Winnicut River

Watershed Restoration and Management Plan

Final Report
August 2017

Prepared by:

Geosyntec consultants

Wright-Pierce
Engineering a Better Environment

Horsley Witten Group

Prepared for:

New Hampshire Rivers Council
Rivers Make New Hampshire!

Acknowledgements

This project was funded, in part, by NOAA's Office for Coastal Management under the Coastal Zone Management Act in conjunction with the NH Department of Environmental Services Coastal Program with additional funding provided through a Watershed Assistance Grant with Clean Water Act Section 319 Funds from the U.S. Environmental Protection Agency, and from the generous contributions from members of the New Hampshire Rivers Council.

Contents

Appendices

Figures

Tables

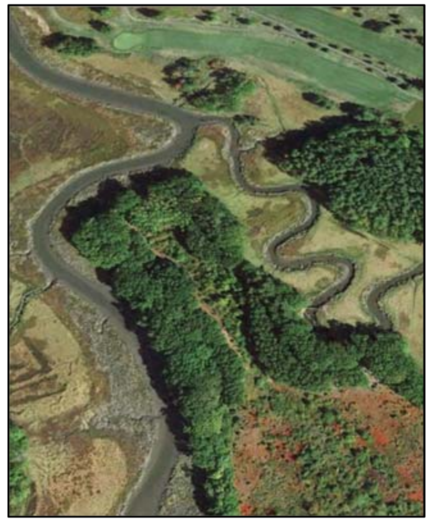
List of Acronyms

BMP	best management practice
CELCP	Coastal and Estuarine Land Conservation Program
CFA	Conservation Focus Area
CTS	counts (bacteria)
DCIA	directly connected impervious area
DO	dissolved oxygen
DPW	Department of Public Works
EMD	Environmental Monitoring Database
GBNNPSS	Great Bay Nitrogen Non-Point Source Study (2014)
GBRPP	Great Bay Resource Protection Partnership
GCNE	Golf Club of New England
GIS	Geographic Information System
GRANIT	New Hampshire Geographic Information Clearinghouse
HRU	hydrologic response unit
HSG	hydrologic soil group
LAC	Local River Management Advisory Committee
LID	low impact development
LO	linear optimization
MPN	most probable number
MS4	Municipal Separate Storm Sewer System
N	nitrogen
NHDES	New Hampshire Department of Environmental Services
NHDOT	New Hampshire Department of Transportation
NHRC	New Hampshire Rivers Council
NPS	nonpoint source
O/M	operation and maintenance
P	phosphorus
PCC	Portsmouth Country Club
PLER	pollutant load export rate
PRB	permeable reactive barrier
PREPA	Piscataqua Region Environmental Planning Assessment
RPC	Rockingham Planning Commission
RSA	New Hampshire Revised Statutes Annotated
SELT	Southeast Land Trust of New Hampshire
SWMM5	USEPA Stormwater Management Model, Version 5.1
TIA	total impervious area
TMDL	Total Maximum Daily Load
TN	total nitrogen
TNC	The Nature Conservancy
TP	total phosphorus
UNH	University of New Hampshire
USD	United States dollars
USDA/NRCS	United States Department of Agriculture/Natural Resources Conservation Service

USEPA	United States Environmental Protection Agency
VTDEC	Vermont Department of Environmental Conservation
WISE	Water Integration for the Squamscott Exeter
WRMP	Watershed Restoration and Management Plan
WQS	water quality standard
WQV	water quality volume
WSP	Watershed Steward Program™
WWMGS	warm-water, medium gradient streams
WWTF	wastewater treatment facility

Introduction

In 2016, the New Hampshire Rivers Council (NHRC) received funding from the New Hampshire Department of Environmental Services (NHDES) and other partners to develop a watershed restoration and management plan (WRMP) for the Winnicut River watershed. The NHRC has long been interested in and valued the Winnicut River watershed. Its work began with supporting a group of citizens who recognized the need for grassroots action. Since then, the citizens and the NHRC have been involved activities such as participation in the Watershed Steward™ Program, and events and speaking engagements throughout the watershed. The NHRC continues to monitor water quality and produce reliable data through the state's Volunteer River Assessment Program.



Tidal reach of the Winnicut River and Haines Brook in Greenland, NH.

The NHRC selected a consultant team of Geosyntec Consultants and Wright-Pierce to lead development of this WRMP. The NHRC also developed a technical Steering Committee for the project and engaged a diverse group of local stakeholders for development and future implementation of this WRMP. The project technical Steering Committee included the following individuals:

Winnicut River Watershed Restoration and Management Plan – Steering Committee	
Michele L. Tremblay	New Hampshire Rivers Council, President
Danna Truslow	New Hampshire Rivers Council, member
Steve Landry	NHDES Watershed Assistance Section, Supervisor
Sally Soule	NHDES Coastal Watershed Supervisor
Greg Comstock	NHDES Water Quality Planning Section, Supervisor
Steve Couture	NHDES Coastal Program, Supervisor
Kevin Lucey	NHDES Coastal Program, Scientist
Ken Edwardson	NHDES Watershed Management Bureau, Sr. Scientist
Bob Hartzel	Geosyntec Consultants (consulting team)
Renee Bourdeau	Horsley Witten Group (consulting team)
Dan Bourdeau	Geosyntec Consultants (consulting team)

The 17.5-square mile Winnicut River watershed is located primarily (93%) within portions of North Hampton, Stratham, and Greenland. Development of this WRMP included significant collaboration between these towns, the NHDES, and a variety of other government agencies, local stakeholder groups, and nonprofit organizations.

The water quality and habitat of the Winnicut River and several of its tributaries have been degraded by increased nonpoint source (NPS) pollution resulting from rapid land development in the watershed over the past 20 years. Impacts associated with NPS pollutants have led to impairments included on the NHDES 2014 303(d) list for Aquatic Life Use, Primary Contact Recreation, and Secondary Contact Recreation, due to low levels of dissolved oxygen (DO) and elevated levels of *E. coli* bacteria. The Winnicut River is one of seven major tributaries to Great Bay, which is also on the 303(d) list for Aquatic Life Use impairment, likely due to nutrient enrichment from nitrogen.

The primary goal of this WRMP is to assess the Winnicut River watershed and provide a plan for implementing actions that will result in measurable improvements in water quality and aquatic habitat. To achieve this goal, this WRMP was developed to include the following nine elements in conformance with the United States Environmental Protection Agency's (USEPA) guidance for watershed-based plans:

USEPA Watershed-Based Plan Elements		
Element A	Identify causes and sources of pollution that need to be controlled.	Sections 1-3
Element B	Determine pollutant load reductions needed to meet water quality goals.	Sections 1-3
Element C	Develop management measures to achieve water quality goals.	Section 4
Element D	Technical and financial assistance needed.	Section 5
Element E	Public information and education	Section 4.3.1
Element F	Implementation schedule	Section 6
Element G	Interim measurable milestones	Section 6
Element H	Criteria to measure progress	Section 7
Element I	Monitoring	Section 7

Recommended actions to restore water quality and meet long-term water quality goals established through this WRMP include a variety of structural and non-structural practices as described in Section 4 and summarized in Table 34. These practices include:

- Stormwater management improvements designed to reduce nutrient loading;
- Culvert improvements to restore natural stream morphology and aquatic organism passage;
- Non-structural practices, including specific recommendations for public education, land conservation, regulatory tools, and changes to institutional practices;
- Wastewater management strategies.

A recommended schedule for implementing these watershed management actions over the next five years is provided in Section 6. Successful implementation of the WRMP will require continued collaboration and partnerships between the watershed communities, state and federal government agencies, local stakeholder groups, and nonprofit organizations such as the NHRC and local land trusts.

Section 1. Winnicut River Water Quality Data

1.1 SAMPLING DATA AND LOCATIONS

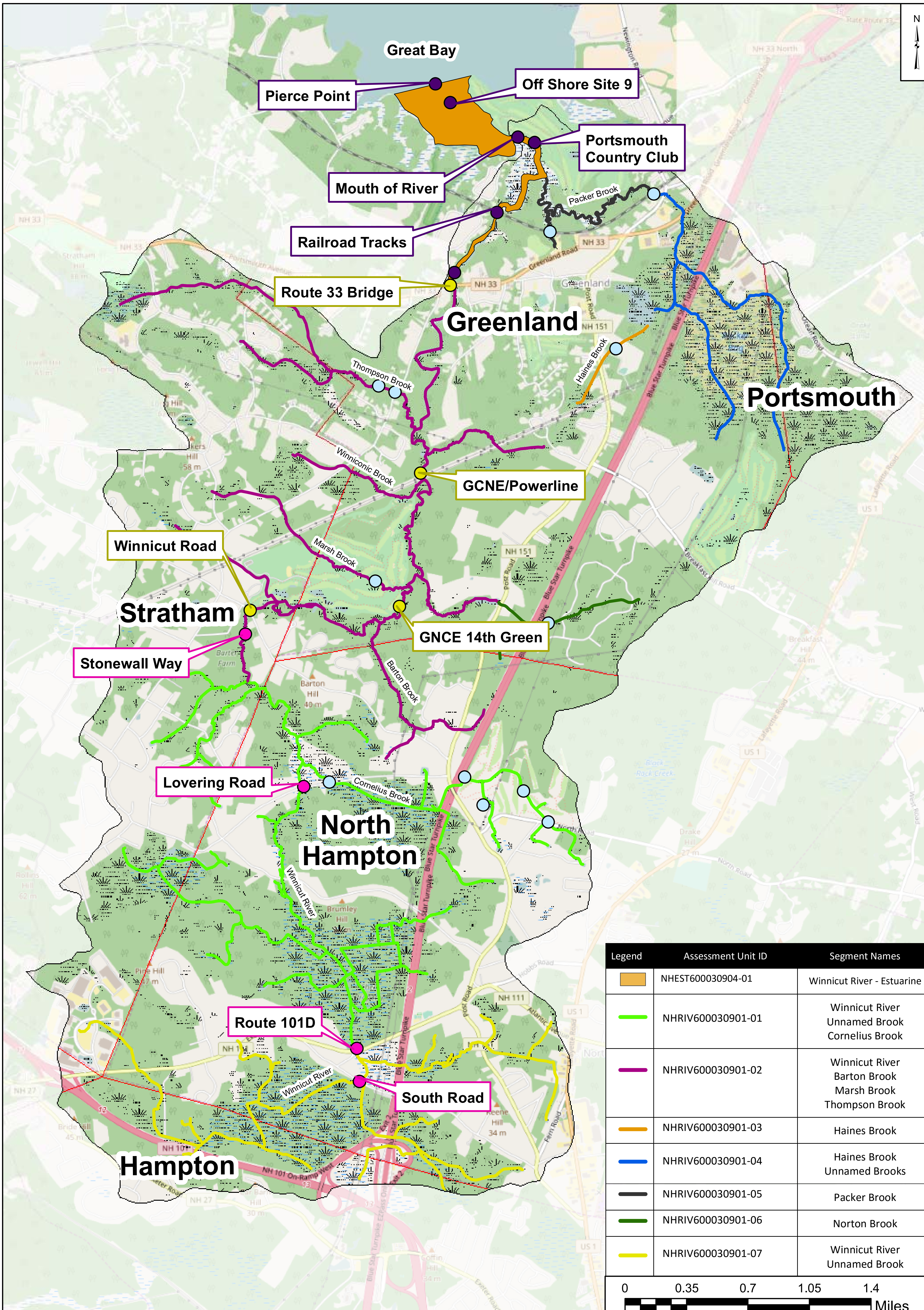
Geosyntec compiled and assessed existing water quality data for the Winnicut River. The goals of this task were to characterize current water quality conditions and historic trends, and identify data gaps and potential opportunities for further monitoring.

Data used to analyze the water quality of the Winnicut River was obtained from the NHDES Environmental Monitoring Database (EMD). The goal of the EMD is to develop a statewide repository of environmental monitoring data that meets USEPA and NHDES data quality standards and reporting requirements. Data can be submitted to the EMD through the OneStop Provider web page according to the following protocol excerpted from: https://www.des.nh.gov/organization/divisions/water/wmb/emd/categories/overview.htm

> *Providers must pre-register and obtain approval to upload data. Data is submitted for stations and activities using Microsoft Excel templates. These templates contain information on the required format and domain lists as well an example of a data record. When templates are uploaded via a web interface, the data is automatically checked for validity and error messages (if any) are displayed detailing the row, column, and problem. Once a file passes validation, it is further reviewed by NHDES data management staff. If approved, it is incorporated into the database and the provider is notified of the inclusion. If there is a problem, the file is rejected and the provider is notified of what is needed to correct the file and encouraged to resubmit.*

The following sampling stations were identified for the Winnicut River:

Headwaters Sampling Locations (pink locations in Figure 1)	**Mainstem Nontidal Sampling Locations** (yellow locations in Figure 1)	**Tidal (Estuarine) Sampling Locations** (dark purple locations in Figure 1)
• South Road • Route 101D • Lovering Road • Winnicut River at Stonewall Way	• Winnicutt Road (Stratham) • Adjacent to Golf Club of New England (GCNE) 14th green • GCNE/Powerline • Route 33 Bridge	• 20-foot culvert under railroad tracks • Winnicut River at Portsmouth Country Club (PCC) • Mouth of Winnicut River • Winnicut River, Bay Shore Drive • Great Bay Off-Shore Site 9 • Pierce Point



Legend	Assessment Unit ID	Segment Names
(orange)	NHEST600030904-01	Winnicut River - Estuarine
(light green)	NHRIV600030901-01	Winnicut River Unnamed Brook Cornelius Brook
(purple)	NHRIV600030901-02	Winnicut River Barton Brook Marsh Brook Thompson Brook
(orange)	NHRIV600030901-03	Haines Brook
(blue)	NHRIV600030901-04	Haines Brook Unnamed Brooks
(black)	NHRIV600030901-05	Packer Brook
(dark green)	NHRIV600030901-06	Norton Brook
(yellow)	NHRIV600030901-07	Winnicut River Unnamed Brook

Legend

Type of Sampling Station

- Main Stem Location
- Tidal Location
- Upstream Location
- Tributary Location
- Wetland
- Watershed Boundary
- Town Boundary

Document Path: Q:\GIS\Projects\BW0291 - Winnicut Watershed\Projects\Sampling_Point_Types_11_17.mxd

NHDES OneStop Environmental Monitoring Database
Winnicut River Sampling Locations

New Hampshire Rivers Council
Rivers Make New Hampshire!

Geosyntec consultants

Figure 1

1.2 DISSOLVED OXYGEN

Dissolved oxygen was analyzed for the nontidal reach of the Winnicut River using data from April 1990 to September 2015. Average DO values for each month were graphed to illustrate the seasonal profile and allow for comparison to the Class B water quality standard (WQS) of 5 mg/L (Figure 2).

