Connecticut Statewide Lake Nutrient TMDL

Appendix 1: **Bantam Lake Watershed TMDL**

1.0 Purpose

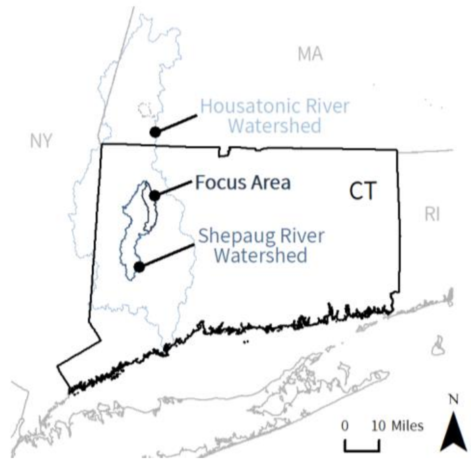
This appendix describes the general waterbody and watershed characteristics, water quality target, potential nutrient load sources, nutrient load reduction targets, existing management activities, potential load reduction and educational opportunities, and targeted monitoring plan for Bantam Lake based on mapping analyses, modeling, and municipal or other local programs review, as described in the Connecticut Statewide Lake Nutrient Total Maximum Daily Load Core Document (core document). More specific pollutant nutrient load sources and implementation strategies identified based on field assessments and stakeholder engagement can be found in the Bantam Lake Watershed Based Plan (WBP) addendum.

2.0 Waterbody & Watershed Description

2.1 Waterbody Description

Bantam Lake, CT6705-00-3-L3_01, is located within the towns of Morris and Litchfield in western Connecticut. As the largest natually formed freshwater lake in Connecticut, Bantam Lake has

BANTAM LAKE WATERSHED



Lake Name: Bantam Lake

Waterbody ID: CT6705-00-3-L3_01

Surface Area: 946 acres

Watershed Area: 20,962 acres

Waterbody Towns: Morris and Litchfield

Watershed Towns: Morris, Litchfield, Goshen, and Torrington

Lake to Watershed Ratio: 1:22

Water Quality Classification: AA

Designated Use Impairment: Recreation (due to nutrients and related parameters: chlorophyll A, algae)

Subregional-Regional-Major Basin Names: Bantam River-Shepaug River-Housatonic River

HUC-12 ID: 011000050702

Percent Impervious Cover: 4%

Percent Forested Lake Buffer: 42%

a total surface area of 946[1] acres, a maximum depth of 26 feet, an average depth of 14.7 feet, and a total volume of over 4.5 billion gallons (Northeast Aquatic Research, 2009). Bantam Lake runs along a north-south axis and is comprised of three primary bays (i.e., "North Bay", "Center Lake", and "South Bay"). As the largest inlet to Bantam Lake, the Bantam River flows into the North Bay approximately one-half mile away from the outlet and continues to the Shepaug River and ultimately to Lake Lillinonah, part of the Housatonic River. Bantam Lake's unique morphometry creates varied retention times throughout its bays. For example, as it is subject to a watershed area 22 times the size of the lake, the North Bay typically flushes once each month while the entire lake flushes approximately once every 115 days or 3 times per year (Northeast Aquatic Research, 2009). Additionally, the lake outlet is in proximity to the lake inlet, which also affects flushing rates and flow of nutrients through the lake.

2.2 Watershed Description

The 20,962-acre[2] watershed of Bantam Lake includes the towns of Goshen (41%), Litchfield (39%), Morris (15%), and Torrington (5%) in northwestern Connecticut (Figure 1) (Northeast Aquatic Research, 2009). Beginning in Goshen, the Bantam Lake watershed includes Fox Brook which flows into Ivy Mountain Brook before Ivy Mountain Brook flows into the Bantam River through Timber Pond (25 acres) (Northeast Aquatic Research, 2009). The West Branch Bantam River begins in Goshen and flows into Dog Pond (66 acres) before continuing south to its confluence with the Bantam River in Litchfield. The Bantam River continues to meander through Litchfield where it flows into Little Pond (14.5 acres). Little Pond also receives inflow from Moulthrop and Tannery Brooks. The Bantam River then continues at the outlet of Little Pond and receives inflow from Miry Brook before flowing into the North Bay of Bantam Lake. In total, the Bantam River drains an area of 18,032 acres (~90% of the Bantam Lake drainage area) and contributes over 7.6 trillion gallons of water to Bantam Lake from April-October (Northeast Aquatic Research, 2009; CEI, Inc., 2020). Bantam Lake also receives inputs from Whittlesey Brook in the South Bay which has a sub-basin (drainage) area of 753 acres (~4% of the Bantam Lake drainage area) and contributes 343.4 million gallons of water to Bantam Lake from April-October. Other inputs from the direct drainage or proximal area to Bantam Lake include 1,219 acres (~6% of the Bantam Lake drainage area), which contribute over 500 million gallons of water to Bantam Lake from April-October. The primary outflow of Bantam Lake, the Bantam River, is located in Outlet Cove in the North Bay.

Major landmarks within the watershed include the town centers of Litchfield and Goshen, White Memorial Foundation, as well as the Torrington and Litchfield country clubs and golf courses (shown in Figure 4). Major roads include Connecticut State Route 63, which runs north-south through the center of the watershed, and Connecticut State Route 4 which runs from east-west across the northern portion of the watershed. Other major roadways include Connecticut State Routes 118, 209, 109, and 61 and US Route 202 in the lower portion of the watershed.

[1] CEI, Inc. (2020) estimates 941-acre surface area.

[2] CEI, Inc. (2020) estimates a 20,959-acre watershed area. Used for percentage calculations.

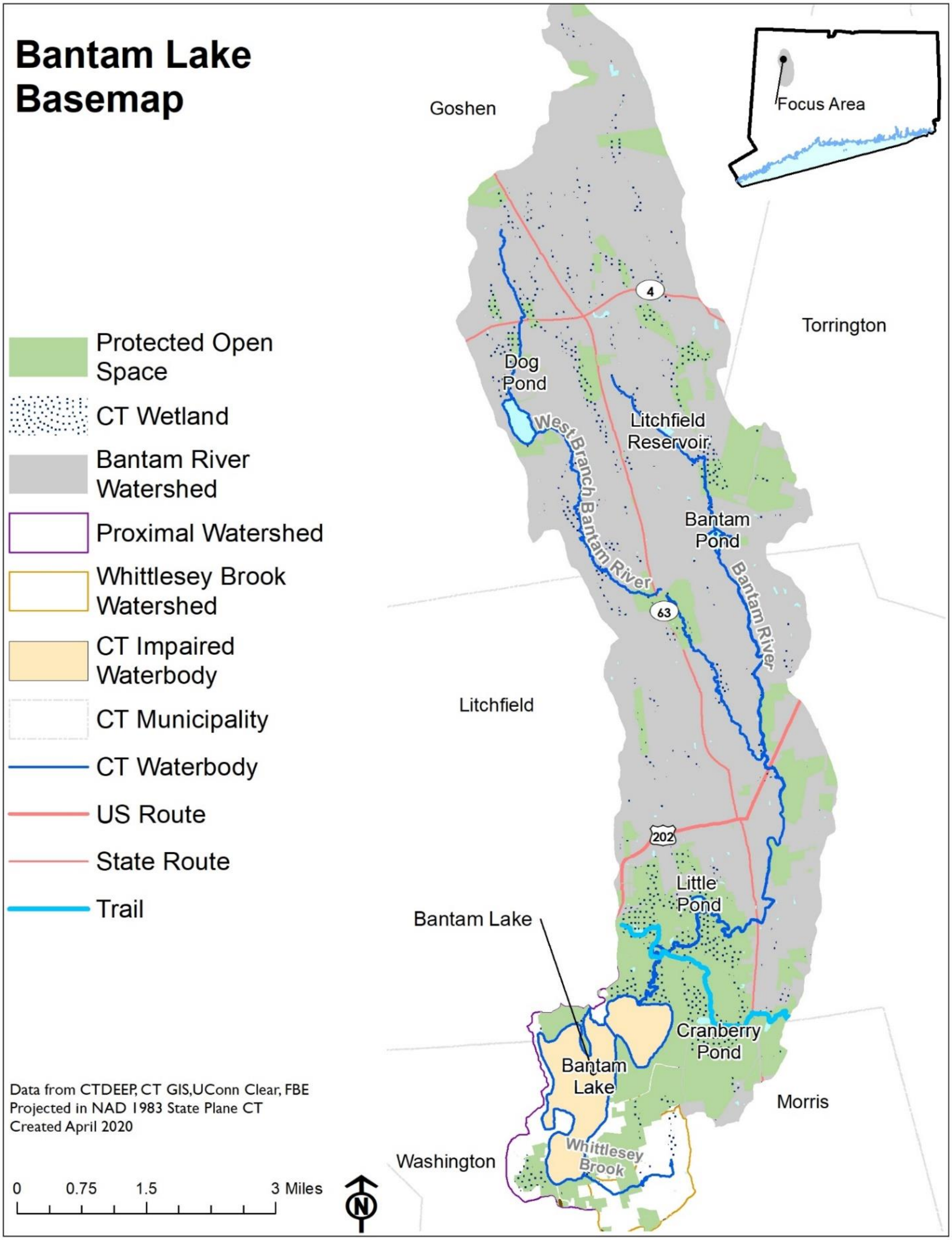


Figure 1: Map of natural resource features in the Bantam Lake watershed.

3.0 Why is a TMDL Needed?

Bantam Lake (CT6705-00-3-L3_01) is classified as a Class AA Inland Surface Water. Class AA waters have designated uses of existing or potential drinking water supply, fish and wildlife habitat, agricultural and industrial supply, and recreational use (CT DEEP, 2020). Bantam Lake regularly experiences reduced water clarity, elevated in-lake phosphorus concentrations, and cyanobacteria blooms beginning in mid to late summer (July-August) and lasting through the remainder of the growing season (Northeast Aquatic Research, 2009). As a result, Bantam Lake was listed on CT DEEP's IWQR *List of Impaired Waters for Connecticut* as impaired for recreation (CT DEEP, 2020). Impairment causes were noted as chlorophyll-*a*, excess algal growth, and nutrient/eutrophication biological indicators. These causes are related to excess anthropogenic nutrient loading.

Nutrient water quality standards, including narrative and numerical criteria for lakes, are described in detail in the core document of this TMDL. Two sections of the Connecticut General Statutes (CT DEEP, 2015b) set WQS goals for nutrients and lakes:

> *22a-426-6(a) Goal for lakes is for restoration/maintenance of natural trophic state. This section also provides WQ characteristics associated with trophic levels and 6(b) discusses the consideration of macrophyte coverage.*
>
> *22a-426-9(a) Table 1. The loading of nutrients shall not exceed that which supports maintenance or attainment of designated uses.*

Specific nutrient criteria derived for Bantam Lake are presented in Section 6.2, below. For additional information on cyanobacteria blooms and harmful algal blooms (HABs), refer to CT DEEP website.

Water quality monitoring data from 2007-2018 for Bantam Lake have been collected consistently at three deep spot stations, North Bay, Center Lake, and South Bay, by Northeast Aquatic Research and Aquatic Ecosystem Research on behalf of the Bantam Lake Protective Association (Figure 2). Data from 2007 and 2008 were used for a Diagnostic Feasibility Study by Northeast Aquatic Research, LLC (2009). Parameters measured have included dissolved oxygen and temperature profiles, Secchi disk transparency readings, total phosphorus, and total nitrogen monthly from April-October, with some minor variability in some years (e.g., extending into March or through November or limited total nitrogen data collected in 2009 and 2012). Total phosphorus and total nitrogen were measured at three column depths near the top, middle, and bottom of the lake profile. Minimal chlorophyll-*a* data were collected only for the North Bay and Center Lake stations (and were combined for two stations in 2008, 2016, and 2017, n=11). Other lake stations, as well as tributary stations, have been measured less consistently and were not used for lake model calibration. A recent water quality report for Bantam Lake is available from the Bantam Lake Protective Association which provides data for 2020.

Other surface waters in the watershed have not been assessed for nutrient impacts related directly to those waters but have been evaluated within this TMDL for their contributions to the observed impairment in Bantam Lake. Some surface waters within the watershed are impaired for other designated uses or remain unassessed. For example, the West Branch Bantam River (CT6703-00_01) was listed as impaired for aquatic life in the 2016 Integrated Water Quality Report but was delisted in 2018 due to improved measurements for the health of the benthic community. Some waters in the watershed are also listed as impaired due to elevated bacteria and are covered by a separate TMDL. Assessment and impairment status for waterbodies in the watershed is presented in Figure 3.

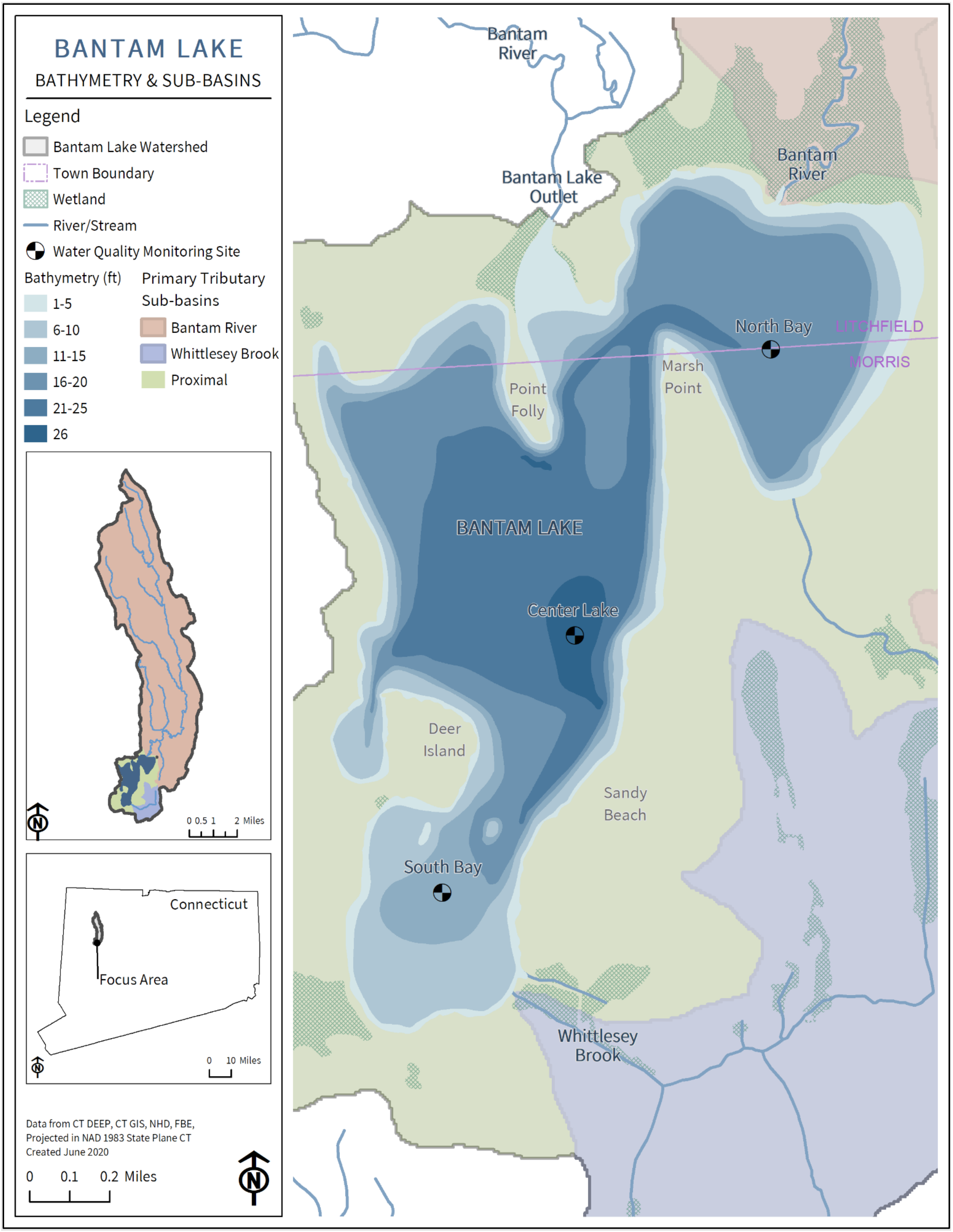


Figure 2: Bantam Lake bathymetry, sub-basins, and water quality monitoring stations.

