NWQI Assessment Report for the Tomaquag Brook-Pawcatuck River Watershed, Rhode Island

NRCS Rhode Island
RHODE ISLAND

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I. Background and Purpose of the Assessment

This section provides an overview of the National Water Quality Initiative (NWQI) assessment area, identifies the primary water quality resource concerns, and outlines the associated water quality objectives. It also summarizes how the problems can be addressed through Natural Resources Conservation Service (NRCS) technical and financial assistance.

General Overview of Assessment Area

This NWQI assessment focuses on the Tomaquag Brook-Pawcatuck River watershed (12-digit hydrologic unit code [HUC]: 010900050205) in southwestern Rhode Island. The broader drainage area, the Wood-Pawcatuck watershed, represents one of the few remaining relatively pristine natural areas along the northeast corridor between New York and Boston and has been identified as containing the last large, forested track south of Boston (WPWA 2022). The Pawcatuck River starts at the outlet of Worden Pond and flows from east to west 35 miles to its mouth at Little Narragansett Bay. The Tomaquag Brook-Pawcatuck River watershed encompasses 57 square miles within the 300 square miles of the broader Wood-Pawcatuck drainage area (WPWA 2022).

The Wood-Pawcatuck watershed is a recreational destination with 57 miles of rivers that support flat-water paddling, numerous streams in pristine forest for fishing native brook trout and stocked brown and rainbow trout, and five state management areas for hiking, biking, hunting, birding and nature studies (WPWA 2022). The coastal town of Westerly is a popular tourism destination due to its scenic views of the Rhode Island Sound and has been a longstanding destination for beach vacations (Wood-Pawcatuck Wild and Scenic Study Committee 2018). In 2019, the *Wood-Pawcatuck Watershed Wild and Scenic River Act* designated the watershed as part of the National Wild and Scenic Rivers System, establishing it as the first river system in Rhode Island with a “Wild and Scenic” designation (National Park Service 2019). This designation formally recognizes the natural, cultural, and recreational characteristics of waterways within the watershed and grants eligibility for additional federal preservation funding for conservation and stewardship. The Tomaquag Brook-Pawcatuck River watershed was formed 20,000 years ago by a retreating glacier creating the Charlestown Moraine, which significantly impacted the hydrology of the area. This geological event changed the southerly flow of historic rivers to instead collect in the Pawcatuck River and flow west into the Little Narragansett Bay. Additionally, the moraine created extensive wetlands in the Tomaquag Brook-Pawcatuck River watershed, including the Great Swamp, Cedar Swamp, and Chapman Swamp (Wood-Pawcatuck Wild and Scenic Study Committee 2018).

23% of the watershed is protected within lands owned and managed by Rhode Island Department of Environmental Management (RIDEM) and Connecticut Department of Energy and Environmental Protection (CTDEEP), while non-government agencies (e.g., The Nature Conservancy [TNC], Audubon Society of Rhode Island [ASRI], and local land trusts) protect another 10% of the watershed. TNC has dubbed the “Borderlands” area along the Connecticut/Rhode Island border valuable due to the thousands of acres of contiguous woodlands. These protected lands and contiguous woodlands allow for high levels of habitat and species diversity, as well as a number of rare and endangered species (including some globally-rare species). For example, the Pawcatuck River system supports approximately 70% of Rhode Island’s globally imperiled species of dragonflies and damselflies. The Pawcatuck River and Pawtuxet River Basins are the only areas in Rhode Island known to support all local mussel species and provide essential habitat to native fish species, such as the Eastern brook trout. In addition, the North Atlantic and lower New England ecoregions intersect within the watershed, providing for plant and animal communities that reflect a mixture of coastal and inland, and northern and southern, influences. The Pawcatuck watershed also provides clean groundwater as the sole source of drinking water for more than 60,000 local residents (Wood-Pawcatuck Wild and Scenic Study Committee 2018).

The watershed area is approximately 75% forested. Agricultural land makes up a little over 5% of the area and is located in the southwestern corner of the state, bordering Connecticut (NRCS 2014). The agricultural land in the watershed is predominantly dedicated to forage (e.g., other hay/non-alfalfa) and corn. Developed land makes up 11% of the area.

Water Quality Degradation Resource Concerns and Impairments

High levels of phosphorus and metals are the main water quality concerns for the Tomaquag Brook-Pawcatuck River watershed. White Brook Pond and Chapman Pond are impaired due to high levels of phosphorus; Chapman Pond is also exceeding lead criteria. Meadowbrook Pond and Watchaug Pond also contain high levels of mercury, evident via the accumulation within fish tissue.

Numerous stream segments exceed recreational water quality standards for *Enterococcus* (indicating the potential presence of pathogenic organisms) and have approved Total Maximum Daily Loads (TMDLs) (RIDEM 2021). Recent U.S. Geological Survey (USGS) water quality monitoring data also indicates elevated levels of nutrients (nitrogen and phosphorus) occurring episodically at sites on Tomaquag Brook and Pawcatuck River.

Constituents of Concern

Water quality concerns are primarily caused by periodically high levels of nutrients (nitrogen and phosphorus), bacteria (enterococcus), and metals in the water bodies of the Tomaquag Brook-Pawcatuck River watershed.

Opportunities and Objectives for Meeting Water Quality Goals

The NWQI assessment provided an opportunity for NRCS and partners to take a focused look at water quality concerns within the Tomaquag Brook-Pawcatuck River watershed. The Agricultural Conservation Planning Framework (ACPF) was applied to identify critical source areas (runoff risk) in agricultural fields and determine priority areas for structural best management practices (BMPs). Existing and potential future water quality loads in the watersheds were estimated using the Spreadsheet Tool for Estimating Pollutant Load (STEPL). Load reductions were modeled using established conservation practice efficiencies. The efficiencies of combined practices were calculated using STEPL's BMP Calculator. Although STEPL does not model bacteria, it is assumed that simulated nutrient and sediment load reductions would result in comparable decreases in bacteria loads from agricultural sources in each drainage area.

The ultimate goal is to meet designated criteria (Class B surface waters and Class SA and Class SB coastal waters). In order to meet this goal, NRCS' focus will be to increase the participation rate and to increase the level of conservation towards water quality within the watershed.

Within the first phase of this effort (2023–2028) NRCS expect to increase participation by 15%. Acreage with conservation treatment (or the level of conservation treatment) is expected to increase by 10%, while the number of conservation practices applied is expected to increase by 15% during the first phase of this effort. Each year of the first phase will include a programmatic review of the data to allow for adjustments for outreach and treatments.

Assessment of NRCS' Ability to Help Partners Reach the Watershed Goals

NRCS in Rhode Island has many partners in the watershed starting with the farmers and landowners. Participation in NRCS' programs has been fairly consistent throughout the years. NRCS also has a number of partners with the local land trusts, local associations, and town, state, and other federal partners.

Southern District Field Office NRCS staff have the capacity and resources to provide effective and timely technical assistance to landowners and operators within the NWQI watersheds. The NRCS staff include the following: District Conservationist, one Soil Conservationist, and access to a Civil Engineer and Civil Engineering Technician. In addition, the field office staff can request assistance from state office technical specialists. Technical assistance will include outreach, conservation planning, design, layout, construction check of practices, and practice evaluation.

The Southern District Soil and Water (SWCD) staff will assist with outreach and promotion of NWQI efforts in addition to providing planning support through agreements with NRCS.

II. Watershed Characterization

This section provides an overview of the Tomaquag Brook-Pawcatuck River watershed and identifies associated resource concerns. The background information is useful context for water quality assessment and watershed planning.

Location of Watershed within the Drainage Network

The Tomaquag Brook-Pawcatuck River watershed (HUC-12 ID: 010900050205), located in Washington County, Rhode Island, is the focus of this NWQI assessment. The watershed drains approximately 57 square miles and lies in the southwestern corner of the state, bordering Connecticut (NRCS 2014). It is fully contained in Washington County and includes the towns of Bradford, Wood River Junction, and Ashaway. The watershed includes several protected areas including Narragansett Reservation, Woody Hill Management Area, and Burlingame State Park. Figure 1 displays the location of the watershed within Rhode Island.

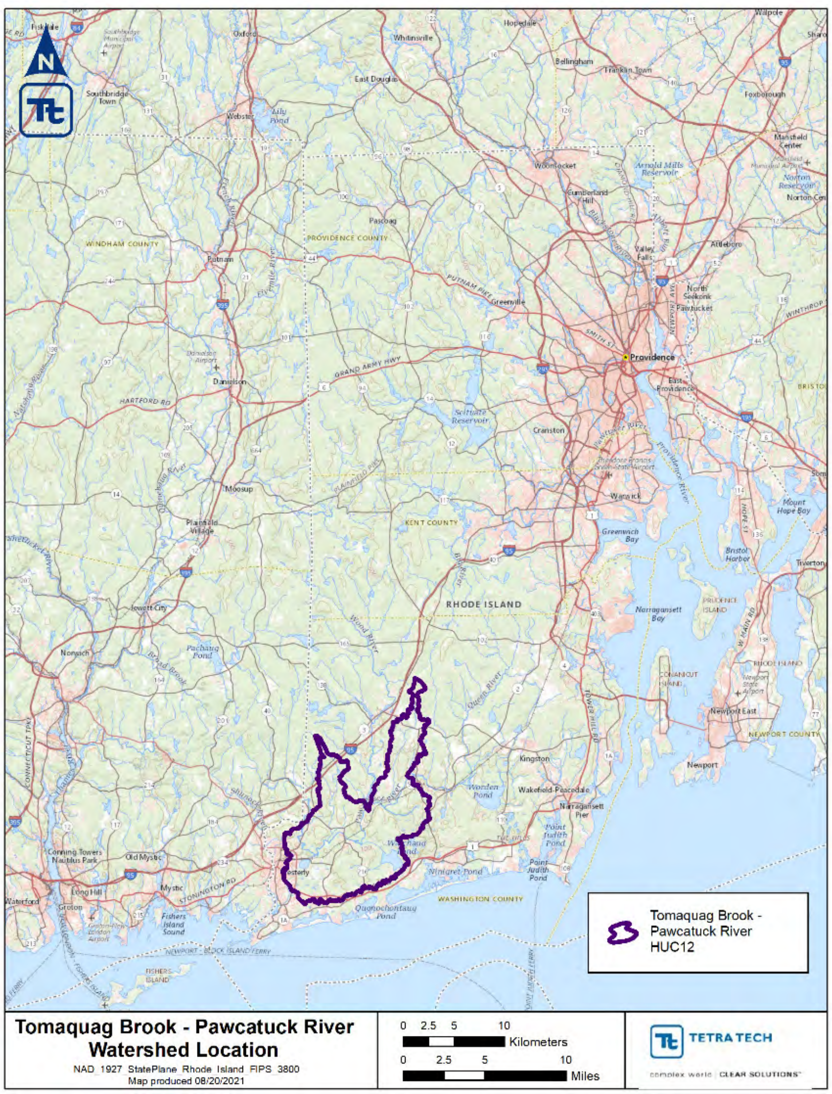


Figure 1. Location of the Tomaquag Brook-Pawcatuck River watershed within Rhode Island.

Landscape Characteristics

A description of landscape characteristics in terms of both [major land resource areas (MLRAs)]() and [ecoregions]() can help inform watershed management.

Major Land Resource Areas

MLRAs are geographic areas located within land resource regions characterized by similar soils, climate, water resources, and land uses (NRCS 2006). Rhode Island forms part of MLRA 144A (part of the larger North Lakes States Land Resource Region), which covers areas of Connecticut, Rhode Island, and Massachusetts, and makes up about 6% of the total MLRA area (Figure 2). The full area covers about 18,590 square miles, and consists of two sections, an eastern and western part, with the Tomaquag Brook-Pawcatuck River watershed area located within the eastern part (NRCS 2006). The MLRA is characterized primarily by forested areas, numerous wetlands, small areas of cropland and pasture, and abundant cranberry bogs. The forested areas include oak-hickory and oak-pine, which have coastal influences and are used for wood products, hunting, and other kinds of recreation. Agriculture in the area is dominated by dairy, nursery, and greenhouse stock. Some forage crops for dairy cattle are still grown in addition to truck crops, small fruits, and apples, which are grown on some farms, mainly near the larger towns and cities (Griffith et al. 2009).

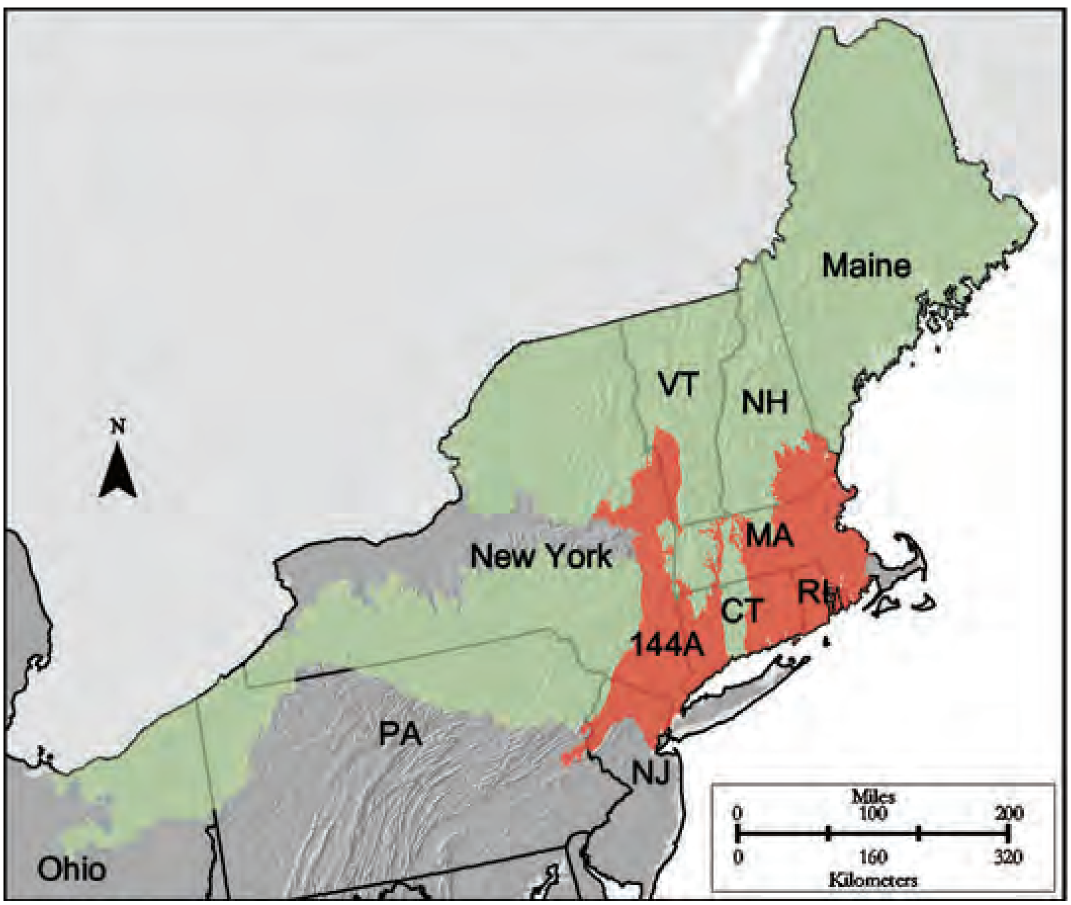


Figure 2. Location of MLRA 144A, with orange shading showing the extent of the MLRA. Green shading indicates North Lakes States Land Resource Region (NRCS 2006).

Ecoregions

Ecoregions are based on abiotic and biotic factors such as climate, geology, vegetation, wildlife, and hydrology. The mapping of ecoregions is therefore beneficial in the management of ecosystems. The Tomaquag Brook-Pawcatuck River watershed falls within the Southern New England Coastal Plains and Hills and the Long Island Sound Coastal Lowland level IV ecoregions (Griffith et al. 2009). A map of the level IV ecoregions found within Rhode Island, together with the Tomaquag Brook-Pawcatuck River watershed location, is shown in Figure 3.

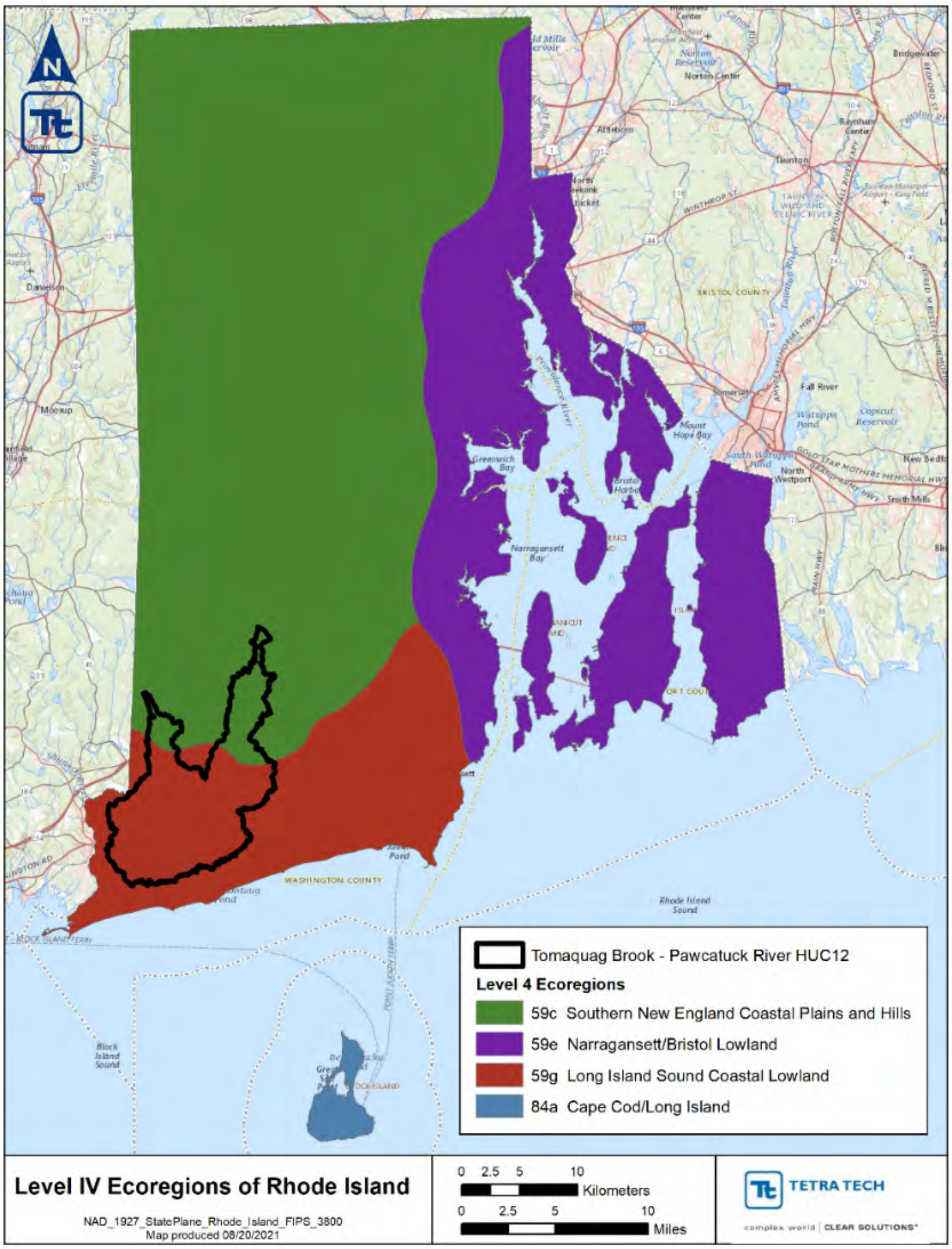


Figure 3. Level IV Ecoregions of Rhode Island.

The Southern New England Coastal Plains and Hills ecoregion stretches through Connecticut, Rhode Island, and southeastern Massachusetts and makes up the northern portion of the Tomaquag Brook-Pawcatuck River watershed. Historic vegetation was cleared for agriculture and charcoal production; vegetation now resembles a typical southern New England forested wetland, dominated by a mix of successional oak and oak-pine forests (Griffith et al. 2009).

The Long Island Sound Coastal Lowland ecoregion exists along the coast of southern Connecticut and Rhode Island and overlaps with the southern portion of the Tomaquag Brook-Pawcatuck River watershed. The terrain of the ecoregion includes low-elevation rolling coastal plain, tidal marshes, estuaries, sandy dunes and beaches, and rocky headlands. The vegetation includes coastal species of hardwood trees, dense shrubs, and vines. While parts of the ecoregion are urbanized, the portion in the Tomaquag Brook-Pawcatuck River watershed is not (Griffith et al. 2009).

Regional Climate

The climate in the region is considered humid continental with hot summers and year around precipitation (Köppen climate classification Dfa). Precipitation near the coasts is slightly lower in the summer and slightly higher in spring and fall in inland areas. Additionally, rainfall occurs as high-intensity, convective thunderstorms during the summer and winter, with most of the precipitation occurring as moderate-intensity storms (Nor'easters) that produce large amounts of rain or snow (Griffith et al. 2009; NRCS 2006). The Long Island Sound Coastal Lowland ecoregion, which comprises part of the watershed, is noted as having one of the mildest climates in New England (Griffith et al. 2009).

Long-term average annual temperature for Washington County, Rhode Island ranges from about 45 °F to 53 °F (Figure 4). Temperatures in the region vary widely on an annual basis, with the coldest month being January (minimum average 1900–2020 temperature being about 19 °F and maximum average 1900–2020 temperature being about 37 °F) and the warmest month generally being July (minimum average 1900–2020 temperature being about 66 °F and maximum average 1900–2020 temperature being about 76 °F). Temperature has increased 0.4 °F per decade over the past 100 years. The annual frost-free period for this region averages 190 days and ranges between 145 and 240 days (NRCS 2006). Long-term average annual precipitation ranges from 28 to 61 inches for Washington County, Rhode Island. Annual precipitation has increased 0.46 inches per decade since 1900 (Figure 5).

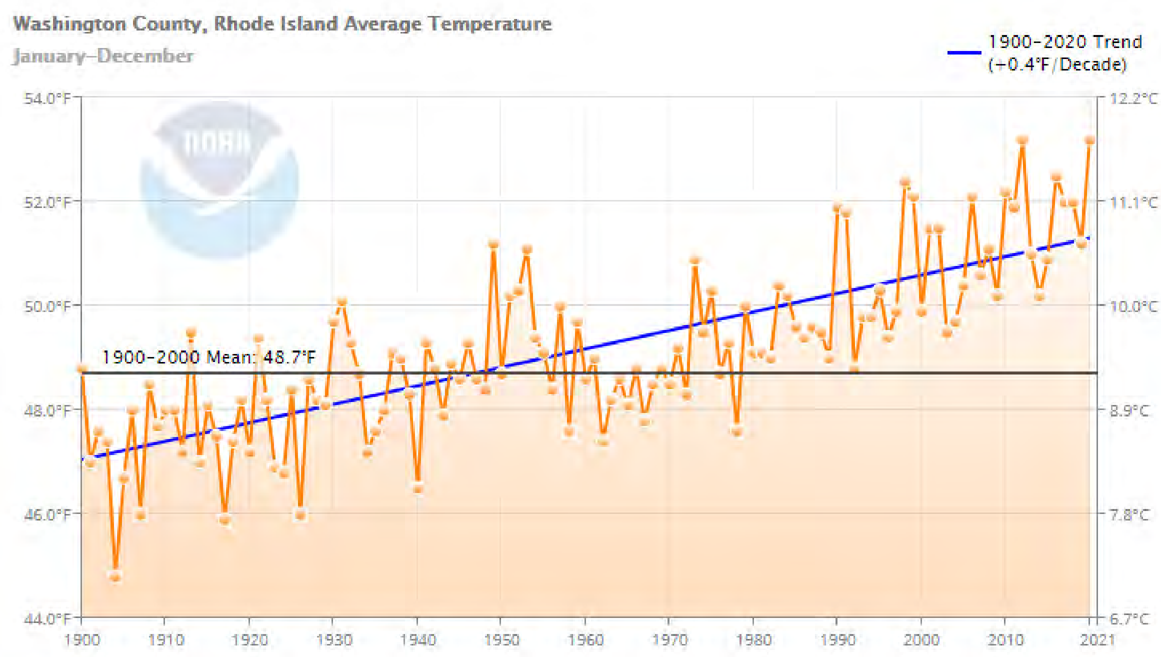


Figure 4. Average annual temperature in Washington County, Rhode Island, 1900–2020 (NOAA 2020).

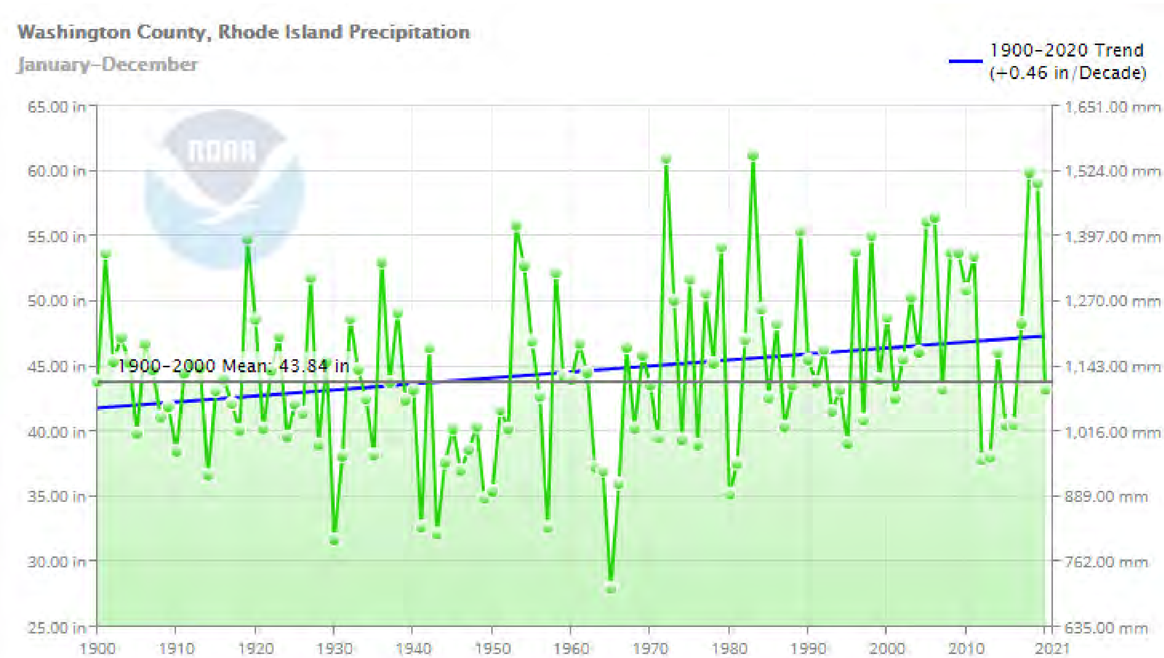


Figure 5. Average annual precipitation in Washington County, Rhode Island, 1900–2020 (NOAA 2020).