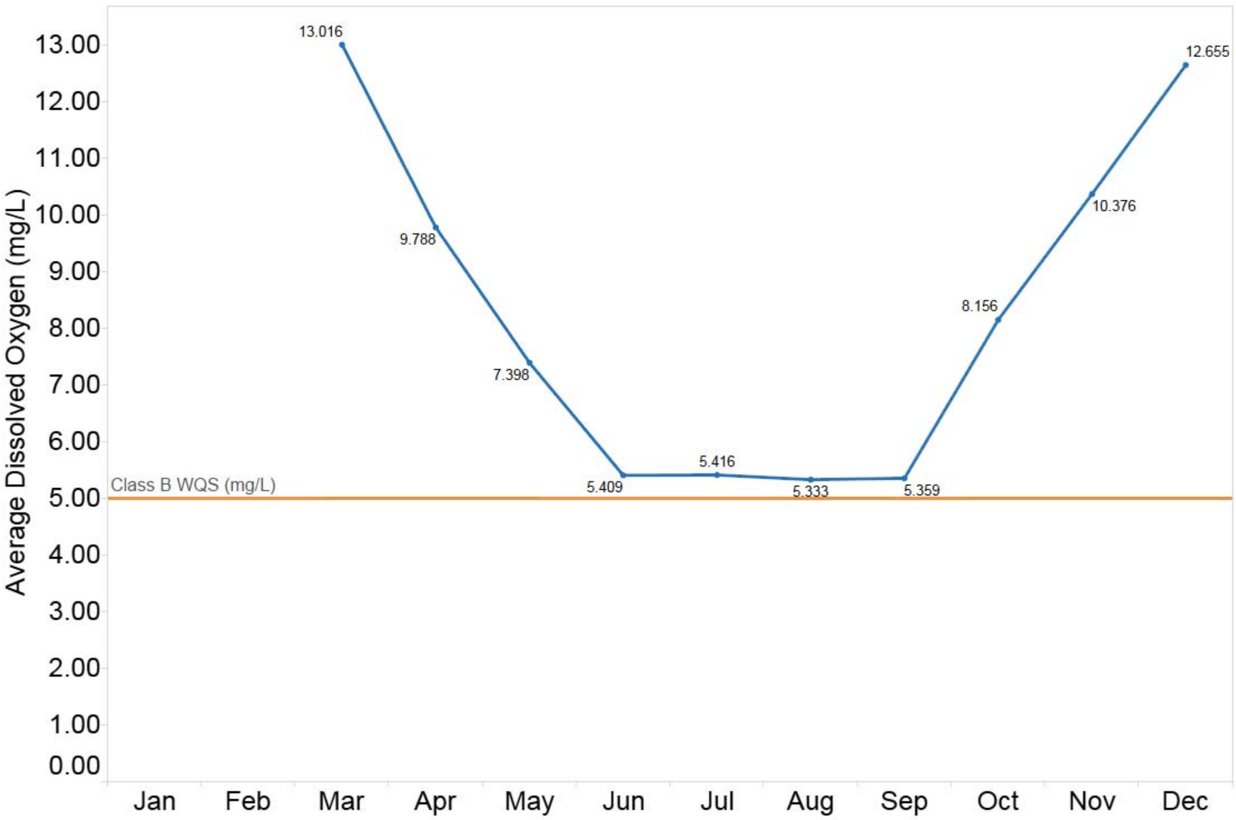


Figure 2. Monthly Average Dissolved Oxygen Concentrations, Winnicut River Nontidal Reach, 2002-2015

As expected, river DO levels are lowest during the summer. This is because cold water can hold more oxygen than warm water and because biochemical oxygen demand increases in warmer weather with higher rates of decomposition of plants, algae and other organic matter. DO concentrations reached a relatively consistent low of 5.3-5.4 mg/L for the summer months (June – September), slightly above the Class B WQS. Although all average monthly values for the river were above the 5 mg/L standard, the frequency and severity of measurements below this standard vary greatly by river reach. Examples of the spatial variation in DO are illustrated in Figures 3 and 4.

Figure 3 shows the individual nontidal DO measurements that were used to calculate the average monthly DO values. The sampling locations denoted by the red, pink, and orange markers represent measurements from the river crossings at Route 101D, South Road, and Lovering Road. These upstream/headwater locations account for nearly half (46%) of all DO measurements below the Class B water quality standard. The headwater areas upstream of Winnicutt Road in Stratham are characterized by shallow, meandering channels through expansive wetlands. Given the physical characteristics of the Winnicut River's upstream/headwaters reach, it does not seem realistic to expect that DO levels should meet the Class B standard in this area. River morphology, the surrounding landscape, and flow regime play large roles in the re-aeration and oxygen capacity of a river. River reaches within and directly downstream from large wetland areas often reflect the low DO concentrations that occur naturally in these wetlands. Low-gradient stream reaches with pools of slow moving water tend have lower re-aeration potential than shallow, high-gradient turbulent streams. The flow regime in these areas also make them prone to the accumulation of nutrients and organic matter which contribute to low DO conditions, particularly during summer when decomposition rates (and associated oxygen consumption rates) are higher.

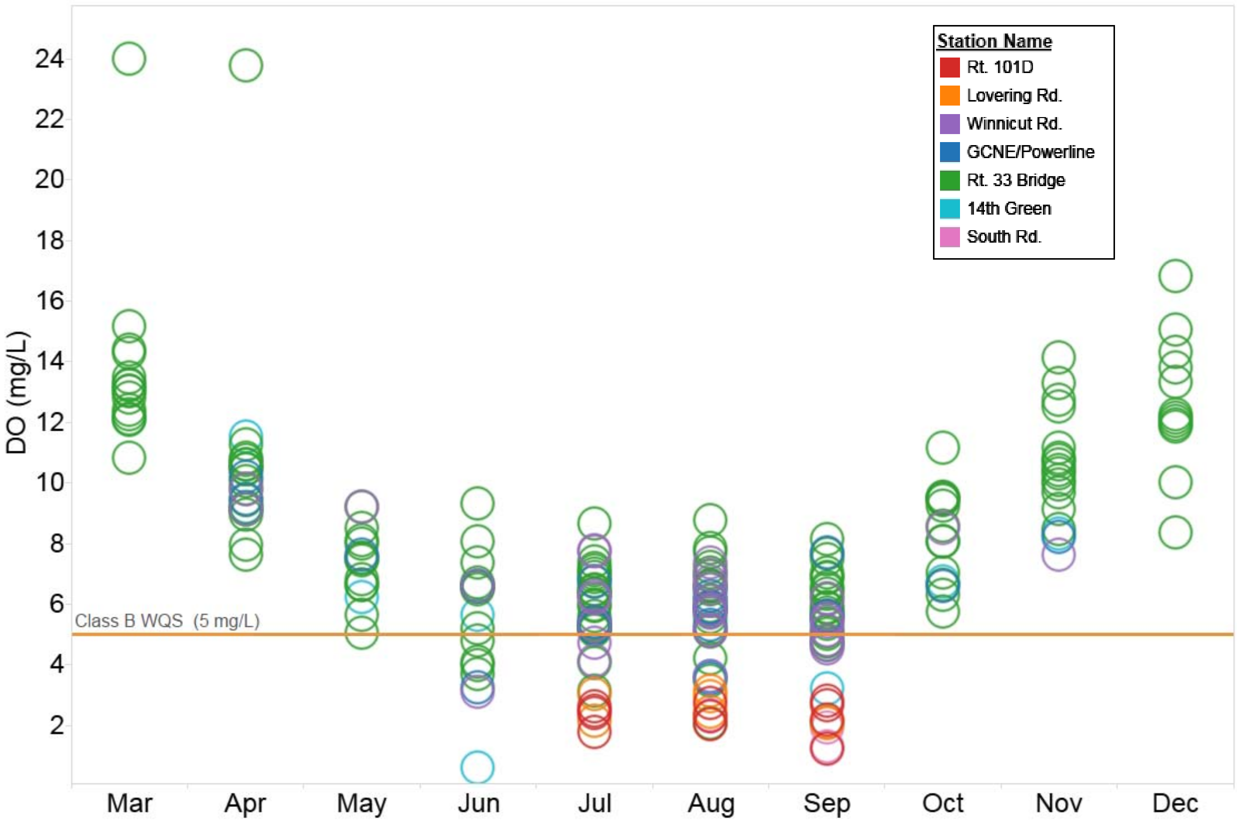


Figure 3. Dissolved Oxygen Concentrations, Winnicut River Nontidal Reach, 2001-2015

The spatial variation in river DO concentrations is further illustrated in Figure 4, which presents the percent of nontidal DO samples below the Class B water quality standard for the three major river segment categories (upstream reaches, nontidal riverine reaches, and tidal reach). As shown, 100% of the summer samples taken upstream of Winnicutt Road (Stratham) were below the Class B WQS, 20% of the nontidal samples downstream of Winnicutt Road were below the Class B WQS, and 6% of the tidal reach samples were below the Class B WQS.

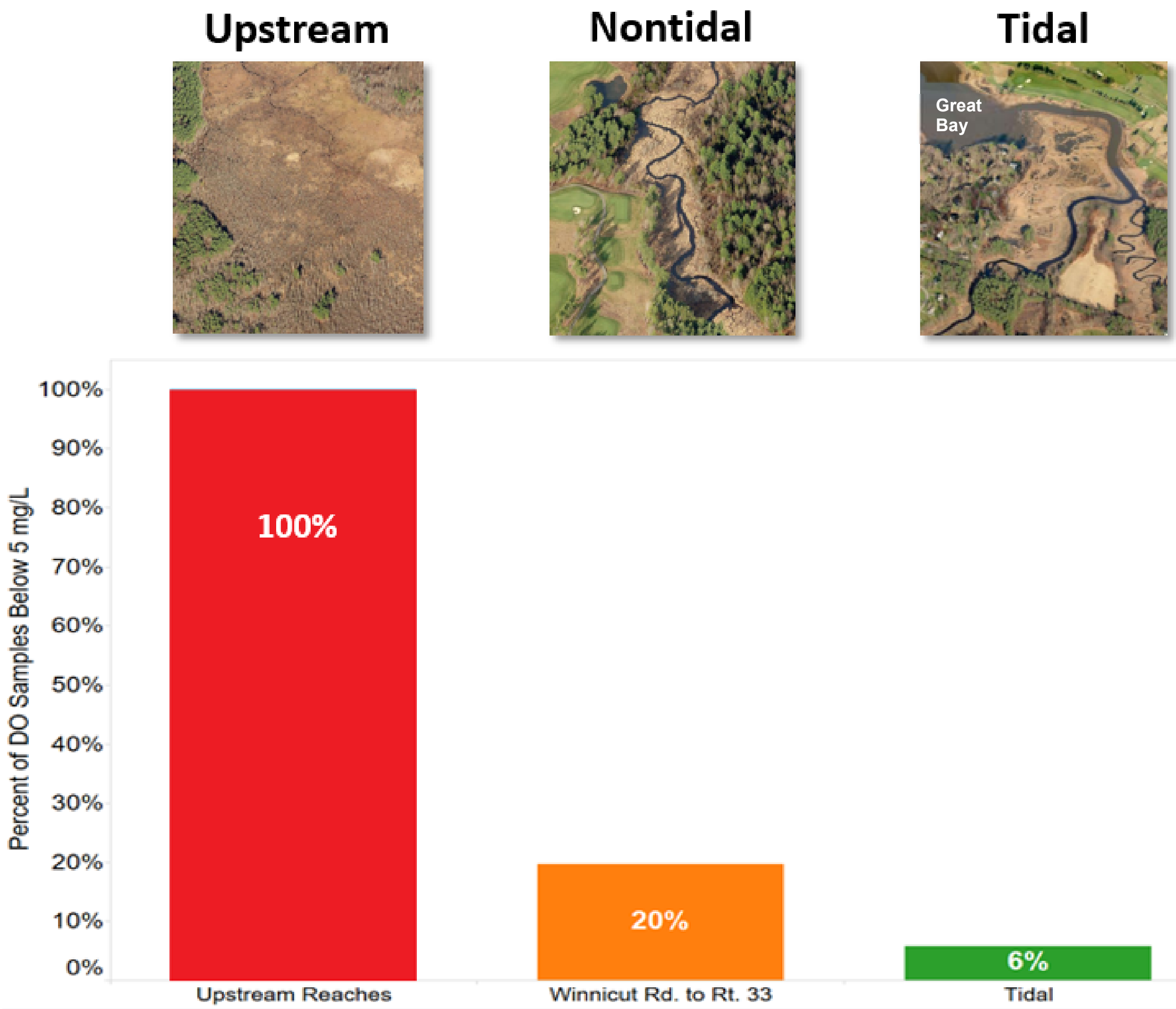


Figure 4. Percent of Summer (June-Sept.) DO Measurements Below Class B WQS (5 mg/L), 2001-2015

1.3 BACTERIA

Bacteria concentrations for the Winnicut River were analyzed using two indicator species: *Escherichia coli* (*E. coli*) and fecal coliform bacteria. As established under New Hampshire Revised Statutes Annotated (RSA) 485-A:8, *E.coli* is used as the bacteria indicator species for fresh water bodies, and fecal coliform bacteria is the indicator for tidal waters used for growing or taking of shellfish for human consumption. Although RSA 485-A:8 specifies *Enterococcus* as the indicator bacteria for tidal waters used for swimming, no *Enterococcus* data were available for the Winnicut watershed sampling locations.

E. coli

E. coli samples were analyzed for the nontidal reach using available data from 1/1/2001 to 9/9/2015. The concentrations were graphed (Figure 5) versus the *E. coli* single sample limit of 406 CTS/100 mL and the geometric mean limit (based on at least 3 samples collected over a 30 day period) of 126 CTS/100 mL, as established per RSA 485-A:8.