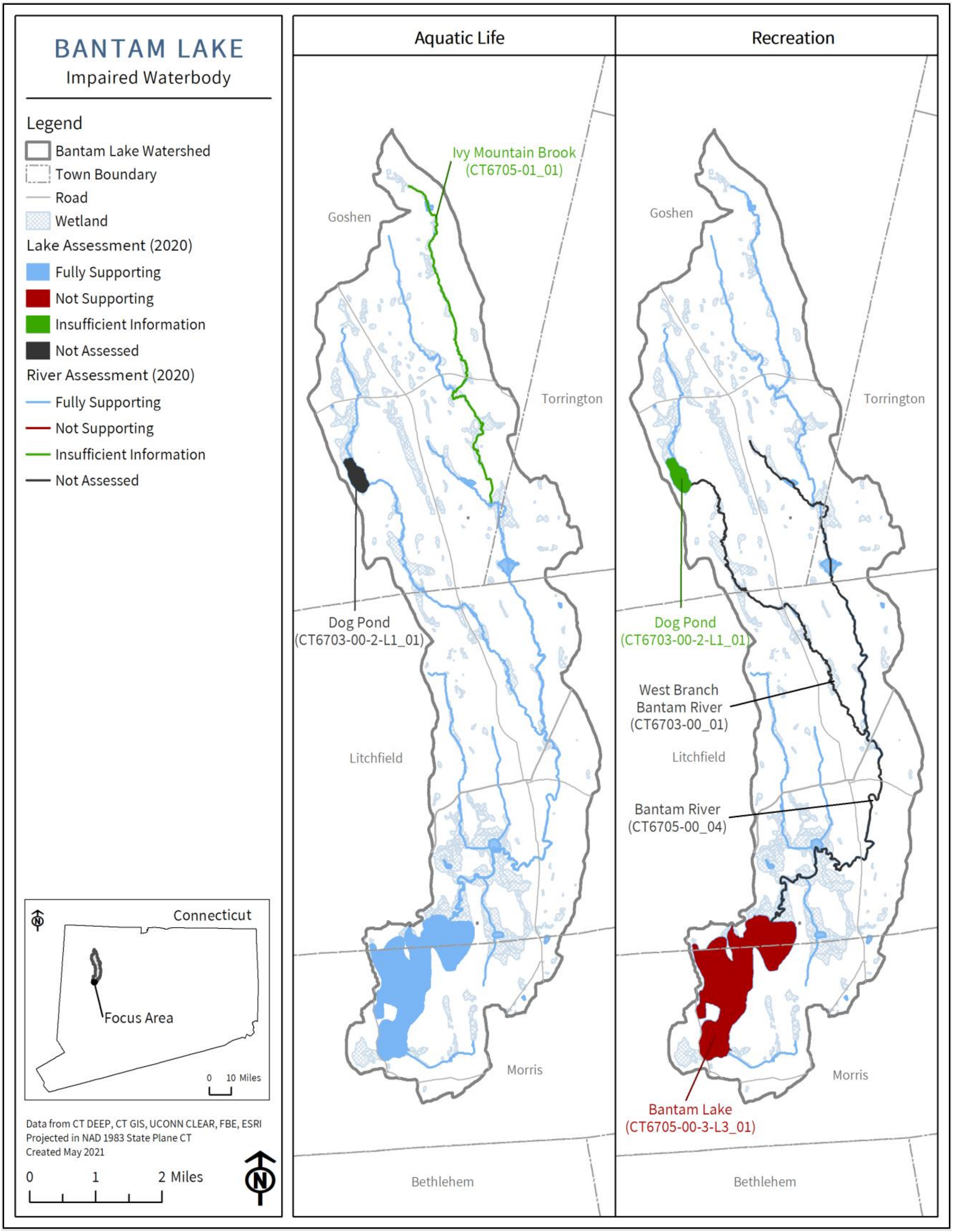


Figure 3: Waterbodies in the Bantam Lake watershed showing assessment and impairment status based on CT DEEP's IWQR List of Impaired Waters for Connecticut (CT DEEP, 2020).

4.0 Potential Nutrient Sources

Potential sources of nutrients in a watershed include both point sources (PS) and nonpoint sources (NPS). PS can be traced back to a specific source such as a discharge pipe and can include Water Pollution Control Facilities (sewage treatment plants), combined sewer overflows, stormwater from regulated point sources and unauthorized point sources of untreated wastewater, if present. NPS pollution comes from many diffuse sources on the landscape such as polluted runoff, Subsurface Sewage Disposal System (SSDS) such as septic systems, erosion, fertilizers, agriculture, pets, and wildlife. Land uses are often correlated with levels of NPS pollution, as described in the Land Use Analysis section below. Potential sources are summarized by category in Table 1 and mapped in Figure 4.

Permitted sources that have been identified in the watershed based on analysis of available data sets are presented in Table 3. However, the list of potential sources is general in nature and should not be considered comprehensive. There may be other sources not listed here that contribute to the observed water quality impairment. Further investigation based on field assessments and stakeholder input as part of the development of a WBP addendum can confirm listed sources and discover any additional sources.

Table 1: Potential nutrient sources in the Bantam Lake watershed.

Impaired Waterbody or Sub-basin	Permit Source	Illicit Discharge	CSO/SSO Issue	Failing SSDS	Agricultural Activity	Stormwater Runoff	Nuisance Wildlife or Pets	Other
Bantam Lake (CT6705-00-3-L3_01), whole watershed	**x**	None known		**x**	**x**	**x**	**x**	**x**
Bantam River sub-basin	**x**	None known		**x**	**x**	**x**	**x**	**x**
Whittlesey Brook sub-basin	**x**	None known		**x**	**x**	**x**	**x**	**x**
Proximal sub-basin		None known		**x**	**x**	**x**	**x**	**x**

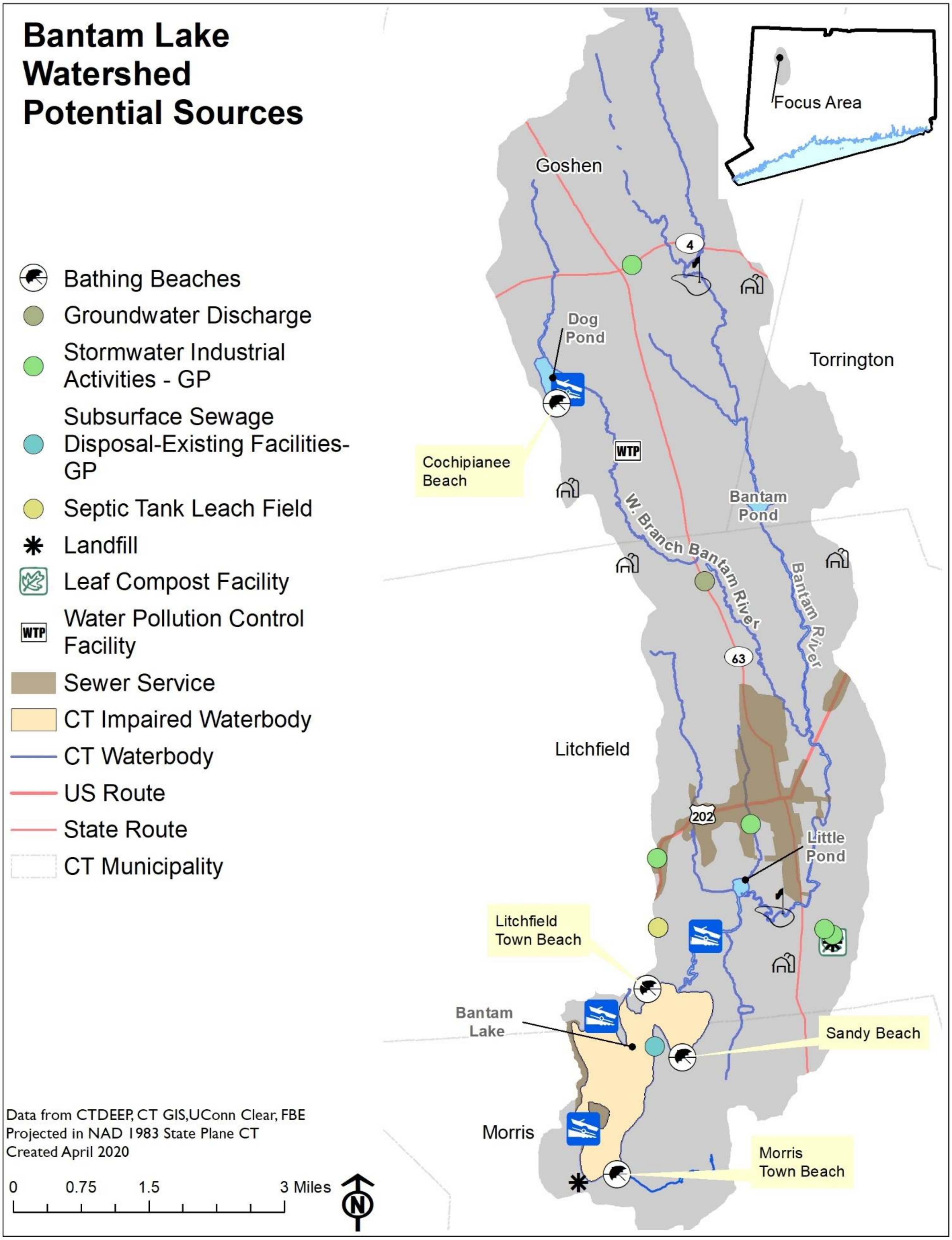


Figure 4: Map of recreation and potential pollution sources.

4.1 Point Sources

Permitted sources within the watershed that could potentially contribute nutrients to Bantam Lake are identified in Table 3.

Permitted Wastewater Point Sources

There is one Wastewater Pollution Control Facility (WPCF) in the watershed. Woodridge Lake WPCF is located off Route 63 in Goshen (Permit # SP0000179). As of this report date, the WPCF is receiving wastewater from 703 connections with capacity for an additional 164 connections, or a total of 877 connections (Woodridge Lake Sewer District, 2016). Nutrient loading from this WPCF is presented in Table 2. There are no Combined Sewer Overflows (CSO) in the watershed.

Table 2: Recent total phosphorus and total nitrogen loading from Woodridge Lake WPCF.

	Total Phosphorus			Total Nitrogen		
Year	**Total Load** (kg/yr)	**Attenuation Factor**	**Delivered Load to Bantam Lake** (kg/yr)	**Total Load** (kg/yr)	**Attenuation Factor**	**Delivered Load to Bantam Lake** (kg/yr)
2011	335.23	0.648	217.23	1,485.55	0.648	962.64
2012	394.64	0.648	255.73	1,344.09	0.648	870.97
2013	375.09	0.648	243.06	1,584.86	0.648	1,026.99
2014	436.93	0.648	283.13	1,705.80	0.648	1,105.36
2015	434.77	0.648	281.73	1,473.45	0.648	954.80
2016	402.93	0.648	261.10	1,438.55	0.648	932.18
2017	315.04	0.648	204.14	1,265.57	0.648	820.09
2018	383.07	0.648	248.23	1,475.28	0.648	955.98
2019	395.44	0.648	256.24	1,437.76	0.648	931.67
2020	662.76	0.648	429.47	2,350.44	0.648	1,523.09

Stormwater from Regulated Point Sources

There are five industrial general permits within the watershed (Table 3). There are no current construction stormwater general permits or commercial general permits in the watershed.

There are no urbanized areas in the watershed that are regulated under the General Permit for the Discharge of Stormwater from Small Municipal Separate Storm Sewer Systems (MS4), and no towns regulated by the Small MS4 General Permit.

The Connecticut Department of Transportation (CT DOT) is covered by the MS4 General Permit, given the six major state routes in the watershed: Routes 63, 4, 118, 209, 109, and 61. CT DOT is responsible for maintaining these roads and implementing permit requirements to protect water quality (Table 3).

Other Regulated Point Sources

One permitted large septic tank leach field is located north of Bantam Lake and owned by the White Memorial Foundation, Inc. (Permit # GSSD000002) in Litchfield. One groundwater discharge by underground injection permit is held by the Connecticut Junior Republic Association (UI0000307) in Litchfield. There is also one Leaf Compost Facility Permit and one Swimming Pool Wastewater General Permit in the watershed (Table 3).

Unpermitted Wastewater Sources

There are no known Sanitary Sewer Overflows (SSOs) in the watershed. Within the watershed, sewer service extends from the Litchfield WPCF (located downstream of Bantam Lake) to the majority of the Litchfield town center, as well as the eastern shore of Bantam Lake (covering 1,716 acres or 9% of the watershed land area but 28% of the buildings in the watershed). There are no known illicit discharges to stormwater systems in the watershed, although given their nature, they may be present but not yet discovered or reported.

Illicit discharges from boats are a possibility in the watershed. There are three marinas and two boat launches on Bantam Lake[3]. The Bantam Lake Yacht Club Marina is located on the eastern shores of Bantam Lake's South Bay at 1 Yacht Club Passway in Morris. Beverly's Marina is on the northeast shore of South Bay in Morris, and White Memorial Marina is near Kilbourne Cove on North Shore Road in Litchfield. The Bantam Lake Boat Launch is located on the northeastern shore of South Bay at the corner of State Route 209 and Palmer Road in Morris. There are no pump-out facilities on the lake; however, there is the possibility that individual boaters could illegally discharge waste overboard or that swimmers are not using proper facilities for their waste. There is a prohibition on the discharge of sewage from any vessel to surface waters in Connecticut.

There is the possibility for improper disposal of septage in the watershed, given that a portion of the watershed is served by Subsurface Sewage Disposal System.

[3] See https://portal.ct.gov/DEEP/Boating/Boat-Launches/Bantam-Lake-Boat-Launch and http://bantamlakect.com/boatlaunches.html.

Table 3: Permitted facilities within the Bantam Lake watershed. See Figure 4.

Town	Client	Permit ID	Permit Type
Goshen	Woodridge Lake WPCF	SP0000179	Wastewater Pollution Control Facility (WPCFs)
Litchfield	Dings Auto Sales & Salvage, Inc.	GSI000776	Industrial General Permit
Goshen	Goshen Public Works Department	GSI001276	Industrial General Permit
Litchfield	Litchfield Highway Garage	GSI000875	Industrial General Permit
Litchfield	Litchfield Maintenance Facility	GSI000034	Industrial General Permit
Litchfield	Litchfield Recycling Facility	GSI000811	Industrial General Permit
Statewide	Connecticut Department of Transportation (CT DOT)	GSM DEEP-WPED-GP-22	MS4 General Permit
Litchfield	White Memorial Foundation, Inc.	GSSD000002	Groundwater Discharge Permit (large septic tank leach field)
Litchfield	Connecticut Junior Republic Association	UI0000307	Groundwater Discharge Permit (underground injection)
Litchfield	Litchfield Leaf Compost Facility	LCF-074-001	Leaf Compost Facility Permit
Litchfield	Connecticut Junior Republic Association	GPL000107	Swimming Pool Wastewater General Permit

4.2 Nonpoint Sources (NPS)

Polluted Runoff

Approximately 3,085 acres (15%) in the watershed are developed, with 765 acres (4%) of impervious cover. Because no areas in the watershed are regulated by the Small MS4 General Permit, all stormwater runoff generated by development is evaluated as nonpoint source. Much of this development is concentrated around the lake, along roads, and in the town centers of Litchfield and Goshen.

Subsurface Sewage Disposal System

Most of the watershed land area (91%) or buildings in the watershed (72%) are served by Subsurface Sewage Disposal System (SSDS) for onsite wastewater treatment. If SSDS fail or are not properly maintained, waste will not be adequately treated and may result in nutrients leaching to surface and ground water.

Erosion

Disturbed ground, especially along roadways, can be a significant source of sediment erosion to surface waters following heavy rainfall. Within the watershed, GIS mapping analysis showed an estimated 141 stream and roadway intersections, 33 of which are located along unmaintained gravel roadways or trails. There are an estimated

20 miles of unmaintained gravel roadways and 12 miles of mapped trails in the watershed (Figure 5). Barren areas which lack vegetation, including rock outcrops, quarries, sand and gravel operations, and other bare soil areas, can accelerate the speed of stormwater flow, providing little opportunity for infiltration. University of Connecticut Center for Land Use Education and Research (UConn CLEAR) 2015 land cover data showed 29 acres (<1%) of barren land in the watershed. Development is concentrated along the eastern and southern shores of Bantam Lake and thus represents a possible source of erosion and sedimentation from unmaintained bare soil or gravel surfaces. It is currently unknown the extent of shoreline erosion because of fluctuating lake levels and/or wake boat action. There are several beaches along the shoreline, both private and public, that likely have erosion issues. Sandy Beach on East Shore Road in Morris is the only beach open to the public.