Topography

The topography for the Southern New England Coastal Plains and Hills ecoregion, which comprises the northern portion of the watershed, ranges from irregular plains with low hills to elevations up to about 1,000 feet in western Connecticut. In the southern portion of the watershed, the Long Island Sound Coastal Lowland ecoregion includes low-elevation rolling coastal plain, tidal marshes, estuaries, sandy dunes and beaches, and rocky headlands (Griffith et al. 2009). Within the watershed, elevation ranges from about 20 feet to just over 450 feet (Horizon Systems Corporation 2022). Figure 6 shows the elevation changes throughout the Tomaquag Brook-Pawcatuck River watershed.

The watershed is relatively flat with an average slope of 4.0% (0.0–48.8%) (Horizon Systems Corporation 2022). About 3.2% of pastureland is estimated to be on slopes ≥ 3% and 0.4% is indicated to be on slopes ≥ 9%. Similarly, for cropland, 1.0% is estimated to be on slopes ≥ 3% and 0.1% is on slopes ≥ 9% (see EnviroAtlas for more information).

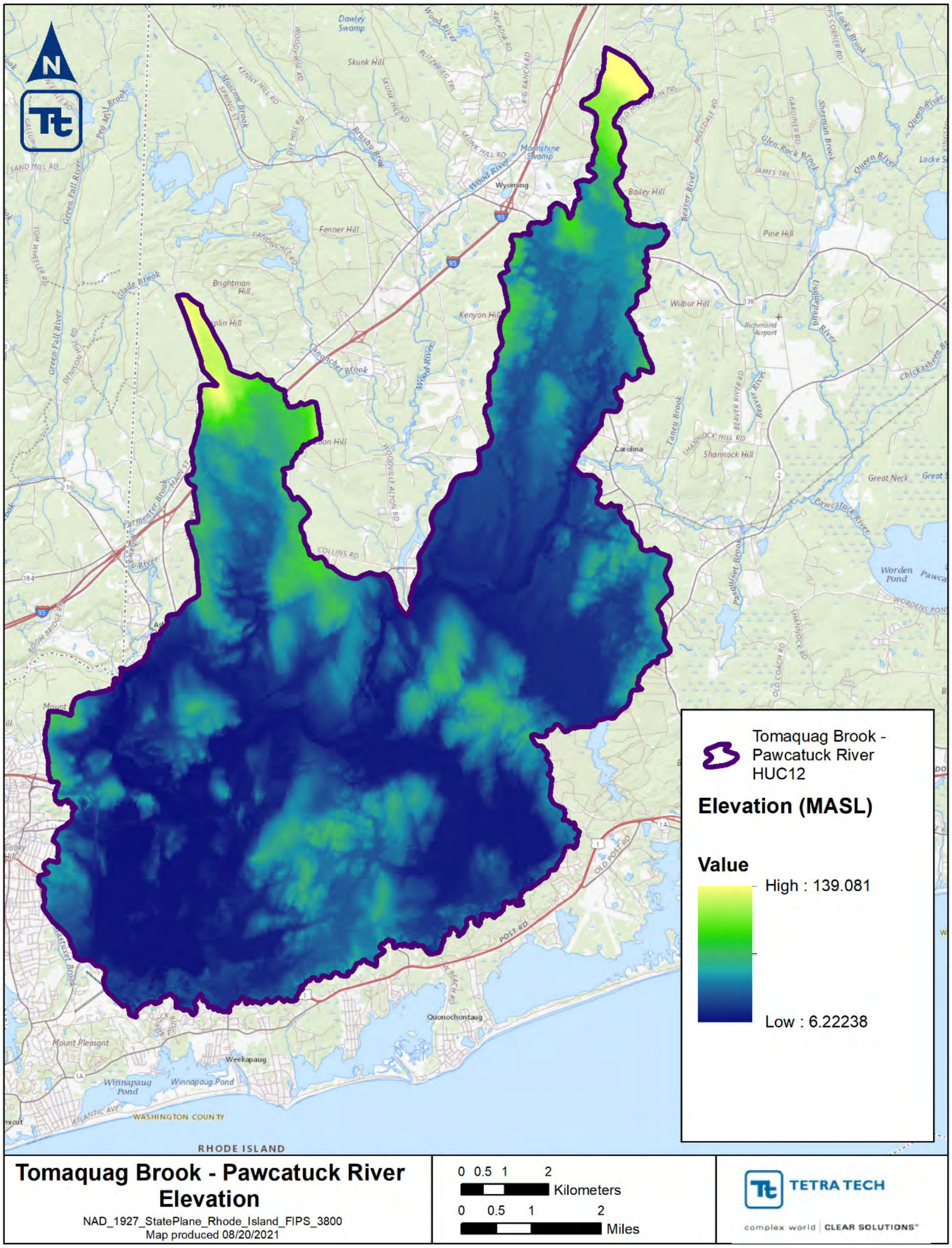


Figure 6. Elevation levels (meters above sea level [masl]) within the Tomaquag Brook-Pawcatuck River watershed (note: 6 to 139 masl = 20.4 to 456.3 feet above sea level).

Geology, Geomorphology, and Soils

Geology and Geomorphology

The Tomaquag Brook-Pawcatuck River watershed is within MLRA 144A (Figure 2). The Wood-Pawcatuck watershed, of which the Tomaquag Brook-Pawcatuck River watershed is a part of, was formed by retreating glaciers that left a recessional moraine, known as the Charlestown Moraine. The moraine land mass caused rivers to collect in the Pawcatuck River and also created widespread wetland areas (Wood-Pawcatuck Wild and Scenic Study Committee 2018). Although bedrock outcrops are not common here, there is an extensive covering of glacial till in the area, which consists almost entirely of till plains and drumlins dissected by narrow valleys with a thin mantle of till. The southernmost boundary of MLRA 144a marks the farthest southward extent of glaciation on the eastern seaboard. The river valleys and coastal plains are filled with glacial lake sediments, marine sediments, and glacial outwash (NRCS 2006).

The bedrock in the MLRA area consists primarily of igneous and metamorphic rocks of early Paleozoic age (NRCS 2006). The bedrock types most common in the Southern New England Coastal Plains and Hills ecoregion, found in the northern part of the watershed, are mostly granites, schist, and gneiss with some soft marble occurring in western Connecticut (Griffith et al. 2009). The underlying material in the Long Island Sound Coastal Lowland ecoregion is primarily glacial till (Griffith et al. 2009). The different rock types that underlay the watershed are shown in Figure 7. Granitic gneiss, granite, and quartzite are the most prominent rock types in the watershed.

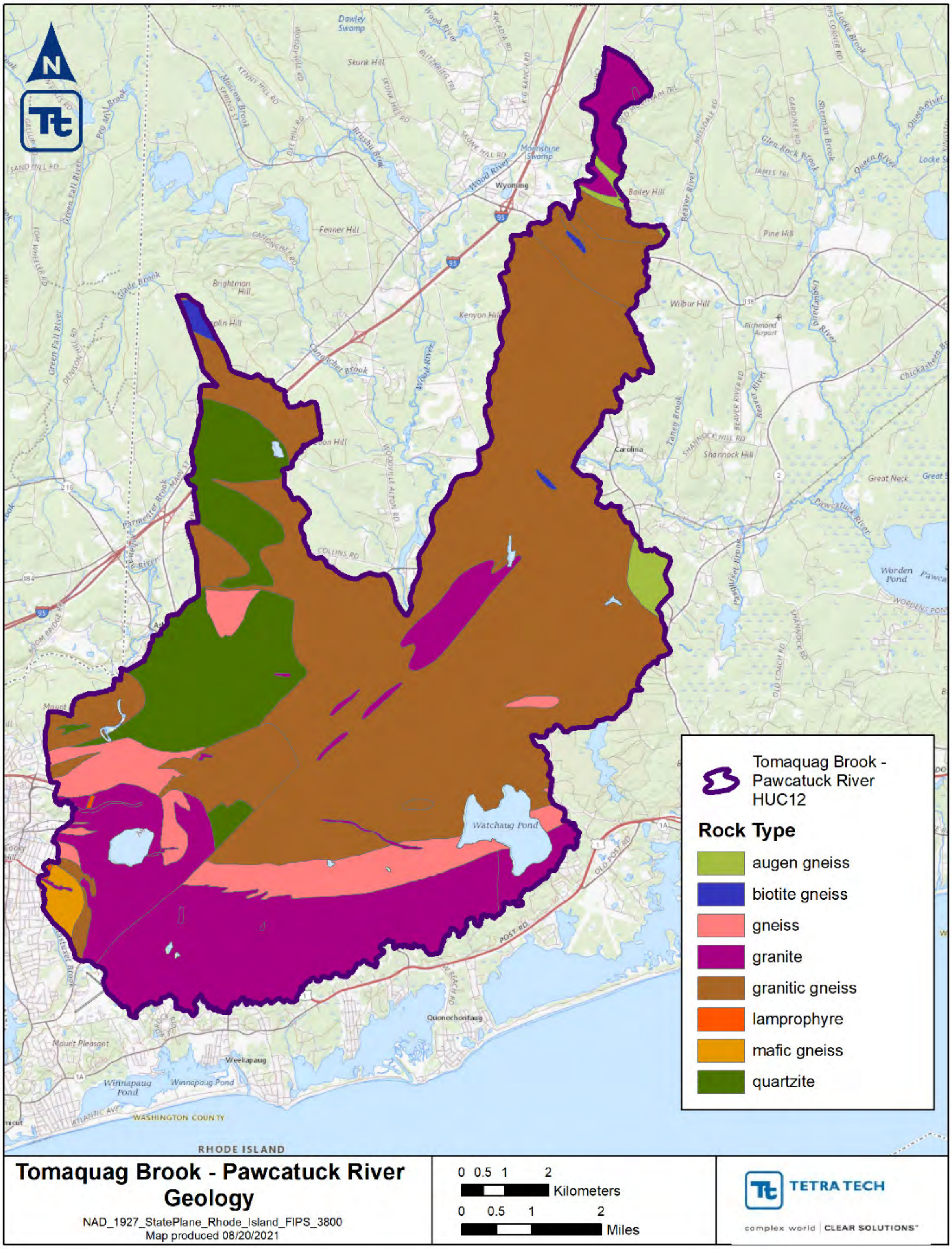


Figure 7. Location of different rock types that underlay the Tomaquag Brook-Pawcatuck River watershed.

Soils

Information about soil types and characteristics is important when planning management practices in a watershed. The dominant soil orders (click the link for more information) in the MLRA are Entisols, Histosols, and Inceptisols (NRCS 2006), and the dominant soils in the ecoregions where the watershed is located include coarse-loamy and sandy, mesic Inceptisols and some Entisols in the Southern New England Coastal Plains and Hills. Gravel, sand, and silt are prominent in the Long Island Sound Coastal Lowland ecoregion (Griffith et al. 2009).

USDA-NRCS has mapped the soils in the area and classified them on the basis of slope as well as type. The main soil types in the watershed are Canton and Charlton; Freetown muck; Ridgebury, Leicester, and Whitman; Hinckley loamy sand; and Canton-Charlton-Rock outcrop complex. Numerous other minor soil types are also present within the assessment area (NRCS 2019). A summary of the main soil types is given in Table 1 (NRCS 2019).

Table 1. Summary of main soil types in the Tomaquag Brook-Pawcatuck River watershed (NRCS 2019)

Soil Name	Soil Profile	Parent Material
Canton and Charlton	Fine sandy loams, very stony fine sandy loams	Coarse-loamy over sandy and gravelly melt-out till derived from gneiss, granite and/or schist
Freetown muck	Muck	Highly decomposed organic material
Ridgebury, Leicester, and Whitman	Mix of Ridgebury (extremely stony soil), Leicester (extremely stony soil), Whitman (extremely stony soil), and other minor components	Coarse-loamy lodgment till derived from gneiss, granite, and/or schist
Hinckley loamy sand	Loamy sand	Sandy and gravelly glaciofluvial deposits derived from gneiss and/or granite and/or schist
Canton-Charlton-Rock outcrop complex	Outcrop complex	Coarse-loamy over sandy and gravelly melt-out till derived from granite and/or schist and/or gneiss

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Values of K range from 0.02 to 0.69—other factors being equal the higher the value, the more susceptible the soil is to sheet and rill erosion by water. Within the Tomaquag Brook-Pawcatuck River watershed, K ranges from 0.05 to 0.43. Areas with K values between 0.3 and 0.43 make up about 8% of the watershed area. Note: not all soil map units within the watershed report an erosion factor.

Hydrologic soil groups (HSGs) are groups of soils that have similar runoff potential under similar storm and cover conditions. Table 2 summarizes the breakdown of HSGs, while Figure 8 shows the spatial extent of HSGs in the Tomaquag Brook-Pawcatuck River watershed. Group B (moderate infiltration) covers the largest amount of the watershed area, followed by group D (slow infiltration) (NRCS 2019). Areas covered by dual HSGs (A/D, B/D, or C/D) are also present in the watershed. Dual HSGs are soils that are assigned based on the presence of a water table within 24 inches of the surface; they are also soils that can be adequately drained and are assigned to a dual soil group based on their saturated hydraulic conductivity and the water table depth when drained. The first letter applies to the drained condition and the second to the undrained condition.

The locations of various soil drainage classes within the watershed are shown in Figure 9. Drainage classes represent the moisture condition of the soil and how frequently the soil is saturated or not throughout the year. The majority of the watershed (~46%) is considered to be “moderately well drained” or “well drained” based on SSURGO drainage classifications. About 29% of the watershed is considered to be “poorly drained” or “very poorly drained.”

Figure 10 shows the locations of various farmland soil classes within the study area. The map identifies the location and extent of the soils that are best suited to food, feed, fiber, forage, and oilseed crops. Areas classified as “prime farmland” represent about 14% of the watershed. The majority of the study area is considered “not prime farmland” (~70%). Farmland considered to be of statewide importance (~16%) is distributed throughout the watershed.

Table 2. Area and coverage of each hydrologic soil group in the Tomaquag Brook-Pawcatuck River watershed (NRCS 2019)

Hydrologic Soil Group Type	**Coverage (%)**
A - High Infiltration	15%
A/D - High/Very Slow Infiltration	10%
B - Moderate Infiltration	25%
B/D - Medium/Very Slow Infiltration	21%
C - Slow Infiltration	4%
C/D - Medium/Very Slow Infiltration	6%
D - Very Slow Infiltration	16%
No rating reported	3%
Total	100%

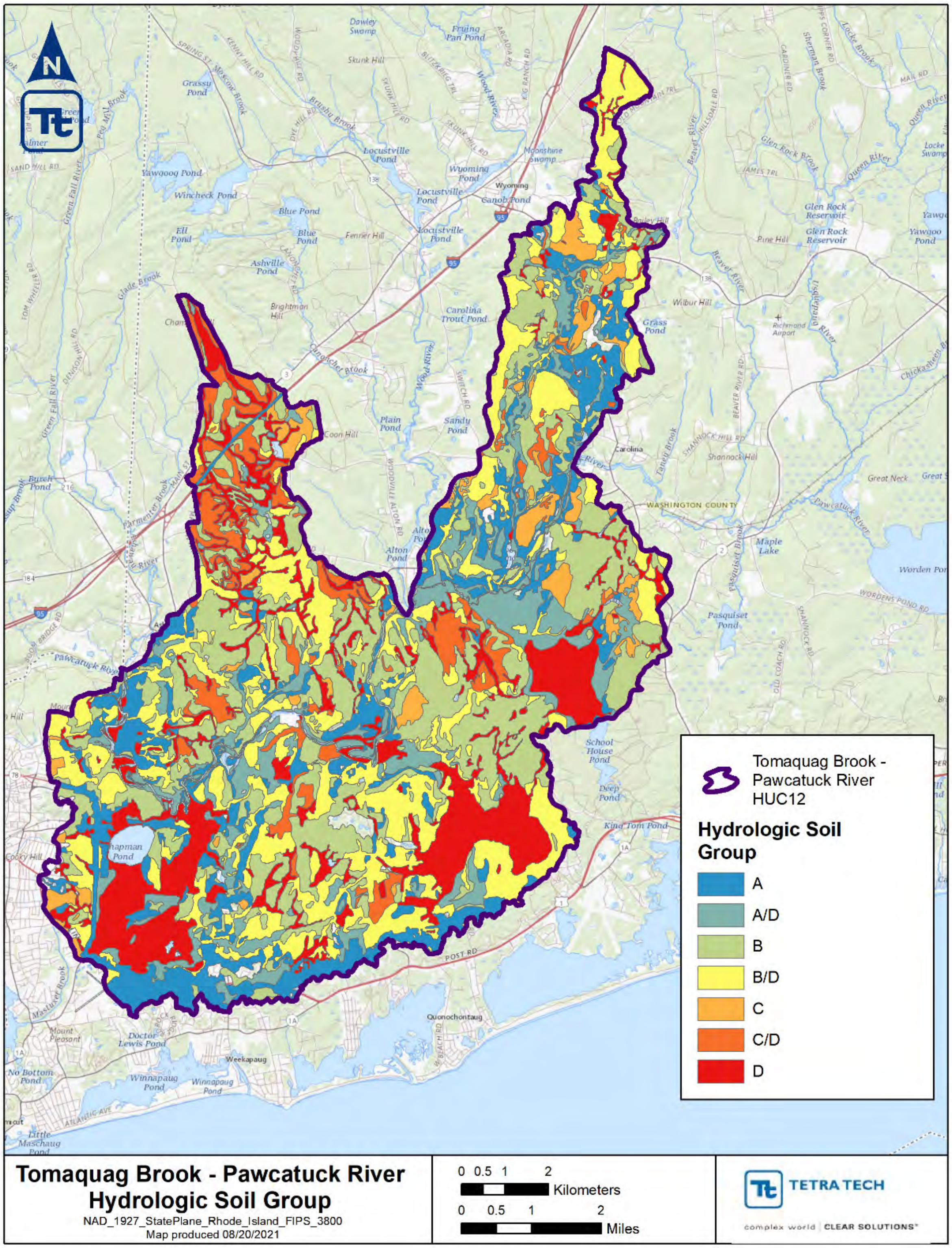


Figure 8. Map of hydrologic soil groups in the Tomaquag Brook-Pawcatuck River watershed.

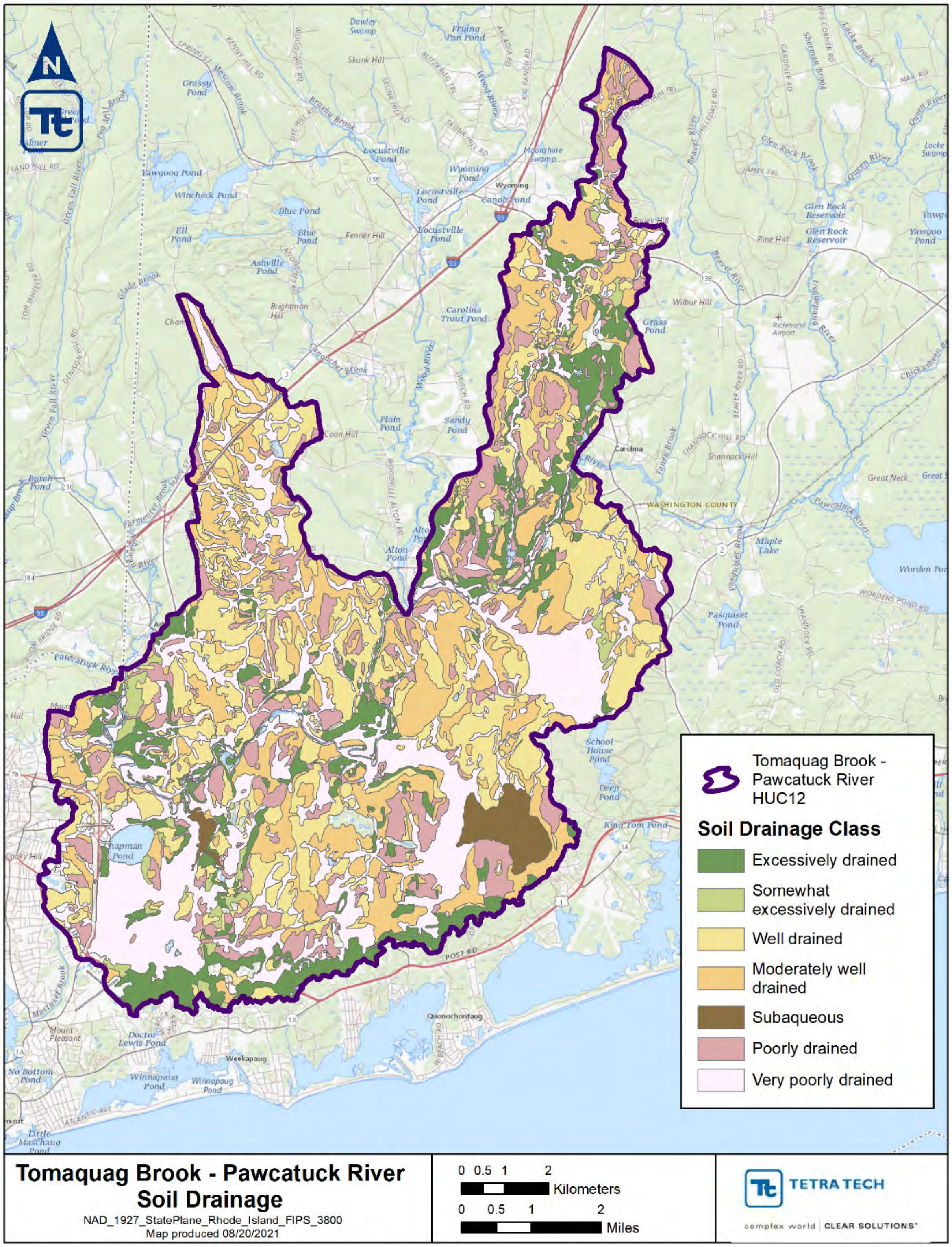


Figure 9. Spatial distribution of soil drainage classes within the Tomaquag Brook-Pawcatuck River watershed.

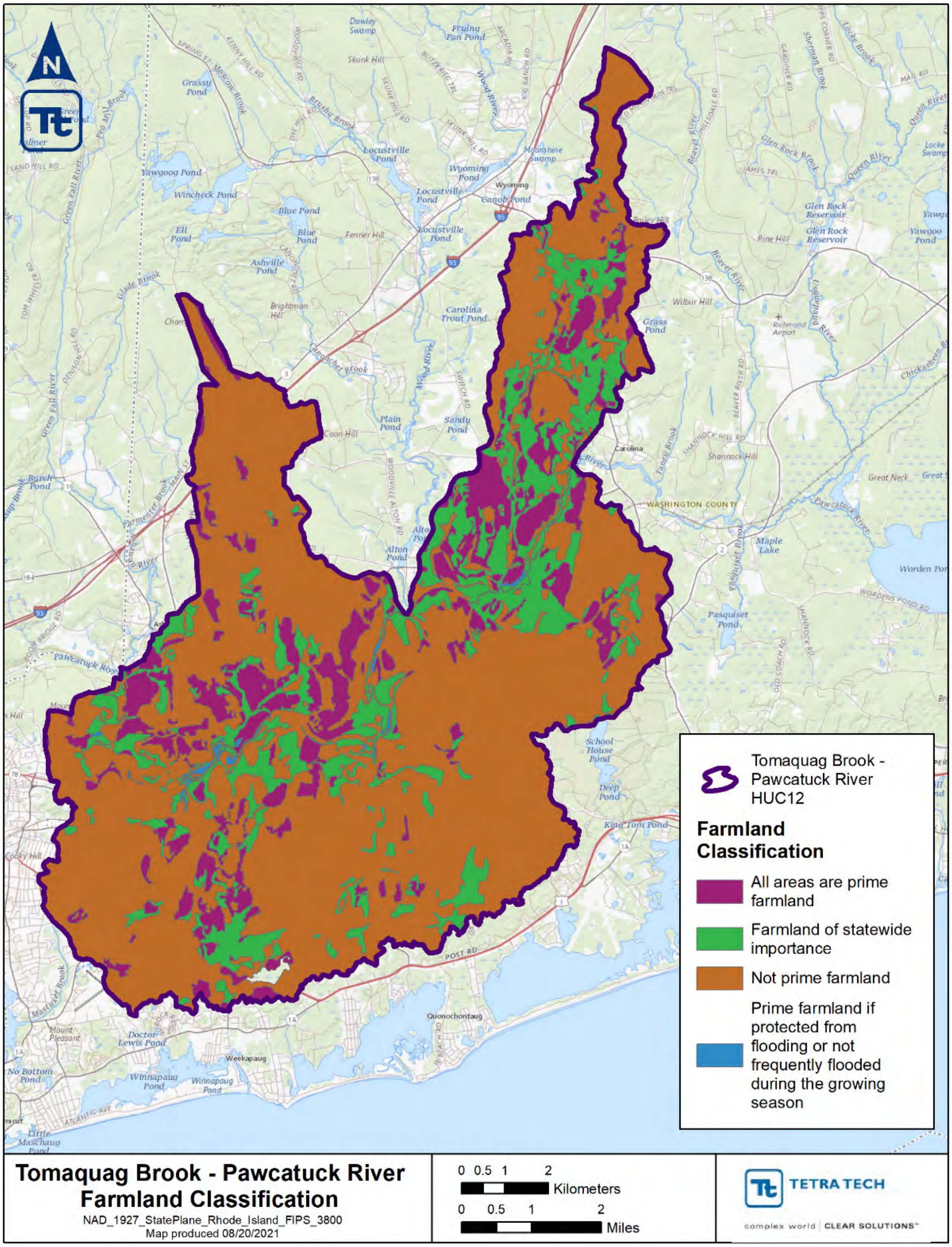


Figure 10. Location of various farmland classes within the Tomaquag Brook-Pawcatuck River watershed.