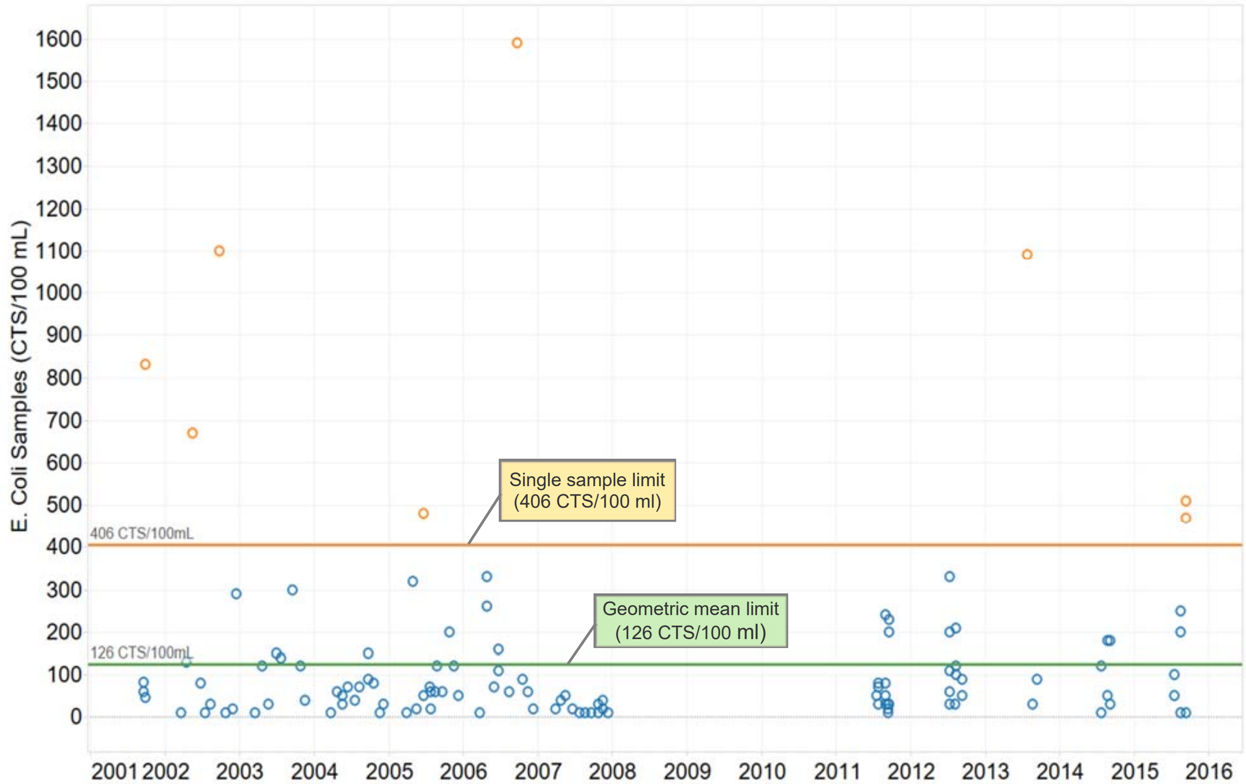


Figure 5. *E. coli* Concentrations, Winnicut River Nontidal Reach, 2002-2015

6.4% of samples exceeded the *E. coli* single sample limit (orange markers) in the nontidal river reach. The geometric mean of the data set was 60.5 CTS/100 mL, less than half of the geometric mean limit of 126 CTS/100 ml. Adequate data of *E. coli* concentrations in the tidal reach of the Winnicut River was not available for comparison. *E. coli* is not typically used as a bacteria indicator species in marine waters.

Fecal Coliform Bacteria

Fecal coliform concentrations were analyzed for the tidal reach of the river using data from 4/8/1990 to 9/9/2015. Fecal coliform data was not available for the nontidal reaches of the river. The concentrations were compared to the criteria established under RSA 485-A:8 based on National Shellfish Sanitation Program protocols, which are a geometric mean not to exceed a most probable number (MPN) of 14 fecal coliforms per 100ml and a 90th percentile not to exceed a MPN of 43 coliforms per 100ml (Figure 6).

The geometric mean of the available data was 22.8 MPN/100ml, well above the geometric mean limit of 14 MPN/100 ml. Figure 6 illustrates the fecal coliform sampling results for each year as compared to the 90^{th} percentile limit of 43 MPN/100 ml.

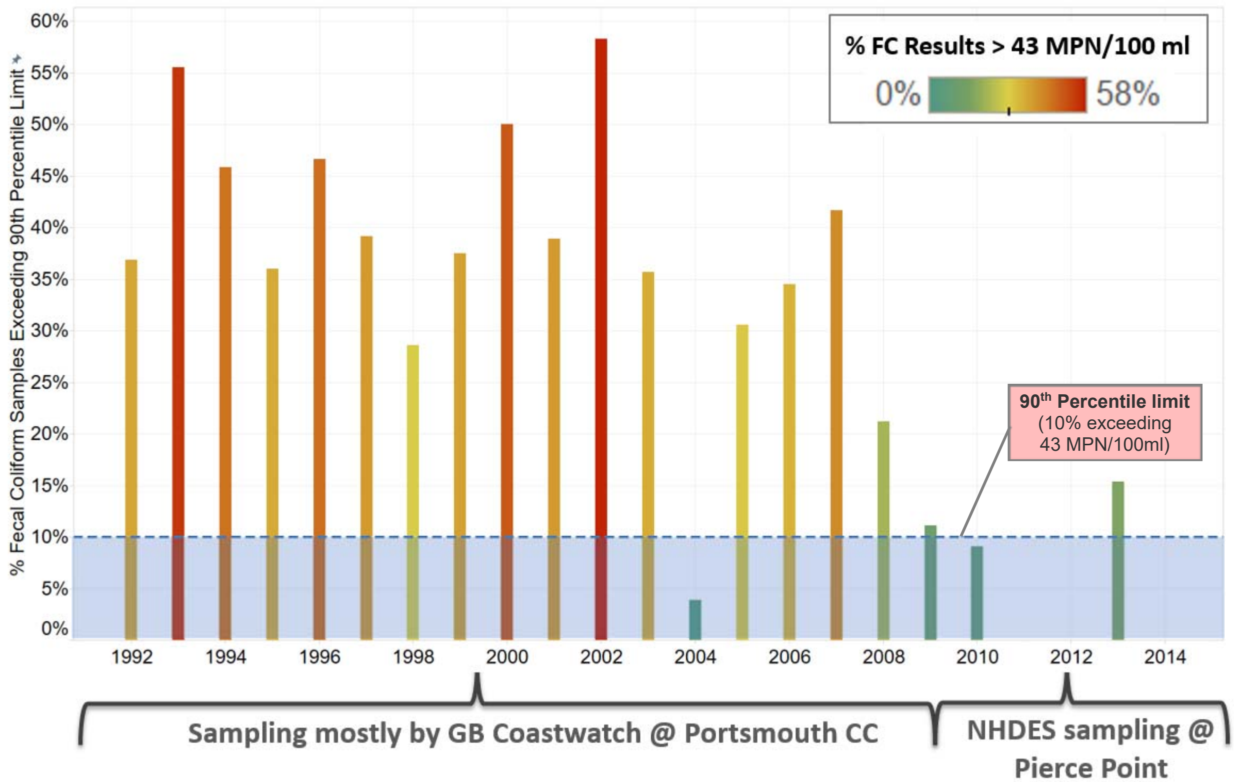


Figure 6. Percent Fecal Coliform Samples Exceeding 90th Percentile Limit (43 MPN/100 ml), Winnicut River Tidal Reach, 1992-2014.

The results indicate a significant decrease in bacteria levels in recent years, with 37% of samples exceeding the 90th percentile limit from 1992 to September 2009 and only a 4% exceeding that limit from October 2009 to 2014. However, this decrease in bacteria levels appears to be explained by a change in sampling locations. Prior to 2005, most fecal coliform data from the river's tidal reach was collected by the Great Bay Coastwatch at a river sampling location immediately adjacent to the PCC. Beginning in 2009, fecal coliform data was collected almost exculsively (64 out of 65 samples) by the NHDES Shellfish Program at the Pierce Point sampling location. Samples were collected at both Pierce Point and PCC between 2005 and 2009. As shown in Figure 1, the Pierce Point sampling location is within open estuarine water at the boundary of Great Bay and the Winnicut River subestuary, and is subject to very different mixing conditions than those at the Portsmouth Country Club sampling location. Geosyntec recommends that the Portsmouth Country Club sampling location be used for future sampling events to allow for continued historical trend analysis and better representation of in-river bacteria conditions within the the tidal reach of the Winnicut River.

1.4 NUTRIENTS

Total nitrogen (TN) and total phosphorus (TP) were analyzed for the nontidal reach of the Winnicut River using available data from 1/1/2001 to 9/9/2015. Concentrations of total nitrogen and total phosphorus were graphed versus the median values (orange lines) in Figures 7 and 8.

No significant trends are apparent for the available TP and TN data. The median TP concentration was 0.036 mg/L and the median TN concentration was 0.80 mg/L (*Note: No nitrogen data was available for* *the tidal portion of the Winnicut River*). As discussed further in Section 2 (Water Quality Goal Considerations), phosphorus is typically the primary nutrient of concern in freshwater and nitrogen is typically the primary nutrient of concern in marine water. Nitrogen sampling is recommended for the existing tidal sampling locations, including the Portsmouth Country Club location.

