).

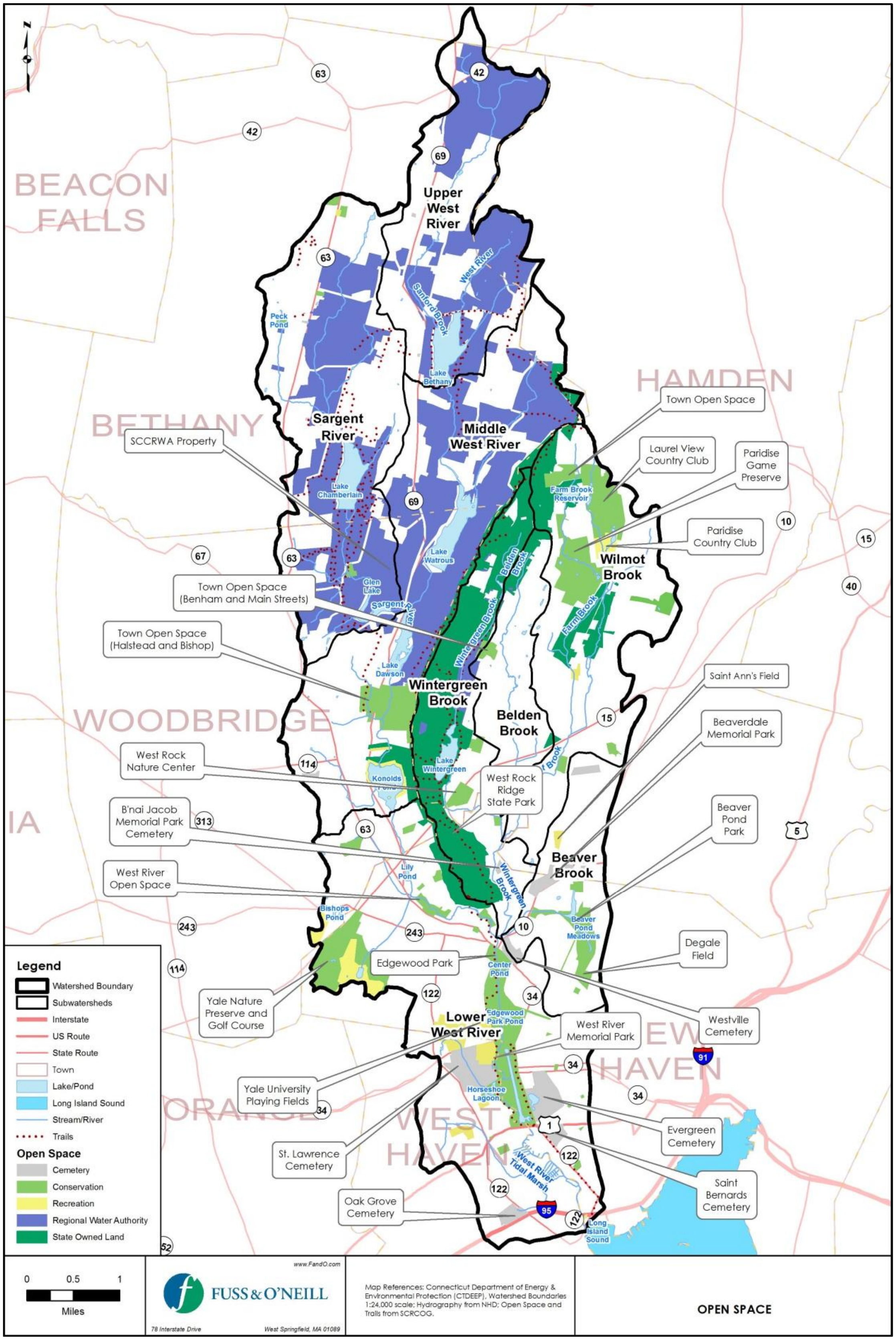

Figure 6-5. Open Space

A master plan for West River Memorial Park was developed in 1999 by Vollmer Associates. The master plan identified a number of issues including poorly maintained dirt trails; no formal parking, leading to illegal parking; use of the soccer fields; some fishing near the tide gates; and the presence of phragmites. The master plan indicated that the installation of tide gates had resulted in the loss of salt marsh. In 2002, a park restoration plan (Milone & MacBroom, 2002a) was developed to focus on natural resources and recreational aspects of the park, with goals that included controlling phragmites; recognizing tidal marsh restoration potential; providing new facilities (restrooms, ranger station, canoe launches); and improving recreational areas, including improvements to the soccer fields and constructing a park playground.

As of 2002, the City of New Haven decided to move forward with improvements to the soccer field, the creation of the playground, and tidal marsh restoration. The tidal marsh and channel restoration involved changes to the tide gate, allowing salt water exchange to occur and preventing stagnant waters in the estuary (Milone and MacBroom, 2002a). The salt marsh restoration is described in greater detail in *Section 4.3.2* of this report.

Edgewood Park

Edgewood Park is located north of West River Memorial Park. It consists of approximately 113 acres (SCROG, 2014) and connects to West Rock Ridge State Park to the north. Duck Pond, located in Edgewood Park and referred to as "Edgewood Park Pond" in the 2012 TMDL, is impaired for recreational uses due to elevated bacteria concentrations. The park is also home to Iris Pond, Center Pond, Long Pond, Lily Pond, and Edgewood Avenue Pond, recreational trails, a dog run, and sports fields.

A *Management Plan for Edgewood Park* was developed by the Yale School of Forestry and Environmental Studies (Brower et al., 1999). The management recommendations in the plan included improvements to the park trails and signage, designating a wetland preserve, maintaining natural meadows within the park and minimizing erosion. In this study, water quality in Duck Pond was found to be degraded, with bank erosion and stormwater discharges from Edgewood Avenue as likely causes.

The New Haven Department of Parks, Recreation, and Trees has been improving the park by blazing trails, installing trail signage, and creating and making available online the Edgewood Park Map. They have also been performing trail work, conducting clean-ups, and have removed the greenbrier along the rhododendron trail (Harry Coyle, Park Ranger, City of New Haven-Department of Parks, Recreation & Trees, personal communication, November 17, 2014).

Friends of Edgewood Park is a volunteer organization that works with local police and park rangers to preserve the park and foster community involvement. Clean-up and maintenance events, such as weeding, mulching, and removing invasive plants, are held frequently in the warmer months. Friends of Edgewood Park has also held a program called Youth at Work in 2013 and 2014, where student interns aid in the maintenance of the park and trails. Their website hosts a SeeClickFix map where visitors can pinpoint and identify maintenance, environmental, or safety issues in or around the park on an interactive map to aid in the maintenance of the park (Friends of Edgewood Park, 2014).

Beaver Pond Park

Owned by the City of New Haven, Beaver Pond Park is approximately 107 acres and contains athletic fields (including Bowen Field) and an approximately 86-acre wetland and pond system that consists of two distinct ponds with dense shoreline vegetation, a red maple swamp, the Sherman Forest, and two small cattail marshes. Southern Connecticut State University abuts the ponds. The ponds receive stormwater from an urban watershed of 1,200 acres (Bates et al., 2007). Although recreation is the primary use of the park, the Friends of Beaver Pond Park is a community group that is interested in preserving and enhancing the pond areas for recreational uses (Bates et al., 2007).