Drainage Network

The stream network and locations of water bodies within the Tomaquag Brook-Pawcatuck River watershed are displayed in Figure 11. The Pawcatuck River originates in Wordens Pond in South Kingstown (east of the Tomaquag Brook-Pawcatuck River HUC-12 drainage area), after which it largely flows east to west. The watershed consists of a complex network of tributaries, wetlands, and smaller ponds with associated rivers and brooks, all of which drain to the Little Narragansett Bay in Westerly, Rhode Island (RIDEM 2011). Tomaquag, Meadow, White, Cedar Swamp, Poquiant, Mile, and Perry Healy Brooks are the main streams in the drainage area. The stream network conisists of approximately 59 stream miles. First order streams account for about 24 miles. It is estimated that approximately 0.67 miles of these streams are located in agricultural areas (NHDPlus Version 2). Several ponds are also located in the watershed including Watchaug Pond, Chapman Pond, Meadow Brook Pond, Saw Mill Pond, Duck Pond, Wells Pond, and Dam Pond.

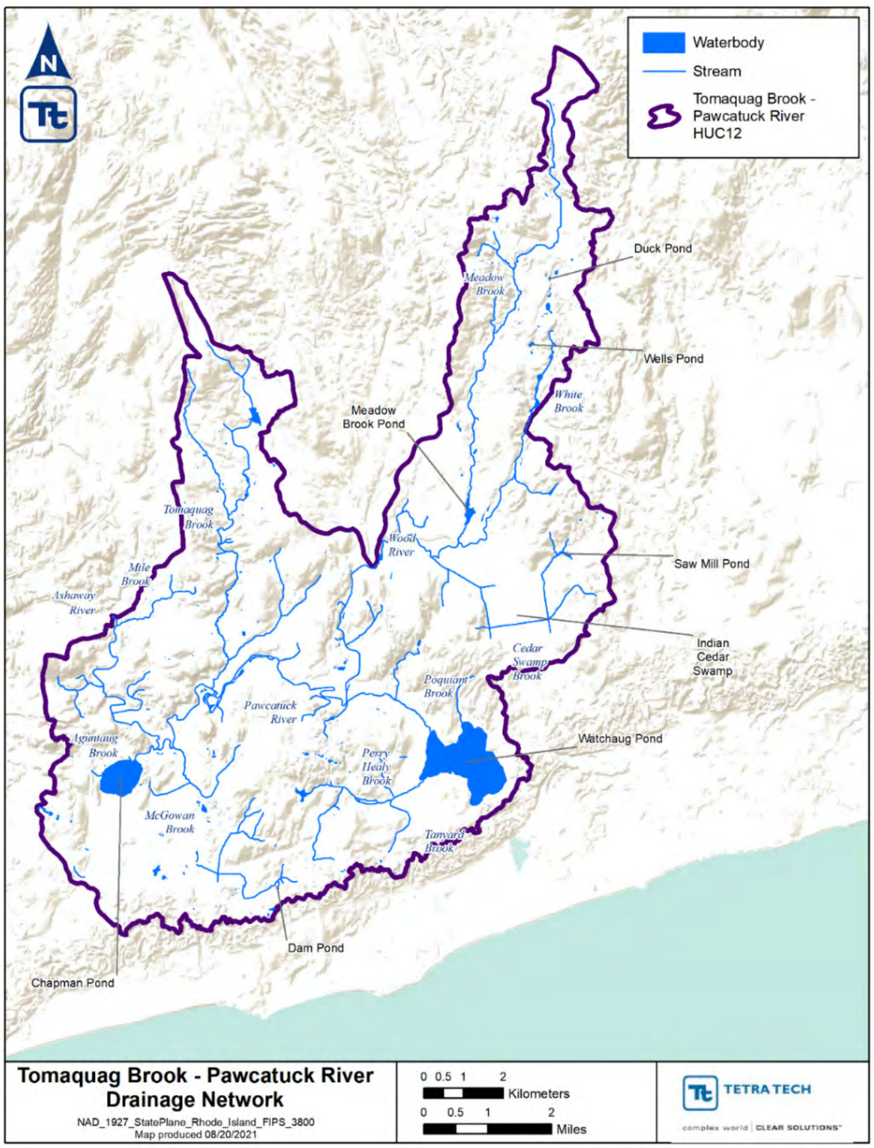


Figure 11. Rivers, streams, and other water bodies within the Tomaquag Brook-Pawcatuck River watershed.

The Tomaquag Brook-Pawcatuck River watershed contains some wetland areas (about 23% of the watershed). These areas mainly consist of freshwater forested/shrub wetlands with some small areas of freshwater emergent wetlands (USFWS 2018). The locations of wetland areas with the watershed extent are displayed in Figure 12.

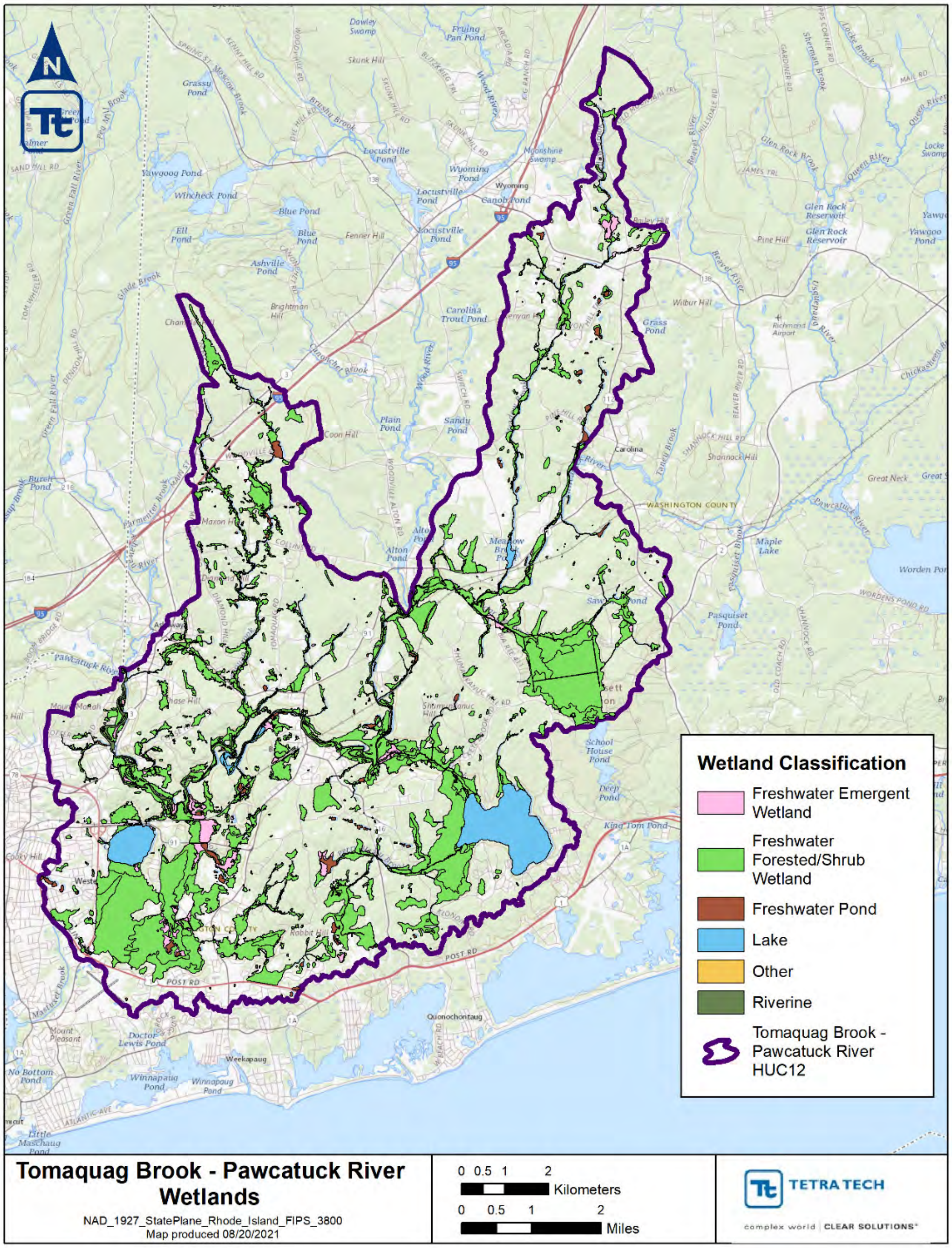


Figure 12. Locations of wetlands within the drainage area (USFWS 2018).

Land Cover and Land Use

Existing land use data within the watershed was determined using the USDA NASS 2020 Cropland Data Layer (CDL). Table 3 provides a breakdown of various CDL classes within the Tomaquag Brook-Pawcatuck River watershed. Agricultural land accounts for just under 6% of the watershed area with other hay/non alfalfa (3.1%) and corn (1.4%), accounting for the majority of the agricultural area within the watershed (USDA NASS 2021). Forested land (more than 77% of the overall area) covers the majority of the Tomaquag Brook-Pawcatuck River watershed. Developed land accounts for approximately 12% of the watershed area (see Table 3). The spatial distribution of various land use types within the watershed is provided in Figure 13.

Table 3. Area and coverage of land use types in the Tomaquag Brook-Pawcatuck River watershed (USDA NASS 2021)

Land Use Type	Acreage (acres)	Coverage (%)
Deciduous Forest	14,295.8	39.2
Woody Wetlands	8,253.7	22.6
Mixed Forest	3,898.8	10.7
Evergreen Forest	1,884.1	5.1
Developed/Low Intensity	1,659.3	4.5
Developed/Open Space	1,470.7	4.0
Developed/Medium Intensity	1,189.1	3.3
Other Hay/Non Alfalfa	1,122.2	3.1
Open Water	959	2.6
Corn	493.7	1.4
Barren	355.4	1.0
Other Crops	249.7	0.7
Sod/Grass Seed	218.4	0.6
Developed/High Intensity	183.3	0.5
Herbaceous Wetlands	97.4	0.3
Shrubland	84.7	0.2
Grass/Pasture	82.5	0.2
Total	36,497.8	100%

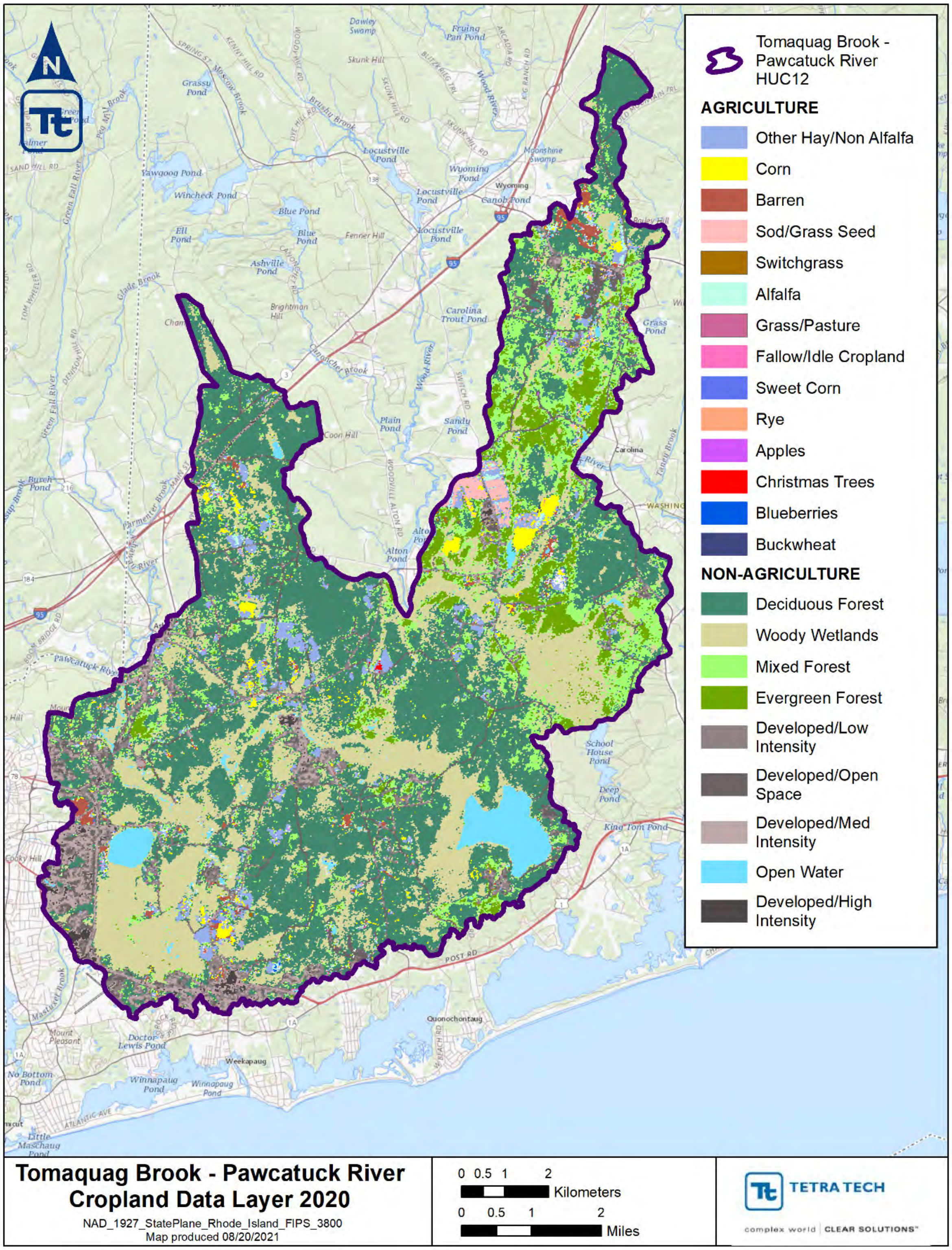


Figure 13. Land use distribution within the Tomaquag Brook-Pawcatuck River watershed (USDA NASS 2021).

Socioeconomic Conditions

The watershed spans Washington County, Rhode Island and includes the county subdivisions of Charlestown, Hopkinton, Richmond, and Westerly (Figure 14). A summary of population data for these locations can be found in Table 4. Based on the 2010 U.S. Census, the population of Washington County is approximately 125,577. The population is expected to remain similar in upcoming years. The main industries in Washington County, Rhode Island are restaurants and food services, elementary and secondary schools, and colleges, universities and professional schools, including junior colleges (U.S. Census Bureau 2020; Data USA 2018).

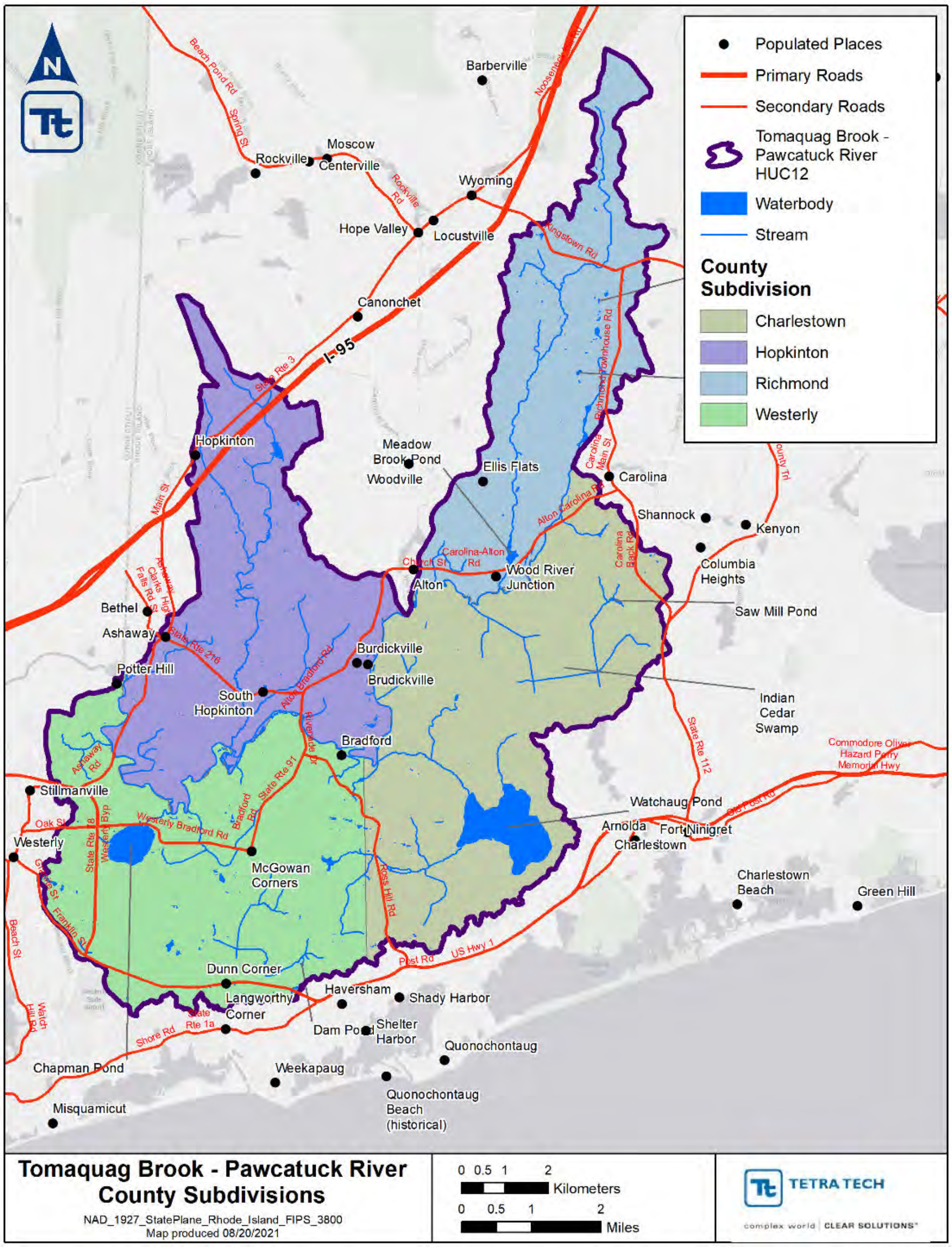


Figure 14. Map of county subdivisions within the Tomaquag Brook-Pawcatuck River watershed.

Table 4. Population data for the state, county, and towns in the Tomaquag Brook-Pawcatuck River watershed from the U.S. 2020 Census

	Rhode Island	Washington County, RI	Charlestown Town, Washington County	Hopkinton Town, Washington County	Richmond Town, Washington County	Westerly Town, Washington County
Total Population	1,097,379	129,839	7,997	8,398	8,020	23,359
Total Households	414,730	50,220	3,438	3,203	2,917	10,375

The 2017 USDA Agriculture Census indicates that there are 319 farms in Washington County that operate over approximately 19,866 acres. The average size of farm within the county is 62 acres, with the majority of farms ranging from 10–49 acres in size (USDA NASS 2017).

The total market value of products sold from these farms was $22,190,000 in 2017, with an average of $69,562 of market value of products sold per farm. Crops make up the majority of share of sales at 77% and livestock and poultry products account for the remaining 23% of share sales. Washington County agricultural sales account for 38% of sales for Rhode Island (USDA NASS 2017).

Out of the crops produced, sod occupies the most acreage, followed by forage, vegetables, corn for silage or greenchop, and sweet corn. The highest sales come from nursery, greenhouse, floriculture, and products. Out of the livestock raised, cattle and calves occupy the most acreage and aquaculture had the highest sales out of livestock products sold (USDA NASS 2017).

Other Relevant Information

The Wood-Pawcatuck watershed, which includes the Tomaquag Brook-Pawcatuck River watershed, is designated as a National Wild and Scenic River. It forms part of the longest Wild and Scenic River System in New England with 110 miles. The Pawcatuck River system has also been identified by TNC as one of the best examples of intact riverine habitat in the Lower New England ecoregion (Wood-Pawcatuck Wild and Scenic Rivers Stewardship Council 2022). In addition, the entire Wood-Pawcatuck watershed has been designated a Sole Source Aquifer by the U.S. Environmental Protection Agency (EPA) (EPA 1988).

III. Hydrologic and Water Quality Characterization

This section describes the hydrology and water quality conditions within the Tomaquag Brook-Pawcatuck River watershed. The objective is to demonstrate the transport mechanisms for pollutants of concern, and the spatial and temporal characteristics of transport. A summary of available information resources compiled for the watershed is also provided.

Available Data and Resources

TMDLs and Management Plans/Report

Table 5 summarizes available plans and reports within the Tomaquag Brook-Pawcatuck River watershed. A statewide bacteria TMDL was completed in 2011 for impaired waters and was updated in 2014. As part of the process, RIDEM also created summary reports for bacteria impaired water body segments across the state and included separate summaries on Tomaquag Brook, Meadow Brook, Mile Brook, and sections of the Pawcatuck River Segments (18C, 18D, and 18E).

The Wood-Pawcatuck Wild and Scenic Study Committee has developed a stewardship plan for eight rivers within the Wood-Pawcatuck watershed, which encompasses the Pawcatuck River within the Tomaquag Brook-Pawcatuck River HUC-12 drainage area. A flood resiliency management plan has also been created for the Wood-Pawcatuck watershed. This plan provides recommendations to protect and enhance the flood resiliency of communities and improve river and stream ecosystems, including water quality and habitat.

Data and Other Resources

Table 6 summarizes the available data and other resources within the watershed. A brief description of available data and resources is provided below.

Hydrological Data: Within the watershed, continuous daily streamflow discharge has been measured at one USGS site on the Pawcatuck River (USGS 01117500). The gaged site provides long term historical observations of discharge from 1940 to present. Another USGS site on Meadow Brook (USGS 01117600) also provides long-term historical discharge observations from 1965–1974 and 2002–2004. Short-term discharge observations (2002–2004) are also available for Perry Healy Brook (USGS 01118022).

Older flow measurements for a selection of discontinued USGS sites are also available but were not included in the compilation for this report. Streamflow discharge has also been recorded occasionally during recent water quality sampling at a number of other USGS sites. USGS has also sampled groundwater depth intermittently at numerous wells in the watershed.

Water Quality Data: Water quality data from USGS is available for a number of locations along the Pawcatuck River and Tomaquag Brook within the HUC-12 watershed area. Recent water quality measurements for 2019–2020 are available for three USGS sampling sites (USGS 01118030 - Pawcatuck River, USGS 01118100 - Pawcatuck River, USGS 01118055 - Tomaquag Brook).

Four sites (listed in Table 6) provide instantaneous water quality data during the 1955 to 2020 period. USGS site 01117500 (Pawcatuck River at Wood River Junction, RI) provides long-term water quality data from 1955 to 1996. Two additional USGS monitoring sites (USGS 01118010 on Pawcatuck River; USGS 01117600 on Meadow Brook) provide older water quality data between the 1960s and 1970s. More information on the water quality parameters measured at these sites is given in Table 6. USGS has also intermittently sampled over 130 sites for groundwater quality within the watershed.

The Wood-Pawcatuck Watershed Association (WPWA) has monitored water quality at a number of sites within the watershed from 1988 to present. Parameters measured include nutrients (nitrogen species and phosphorus species), bacteria, chloride, and pH. The results of bacteria monitoring by WPWA was also used to inform the 2011 Bacteria TMDL.

Biological Monitoring Data: Little information exists about biological monitoring within the watershed. In the summer of 2005, WPWA conducted aquatic benthic macroinvertebrate monitoring at three sites in Meadow Brook.

Other Data: Historical climate data are available for the National Oceanic and Atmospheric Administration (NOAA) Westerly State Airport, Rhode Island climate station, located in the southwest of the watershed.

Reports

Table 5. Compilation of available reports used to characterize hydrology and water quality conditions in the watershed

Title	Year Published	Author(s)	Type of Resource	Description
State of Rhode Island 2022 Impaired Waters Report	2021	Rhode Island Department of Environmental Management	Impaired Waters Report	This report includes a complete list of all impaired water bodies in Rhode Island.
State of Rhode Island 2018-2020 Impaired Waters Report	2021	Rhode Island Department of Environmental Management	Impaired Waters Report	This report includes a complete list of all impaired water bodies in Rhode Island.
Benthic Macroinvertebrate Sampling on Selected Streams in the Pawcatuck Watershed	2005	Wood-Pawcatuck Watershed Association	Biological Monitoring Report	This report includes benthic macroinvertebrate sampling data from streams in the Pawcatuck watershed.
Rhode Island Statewide Total Maximum Daily Load (TMDL) for Bacteria Impaired Waters	2011	Rhode Island Department of Environmental Management	TMDL Report	This Statewide TMDL provides a framework to address bacterial pollution by establishing the allowable bacterial contributions for Rhode Island's surface waters, providing documentation of impairment, and specifying the pollutant reductions needed to meet water quality standards.
Updates to the Rhode Island Statewide Total Maximum Daily Load (TMDL) for Bacteria Impaired Waters	2014	Rhode Island Department of Environmental Management	TMDL Report	Provides TMDL updates for six bacteria impaired water bodies on the 2012 303(d) list with the goal of providing guidance to attaining water quality standards in each water body.