Fertilizers

Large scale fertilizer application can be used on sporting fields, golf courses, agricultural fields, and large private lawns. It is currently unknown the extent that fertilizers are used throughout the watershed.

Agriculture

Agricultural land accounts for 3,230 acres (16%), with a mix of cropland and pastureland in the watershed. There are five active dairy farms identified by CT DEEP, with a total of 220 dairy cows in Litchfield (3 dairy farms) and 113 dairy cows in Goshen (2 dairy farms). There are no farms designated solely as poultry farms, but there are 58 documented domesticated birds at the dairy farms in Litchfield and 12 birds at the dairy farms in Goshen. Goshen is also home to 70 beef cows and 3 horses. The closest farm to Bantam Lake is located in Litchfield and contains 20 dairy cows and 50 poultry. It is currently unknown the extent of manure use as a fertilizer on croplands and hayfields in the watershed or the extent of proper manure handling on site. Also, the information on agricultural resources may be outdated. Any Natural Resources Conservation Service (NRCS) Comprehensive Nutrient Management Plans should be obtained and reviewed for the WBP addendum.

Pets

There are likely a number of domesticated pets living along the shoreline and throughout the watershed near critical water resources. It's important that pet owners clean up after their pets in their own yards or along public or private trails in open space areas such as parks, preserves, or wildlife management areas. There are several public access points to Bantam Lake (such as along Route 209, at the two marinas and boat launches, and from the Point Folly parking lot on East Shore Road) and those may be spots where dog owners take their dogs to recreate. In total, there are over 5,173 acres of protected open space (505 acres of which are operated by a local land trust) in the watershed, including parks, camps, beaches, and conservation areas with public and private trails for dogs and their owners to use. It is unknown whether pet waste signage or kiosks for disposal bags are installed at any public areas. Many of the White Memorial Foundation's 40 miles of trails (in Litchfield and Morris) are open to dogs and horseback riding.

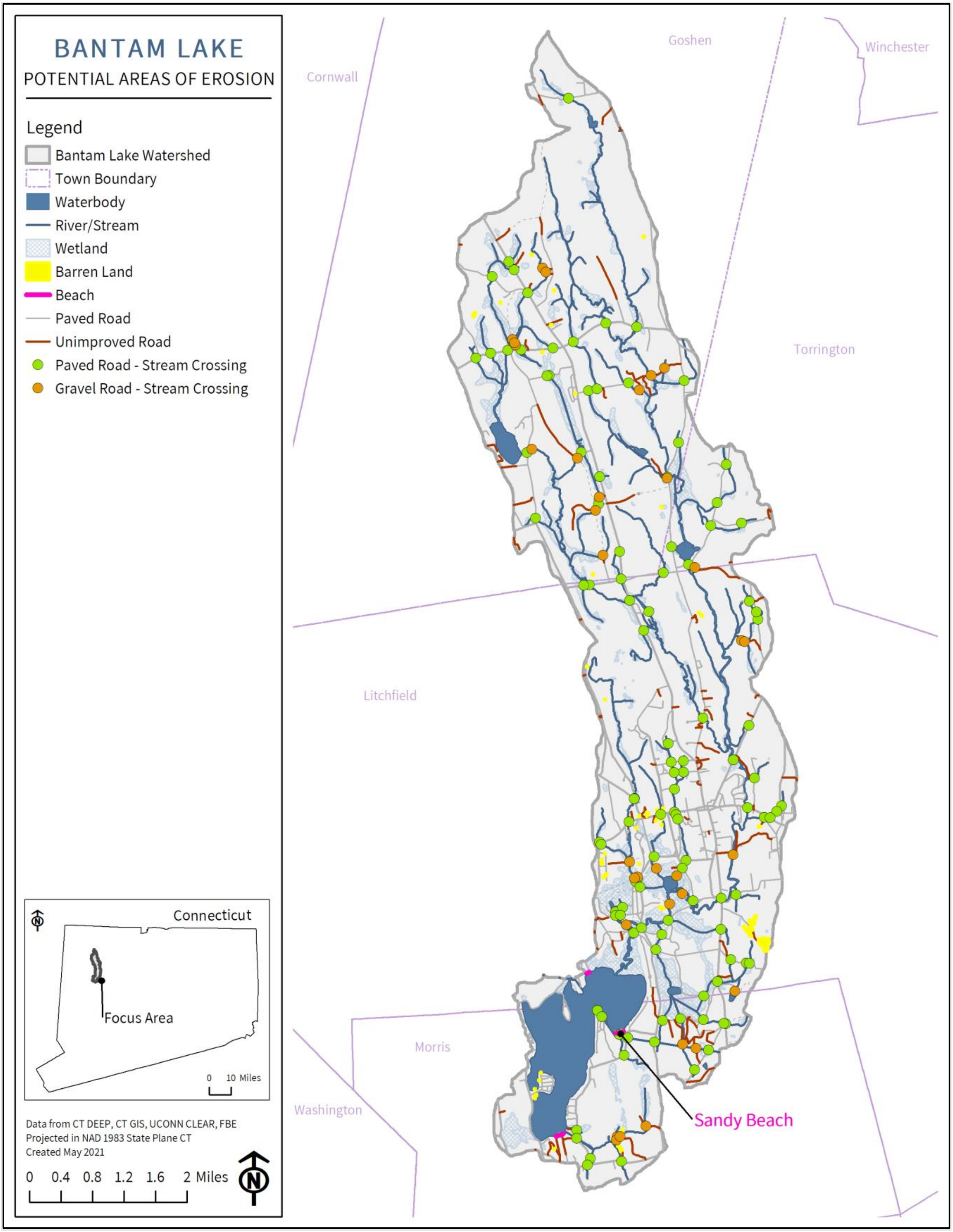


Figure 5: Map of potential erosion sites within the watershed.

Wildlife

Bantam Lake's North Bay and Center Lake have been designated as habitat for migratory waterfowl, such as the bufflehead, Canada Goose, mallard, green-winged teal, and wood duck. The watershed also contains prime wetland habitat for waterfowl, with 524 acres (3%) of open water and emergent wetlands and 1,677 acres (8%) of forested or scrub-shrub wetlands. Operated and maintained by the State of Connecticut, the Goshen Wildlife Management Area in the northern headwaters of the watershed is home to an abundance of New England cottontails, woodcock, and ruffed grouse, along with many other species of wildlife (Goshen Wildlife Management Area, Litchfield County, n.d.). Conservationists maintain some forest and shrub areas to support native species and control for invasive species.

Atmospheric Deposition

According to the Bantam Lake BATHTUB model results (CEI, Inc., 2020), atmospheric deposition accounts for 42 kg/yr (2.6%) of total phosphorus and 3,945 kg/yr (14.2%) of total nitrogen loads to the lake for the averaging period from April-October.

Internal Phosphorus Loading

According to the Bantam Lake BATHTUB model results (CEI, Inc., 2020), internal loading accounts for 560 kg/yr (34.8%) of total phosphorus for the averaging period from April-October. A significant amount of the total phosphorus load to Bantam Lake comes from the reactivation of legacy phosphorus in bottom sediments. In-lake treatments for internal loading may be considered and/or recommended as a restorative strategy. Internal loading for total nitrogen was not able to be calculated.

4.3 Land Use Analysis

Current Land Use

Excluding the surface area of Bantam Lake, the Bantam Lake watershed is predominantly forested (66%) with agricultural (16%) and developed (15%) land uses distributed throughout the watershed (Figure 6). Development is concentrated along roads, near the Litchfield and Goshen town centers, and along the western shores of Bantam Lake (on Deer Island). Two large areas identified as developed in the northeast portion of the watershed and south of the Litchfield town center are golf courses (Figure 6). Agriculture includes both pastureland and cropland, and five dairy cow farms were identified within the watershed by CT DEEP (Figure 4). Rivers, ponds, streams, and wetlands comprise the water/wetlands category and represent 3% of the watershed, with a significant wetland complex that begins at Little Pond and ends at the outlet of the Bantam River to Bantam Lake that has important filtration and retention functions for lake water quality protection (Northeast Aquatic Research, 2009).

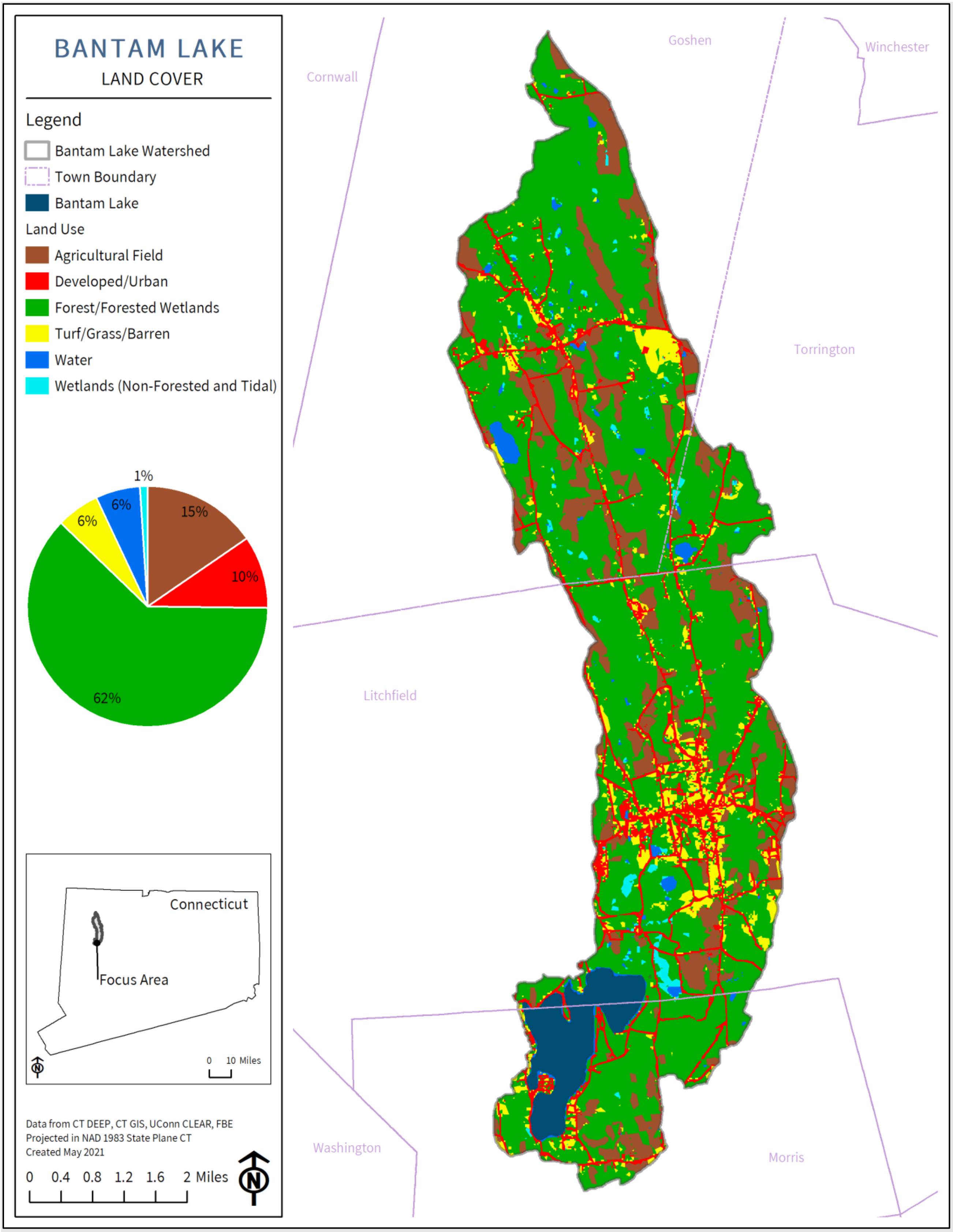


Figure 6: Map of land cover in the watershed.

Land Use Trends

Land use changes within a watershed over time can have measurable consequences on receiving water quality. As watersheds become more developed with commercial, residential, and industrial land uses, the amount of forest that would naturally help infiltrate precipitation may be converted to impervious surfaces, such as rooftops, roads, parking lots, and sidewalks, which force untreated and often polluted runoff to surface waters. Understanding the type and rate of land use change within a watershed can help target effective restoration strategies, including public outreach and ordinance revisions. In reviewing the UConn CLEAR Changing Landscape mapping project results for the time period of 1985 to 2015, the Bantam Lake watershed has experienced a net increase in agricultural (11 acres) and developed (314 acres) land uses and decreased forested (242 acres) and wetland (83 acres) land uses (Figures 7, 8). While some new development cropped up near the southern end of the lake in Morris, most new development was concentrated around Litchfield and Goshen town centers and around Timber Pond, also known as Bantam Pond, in Torrington (Figure 8).

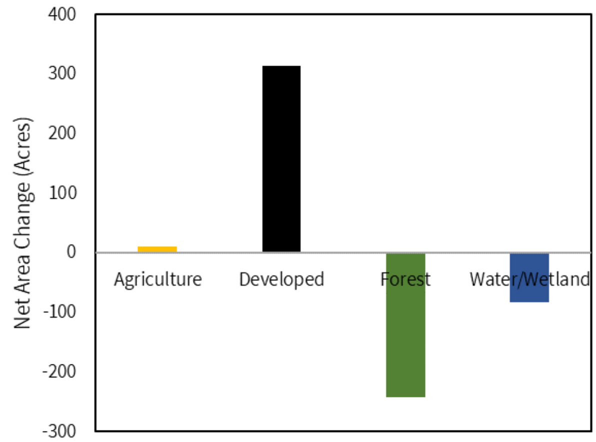


Figure 7: Net change in major land use types (agriculture, developed, forest, and water/wetland) from 1985-2015 in the Bantam Lake watershed. Data obtained from UConn CLEAR's Changing Landscape mapping project.

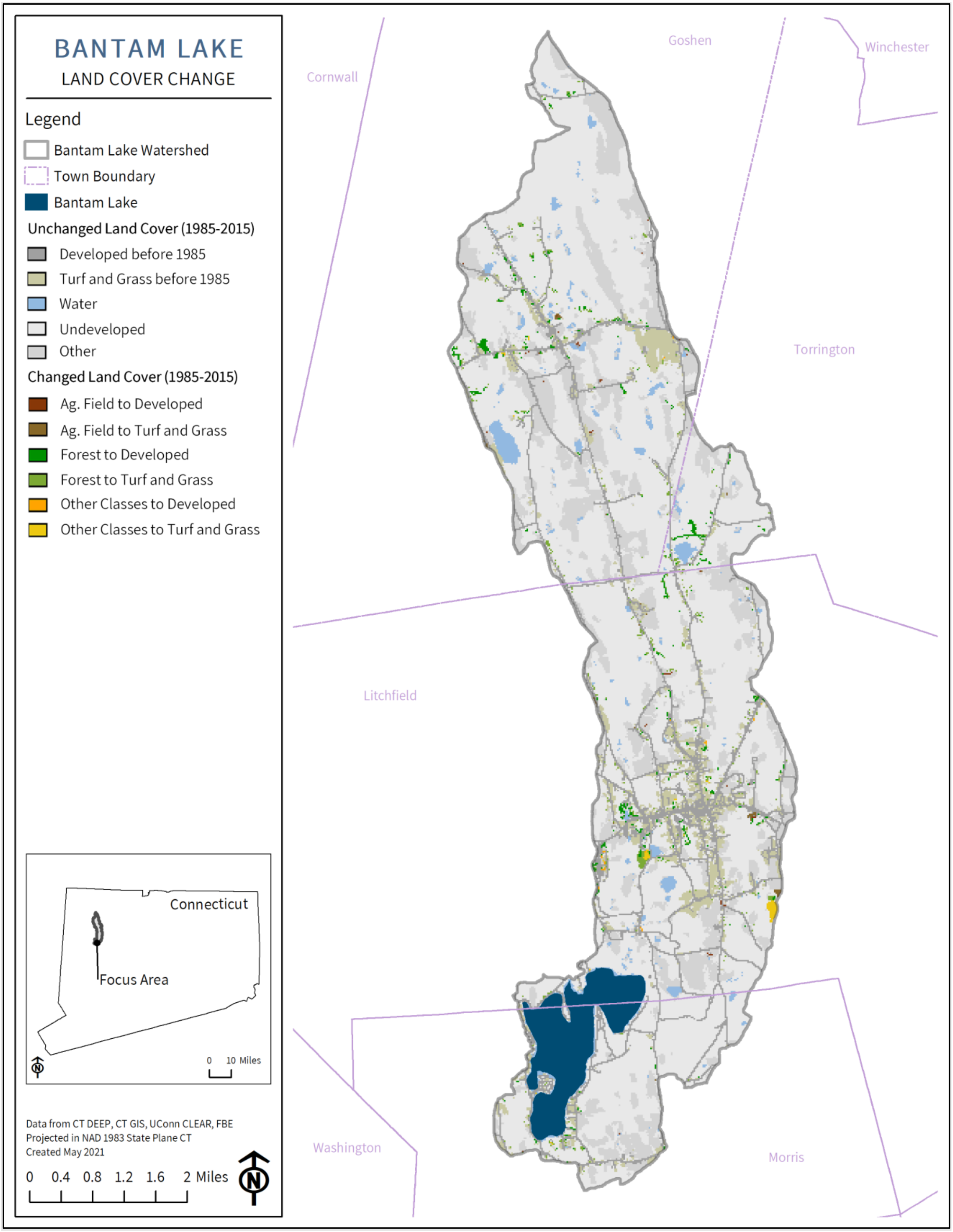


Figure 8: Land cover change from 1985 to 2015 in the watershed.