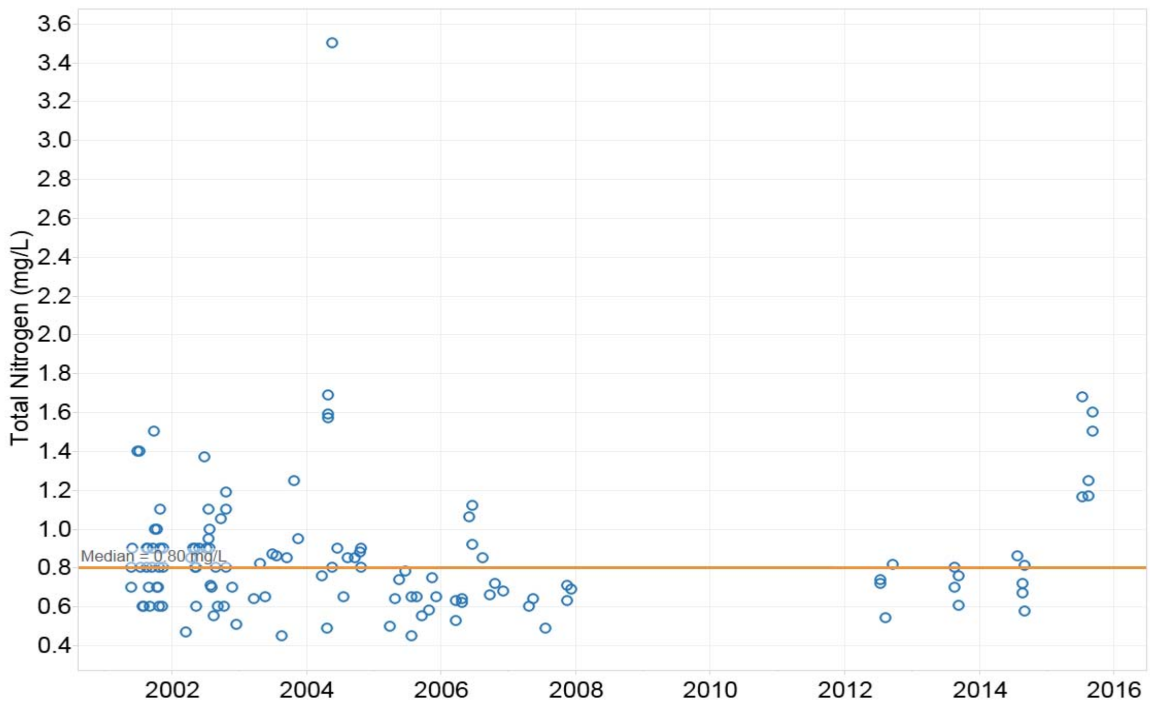


Figure 7. Total Nitrogen Concentrations, Winnicut River

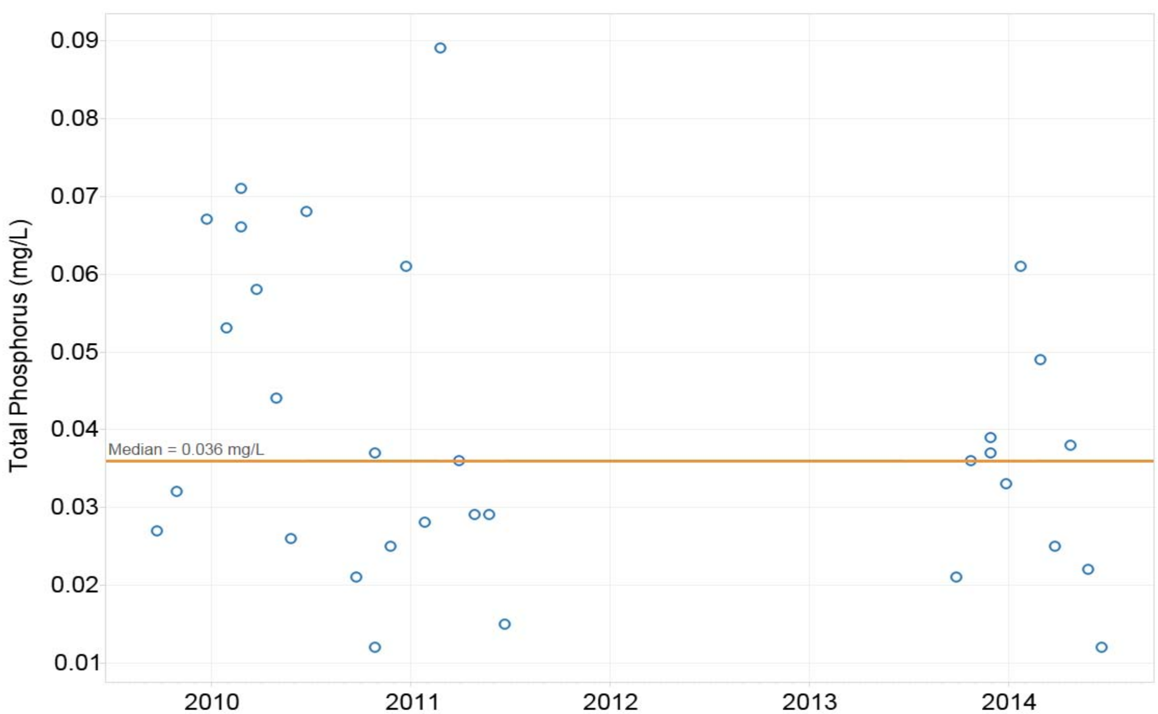


Figure 8. Total Phosphorus Concentrations, Winnicut River

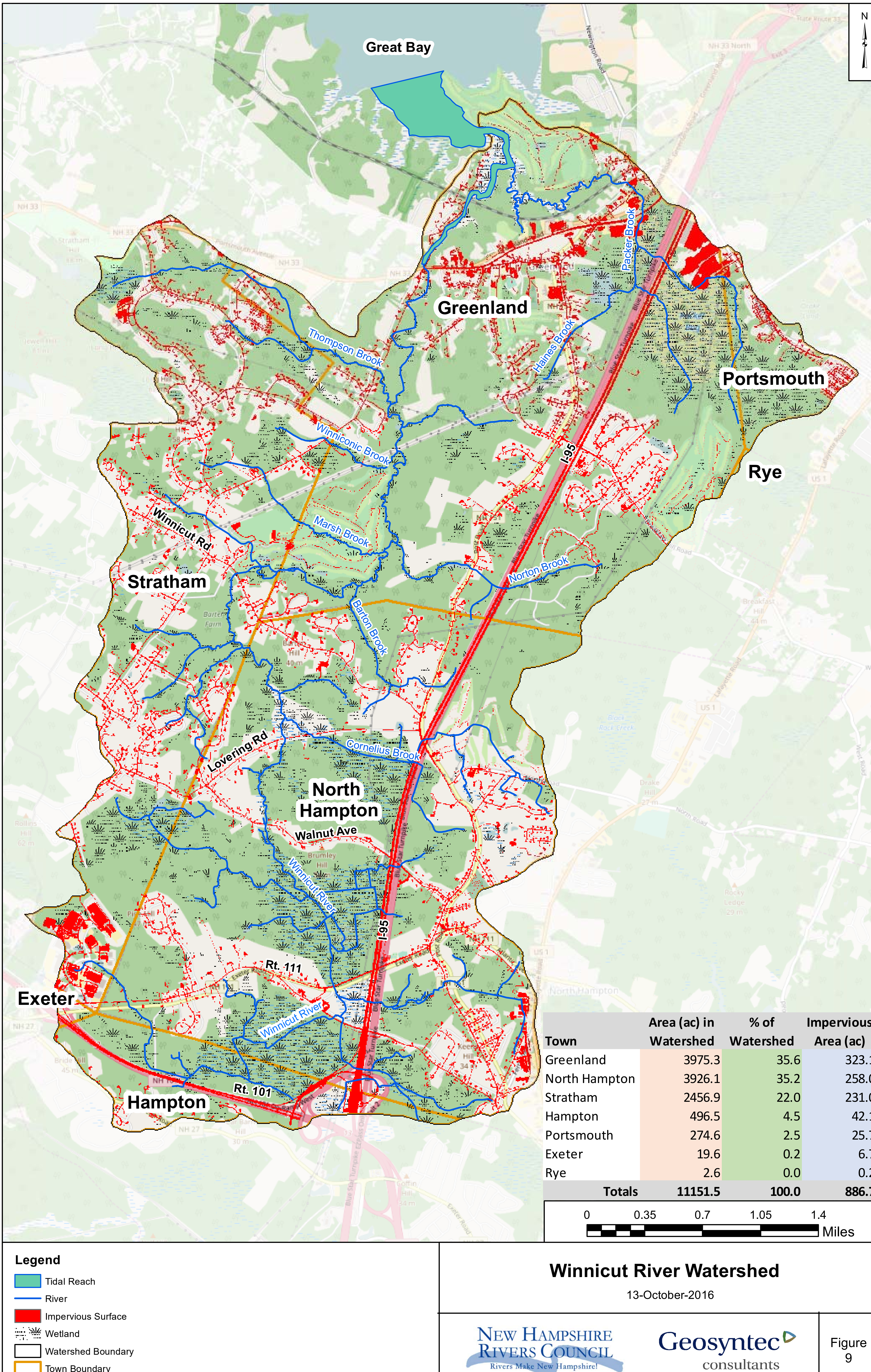
1.5 WATERSHED IMPERVIOUS SURFACES

There is a strong link between impervious land cover and stream water quality. Impervious cover includes land surfaces that prevent the infiltration of water into the ground, such as paved roads and parking lots, roofs, basketball courts, etc. Impervious areas that are directly connected to receiving waters (via storm sewers, gutters, or other impervious drainage pathways) produce higher runoff volumes and transport stormwater pollutants with greater efficiency than disconnected impervious cover areas which are surrounded by vegetated, pervious land. Runoff volumes from disconnected impervious cover areas are reduced as stormwater infiltrates when it flows across adjacent pervious surfaces.

Figure 9 presents a map of impervious surfaces, which are estimated to comprise approximately 8% of the Winnicut River watershed (based on NH GRANIT, Impervious Surfaces in Rockingham County, 2010). The relationship between total impervious area (TIA) and water quality can generally be categorized as presented in Table 1 (Schueler et al. 2009).

Table 1. Relationship Between Total Impervious Area and Water Quality (Schueler et al. 2009)

% Total Impervious Area in Watershed	Stream Water Quality
0-10%	Typically high quality, and typified by stable channels, excellent habitat structure, good to excellent water quality, and diverse communities of both fish and aquatic insects.
11-25%	These streams typically show clear signs of degradation. Elevated storm flows begin to alter stream geometry, with evident erosion and channel widening. Streams banks become unstable, and physical stream habitat is degraded. Stream water quality shifts into the fair/good category during both storms and dry weather periods. Stream biodiversity declines to fair levels, with most sensitive fish and aquatic insects disappearing from the stream.
26-60%	These streams typically no longer support a diverse stream community. The stream channel becomes highly unstable, and many stream reaches experience severe widening, downcutting, and streambank erosion. Pool and riffle structure needed to sustain fish is diminished or eliminated and the substrate can no longer provide habitat for aquatic insects, or spawning areas for fish. Biological quality is typically poor, dominated by pollution tolerant insects and fish. Water quality is consistently rated as fair to poor, and water recreation is often no longer possible due to the presence of high bacteria levels.
>60%	These streams are typical of “urban drainage”, with most ecological functions greatly impaired or absent, and the stream channel primarily functioning as a conveyance for stormwater flows.



Town	Area (ac) in Watershed	% of Watershed	Impervious Area (ac)
Greenland	3975.3	35.6	323.1
North Hampton	3926.1	35.2	258.0
Stratham	2456.9	22.0	231.0
Hampton	496.5	4.5	42.1
Portsmouth	274.6	2.5	25.7
Exeter	19.6	0.2	6.7
Rye	2.6	0.0	0.2
Totals	11151.5	100.0	886.7

Winnicut River Watershed

13-October-2016

New Hampshire Rivers Council — Rivers Make New Hampshire!

Geosyntec consultants

Figure 9

Document Path: O:\GISProjects\BW0291 - Winnicut Watershed\Projects\Winnicut_River_Watershed11_17.mxd

1.5 SUMMARY OF WATER QUALITY IMPAIRMENTS

A summary of existing water quality impairments for assessed segments of the Winnicut River and its tributaries is provided below in Figure 10 (Impairments to Designated Uses) and Figure 11 (Impaired Parameters), based on the NHDES 2014 Watershed Report Card from the 2014 303d List.

Legend
Good
Likely Good
No Data
Likely Bad
Poor
Severe

		Uses			
Assessment Unit ID*	Segment Names	Aquatic Life	Swimming	Boating	Fish Consumption
NHEST600030904-01	Winnicut River - Estuarine		No Data	No Data	
NHIMP600030901-02	Winnicut River Dam Pond				
NHRIV600030901-01	Winnicut River Unnamed Brook Cornelius Brook				
NHRIV600030901-02	Winnicut River Barton Brook Marsh Brook Thompson Brook				
NHRIV600030901-03	Haines Brook	No Data			
NHRIV600030901-04	Haines Brook Unnamed Brooks	No Data	No Data	No Data	
NHRIV600030901-05	Packer Brook				
NHRIV600030901-06	Norton Brook				
NHRIV600030901-07	Winnicut River Unnamed Brook				

Figure 10. Winnicut River Watershed – Impairments to Designated Uses

Poor
Severe

Assessment Unit ID	Segment Names	Impaired Parameters (from 2014 303d List)				
NHEST600030904-01	Winnicut River - Estuarine	Fecal coliform	Estuarine bioassessments	Mercury	PCBs	Dioxin
NHIMP600030901-02	Winnicut River Dam Pond	Dissolved Oxygen	E. coli	Mercury	pH	
NHRIV600030901-01	Winnicut River Unnamed Brook Cornelius Brook	Benthic macroinvertebrates	Dissolved Oxygen	Dissolved Oxygen Saturation	Mercury	pH
NHRIV600030901-02	Winnicut River Barton Brook Marsh Brook Thompson Brook	Dissolved Oxygen	Mercury	pH		
NHRIV600030901-03	Haines Brook	E. coli	Mercury			
NHRIV600030901-04	Haines Brook Unnamed Brooks	Mercury				
NHRIV600030901-05	Packer Brook	Dissolved Oxygen	Dissolved Oxygen Saturation	Mercury	pH	
NHRIV600030901-06	Norton Brook	E.coli	Mercury	pH		
NHRIV600030901-07	Winnicut River Unnamed Brook	Dissolved Oxygen	Dissolved Oxygen Saturation	Mercury	pH	

Figure 11. Winnicut River Watershed - Impairements to Designated Areas

1.6 TRIBUTARY DATA REVIEW

Data used to analyze the water quality of tributaries to the Winnicut River was obtained from the NHDES OneStop Environmental Monitoring Database using a query for data associated with the HUC12 code 010600030901. Table 2 lists the median DO, bacteria, and nutrient concentration values for each tributary. In general, tributary data was very limited. Data for each parameter was not available for each tributary (indicated by "N/A" in the table). Tributary locations are presented in Figure 1.

Table 2. Tributary Water Quality Data Review

Tributary	Dissolved Oxygen	Bacteria	Nutrients
Cornelius Brook	2.93 mg/L (7 measurements: 7/2011 – 8/2012)	*E. Coli*: 180/100 mL (7 measurements: 6/2005 – 8/2012)	N/A
Haines Brook	N/A	*E. Coli*: 390/100 mL (9 measurements: 5/2007 to 7/2008)	N/A
Marsh Brook	8.30 mg/L (9 measurements: 5/2001 – 4/2004)	N/A	TN: 0.80 mg/L (15 measurements: 5/2001- 4/2004)
Norton Brook	5.43 mg/L (23 measurements: 7/2006 – 9/2015)	*E. Coli:* 340/100 mL (22 measurements: 8/2006 to 7/2016)	TN: 0.92 mg/L (11 measurements: 7/2011 – 7/2015)
Packers Brook	3.07 mg/L (17 measurements: 7/2011- 8/2015)	*E. Coli:* 235/100 mL (10 measurements: 9/2001 to 8/2015) Fecal Coliform: 680/100 mL (10 measurements: 9/2001 to 9/2007)	TN: 2.27 mg/L (1 measurement: July 2015)
Thompson Brook	7.86 mg/L (8 measurements: 8/2013 – 9/2014)	*E. Coli*: 80/100 mL (4 measurements: 10/1996 – 7/2016; *no data from 1997 to 2014*)	TN: 0.69 mg/L (7 measurements: 8/2013 – 9/2014)

Section 2. Water Quality Goals

The sections below summarize water quality goal considerations and recommendations provided to NHRC and the project Steering Committee in a technical memorandum dated August 9, 2016. This memorandum was provided in preparation for the first project stakeholder meeting on August 24, 2016, which was used to reach consensus on water quality goals as discussed in Section 2.2.

2.1 DISSOLVED OXYGEN

The New Hampshire Surface Water Quality Regulations establish the following DO standards for Class B waters at Env-Wq 1703.07:

> "*Except as naturally occurs, or in waters identified in RSA 485-A:8, III, or subject to (c), below, class B waters shall have a dissolved oxygen content of at least 75% of saturation, based on a daily average, and an instantaneous minimum dissolved oxygen concentration of at least 5 mg/L.*"

The Winnicut River is 303(d)-listed as impaired for low DO in 2014 NHDES List of Impaired or Threatened Waters. As discussed in Section 1.2, river DO levels are lowest during the summer, as expected. Although all average monthly values for the river were above the 5 mg/L standard, the frequency and severity of measurements below this standard vary greatly by river reach (see Figures 3 and 4).

As discussed in Section 1.2, it is not realistic to expect that DO levels should meet the Class B standard in this area in the low-flow, wetland-dominated headwater reaches of the Winnicut River. River reaches within and directly downstream from large wetland areas often reflect the low DO concentrations that occur naturally in these wetlands. Low-gradient stream reaches with pools of slow moving water tend have lower re-aeration potential than shallow, high-gradient turbulent streams. The flow regime in these areas also make them prone to the accumulation of nutrients and organic matter which contribute to low DO conditions, particularly during summer when decomposition rates (and associated oxygen consumption rates) are higher.

For purposes of the Winnicut River WRMP, Geosyntec recommended identifying the river reaches that should be expected to meet the Class B DO standards, and using data from 2009-present (where sufficient data is available) to determine the river's status in comparison to the standard. Based on the transition in stream morphology that occurs between Lovering Road and Winnicutt Road (both in Stratham), Geosyntec recommended that data from the Winnicutt Road sampling station and downstream stations should be used for this purpose.

2.2 NUTRIENTS

New Hampshire currently has numeric nutrient criteria for lakes, but not for rivers. The following non-numeric water quality indicator is established at Env-Wq 1703.14:

> "*Class B water shall contain no phosphorus or nitrogen in such concentrations that would impair any existing or designated uses, unless naturally occurring.*"

Correlations between phosphorus and nitrogen concentrations in surface waters make it difficult to statistically separate the independent effects of each nutrient on designated uses. Because of this uncertainty, a common approach to water quality goal setting is to focus on the limiting nutrient in a system, which is typically phosphorus in freshwater and nitrogen in marine systems.

The Winnicut River is not 303(d)-listed for impairment due to either P or N. As such, there is no state or USEPA requirement to develop a load reduction target or Total Maximum Daily Load (TMDL) allocations for these nutrients, although a New Hampshire TMDL for DO in freshwater will typically set a TP target. Any goals set through development of the Winnicut River WRMP should be based on stakeholder consensus with regard to protection of the long-term ecological health, functions, and values of the river, as well as those of its receiving water, the Great Bay Estuary. These collectively established goals can serve as guidelines for planning purposes, but would not have any regulatory purpose or be enforceable on any party.

2.2.1 Nitrogen

In absence of regulatory numeric criteria for nitrogen, the following provide some useful points of reference when considering water quality goals for the tidal reach of the Winnicut River:

- *Numeric Nutrient Criteria for Great Bay Estuary (2009):* NHDES developed numeric water quality criteria for the Great Bay Estuary in 2009. NHDES considered low DO and loss of eelgrass habitat as the most important impacts to aquatic life from nutrient enrichment. NHDES established a threshold for total nitrogen and a threshold for a response variable. The study found "*to maintain instantaneous dissolved oxygen concentrations greater than 5 mg/L and average daily concentrations greater than 75% saturation, the annual median total nitrogen concentration should be less than or equal to 0.45 mg/L of total nitrogen.*" Further, for protection of eelgrass habitat, "*the annual median total nitrogen concentration should be less than or equal to 0.25-0.30 mg/L of total nitrogen.*" (Note: These recommended criteria are relevant to estuarine waters only, not freshwater (non-tidal) reaches of tributary rivers, such as the portion of the Winnicut River upstream of Rt. 33).