Title	Year Published	Author(s)	Type of Resource	Description
Meadow Brook Bacteria TMDL	2011	Rhode Island Department of Environmental Management	TMDL Report	Water body summary TMDL report from the Rhode Island Statewide Bacteria TMDL.
Mile Brook Bacteria TMDL	2011	Rhode Island Department of Environmental Management	TMDL Report	Water body summary TMDL report from the Rhode Island Statewide Bacteria TMDL.
Pawcatuck River Segment 18C Bacteria TMDL	2011	Rhode Island Department of Environmental Management	TMDL Report	Water body summary TMDL report from the Rhode Island Statewide Bacteria TMDL.
Pawcatuck River Segment 18D Bacteria TMDL	2014	Rhode Island Department of Environmental Management	TMDL Report	Water body summary TMDL report from the Rhode Island Statewide Bacteria TMDL.
Pawcatuck River Segment 18E Bacteria TMDL	2014	Rhode Island Department of Environmental Management	TMDL Report	Water body summary TMDL report from the Rhode Island Statewide Bacteria TMDL.
Tomaquag Brook Bacteria TMDL	2011	Rhode Island Department of Environmental Management	TMDL Report	Water body summary TMDL report from the Rhode Island Statewide Bacteria TMDL.
Wood-Pawcatuck Wild and Scenic Rivers Stewardship Plan	2018	Wood-Pawcatuck Wild and Scenic Rivers Study Committee	Report	Wild and Scenic Stewardship plan for the Wood-Pawcatuck watershed and its rivers, the Beaver, Chipuxet, Green Fall-Ashaway, Queen-Usquepaugh, Pawcatuck, Shunock, and Wood.
Wood-Pawcatuck Watershed Flood Resiliency Management Plan	2017	Wood-Pawcatuck Watershed Association, Rhode Island Department of Environmental Management, National Fish and Wildlife Foundation, U.S. Department of the Interior.	Watershed Management Plan	Watershed management plan provides recommendations to protect and enhance the flood resiliency of communities in the 300-acre Wood-Pawcatuck watershed and improve river and stream ecosystems, including water quality and habitat.
Development of an Index of Biotic Integrity for Macroinvertebrates in Freshwater Low Gradient Wadeable Streams in Southeast New England Final Report	2021	Tetra Tech, New England Interstate Water Pollution Control Commission, and Restore America's Estuaries Southeast New England Program	Report	Report describing the development of a statewide low gradient multihabitat index of biotic integrity for Massachusetts. The index calibration dataset included data from 178 sites, some of which were located in Rhode Island.
Pawcatuck River Watershed HSPF Modeling Report	2022	RESPEC, Connecticut Department of Energy and Environmental Protection, and Long Island Sound Study	Report	HSPF modeling approach for the Pawcatuck River modeling project.

Data

Table 6. Compilation of available data used to characterize hydrology and water quality conditions in the watershed

Title	Year(s) of Data Included	Description	Available Data Parameters	Monitoring Frequency
Wood-Pawcatuck Water Quality Monitoring Data	1988–present	Water quality monitoring data collected by WPWA for sampling sites within the watershed.	Water quality: nutrients, sediment, bacteria, and conventional parameters	Monthly from May through October
USGS 01117500: Pawcatuck River at Wood River Junction, RI	1940–present	Flow data collected by USGS located on the Pawcatuck River within the watershed.	Streamflow Water quality: nutrients, sediment, and conventional parameters	Daily (streamflow) Grab samples intermittently (water quality)
USGS 01118030: Pawcatuck R At Alton-Bradford Rd At Bradford, RI	2019–2020	Water quality data collected by USGS located on the Pawcatuck River within the watershed.	Streamflow Water quality: nutrients, sediment, and conventional parameters	Monthly (streamflow) Monthly (water quality)
USGS-01118100 Pawcatuck River Near South Hopkinton, RI	2019–2020	Water quality data collected by USGS located on the Pawcatuck River within the watershed.	Streamflow Water quality: nutrients, sediment, conventional parameters	Monthly (streamflow) Monthly (water quality)
USGS 01118010 Pawcatuck River at Burdickville, RI	1967–2004	Water quality data collected by USGS located on the Pawcatuck River within the watershed.	Streamflow Water quality: nutrients, metals, conventional parameters	Daily (streamflow) Grab samples intermittently (water quality)
USGS 01118020 Perry Healy Brook near Bradford, RI	1966–1973	Water quality data collected by USGS located on the Perry Healy Brook within the watershed.	Streamflow	Grab samples intermittently
USGS 01118022 Perry Healy Brook, Klondike Rd., near Bradford, RI	2002–2004	Water quality data collected by USGS located on the Perry Healy Brook within the watershed.	Streamflow	Grab samples intermittently
USGS 01117600 Meadow Brook Near Carolina, RI	1965–2004	Water quality data collected by USGS located on Meadow Brook within the watershed.	Streamflow Water quality: nutrients, metals, conventional parameters	Daily (streamflow) Grab samples intermittently (water quality)
USGS-01118055 Tomaquag Brook, At RT. 216, At Bradford, RI	1991–2020	Water quality data collected by USGS located on the Tomaquag Brook within the watershed.	Streamflow Water quality: nutrients, sediment, conventional parameters	Grab samples intermittently (streamflow) Grab samples intermittently (water quality)

Title	Year(s) of Data Included	Description	Available Data Parameters	Monitoring Frequency
USGS StreamStats Tool	2020	USGS web-based geographic information systems application that provides access to additional flow statistics and estimates and previously published information for USGS.	Various stream flow statistics, groundwater recharge statistics	Daily, monthly
Base-flow index grid for the conterminous United States	2014	This 1-kilometer raster (grid) dataset for the conterminous United States was created by interpolating base-flow index (BFI) values estimated at USGS stream gages; base flow is the component of streamflow that can be attributed to groundwater discharge into streams.	Baseflow indices	N/A
Water Balance (estimated)	1960–1990	The Model My watershed model simulates 30 years of daily water fluxes using the Generalized watershed Loading Function Enhanced (GWLF-E) model that was developed for the MapShed desktop modeling application.	Average monthly water fluxes: stream flow, surface runoff, subsurface flow, evapotranspiration, precipitation	Daily
Westerly State Airport, RI climate station data	1981–2010	Climate data collected from the Westerly State Airport, RI climate station, located within the watershed.	Average precipitation, average minimum temperature, average mean temperature, average maximum temperature	Daily

Runoff and Streamflow Hydrology

Overview

Runoff and streamflow vary naturally in response to changes in the rate and timing of water inputs to a watershed (e.g., precipitation), water outputs from a watershed (e.g., evapotranspiration), and changes in watershed storage (e.g., groundwater, snow, ice). Other factors like soils, land use, and human activity also impact runoff and hydrology. Runoff and streamflow are the principal drivers of changes in water quality. The soils, geology, and hydrology of the watershed indicate that infiltration, upland recharge, and local discharge of shallow subsurface flow are important in the maintenance of stream baseflow. The section summarizes the climate and hydrologic regime in the watershed using available data and modeling tools.

Methods Used in the Analysis

Available hydrological data were used to characterize hydrology when measured data were not available:

- The *Model My Watershed* application was applied to simulate the precipitation-runoff budget for the area.
- Flow observations from USGS site 01117500 were used to characterize streamflow in the watershed.
- The ACPF was used to assess runoff risk for agricultural fields in the watershed.
- USGS flow estimations were used to assess the baseflow contributions and calculate a variety of other flow metrics for the location.
- The USGS StreamStats tool was used to estimate low flow and peak flow statistics.
- NOAA National Weather Climate data from the Westerly State Airport, Rhode Island station was used to assess climate conditions within the watershed.

Climate Data

The NOAA station at Westerly State Airport, Rhode Island, located in the southwest of the watershed (Network ID: GHCND:USW00014794; latitude/longitude: 41.34972°, -71.79889°; elevation: 81 ft), provides long-term data on climate. Table 7 summarizes temperature and precipitation data for the 1981–2010 climate period at the station (data from NOAA's Data Tools: 1981-2010 Normals). The mean monthly temperature for January was 29.1 °F and 70.9 °F for July. Monthly air temperatures range from about 20.9–37.3 °F (average minimum to average maximum) in January to 62.4–79.4 °F (average minimum to average maximum) in July (Table 7).

The average annual precipitation for this period was 47.39 inches. Average monthly precipitation ranges from 3.00–4.83 inches. Precipitation is evenly distributed throughout the year, with precipitation slightly higher in the spring and fall and occurring as high-intensity thunderstorms during the summer (NRCS 2006). Most precipitation during the winter occurs as moderate-intensity storms, or northeasters, that produce large amounts of rain or snow (NRCS 2006).

Table 7. Average temperature and precipitation measurements from Westerly State Airport, RI climate station, 1981–2010

Month	Average Precipitation (inches)	Average Minimum Temperature (°F)	Average Mean Temperature (°F)	Average Maximum Temperature (°F)
January	3.39	20.9	29.1	37.3
February	3.00	23.7	31.8	39.8
March	4.83	28.9	37.3	45.7
April	4.64	38.3	46.6	54.9
May	3.79	47.1	56.2	65.2
June	3.68	57.2	65.5	73.8
July	3.79	62.4	70.9	79.4
August	4.15	61.7	70.1	78.6
September	3.92	53.8	63.1	72.4
October	3.92	43.0	52.4	61.8
November	4.52	35.4	44.0	52.7
December	3.76	26.8	34.6	42.5
Summary	47.39 (total)	41.6 (mean)	50.1 (mean)	58.7 (mean)

Precipitation-Runoff Budget

The water balance for the watershed was generated using the Model My Watershed application (30 years of daily water balance) and shows how much of the annual average precipitation that falls on the watershed leaves as streamflow and evapotranspiration. It also indicates the proportion of streamflow provided by surface runoff and subsurface flow. Table 8 summarizes the estimated average annual and average monthly water flux. Of the approximately 47 inches of average annual precipitation falling on the watershed, 19.2 inches (41.1%) leaves as streamflow (5.9 inches surface runoff, 13.3 inches groundwater discharge), and 27.3 inches (58.5%) leaves as evapotranspiration.

Table 8. Average monthly water fluxes (units in inches) from 30-years of daily water balance (simulated by GWLF-E MapShed Model) for the watershed

Month	Stream Flow (in.)	Surface Runoff (in.)	Subsurface Flow (in.)	Evapotranspiration (in.)	Precipitation (in.)
January	**1.9**	0.9	1.0	**0.2**	**3.8**
February	**2.2**	0.9	1.3	**0.3**	**3.5**
March	**2.8**	1.0	1.8	**0.9**	**4.0**
April	**2.4**	0.5	2.0	**2.1**	**4.0**
May	**2.0**	0.2	1.8	**4.0**	**4.1**
June	**1.6**	0.2	1.4	**5.8**	**3.6**
July	**1.2**	0.1	1.1	**4.7**	**3.5**
August	**1.0**	0.2	0.8	**3.4**	**3.7**
September	**0.8**	0.2	0.6	**2.7**	**3.8**
October	**0.9**	0.4	0.5	**1.9**	**4.0**
November	**1.0**	0.5	0.5	**1.0**	**4.5**
December	**1.4**	0.7	0.7	**0.3**	**4.2**
Annual	**19.2**	5.9	13.3	**27.3**	**46.7**

Note:
A database of national-scale daily weather data was previously compiled by EPA for use in water balance simulations. These data were used to estimate daily weather data (i.e., precipitation and temperature; compiled for the time period 1960–1990) for use in driving runoff calculations.

Baseflow contributes a large proportion of streamflow in watershed. USGS has conducted baseflow modeling in the region that relates annual precipitation and recharge rates to streamflow. Analysis for Tomaquag Brook-Pawcatuck River watershed showed baseflow index rates of approximately 65–71%. As a reference, modeling suggests that baseflow indices range from about 51% (northwestern parts of the state) to approximately 71% (southwest part of the state where the watershed is located) in Rhode Island.

Streamflow

Runoff within the watershed was estimated for hypothetical 1-inch and 2-inch storm events over 24 hours using Model My Watershed. The results are displayed in Table 9. For a 2-inch storm event, 49% of the precipitation forms runoff and approximately 43% infiltrates into the soils.

Table 9. Runoff generated by hypothetical 24-hour storm events in the Tomaquag Brook-Pawcatuck River watershed (simulated by SLAMM and TR-55 algorithms in Model My Watershed)

	Water Depth (in.)		Water Volume (ft^3)	
Storm Event Precipitation Fate	**1-inch Storm Event**	**2-inch Storm Event**	**1-inch Storm Event**	**2-inch Storm Event**
Runoff	0.07	0.22	8,954,163	28,962,101
Evapotranspiration	0.2	0.2	26,753,692	26,753,692
Infiltration	0.73	1.58	96,897,624	209,495,166

Available flow data (continuous records, partial records, low flow, and peak flow) and statistics for all USGS streamflow sites in the watershed can viewed using the StreamStats tool. Only one long-term USGS flow gage (USGS 01117500) is currently maintained within the Tomaquag Brook-Pawcatuck River watershed. The site is located on the Pawcatuck River at Wood River Junction and has a contributing drainage area of 100 square miles. Annual mean daily discharges are shown in Figure 15, annual peak discharges are shown in Figure 16, and monthly mean discharges are shown in Figure 17. Over the period of record 1940–2021, monthly streamflow ranged from 11.6 cubic feet per second in September to 907.7 cubic feet per second in March. According to the USGS StreamStats tool, the maximum daily flow recorded at the gage over the period of record was 3,320 cubic feet per second, while the minimum daily flow recorded was 11 cubic feet per second.

One location on Meadow Brook (USGS 01117600) provides daily flow measurements from 1965 to 1974 and 2002 to 2004. A summary of monthly mean discharge measurements at this site are shown in Figure 18. Partial flow records also exist for Tomaquag Brook (USGS:01118055; occasional flow data from 1991 to 2020), Perry Healy Brook (USGS 01118020: peak flow, partial record; and USGS 01118022: low flow, partial record), Meadow Brook (USGS 01117600: continuous from 1965–1974 and 2002–2004), and the Pawcatuck River at Burdickville (USGS 01118010: continuous from 2002–2004).

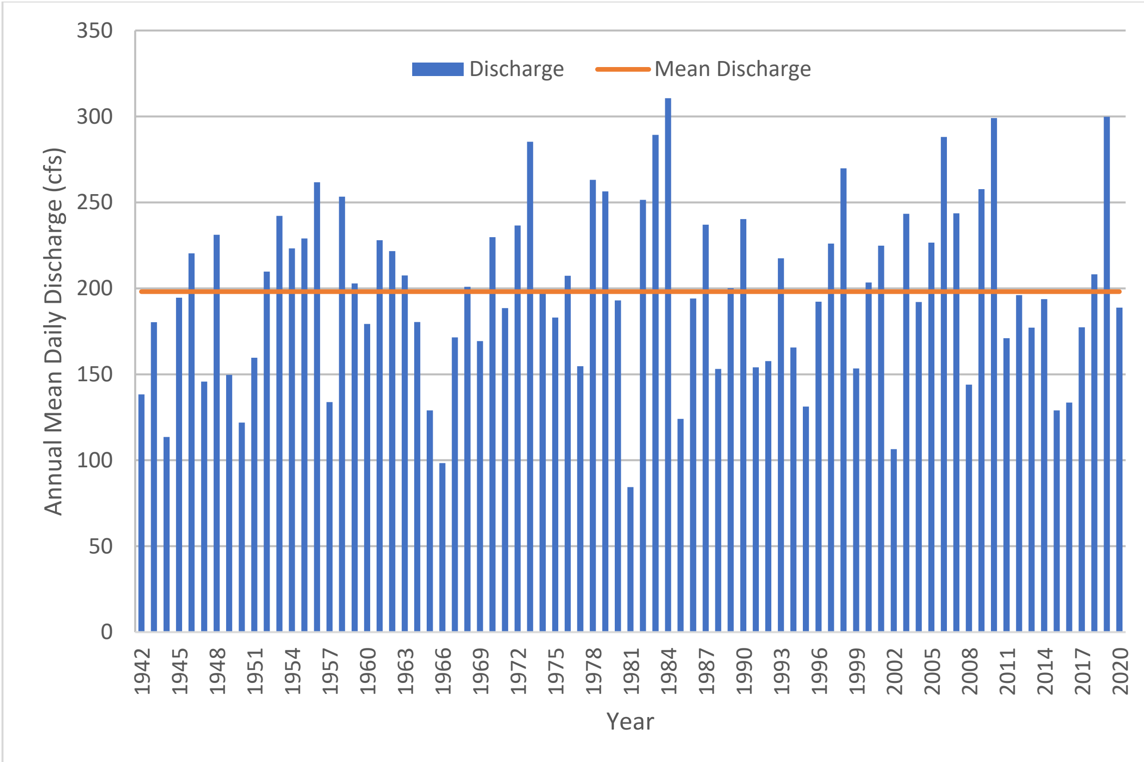


Figure 15. Annual mean daily discharge at the Pawcatuck River, Wood River Junction (USGS 01117500), 1942–2020.

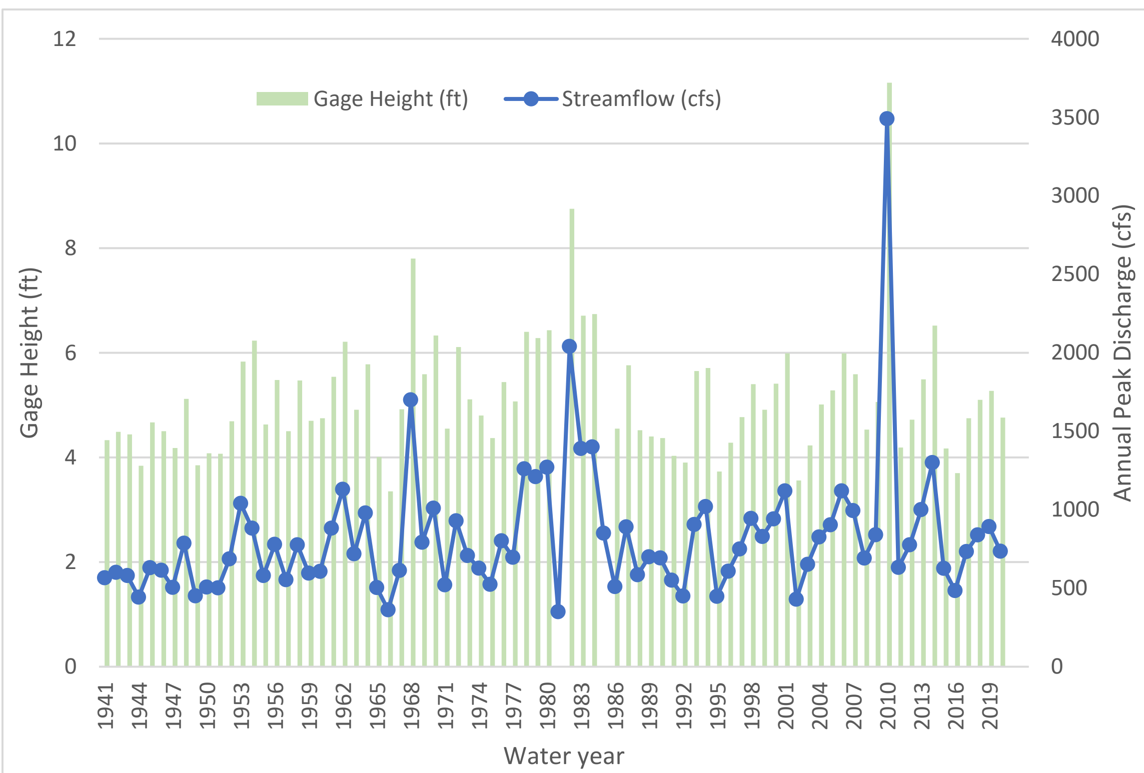


Figure 16. Annual peak discharge and gage height measurements at the Pawcatuck River, Wood River Junction (USGS 01117500), 1941–2020.

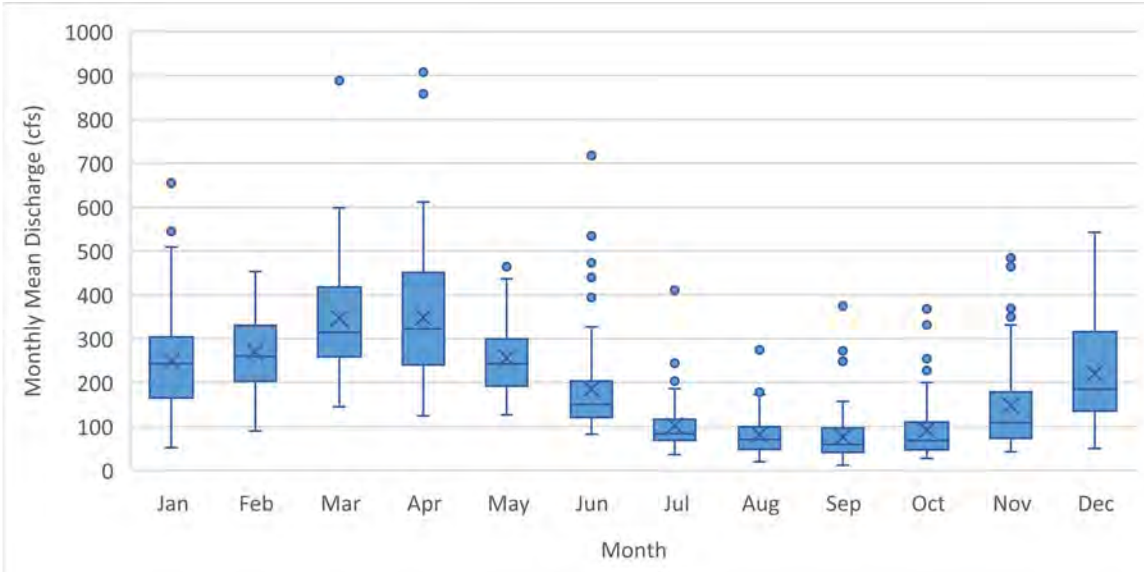


Figure 17. Monthly mean discharge measurements at the Pawcatuck River, Wood River Junction (USGS 01117500), 1941–2021; box and whisker plots show max/min (whiskers); 25th, 50th, and 75th percentiles (box); and individual values for each record (circles).

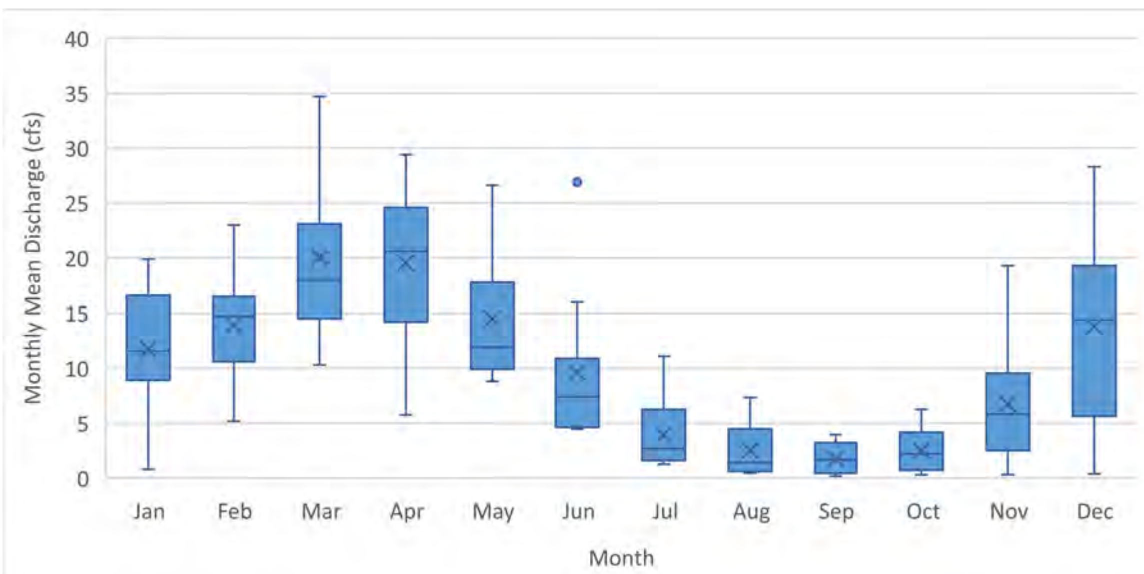


Figure 18. Monthly mean discharge measurements at Meadow Brook Near Carolina, Rhode Island (USGS 01117600), 1965–1974 and 2002–2004; box and whisker plots show max/min (whiskers); 25th, 50th, and 75th percentiles (box); and individual values for each record (circles).

Water Quality Conditions

Overview

This section reviews applicable standards, details current impairments, and assesses available water quality monitoring data for the Tomaquag Brook-Pawcatuck River watershed. Numerous stream segments exceed recreational water quality standards for *Enterococcus* (indicating the potential presence of pathogenic organisms) and have approved TMDLs (RIDEM 2021). Impairments caused by lead (part of Pawcatuck River and Perry Healy Brook) and iron (Mile Brook) have also been reported. In addition, recent water quality monitoring data for some stream sections indicates that total nitrogen (TN) and total phosphorus (TP) concentrations occasionally exceed EPA guidance. Some ponds in the watershed are impaired due to exceedances related to phosphorus, mercury (in fish tissue), and lead.

Applicable Water Quality Standards

Water quality standards serve as the basis for the state's water quality management program. They define the goals for a water body by designating its uses, setting criteria to protect those uses, and establishing provisions to maintain and protect water quality from pollutants. The standards are composed of three parts: designated uses, water quality criteria, and antidegradation. Each of these components is briefly discussed below.

Surface Water Classes and Designated Uses

As described in the state's water quality standards (RIDEM 2020), all surface waters are assigned to one of four freshwater classes (AA, A, B, B1) or one of three saltwater classes (SA, SB, SB1) (see RIDEM 2020). Freshwaters in the Tomaquag Brook-Pawcatuck River watershed have been assigned to Class A, Class B, and Class B1 (see Figure 19). Table 10 summarizes the freshwater classes that are applicable in the watershed.

Table 10. Designated uses for the Tomaquag Brook-Pawcatuck River watershed (source: RIDEM 2020)

Classification	Designated Uses from Regulation ***250-RICR-150-05-1***
Class A	These waters are designated for primary and secondary contact recreational activities and for fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have excellent aesthetic value.
Class B	These waters are designated for fish and wildlife habitat and primary and secondary contact recreational activities. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value.
Class B1	These waters are designated for primary and secondary contact recreational activities and fish and wildlife habitat. They shall be suitable for compatible industrial processes and cooling, hydropower, aquacultural uses, navigation, and irrigation and other agricultural uses. These waters shall have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges. However, all Class B criteria must be met.