Riparian Buffer Zone Analysis

The riparian buffer zone is the area of land located immediately adjacent to streams, lakes, or other surface waters. While the boundary of the riparian zone and adjoining uplands is gradual and not always well-defined, riparian zones differ from uplands in many distinct ways, such as soil moisture levels, flooding frequency, and assemblages of water-tolerant plant and animal communities. The critical dynamics of these unique soil, hydrologic, and biological community characteristics within riparian zones function as effective filters for contaminants, which can be taken up into plant tissues, adsorbed onto soil particles, or modified by soil organisms before ever reaching surface waters. Any change to the natural riparian zone can reduce the effectiveness of the filter function and has the potential to contribute to water quality impairment.

The UConn CLEAR program created a 300-ft streamside riparian buffer layer for the entire State of Connecticut. Analyzing this information can reveal areas along river and lake corridors that are vulnerable to contamination inputs and help identify implementation opportunities at a local level. Most of the riparian zone around Bantam Lake is characterized by forested (41%) and wetland (15%) land uses along the northern and northeastern shores (Figure 9). Development (43%) is concentrated along State Route 209 along the western shore of the lake, as well as along the southeastern shore (Figure 9). The riparian zone for the streams draining to Bantam Lake are characterized mostly as forested land (72%), followed by development (13%), agriculture (9%), and water/wetlands (7%) (Figure 10). About 30% of the riparian zone for both the lake and streams is protected open space, while 57% of the riparian zone for the lake is protected open space.

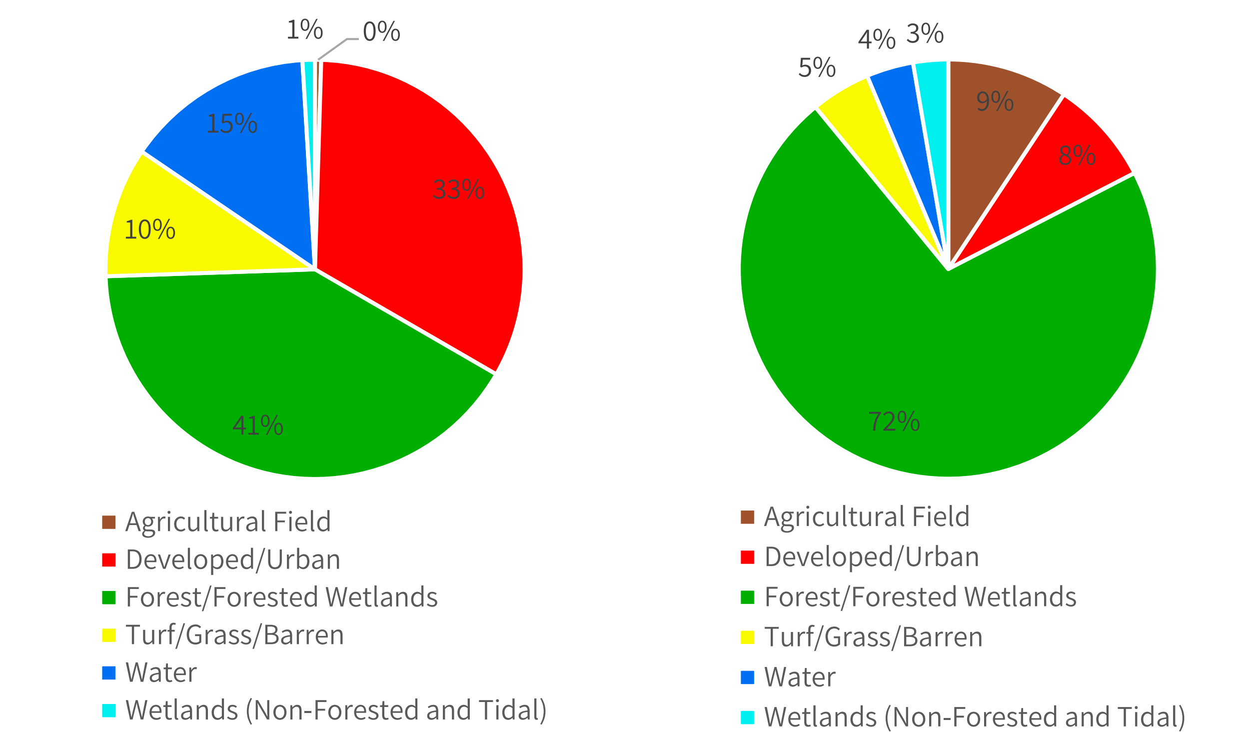


Figure 9: Riparian land cover in 300-ft buffer around Bantam Lake (left) and around streams in the watershed (right).

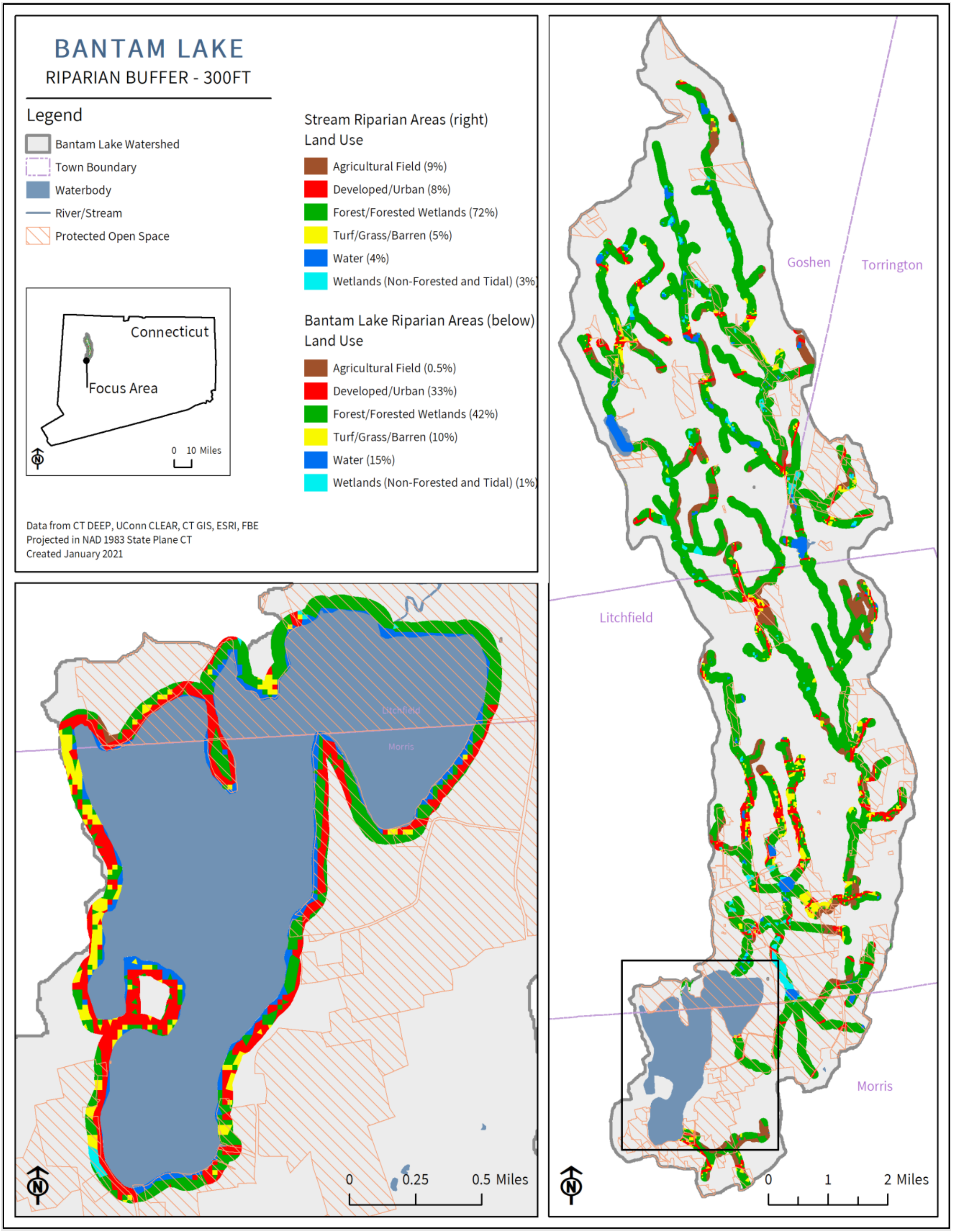


Figure 10: Riparian buffer areas around the lake shoreline and in the watershed.

5.0 Existing Local Activities

The following briefly describes any existing local management efforts related to water quality protection conducted by municipalities or other relevant watershed groups.

Municipalities

Existing local management efforts related to water quality protection for the four watershed towns of Morris, Litchfield, Goshen, and Torrington are presented in Table 4. Any gaps in the table indicate areas for possible improvement. In 2018, the Town of Morris adopted the *Morris Low Impact Development and Stormwater Management Design Manual* (Trinkaus, 2017) to address the adverse impacts of development on natural and aquatic resources in the town, including Bantam Lake, through the integration and use of LID strategies. This progressive manual could be tailored to the adjacent towns and integrated to existing development regulations.

Table 4: Summary of existing local management efforts in the watershed, by municipality.

Town	Morris	Litchfield	Goshen	Torrington
NPDES Phase II MS4 Program	CT DEEP classified Morris, Litchfield, Goshen, and Torrington are unregulated by the MS4 permit. As such, there are no stormwater management plans, IDDE, erosion and sedimental control, or post-construction stormwater regulation rules or documents required to be produced by the towns.			
Master Plans	None found	None found	None found	None found
Water Pollution Control Plans (WPCP)		Litchfield Water Pollution Control Authority 2018 Report	2016 WPCP	2008 WPCP
Zoning / Subdivision Regulations	Zoning Regulations; Subdivision Regulations	Zoning Regulations; Subdivision Regulations	Zoning Regulations; Subdivision Regulations	Zoning Regulations; Subdivision Regulations
Special Documents	2018 Low Impact Sustainable Development and Stormwater Management Design Manual		Beach Maintenance Guide	
Pet Waste Ordinances	None found	None found	None found	None found
Open Space Plans	2009 Plan of Conservation and Development; 2020 Draft Update	2017 Plan of Conservation and Development	2015 Open Space Plan; 2016 Plan of Conservation and Development	2019 Plan of Conservation and Development

Town	Morris	Litchfield	Goshen	Torrington
Wetland Protections		Inland Wetlands Regulations; Inland Wetlands Bylaws		Inland Wetlands and Watercourses Regulations; Stream Maintenance: A Homeowner's Summary
Aquifer or Groundwater Protections		Aquifer Protection Regulations	Aquifer Protection Regulations	

Bantam Lake Protective Association

The Bantam Lake Protective Association is a private nonprofit organization devoted to the preservation of Bantam Lake and its surroundings. Working with the Town of Morris, Town of Litchfield, the White Memorial Foundation, CT DEEP, and the Torrington Area Health Department, the Association strives to maintain the highest practical water quality for lake recreation (including swimming, fishing, boating, and water and ice sports). The Association hires professional limnology firms to complete annual monitoring and manage invasive aquatic species in the lake.

The White Memorial Foundation

The White Memorial Foundation operates the White Memorial Conservation Center facility, and stewards over 4,000 acres of forest, meadows, and wetlands (as well as 10 ponds, over 6 miles of the Bantam River, and nearly 60% of the Bantam Lake shoreline) in the towns of Morris and Litchfield. The mission of the Foundation is to protect its forests and countryside so that all may enjoy. The Center provides year-round environmental education programs for children and adults that inspire understanding and appreciation for the natural world. The Foundation is guided by four principles: conservation, education, recreation, and research.

Northwest Conservation District

Located in Torrington, the Northwest Conservation District covers 34 towns and cities in the state and offers many solutions and sources of information for conserving land and water resources in the area. They offer a range of services, including education, soil erosion and sediment control plan review, wetland identification assistance, on-site plan review, low impact development (LID) strategy guidance, open space preservation technical advice, open space mapping, farmland preservation promotion, prime farmland mapping, agricultural practices assistance (such as nutrient management, pasture management, rotational grazing, forest management, and special programs for horse owners), NRCS partnership, environmental review, and watershed management assistance.

Other Relevant Programs & Resources

Other existing programs in the area or helpful resources applicable to Bantam Lake include the following:

- The Northwest Hills Council of Governments (NHCOG) is the Regional Planning Organization (RPO) for northwest Connecticut advising municipalities, private business groups, and state and federal governments on a range of matters such as research, coordination, and technical assistance on cross-boundary issues such as NPS pollution. NHCOG developed the *Northwest (CT) Regional Plan of Conservation and Development (2017-2027)* (NHCOG, 2017), and the *Litchfield Hills Natural Hazard Mitigation Plan* (NHCOG, 2016).
- The Connecticut Watershed Response Plan for Impervious Cover (CT DEEP, 2015a).
- The Rivers Alliance of Connecticut created the Connecticut Watershed Conservation Network (CWC Network) to integrate river, lake, and watershed associations with land trusts, conservation commissions, and government agencies, who can provide assistance and resources.
- SustainableCT is an independently funded organization that works with municipalities on a range of environmental and social issues. Through a municipal certification program, grant funding, and educational resources, they support watershed education, creation of watershed management plans, and implementing watershed protection and restoration.
- The US Forest Service updated in 2010 a study of conservation related issues affecting the Highland Region, which includes northwest Connecticut: *Highlands Regional Study: Connecticut and Pennsylvania 2010 Update* (USFS, 2010).

6.0 TMDL & Water Quality Targets Determination

6.1 Model Analysis

This TMDL was derived through a series of water quality analysis and modeling steps, documented in the *Bantam Lake Nutrient TMDL Model Modeling Report* (CEI, Inc., 2020) and updated by CT DEEP. A summary of these steps follows.

A Lake Loading Response Model (LLRM) model for Bantam Lake watershed was developed to determine the current nutrient loading to Bantam Lake for TMDL development purposes. The nutrient loading was categorized by source for watershed land uses, treatment system discharges, nearshore Subsurface Sewage Disposal System, and birds. The watershed land use category within LLRM includes stormwater discharges. The LLRM model attenuates watershed land use loading for nested subwatersheds, although due to a limitation of the model, triple nested (and greater) watersheds require and received a corrected attenuation calculation. Current nutrient loading to Bantam Lake was also separated by tributary into the proximal (direct drainage to lake), Whittlesey Brook, and Bantam River subwatersheds.

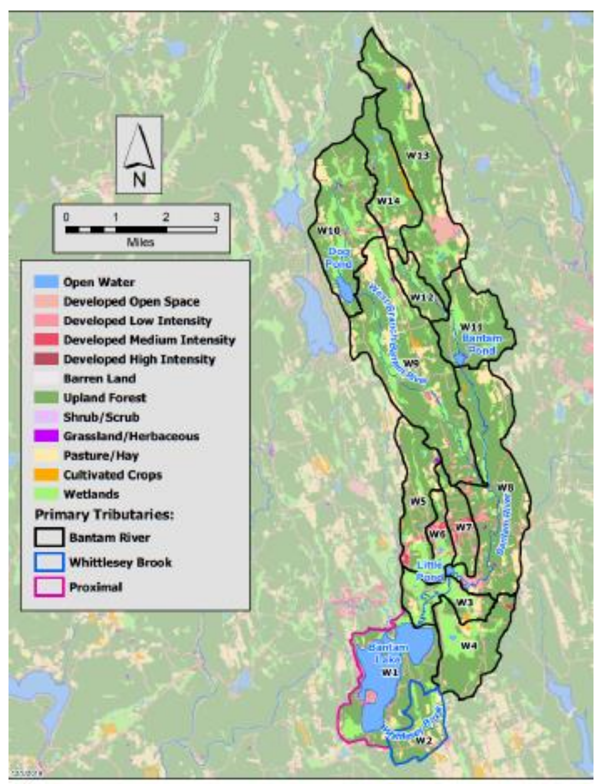


Figure 11: Subwatersheds Used in LLRM

The model estimated average annual nutrient loads that enter the lake, and not the in-lake response to those nutrients. The LLRM model was not calibrated due to insufficient tributary water quality data; however, its results were adjusted based on calibration of the BATHTUB model (described below).