  Based on an independent peer review panel of this study in 2014, it was concluded that this study "did not adequately demonstrate that nitrogen is the primary factor causing eelgrass decline in the Great Bay Estuary because the report did not explicitly consider all the other important, confounding factors in developing relationships between nitrogen and presence of eelgrass." As a result of a court approved settlement, the department has ceased using the nitrogen concentration thresholds from this study to assess nitrogen impairments.

- *Draft Analysis of Nitrogen Loading Reductions for Wastewater Treatment Facilities and Non-Point Sources in the Great Bay Estuary Watershed:* This NHDES 2010 draft study estimated existing nitrogen loads and nitrogen loading thresholds for subestuaries to comply with the 2009 numeric nutrient criteria established by NHDES. The study states that although the Winnicut River is the "the only subestuary included in this study that is not impaired for nitrogen", it was included "because its watershed contributes nitrogen to the Great Bay, which is impaired". This study estimated that the Winnicut River's target nitrogen loading thresholds to prevent low DO and to protect eelgrass in the subestuary are 24.3 tons per year and 14.6 tons per year, respectively.

- *Great Bay Nitrogen Non-Point Source Study (GBNNPSS):* This 2014 NHDES study estimated that the Winnicut River delivers a nitrogen load of 24 tons per year to the Great Bay Estuary. Total N input to the watershed was estimated at 94 tons, indicating that 74% of the load was attenuated by soils, vegetation, and other physical/chemical processes during transport from the watershed to the Winnicut River and then to the Great Bay Estuary.

- *Massachusetts Nitrogen Total Maximum Daily Loads*: For comparison to potential nitrogen water quality goals for the Winnicut River, nitrogen concentration targets established in USEPA-approved Massachusetts TMDLs for estuarine waters are listed in Table 3.

Table 3. Total Nitrogen Targets for Approved Massachusetts TMDLs for Estuarine Waters

TMDLs for Total Nitrogen	Total Nitrogen Target
West Falmouth Harbor Embayment System	0.35 mg/L
Phinneys Harbor Embayment System	
Sengekontacket Pond Estuarine System	
Lagoon Pond Estuarine System	
Nantucket Harbor Embayment System	0.36 mg/L
Centerville River - East Bay System	0.37 mg/L
Chatham Embayments	0.38 mg/L
Popponesset Bay	
Lewis Bay System and Halls Creek	
Three Bays System	0.38 - 0.50 mg/L
Quashnet River, Hamblin Pond, Little River, Jehu Pond, and Great River in the Waquoit Bay System	
Great, Green and Bournes Pond Embayment Systems	0.40 - 0.45 mg/L
Little Pond Embayment System	0.45 mg/L
Farm Pond Estuarine System	
Madaket Harbor and Long Pond Estuarine System	
Herring River Estuarine System	0.48 mg/L
Allen, Wychmere and Saquatucket Harbors Embayment Systems	0.50 mg/L
Edgarton Great Pond System	
Oyster Pond	0.55 mg/L
Median Total Nitrogen Target for all TMDLs	**0.42 mg/L**

The numeric nitrogen concentration targets previously established by NHDES to prevent low DO (0.45 mg/L) is within the middle range for TMDL nitrogen criteria for New England estuarine waters. For the estuarine portion of the Winnicut River, this target appears to provide a reasonable standard to use for the planning purposes of the Winnicut WRMP. Data was not available for assessment of the current nitrogen concentration status of the Winnicut River tidal reach. For the reasons described above with regard to the typical limiting nutrients in freshwater (P) and marine waters (N), Geosyntec did not recommend establishing an additional freshwater nitrogen concentration target as part of the Winnicut River WRMP.

2.2.2 Phosphorus

The median TP concentration of all Winnicut River samples for the 2001-2015 period of record was 0.036 mg/L. In absence of regulatory numeric criteria for phosphorus, the following provide some useful points of reference when considering water quality goals for freshwater (non-tidal) reaches of the Winnicut River:

- The most recent national guidance on nutrient standards is provided by the USEPA in Quality Criteria for Water (1986). According to this guidance, total phosphorus should not exceed 0.050 mg/L in any stream at the point where it enters any lake or reservoir.

- *Current state criteria*: As listed below, existing state phosphorus criteria for rivers and streams vary widely. The criteria ranges in Table 4 reflect that states often have multiple standards that are applicable only to specified rivers or river segments.   Only Vermont currently has statewide standards for a class of rivers that have similar characteristics to the Winnicut River (Warm-Water, Medium Gradient Streams, WWMGS). However, as indicated below, the WWMGS standard only applies to streams additionally classified as A(1) "Ecological Waters".

Table 4. Existing U.S. State and Territory Total Phosphorus Criteria*

TP Criteria for Rivers/Streams	TP Target
American Samoa	0.15 mg/L
Arizona	0.08 - 0.80 mg/L
California	0.005 - 0.14 mg/L
Florida	0.18 - 0.49 mg/L
Minnesota	0.05 - 0.15 mg/L
Montana	0.020 - 0.105 mg/L
Nevada	0.05 - 0.33 mg/L (most at 0.10 mg/L)
New Jersey	0.10 mg/L (non-tidal)
Oklahoma	0.037 mg/L (for "scenic rivers")
Puerto Rico	0.16 mg/L
Vermont	0.009 - 0.018 mg/L (0.018 mg/L for Class A(1) Warm-Water, Medium Gradient Streams)

* From USEPA website listing *State Progress Toward Developing Numeric Nutrient Water Quality Criteria for Nitrogen and Phosphorus. https://www.epa.gov/nutrient-policy-data/state-progress-toward-developing-numeric-nutrient-water-quality-criteria*

- *Proposed Nutrient Criteria for Vermont's Inland Lakes and Wadeable Streams (VTDEC, 2014)*: For reference to the Winnicut River, the most relevant of these recently proposed criteria is the standard for Class B WWMGS, which is 0.027 mg/L.

Vermont's proposed TP standard for Class B WWMGS (0.027 mg/L) would provide a protective target, but one that may be difficult to achieve for the Winnicut River in the near future. To achieve this target, a 25% reduction from the river's current median TP concentration (0.036 mg/L) would be required. Alternatively, NHRC and other stakeholders considered a long-term goal of maintaining current TP concentrations as land development continues in the watershed. A moderate target between the 0.027 mg/L goal and the "maintain existing water quality" goal would be a 12% TP reduction to 0.032 mg/L. For the reasons described above with regard to the typical limiting nutrients in freshwater (P) and marine waters (N), Geosyntec did not recommend establishing an additional marine water TP concentration target as part of the Winnicut River WRMP.

2.3 ESTABLISHMENT OF WATER QUALITY GOALS

For the purposes of this Winnicut River Watershed Based Plan, the process of water quality goal setting involved the following steps:

1. Geosyntec analyzed existing water quality data and relevant water quality standards as presented above in Sections 1-4. This information was summarized and submitted to NHRC and the project Steering Committee (SC) in a technical memorandum dated August 9, 2016.

2. A conference call was held with NHRC, the project SC, and Geosyntec on August 10, 2016, to discuss the technical memorandum and associated water quality goals. The consensus reached during this conference call provided the basis for the water quality goal options and recommendations presented at the first project stakeholder meeting, as described below.

3. The first project stakeholder meeting was held on August 24, 2016 at North Hampton Town Hall. Participants at this meeting included the following:

Name	Affiliation
Michele L. Tremblay	New Hampshire Rivers Council
Ray Senecal	Watershed resident (Greenland)
Tavis Austin	Town of Stratham – Town Planner
Jennifer Rowden	Rockingham County Planning Commission
Jill Farrell	Piscataqua Region Estuaries Partnership
Steve Landry	NHDES
Kevin Lucey	NHDES
Sally Soule	NHDES
Miranda Adams	NHDES
Mason Caceres	Town of North Hampton
Cheri Patterson	New Hampshire Fish and Game Department
Jeff Barnum	Conservation Law Foundation (Great Bay-Piscataqua Waterkeeper)
Danna Truslow	New Hampshire Rivers Council
Chris Ganotis	North Hampton Conservation Commission
Laura Byergo	Greenland Conservation Commission
Paul Deschaine	Town of Stratham – Town Administrator
Bob Hartzel	Geosyntec Consultants, Inc.
Renee Bourdeau	Wright Peirce

Based on discussion during the stakeholder meeting, consensus was reached on the following water quality goals:

1. **River Assessment Units**: Water quality assessments will focus on three distinct sections of the Winnicut River:

    - **Upstream/headwaters** reaches which are dominated by expansive wetlands;
    - **Non-tidal riverine** reach beginning in the vicinity of where the Winnicut River crosses Winnicutt Road in Stratham; and
    - **Estuarine** reach beginning at the Route 33 fish ladder.

2. **Dissolved Oxygen:** Based on analysis of stream and wetland morphology and existing data, it was agreed that the upstream/headwaters reaches will naturally have DO that is lower than the state Class B standard of 5.0 mg/L. Low-gradient stream reaches with pools of slow moving water tend have lower re-aeration potential than shallow, high-gradient turbulent streams. The flow regime in these areas also make them prone to the accumulation of nutrients and organic matter which contribute to low DO conditions, particularly during summer when decomposition rates (and associated oxygen consumption rates) are higher.

   It was agreed that data collected downstream of Winnicutt Road in Stratham would be appropriate for assessing the River's status with regard to the Class B DO standard, with the specific location of this assessment unit boundary to be determined based on further discussion and field investigation in coordination with NHDES.

3. **Total Nitrogen:** The estuarine TN target previously recommended by NHDES in 2009 for prevention of low DO (0.45 mg/L) was agreed upon as a planning target. There is no monitoring data available to assess the status of the Winnicut River in comparison to this target, and future monitoring to collect such data for the river's tidal reach is recommended (*see Section 7.2 for all recommendations related to future monitoring*). However, based on the 2010 NHDES target TN loading of 24.3 tons/year (as estimated to prevent low DO, see section 2.2.1) and the estimated current attenuated TN load to the river of 30.4 tons/year (see Section 3.4), a required TN load reduction of 6.1 tons/year (20%) is estimated. Since nitrogen is not typically the limiting nutrient in fresh water, a target TN concentration was not selected for the non-tidal river reaches.

4. **Total Phosphorus:** A target TP concentration of 0.027 mg/L was selected, based on the draft Vermont criteria for Class B warm-water, medium-gradient streams. Achieving this target will require a 25% reduction from the current median TP of 0.036 mg/L. Since phosphorus is not the limiting nutrient in marine waters, a target TP concentration was not selected for the tidal river reach.

Section 3. Nutrient Load Modeling

This section presents the methodology and results for development of current and future pollutant load estimates for the Winnicut River. A nutrient load model along with existing regional studies were used to estimate the current baseline and future total nutrient load from stormwater (nitrogen and phosphorus) and groundwater (septic and non-septic for nitrogen only) source pathways to the Winnicut River and ultimately the Great Bay estuary.

3.1 MODELING OVERVIEW

A nutrient pollutant load model was developed building on a number of existing studies and methods to account for surface water and groundwater loads to the Winnicut River and ultimately to the Great Bay estuary. These studies include:

- Great Bay Nitrogen Non-Point Source Study (GBNNPSS) (NHDES, 2014); and
- Water Integration for the Squamscott Exeter (WISE) Preliminary Integrated Plan, Final Technical Report (2015).

The modeling components and their associated methodology data source are summarized below:

- Stormwater Load Model (Unattenuated) (WISE);
- Aerial Deposition Load Model (GBNNPSS);
- Septic System Load Model (GBNNPSS);
- Agricultural Load Model (GBNNPSS);
- Pollutant Load Export Rates (PLERs) (WISE and EPA, 2016); and
- Attenuation in pathways in groundwater and surface water (GBNNPSS).

The model was developed to estimate total source loads which represent the amount of nitrogen or phosphorus deposited on land from the following sources:

- aerial deposition;
- human application of pesticides and fertilizers on agricultural land;
- residential land and managed open space (e.g., golf courses and ball fields);
- pet waste from both domestic and farm animals; and
- natural deposition from leaf litter, grass clippings, wetlands and forests.

The model also estimates the human waste load exported from septic systems into groundwater. From the source load, a stormwater load and a groundwater load were estimated. The stormwater load represents the portion of the source load is transported which during a rain event from the land surface directly to a storm drain or receiving water. The groundwater load represents the portion of the load on the land surface which infiltrates during a rain event plus the human waste load from septic systems.

3.1.1 Subject Area

The Winnicut River Watershed is located in Seacoast New Hampshire and includes portions of the towns of Exeter, Greenland, Hampton, North Hampton, Portsmouth, Rye, Stratham and North Hampton. The Winnicut River is approximately 11,200 acres in land area of which 30% is forested, 23% wetlands and 19% residential (Figure 12). Based on 2010 impervious area data from GRANIT, 8% of the watershed is impervious. Of the estimated 900 acres of impervious area, approximately 41% represents transportation (i.e., roads), communications and utilities, followed by 35% within residential land use (Figure 13).