The *Management Plan for Beaver Pond Park* (Bates et al., 2007) developed recommendations for the park including:

- Install catchment basins at stormwater inlet drains
- Consider managing the dam on Wintergreen Brook to control water levels in the ponds
- Apply for the State of Connecticut's Phragmites removal program
- Undertake a targeted plan for the removal of specific invasive species
- Advocate for the relocation of the firing range
- Construct a trail circumnavigating the pond/wetland area
- Create a simple structure for the Friends of Beaver Pond Park that divides well-defined responsibilities between specific group members.

A trash study was conducted in 2009. The study found that residential waste including plastic bags, bottles, cigarette butts, food wrappers, etc. from the areas surrounding Beaver Pond Park are improperly discarded and are transported by the stormwater system into the pond (DTC, 2009). The study recommended several structural practices (including debris collection units to retrofit existing catch basin inlets) and non-structural practices (include street sweeping, public education campaigns, and pond clean-up programs) to address the problem.

Recent activities of the Friends include advocating for the firing range to be moved, for which the Mayor of New Haven is in favor and is seeking funding, and securing funds to construct a nature trail along the pond with educational signage (Nan Bartow, Friends of Beaver Ponds Park, President, personal communication, November 18, 2014).

West Rock Ridge State Park

West Rock Ridge State Park (WRRSP) is a 1,691-acre state park located in New Haven, Hamden, and Woodbridge. The park encompasses West Rock Ridge, which forms the boundary between the towns of Woodbridge and Hamden. It is bordered by Konolds Pond, Lake Dawson, and Lake Watrous on its western side and by Lake Wintergreen to the east. West Rock Ridge State Park is part of a larger area of protected open space including state, municipal, and non-profit owned land. Biodiversity of the park includes an estimated 230 species of birds, attributed to its unique location of a high altitude near lowlands, and its proximity to salt and fresh water. Peregrine falcons have recently begun nesting and breeding on the rock ridge (West Rock Ridge Park Association, 2014). There are also nesting colonies of Great Blue Herons and ravens. The ridge top is important habitat for migrating birds, including cuckoos, flycatchers, vireos, swallows, wood warblers, and orioles (West Rock Ridge Park Association, 2013).

While the park is maintained by the state, volunteer groups also help maintain the park. The West Rock Ridge Park Association is a volunteer organization originally formed to stop development on the ridge and to preserve the area as a state park. Today, they maintain Regicides Trail, which runs along the ridge crest, and perform periodic bird counts at the ridge to record species that inhabit the area.

SCCRWA-Owned Land

The South Central Connecticut Regional Water Authority (SCCRWA or RWA) is a non-profit public corporation that supplies much of the drinking water in the West River watershed (See *Section 5.2)*. SCCRWA owns approximately 4,211 acres within the watershed, including (SCROG, 2014):

- 1,469 acres in the Middle West River subwatershed
- 1,519 acres in the Sargent River subwatershed
- 1,223 acres in the Upper West River subwatershed.

The SCCRWA source water protection program focuses on pollution prevention and watershed management. SCCRWA is active in securing watershed land for protection, and owns over 27,000 acres of land in total (including land outside of the West River watershed). The SCCRWA monitors land use and proposed development activities on public water supply watershed and aquifer lands, and often recommends implementation of stormwater management controls for development projects on privately-owned land as well as stormwater management practices for existing SCCRWA-owned land. SCCRWA also inspects business, residential, and construction sites annually to identify potential sources of pollution. SCCRWA supports state legislation that protects water quality such as the CTDEEP's efforts to adopt regulations for the protection of Connecticut's public water supply aquifers (SCCRWA, 2014).

SCCRWA's 30-year old recreation program is a fee-based (i.e., permit) program that promotes public access to the Regional Water Authority watershed lands for hiking, fishing, bicycling, horseback riding, cross-country skiing, and special events. SCCRWA recreation areas in or near the West River watershed include the Lake Chamberlain Recreation Area, Lake Bethany Recreation Area, and Maltby Lakes Recreation Area.

Yale University Athletic Fields

Yale University athletic fields are located to the south and west of the Yale Bowl in the Lower West River subwatershed. They include Yale Field, Dewitt Family Field, and Johnson Fields, which are athletic fields for various Yale teams. They consist of 71 acres of primarily of open, managed turf.

Golf Courses

Golf courses in the watershed include the Laurel View Country Club (162 acres) in Hamden in the Wilmot Brook subwatershed and The Course at Yale in New Haven in the Lower West River subwatershed. Originally marshland and forest, The Course at Yale is 700 acres, of which approximately 272 acres are located within the West River watershed. Cross country running trails are also located near The Course at Yale and the Maltby Lakes Recreation Area.

Cemeteries

Cemeteries make up a substantial amount of open space (approximately 287 acres) in the southern half of the watershed. The largest include:

- St. Lawrence Cemetery (approximately 94 acres)
- Evergreen Cemetery (approximately 86 acres)
- St. Bernards Cemetery (approximately 27 acres)
- Oak Grove Cemetery (approximately 21 acres)
- Beaverdale Memorial Park (approximately 43 acres)

7 Watershed Pollutant Loads

A pollutant load is the amount or mass of a given pollutant within or delivered to a water body over a period of time. Estimation of pollutant loads from a watershed provides insight into the relative contributions of different land uses and land use practices and is a key element of the EPA watershed-based planning process. Pollutant load estimation using simulation models typically involves a screening-level analysis to help identify and rank pollutant sources, as well as to assist in identifying, prioritizing, and evaluating subwatershed pollutant control strategies. It is not meant to provide predictions of future water quality.

Pollutant loads were estimated for the West River watershed. The pollutant load estimation methods and results are described below.

7.1 Model Description

The Watershed Treatment Model (WTM), Version June, 2013, developed by the Center for Watershed Protection, was used to estimate existing pollutant loads for the West River watershed. The model calculates annual watershed pollutant loads primarily based on nonpoint source (NPS) runoff from various land uses. It also calculates pollutant loads and reductions from other sources such as combined sewer overflows (CSOs), illicit connections, marinas, subsurface disposal systems (septic systems), road sanding, livestock, and stream channel erosion. A model of existing conditions was developed for the West River watershed based on the land use data described in *Section 6* and other information on watershed conditions and management practices. Loads were also estimated for each of the study subwatersheds.

Developed land uses that were represented in the model include commercial, residential, roadway, industrial, institutional, and agricultural uses. Other modeled land uses include open space/recreational areas, wetlands, and open water.

In addition to primary land uses, the model was also used to estimate loads from other pollutant sources within the watershed, including:

- Combined Sewer Overflows (CSOs)
- Illicit sewer connections
- Livestock and hobby farms
- Subsurface sewage disposal systems (SSDSs)
- Road sanding
- Marinas
- Stream channel erosion

Load reductions were estimated for street sweeping, catch basin cleaning, marina pumpouts, and riparian buffers, which tend to reduce the amount of pollutants that reach receiving water bodies.

The modeled pollutants include total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS), and fecal coliform bacteria (FC). These pollutants, particularly fecal indicator bacteria, are the major nonpoint source pollutants of concern for the West River watershed .