Current total phosphorus loading to Bantam Lake was determined to be 1614.3 kg/yr., with 63% contributed by tributary sources and 35% by internal sources. Current total annual nitrogen loading to Bantam Lake was estimated to be 26,806.2 kg/yr, with 85% contributed by tributary sources. Current nutrient load by tributary is provided in Table 5, and current nutrient load by source is provided in Table 6 (CEI, Inc., 2020).

Table 5: Current nutrient loading to Bantam Lake by tributary as determined by LLRM (CEI, Inc., 2020).

Variable	Units	Tributary			
		Proximal	Whittlesey Brook	Bantam River	Totals
Watershed Area	ha	493.2	304.7	7,302.9	8,100.8
Discharge	hm^3/y	1.9	1.3	28.8	31.9
Total Phosphorus Load	kg/yr	114.9	51.2	846.2	1,012.3
Total Phosphorus Concentration	µg/L	43	41	29	-
Total Nitrogen Load	kg/yr	2,303.2	1130.9	19,427.2	22,861.3
Total Nitrogen Concentration	µg/L	962	904	675	-

Notes:

1. *Time period is 2007-2016 with 2011 and 2016 outlier years removed during April-Oct. averaging period.*
2. *Proximal load and concentration predictions include SSDS (9.7 kg/yr TP; 388.2 kg/yr TN) and Waterfowl (25.2 kg/yr TP; 119.7 kg/yr TN) predictions for Total Phosphorus and Total Nitrogen.*
3. *Surface area of Bantam Lake excluded from "Proximal tributary (a.k.a., subwatershed W1).*

Table 6: Current nutrient loading to Bantam Lake by category as determined by LLRM and BATHTUB (CEI, Inc., 2020).

Load Source	Total Phosphorus		Total Nitrogen	
	Load (kg/yr)	Percent	Load (kg/yr)	Percent
Tributary	1012.3	62.7%	22861.2	85.3%
Internal	560	34.7	-	0.0%
Atmospheric	42	2.6%	3,945	14.2%
Totals	1614.3	100.0%	26806.2	100.0%

Notes:

1. *Time period is 2007-2016 with 2011 and 2016 outlier years removed for April-Oct. averaging period.*
2. *Tributary (which includes SSDS and waterfowl) load estimates obtained from LLRM.*

3. *Internal load and atmospheric load estimates obtained from BATHTUB.*

The LLRM nutrient loading estimates were used as inputs to the BATHTUB model to predict in-lake responses to nutrient loading. The BATHTUB model also was used to model nutrient loads from atmospheric deposition and internal phosphorus loading. The in-lake responses include total phosphorus concentration, total nitrogen concentration, chlorophyll-*a*, transparency, and hypolimnetic oxygen depletion. The BATHTUB model was calibrated and validated.

To estimate the annual total phosphorus and total nitrogen loads at which WQS targets would be attained, the BATHTUB model for Bantam Lake was run iteratively for five hypothetical loading scenarios, each with sequentially adjusted tributary input concentrations (i.e., 0, 15, 25, existing conditions, and 60 µg/L for total phosphorus and 250, 500, 600, existing conditions, and 1000 µg/L for total nitrogen). A best-fit trend line was established to define the relationship between the hypothetical nutrient loading scenarios and resulting in-lake nutrient concentrations (Figure 5-1 and Figure 5-2 in the modeling report, reproduced below). The resulting relationships were:

$$L_{phosphorus} = 16.7 \cdot C_{phosphorus}^{1.43}$$

$$L_{nitrogen} = 50.81 \cdot C_{nitrogen} + 1.79$$

Where,

L = Predicted annual average loading during the averaging period (includes all potential loading sources: tributary, internal, SSDS, atmospheric, waterfowl) (kg/yr)

C = Predicted average in-lake concentration in the upper mixed layer (0-3 m) during the averaging period (µg/L).

These relationships were used to estimate Bantam Lake's loading capacity (i.e., the maximum total loads that result in compliance with the numeric water quality targets), which is the basis for the TMDL presented below in Section 6.2.

The following nutrient loading analysis figures are from *Bantam Lake Nutrient TMDL Model Modeling Report* (CEI, Inc., 2020).

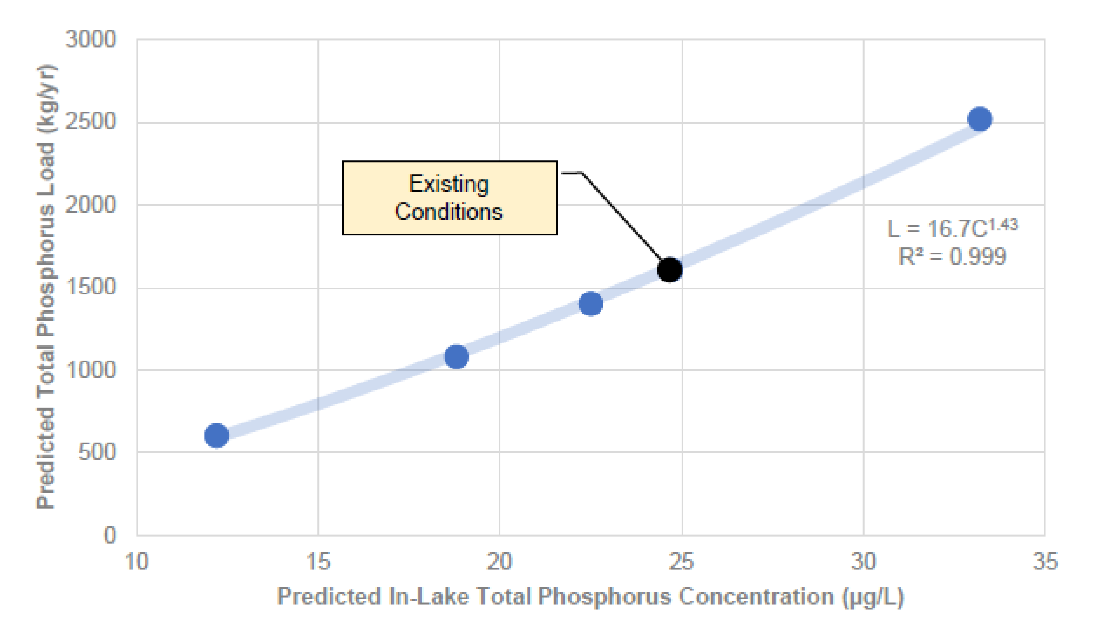


Figure 12: Modeled Relationship for Phosphorus in Bantam Lake

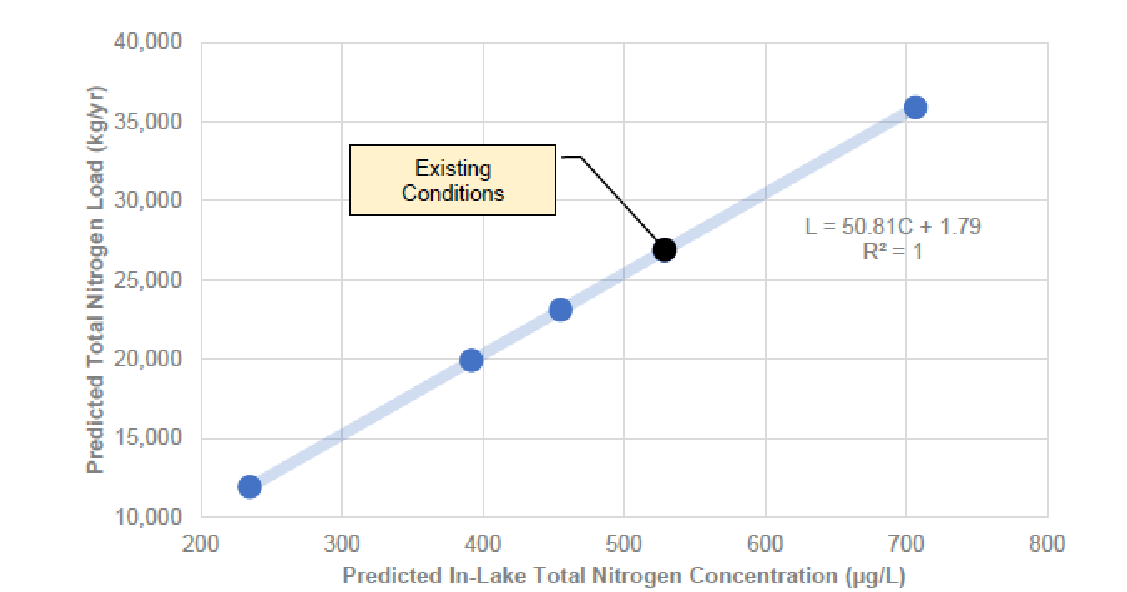


Figure 13: Modeled Relationship for Nitrogen in Bantam Lake

6.2 Water Quality Target Analysis

To identify the natural trophic state for Bantam Lake, a systematic weight of evidence approach was implemented (see core document) which uses the expected trophic range for the lake, relationships between landscape level variables and predicted nutrient loading and lake-specific studies.

IDENTIFYING THE POTENTIAL RANGE OF TROPHIC CONDITIONS FOR BANTAM LAKE

Current Trophic Level

The current trophic status provides the upper range limit which should not be exceeded. It is determined based on observed water quality data for chlorophyll A, total phosphorus, total nitrogen, and water clarity (as measured by secchi disk) and compared with the values for trophic levels as established in the CT WQS. For this TMDL, water quality data was collected by the Bantam Lake Protective Association during April through October in 2007-2018. The average chlorophyll A value for Bantam Lake is 37 ug/L, which falls under the highly eutrophic category for CT nutrient. Average measured total nitrogen and total phosphorus are 513.8 ug/L and 23.7 ug/L, respectively. Based on the CT WQS, these nutrient concentrations fall under the mesotrophic category. Water clarity is measured at an average of 2.1 m, which puts it in the eutrophic category. Macrophyte coverage in Bantam Lake is approximately 30%, assuming no herbicide treatment. This is considered extensive macrophyte growth. Based on the range of water chemistry data, macrophyte coverage and the provisions in the WQS for determining trophic state, the current trophic status of Bantam Lake is considered eutrophic (Table 7).

Table 7: Average nutrient data for Bantam Lake Compared to EPA and CTDEEP Trophic Information

	EPA	CT	CT	CT	CT
	Chlorophyll A (ug/L)	Chlorophyll A (ug/L)	Total Nitrogen (ug/L)	Total Phosphorus (ug/L)	Secchi (m)
# Samples	4	4	150	182	132
Range	27 to 48	27 to 48	175 to 1630	8 to 78	0.85 to 4.20
Average	**37**	**37**	**513.8**	**23.7**	**2.1**
Oligotrophic	0-2	0-2	0-200	0-10	6+
Mesotrophic	2-7	2-15	200-600	10-30	2-6
Eutrophic	7-30	15-30	600-1000	30-50	1-2
Highly Eutrophic	>30	>30	>1000	>50	0-1

Lake Trophic Level under Reference Conditions

Reference conditions provide an estimate of the trophic status of the lake without anthropogenic inputs and sets a lower boundary for the expected trophic range of the lake. Reference conditions are modeled based on removing anthropogenic nutrient sources such as discharges, SSDS inputs and developed landuse. An iteration of the Lake Loading Response Model (LLRM) setting land cover to fully forested conditions and including inputs from waterfowl is run. The loads from that model run were then added to the loads from atmospheric deposition to define the reference conditions. The loading predictions from the reference condition-based LLRM are converted to in-lake nutrient concentrations using the relationships between loads delivered to the lake and in-lake water quality developed from the calibrated LLRM/BathTub models developed for Bantam Lake (Figures 13 & 14). These in-lake nutrient concentrations are then used to identify the predicted trophic level for reference conditions based on CT WQS.

In the modeled reference condition, phosphorus and nitrogen concentrations are 11.5 ug/L and 281 ug/L (Table 9), which corresponds to the lower mesotrophic range, and provides the lower boundary for the natural trophic range of the Bantam Lake.

Table 8: Modeled in-lake concentrations of total nitrogen and total phosphorus in Bantam Lake

	Total Phosphorus (ug/L)		**Total Nitrogen (ug/L)**	
	Current Conditions	*Reference Conditions*	*Current Conditions*	*Reference Conditions*
Modeled In-Lake Concentration	24.7	11.5	528.6	281
CT WQS Mesotrophic Range	10-30		200-600	

PREDICTING NATURAL TROPHIC LEVEL

Models that relate landscape condition and lake morphometry to lake trophic status provide tools to estimate the expected trophic conditions for a specific lake based on these physical factors. CTDEEP has identified three models that provide this analysis and used them to evaluate Bantam Lake.

Taylor Approach

The Taylor approach is a landscape model based on a graphical analysis technique developed by Robert Taylor (1979). The model is based on a commonly used mass balance equation that is one of the relationships used in the LLRM. The mass balance equation relates the observed concentration of total nutrients to the expected loading of nutrients to the lake and lake morphometry. The Taylor approach is a graphical analysis that uses the watershed area to lake area ratio as a substitution of nutrient loading and assesses its relationship with mean depth of the lake.

CTDEEP developed a baseline plot for this analysis using the Taylor approach and data from least disturbed lakes in New England that were assessed by EPA within the National Lakes Assessment(NLA) as meeting designated uses, based on data from the 2007 and 2012 surveys. Line boundaries differentiate between the trophic conditions of the lakes based on NLA chlorophyll A data and the trophic ranges specified in the CT WQS.

In Figure 14, Bantam Lake is plotted on the base plot using data available for mean lake depth, total watershed area, and total lake area. According to this analysis, Bantam Lake falls in the mesotrophic category.

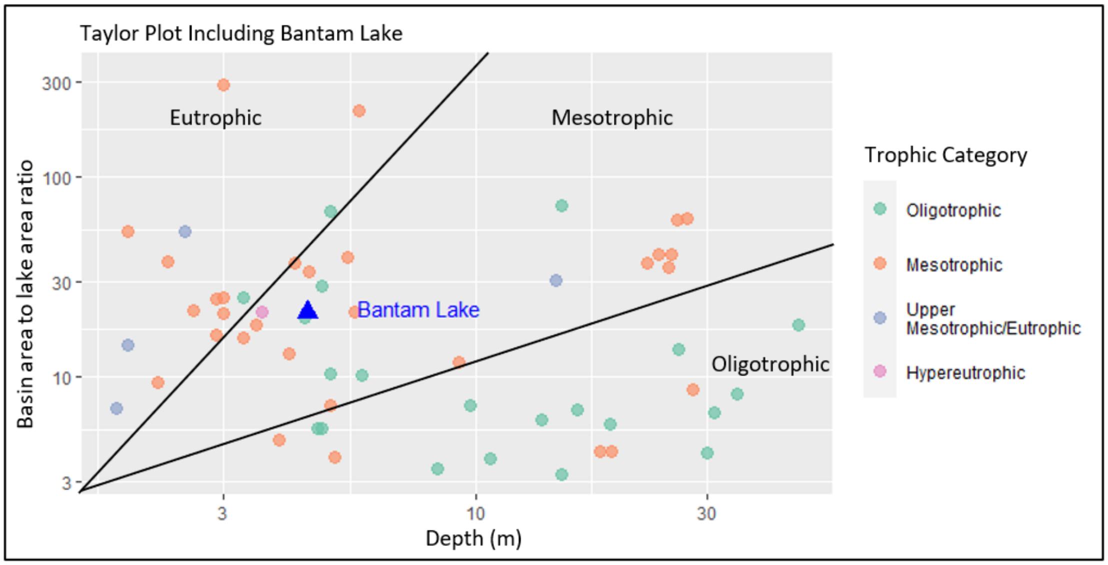


Figure 14: Taylor model base plot, including Bantam Lake.