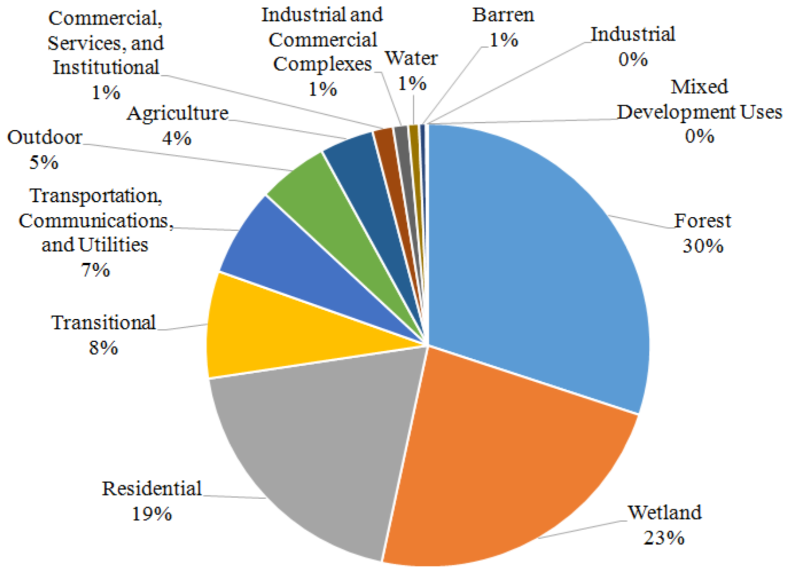


Figure 12. Winnicut River Watershed Land Use[1]

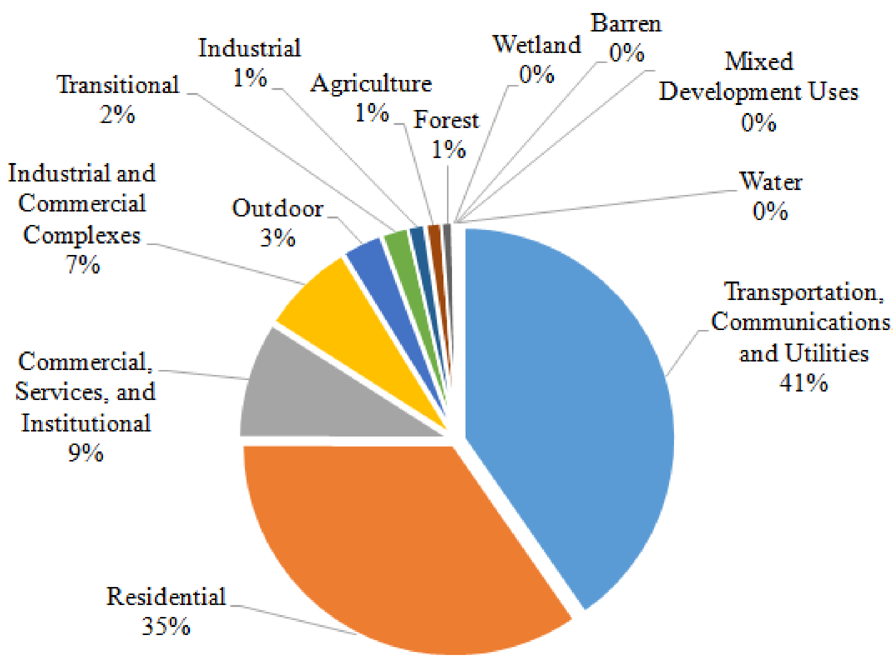


Figure 13. Winnicut River Watershed Impervious Area

1 [1] Land use categories are consistent with the NH Land Use Mapping Standards (March, 2007). Residential represents single family, multi-family, mobile home parks and other residential. Commercial, services and institutional represents commercial retail, commercial wholesale, services, lodging, government, institutional, educational, indoor cultural/public assembly and other commercial, services and institutional. Transportation, communication and utilities represents air, rail, water, and road transportation, highway and road right-of-way park and ride lots, parking lots, communication, electric, gas and other utilities, water and wastewater utilities, and solid waste utilities. Industrial and commercial complexes represent industrial parks, office parks and shopping malls. Outdoor represents outdoor recreation (i.e., golf courses, baseball fields), public assembly, cemeteries and other urban or built-up land. Transitional represents brush or transitional land between open space and forested. Barren represents salt flats, beaches and river banks, sandy areas, bare and exposed rock, gravel pits, and disturbed land.

3.2 STORMWATER LOAD

The purpose of the stormwater model is to estimate annual PLERs and annual pollutant load from the land uses within the Winnicut River Watershed. The model used the methodology developed as part of the WISE project (Geosyntec, 2015), which included the use of the USEPA Stormwater Management Model, Version 5.1 (SWMM5). SWMM5 is a dynamic rainfall-runoff model which was used to create idealized 1-acre watersheds, or hydrologic response units (HRUs), to quantify the volume of stormwater runoff and pollutant load from the land uses represented in the watershed.

3.2.1 Hydrologic Response Units

The HRU approach considers varying combinations of land use, hydrologic soil group (HSG) category (A-D), and impervious cover in the watershed. Example combinations include: HSG A soils with pervious cover or residential land use underlain by D soils with impervious cover. Precipitation data from a local National Climatic Data Center (NCDC) gauge (Durham, New Hampshire) was used to perform a continuous rainfall-runoff simulation of the HRUs to estimate the amount of stormwater volume generated by each HRU.

Table 5 presents the area of each HRU within the Winnicut River Watershed. To quantify the area of each HRU within the watershed, the following geospatial data layers were used:

- 2010 Land Use Data, provided by Rockingham Planning Commission (RPC);
- USDA/NRCS SSURGO-Certified Soils; and
- 2010 Impervious Cover, provided by New Hampshire GRANIT.

Hydrologic soil groups are defined by the following characteristics (NRCS, 2007):

- **A soils** have low runoff potential when thoroughly wet. Soils typically have less than 10 percent clay and more than 90 percent sand or gravel. The saturated hydraulic conductivity of the soil layers typically exceeds 5.67 inches per hour.
- **B soils** have moderately low runoff potential when thoroughly wet. Soils typically have between 10 and 20 percent clay and 50 to 90 percent sand and have loamy sand or sandy loam textures. The saturated hydraulic conductivity of the soil layers typically ranges from 1.42 to 5.67 inches per hour.
- **C soils** have moderately high runoff potential when thoroughly wet. Soils typically have between 20 and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, silty clay, or sandy clay textures. The saturated hydraulic conductivity of the soil layers typically ranges from 0.14 to 1.42 inches per hour.
- **D soils** have high runoff potential when thoroughly wet. Soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. The saturated hydraulic conductivity of the soil layers is less than or equal to 0.14 inches per hour.

Within the Winnicut River Watershed, D soils are most common (54% of pervious area), followed by A soils (22% of pervious area). The most common HRU is wetlands pervious area underlain by D soils, followed by forested pervious land underlain by D soils. When assessing only the developed portion of the watershed, the most common HRU is residential pervious land use underlain by A soils.

Table 5. Area of Hydrologic Response Units within the Winnicut River Watershed

Land Use Type	Pervious Areas (acres)				Impervious Areas (acres)		TOTALS (acres)
	A soil	B soil	C soil	D soil	Total Impervious Area	Water	
Developed Sources							
Agriculture	124	10	60	235	10	0	439
Commercial, Services, and Institutional	35	5	14	34	81	0	169
Industrial	0	0	0	2	11	0	14
Industrial and Commercial Complexes	21	8	3	26	65	0	123
Mixed Development Uses	1	1	0	0	0	0	2
Outdoor*	121	104	92	230	28	0	574
Residential	888	223	313	424	312	0	2,159
Transportation, Communications, and Utilities	73	45	72	177	362	0	729
Total Developed Sources	**1,263**	**396**	**554**	**1,128**	**868**	**0**	**4,209**
Undeveloped Sources							
Barren	12	2	19	22	1	0	56
Forest	623	580	591	1,562	8	7	3,371
Transitional	265	75	119	398	18	0	875
Water	10	2	1	31	0	45	89
Wetland	51	87	52	2,404	1	17	2,612
Total Undeveloped Sources	**961**	**746**	**782**	**4,417**	**28**	**69**	**7,003**
TOTAL	**2,224**	**1,142**	**1,336**	**5,545**	**896**	**69**	**11,212**

* *Outdoor represents outdoor recreation (i.e., golf courses, baseball fields), public assembly, cemeteries and other urban or built-up land.*

3.2.2 Impervious Surface Disconnection

Impervious surface disconnection allows for some runoff volume and pollutant load generated on impervious surfaces to infiltrate as it passes overland onto downgradient pervious surfaces. Impervious cover that is not directly connected to receiving waters (via storm sewers, gutters, or other impervious drainage pathways) contributes to a reduced stormwater pollutant load due to attenuation and infiltration as runoff moves across pervious surfaces. To account for this decrease in pollutant load, the quantity of directly connected impervious area (DCIA) was quantified for each land use type.

Estimates of DCIA for the watershed were developed based on the use of the Sutherland equations. These equations were developed to predict the estimated level of directly connected impervious area based on land use type and TIA. EPA provides guidance on the use of the Sutherland equations (EPA, 2014b) for prediction of the level of DCIA specific to each type of developed land use. The Sutherland equations used in this project are summarized in Table 6. For the watershed TIA (900 acres), the Sutherland equations estimate that approximately 460 acres is DCIA (51%), which is consistent with the majority of the watershed having country drainage (uncurbed, and not dominated by piped stormwater conveyances). The DCIA was assumed to be routed over hydrologic soil group D, which is the most common soil group in the watershed. The revised HRU areas factoring in DCIA are provided in Table 7. When compared to Table 5, the total acres of D soils is greater in Table 7 due to the routing of the disconnected impervious cover onto D soils.

Table 6. Directly Connected Impervious Area Equations

Land Use Category	Sutherland Equation for DCIA
Residential	DCIA = 0.04(TIA)^1.7
Commercial, Services	DCIA = 0.1(TIA)^1.5
Institutional, Government	DCIA = 0.1(TIA)^1.5
Industrial	DCIA = 0.1(TIA)^1.5
Industrial and Commercial Complexes	DCIA = 0.1(TIA)^1.5
Outdoor and Other Urban and Built-up Land	DCIA = 0.1(TIA)^1.5
Agricultural and Forested	DCIA = 0.01(TIA)^2

Table 7. Area of Hydrologic Response Units with Directly Connected Impervious Cover

Land Use Type	Pervious Areas (acres)				Impervious Areas (acres)		TOTALS (acres)
	A soil	B soil	C soil	D soil[2]	DCIA	Water	
Developed Sources							
Agriculture	124	10	60	243	2	0	439
Commercial, Services, and Institutional	35	5	14	59	56	0	169
Industrial	0	0	0	3	10	0	14
Industrial and Commercial Complexes	21	8	3	44	47	0	123
Mixed Development Uses	1	1	0	0	0	0	2
Outdoor	121	104	92	251	6	0	574
Residential	888	223	313	655	81	0	2,159
Transportation, Communications, and Utilities	73	45	72	284	255	0	729
Total Developed Sources	**1,263**	**396**	**554**	**1,539**	**457**	**0**	**4,209**
Undeveloped Sources							
Barren	12	2	19	23	0	0	56
Forest	623	580	591	1,570	0	7	3,371
Transitional	265	75	119	413	3	0	875
Water	10	2	1	31	0	45	89
Wetland	51	87	52	2,405	0	17	2,612
Total Undeveloped Sources	**961**	**746**	**782**	**4,442**	**3**	**69**	**7,003**
TOTAL	**2,224**	**1,142**	**1,336**	**5,981**	**460**	**69**	**11,212**

** Outdoor represents outdoor recreation (i.e., golf courses, baseball fields), public assembly, cemeteries and other urban or built-up land.*

[2] D soil acreage is greater, when compared to Table 5 due to the routing of disconnected impervious cover onto pervious cover in this soil group.

3.2.3 Unattenuated Stormwater Load

To quantify the unattenuated annual stormwater pollutant load washed from the land surface, the HRU land area is multiplied by a PLER. The PLERs for total nitrogen were developed as part of the WISE Project (Geosyntec, 2015) and the total phosphorus PLERs were developed by USEPA as part of the Charles River Watershed TMDL study (USEPA, 2014a).

Table 8 presents the total nitrogen stormwater pollutant load by land use for the watershed. Stormwater runoffs from land uses within the watershed generate approximately 26,000 pounds (13 tons) of total nitrogen per year. The developed portion of the watershed contributes approximately 59 percent of the annual total nitrogen load, with residential land use having the greatest total nitrogen pollutant load contribution, followed by transportation, communications and utilities.

Table 8. Stormwater Unattenuated Total Nitrogen Stormwater Pollutant Load by Land Use

Land Use Type	Total Nitrogen Pollutant Load (LBS/YR)					TOTAL (LBS/YR)
	A soil	B soil	C soil	D soil	DCIA	
Developed Sources						
Agriculture	77	17	189	1,071	28	1,382
Commercial, Services, and Institutional	19	7	37	219	775	1,057
Industrial	0	0	0	12	142	155
Industrial and Commercial Complexes	11	12	8	163	649	844
Mixed Development Uses	0	1	0	1	4	6
Outdoor	131	306	509	1,937	85	2,967
Residential	471	318	838	2,443	1,270	5,340
Transportation, Communications, and Utilities	18	29	90	488	2,886	3,511
Total Developed Sources						**15,262**
Undeveloped Sources						
Barren	4	2	32	53	3	94
Forest	174	447	851	3,155	2	4,629
Transitional	72	55	164	790	30	1,110
Water	0	0	0	0	0	0
Wetland	14	65	73	4,688	0	4,841
Total Undeveloped Sources						**10,674**
TOTAL						**25,936**

* *Outdoor represents outdoor recreation (i.e., golf courses, baseball fields), public assembly, cemeteries and other urban or built-up land.*

Table 9 presents the total phosphorus stormwater pollutant load by land use for the watershed. Stormwater runoff from land uses within the watershed generate approximately 2,300 pounds (1.2 tons) of total phosphorus per year. The developed portion of the watershed contributes approximately 65 percent of the total phosphorus in the watershed. Residential land use contributes 35% of the annual phosphorus load and transportation, communications and utilities land use contributes 30%.

Table 9. Stormwater Unattenuated Total Phosphorus Stormwater Pollutant Load by Land Use

Land Use Type	Total Phosphorus Pollutant Load (LBS/YR)					TOTAL (LBS/YR)
	A soil	B soil	C soil	D soil	DCIA	
Developed Sources						
Agriculture	55	5	27	108	4	199
Commercial, Services, and Institutional	1	1	3	21	100	126
Industrial	0	0	0	1	18	20
Industrial and Commercial Complexes	1	1	1	16	84	102
Mixed Development Uses	0	0	0	0	0	1
Outdoor	14	12	11	29	9	75
Residential	24	26	67	240	158	515
Transportation, Communications, and Utilities	9	5	8	33	387	442
Total Developed Sources						**1,480**
Undeveloped Sources						
Barren	1	0	2	3	0	7
Forest	72	67	69	182	0	390
Transitional	31	9	14	48	4	105
Water	0	0	0	0	0	0
Wetland	6	10	6	279	2	303
Total Undeveloped Sources						**805**
TOTAL						**2,285**

* *Outdoor represents outdoor recreation (i.e., golf courses, baseball fields), public assembly, cemeteries and other urban or built-up land.*

3.2.4 Attenuated Stormwater Load

When stormwater falls on the land surface, natural attenuation occurs as water travels across pervious surfaces and vegetated buffers, through streams and natural waterways. Attenuation is caused by particulate settling, filtering, and biological uptake. By accounting for natural attenuation, the pollutant load which ultimately arrives to the receiving water can be estimated. Attenuated load is presented for nitrogen but not provided for phosphorus, as attenuated loading rates for nitrogen have been studied and are available from NHDES and phosphorus attenuation rates are not readily available. Phosphorus typically has a much greater attenuation rate in soil than nitrogen.

As part of the GBNNPSS, it was estimated that approximately 87% of nitrogen traveling in stormwater through surface water pathways will be transported from its origin to the receiving waters. The stormwater attenuated load for nitrogen is presented in Table 10.

Of the attenuated stormwater load, approximately 41% is from natural or undeveloped sources (i.e., barren, forested, water, and wetlands). The remaining 59% is from developed sources with the largest load from residential development, which is 35% of the total developed load. Transportation land use (i.e., roads) contributes approximately 23% of the total developed load, followed by outdoor land use with 19% of the total developed load. The difference between the unattenuated stormwater nitrogen load and the attenuated stormwater nitrogen load is approximately 3,300 pounds per year.