7.2 Model Inputs

7.2.1 Land Use Nonpoint Source Runoff

Land use data described in *Section 6.1* were adapted for use in WTM. The basis of WTM is a pollutant loading calculation developed by Schueler (1987), called the Simple Method, which calculates nutrient, sediment, and bacteria loads from various land uses. The user specifies several model parameters for each land use type in the watershed, and these parameters are used to estimate runoff quantity and pollutant loads. These parameters include event mean concentrations (EMCs), which are values of the mean concentration of a pollutant in stormwater runoff for each land use type, and an average impervious cover percentage for each land use. A literature review was conducted to determine EMC values and impervious cover percentages for use in the model. Impervious cover coefficients for each land use category were selected from WTM default impervious cover coefficients and literature values to reflect local conditions. EMC and impervious cover coefficient values used for the existing conditions model of the West River watershed are included in *Appendix A*. Average annual precipitation for the watershed (47 inches) was based on data from the NOAA National Climatic Data Center for New Haven between 1981 and 2010.

7.2.2 Other Pollutant Sources and Reductions

Combined Sewer Overflows (CSOs)

The CSO locations within the Lower West River subwatershed are described in *Section 5.3*. CSO discharge volumes from the recently updated hydraulic model of the City's combined sewer system were used in the pollutant loading model, along with pollutant concentrations reported in the City of New Haven Long-Term CSO Control Plan Technical Memorandum #6: Hydraulic Characterization Report (CH2MHILL, 2000), which are based on CSO water quality data from other medium-sized cities in New England with similar land use.

Subsurface Waste Disposal Systems

While most of the West River watershed is served by sanitary sewers, the Upper West River subwatershed and Sargent River subwatershed are unsewered. The Middle West River subwatershed is partially sewered. Unsewered areas in the West River watershed rely on subsurface sewage disposal systems (SSDs) (i.e., septic systems). An estimated average failure rate of 10% (Caraco, 2013) was assumed for existing septic systems in the watershed.

Illicit Connections

Illicit connections to the storm drainage system (including leaks or connections from sanitary sewers) or to surface waters were estimated as 0.1% of all residential and 10% of business connections (Johnson, 1999). Pollutant concentrations associated with illicit connections were assumed to be typical of raw sewage (EPA, 1980).

Road Sanding

The Connecticut Department of Transportation (CTDOT) maintains state roads without the use of sand. CTDOT switched from a winter highway treatment program using a combination of sand and salt to one using liquid chemicals and salt in 2006 (Frisman, 2014). Local roads are maintained by the municipalities within the watershed. Woodbridge, Hamden, and New Haven use a combination of sand and salt as deicing agents for local roads. A 50/50 sand/salt mix was assumed in the model, with application rates of 5 tons of mix per lane-mile annually (NRC, 1991).

Stream Channel Erosion

WTM estimates stream bank erosion based on stream channel stability. Stream channels within the watershed were modeled as having moderate bank stability, with channels showing some evidence of erosion and degradation, which is common in urban watersheds. Sediment nutrient concentrations were based on literature values of soil nutrient levels in the Northeast (Haith et. al, 1992).

Livestock

In the northern part of the watershed, there are several small farms that raise dairy cows and chickens, as well as several equine (i.e., horse) facilities. The livestock population was estimated based on aerial photography, which may slightly underestimate actual livestock numbers in the watershed. WTM default values were used for nutrient loading from livestock.

Note that pollutant loads from domestic animals and wildlife, which are potentially significant sources of bacteria and nutrients to the West River given the large amount of residential land use, open space, and parkland in the watershed, are accounted for in the modeled land use pollutant export coefficients.

Catch Basin Cleaning

Annual catch basin cleaning was assumed throughout the watershed, based on information provided by several of the watershed communities including Woodbridge and New Haven. Catch basin capture area was based on the acreage of impervious surfaces within the watershed as calculated by the model and the percentage of the subwatershed serviced by storm sewers, with a minimum of 50% of impervious area captured.

Street Sweeping

The watershed municipalities generally perform annual street sweeping in the spring after the winter deicing season. Annual street sweeping was assumed in the model. Mechanical sweepers and parking restrictions were also assumed.

Riparian Buffers

The effects of riparian buffers on pollutant load reduction are calculated within the model based on the area of natural land between developed land (residential, commercial, industrial, roadway, etc.) and the stream in each subwatershed. The areas of riparian buffers were estimated from GIS-processed land cover data.

Marinas and Pump-outs

Two marinas are located in the estuary portion of the West River. Their combined berths (270) were estimated from aerial photography. They are serviced by two pump-out stations. Usage of pump-out stations was assumed to be 90%.

7.3 Existing Pollutant Loads

Table 4-1 presents the existing modeled pollutant loads for the West River watershed for each pollutant source. Before load reductions are applied, nonpoint source runoff associated with land use alone accounts for approximately 92% of the total nitrogen (TN) load, 73% of the total phosphorus (TP) load, 46% of the total suspended solids (TSS) load, and 43% of the fecal coliform (FC) load for the entire watershed. The greatest land use TN loading is from residential areas and roadways, and land use TP loading is primarily from high density residential areas and roads. Roadways generate the greatest TSS load, although high and medium density residential areas are also substantial contributors to the modeled TSS load. Residential areas are the greatest contributors to FC loads, particularly high and medium density residential areas.

Of the other pollutant sources discussed in *Section 7.2*, estimated illicit connections and CSOs are the greatest contributors of FC loading in the watershed. Illicit connections and CSOs account for 29% and 19% of the modeled FC load, respectively.[12] Channel erosion accounts for 5.7% of the modeled TN load, 22.3% of the modeled TP load and 45.5% of the modeled TSS load. Road sanding contributes 8.6% of the modeled TSS load in the watershed.

Riparian buffers are estimated to reduce TN loads in the watershed by 8.8%, TP loads by 12.4%, TSS loads by 8.1%, and FC loads by 11.2%. They also reduce the modeled annual runoff volume by 6.5%. Catch basin cleaning is estimated to reduce TN loads by 1.9 %, TP loads by 3.0%, and TSS loads by 8.3%.

Table 7-1. Annual Pollutant Loads and Yields by Subwatershed

Subwatershed	TN tons	TP tons	TSS tons	FC CFU x 10^{12}	Runoff Volume 1000 acre-feet	TN lb/acre	TP lb/acre	TSS lb/acre	FC CFU x 10^9/acre	Runoff Depth feet
Beaver Brook	15.1	2.1	742	294	12.4	24.0	3.3	1,176	233	9.86
Belden Brook	7.6	0.6	366	83	0.9	15.9	1.3	771	87	0.91
Lower West River	50.6	6.7	2,123	1,373	6.9	20.3	2.7	851	275	1.37
Middle West River	23.5	1.9	979	237	3.1	11.4	0.9	476	57	0.75
Sargent River	17.0	1.3	683	142	2.3	9.3	0.7	374	39	0.62
Upper West River	8.6	0.7	322	78	1.1	6.7	0.6	250	30	0.43
Wilmot Brook	26.6	3.2	1,111	278	2.8	19.5	2.4	816	102	1.04
Wintergreen Brook	6.6	0.8	339	83	1.0	7.3	0.9	377	46	0.57
Total	155.6	17.3	6,665	2,568	30.5					

[12] The modeled fecal coliform bacteria loads from CSOs are based on CSO discharge volumes predicted by the GNHWPCA's updated hydraulic model, which assumes implementation of proposed improvements to the Truman Storage Tank.