Hollister et al Model

A landscape-based model developed by Dr. Jeffrey Hollister et al. (2016) uses universally available landscape variables in a random forest analysis to build predictive models using chlorophyll A in a waterbody to classify the most likely trophic tendency of the lake. The landscape variables identified as the most impactful to chlorophyll A levels include ecoregion, percent cropland, elevation, latitude, percent evergreen forest, and mean lake depth. The chlorophyll A models for each lake are aggregated by the random forests and assigned a trophic condition based on those results. Results for a model run for Bantam Lake can be accessed through The Nature Conservancy New England Lake and Pond Study (NELP). This model identifies Bantam Lake as mesotrophic.

New England Lake and Pond Study Model

The Nature Conservancy New England Lake and Pond Study (NELP) (Olivero-Sheldon and Anderson 2016) is a model using a random forest approach to determine trophic status by estimating the percent chance a lake falls into each trophic category. The landscape variables identified as the best predictor of trophic status were % natural, cover, longitude, latitude, maximum depth, elevation, % deciduous forest and % agriculture. Lakes are assigned an estimated probability that it falls into the various trophic categories. Bantam Lake is assigned the following probabilities based only on its landscape variables:

Table 9: NELP Model Trophic Level Probabilities for Bantam Lake

Oligotrophic	Mesotrophic	Eutrophic	Highly eutrophic
0.457	0.286	0.21	0.047

LAKE SPECIFIC STUDIES

A paleolimnological study was conducted on a sediment core collected at Bantam Lake in 1991 (Siver et al. 2021). This study evaluated diatom relative abundance and mean diatom size to identify lake trophic status at various core depths, which were dated using lead isotopes, and covered the period of 1857 - 1991. Inferred trophic scores were developed using information on scaled chrysophytes based on a model by Siver and Marsicano (1996). The cores allowed researchers to examine the historical water quality record. Based on this record, in the 1940s and previous, Bantam Lake was mesotrophic with a strong shift to a eutrophic condition occurring in the mid-1960s. The rapid shift in trophic condition is indicative of changing environmental conditions with probable anthropogenic causes and suggests that the natural trophic condition for Bantam Lake leans towards mesotrophic.

SELECTING WATER QUALITY TARGETS BASED ON WEIGHT OF EVIDENCE EVALUATION

A summary of the trophic level predictions for the various lines of evidence developed for this analysis are presented in Table 10. The general trophic category identified by each analysis is highlighted in green with a star added to indicate in more detail the predicted trophic level within the range. In general, observed data was regarded with a high level of confidence and well-established models were given medium confidence. The Taylor analysis was given low confidence since this evaluation is based on an interpretation of a graph and is not as well calibrated as the other models used.

The potential trophic range for Bantam Lake is between the lower mesotrophic and eutrophic levels based on modeled reference and current conditions.

The predicted trophic status based on landscape level and lake morphometry-based models place Bantam Lake within the Mesotrophic range. While the Taylor analysis placed Bantam Lake within the upper portion of the mesotrophic range, the Hollister and New England Lake and Pond Models suggested that Bantam Lake would fall within lower to middle Mesotrophic range. These models have a more robust calibration and so the results were favored over that of the Taylor analysis.

The Bantam Lake specific paleolimnological study identified that the long-term trophic status for Bantam Lake was mesotrophic, prior to a rapid shift in lake productivity, that is assumed to be caused by anthropogenic changes within the watershed.

Considering all these lines of evidence, CTDEEP has established the natural trophic state for Bantam Lake as mesotrophic and recommends that the mid-range of the mesotrophic concentrations for phosphorus and nitrogen be established as the water quality goals for the lake's trophic condition consistent with the CT WQS. This corresponds to in-situ nutrient levels of 20 ug/L and 400 ug/L for total phosphorus and total nitrogen, respectively.

Table 10: Weight of evidence for Bantam Lake

Weight of Evidence Evaiuation	EPA Chl A Targets (ppb)	0-2	2-7	7-30	>30
Bantam Lake	CT Chl A Targets (ppb)	0-2	2-15	15-30	>30
	CT Total Phosphorus (ppb)	0-10	10-30	30-50	>50
	CT Total Nitrogen (ppb)	0-200	200-600	600-1000	>1000
	CT Secchi Disk (m)	6+	2-6	1-2	0-1
Line of Evidence	**Confidence**	**Oligotrophic**	**Mesotrophic**	**Eutrophic**	**Highly Eutrophic**
Current Trophic Level	High			★	
Reference Condition Model	Medium		★		
Taylor Landscape Analysis	Low		★		
EPA Hollister et al Model	Medium		★		
New England Lake & Pond Model	Medium	0.457 ★	0.286	0.21	0.047
Lake Specific Studies	High		★		

6.3 TMDL Analysis

The nutrient loading goals for Bantam Lake were developed using the modeled best-fit trend line relating nutrient loading to in-lake nutrient concentrations determined by the calibrated LLRM/BathTub models for the lake (Section 6.1) and the water quality targets corresponding to the natural trophic state of the lake (Section 6.2). The TMDL for Bantam Lake was set as the annual mass load, on a seasonal basis, for total phosphorus and total nitrogen at which the in-lake concentration of each nutrient was at middle of the mesotrophic range, the natural trophic status determined for Bantam Lake by CT DEEP.

The resulting TMDL targets are set at 1,211.1 kg/year (3.32 kg/day) total phosphorus and 20,326 kg/year (55.7 kg/day) total nitrogen (Table 11) for loads delivered directly to the lake in order to achieve the in-lake concentrations of 20 ug/L total phosphorus and 400 µg/L total nitrogen. At those levels, the BATHTUB model predicts an in-lake chlorophyll-*a* concentration of 11.8 µg/L and Secchi depth of 2.1 m which also fall within the mesotrophic range within the CT WQS. The BATHTUB model also predicts that under current conditions, Harmful Algal Blooms may occur at a probability (defined as chlorophyll-*a* > 30 ppb) of 4.5%. This rate is expected to decline once the TMDL is implemented.

Table 11: Bantam Lake existing nutrient loading conditions and TMDL.

	Total Phosphorus		**Total Nitrogen**	
	Existing Conditions	*Load Reduction (TMDL Target)*	*Existing Conditions*	*Load Reduction (TMDL Target)*
In-Lake Concentration (µg/L)	24.7	20.0	528.6	400.0
Total Loading (kg/yr)*	1,614.3	1,211.1	26,806.0	20,326

** Loading calculated based on target in-lake concentration and equations from paired models to relate watershed load to in lake concentration.*

The TMDL is comprised of a Waste Load Allocation (WLA; for point sources, PS), Load Allocation (LA; for nonpoint sources, NPS), and Margin of Safety (MOS). In practice, data are usually not sufficiently detailed to allow a precise separation of PS and NPS pollution. Therefore, in this TMDL, the WLA is set as the MS4-regulated watershed load plus the load from the NPDES regulated discharges. The LA is set as the sum of the non-regulated watershed load[4], excluding background loads, atmospheric deposition, SSDS, waterfowl, and internal loading.

Waste Load Allocation

The only point source allocation included in this TMDL is for the Woodridge Lake Water Pollution Control Facility (WPCF) which treats sewage and discharges to the upper watershed of the West Branch of the Bantam River, below Dog Pond. The load from this facility is assigned to the WLA. There are no areas municipal areas in the Bantam Lake watershed that are regulated under the MS4 general permit for stormwater.

The CTDOT is covered under the General Permit for the Discharge of Stormwater from Department of Transportation Separate Storm Sewer Systems. The TMDL analysis conducted did not include a separate evaluation of the potential nutrient loading from CTDOT roadways. The permit has required activities to install BMPs and take measures to reduce pollutant loadings to impaired waters from CTDOT roadways. Continued implementation to address the requirements in that permit, especially for any CTDOT roadways within the Bantam Lake watershed, will potentially provide additional load reductions to the lake. Information on the General Permit for CTDOT MS4 systems is available from CTDEEP and information on CTDOT implementation activities under this permit can be found on their website.

The WLA set for Woodridge Lake WPCF which is located in Goshen and represents a reduction from current loading from the facility and is based on predicted effluent quality after an upgrade to the treatment system is implemented. Effluent quality is predicted to be 0.20 mg/l (0.21 lbs/day) and 3.0 mg/l (3.13 lbs/day) for total phosphorus and total nitrogen, respectively, assuming an upgrade to a Membrane Bioreactor treatment system or equivalent and a design capacity of 125,000 gallons per day.

This level of effluent quality will result in delivery of 22.5 kg/yr TP and 335.7 kg/yr TN to Bantam Lake. These values are calculated by applying an attenuation factor of 0.648 to the predicted effluent quality, based on attenuation of nutrient loads from the facility as it moves through the watershed. For the purpose of the model, the discharge is located in Basin 9 (W9). Within the LLRM, effluent waters from WLSD and Basin 9 (W9) are routed to Basin 8 (W8), Basin 3 (W3), and then terminate into Bantam Lake. The subwatersheds used in the model are shown in Figure 11. As part of the LLRM for Bantam Lake, each nested basin's attenuation factor has been calibrated using data from 2012 - 2015 and validated using data from 2017 and 2018. The attenuation factors for W9, W8, and W3 are 0.90, 0.90, and 0.80 respectfully. By multiplying these attenuation factors together, a final attenuation factor of 0.648 is obtained.

[4] The percent of directly connected impervious area (DCIA) will be determined for MS4-regulated areas in the watershed (percent out of the total DCIA in the watershed) and applied to the total watershed load. The difference between the MS4-regulated watershed load and the total watershed load will be the non-regulated watershed load.

Table 12: Proposed Effluent Loading from the Woodridge Lake WPCF

Proposed Effluent Quality (Info from Facility for MBC Treatment)					
Parameter	**Unit**	**Value**	**kg/yr**	**Watershed Attenuation Factor**	**Delivered Load to Bantam Lake** (kg/yr)
Flow	MGD	0.125			
TN	mg/l	3.00			
TN	lbs/day	3.13	518.12	0.648	335.7
TP	mg/l	0.20			
TP	lbs/day	0.21	34.76	0.648	22.5

The long-term goal is for the elimination of the contributions from the Woodridge Lake Facility to Bantam Lake. However, at this time, the goal within the TMDL is based on improving effluent water treatment practices to achieve a reduction in nutrient loading to Bantam Lake.

Margin of Safety

An explicit Margin of Safety of 5% of the total load to the lake was set for this TMDL. In the Bantam Lake Modeling Report (CEI, 2020), Section 4.4, the percent difference between the water quality observations used to calibrate the model and the model predictions for TP and TN were 4.2% and 2.9%, respectively. A value of 5% was selected based on the strength of the calibrated LLRM and BathTub models for Bantam Lake. This provides more than 75% certainty that the TMDL loading targets will be achieved as calculated using Walker 2001.

Background Load

The nutrient loads associated with reference conditions provide an estimate of nutrient loading to the lake without anthropogenic inputs. Reference conditions were modeled based on removing anthropogenic nutrient sources such as discharges, SSDS inputs and developed landuse from the calibrated LLRM/Bathub Models for Bantam Lake. An iteration of the LLRM was then run setting land cover to fully forested conditions and including inputs from waterfowl. The load of nutrients to the lake from that adjusted model together with the addition of the load from atmospheric deposition is calculated as the background load of nutrients to the lake. It is assumed that this baseline loading to the lake would not be changed through implementation of Best Management Practices other nutrient source improvements in the watershed.

Load Allocation

The Load Allocation represents the anthropogenic loading of nutrients from nonpoint sources. It is calculated as the remainder of the load after the WLA, background load, and MOS are subtracted from the total target nutrient loads.

6.4 TMDL Load Reduction Summary

Pollutant load reductions needed to comply with the TMDL are presented in Table 13. An estimated 403.2 kg/yr reduction (25.0%) in total phosphorus loading to Bantam Lake is expected to be required to achieve an in-lake total phosphorus concentration of 20 µg/L (i.e., middle of the mesotrophic range). Similarly, a 6,481.0 kg/yr reduction (24.2%) in total nitrogen loading is expected to be required to meet an in-lake total nitrogen concentration of 400 µg/L (i.e., middle of the mesotrophic range). If these load reduction targets are met, the model predicts an in-lake chlorophyll-*a* concentration of 11.8 µg/L and Secchi depth of 2.1 m. These values are both within the water quality target ranges to achieve mesotrophic conditions.

Table 13: Waste load and load allocations (WLA, LA) for existing conditions, target load (including MOS), and nutrient load reductions for Bantam Lake.

		Current Conditions (kg/year)		**TMDL Load (kg/year)**		**Load Reduction kg/yr (%)**	
		TP	TN	TP	TN	TP	TN
Total Load to Lake	All Sources	1,614.3	26,806	1,211.2	20,325.7	403.2 (25.0%)	6,481 (24.2%)
Total WLA[1]	Woodridge Lake WPCF[2]	265.9	989.5	22.5	335.7	245.6 (91.5%)	653.80 (66.1%)
Total LA	Sum of internal load, nonpoint pollution sources, and Subsurface Sewage Disposal System	733.5	7,458.6	513.2	615.6	220.3 (30.0%)	6,843 (91.7%)
Total Background Load	Sum of forested land use load, waterfowl, and atmospheric loads	614.9	18,358	614.9	18,358.1	NA	NA
Margin of Safety (MOS)	5% of total load to lake for TMDL	NA	NA	60.6	1,016.3	NA	NA

Notes:

1. *Assumes additional treatment to reduce loads from Woodridge Lake WPCF.*
2. *Woodridge Lake WPCF is the only point source for nutrients considered in this TMDL. There are no MS4 stormwater areas in watershed.*

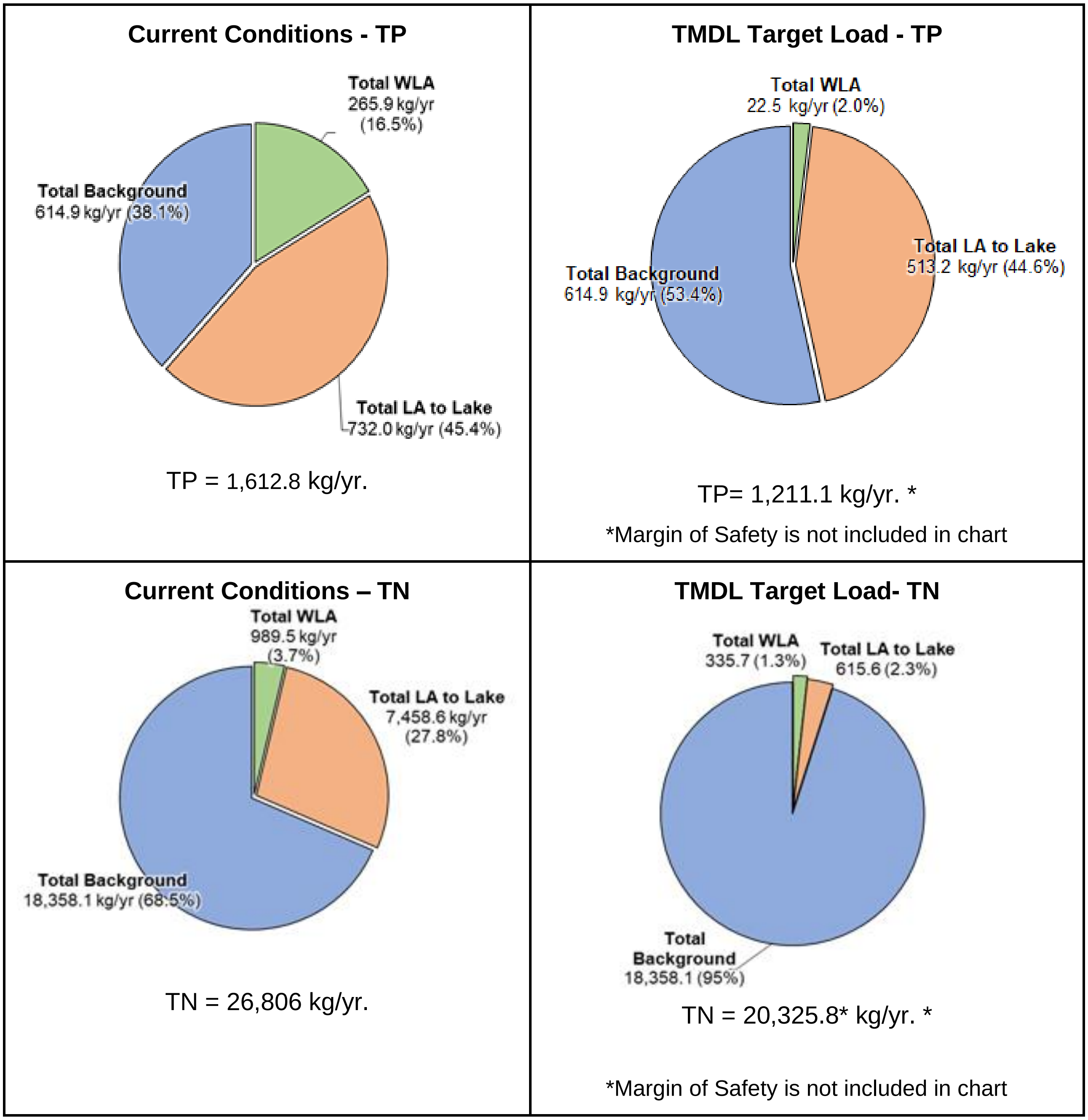


Figure 15: Charts of current conditions of Total Phosphorus and Total Nitrogen. Margin of Safety is not included in these charts.