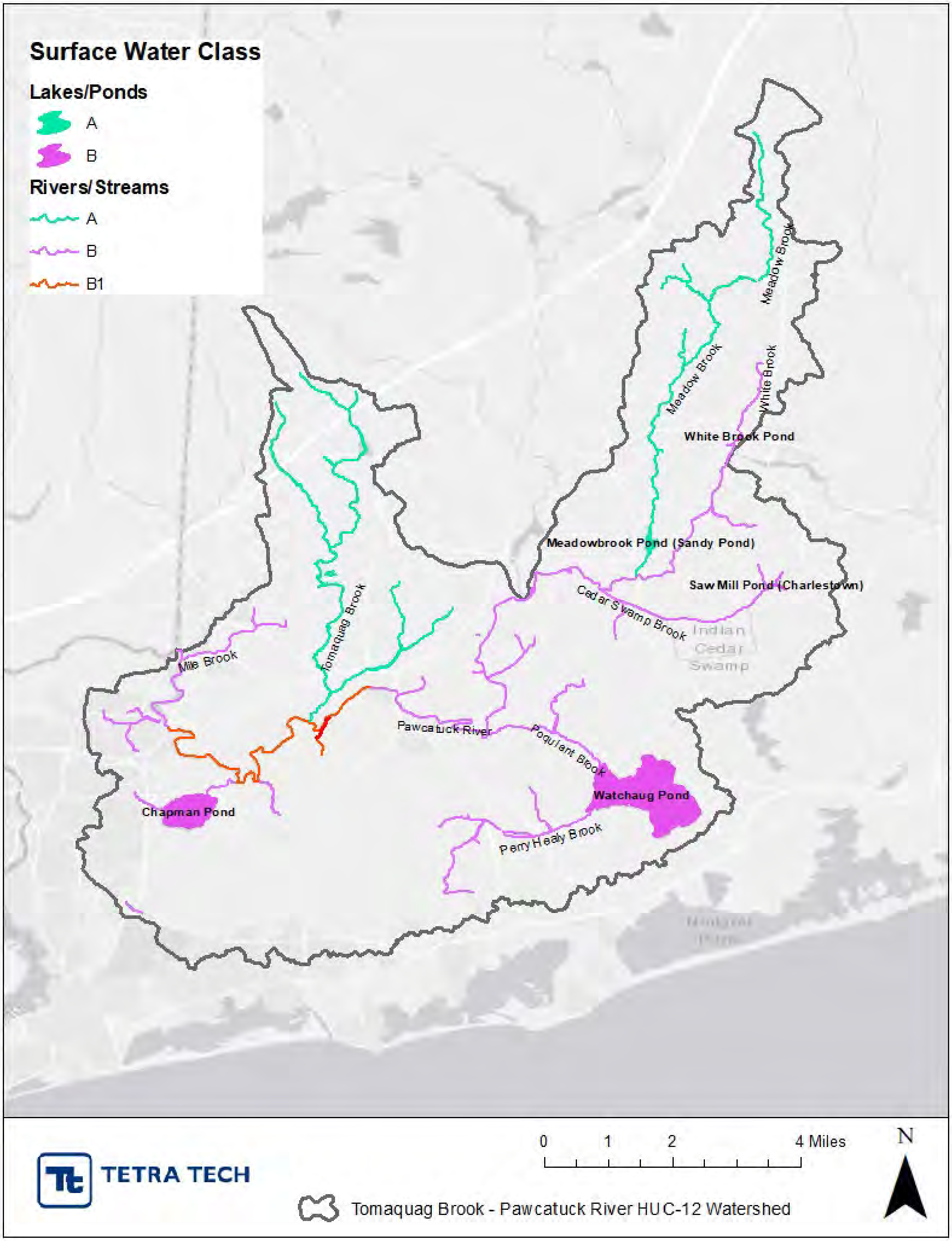


Figure 19. Surface water classifications for the Tomaquag Brook-Pawcatuck River watershed.

Water classes are in turn defined by the designated uses. Designated uses are the desirable uses that surface waters should support such as swimming (i.e., primary contact recreation) and fishing (i.e., aquatic life). Table 11 summarizes the designated uses and associated water classes that are applicable to the watershed (all uses are outlined in Rhode Island's state surface water quality regulations *250-RICR-150-05-1*). Freshwaters in the Tomaquag Brook-Pawcatuck River watershed are assigned to classes A, B, and B1 and therefore should support fish and wildlife habitat and primary and secondary contact recreational activities.

Table 11. Designated uses and applicable surface water classes for surface waters in the Tomaquag Brook-Pawcatuck River watershed (source: RIDEM 2021)

Designated Use	Description	Applicable Surface Water Class
Primary Contact Recreation	Swimming, water skiing, surfing and similar water contact activities where a high degree of bodily contact with the water, immersion and ingestion are likely.	A, B, B1
Secondary Contact Recreation	Boating, canoeing, fishing, kayaking or other recreational activities in which there is minimal contact by the human body with the water and the probability of immersion and/or ingestion of the water is minimal.	A, B, B1
Fish and Wildlife Habitat	Waters suitable for the protection, maintenance, and propagation of a viable community of aquatic life and wildlife.	A, B, B1

Relevant Water Quality Criteria (Nutrients, Sediment, Bacteria)

The second major component of the Rhode Island water quality standards is the criteria intended to protect the designated uses of all surface waters. Criteria can be expressed in either numeric or narrative form. A water body that meets the criteria for its assigned classification is considered to meet its intended use.

A summary of applicable water quality standards found for key water quality parameters in the NWQI assessment area are given in Table 12. More details can be found in Rhode Island's Water Quality Regulations (*250-RICR-150-05-1*) and in Rhode Island's *2022 Consolidated Assessment and Listing Methodology (CALM) for Section 305(B) and 303(D) Integrated Water Quality Monitoring and Assessment Reporting*.

The regulations do not contain numeric criteria for nutrients and sediment in rivers or estuarine waters. However, numeric water quality criteria for total phosphorus (TP) have been adopted in lakes and tributaries at the point they enter lakes. TP may be listed as the suspected cause of impairment in freshwater rivers with persistent eutrophication and/or low dissolved oxygen (RIDEM 2021). The state's regulations also contain narrative nutrient criteria for nutrient concentrations associated with cultural eutrophication that cause undesirable or nuisance aquatic vegetation or render waters unsuitable for the designated uses.

For bacteria, Rhode Island primarily uses enterococci to determine risk associated with primary and secondary contact recreation activities in freshwater. Sections 1.10(D)(1) and 1.10(E)(1) of Rhode Island's *Water Quality Regulations* (RIDEM 2020) identify two types of recreational uses:

1. Primary Contact Recreation defined as "those water-related recreational activities that involve significant ingestion risks and includes, but is not limited to, swimming, diving, surfing, and water skiing."
2. Secondary Contact Recreation defined as "those water-related recreational activities where the probability of water ingestion is minimal and includes, but is not limited to, boating and fishing."

The water quality standards have maintained fecal coliform criteria for use in evaluating swimming use when adequate enterococci data are not available. In some freshwaters where *Escherichia coli* (*E. coli*) data are available, the EPA criteria for this indicator is used to evaluate exceedances.

Table 12. Applicable water quality standards in the Tomaquag Brook-Pawcatuck River watershed (source: RIDEM 2020)

Water Quality Parameter	**Water Quality Criteria**	**Comment**
Total Phosphorus	Numeric: Average TP < 0.025 mg/L in any lake, pond, kettle hole or reservoir, and tributaries at the point where they enter such bodies of water. Narrative: None in such concentration that would impair any usages specifically assigned to said class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedance of the criterion above in a downstream lake, pond, or reservoir.	Exception if as naturally occurs
Nitrogen	Narrative: None in such concentration that would impair any usages specifically assigned to said class, or cause undesirable or nuisance aquatic species associated with cultural eutrophication, nor cause exceedance of the criterion above in a downstream lake, pond, or reservoir.	
Turbidity	Narrative: None in such concentrations that would impair any usages specifically assigned to this class. Turbidity not to exceed 5 NTU over background.	
Bacteria – Fecal Coliform	Primary Contact Recreation: • Geometric mean < 200 MPN/100 mL • No more than 10% of the total samples taken > 400 MPN/100 mL	Applied only when adequate enterococci data are not available
Bacteria – Enterococci	**Primary Contact Recreation:** • Non-designated bathing beach waters geometric mean density: 54 colonies/100 mL	Only applies May through October

Water Quality Parameter	Water Quality Criteria	Comment
Dissolved Oxygen	Cold Water Fish Habitat: • Daily average ≥ 75% saturation • Instantaneous minimum 5 mg/L	Exception if naturally occurs
	Cold water fish spawning areas; early life stages not directly exposed to the water column: • 7 day mean ≥ 9.5 mg/L • Instantaneous minimum ≥ 8 mg/L	October 1 to May 14
	Cold water fish spawning areas; early life stages exposed to the water column: • 7 day mean ≥ 6.5 mg/L • Instantaneous minimum ≥ 5.0 mg/L	October 1 to May 14
	Warm Water Fish Habitat: • Daily average ≥ 60% saturation • Instantaneous minimum 5.0 mg/L • 7 day mean ≥ 6 mg/L	Exception if naturally occurs
pH	6.5–9.0 pH units or as naturally occurs	
Lead	Freshwater acute hardness-based equation: • $[1.46203 - [(\ln \text{hardness}) \times 0.145712]] \times e^{1.273 [\ln \text{Hardness}]-1.46)}$ Freshwater chronic hardness-based equation: • $[1.46203 – [(\ln \text{hardness}) \times 0.145712]] \times e^{1.273 [\ln \text{Hardness}]-4.705)}$	When an ambient hardness of less than 25 mg/L is used, the hardness dependent conversion factor (1.46203 - [(ln hardness) x 0.145712]) should not exceed one
Iron	Freshwater aquatic life, chronic: 1000 µg/L Human health, consumption of water and aquatic organisms: 300 µg/L	
Mercury (in fish tissue)	Freshwater aquatic life, acute: 1.4 µg/L Freshwater aquatic life, chronic: 0.012 µg/L	Note that 0.012 µg/L is the CWA-effective freshwater aquatic life chronic value. EPA has not approved the state-effective, revised freshwater aquatic life chronic value of 0.77 µg/L.

Antidegradation

The third component of water quality standards is antidegradation, which is a provision designed to preserve and protect the existing beneficial uses and to minimize degradation of the state's surface waters (Part 250-RICR-150-05-1.20 of Rhode Island's Surface Water Quality Regulations).

Antidegradation applies to "to all projects or activities subject to these regulations which will likely lower water quality or affect existing or designated water uses, including but not limited to all Water Quality Certification reviews and any new or modified RIPDES permits." The antidegradation regulations consist of four tiers of water quality protection:

- Tier 1: Protection of Existing Uses
- Tier 2: Protection of Water Quality in High Quality Waters
- Tier 2½: Protection of Water Quality for Special Resource Protection Waters (SRPWs)
- Tier 3: Protection of Water Quality for Outstanding National Resource Waters (ONRWs)

Impairments

The recent *State of Rhode Island 2022 Impaired Waters Report* provides information about impaired water bodies in the Tomaquag Brook-Pawcatuck River watershed. Table 13 summarizes impaired water bodies within the watershed and lists the causes of impairments based on the 2018–2020 report (RIDEM 2021). Parts of the Pawcatuck River, Tomaquag Brook, Mile Brook, Meadow Brook, Perry Healy Brook, and other unnamed tributaries are impaired due to excessive levels of bacteria (*Enterococcus*). TMDLs have been approved for most of these sections. Impairments due to high levels of metals, such as of iron and lead, are also evident for some stream segments (see Table 13). Figure 20 shows the location of impaired assessment units within the waters based on information from the 2022 impaired waters report.

Table 13. List of impaired water bodies within the Tomaquag Brook-Pawcatuck River watershed

Water body ID (WBID)	Water body Name	Impairments (Category)
RI0008039R-13	Meadow Brook	*Enterococcus* (4A)
RI0008039R-14	Mile Brook	*Enterococcus* (4A), Iron (5)
RI0008039R-18C	Pawcatuck River	*Enterococcus* (4A)
RI0008039R-18D	Pawcatuck River	*Enterococcus* (4A)
RI0008039R-18E	Pawcatuck River	Lead (5); *Enterococcus* (4A); non-native aquatic plants (4C)
RI0008039R-19	Perry Healy Brook	*Enterococcus* (5); Lead (5)
RI0008039R-24	Tomaquag Brook	*Enterococcus* (4A)
RI0008039L-26	White Brook Pond	Phosphorus, Total (5)
RI0008039L-05	Meadowbrook Pond (Sandy Pond)	Mercury in fish tissue (4A); non-native aquatic plants (4C)
RI0008039L-02	Watchaug Pond	Mercury in fish tissue (4A)
RI0008039L-01	Chapman Pond	Lead (5); non-native aquatic plants (4C); Phosphorus, Total (5)

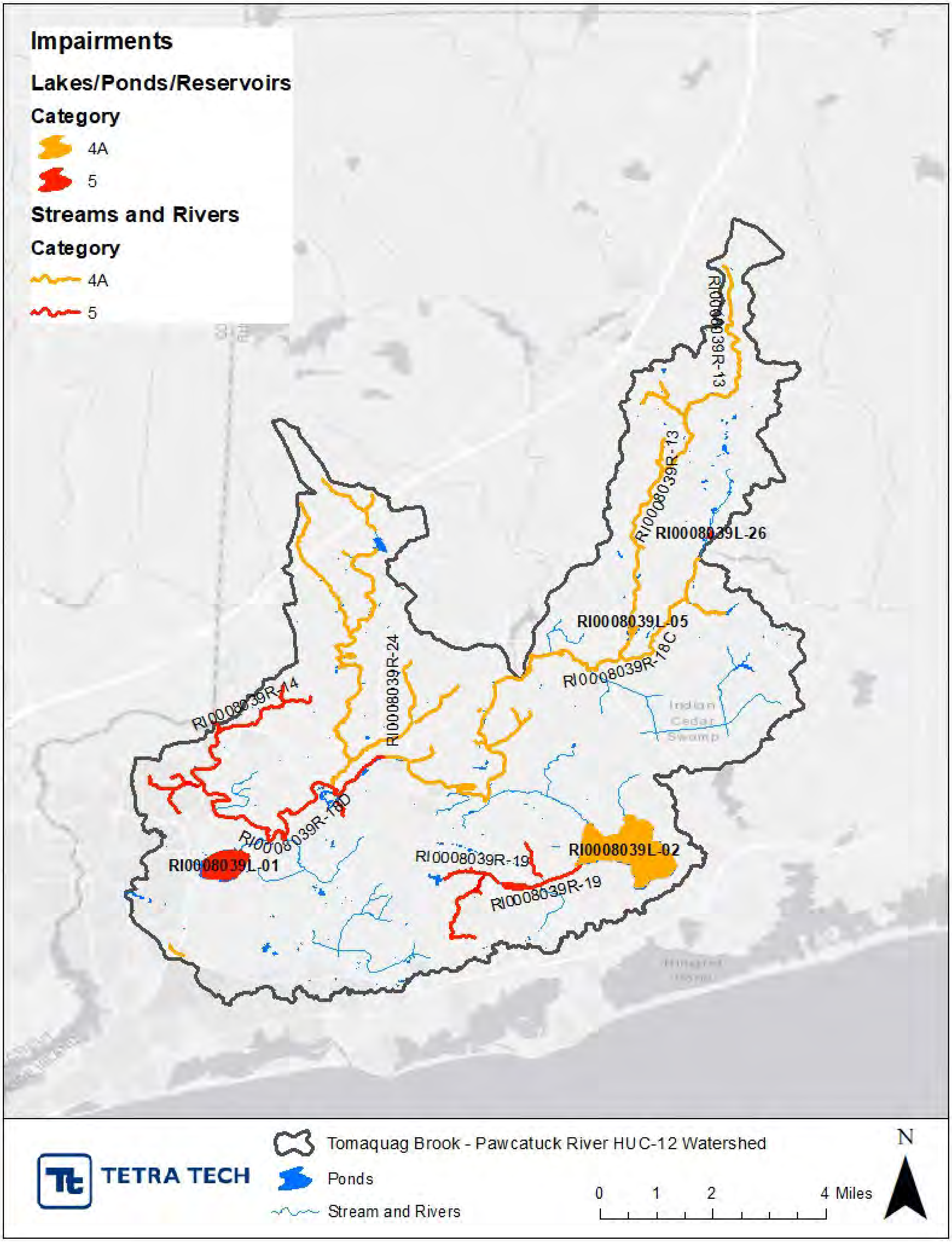


Figure 20. Impaired water bodies in the Tomaquag Brook-Pawcatuck River watershed. Impairment classes include 4A: Impaired water body with approved TMDL and 5: Impaired water body requiring a TMDL.

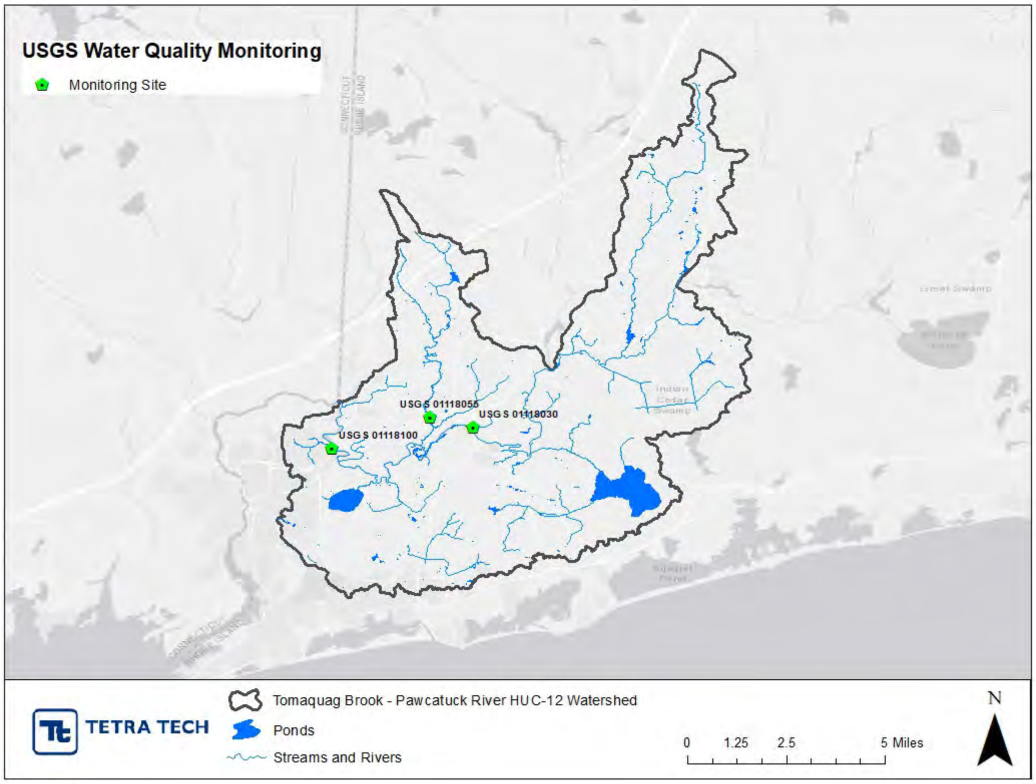
Water Quality Monitoring

Available Data and Site Locations

A selection of available water quality data are used to characterize current conditions in the Tomaquag Brook-Pawcatuck River watershed. Nutrients, sediment, and other water quality parameters have been monitored from May 2019 to June 2020 at three USGS stream sites:

- USGS 01118055: Tomaquag Brook at RT. 216, At Bradford, Rhode Island
- USGS 01118030: Pawcatuck River at Alton-Bradford Rd At Bradford, Rhode Island
- USGS 01118100: Pawcatuck River Near South Hopkinton, Rhode Island

Additionally, bacteria monitoring has been conducted by RIDEM and WPWA at a number of other stream locations since the mid-2000s. A selection of this monitoring data was used to characterize microbial water quality for three impaired water bodies within the Tomaquag Brook-Pawcatuck River watershed (RI0008039R-18C at sampling sites WW252, WW249, and WW31; RI0008039R-24 at sampling site WW310; and RI0008039R-19 at sampling site WW133). Figure 21 displays the locations of the water quality monitoring sites used to assess current conditions in the watershed.



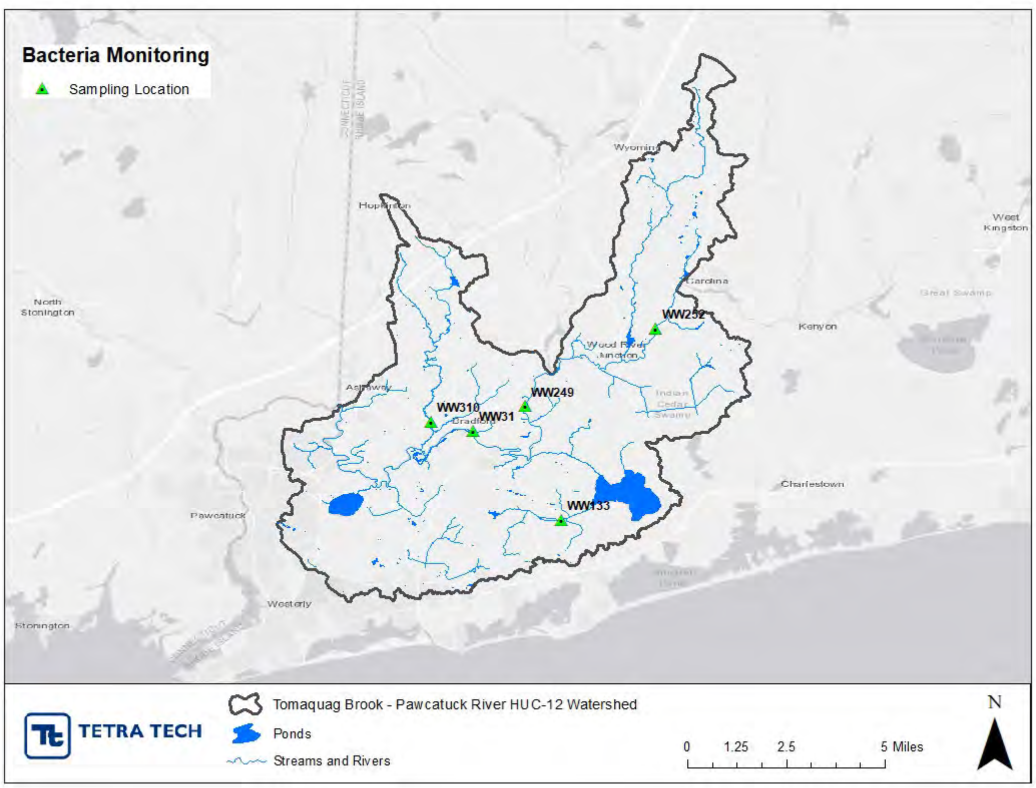


Figure 21. Location of USGS monitoring sites (top) and bacteria monitoring sites (bottom; RIDEM and WPWA) within the Tomaquag Brook-Pawcatuck River watershed.

Rivers and Streams

Total Phosphorus: observed TP concentrations at USGS sites are displayed in Figure 22, Figure 23, and Figure 24. TP concentrations ranged from 0.024 to 0.1055 mg/L at USGS 01118055 (Figure 22), 0.02 to 0.0795 mg/L at USGS 01118030 (Figure 23), and 0.02 to 0.099 mg/L at USGS 01118100 (Figure 24). The level III ecoregion derived guidance TP concentration was occasionally exceeded at these sites. Median TP concentrations at all locations between May 2019 and June 2020 exceeded the EPA derived level III ecoregion guidance (reference condition for level III ecoregion 59 streams) of 0.02375 mg/L.

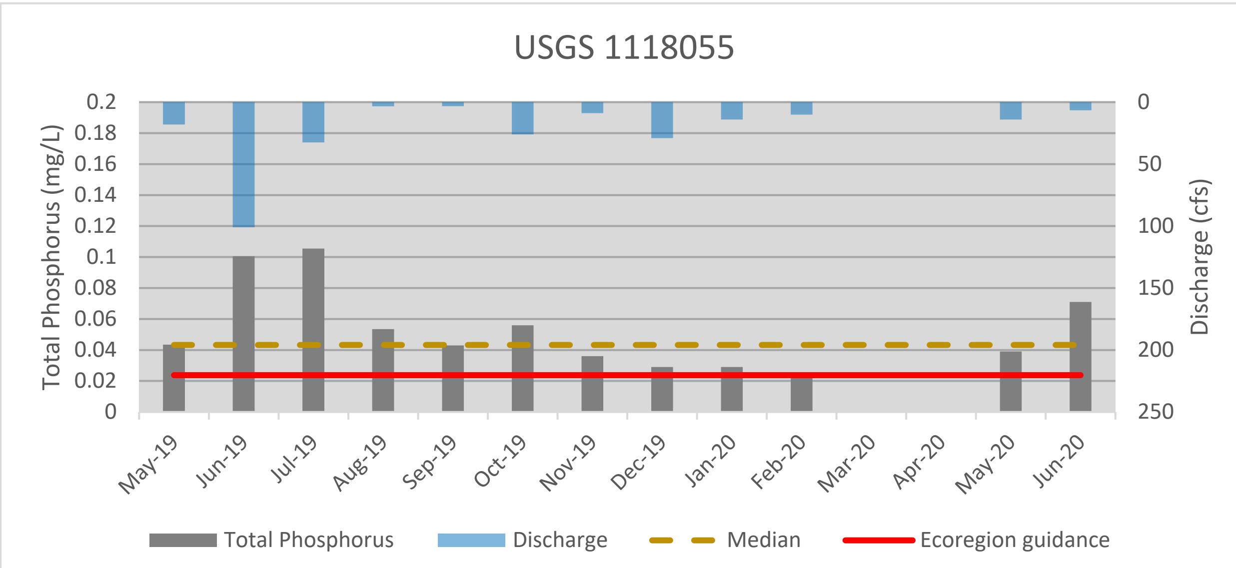


Figure 22. Observed total phosphorus concentrations from May 2019 to June 2020 at USGS 01118055 (Tomaquag Brook).