Because the study subwatersheds vary in size, pollutant loads were also evaluated in terms of pollutant yield (i.e., pollutant load per acre of land area), as shown in *Table 7-1*. *Figures 7-1* through *7-4* depict the variability in pollutant yields among subwatersheds. A higher yield indicates relatively greater pollutant sources per unit area. Below are subwatersheds identified as having high pollutant loads and/or yields, and the major contributing sources within those subwatersheds:

- Beaver Brook Subwatershed – The Beaver Brook subwatershed is the second smallest subwatershed but has the highest annual yield for TN, TP, and TSS. It also has the largest runoff depth, and contributes the second highest FC load and the third highest for TP load. The Beaver Brook subwatershed is highly urbanized, with 37% of its land use as high density residential. Institutional land use and roadways make up another 17% and 18% respectively. Illicit connections are the highest contributors to FC loads, while channel erosion is the greatest contributor to TSS. Nutrient loading is primarily from land use, particularly residential areas and roadways.

- Lower West River Subwatershed – The Lower West River subwatershed is the largest of the subwatersheds in this study. It contributes the greatest loads of all modeled pollutants, and is the subwatershed with the second highest runoff volume. It has the second highest runoff depth, and the highest FC yield, due in large part to the CSOs located in this subwatershed, which make up approximately 35% of the FC load, and estimated illicit connections which make up 34%. Marinas also contribute to FC loads in the lower portion of this subwatershed.. This urbanized subwatershed has high nutrient loadings, with approximately 21% of the land area consisting of high density residential areas and 15% consisting of roadways. Channel erosion and high density residential land use contribute significant TSS loads.

- Wilmot Brook Subwatershed – The Wilmot Brook subwatershed contributes the second highest loads of TN, TP, and TSS, and the third highest FC load. It has the third highest TSS, FC, and nutrient yields, and the third highest runoff depth. It is moderately sized compared to the other subwatersheds in the West River watershed. It is highly urbanized, with 38% of the land use being high density residential. Low and medium residential areas together constitute nearly 24% of the remaining land, with roadways making up another 11%. Major contributors to FC loads are estimated illicit connections and residential areas, while channel erosion contributes most to TSS. High and medium density residential areas and roadways are the greatest contributors to nutrient loads in this subwatershed.

The model results confirm that CSOs are a significant source of fecal indicator bacteria in the lower West River, and that continued reductions of bacteria loading from this source will have a positive impact on the bacterial impairment in the river. Land use and other pollutant sources such as channel erosion and illicit connections are also significant contributors of pollutants to the lower portion of the West River and the Wintergreen Brook system. The southern portions of the watershed are heavily urbanized, while the northern portions are more rural. Subwatershed pollutant yields generally increase from north to south, which corresponds to the locations of the impaired river segments where monitoring data is available. In general, high density residential land use found in the southern subwatersheds correlates with higher pollutant loadings.