6.5 Analysis of Loading Scenarios

The following analysis is provided to give additional information on each source and its role in achieving nutrient reductions consistent with the TMDL in order to guide development of future implementation plans.

Waste Load Allocation (WLA)

Current Conditions & TMDL Target - Total Phosphorous

The discharge from the Woodridge Lake Sewer District (WLSD) is the only contributing source to the total Waste Load Allocation (WLA). Current discharge from WLSD conditions contributes a total of 265.9 kg of phosphorus to Bantam Lake annually. This accounts for 16.5% of the annual TP load to Bantam Lake. A 245.7 kg/yr. (92.4%) reduction of annual TP discharge from WLA is recommended, based on the assumption that additional treatment using Membrane Bioreactor System technology, or the equivalent would be installed to meet the TMDL's target for TP. This would reduce the WLA to 20.3 kg/yr.

A total of 403.2 kg (25%) annual reduction from all sources is recommended for Bantam Lake. Of this 403.2 kg/yr., WLSD's current contribution makes up 66% of the TP to Bantam Lake. The WLSD facility is the single most significant source of TP to Bantam Lake.

Current Conditions & TMDL Target - Total Nitrogen

For nitrogen, the current discharge from WLSD facility contribute a total of 989.5 kg of nitrogen to Bantam Lake annually. This accounts for 3.7% of the annual TN load to Bantam Lake. A 653.8 kg/yr. (66.1%) reduction of annual TN discharge from WLA is recommended to meet the TMDL's target for TN and is based on an expected upgrade to treatment at the facility. This would reduce the WLA to 335.7 kg/yr.

A total of 6,480.4 kg (24.2%) annual reduction is recommended for Bantam Lake. Of this 6,480.4 kg/yr., WLSD's current contribution makes up 15.3% of the TN to Bantam Lake. While a decrease in WLSD's TN discharge is less significant than from other nitrogen sources, WLSD's contribution may be more easily addressed than managing other sources (See Figure 15).

Potential Elimination of the WLA for Total Phosphorus and Total Nitrogen

If WLSD were to eliminate its discharge from the watershed contributing to Bantam Lake, that would remove 265.9 kg/yr. of phosphorus and 989.5 kg/yr. of nitrogen loading to the Lake. This is different than the proposed amounts in this TMDL. This TMDL proposes to remove 245.6 kg/yr. of phosphorus and 653.8 kg/yr. of nitrogen.

By itself, the elimination of the TP & TN loading from the WLSD facility is insufficient to meet the overall load reduction goals for Bantam Lake. A complete removal of nutrients from WLSD alone would decrease the TP load to the lake from 1,614.3 kg/yr. to 1,348.4 kg/yr and decrease the TN load from 26,806.2 kg/yr. to 25,816.7 kg/yr.

This would not independently allow the target of 1,211.1 kg/yr. and 20,325 kg/yr of TP & TN respectfully to be met. An additional TP reduction of 137.3 kg/yr. (10.2%) and TN reduction of 5,490.9 kg/yr. (20.5%) from Load Allocation (which includes Non-regulated Stormwater, SSDS, and Internal Load) would still be needed to meet the TMDL target of 1,211.1 kg/yr.

Additionally, if WLSD were to eliminate its discharge from the Bantam Lake watershed, a potential increase in the Load Allocation for nonpoint sources of 20.3 kg/yr for TP and 335.7 kg/yr for TN, the current allowable WLA for the facility, could be considered. The cost-effectiveness of seeking additional pollutant loading from the WLSD facility should be evaluated as compared with obtaining that load reduction from nonpoint sources of pollution. Load Allocation (LA): Nonpoint Pollution Sources, SSDS, and Internal Load

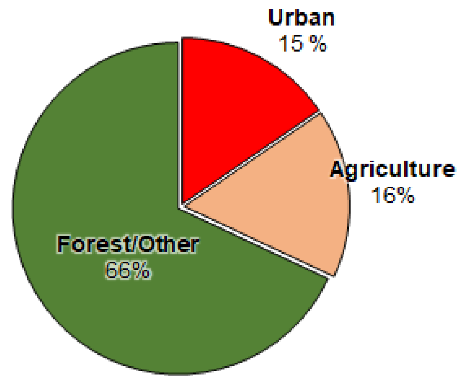
Nonpoint Pollution Sources

Nonpoint Pollution Sources can contribute nutrients to surface waters under both wet and dry conditions. Of these, nutrient loadings are predicted to be much larger in wet weather.

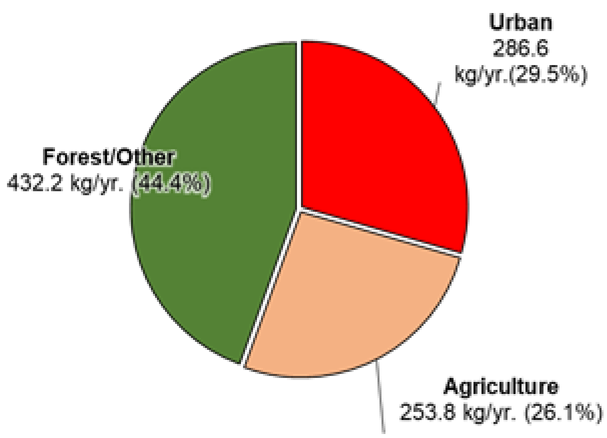
Stormwater Runoff that is not regulated under federal permit programs is one of the most common sources of nonpoint source pollution. It is the watershed load associated with wet weather. Current Land Use (LU) in the Bantam Lake Watershed consists of 66% Forested, 15% Urban and 16% Agriculture. Although Forested/Other LU types accounts for almost 2/3 of the total land use, it only accounts for 44.4% of the TP and 50% TN to Bantam Lake.

Forested/other LU types are mostly in their natural states and typically contribute less nutrients to the watershed than Urban and Agriculture land use types. For example, the Urban and Agriculture land uses combined, account for 540 kg/yr (55.5%) TP and 10,095.6 kg/yr (50%) TN of the nonregulated stormwater runoff. Identifying Best Management Practices to reduce the loading from nonpoint sources would benefit from a focus on Urban and Agriculture land use areas.

Bantam Watershed – Land Use Totals (acres)



Current Phosphorous Runoff load by Land Use (All Bantam Watersheds)



Current Nitrogen Runoff load by Land Use (All Bantam Watersheds)

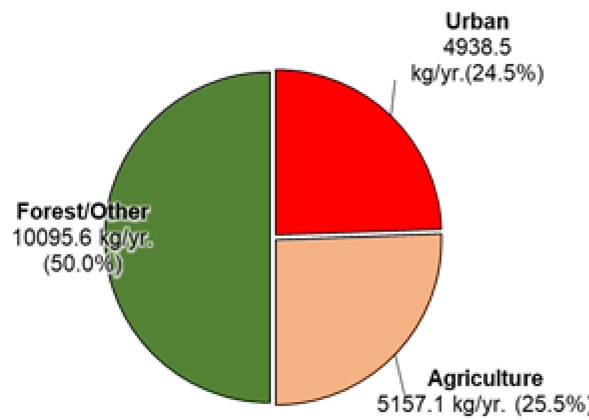


Figure 16: Land Use and the Land Use's contribution to nutrient loading into Bantam Lake

Nonregulated baseflow is the watershed load associated with dry weather. Combined, all three Land Use types account for 0.6% of TP and 5.6% TN loading to Bantam Lake, considering all sources and both wet and dry conditions. Baseflow does not change the TP load to Bantam Lake in any significant way. Due to baseflow's very low contribution, seeking TP & TN load reductions from dry weather conditions does not provide a significant opportunity to reduce loading to Bantam Lake.

Subsurface Sewage Disposal Systems

The LLRM Model includes an estimation of the nutrient load from Subsurface Sewage Disposal System (SSDS), which include septic systems, in close proximity to the lake. SSDS in other portions of the watershed are not represented by the loading estimates in the TMDL but may be contributing to the overall nutrient load to the lake. The contributions from these systems would be included in the general LA within this TMDL.

SSDS in the Bantam Lake Watershed currently contribute 9.7 kg/yr or 0.6% of the current TP load to Bantam Lake and are expected to make up 0.8% of the final TP load to the lake, once the TMDL is fully implemented. Similarly, SSDS also contribute 388.2 kg/yr. or 1.7% of the current TN load to Bantam Lake and are expected to make up 1.9% of the final TN load to the lake.

The loading values for SSDS within this TMDL are based on the assumption that the systems are functioning properly and are well maintained. Although SSDS are a relatively low contributor to TP and TN in the watershed, a malfunctioning system could contribute more loading to the lake. SSDS should be evaluated periodically to make sure that they are working properly to keep their loading contributions to the lake low. Since the loading from these systems is low, elimination of SSDS discharges from the watershed is not expected to provide a significant contribution towards lowering the overall amount of TP inputs to Bantam Lake by itself.

Internal Load

Internal Loading, which is retention and cycling of nutrients within a lake, currently contributes to a model estimated 560 kg/yr. (35%) of TP loading to the lake and is expected, if unchanged, to contribute 46% of the loading, based on target TP loads to the lake. Internal loading for nitrogen was not able to be calculated. While this source is significant, it is difficult to quantify accurately. Anthropogenic sources as such as the discharge from the Woodridge Lake Sewer District (WLSD), stormwater runoff and other nonpoint pollution sources contribute to Internal Loading in the lake. While it may seem helpful to address internal loading to the lake first, focus should first be placed on other contributing sources since they also contribute to internal loading. Without addressing those other sources first, any initial reduction in internal loading would likely be temporary as the internal nutrient load would once again build up based on continued elevated inputs from the point and nonpoint sources. Over time, as the loading to the lake decreases, there should be some decrease in Internal Loading. Therefore, these anthropogenic sources should be addressed before consideration is given to reducing the internal loading to the lake. It is possible that some action may need to be taken to reduce internal loading after the other sources within the watershed have been addressed.

Impervious cover – TP & TN

The Bantam Watershed contains 764.91 acres of impervious cover (IC), which represents 3.6% of the total land area in the Bantam Lake Watershed (Figure 17). Impervious cover is any human-made surface that prevents the absorption of stormwater. Structures include, buildings, roads, or other cover (parking lots, sidewalks, driveways, patios, swimming pools and decks). A majority of stormwater (50%) that falls on natural ground cover infiltrates the ground and attenuates its nutrient load before it slowly seeps into streams. Stormwater that runs off impervious cover can pick up and transport contaminants including motor oils, gasoline, antifreeze, and brake dust (commonly found on pavements), fertilizers and pesticides (found on landscaped areas), and soil sediments (from construction and other sites). The stormwater eventually flows into a local stream, river, or lake via a storm drain system.

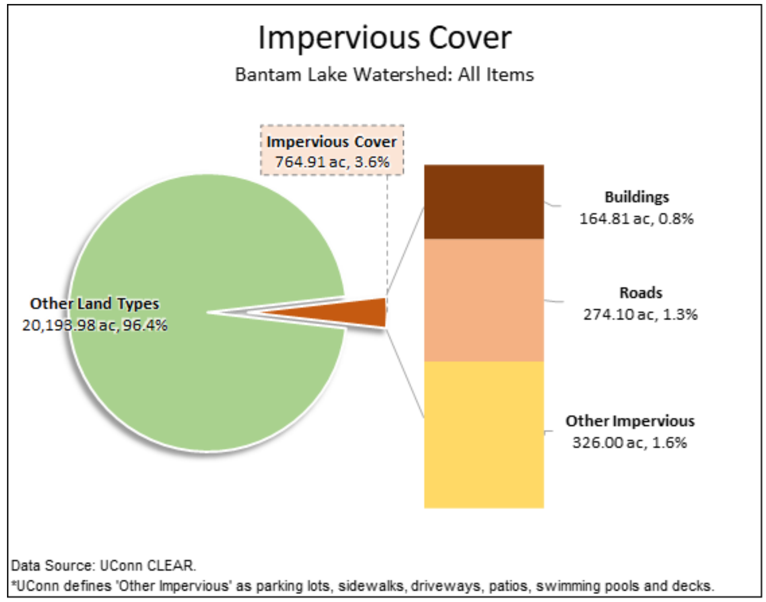


Figure 17: Impervious Cover for all Bantam Lake Watershed. IC type percentages is out of the whole watershed.

In general, the vast majority of the current Bantam Lake IC is located in Developed (Urban) and Agriculture land uses. An example of this can be seen in Figure 18. The current total impervious cover amount suggest that the current level of IC will contribute nutrient runoff loads to the Bantam Watershed (Figure 19). It is recommended that practices be installed to disconnect impervious cover from delivering the generated pollutant load to the surface waters in order to reduce loading to Bantam Lake Additionally, it is important to monitor the total

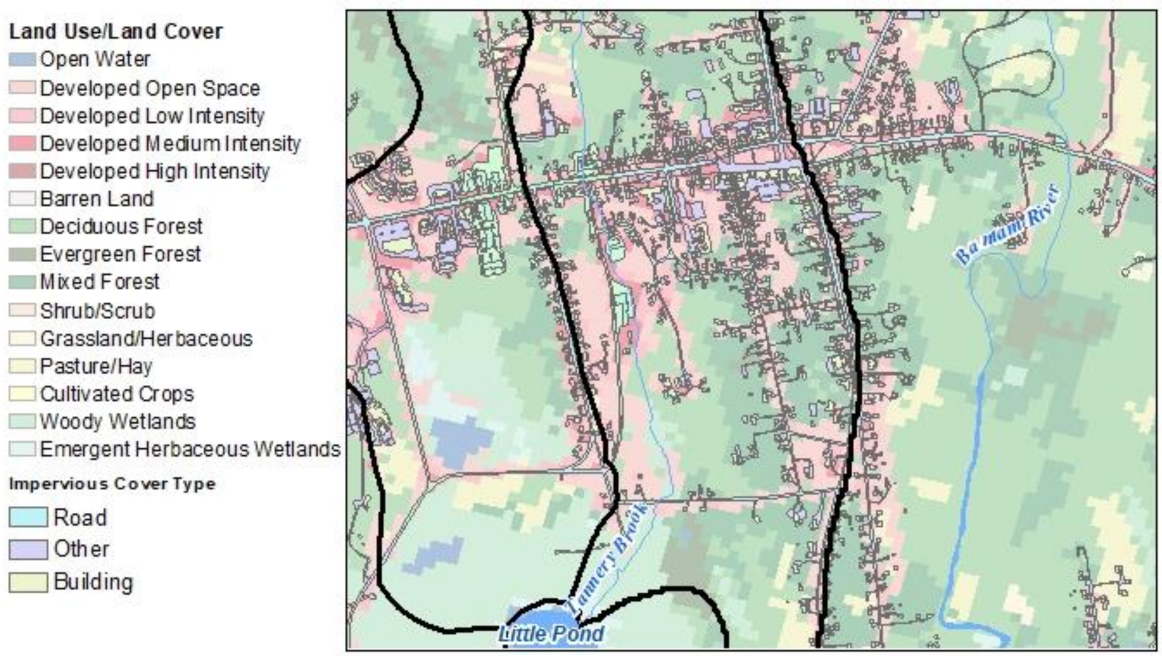


Figure 18: Impervious Cover overlayed with Land Use Types.

impervious cover in the watershed moving forward. If the area of impervious cover increases, so too will its contribution to runoff and pollutant loading.