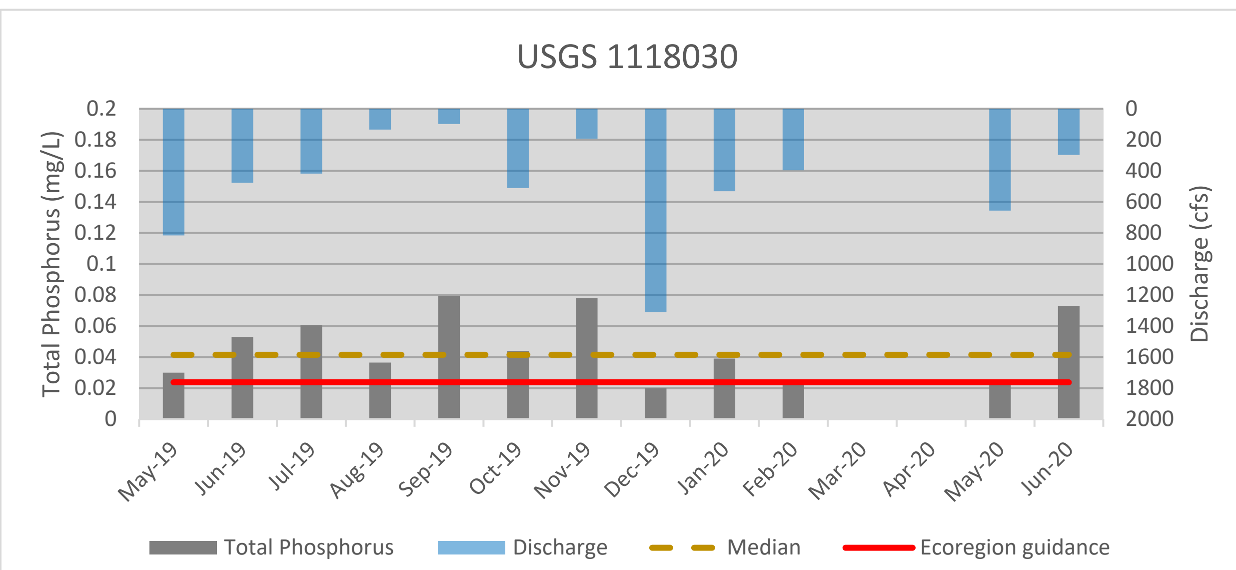


Figure 23. Observed total phosphorus concentrations from May 2019 to June 2020 at USGS 01118030 (Pawcatuck River at Alton-Bradford Rd at Bradford).

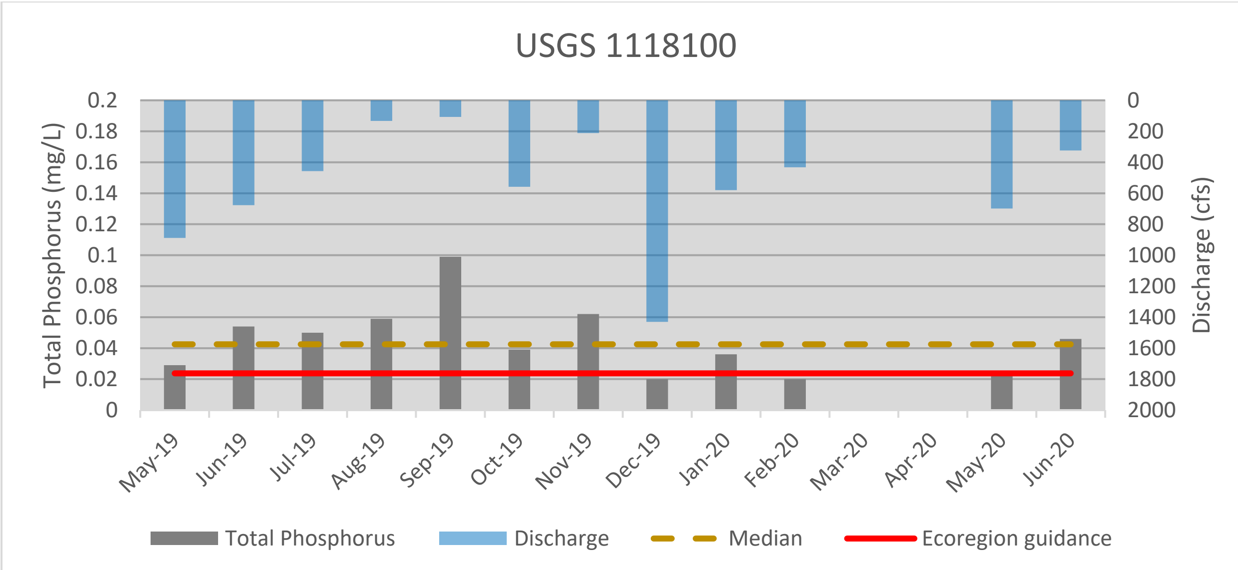


Figure 24. Observed total phosphorus concentrations from May 2019 to June 2020 at USGS 01118100 (Pawcatuck River near South Hopkinton).

Total Nitrogen: observed TN concentrations at USGS sites are displayed in Figure 25, Figure 26, and Figure 27. TN concentrations ranged from 0.55 to 1.3 mg/L at USGS 01118055 (Figure 25), 0.4 to 1.065 mg/L at USGS 01118030 (Figure 26), and 0.46 to 1.2 mg/L at USGS 01118100 (Figure 27). The EPA level III ecoregion guidance of 0.61 mg/L (reference condition for level III ecoregion 59 streams) was frequently exceeded at the three sites between May 2019 and June 2020. Median TN concentrations were equal to or exceeded ecoregion derived criteria at all sites between May 2019 and June 2020.

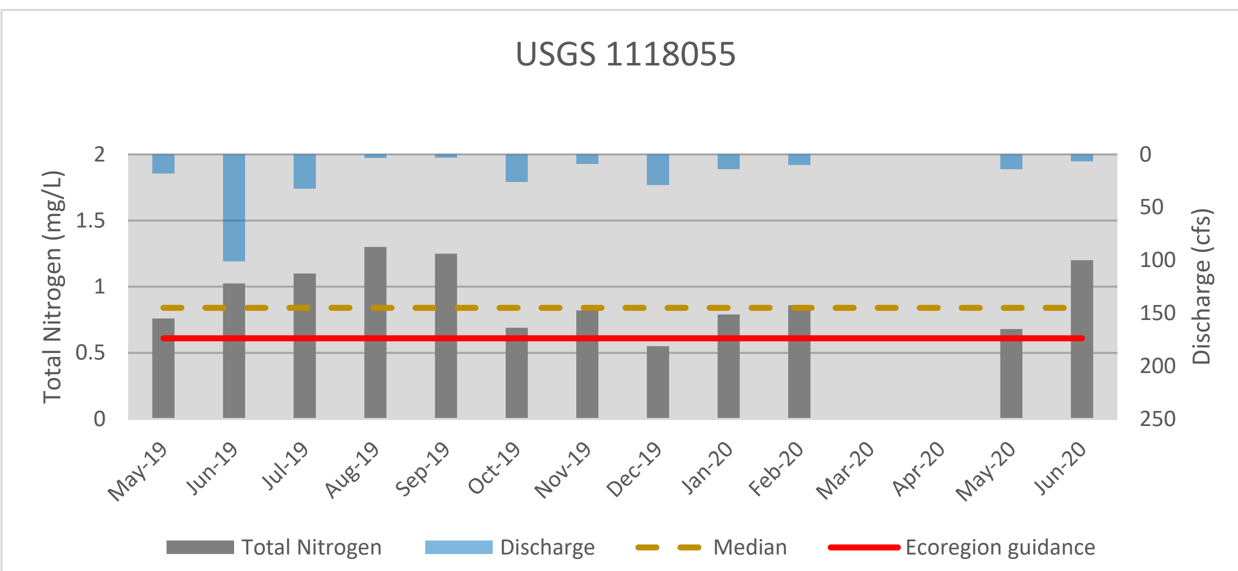


Figure 25. Observed total nitrogen concentrations from May 2019 to June 2020 at USGS 01118055 (Tomaquag Brook).

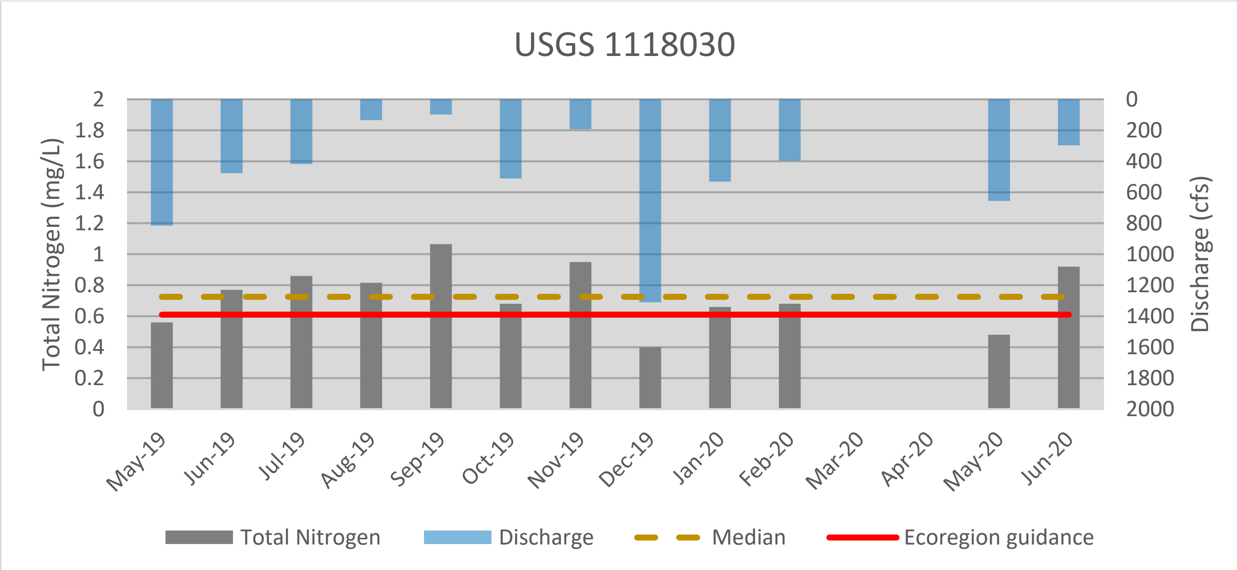


Figure 26. Observed total nitrogen concentrations from May 2019 to June 2020 at USGS 01118030 (Pawcatuck River at Alton-Bradford Rd at Bradford).

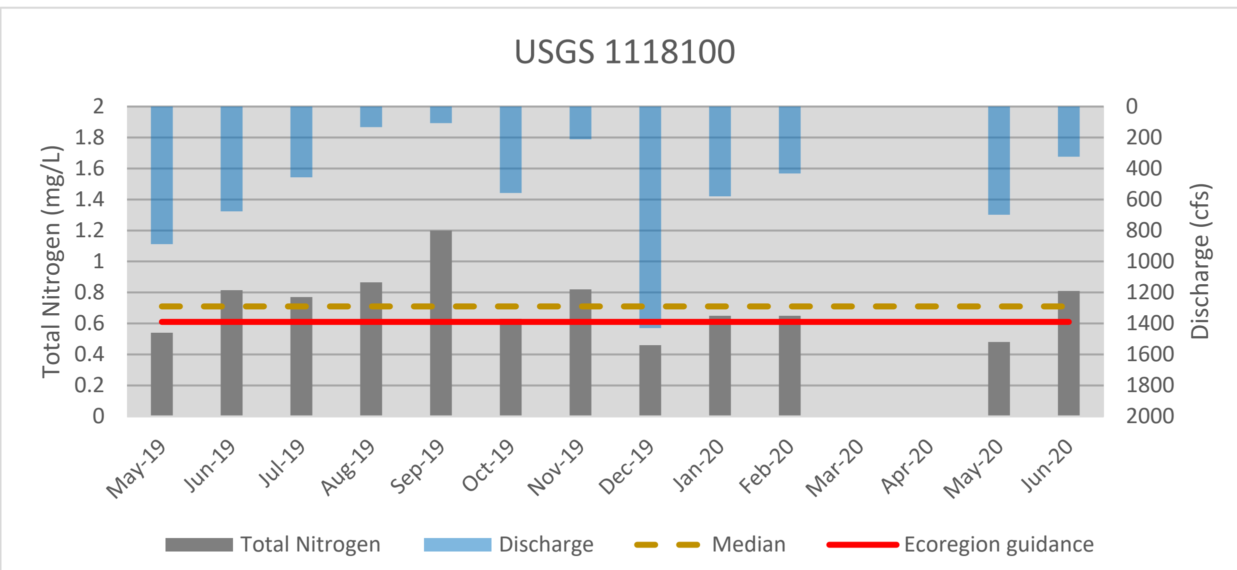


Figure 27. Observed total nitrogen concentrations from May 2019 to June 2020 at USGS 01118100 (Pawcatuck River near South Hopkinton).

Total Suspended Solids: measurements for total suspended solids at all three USGS sites were below the detection limit based on available data between May 2019 and June 2020.

Bacteria (*Enterococcus*): *Enterococcus* monitoring at three sites along the Pawcatuck River (RI0008039R-18C) are presented in Figure 28. At the site WW252 (upstream), *Enterococcus* concentrations ranged from 2.0 to 1,376.4 MPN/100 mL between 2006 and 2020. The annual geometric mean concentration prior to TMDL development ranged from 37.7 to 168.3 MPN/100 mL. From 2012 to 2020, the annual geometric mean *Enterococcus* concentration ranged from 17.3 to 76.6 MPN/100 mL.

Enterococcus concentrations at site WW31 (downstream) ranged from 2.0 to 613.1 MPN/100 mL between 2006 and 2017. The annual geometric mean concentration at this downstream site ranged from 23.4 to 117.9 MPN/100 mL prior to TMDL development (pre-2012), and 28.1 to 50.9 MPN/100 mL post 2012. The observed annual geometric mean concentration at all three sites along RI0008039R-18C has been below the primary contact recreation criterion of 54 MPN/100 mL in recent years.

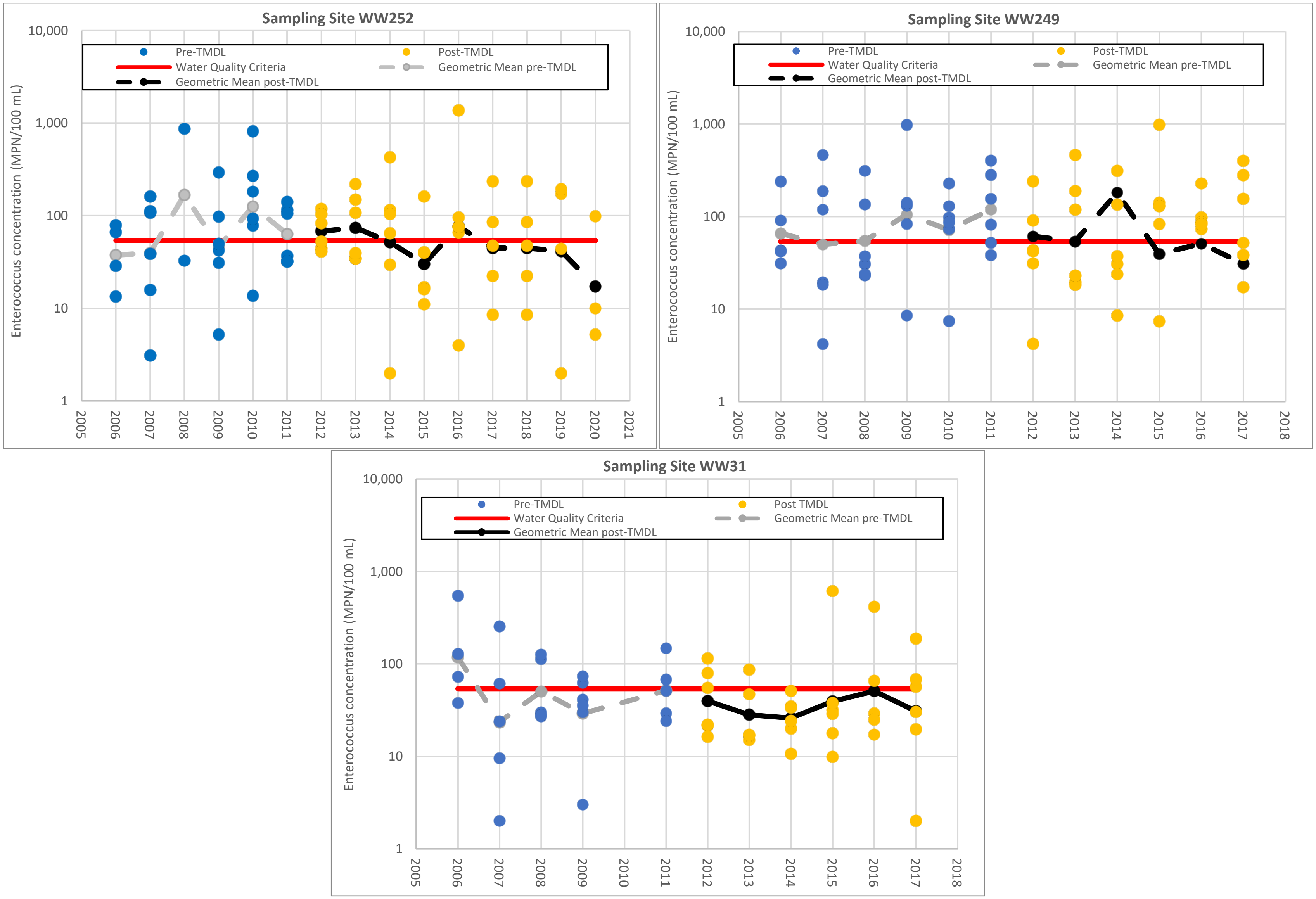


Figure 28 Observed Enterococcus concentrations measured by WPWA between 2006–2020 at sites on WBID RI0008039R-18C (Pawcatuck River). The three sampling site figures are listed from upstream to downstream (left to right).

Figure 29 displays *Enterococcus* concentrations at site WW310, located on Tomaquag Brook (WBID RI0008039R-24). Values at the site ranged from 7.5 to 4,839.2 MPN/100 mL between 2006 and 2020. The annual geometric mean concentration prior to TMDL development at this site ranged from 110.6 to 245.1 MPN/100 mL. From 2012 to 2017, the annual geometric mean concentration ranged from 73.4 to 133.7 MPN/100 mL. Observed annual geometric mean concentrations were above the state's primary contact recreation criterion of 54 MPN/100 mL.

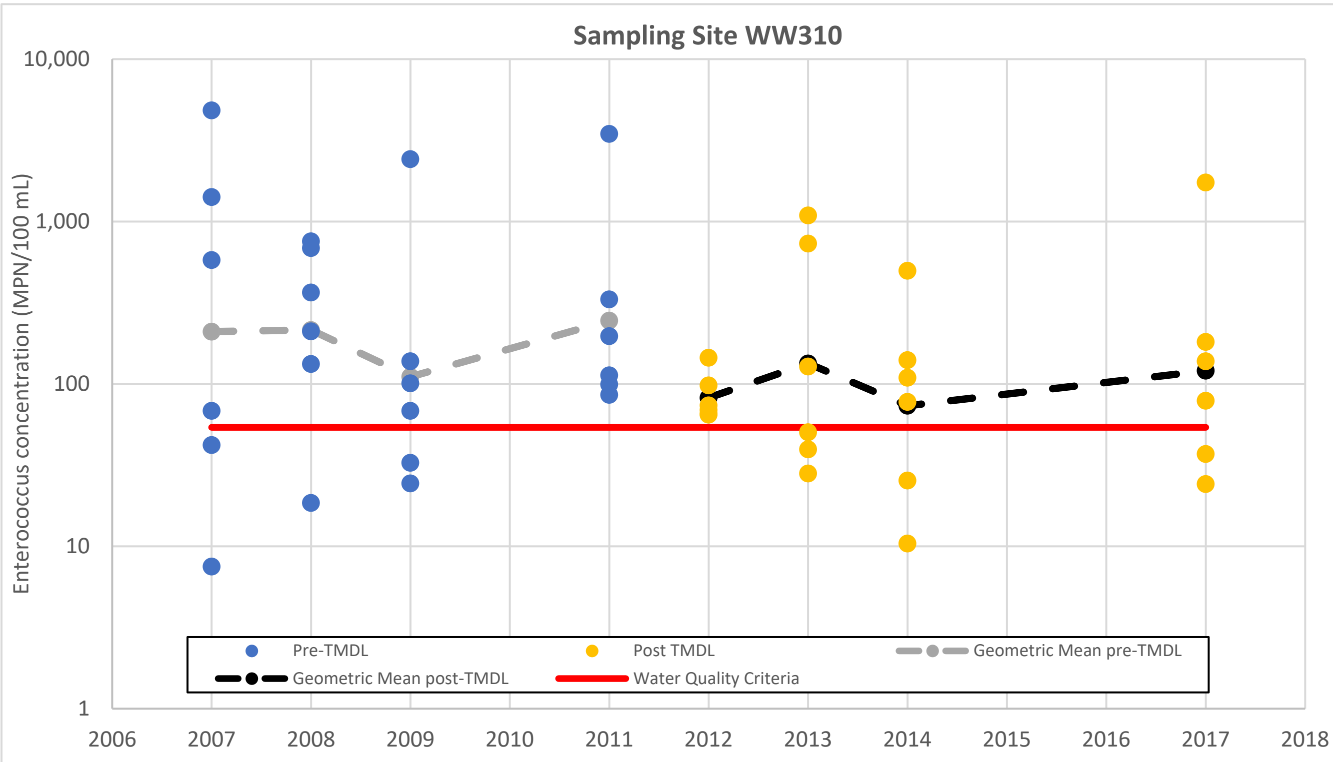


Figure 29. Observed Enterococcus concentrations measured by WPWA between 2007–2017 at one site on WBID RI0008039R-24 (Tomaquag Brook).

Figure 30 displays *Enterococcus* concentrations at site WW133, located in Perry Healy Brook (WBID RI0008039R-19). *Enterococcus* concentrations at the site ranged from 1.0 to 4,840.0 MPN/100 mL between 2006 and 2020. The annual geometric mean concentration prior to TMDL development ranged from 16.9 to 138.1 MPN/100 mL at this site. Between 2012 and 2017, the annual geometric mean *Enterococcus* concentration ranged from 55.8 to 116.3 MPN/100 mL and was above the state primary contact recreation criterion of 54 MPN/100 mL.

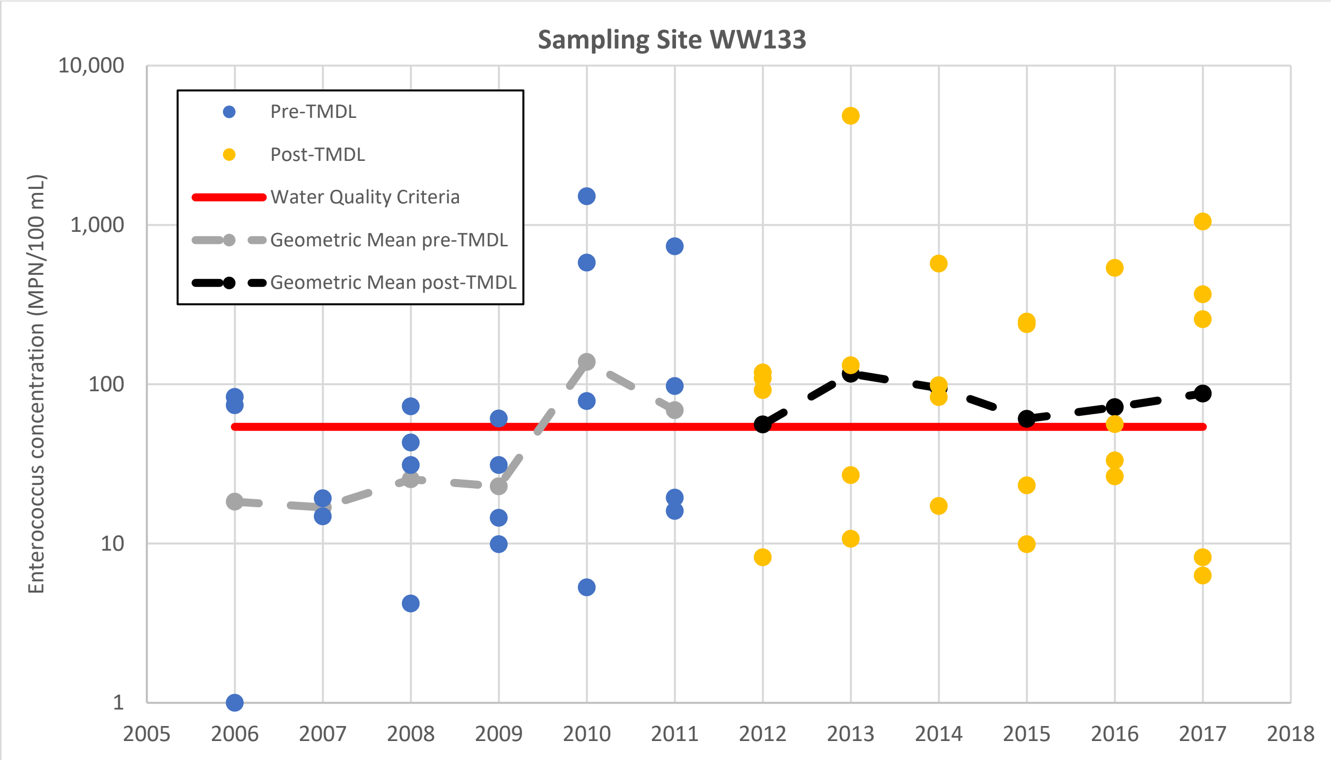


Figure 30. Observed Enterococcus concentrations measured by WPWA between 2006–2017 at one site on WBID RI0008039R-19 (Perry Healy Brook).

Other Water Quality Parameters: a summary of observations for other conventional water quality parameters at the three USGS sites is provided in Table 14. The median pH at all three of the USGS sites is below the criteria range for water classes that appear in the watershed (classes A, B, B1). Observed dissolved oxygen concentrations met instantaneous minimum criteria at all three sites. Rhode Island does not have criteria for specific conductance. Median turbidity meets the criteria at all locations, even if background levels are 0 NTU. Observed temperatures at sites on the Pawcatuck River were below the 83 °F (28.3 °C) threshold for warmwater habitat. The median temperature for Tomaquag Brook (considered a cold water habitat) was also below the applicable criteria (68 °F, or 20 °C) for cold water habitats.

Table 14. Summary of additional observations for conventional water quality parameters at USGS sites USGS 01118055, 01118030, and 01118100

Parameter	Tomaquag Brook (USGS 01118055)		Pawcatuck River at Bradford (USGS 01118030)		Pawcatuck River near South Hopkinton (USGS 01118100)		Criteria
	Range	Median	Range	Median	Range	Median	
pH	5.8–7	6.4	5.3–7.1	6.3	5.4–7	6.4	6.5–9.0
Dissolved Oxygen (mg/L)	7.1–12.5	8	7.3–12.6	9	6.8–13.2	8.4	Variable; see Table 12. Instantaneous minimum 5.0 mg/L.
Specific Conductance (µS/cm)	78–156	124	87–142	104	77–147	107	N/A
Turbidity (NTU)	1.4–9.2	2.9	1.2–6.2	1.9	1.3–6.3	2	Class A: 5 NTU over background Classes B, B1: 10 NTU over background
Water Temperature (°C)	2.9–20.9	16	3.3–22.9	18.5	3.5–23.7	18.6	Variable. See WQS (RIDEM 2020).