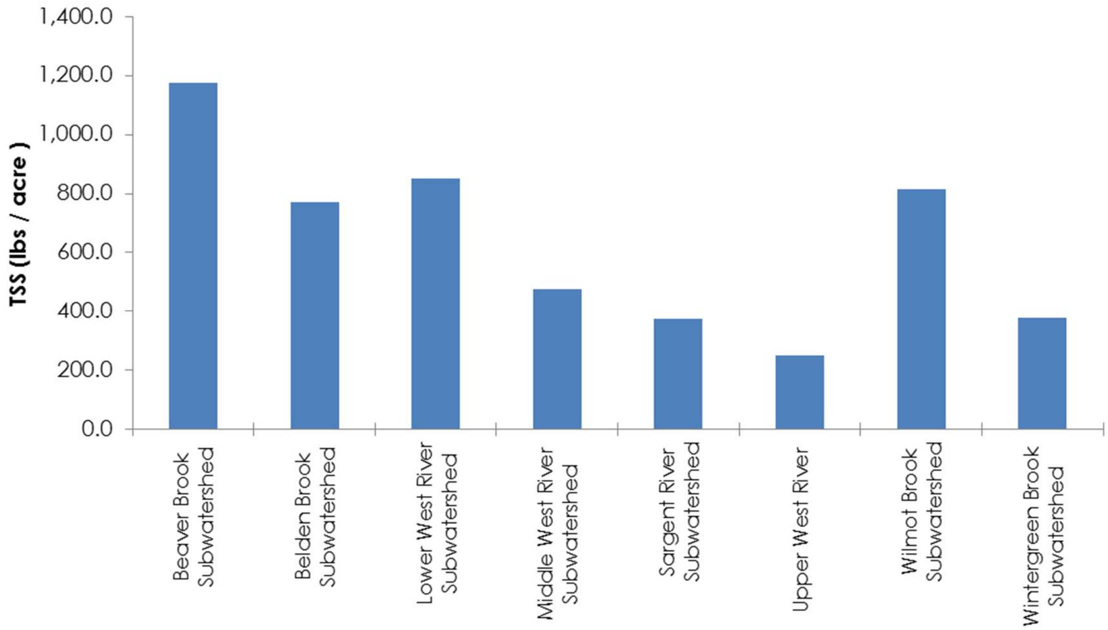

Figure 7-1. Annual TSS Yield by Subwatershed

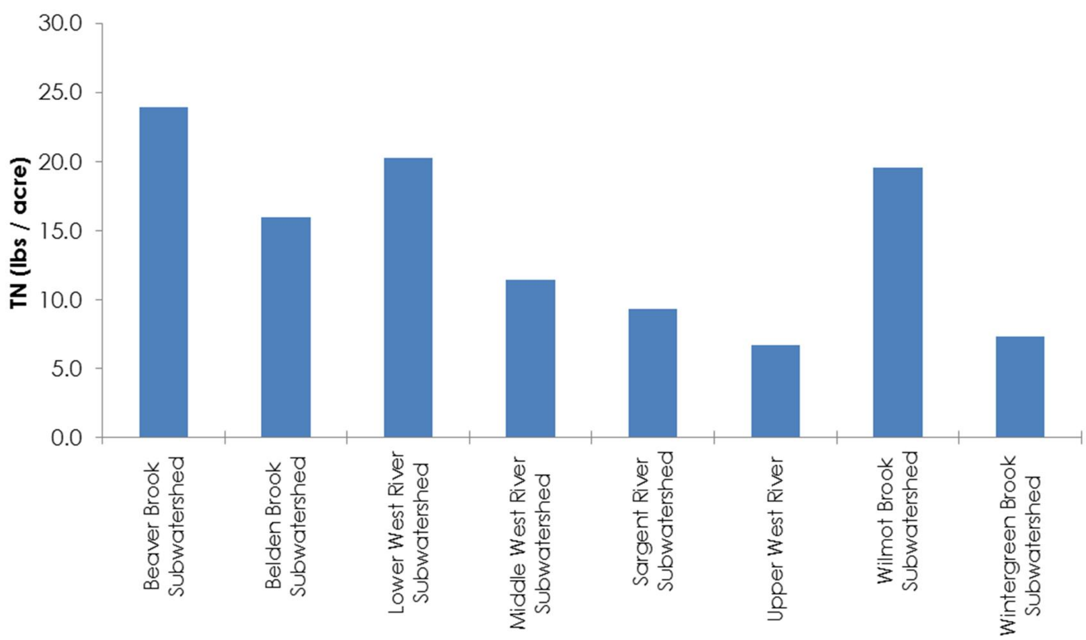

Figure 7-2. Annual TN Yield by Subwatershed

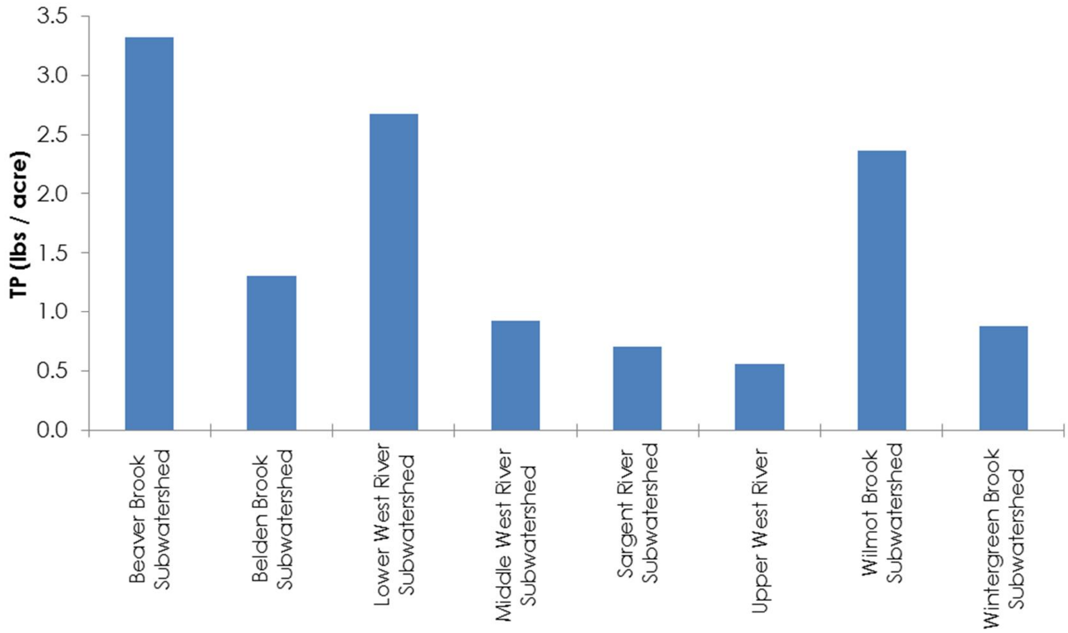

Figure 7-3. Annual TP Yield by Subwatershed

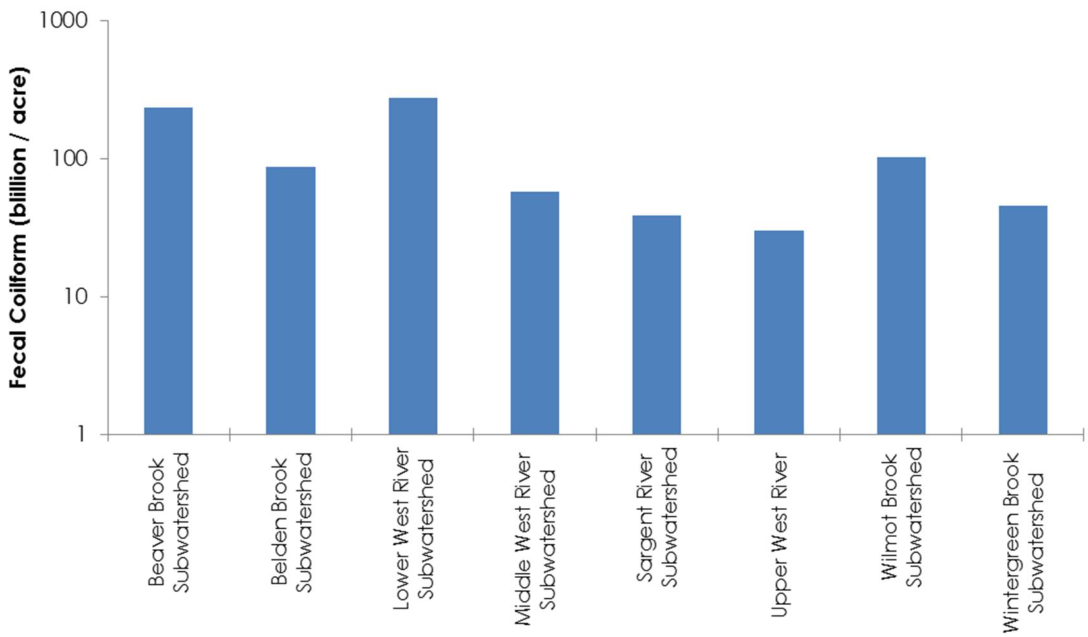

Figure 7-4. Annual FC Yield by Subwatershed

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Appendix A

Pollutant Loading Model

Table A-1. Impervious Cover Coefficients for Modeled Land Uses

Land Use	Impervious Cover Coefficients				
	New York State Stormwater Design Manual	Sleavin et al. (2000)	Prisloe et al. (2003)	WTM (2013)	Selected
Low Density Residential	0.11-0.14	0.08 - 0.14	0.088-.26	0.12	0.1
Medium Density Residential	0.14 - 0.21	0.16- 0.21	0.29	0.21	0.21
High Density Residential	0.28 -0.44	0.21 - 0.39	0.38	0.33-0.44	0.33
Agriculture	0.02	0.022 - 0.045	0.003 - 0.037	-	0.03
Commercial	0.70 -0.74	0.54	0.26 - 0.56	0.72	0.7
Forest	-	0.01 - 0.068	0.007 - 0.197	-	0.01
Institutional	0.31 - 0.38	-	-	-	0.34
Industrial	0.50 - 0.56	0.53	0.32	0.53	0.4
Open Space	0.09	0.050 - 0.094	0.036 - 0.056	-	0.05
Roadway	-	0.433	0.088-.26	0.8	0.8
Water	-	-	-	-	0
Wetland	-	-	-	-	0

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Table A-2. Runoff Event Mean Concentrations (EMCs) for Modeled Land Uses