Table 10. Stormwater Attenuated (Delivered) Total Nitrogen Load

Land Use Type	Attenuated Total Nitrogen Pollutant Load (LBS/YR)					TOTAL (LBS/YR)
	A soil	B soil	C soil	D soil	DCIA	
Developed Sources						
Agriculture	67	15	164	932	25	1,202
Commercial, Services, and Institutional	16	6	32	190	675	920
Industrial	0	0	0	11	124	135
Industrial and Commercial Complexes	10	10	7	142	565	734
Mixed Development Uses	0	1	0	1	3	5
Outdoor*	114	266	443	1,685	74	2,582
Residential	410	277	729	2,125	1,105	4,646
Transportation, Communications, and Utilities	15	26	78	425	2,510	3,054
Total Developed Sources						**13,278**
Undeveloped Sources						
Barren	4	2	28	46	2	82
Forest	152	389	740	2,745	2	4,028
Transitional	62	48	142	688	26	966
Water	0	0	0	0	0	0
Wetland	12	57	63	4,079	0	4,211
Total Undeveloped Sources						**9,287**
TOTAL						**22,565**

** Outdoor represents outdoor recreation (i.e., golf courses, baseball fields), public assembly, cemeteries and other urban or built-up land.*

3.3 GROUNDWATER NITROGEN LOAD

The amount of the initial nitrogen load deposited on the pervious land surface which makes its way to groundwater is quantified as the groundwater non-septic system load. Nitrogen that leaches from septic systems is quantified as the groundwater septic system load. The nitrogen load estimation methodology and the estimated total nitrogen loads for groundwater (both unattenuated and attenuated) are described in the following sections.

3.3.1 Unattenuated Groundwater Nitrogen Load

Groundwater Nitrogen from Septic Systems

The estimated annual nitrogen load derived from the use of septic systems is based on initial estimates from GBNNPSS and revised to include more refined estimates in the watershed. The estimated direct load to the receiving water from septic systems is based on the distance of the septic system to the receiving water body. The GBNNPSS quantifies population and associated septic systems within 200 meters of a 5th order stream, which literature suggests contributes a greater proportion of nitrogen to the Great Bay estuary than those septic systems located outside of 200 meters.

The entire Winnicut River watershed is serviced by on-site septic systems as no municipally owned wastewater treatment facilities exist within the watershed. To better quantify local impacts to the Winnicut River and its tributaries, the number of septic systems and associated population (based on an estimated 2.4 persons per household) were quantified within and outside of 200 meters of any water body in the

Winnicut River watershed. For this analysis, water bodies included the main stem of the Winnicut River, all tributaries to the main stem, and associated wetlands.

The number of septic systems was based on the number residential homes, and quantified using GIS software to establish a 200 meter buffer around all water bodies. The number of residential homes within the 200 meter buffer was then estimated manually. To estimate the population-based annual groundwater load from septic systems, the number of residential homes was multiplied by 2.4 persons per household to get an estimated population within the buffer zone. To estimate the population outside the 200 meter buffer, the 2010 watershed population was subtracted from the number of people within the 200 meter buffer. As defined in the GBNNPSS, the initial (unattenuated load) is quantified as the population multiplied by 10.58 pounds of nitrogen per person.

Table 11 presents a comparison of the unattenuated nitrogen load estimates from the GBNNPSS and the refined estimates prepared for this Winnicut River WRMP. Septic systems within the watershed contribute approximately 72,300 pounds of total nitrogen per year to the Winnicut River and the Great Bay Estuary, which is approximately 9,200 pounds more than estimated as part of the GBNNPSS. This increase is due to the refined definition of how the 200-meter buffer is applied, as described above.

Table 11. Groundwater Septic System Unattenuated Total Nitrogen Load

Groundwater Pathway	GBNNPSS Estimated Annual Unattenuated Total Nitrogen Load (lbs/year)	Refined Estimated Annual Unattenuated Total Nitrogen Load (lbs/year)
Septic Systems Inside 200 meters	1,356	31,461
Septic Systems Outside 200 meters	61,724	40,852
TOTAL	**63,080**	**72,313**

Groundwater Nitrogen from Non-Septic System Sources

The annual unattenuated load to groundwater from non-septic system sources (i.e., infiltration) is estimated by subtracting the stormwater and groundwater septic load from the total source load deposited on the surface as estimated by the GBNNPSS and presented in Table 12.

Table 12. Groundwater Load Non-septic Unattenuated Total Nitrogen Load

Source	Estimated Annual Unattenuated Total Nitrogen Load (lbs/yr)
Total Watershed Load (GBNNPSS)	185,496
Stormwater Load (Calculated)	25,936
Groundwater Septic Load (Calculated)	72,313
Groundwater Non-Septic Load (Estimated)	**87,247**

3.3.2 Attenuated Groundwater Load

Attenuated groundwater from the non-septic load refers to nitrogen which originates from deposition on the ground surface and infiltrates, as opposed to surface runoff, which ultimately makes its way through the soil layers and into a groundwater aquifer. To estimate the amount of total nitrogen which is “lost” during this transport pathway through the soil layers and ultimately to an aquifer, a delivery factor is applied. Based on the GBNNPSS, a generalized groundwater delivery factor for non-septic system groundwater, equivalent to 10%, was applied in order to estimate the attenuated groundwater load that is eventually delivered from the aquifer to the Winnicut River.

As with the groundwater non-septic load, the unattenuated load from septic systems was multiplied by a delivery factor to account for natural attenuation within the groundwater pathway. For septic systems inside 200 meters, a delivery factor of 60% was applied and for septic systems outside 200 meters, a delivery factor of 26% was applied. The groundwater attenuated loads from both septic and non-septic are presented in Table 13.

Table 13. Groundwater Attenuated (Delivered) Total Nitrogen Load

Unattenuated Source	Unattenuated Total Nitrogen Load (lbs/year)	Delivery Factor	Attenuated Total Nitrogen Load (lbs/year)
Groundwater Non-Septic	87,247	x 0.10	8,725
Groundwater Septic (inside 200m)	31,461	x 0.60	18,876
Groundwater Septic (outside 200m)	40,852	x 0.26	10,622
TOTAL			**38,223**

3.4 BASELINE TOTAL NITROGEN LOAD ESTIMATES

For the baseline assessment of existing watershed conditions as of 2010, the estimate total nitrogen delivered or attenuated load to the Winnicut River from the watershed is 60,788 pounds (30.4 tons) per year (Figure 14). Of the total baseline load, approximately 37% (22,565 pounds per year) is from stormwater and approximately 49% (29,498 lbs/yr) is from septic systems.

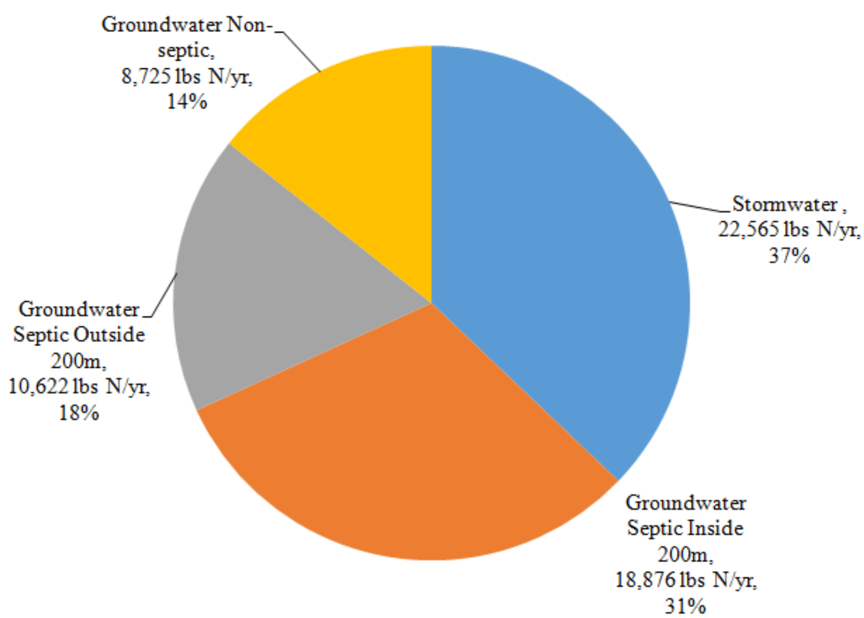
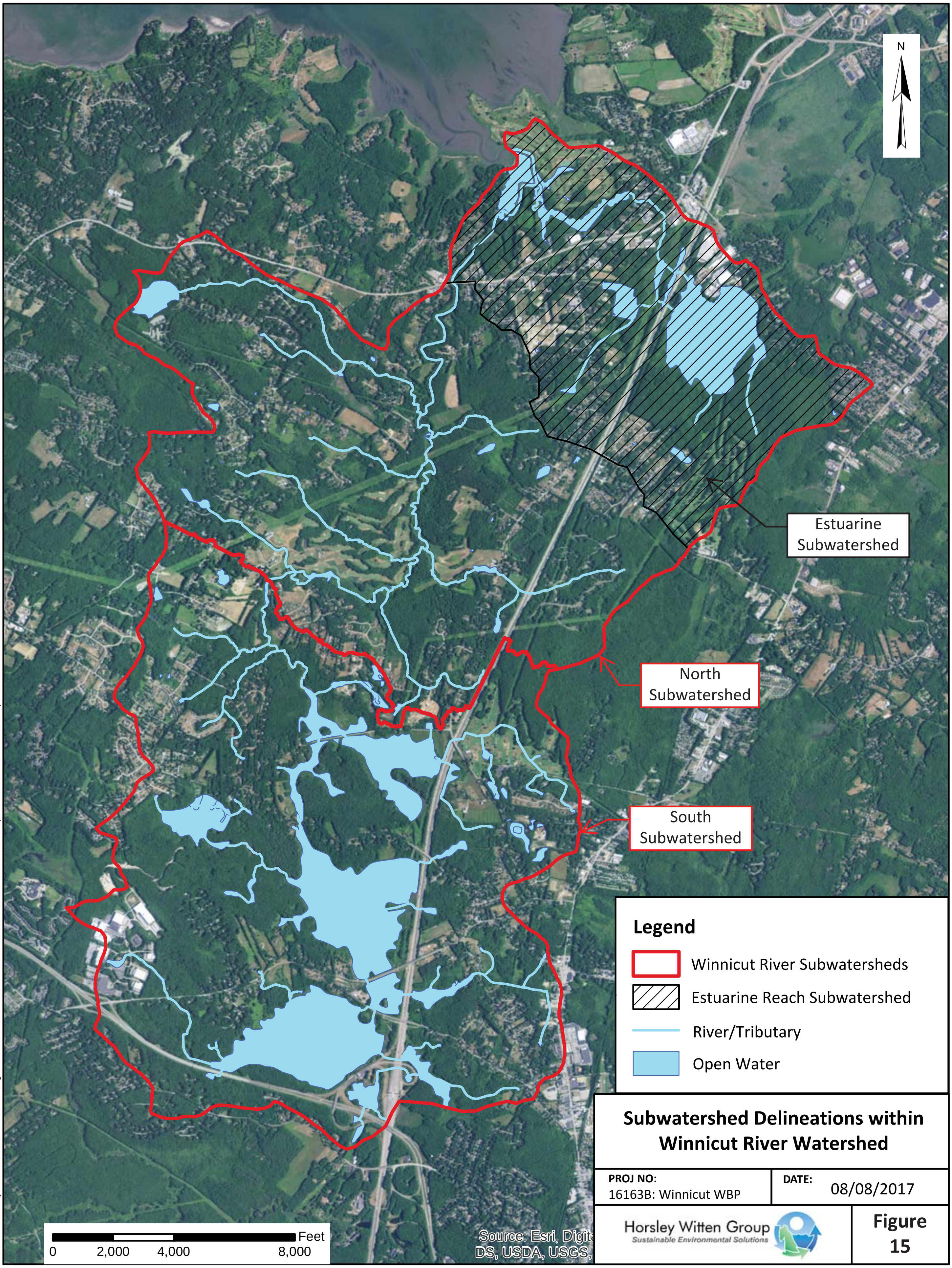


Figure 14. Baseline Total Nitrogen Load for Winnicut River Watershed (Total Load = 60,788 lbs/yr)

3.5 SUBWATERSHED LOADS

During establishment of the water quality goals for the Winnicut River, differences in the hydraulic regime and physical characteristics between major segments of the Winnicut River were noted. These differences led to establishment of different water quality goals for DO for the wetland-dominated "headwaters" reach of the river and the truly "riverine" reaches of the river that can be reasonably expected to meet the Class B water quality standards for DO. The divide between these reaches is where the Winnicut River crosses Winnicutt Road in Stratham, as shown in Figure 15.

The headwaters reach in the southern portion of the watershed (referred to hereafter as the South Subwatershed) is characterized by broad areas of low-gradient wetlands and relatively low flow. The northern riverine reaches (referred to hereafter as the North Subwatershed) is characterized by a well-defined meandering river channel with reaches that include riffle-pool sequences. Figure 15 includes the estuarine reach of the River as a subsection of the North Subwatershed, since this reach of the river can be reasonably expected to meet the Class B water quality standards for DO.



Subwatershed Delineations within Winnicut River Watershed

PROJ NO:	DATE:
16163B: Winnicut WBP	08/08/2017

Horsley Witten Group
Sustainable Environmental Solutions

Figure 15

TAH H:\Projects\2016\16163 Wright-Pierce\16163B Winnicut River WBP\GIS\Maps\Subwatershed Map.mxd

3.5.1 Land Use

The land use by hydrologic response unit for both the northern and southern subwatersheds is presented in Tables 14 and 15, respectively.

- The North Subwatershed is approximately 6,000 acres of which 41 percent is developed land. Of the developed land, approximately 9 percent is directly connected impervious cover and 50 percent of the northern watershed is residential land use. Additionally, 17 percent of the developed portion of the northern watershed is outdoor use (i.e., golf courses and sports fields).

- The South Subwatershed is approximately 5,220 acres, of which 33 percent is developed land. Of the developed land, approximately 13 percent is impervious cover and 53 percent of the northern watershed is residential land use. Additionally, 9 percent of the developed portion of the northern watershed is outdoor use (i.e., golf courses and sports fields).