Ponds

Monitoring data for Chapman Pond (1988–2017), Watchaug Pond (1988–2017), and White Brook Pond (2004–2008) is available from WPWA. A summary of recent water quality monitoring data for these ponds is shown in Table 15.

Mean TP values for White Brook Pond and Chapman Pond were above the state standard. Both ponds are currently listed as impaired due to exceedances of TP. Mean TN values for all three ponds were above the EPA's 320 µg/l (level III ecoregion; Eastern Coastal Plain) guidance for lakes and reservoirs. Mean pH concentrations for White Brook Pond and Watchaug Pond were slightly below the RIDEM threshold standard of 6.5–9.0.

Table 15. Summary of water quality monitoring results for Chapman Pond, Watchaug Pond, and White Brook Pond

Parameter	Chapman Pond (2002–2017)		White Brook Pond (2004–2008)		Watchaug Pond (2002–2017)		Thresholds
	Range	Mean	Range	Mean	Range	Mean	
Total Phosphorus (µg/L)	8–93	**27**	12–87	**45**	2–27	11	RIDEM: Average TP < 25 µg/L
Dissolved Phosphorus (µg/L)	2–15	6	8–65	24	2–10	4	N/A
Total Nitrogen (µg/L)	450–2,840	**925**	900–3,240	**1711**	210–650	**425**	Level III Ecoregion Guidance: 320 µg/L
Nitrate (µg/L)	8–447	72	20–2,320	1203	3–90	22	N/A
Ammonium (µg/L)	5–175	46	70–370	160	8–120	36	N/A
pH	6.1–10.1	7.5	5.9–6.7	**6.3**	4.5–7.2	**6.3**	RIDEM: 6.5–9.0

Note:

Bolded red font for median and mean values indicates that the concentration was above the threshold (provided in the last column)

IV. Resource Analysis and Source Assessment

The resource analysis of the watershed includes a source assessment, comparisons between existing and potential conditions, and the types/extent of conservation practices needed to assist in meeting the water quality goals. Ultimately these results will help establish what land uses are producing the most pollution and what practices would be the most useful in reducing nutrient and sediment loads within the watershed. Although bacteria loads are not explicitly considered in the analysis, it is expected that results would help target the main sources and lead to reductions.

Causes and Sources of the Resource Problem

Nutrients, bacteria, and sediment are the main surface water resource stressors in the Tomaquag Brook-Pawcatuck River watershed. Water quality monitoring data for some stream sections indicates that TN and TP concentrations occasionally exceed EPA guidance values. White Brook Pond and Chapman Pond are impaired due to exceedances related to phosphorus. Additionally, bacteria impairments (*Enterococcus*) are evident for many of stream reaches within the watershed (see Table 13).

Information from the watershed characterization, hydrologic characterization, and water quality characterization suggests that areas of agricultural land are likely to be key contributors of pollutant loading to water bodies in the watershed. Impaired water bodies in the watershed are adjacent to areas of agricultural land.

Potential Assessment Tools

Existing and potential future water quality loads in the watersheds were estimated using STEPL. STEPL uses simple algorithms to calculate nutrient and sediment loads from different land uses and load reductions from implementation of conservation practices (Tetra Tech, Inc. 2018). Annual nutrient loading was calculated based on the annual runoff volume and established land use specific pollutant concentrations. The annual sediment load from sheet and rill erosion was calculated based on the Universal Soil Loss Equation (USLE) and the sediment delivery ratio. Accuracy is primarily limited by the wide variability in pollutant runoff concentrations across watersheds since these concentrations are used to calculate annual pollutant loadings.

Load reductions for the watersheds were modeled with STEPL using established conservation practice efficiencies provided in STEPL version 4.4. The efficiencies of combined practices were calculated using STEPL's BMP Calculator. Although STEPL does not model bacteria, it is assumed that simulated nutrient and sediment load reductions would also likely help to reduce bacteria loads from agricultural sources in each drainage area.

The ACPF was applied to identify critical source areas (runoff risk) in agricultural fields and determine priority areas for structural BMPs. The Framework identifies locations where specific landscape attributes are favorable for implementing certain conservation practices and includes methods to help prioritize these locations according to their susceptibility to runoff and erosion. It was developed by the USDA's Agricultural Research Service in partnership with USDA NRCS to support agricultural watershed management using high-resolution elevation data and uses an ArcGIS toolbox to identify site-specific opportunities for installing conservation practices across small watersheds. It is used in conjunction with local knowledge of water and soil resource concerns, landscape features, and producer conservation preferences. Together, these provide a better understanding of the options available in developing a watershed conservation plan.

Analysis and Assessment of Watershed Conditions

STEPL Model Inputs

Models were developed for the Tomaquag Brook-Pawcatuck River watershed following methods and input requirements outlined in the STEPL user's guide. Model inputs include drainage area, soil hydrologic group, land use, animal numbers, and estimates for septic systems. Land use was derived from the 2020 USDA CDL (USDA NASS 2021). Animal numbers were based on STEPL Input Data Server values with modifications from local NRCS staff, and cropland irrigation amounts were based on input from local NRCS staff. The number of septic systems within the watershed was based on an area-weighted ratio of the number of septic systems by county in the STEPL Input Data Server. Septic failure rates were also based on the default values in the STEPL Input Data Server. The average population per household was updated using U.S. Census data from 2016–2020 (U.S. Census Bureau 2020).

Feedlots were assumed to be 800 square feet each, and the number of feedlots in the watershed was estimated by local NRCS staff. Local NRCS staff estimated that 10% of feedlots are zero discharge facilities.

The number of gullies and their dimensions were estimated by NRCS staff based on local knowledge. The current level of BMP treatment in the Tomaquag Brook-Pawcatuck River watershed was also estimated by NRCS field staff using available data and best professional judgement. Details on currently implemented practices are outlined in upcoming sections.

Current Conditions

Average annual pollutant loads, yields, and concentrations simulated by STEPL under current conditions in each drainage area are summarized in Table 16. Table 17 summarizes pollutant loads from various sources within the Tomaquag Brook-Pawcatuck River watershed.

Results indicate that urban land is the main source of nutrient and sediment pollution in the watershed. After urban land uses, cropland is the second largest contributor to nitrogen and phosphorus pollution. Pastureland is a relatively small source of nutrients and sediment; however, feedlots are a key source of nitrogen. Gullies and cropland are the key sources of sediment, after urban land. Cropland, feedlots, and pasture/hay are the key non-urban land uses with potentially reducible pollutant sources in the watershed to be addressed in this plan (see Table 17).

Table 16. STEPL results for existing pollutant loads, yields, and concentrations in the Tomaquag Brook-Pawcatuck River Watershed

Drainage Area	Runoff (ac-ft)	Runoff Yield (ac-ft/ac)	% Rainfall as runoff	Annual Load			Annual Yield			Mean Concentration (mg/L)		
				TN (lb/yr)	TP (lb/yr)	Sed (t/yr)	TN (lb/ac/yr)	TP (lb/ac/yr)	Sed (t/ac/yr)	TN	TP	Sed
Tomaquag Brook-Pawcatuck River Watershed	15,784	0.58	14%	67,720	12,135	1,550	2.42	0.45	0.06	1.52	0.28	72.21

Notes:

TN = total nitrogen; TP = total phosphorus; Sed = sediment; ac-ft = acre-feet; ac-ft/ac = acre-feet per acre; lb/yr = pounds per year; t/yr = tons per year; lb/ac/yr = pounds per acre per year; t/ac/yr = tons per acre per year; mg/L = milligrams per liter

Table 17. Summary of current source contributions within the Tomaquag Brook-Pawcatuck River watershed

Sources	TN Load		TP Load		Sediment Load	
	(lb/yr)	%	(lb/yr)	%	(t/yr)	%
Urban[a,b]	36,628	56%	5,636	45%	842	54%
Cropland	11,727	18%	2,605	22%	212	14%
Pasture/Hay	4,057	6%	447	4%	53	3%
Forest	4,552	7%	2,245	19%	89	6%
Feedlots	6,707	10%	349	3%	0	0%
Septic	1,022	2%	400	3%	0	0%
Gullies	1,028	2%	452	4%	354	23%
Total	***65,720***	***100%***	***12,135***	***100%***	***1,550***	***100%***

Notes:

[a] Urban loads are presented for information only and may represent an overestimate, as no existing BMPs or other load reduction measures have been applied to the existing conditions for this land use.

[b] Urban sources include both residential and commercial sources.

Potential Conditions

Load Reduction Analysis

As reported previously, the current level of BMP treatment in the Tomaquag Brook-Pawcatuck River watershed was estimated by NRCS field staff using available data and best professional judgement. 73% of cropland and 75% of pastureland currently have some existing level of treatment in place (current conditions). The pollutant loads associated with current conditions were initially estimated using STEPL (see previous tables) and used as a baseline to assess the potential reductions associated with further implementation of BMPs across each watershed.

As no water quality target (e.g., a TMDL) has been proposed for nutrients or sediment in the watershed at this time, a load reduction analysis was subsequently conducted that applied incremental increases in BMP implementation (implementation scenarios) from current conditions to meet the following targets:

- **Phase 1 Scenario:** 25% reduction in TP from agricultural sources across the watershed.
- **Phase 2 Scenario:** 50% reduction in TP from agricultural sources across the watershed.
- **Phase 3 Scenario:** 75% reduction in TP from agricultural sources across the watershed.

The analysis provides information about the extent of practices that could be deployed on agricultural land to achieve the realistic goals and get the most water quality benefit across the Tomaquag Brook-Pawcatuck River watershed. The associated load reductions provide a suite of targets that could be achieved through phased implementation. A summary of the scenarios modeled and the associated BMPs is given in Table 18.

Table 18. Summary of implementation scenarios and load reductions simulated in the Tomaquag Brook-Pawcatuck River Watershed

Implementation Scenario	Level of Implementation (% of Land Treated)			
	*Current	Phase 1	Phase 2	Phase 3
Cropland				
Buffer - Forest (100ft wide)	5%	5%	-	-
Buffer - Grass (35ft wide)	15%	10%	-	-
Conservation Tillage1, Cover Crop 2, Nutrient Management 1, Forest Buffer	1%	1%	1%	-
Conservation Tillage1, Cover Crop 2, Nutrient Management 1, Grass Buffer	5%	7%	11%	7%
Conservation Tillage1, Cover Crop 2, Nutrient Management 1	5%	10%	12%	-
Conservation Tillage1, Nutrient Management 1, Forest Buffer	1%	1%	1%	-
Conservation Tillage1, Nutrient Management 1, Grass Buffer	5%	7%	7%	4%
Conservation Tillage1, Nutrient Management 1	5%	10%	10%	-
Cover Crop2, Nutrient Management 1, Forest Buffer	1%	1%	1%	-
Cover Crop2, Nutrient Management 1, Grass Buffer	5%	5%	5%	-
Cover Crop2, Nutrient Management 1	5%	7%	7%	-
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2, Forest Buffer	-		3%	8%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2, Grass Buffer	-		7%	19%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2	-	-	18%	59%
Conservation Tillage 1	5%	2%	-	-
Conservation Tillage 2	2%	5%	-	-
Contour Farming	1%	1%	1%	1%
Controlled Drainage	2%	2%	2%	2%
Cover Crop 2	5%	-	-	-
Land Retirement	-	-	-	-
Nutrient Management 1	5%	-	-	-
Total	**73%**	**74%**	**88%**	**100%**
Pasture/Hay				
30m Buffer with Optimal Grazing	2%	2%	5%	
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection, Forest Buffer	2%	2%	5%	5%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection, Grass Buffer	2%	5%	10%	40%

Implementation Scenario	Level of Implementation (% of Land Treated)			
	*Current	Phase 1	Phase 2	Phase 3
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection	1%	5%	-	-
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Forest Buffer	5%	5%	10%	10%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Grass Buffer	5%	8%	12%	30%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting	1%	3%	-	-
Prescribed Grazing, Pasture and Hayland Planting, Forest Buffer	5%	10%	-	-
Prescribed Grazing, Pasture and Hayland Planting, Grass Buffer	5%	10%	15%	-
Prescribed Grazing, Pasture and Hayland Planting	2%	3%	-	-
Forest Buffer (minimum 35 feet wide)	5%	-	-	-
Grass Buffer (minimum 35 feet wide)	15%	15%	15%	-
Grazing Land Management (rotational grazing with fenced areas)	5%	5%	5%	-
Heavy Use Area Protection	2%	2%	-	-
Litter Storage and Management	2%	2%	-	-
Livestock Exclusion Fencing	2%	2%	2%	-
Pasture and Hayland Planting (Forage Planting)	5%	-	-	-
Prescribed Grazing	5%	-	-	-
Streambank Stabilization and Fencing	2%	2%	10%	10%
Winter Feeding Facility	2%	5%	5%	5%
Total	**75%**	**86%**	**94%**	**100%**
Gully Restoration	**0%**	**100%**	**100%**	**100%**
Feedlots				
Diversion	5%	5%	5%	0%
Filter strip	30%	30%	30%	35%
Runoff Management System	30%	30%	30%	20%
Waste Management System	10%	10%	25%	35%
Waste Storage Facility	15%	15%	0%	0%
Zero Discharge	10%	10%	10%	10%
Total	**100%**	**100%**	**100%**	**100%**

Results

Load reductions associated with different management scenarios modeled in each watershed are given in Table 19. The analysis suggests that further adoption of management practices on agricultural land can significantly reduce nutrient and sediment loads within the Tomaquag Brook-Pawcatuck River watershed. Simulations suggest that load reductions of 15–49% for TN, 25–75% for TP, and 56–81% for total suspended solids (TSS) could be achieved depending on the implementation scenario. The scenarios assume that those agricultural operations that currently implement one or two conservation practices will adopt additional practices to achieve further reductions, and those operations currently without conservation practices will adopt several new practices as well. Grass and forest buffers, coupled with other practices on crop and pastureland are indicated to be integral to achieving reduction targets (see Table 18).

Table 19. Summary of management scenarios and load reductions simulated in the Tomaquag Brook-Pawcatuck River Watershed

	Load Reduction Analysis			
Implementation Scenario	***Current**	**Scenario 1**	**Scenario 2**	**Scenario 3**
TP Load (lbs) Total	**3,853**	**2,882**	**1,852**	**955**
Total Load Reduction	**-**	**25 %**	**52%**	**75%**
Reductions by Source				
Cropland	-	18%	50%	80%
Pastureland	-	22%	44%	68%
Feedlots	-	0%	25%	32%
Gully	-	90%	90%	90%
TN Load (lbs) Total	***23,518***	**19,848**	**15,870**	**12101**
Total Load Reduction	**-**	**15%**	**33%**	**49%**
Reductions by Source				
Cropland	-	14%	39%	57%
Pastureland	-	26%	49%	76%
Feedlots	-	0%	3%	11%
Gully	-	90%	90%	90%
TSS Load (tons) Total	*619.27*	271.92	202.94	116.14
Total Load Reduction	**-**	**56%**	**66%**	**81%**
Reductions by Source				
Cropland	-	8%	32%	70%
Pastureland	-	21%	38%	68%
Gully	-	90%	90%	90%

Notes:
* Current: existing BMP implementation estimated by NRCS

Conservation Practice Effectiveness

Beyond the standard individual crop and pastureland conservation practices, several combinations of practices were assumed to occur throughout the watershed for the existing conditions scenario, as well as for the future pollutant reduction phases of implementation. These practices have pollutant removal efficiencies that are higher than the individual practices.

Table 20 shows the modeled reduction efficiencies (%) associated with combinations of conservation practices in the Tomaquag Brook-Pawcatuck River watershed. This information can be useful to help identify the most effective combination of conservation practices or conservation practice in reducing pollutant loads. Full details on efficiencies associated with individual practices can be found in Appendix A.

For cropland, simulations for the combination of cover crops, nutrient management, conservation tillage (>60% residue), and forest buffers (100 ft) was most effective at reducing nutrient and sediment loads. Substituting a grass buffer or removing the buffer component still yielded very high phosphorus removal efficiencies. For pasture/hay, the combination of alternative water supply, prescribed grazing, pasture and hayland planting, heavy use area protection and a grass buffer was the most effective management option, followed closely by alternative water supply, prescribed grazing, pasture and hayland planting, and a grass buffer.

Most of the feedlot areas were already significantly treated by nutrient reducing practices, so while the practices are very efficient, there was limited scope for additional reductions. Gully treatment was assumed to address all gullies that appear annually at a 90% efficiency. Gullies are caused by erosive forces triggered by a number of factors, including excess rainfall, poor infiltration, concentrated runoff from upslope or excessive erosion within wheel tracks and furrows. Gully prevention strategies vary based on the cause of erosion, but generally focus on vegetation as mitigation. Measures could include cover crops, contouring, no-till, strip cropping, residue cover, and grassed waterways.

Table 20. Summary of conservation practices efficiencies in the Tomaquag Brook-Pawcatuck River Watershed.

Conservation Practices	TN Efficiency	TP Efficiency	TSS Efficiency
Cropland			
Conservation Tillage1, Cover Crop 2, Nutrient Management 1, Forest Buffer	70%	82%	78%
Conservation Tillage1, Cover Crop 2, Nutrient Management 1, Grass Buffer	62%	81%	75%
Conservation Tillage1, Cover Crop 2, Nutrient Management 1	42%	67%	46%
Conservation Tillage1, Nutrient Management 1, Forest Buffer	63%	81%	75%
Conservation Tillage1, Nutrient Management 1, Grass Buffer	52%	80%	72%
Conservation Tillage1, Nutrient Management 1	28%	65%	40%
Cover Crop2, Nutrient Management 1, Forest Buffer	65%	73%	63%
Cover Crop2, Nutrient Management 1, Grass Buffer	55%	71%	58%
Cover Crop2, Nutrient Management 1	32%	49%	10%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2, Forest Buffer	76%	93%	91%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2, Grass Buffer	70%	93%	90%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2	55%	87%	79%

Conservation Practices	TN Efficiency	TP Efficiency	TSS Efficiency
Pastureland			
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection, Forest Buffer	81%	72%	83%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection, Grass Buffer	96%	89%	87%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection	66%	53%	64%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Forest Buffer	77%	65%	75%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Grass Buffer	95%	86%	81%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting	58%	42%	46%
Prescribed Grazing, Pasture and Hayland Planting, Forest Buffer	73%	61%	69%
Prescribed Grazing, Pasture and Hayland Planting, Grass Buffer	94%	85%	77%
Prescribed Grazing, Pasture and Hayland Planting	52%	34%	33%

Notes:

Conservation Tillage 1 = 30-59% residue
Conservation Tillage 2 = 60% or more residue
Cover Crop 2 = (Group A traditional normal planting time)
Nutrient Management 1 = Determined rate
Nutrient Management 2 = Determined rate plus additional considerations

Summary of Agricultural Risk Areas

To target areas with the most pollution potential, a map of runoff risk was developed using ACPF to help field staff isolate areas of concern and prioritize projects. Four vulnerability classes were used to rank the agricultural risk based on runoff potential. Risk classification includes A (very high risk), B (high), C (moderate), and D (low) designations (Porter et al. 2018). Figure 31 shows the process applied in ACPF assigned run off risk classifications to fields.

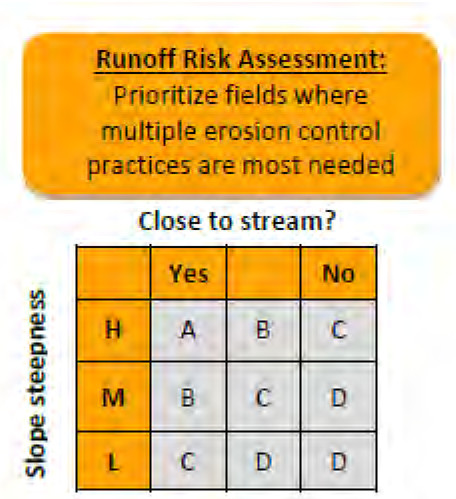


Figure 31. Runoff risk assessment matrix applied in the ACPF.

Fields with “very high” or “high” runoff risk represents the most critical areas for pollution potential from agricultural land and should be prioritized for planning. Land areas indicated to have a “moderate” runoff risk are also a key as a pollution source. “Low” risk fields are considered a lesser priority for treatment. A “low” classification does not mean that a runoff-control conservation practice would not benefit a given field, but rather indicates that other fields have a greater potential to deliver sediment and nutrients to the streams via surface runoff (Porter et al. 2018).

Figure 32 shows the spatial distribution of vulnerable fields in the watersheds and helps to locate agricultural land areas where conservation measures could be focused in order to meet water quality goals. The breakdown of classifications by drainage area is provided in Table 21.

It should be noted that agricultural land areas only make up a small proportion (< 10%) of the watershed. The majority of the watershed is forest land, which is also eligible for treatment within the NWQI program; however, pollutant loadings from agricultural sources are considered to be key controllable contributing factors.

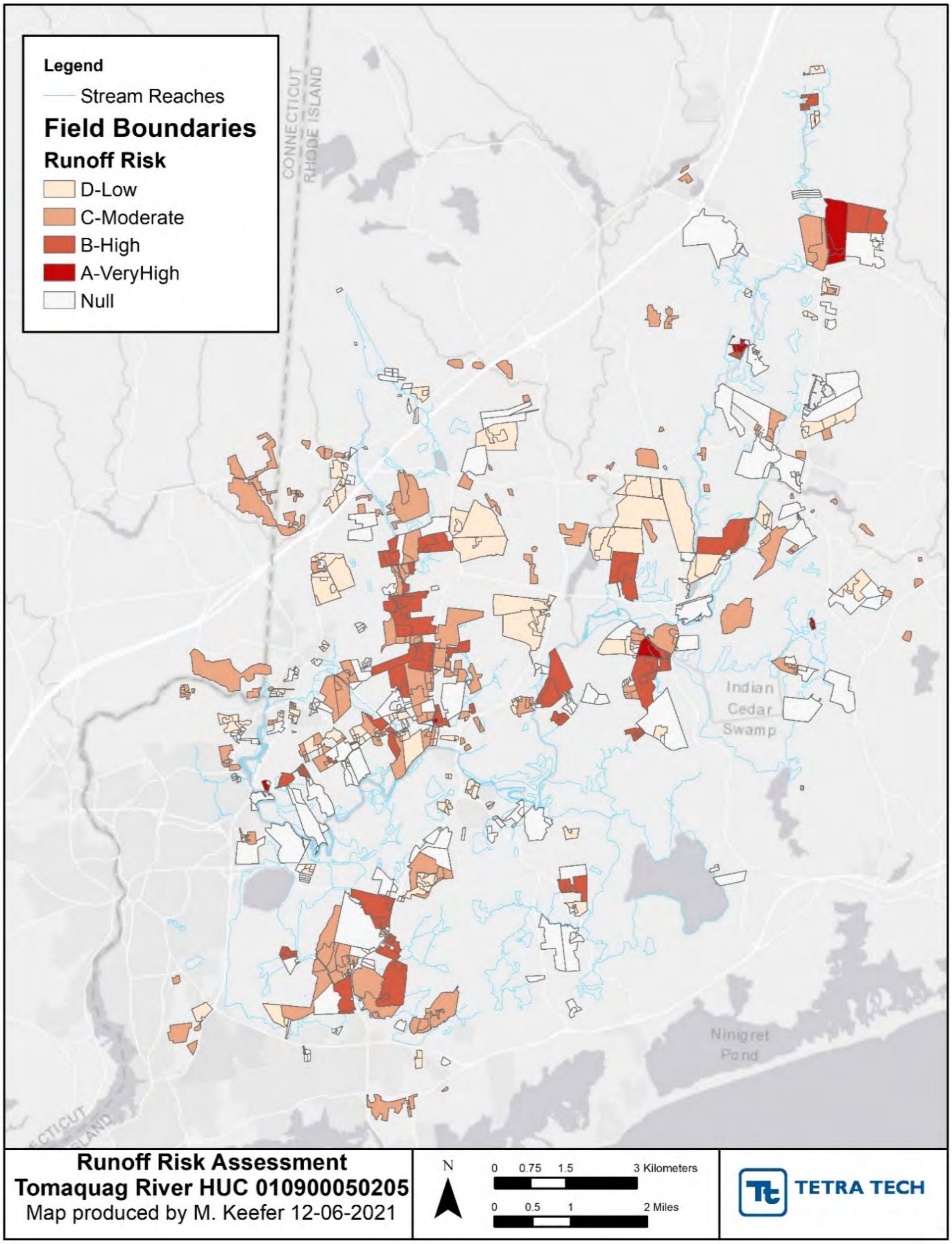


Figure 32. Spatial distribution of run off risk classifications for fields within the Tomaquag Brook-Pawcatuck River watershed.

Table 21. Summary of runoff risk acres for fields within the Tomaquag Brook-Pawcatuck River watershed.

Drainage Class	Area (acres)	No. of Fields
A-Very High	192	12
B-High	1,577	76
C-Moderate	2,898	207
D-Low	2,209	158
Null	3,632	238

Analysis of Treatment and Opportunities

Current Level of Treatment in the Watershed

Rhode Island is not a traditional agricultural state. Since it is not a traditional agricultural state, it is challenging to follow normal characterization of the watershed, which use conventional methods of inventory such as land use or land cover to characterize how the land is utilized. Still, it is the best data available and should be used as a guideline for characterization. Rhode Island's farms are small and diverse and often contribute to the acres of land outside of the lands that are characterized as agricultural. Because of this, acres contributing to agriculture may seem over-reported when in fact they are being more accurately accounted for and reported. It is this reasoning in which NRCS in Rhode Island seeks to reach those individuals by utilizing conventional land cover data but also looking beyond the normal land cover acres to account for "backyard farms" which are a big impact in Rhode Island.

In 2012, NRCS in Rhode Island teamed up with the RIDEM and with the Rhode Island Association of Conservation Districts to develop a statewide agricultural inventory. This inventory provided NRCS and RIDEM a glimpse into "backyard farming" and provided some much-needed information on conservation needs across the state. As a result of this information and good outreach, Rhode Island's conservation acres have gone beyond normal land cover acres.