Source	NH Stormwater Manual			PLOAD/ CH2M HILL	NY State Stormwater Design Manual				WTM Defaults				Selected			
Pollutant	TN	TP	TSS	FC	TN	TP	TSS	FC	TN	TP	TSS	FC	TN	TP	TSS	FC
Units	mg/L	mg/L	mg/L	#/ 100 ml	mg/L	mg/L	mg/L	#/ 100 ml	as noted	as noted	as noted	as noted	mg/L	mg /L	mg /L	MPN/ 100 ml
Low Density Residential	5.15	0.52	85	8700	1.5 - 9.1	0.11 - 2.1	1.5 - 602	2.6 - 18	2.1 mg/L	0.31 mg/L	49 mg/L	20000 MPN/100 ml	5	0.5	50	8700
Medium Density Residential	5.15	0.52	85	8700	1.5 - 9.1	0.11 - 2.1	1.5 - 602	2.6 - 18	2.1 mg/L	0.31 mg/L	50 mg/L	20000 MPN/100 ml	7	0.11	100	8700
High Density Residential	5.15	0.52	85	8700	1.5 - 9.1	0.11 - 2.1	1.5 - 602	2.6 - 18	2.1 mg/L	0.31 mg/L	51 mg/L	20000 MPN/100 ml	9	1	120	8700
Agriculture	5.98	0.37	145	-	-	-	-	-	-	-	-	-	5.98	0.37	145	800
Commercial	2.97	0.33	77	1400	2.1 - 27	0.14 - 0.15	1.9 - 9	11 - 18	2.1 mg/L	0.31 mg/L	43 mg/L	20000 MPN/100 ml	3	0.2	80	1400
Forest	1.78	0.11	51	500	-	-	-	-	2.5 lbs/acre	0.2 lbs/ acre	100 lbs/acre	100 billion/ acre	1.78	0.11	51	500
Institutional	2.97	0.33	77	1400	-	-	-	-	-	-	-	-	3	0.5	85	1400
Industrial	3.97	0.32	149	2300	-	-	17-228	27 - 58	2.2 mg/L	0.25 mg/L	81 mg/L	20000 MPN/100 ml	4	0.3	150	2300
Open Space	1.74	0.11	51	500	0- 9.1	0 - 2.1	37-602	240 - 940	-	-	-	-	5	1	50	500
Roadway	2.65	0.43	141	1400	1.4 - 22	0- 0.55	51-468	120 - 370	2.3 mg/L	0.25 mg/L	81 mg/L	20000 MPN/100 ml	2.7	0.4	150	1400
Water	1.38	0.08	6	500	-	-	-	-	12.8 lbs/acre	0.5 lbs/ acre	155 mg/L	-	1.38	0.08	6	500
Wetland	1.38	0.08	6	500	-	-	-	-	-	-	-	-	1.3	0.2	22	500

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PLOAD version 3.0 An ArcView GIS Tool to Calculate Nonpoint Sources of Pollution in Watershed and Stormwater Projects User's Manual. Accessed at http://water.epa.gov/scitech/datait/models/basins/upload/2002_05_10_BASINS_b3docs_PLOAD_v3.pdf

Table A-3. Existing Land Use Composition by Subwatershed in Acres

Subwatershed	Agriculture	Commercial	Forest	High Density Residential	Industrial	Institutional	Low Density Residential	Medium Density Residential	Open Space	Road	Water	Wetland
Beaver Brook Subwatershed (1261 acres)	0	57	0	468	6	214	0	110	149	229	13	15
Belden Brook Subwatershed (950 acres)	108	0	67	142	0	21	0	433	63	110	3	3
Lower West River Subwatershed (4993 acres)	7	355	280	1073	343	290	0	601	998	762	101	185
Middle West River Subwatershed (4118 acres)	149	25	1529	5	441	61	536	905	21	156	238	52
Sargent River Subwatershed (3656 acres)	413	142	1565	0	0	119	402	711	15	118	126	44
Upper West River (2579 acres)	88	48	1338	0	17	0	592	225	2	84	106	80
Wilmot Brook Subwatershed (2724 acres)	160	0	209	1025	15	138	171	313	336	298	26	32
Wintergreen Brook Subwatershed (1795 acres)	15	3	1137	64	50	159	0	137	80	83	46	19
Total (Watershed)	940	630	6125	2777	872	1002	1701	3436	1665	1840	659	430

Table A-4. Existing Land Use Composition Percentages

Subwatershed	Agriculture	Commercial	Forest	High Density Residential	Industrial	Institutional	Low Density Residential	Medium Density Residential	Open Space	Road	Water	Wetland
Beaver Brook Subwatershed (1261 acres)	0%	4%	0%	37%	1%	17%	0%	9%	12%	18%	1%	1%
Belden Brook Subwatershed (950 acres)	11%	0%	7%	15%	0%	2%	0%	46%	7%	12%	0%	0%
Lower West River Subwatershed (4993 acres)	0%	7%	6%	21%	7%	6%	0%	12%	20%	15%	2%	4%
Middle West River Subwatershed (4118 acres)	3%	1%	37%	0%	11%	1%	13%	22%	1%	4%	6%	1%
Sargent River Subwatershed (3656 acres)	11%	4%	43%	0%	0%	3%	11%	19%	0%	3%	3%	1%
Upper West River (2579 acres)	3%	2%	52%	0%	1%	0%	23%	9%	0%	3%	4%	3%
Wilmot Brook Subwatershed (2724 acres)	6%	0%	8%	38%	1%	5%	6%	11%	12%	11%	1%	1%
Wintergreen Brook Subwatershed (1795 acres)	1%	0%	63%	4%	3%	9%	0%	8%	4%	5%	2%	1%
Total (Watershed)	4%	3%	28%	12%	4%	5%	8%	16%	7%	8%	3%	2%