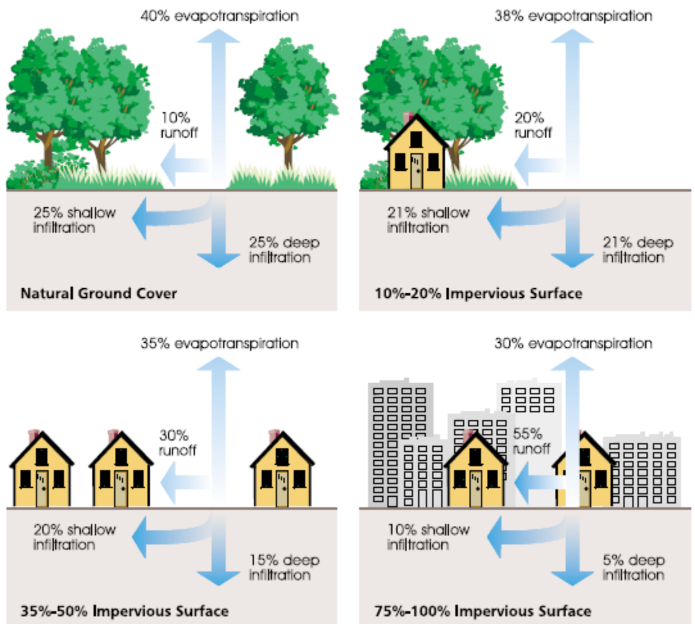


Figure 19: Runoff, infiltration, and evapotranspiration estimates in natural land cover and anthropogenic cover.

7.0 Recommended Implementation Strategies

The following recommended implementation strategies relevant to Bantam Lake provide broad categories under which more specific action items and milestones can be developed for the WBP addendum or other implementation plans, using Table 5-2 in the core document as a template.

The first and most essential management measure is the continued engagement of stakeholders within the Bantam Lake watershed. Existing partners within the watershed are very engaged and have provided substantial information, support and outreach to assist in the development of this TMDL and an associated Watershed-based Plan. Continuing that engagement with an expanded focus on addressing implementation activities withing the watershed would be beneficial. Improving a lake's water quality is a major endeavor, requiring a cohesive effort from the whole watershed community. Examples of recommended members for a watershed management team include many groups that are already engaged within the watershed, such as municipalities, local health departments, the lake association, local businesses, the soil and water conservation district, watershed residents, Council of Government, regional or local non-profits, CT DEEP, and CT DOT. The watershed stakeholder team should establish a funding strategy that accesses funds through a variety of programs and sources so that execution of the WBP addendum's implementation strategy can begin right away. In addition, the watershed stakeholder team should seek technical and scientific assistance as needed to ensure that implementation efforts are sound, and this assistance may come from academic, consulting, or any other nontraditional sources the team can identify.

7.1 Reduce Pollutant Loading from Regulated Discharges in the Watershed

Reducing nutrient loads from the Woodridge Lake Water Pollution Control Facility to the Bantam Lake watershed is am important step in meeting this TMDL. The facility should evaluate, plan for and install upgrades to the existing treatment system to achieve the necessary load reductions to meet the WLA in this permit. The WLA is based on effluent quality of 0.2 mg/l total phosphorus and 3.0 mg/l total nitrogen and a design flow of 125,000 gpd.

CTDOT should continue to implement the MS4 permit, including permit requirements to reduce pollutant loadings to impaired waters.

7.2 Amend local ordinances to better protect water resources and reduce future NPS pollution in stormwater runoff through such strategies as low impact development or green infrastructure.

Municipal land use planning and zoning ordinances are arguably the most critical components of watershed and water resource protection. Municipalities should strongly consider conducting a thorough review of town ordinances to ensure that existing regulations encourage the use of Low Impact Development (LID) and green infrastructure strategies on new and redevelopment projects. Municipal regulations should encourage and/or require the use of innovative approaches to stormwater management such as the use of bioretention, vegetated swales, and permeable paving, as well as the protection and maintenance of natural green infrastructure such as forests, riparian buffers, floodplains, and wetlands. Improved ordinance language should address site plan review regulations, LID, road and right of way standards, minimum lot sizes, minimum shore frontage per lot, setbacks, buffers, lot coverage, steep slopes, stormwater management, open space, fertilizer/pesticide use, and pet waste.

7.3 Identify areas in the watershed or ways to implement both structural and non-structural BMPs to control existing NPS pollution in stormwater runoff.

As part of the development of a WBP addendum, field surveys of the watershed and shoreline should be completed to identify target areas in the watershed for the installation of structural (or engineered) BMPs designed to encourage stormwater to infiltrate to the ground before entering surface waters (note: infiltration BMPs must be appropriate to the situation and consider the site conditions within which stormwater is to be infiltrated; for example, it may not be appropriate to infiltrate some types of stormwater into an Aquifer Protection Area or into contaminated soils). These structural BMPs would aim to disconnect impervious areas and reduce pollutant loads to waterbodies. Restoration of shoreline buffers, especially for agricultural and developed lands adjacent to surface waters is an effective and recommended BMP strategy. These buffers would facilitate stormwater infiltration and act as the first line of defense in water quality protection efforts. Additionally, evaluating culverts throughout the watershed to identify potential culvert issues that contribute to nutrient loading via transport of sediment and attached nutrients is recommended. An example of a program designed to evaluate the impacts from stream crossings is available at the Housatonic Valley Association's Reconnect Rivers and Streams web page. There are numerous funding opportunities to cover part of the cost of BMP implementation (see Section 7 in the core document). Establishing a stormwater utility or capital reserve fund can also provide the financial means to implement and maintain stormwater BMPs.

A variety of non-structural BMPs can also be implemented by the towns and be effective at reducing or preventing pollutant loading to surface waters. Regular catch basin cleaning, street sweeping, and road/ditch maintenance (with particular emphasis on transportation corridors and parking areas) are common practices already being implemented by municipalities, institutions, and CT DOT, as enforced by MS4 permit programs. In the Bantam Lake watershed, only CT DOT is bound by the MS4 program. MS4 permits cover illicit discharge detection and elimination plans (and ordinance inclusion), source control and pollution/spill prevention protocols, and education/outreach and/or training for residents, municipal staff, and stormwater operators. It is recommended that all municipalities attempt to comply with MS4 general permit program regardless of their obligations for compliance, as general good practices for minimizing polluted runoff to surface waters. Examples of structural and non-structural BMPs are provided in the core document.

7.4 Address groundwater leachate pollutant sources from Subsurface Sewage Disposal System.

Most residents in the watershed rely on Subsurface Disposal Systems (SSDS). If not already in place, the towns and Health District should establish programs to ensure that existing systems are properly operated and maintained. For instance, communities can create an inventory of existing SSDS through mandatory inspections. Inspections help encourage proper maintenance and identify failed or sub-standard systems. Another option would be for municipalities to institute minimum pump-out intervals, for example once per 3 or 5 years, with pump-out firms submitting monthly or quarterly reports to the municipality of systems served. Policies that govern the eventual replacement of the sub-standard systems within a reasonable timeframe could also be adopted. The towns can also develop programs to assist citizens with the replacement and repair of older and failing systems. Active engagement with local health districts and evaluating SSDS ordinances in other municipalities can help communities start to address this issue.

7.5 Address groundwater leachate pollutant sources from sewer systems.

A smaller portion of the watershed relies on a municipal sewer system and ensuring there are no leaks or overflows from the sanitary sewer system should be made a priority. It is important for towns with sewer service to develop a program to evaluate their sanitary sewer system and reduce leaks and overflows, especially in areas near waterbodies. This program should include periodic inspections of the sewer line. Litchfield, Goshen, and Torrington have Water Pollution Control Plans in place to prevent and/or minimize the occurrence of system failure and resulting water quality contamination. Each applicable municipality's Plan of Conservation and Development also identifies sewer maintenance priorities. For example, the Litchfield Plan of Conservation and Development identifies the need to prioritize repairs and enhancements to the current network of sewer and water infrastructure prior to expanding the system, in addition to working with homeowners that have failing septic systems.

7.6 Ensure proper use of BMPs on agricultural lands.

If not already in place, agricultural producers should work with the Connecticut Department of Agriculture and the NRCS to develop Comprehensive Nutrient Management Plans for their farming activities. These plans should focus on ensuring that there are adequate stream and lakeshore riparian buffers, that fencing exists to restrict access from livestock and horses to streams and wetlands, that animal waste handling, disposal, and other appropriate BMPs are in place, and that proper manure amounts are applied to fields at the appropriate times of year. Farmers should also work with the NRCS to implement soil conservation practices such as cover crops, no-till methods, and other strategies which reduce erosion and nutrient pollution to surface waters. NRCS has been actively working with farmers in Connecticut to promote "Healthy Soils" concepts and management techniques. Other organizations that can assist landowners who may not be eligible for NRCS assistance with nutrient management and soil conservation efforts include UConn Extension and their local conservation district.

The State of Connecticut has the second highest horse density in the nation, which makes proper horse farm management a priority for farm operations in the State. The Horse Environmental Awareness Program (HEAP) developed the "*Good Horse Keeping: Best Practices Manual for Protecting the Environment 2011*," which identified the BMPs for sustainable horse management and environmental protection.

Additionally, CT DEEP is developing a *General Permit for Concentrated Animal Feeding Operations (CAFOs)* to regulate manure management activities currently practiced on Connecticut Animal Feeding Operations (CT AFOs), specifically those with many animals, defined as CAFOs. However, many CAFOs would likely not have enough land to apply their manure and alternative use or transfer of manure is being investigated.

It should be noted that watersheds with documented agricultural dominance over a 150-250+ year history will likely require different nutrient-related management strategies. Watershed-specific historical reviews should be conducted to estimate the extent and type of agricultural legacy nutrients in soils and groundwater.

7.7 Evaluate local education and outreach programs regarding waterfowl, pet waste, and fertilizer/pesticide use.

Towns and/or watershed groups can take measures to minimize waterfowl-related impacts such as encouraging residents and businesses to allow tall, coarse vegetation to grow in shoreline areas that are frequented by waterfowl, particularly within parks, golf courses, and recreational fields. Waterfowl, especially grazers like geese, prefer easy access to water, therefore maintaining an uncut vegetated buffer along the shoreline will make the habitat less desirable to geese and encourage migration. In addition, any educational program should emphasize that feeding waterfowl, such as ducks, geese, and swans, may contribute to water quality impairments and can harm human health and the environment. A regional assessment of waterfowl populations could be conducted to better inform a multi-pronged management approach with identified and engaged stakeholders. For example, a non-migratory Canada Goose education and control project was conducted in Baker Cove in Groton.

In addition, pet waste should be disposed of away from any waterbody or storm drain system. BMPs effective at reducing the impact of pet waste on water quality include installing signage, providing pet waste receptacles in high-use areas, enacting ordinances requiring the cleanup of pet waste, and targeting education and outreach programs in problem areas.

Towns should also consider enacting ordinances that prohibit or limit the use of fertilizers and pesticides, especially on agricultural lands and for any use within proximity to a surface water. Soil tests should be used to ensure that fertilizer applications are appropriate and proportional to site needs.

7.8 Regulate illegal overboard discharge of sanitary sewage from boats and marinas.

State and municipal governments can ensure that there is adequate availability of pump-out facilities for large bodies of water with the potential for boats with on-board waste systems. Marina owners can also provide clean and safe onshore restrooms. Outreach related to regulated control of overboard discharge can be targeted to marina owners, boat dealers, and boaters. The Connecticut Clean Marina Program encourages adoption of BMPs by boaters. This program is administered by the CT Marine Trades Association (CMTA).

7.9 Consider in-lake treatments to reduce internal phosphorus load.

While reducing nutrient loads from the watershed to the lake are the highest priority and should be pursued first, reducing internal phosphorus loading from lake sediments to the water column is also a possible approach to improving lake water quality. As a general rule, internal phosphorus sources contributing more than 25% of the total phosphorus load to a lake are likely candidates for possible in-lake treatments (K. Wagner, pers. comm.). An assessment can be completed to determine the most appropriate in-lake treatment option for phosphorus reduction. Options include, but are not limited to, nonpoint source control of phosphorus and pollutant trapping, point source control of phosphorus, dilution and flushing, drawdown, dry excavation of sediment after drawdown, wet excavation of sediment from shore, light limiting dyes, surface covers, selective withdrawal of water, hypolimnetic oxygenation, phosphorus inactivation (i.e., alum), and settling agents.

8.0 Monitoring Plan

8.1 Existing Monitoring Data & Resources

Past monitoring efforts are described in Section 3.0, Why is a TMDL Needed.

8.2 Future Monitoring Recommendations

A water quality monitoring plan for the lake and tributaries[5] should include which parameters will be collected, how often, from where, and by whom. It is best to incorporate previously used monitoring sites to bolster long-term datasets. If funds allow, new sites can be added for expanded monitoring efforts to help identify where NPS pollutants are entering surface waters. Sampling during heavy rain events can also shed light on how stormwater is affecting the water quality of Bantam Lake.

We recommend that monitoring in Bantam Lake continue and, in some cases, be expanded. Ideally, a monitoring program would consist of the following components.

- North Bay, Center Lake, and South Bay stations Dissolved oxygen, temperature, and Secchi disk transparency should be measured bi-weekly (ideally) or monthly (minimum) each year from April-October.
- Total phosphorus and total nitrogen should be measured monthly each year from April-October at three water column depths near the top, middle, and bottom of the lake profile.
- Chlorophyll-*a* should be added to the regular monitoring schedule and collected in the epilimnion (top to middle) monthly each year from April-October. Chlorophyll-*a* levels are one of the important in understanding the trophic state of the lake and are therefore important to monitor.
- Monitoring the frequency and occurrence of algal blooms would be beneficial. Consider collecting samples for phytoplankton speciation (i.e., cyanobacteria) along with the chlorophyll-*a* samples, and any samples collected during a cyanobacteria bloom should be sent for a toxicity analysis, which provides critical information to protect human and animal (pet) life.
- Tributary monitoring should also be added to the regular monitoring schedule and include the monthly collection of total phosphorus, total nitrogen, and flow each year from April-October. Tributary monitoring helps identify the geographic source area and timing of pollutant loading to the lake. Essential tributary monitoring would be at the inlet and outlet of Bantam Lake. Additional recommended tributary stations are:
    - Dog Pond outlet
    - Bantam (Timber) Pond outlet
    - West Branch Bantam River
    - Little Pond outlet
    - Whittlesey Brook outlet

More frequent sampling will help track implementation progress in the watershed as management measures and BMPs take effect. If long term stations cannot be established in watershed, that monitoring be planned before and after implementation projects, with sampling located to capture potential water quality changes. Table 14 provides recommendations for a continued and expanded monitoring program for the Bantam Lake watershed.

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[5] Note that monitoring should also continue and/or expand for all permitted discharge sources to ensure compliance with permit requirements and to determine if current requirements are adequate or if additional measures are necessary for water quality protection. This includes NPDES industrial and commercial permits, as well as the MS4 permit program which prioritizes monitoring of stormwater outfalls. Outfalls with results over a specified threshold require follow-up investigation and improvements to BMPs in the portion of the drainage network upstream of the outfall.

Table 14: Recommended monitoring plan for Bantam Lake.

Parameters	Frequency	Location(s)	Priority / Status
Dissolved oxygen and temperature profiles, Secchi disk transparency readings	Bi-weekly (ideal) or monthly (minimum) from April-October	North Bay, Center Lake, and South Bay stations	High / Existing
Total phosphorus, total nitrogen	Monthly from April-October	North Bay, Center Lake, and South Bay stations at three depths (top, middle, bottom)	High / Existing
Chlorophyll-*a*	Monthly from April-October	North Bay, Center Lake, and South Bay stations in epilimnion (top to middle)	High / **Add**
Phytoplankton speciation	Monthly from April-October	North Bay, Center Lake, and South Bay stations in epilimnion (top to middle)	High / **Add**
Toxicity analysis	As needed during cyanobacteria bloom	North Bay, Center Lake, and South Bay stations in epilimnion (top to middle)	High / **Add**
Total phosphorus, total nitrogen, flow estimate	Monthly from April-October	Dog Pond outlet, Bantam Pond outlet, West Branch Bantam River, Little Pond outlet, and Whittlesey Brook outlet	High / **Add**
Total phosphorus, total nitrogen, total suspended solids, flow estimate	Before and after BMP construction	Above and below BMP site(s) for reference control and downstream test sites	Medium / Add
Dissolved oxygen, pH, *E. coli*	Monthly from April-October	Dog Pond outlet, Bantam Pond outlet, West Branch Bantam River, Little Pond outlet, and Whittlesey Brook outlet	Medium / Add
pH, color, alkalinity	Monthly from April-October	North Bay, Center Lake, and South Bay stations in epilimnion (top)	Medium / Add
Invasive species (visual surveys, boat inspections)	Annually	In-lake especially near boat ramps and other access points, and during boat inspections	High / Existing

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