The Tomaquag Brook-Pawcatuck watershed follows this characterization. Since 2012, the Tomaquag Brook-Pawcatuck River watershed has applied 387 conservation practices across 4,769 planning land unit (PLU) distinct acres of land. A PLU is the equivalent of a field that has similar management. Of those practices, 110 were "Core" conservation practices as identified by the NWQI. NWQI "Core" conservation practices are conservation practices that have the most benefit for addressing water quality issues. The 110 "Core" conservation practices were applied on 2,861 PLU acres across the Tomaquag Brook-Pawcatuck River watershed. During the last 10 years, "Core" conservation practices have accounted for 60% of the total applied conservation practices PLU acreage. NWQI "supporting" conservation practices are conservation practices that are applied in support of the "Core" conservation practices. Over the last 10 years, there have been 84 "Supporting" conservation practices applied across 1,908 PLU acres. Core and supporting conservation practice are shown in Table 22.

Table 22. Number (no.) of core and supporting conservation practices applied (2012-2022)

Conservation Practices	**Core (no.)**	**Supporting (no.)**	**Grand Total**
Prescribed Grazing	36		36
Nutrient Management	35		35
Conservation Cover	15		15
Brush Management		10	10
Fence		10	10
Pasture and Hay Planting		8	8
Access Road		8	8
Heavy Use Area Protection	8		8
Watering Facility		8	8
Lined Waterway or Outlet		7	7
Forage Harvest Management		6	6
Critical Area Planting	4		4
Roof Runoff Structure		3	3
Stream Crossing		3	3
Tree/Shrub Establishment	3		3
Mulching		3	3
Access Control	3		3
Livestock Pipeline		3	3
Field Border	2		2
Water Well		2	2
Underground Outlet		2	2
Irrigation Pipeline		2	2
Restoration of Rare or Declining Natural Communities		2	2
Structure for Water Control		2	2
Wetland Enhancement		1	1
Roofs and Covers		1	1
Herbaceous Weed Treatment		1	1
Cover Crop	1		1
Grassed Waterway	1		1
Diversion		1	1
Wetland Wildlife Habitat Management		1	1
Irrigation Reservoir	1		1
Waste Storage Facility	1		1
Grand Total	**110**	**84**	**194**

Analysis of Producers Available in the Watershed to Participate in the Initiative and Their Likely Willingness to Participate

Farm Service Agency (FSA) data indicates 157 distinct tracts within the Tomaquag Brook-Pawcatuck watershed. NRCS data indicates that there are 96 distinct tracts that have utilized NRCS programs over the last 10 years and implemented 387 conservation practices. Of those tracts, 28 distinct tracts have applied 110 “Core” conservation practices.

One goal will be to increase participation from the 157 distinct tracts for water quality purposes. Some producers may be ineligible to participate, but the local field office will offer technical assistance to encourage treatment in critical source areas. Eligible producers throughout the watershed will be able to apply for programs to receive financial assistance for implementing conservation practices to promote water quality. As part of NRCS’ financial assistance programs, applicants go through a ranking process that ranks the applicants’ assessment and planned practices in order to provide assistance in areas that are the most vulnerable with practices that do the most to address the resource concern. To promote areas that are most vulnerable, additional ranking points will be given to producers located in areas that are rated very high, high, or moderate within high priority critical source areas. Ranking points will be greatest for locations rated very high and lowest for locations rated moderate or low.

NRCS data indicates that while there is a considerable willingness for producers to participate in NRCS programs within the Tomaquag Brook-Pawcatuck watershed, there are varying levels of conservation throughout the watershed. Another goal will be to increase the level of conservation by promoting pollutant reduction conservation practices in a systematic approach in which a suite of conservation practices will be applied together to achieve the desired level of pollutant load reduction. To promote pollutant reduction conservation practices, additional ranking points will be given to producers willing to increase their level of conservation based on load reduction conservation practices.

When an applicant receives extra points for high priority critical source areas and/or increasing their level of conservation based on load reduction conservation practices, the applicant will have a higher overall score and therefore have a better opportunity to receive funding. This ranking process is critical, especially when there is a limited amount of funding. By providing extra points, funding is able to go to areas where it will provide the most benefit.

NRCS in Rhode Island will continue using an Outreach Agreement with the Districts in support of providing outreach to the Tomaquag Brook-Pawcatuck watershed. Outreach events will be tracked to provide information such as type of event and number of participants attending. NRCS will monitor the participation in terms of number of contracts and number of practices, and adjust the number of outreach events that occur each year.

Assessment of Balancing Critical Area Treatment with Participation to Achieve the Most Effective Prioritization of Implementation

To effectively prioritize implementation of conservation practices the ACPF Runoff Risk Assessment was used to provide “Critical Areas of Treatment” as shown in the Summary of Vulnerable Acres section, above. These “Critical Areas of Treatment” will receive additional ranking points. Projects in these Critical Areas will receive increasing points for projects that are within “Moderate”, “High”, and “Very High” areas. Additional ranking points will also be provided to participants that increase the level of conservation by implementing load reduction conservation practices as a bundle to achieve a better level of load reduction. Providing additional points for these criteria will allow participants the highest opportunity for NRCS program funding. Additionally, participants will have opportunities for selection within the EQIP fund pool as well as the NWQI fund pool.

Set of Preferred Practices, Locations, Responsible Parties, Costs, and Timelines

NRCS in Rhode Island will seek to provide assistance in the Tomaquag Brook-Pawcatuck watershed utilizing multiple approaches to planning. This is needed to achieve the different levels of load reductions that are suggested for the watershed. NRCS in Rhode Island will continue to work within the NWQI conservation practice concepts for “Avoiding, Controlling, and Trapping” nutrients to benefit water quality while also increasing the level of conservation by promoting load reduction conservation practices as a systematic approach in which a suite of conservation practices will be applied together to achieve the desired level of load reduction.

NRCS’ NWQI program has a set of approved conservation practices that benefit water quality by avoiding, controlling, or trapping nutrients. This list is broken down into “Core” or “Supporting” conservation practices. For NWQI purposes a “Core” practice is required and may be accompanied by “Supporting” practices but “Supporting” practices cannot be planned alone. These practices may be planned in the watershed. Below are the tables of the approved “Core” and “Supporting” conservation practices (Table 23; Table 24).

Table 23. Approved list of "core" conservation practices

Core Practices	Code	Avoiding	Controlling	Trapping
Conservation Cover	327	X		
Conservation Crop Rotation	328	X		
Residue and Tillage Management, No Till/Strip Till/Direct Seed	329		X	
Contour Farming	330		X	
Contour Orchard and Other Perennial Crops	331		X	
Contour Buffer Strips	332			X
Cover Crop	340	X		
Critical Area Planting	342		X	X
Residue Management, Seasonal	344		X	
Residue and Tillage Management, Mulch Till	345		X	
Residue and Tillage Management, Ridge Till	346		X	
Field Border	386		X	
Riparian Herbaceous Cover	390			X
Riparian Forest Buffer	391			X
Filter Strip	393			X
Stream Habitat Improvement	395	X		
Grade Stabilization Structure	410		X	X
Grassed Waterway	412		X	
Irrigation Water Management	449		X	
Access Control	472	X		
Prescribed Grazing	528	X		
Range Planting	550		X	
Heavy Use Area Protection	561	X		
Streambank and Shoreline Protection	580	X		
Nutrient Management	590	X		
Terrace	600		X	
Vegetative Buffer	601			X
Tree/Shrub Establishment	612	X		
Water and Sediment Control Basin	638		X	X

Table 24: Approved list of "supporting" conservation practices

Supporting Practices	Code	Avoiding	Controlling	Trapping
Alley Cropping	311		X	X
Waste Storage Facility	313	X		
Brush Management	314	X		
Herbaceous Weed Control	31S	X		
Animal Mortality Facility	316	X		
Composting Facility	317	X		
Prescribed Burning	338	X		
Well Water Testing	355	X		
Dike	356			X
Waste Treatment Lagoon	359		X	
Diversion	362		X	
Roofs and Covers	367	X		
Pond	378			X
Windbreak/Shelterbelt Establishment	380		X	X
Silvopasture Establishment	381	X		
Fence	382	X		
Dam	402		X	X
Hedgerow Planting	422	X		
Hillside Ditch	423		X	
Irrigation Ditch Lining	428	X		
Irrigation System, Micro irrigation	441	X		
Irrigation System, Sprinkler	442	X		
Irrigation System, Surface & Subsurface	443	X		
Irrigation System, Tailwater Recovery	447		X	
Land Reclamation Landslide Treatment	453		X	
Irrigation Land Leveling	464	X		
Lined Waterway Outlet	468		X	
Mulching	484		X	
Forage Harvest Management	511	X		
Forage and Biomass Planting	512	X		
Livestock Pipeline	516	X		
Irrigation Regulating Reservoir	552	X		
Drainage Water Management	554		X	

Costs and Timeline

Cropland

It is estimated that over the next 10 years NRCS can increase the level of participation for conservation on 336 acres of cropland (see Table 25). It is also estimated that over the next 10 years NRCS can increase the level of conservation on 107 acres of cropland. Using a systems approach to achieve a higher level of conservation can be accomplished focusing on the conservation practices which are commonly used in Rhode Island and provide benefit for water quality. Other conservation practices may be used from the NWQI Conservation Practice list for Core and Supporting conservation practices.

Table 25. Conservation investment information for cropland

	FUTURE	USDA INVESTMENT		
CONSERVATION SYSTEMS BY TREATMENT LEVELS	**New Treatment Units**	**Installation Cost 75%**	**Technical Assistance 20%**	**Total Present Value Cost**
Progressive System Acres Treated	**336**			
Conservation Crop Rotation (ac.) 328	118	$3,487	$697	$4,184
Cover Crop (ac.) 340	252	$16,201	$3,240	$19,441
Irrigation System, Microirrigation (ac.) 441	168	$413,532	$82,706	$496,238
Irrigation Water Management (ac.) 449	235	$6,973	$1,395	$8,368
Mulching (ac.) 484	235	$60,682	$12,136	$72,818
Nutrient Management (ac.) 590	151	$35,381	$7,076	$42,457
Residue and Tillage Management, Mulch Till (ac.) 345	252	$3,969	$794	$4,763
	Subtotal	**$540,224**	**$108,045**	**$648,269**
Resource Management System (RMS) Acres Treated	**107**			
Access Road (ft.) 560	2,803	$69,365	$13,873	$83,238
Conservation Crop Rotation (ac.) 328	40	$1,187	$237	$1,425
Cover Crop (ac.) 340	90	$5,762	$1,152	$6,914
Diversion (ft.) 362	28,026	$168,158	$33,632	$201,789
Grassed Waterway (ac.) 412	319,500	$76,680	$15,336	$92,016
Irrigation System, Microirrigation (ac.) 441	69	$168,920	$33,784	$202,705
Irrigation Water Management (ac.) 449	85	$2,533	$507	$3,039
Lined Waterway or Outlet (ft.) 468	1,121	$106,780	$21,356	$128,136
Mulching (ac.) 484	85	$22,040	$4,408	$26,448
Nutrient Management (ac.) 590	64	$15,075	$3,015	$18,091
Residue and Tillage Management, Mulch Till (ac.) 345	90	$1,412	$282	$1,694
Riparian Forest Buffer (ac.) 391	27	$57,430	$11,486	$68,916
Riparian Herbaceous Cover (ac.) 390	27	$379,406	$75,881	$455,288
	Subtotal	**$1,074,749**	**$214,950**	**$1,289,699**
TOTAL ACRES TREATED / ESTIMATED TREATMENT COSTS	**443**	**$1,614,973**	**$322,995**	**$1,937,968**

Pasture

It is estimated that over the next 10 years NRCS can increase the level of participation for conservation on 410 acres of pastureland (see Table 26). It is also estimated that over the next 10 years NRCS can increase the level of conservation on 130 acres of pastureland. Using a systems approach to achieve a higher level of conservation can be accomplished focusing on the conservation practices that are commonly used in Rhode Island and provide benefit for water quality. Other conservation practices may be used from the NWQI Conservation Practice list for Core and Supporting conservation practices.

Table 26. Conservation investment information for pasture

CONSERVATION SYSTEMS BY TREATMENT LEVELS	FUTURE New Treatment Units	Installation Cost 75%	Technical Assistance 20%	Total Present Value Cost
Progressive System Acres Treated	**410**			
Fence (ft.) 382	20,485	$118,608	$23,722	$142,330
Heavy Use Area Protection (ac.) 561	6,146	$74,630	$14,926	$89,556
Nutrient Management (ac.) 590	205	$90,649	$18,130	$108,779
Pasture & Hayland Planting (ac.) 512	307	$158,978	$31,796	$190,774
Pipeline (ft.) 516	40,970	$218,594	$43,719	$262,313
Prescribed Grazing (ac.) 528	410	$10,243	$2,049	$12,291
Water Well (no.) 642	41	$144,535	$28,907	$173,442
Watering Facility (no.) 614	164	$61,455	$12,291	$73,746
	Subtotal	**$877,693**	**$175,539**	**$1,053,231**
Resource Management System (RMS) Acres Treated	**130**			
Fence (ft.) 382	18,075	$104,654	$20,931	$125,585
Grassed Waterway (ac.) 412	3	$120,612	$24,122	$144,734
Heavy Use Area Protection (ac.) 561	1,536	$18,658	$3,732	$22,389
Lined Waterway or Outlet (ft.) 468	2,591	$7,590	$1,518	$9,108
Nutrient Management (ac.) 590	116	$51,323	$10,265	$61,588
Pasture & Hayland Planting (ac.) 512	109	$56,500	$11,300	$67,799
Pipeline (ft.) 516	16,719	$89,206	$17,841	$107,047
Prescribed Grazing (ac.) 528	102	$2,561	$512	$3,073
Riparian Forest Buffer (ac.) 391	6	$11,945	$2,389	$14,334
Riparian Herbaceous Cover (ac.) 390	13	$58,876	$11,775	$70,651
Roof Runoff Structure (no.) 558	1,295	$14,573	$2,915	$17,488
Waste Facility Cover (no.) 367	12,954	$242,883	$48,577	$291,459
Waste Storage Facility (no.) 313	12,954	$312,225	$62,445	$374,670
Water Well (no.) 642	10	$36,134	$7,227	$43,361
Watering Facility (no.) 614	106	$39,652	$7,930	$47,582
	Subtotal	**$1,167,391**	**$233,478**	**$1,400,869**
TOTAL ACRES TREATED / ESTIMATED TREATMENT COSTS	**539**	**$2,045,084**	**$409,017**	**$2,454,100**

V. Summary and Recommendations

This section summarizes water quality resource concerns, the water quality goals, and the extent that the problem can be addressed through NRCS technical and financial assistance.

Description of Water Quality Impairments.

The most recent *State of Rhode Island 2022 Impaired Waters Report* indicates that parts of the Pawcatuck River (RI0008039R-18C, RI0008039R-18D and RI0008039R-18E), Tomaquag Brook (RI0008039R-24), Mile Brook (RI0008039R-14), Meadow Brook (RI0008039R-13), Perry Healy Brook (RI0008039R-19), and other unnamed tributaries are impaired due to excessive levels of bacteria (*Enterococcus*). TMDLs have been developed and approved for most of these stream sections. White Brook Pond (RI0008039L-26) and Chapman Pond (RI0008039L-01) were recently listed as impaired due to high levels of phosphorus. Other impairments due to high levels of metals, including iron and lead, are also evident for some streams and ponds in the watershed.

While there are no stream segments within the watershed currently deemed impaired for nutrients or sediment, recent water quality monitoring data (from USGS) suggests that elevated levels of nutrients occur episodically, particularly along Tomaquag Brook (RI0008039R-24), and the Pawcatuck River at Bradford (RI0008039R-18C) and near South Hopkinton (RI0008039R-18E).

Description of the Water Quality Reduction Goals.

The main goal is to meet designated criteria for surface water classes in the Tomaquag Brook-Pawcatuck River watershed as in the state's water quality standards (RIDEM 2020). Freshwaters in the Tomaquag Brook-Pawcatuck River watershed have been assigned to Class A, Class B, and Class B1 (see Figure 19 for details).

- Class A waters: are designated as a habitat for fish and wildlife, and for primary and secondary contact recreation. They should have excellent aesthetic value.
- Class B: are designated as a habitat for fish and wildlife, and for primary and secondary contact recreation. They should have good aesthetic value.
- Class B1: are designated as a habitat for fish and wildlife, and for primary and secondary contact recreation. They should have good aesthetic value. Primary contact recreational activities may be impacted due to pathogens from approved wastewater discharges. However, all Class B criteria must be met.

The NWQI is focused on agricultural sources of nonpoint sources of pollution. The key objective is therefore to reduce nutrient and bacterial loadings from agricultural sources and meet criteria that ensure waters are suitable for fish, wildlife, and recreation. Conservation practices for agricultural operations should reduce the potential of both nutrient, sediment, and bacterial laden runoff from reaching water bodies. For the periods of 2023-2033 goals will be focused on increasing participation and increasing level of conservation for water quality. Water quality monitoring will continue to be done by RIDEM.

Establish Interim Metrics to Track Progress.

The NRCS based metrics for tracking progress would utilize:

1. Integrated Data for Enterprise Analysis (IDEA) which provides reports for internal analysis of National Planning and Agreements Database (NPAD).
2. Protracts which provides contracting information.

Metrics will include the number of clients, acres treated, and practices planned and installed. Metrics will include the number of clients, acres treated, and practices planned and installed. The percent of pollutant load reduction based on modeled efficiencies for conservation practices will also be tracked throughout the watershed. Annual review of these metrics will allow progress to be analyzed and discussed to better determine if goals for implementation and effectiveness are on track.

Locations of Critical Source Areas or Vulnerable Acres Needing Treatment.

Fields with “very high” or “high” runoff risk represent the most critical areas for pollution potential from agricultural land and should be prioritized for planning. Land areas indicated to have a “moderate” runoff risk are also a key as a pollution source. “Low” risk fields are considered a lesser priority for treatment. A “low” classification does not mean that a runoff-control conservation practice would not benefit a given field, but rather indicates that other fields have a greater potential to deliver sediment and nutrients to the streams via surface runoff (Porter et al. 2018). Locations of these critical source areas are shown in Figure 32, with a summary of runoff risk acres for fields within the Tomaquag Brook-Pawcatuck watershed detailed in Table 21.

Description and Evaluation of Planned Practice Scenarios and Alternatives that Meet the Water Quality Goals, Including Estimation of Treatment Costs.

To increase the level of conservation, NRCS in Rhode Island will promote conservation systems to improve nutrient reducing efficiencies. Conservation systems that will be included are listed in Table 20. Conservation practices included on the NWQI list of core and supporting conservation practices will also be utilized as needed.

Documentation of NEPA Concerns

The National Environmental Policy Act of 1964 requires all federal agencies to conduct an environmental review of all federal actions. This requirement also applies to area wide or watershed planning activities. As part of these plans the responsible federal agency is required to evaluate the individual and cumulative effects of the actions being proposed. Any project that has significant environmental impacts must be evaluated with an Environmental Assessment (EA) or Environmental Impact Statement (EIS) unless the activities are eligible under a categorical exclusion or are covered by an existing EA or EIS.

NRCS utilizes a planning process that incorporates an evaluation of potential environmental impacts using an Environmental Evaluation checklist. NRCS also has categorical exemptions for a number of different activities that include many NRCS conservation practices. These categorical exemptions include conservation practices that reduce soil erosion, involve the planting of vegetation and/or restoring areas to natural ecological systems.

As mentioned above, as part of the planning process, each planned practice will be evaluated individually and combination with other planned practices to ensure it meets the criteria of the categorical exclusions and any existing EAs. Any significant negative practice impacts, either individually or cumulatively, will first try to be avoided, then minimized and/or mitigated to the extent possible or eliminated from the individual farm plan if necessary.

Outreach Strategy and Plan

NRCS in Rhode Island has a Public Affairs Specialist on staff and utilizes partnership agreements with the Soil and Water Districts of Rhode Island to provide assistance with outreach. This partnership allows NRCS to increase outreach efforts, as well as reach more of the public than NRCS could alone. The SWCDs coordinate outreach events with NRCS staffing to place the right people in the right place at the right time. This model has demonstrated benefits and value in our efforts to reach the public with NRCS programs over the years.

The overall objective of community outreach in the Tomaquag Brook-Pawcatuck River watershed is to develop an atmosphere that promotes the understanding and desire for sustained, long-term protection and improvement of the aquatic resources in the watershed. Specific goals of education efforts in the watershed include the following:

- Increase public awareness of the value of clean water.
- Increase public awareness of agricultural runoff and encourage behaviors that will help reduce levels of nutrients and sediment in the watershed, better understand watershed dynamics, and foster stewardship opportunities.
- Increase public awareness of how BMPs can help improve water quality and habitat restoration.
- Increase public awareness of the long term environmental and economic advantages of protecting and improving water quality and habitat in the Tomaquag Brook-Pawcatuck River watershed.

Table 27 outlines objectives, indicators, and an implementation schedule identified to meet the education and outreach goals defined above.

Table 27. Outlined objectives, indicators, and implementation schedule identified in order to meet education and outreach goals

Education Objective	Indicator	Schedule
Outreach Events: Outreach events will be scheduled and advertised to provide information to the public on clean water, agricultural runoff, the effect of BMPs and where to find help.	A field day will be held for landowners and interested public to provide information on clean water, agricultural runoff, the effect of BMPs and where to find help to promote public interest. The number of attendees will be documented.	Once a year or on request throughout the life of the project.
Field Days: A field day will be held to showcase some of the BMPs installed under NWQI. This will allow the landowners and the interested public to view some of the practices that are being installed to benefit water quality in the watershed.	Attendance at this field day will be documented and reported.	Field day in the watershed will take place around months 20 and 30 of the project.
Educational Literature: Brochures and a fact sheet will be developed to inform landowners/operators about water quality and ways they can protect and improve the water quality in their watershed. The fact sheet contains information about the watershed and the numbers and types of BMPs installed.	Brochures and a fact sheet will be distributed at the field days and outreach meetings and will also be available at the district offices.	Throughout the life of the project

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Appendix A

Conservation Practices	TN Efficiency	TP Efficiency	TSS Efficiency
Cropland			
Combination Practices			
Conservation Tillage1, Cover Crop 2, Nutrient Management 1, Forest Buffer	70%	82%	78%
Conservation Tillage1, Cover Crop 2, Nutrient Management 1, Grass Buffer	62%	81%	75%
Conservation Tillage1, Cover Crop 2, Nutrient Management 1	42%	67%	46%
Conservation Tillage1, Nutrient Management 1, Forest Buffer	63%	81%	75%
Conservation Tillage1, Nutrient Management 1, Grass Buffer	52%	80%	72%
Conservation Tillage1, Nutrient Management 1	28%	65%	40%
Cover Crop2, Nutrient Management 1, Forest Buffer	65%	73%	63%
Cover Crop2, Nutrient Management 1, Grass Buffer	55%	71%	58%
Cover Crop2, Nutrient Management 1	32%	49%	10%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2, Forest Buffer	76%	93%	91%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2, Grass Buffer	70%	93%	90%
Conservation Tillage 2, Cover Crop 2, Nutrient Management 2	55%	87%	79%
Individual Practices			
Bioreactor	45%	ND	ND
Buffer - Forest (100ft wide)	48%	47%	59%
Buffer - Grass (35ft wide)	34%	44%	53%
Combined BMPs-Calculated	0%	0%	0%
Conservation Tillage 1 (30-59% Residue)	15%	36%	40%
Conservation Tillage 2 (equal or more than 60% Residue)	25%	69%	77%
Contour Farming	28%	40%	34%
Controlled Drainage	39%	35%	ND
Cover Crop 1 (Group A Commodity) (High Till only for Sediment)	1%	ND	ND
Cover Crop 2 (Group A Traditional Normal Planting Time) (High Till only for TP and Sediment)	20%	7%	10%
Cover Crop 3 (Group A Traditional Early Planting Time) (High Till only for TP and Sediment)	20%	15%	20%
Land Retirement	90%	81%	95%
Nutrient Management 1 (Determined Rate)	15%	45%	ND
Nutrient Management 2 (Determined Rate Plus Additional Considerations)	25%	56%	ND
Streambank Stabilization and Fencing	75%	75%	75%
Terrace	25%	31%	40%
Two-Stage Ditch	12%	28%	ND
Pastureland			
Combination Practices			
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection, Forest Buffer	81%	72%	83%

Conservation Practices	TN Efficiency	TP Efficiency	TSS Efficiency
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection, Grass Buffer	96%	89%	87%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Heavy Use Area Protection	66%	53%	64%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Forest Buffer	77%	65%	75%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting, Grass Buffer	95%	86%	81%
Prescribed Grazing, Alternative Water Supply, Pasture and Hayland Planting	58%	42%	46%
Prescribed Grazing, Pasture and Hayland Planting, Forest Buffer	73%	61%	69%
Prescribed Grazing, Pasture and Hayland Planting, Grass Buffer	94%	85%	77%
Prescribed Grazing, Pasture and Hayland Planting	52%	34%	33%
Individual Practices			
30m Buffer with Optimal Grazing	36%	65%	ND
Alternative Water Supply	13%	12%	19%
Combined BMPs-Calculated	0%	0%	0%
Critical Area Planting	18%	20%	42%
Forest Buffer (minimum 35 feet wide)	45%	40%	53%
Grass Buffer (minimum 35 feet wide)	87%	77%	65%
Grazing Land Management (rotational grazing with fenced areas)	43%	26%	ND
Heavy Use Area Protection	18%	19%	33%
Litter Storage and Management	14%	14%	0%
Livestock Exclusion Fencing	20%	30%	62%
Multiple Practices	25%	21%	22%
Pasture and Hayland Planting (also called Forage Planting)	18%	15%	ND
Prescribed Grazing	41%	23%	33%
Streambank Protection w/o Fencing	15%	22%	58%
Streambank Stabilization and Fencing	75%	75%	75%
Use Exclusion	39%	4%	59%
Winter Feeding Facility	35%	40%	40%
Feedlots			
Diversion	45%	70%	ND
Filter strip	ND	85%	ND
Runoff Mgmt System	ND	83%	ND
Solids Separation Basin	35%	31%	ND
Solids Separation Basin w/Infilt Bed	ND	80%	ND
Terrace	55%	85%	ND
Waste Mgmt System	80%	90%	ND
Waste Storage Facility	65%	60%	ND