Figure A-1. Existing Land Use Composition

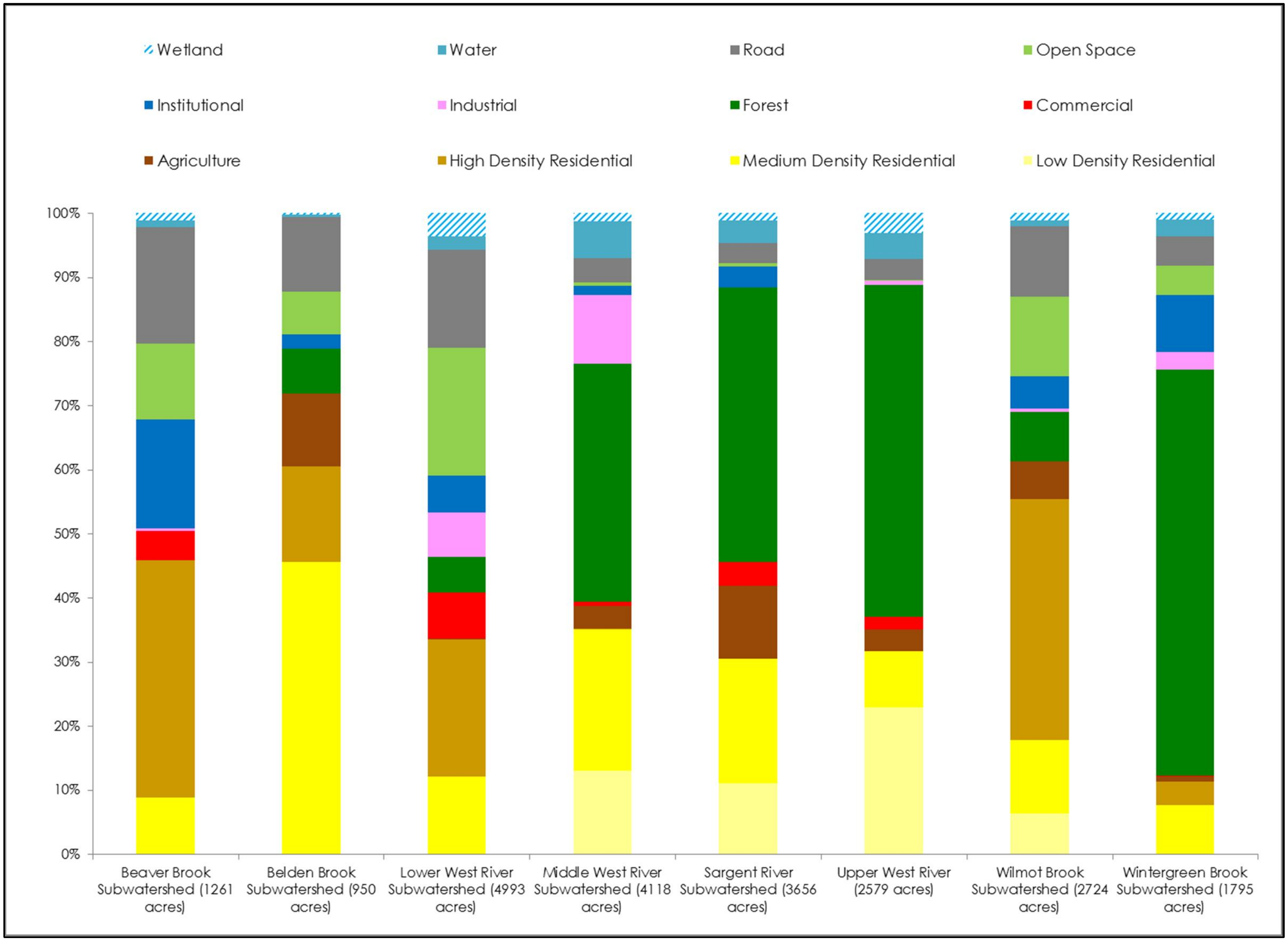

Table A-5. Model Input Data – Dwelling Units, Percent Unsewered Households, Businesses, Riparian Buffer Area, and Road Information

Subwatershed	Dwelling Units	Percent of Households in Subwatershed Unsewered	Businesses	Riparian Buffer Area (acres)	Length of Roads (mi)	Road Sanding (lbs/yr)
Beaver Brook Subwatershed (1261 acres)	6,201	0%	310	0	32.9	328,523
Belden Brook Subwatershed (950 acres)	679	9%	2	29	11.1	110,542
Lower West River Subwatershed (4993 acres)	16,889	0%	1,391	51	85.0	850,471
Middle West River Subwatershed (4118 acres)	593	47%	264	2	16.8	168,111
Sargent River Subwatershed (3656 acres)	347	100%	70	32	15.8	158,199
Upper West River (2579 acres)	196	100%	16	25	10.4	104,452
Wilmot Brook Subwatershed (2724 acres)	3,174	0%	17	139	40.7	407,302
Wintergreen Brook Subwatershed (1795 acres)	963	9%	43	278	12.3	122,890

Table A-6. Modeled Existing Annual Pollutant Loads by Source Type

	TN lb	TP lb	TSS lb	FC billion	Runoff Volume acre-ft
Land Use	316,315	28,643	6,597,601	1,246,814	32,578
Other Sources	29,345	10,420	7,885,006	1,659,056	0
Septic Systems	1,812	302	12,081	34,953	0
CSOs	2,529	241	18,062	548,800	0
Illicit Connections	2,041	802	16,609	843,737	0
Channel Erosion	19,758	8,694	6,586,019	0	0
Farms/Livestock	2,914	333	0	11,116	0
Marinas	291	49	1,942	220,450	0
Road Sanding	0	0	1,250,292	0	0
Total before existing load reductions	345,661	39,063	14,482,607	2,905,869	32,578
Existing practices load reductions (negative is a reduction)	*-34,425*	*-4,490*	*-1,152,235*	*-3,37976*	*-2114*
Total minus existing load reductions	311,236	34,573	13,330,372	2,567,894	30,464

Table A-7. Modeled Existing Annual Pollutant Loads by Land Use

Land Use	TN lb	TP lb	TSS lb	FC billion	Runoff Volume acre-ft	TN % of contribution to total land use load	TP % of contribution to total land use load	TSS % of contribution to total land use load	FC % of contribution to total land use load	Runoff Depth % of contribution to total land use load
Low Density Residential	21,009	2,101	210,089	166,602	1,549	6.6%	7.3%	3.2%	13.4%	4.8%
Medium Density Residential	77,666	1,220	1,109,519	439,929	4,091	0.2%	0.1%	16.8%	35.3%	12.6%
High Density Residential	99,078	11,009	1,321,034	436,497	4,059	4.1%	2.5%	20.0%	35.0%	12.5%
Agriculture	10,918	676	264,741	6,657	673	5.0%	10.0%	4.0%	0.5%	2.1%
Commercial	12,912	861	344,328	27,462	1,587	0.4%	0.3%	5.2%	2.2%	4.9%
Forest	4,042	250	115,819	5,175	837	3.7%	5.5%	1.8%	0.4%	2.6%
Industrial	16,136	1,210	605,088	42,285	1,487	1.2%	2.4%	9.2%	3.4%	4.6%
Institutional	12,369	2,062	350,463	26,308	4,971	32.5%	24.4%	5.3%	2.1%	15.3%
Open Space	15,929	3,186	159,288	7,260	1,175	6.5%	9.7%	2.4%	0.6%	3.6%
Road	37,374	5,537	2,076,328	88,321	12,095	8.1%	13.5%	31.5%	7.1%	37.1%
Water	8,700	504	37,825	0	0	9.5%	5.5%	0.6%	0.0%	0.0%
Wetland	182	28	3,078	319	52	14.7%	17.3%	0.0%	0.0%	0.2%
Total	316,315	28,643	6,597,601	1,246,814	32,578					

Table A-8. Modeled Load Reductions from Existing Practices

Load Reduction from Existing Practices (lbs/year)	TN lb	TP lb	TSS lb	FC billion	Runoff Volume acre-ft	TN % reduction	TP % reduction	TSS % reduction	FC % reduction	Runoff Volume % reduction
Street Sweeping	408	35	7,461	0	0	0.1%	0.1%	0.1%	0.0%	0.0%
Street Sweeping - Sanding	0	0	36,217	0	0	0.0%	0.0%	0.9%	0.0%	0.0%
Riparian Buffers	27,871	3,539	561,950	139,571	2,114	8.8%	12.4%	8.1%	11.2%	6.5%
Catch Basin Cleaning	5,884	872	544,859	0	0	1.9%	3.0%	8.3%	0.0%	0.0%
Marina Pumpouts	262	44	1,748	198,405	0	0.1%	0.2%	0.0%	15.9%	0.0%
Total Reduction	34,425	4,490	1,152,235	337,976	2,114	10.9%	15.7%	17.4%	27.1%	6.5%

Appendix B

Maltby Lakes Subwatershed

FUSS & O'NEILL

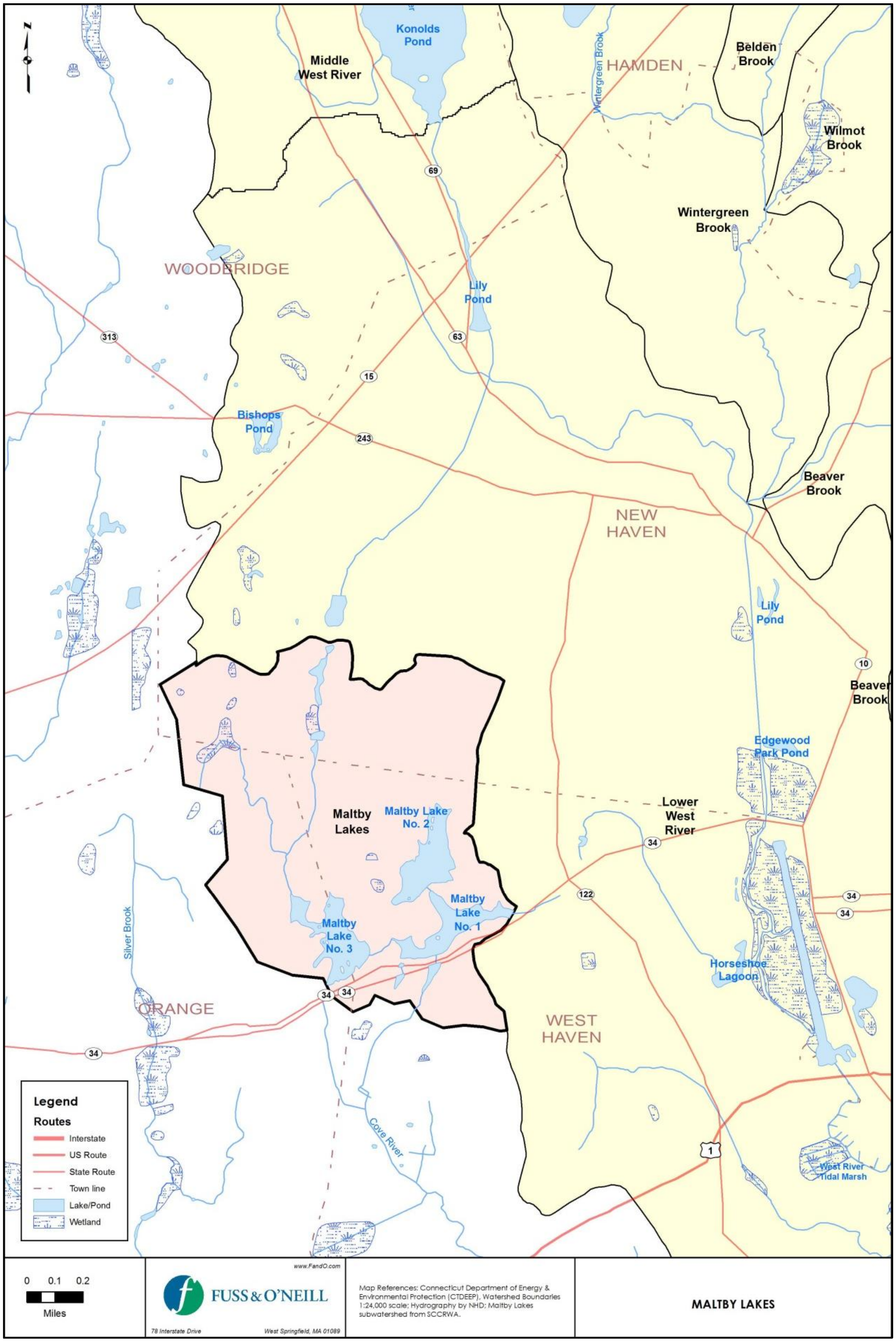

Figure B-1. Maltby Lakes Subwatershed

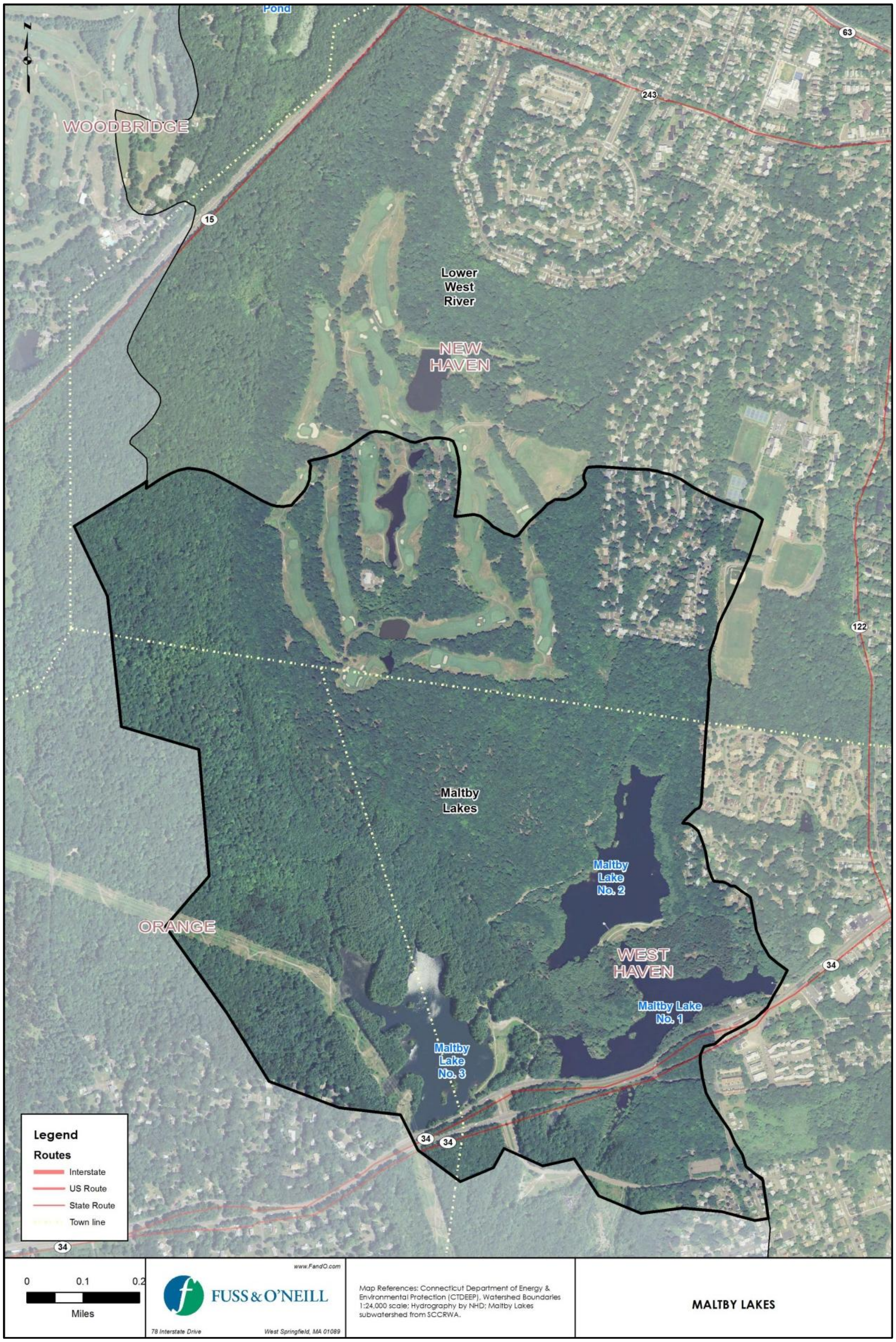

Figure B-2. Maltby Lakes Subwatershed Aerial Photo