Table 14. North Subwatershed Land Use

Land Use Type	Pervious Area (acres)				Impervious Area (acres)		TOTALS (acres)
	A soil	B soil	C soil	D soil	DCIA	Water	
Developed Area							
Agriculture	47	2	44	150	1	0	244
Commercial, Services, and Institutional	28	0	14	46	45	0	133
Industrial	0	0	0	3	10	0	13
Industrial and Commercial Complexes	1	0	2	10	11	0	24
Mixed Development Uses	0	0	0	0	0	0	0
Outdoor	75	70	91	186	5	0	427
Residential	490	55	233	417	49	0	1,244
Transportation, Communications, and Utilities	56	27	58	146	109	0	396
Total Developed Area:							**2,481**
Undeveloped Area							
Barren	8	2	16	21	0	0	46
Forest	307	209	422	895	0	7	1,840
Transitional	119	15	93	245	1	0	473
Water	8	0	1	13	0	44	65
Wetland	25	25	33	987	0	14	1,084
Total Undeveloped Area:							**3,510**
TOTAL	**1,164**	**405**	**1,007**	**3,119**	**231**	**65**	**5,991**

Table 15. South Subwatershed Land Use

Land Use Type	Pervious Area (acres)				Impervious Area (acres)		TOTALS (acres)
	A soil	B soil	C soil	D soil	DCIA	Water	
Developed Area							
Agriculture	77	8	16	93	1	0	195
Commercial, Services, and Institutional	7	5	0	13	11	0	36
Industrial	0	0	0	0	0	0	0
Industrial and Commercial Complexes	20	8	1	34	36	0	99
Mixed Development Uses	1	1	0	0	0	0	2
Outdoor	46	34	1	65	1	0	147
Residential	398	168	80	238	32	0	916
Transportation, Communications, and Utilities	17	18	14	138	146	0	333
Total Developed Area							**1,728**
Undeveloped Area							
Barren	4	0	3	2	0	0	9
Forest	316	371	169	675	0	0	1,531
Transitional	146	60	26	168	2	0	402
Water	2	2	0	18	0	1	23
Wetland	26	62	19	1,418	0	3	1,528
Total Undeveloped Area							**3,498**
TOTAL	**1060**	**737**	**329**	**2862**	**229**	**4**	**5,221**

3.5.2 Total Nitrogen

To aid the development of management recommendations for Winnicut River watershed, the attenuated total nitrogen stormwater load was estimated for both the northern and southern subwatersheds by land use category.

Tables 16 and 17 present the stormwater attenuated total nitrogen load for the North and South subwatersheds, respectively. The total load was area-weighted to account for the difference in total area of each of the subwatersheds. The North Subwatershed receives approximately 12,700 pounds of nitrogen per year, or approximately 2.12 pounds per acre per year. The South Subwatershed receives approximately 9,860 pounds of nitrogen per year, or approximately 1.89 pounds per acre per year. Based on these calculations, the North Subwatershed contributes more nitrogen per acre than the South Subwatershed. The watershed as a whole contributes approximately 2.0 pounds per acre per year of total nitrogen.

Table 16. North Subwatershed Stormwater Attenuated Total Nitrogen Load

Land Use Type	Attenuated Total Nitrogen Pollutant Load (lbs/yr)					Total Load (lbs/yr)
	A soil	B soil	C soil	D soil	DCIA	
Developed Sources						
Agriculture	25	3	120	576	13	738
Commercial, Services, and Institutional	13	0	32	149	546	740
Industrial	0	0	0	11	124	135
Industrial and Commercial Complexes	1	0	5	32	134	172
Mixed Development Uses	0	0	0	0	0	0
Outdoor (i.e., playgrounds, sports fields, cemeteries, parks, golf courses)	71	179	438	1,246	59	1,993
Residential	226	69	543	1,354	675	2,867
Transportation, Communications, and Utilities	12	15	63	218	1,067	1,375
Total Developed Sources						**8,020**
Undeveloped Sources						
Barren	2	2	23	42	1	70
Forest	75	140	529	1,565	1	2,310
Transitional	28	10	111	407	11	567
Water	0	0	0	0	0	0
Wetland	6	16	40	1,674	0	1,736
Total Undeveloped Sources						**4,683**
TOTAL	**459**	**435**	**1,904**	**6,511**	**2,643**	**12,703**
Subwatershed (acres)						5,993
Subwatershed Area-Weighted Load (lbs/ac/yr)						**2.12**

Table 17. South Subwatershed Stormwater Attenuated Total Nitrogen Load

Land Use Type	Attenuated Total Nitrogen Pollutant Load (lbs/yr)					Total Load (lbs/yr)
	A soil	B soil	C soil	D soil	DCIA	
Developed Sources						
Agriculture	42	12	44	356	11	464
Commercial, Services, and Institutional	3	6	0	42	129	180
Industrial	0	0	0	0	0	0
Industrial and Commercial Complexes	9	10	2	110	432	563
Mixed Development Uses	0	1	0	1	3	5
Outdoor (i.e., playgrounds, sports fields, cemeteries, parks, golf courses)	43	87	5	438	15	588
Residential	184	208	186	771	431	1,779
Transportation, Communications, and Utilities	4	10	15	207	1,443	1,679
Total Developed Sources						**5,258**
Undeveloped Sources						
Barren	1	0	5	5	1	12
Forest	77	249	211	1,180	1	1,717
Transitional	34	38	31	280	15	399
Water	0	0	0	0	0	0
Wetland	6	41	23	2,405	0	2,476
Total Undeveloped Sources						**4,604**
TOTAL	**403**	**662**	**522**	**5,290**	**2,491**	**9,862**
Subwatershed (acres)						5,221
Subwatershed Area-Weighted Load (lbs/ac/yr)						**1.89**

3.5.3 Total Phosphorus

To aid the development of watershed management recommendations, the unattenuated total phosphorus stormwater load was estimated for both the North and South Subwatersheds by land use category. Tables 18 and 19 present the stormwater unattenuated total phosphorus load for the North and South Subwatersheds, respectively. The total load was area-weighted to account for the difference in total land area of each of the subwatersheds. The North Subwatershed receives approximately 1,230 pounds of phosphorus per year, or approximately 0.21 pounds per acre per year. The South Subwatershed receives approximately 1,050 pounds of phosphorus per year, or approximately 0.20 pounds per acre per year. Both subwatersheds appear to contribute equivalent amounts of phosphorus per acre per year.

Table 18. North Subwatershed Stormwater Unattenuated Total Phosphorus Load

Land Use Type	Unattenuated Total Phosphorus Pollutant Load (lbs/yr)					Total Load (lbs/yr)
	A soil	B soil	C soil	D soil	DCIA	
Developed Sources						
Agriculture	21	1	19	67	2	110
Commercial, Services, and Institutional	1	0	3	17	81	101
Industrial	0	0	0	1	18	19
Industrial and Commercial Complexes	0	0	1	4	20	25
Mixed Development Uses	0	0	0	0	0	0
Outdoor (i.e., playgrounds, sports fields, cemeteries, parks, golf courses)	9	8	11	22	7	57
Residential	13	6	50	153	97	319
Transportation, Communications, and Utilities	7	3	7	17	166	199
Total Developed Sources						**830**
Undeveloped Sources						
Barren	1	0	2	2	0	5
Forest	36	24	49	104	0	213
Transitional	14	2	11	28	2	57
Water	0	0	0	0	0	0
Wetland	3	3	4	114	0	124
Total Undeveloped Sources						**399**
TOTAL	**103**	**48**	**155**	**528**	**393**	**1,229**
Subwatershed (acres)						5,991
Subwatershed Area-Weighted Load (lbs/ac/yr)						**0.21**

Table 19. South Subwatershed Stormwater Unattenuated Total Phosphorus Load

Land Use Type	Unattenuated Total Phosphorus Pollutant Load (lbs/yr)					Total Load (lbs/yr)
	A soil	B soil	C soil	D soil	DCIA	
Developed Sources						
Agriculture	34	4	7	41	2	88
Commercial, Services, and Institutional	0	1	0	5	19	25
Industrial	0	0	0	0	0	0
Industrial and Commercial Complexes	1	1	0	12	64	78
Mixed Development Uses	0	0	0	0	0	0
Outdoor (i.e., playgrounds, sports fields, cemeteries, parks, golf courses)	5	4	0	8	2	19
Residential	11	19	17	87	62	196
Transportation, Communications, and Utilities	2	2	2	16	224	246
Total Developed Sources						**652**
Undeveloped Sources						
Barren	0	0	0	0	0	0
Forest	37	43	20	78	0	178
Transitional	17	7	3	20	2	49
Water	0	0	0	0	0	0
Wetland	3	7	2	165	0	177
Total Undeveloped Sources						**404**
TOTAL	**110**	**88**	**51**	**432**	**376**	**1,056**
Subwatershed (acres)						5,221
Subwatershed Area-Weighted Load (lbs/ac/yr)						0.20

3.6 PRISTINE LOAD

To best understand the impacts that development has had on the watershed and ultimately the receiving water quality of the Winnicut River, estimates of the pristine stormwater load, prior to development, have been calculated. To estimate this load, all developed land (all land uses other than forested, water and wetlands) were converted back to undeveloped land. To do this, the existing ratio between forested and wetlands was preserved, which is 56% forest compared to 44% wetlands. It is understood that over time, wetlands were filled to create developable land and that forested areas were harvested to create buildable lots. All of the developed areas, including impervious cover areas, are underlain by a hydrologic soil group (A, B, C or D). It was assumed that this underlying soil group is consistent with what existed in a pristine condition. Based on these assumptions, all developed land uses were converted to a forest or wetland area, based on the above ratio, in each of the underlying hydrologic soil groups. Table 20 presents the land area within the watershed under the pristine condition.

Table 20. Pristine Land Area

Land Use Type	Area (acres)				Total Area (Ac)
	A soil	B soil	C soil	D soil	
Forest	1,686	902	1,061	2,611	6,260
Water	10	2	1	101	114
Wetland	873	336	415	3,215	4,839
TOTAL	**2,569**	**1,240**	**1,477**	**5,927**	**11,213**

To quantify the pristine stormwater load for both Total Nitrogen and Total Phosphorus, each of the HRU land areas from Table 20 were multiplied by the PLERs to quantify the unattenuated pollutant load. Table 21 presents the unattenuated total nitrogen load for the watershed. The estimated load of 15,290 pounds per year is approximately 10,650 pounds less than the developed watershed load in 2010. Table 22 presents the unattenuated total phosphorus load for the watershed. The estimated load of 1,288 pounds per year is approximately 1,000 pounds less than the developed watershed load in 2010.

Table 21. Pristine Stormwater Unattenuated Total Nitrogen Load (lbs/yr)

Land Use Type	Unattenuated Total Nitrogen Load (Lbs/Year)				Total Load (Lbs/Yr)
	A Soil	B Soil	C Soil	D Soil	
Forest	472	695	1,527	5,249	7,943
Water	0	0	0	0	0
Wetland	244	252	581	6,270	7,347
TOTAL	**716**	**947**	**2,108**	**11,519**	**15,290**

Table 22. Pristine Stormwater Unattenuated Total Phosphorus Load (lbs/yr)

Land Use Type	Unattenuated Total Phosphorus Load (Lbs/Year)				Total Load (Lbs/Yr)
	A soil	B soil	C soil	D soil	
Forest	196	105	123	303	727
Water	0	0	0	0	0
Wetland	101	39	48	373	561
TOTAL	**297**	**144**	**171**	**676**	**1,288**

The attenuated stormwater load for total nitrogen, which accounts for reductions in load due to natural attenuation in the environment, is presented in Table 23.

Table 23. Pristine Stormwater Attenuated Total Nitrogen Load

Unattenuated Source	Unattenuated Total Nitrogen Load (lbs/year)	Delivery Factor	Attenuated Total Nitrogen Load (lbs/year)
Pristine Stormwater	15,290	x 0.87	13,302

For the pristine condition, it is also assumed that no humans are present on the land contributing human waste (i.e., septic systems) to the watershed load. Therefore, to fully account for this human impact, an additional reduction of 29,500 pounds per year (delivered load) would need to be reduced to mimic the pristine condition. More refined estimates of the pristine groundwater non-septic load, or the estimated load to be applied to the surface of the land, are not available or easily calculated and therefore are not presented in this discussion. To reduce the quantifiable human impact on the watershed, approximately 38,827 pounds per year would need to be reduced from the current baseline stormwater and groundwater (septic) load which assumes no future impacts (Table 24).

Table 24. Reductions Required to Achieve Pristine Condition

Attenuated Source	Attenuated Total Nitrogen Load (lbs/year)
Baseline Stormwater + Groundwater (Septic)	49,129
Pristine Stormwater Load	13,302
Reduction Required	**35,827**

3.7 FUTURE IMPACTS

Future land development within the watershed will increase future pollutant loads to the Winnicut River and its tributaries unless additional protective measures are implemented, such as stormwater and wastewater management improvements, or additional site development and zoning regulations. To estimate the potential water quality impacts of future development, historic population and land use trends were analyzed as well as future projections of population. The future projections were used to estimate the expected land development within the watershed through the year 2040. The future projections also provided the basis for a comparison of future pollutant loading to the Winnicut River under several scenarios, including traditional zoning, low impact development zoning, and with implementation of stormwater best management practices (BMPs).

3.7.1 Historic Population and Land Use Trends

Historic population values for the towns within the Winnicut River watershed were compiled from the United States Census for the years from 1960 through 2010. Since the watershed boundary does not coincide with town political boundaries, each town's population within the watershed was estimated by scaling according to the percentage of town area within the watershed. Figure 16 provides the estimated historic population in the Winnicut River watershed. The watershed's population increased by an estimated average annual rate of 2 percent from 1960 to 2010, with the greatest average annual rate increase from 1960 to 1970 at 4 percent.

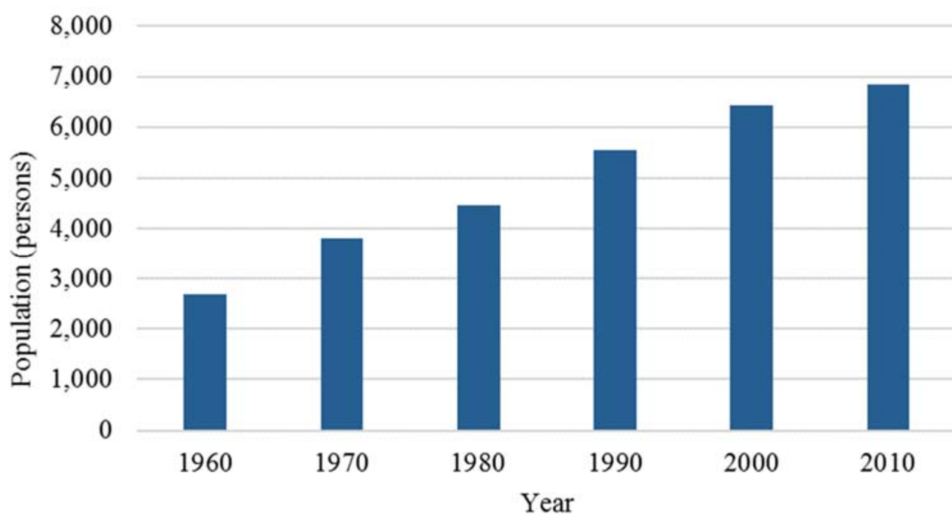
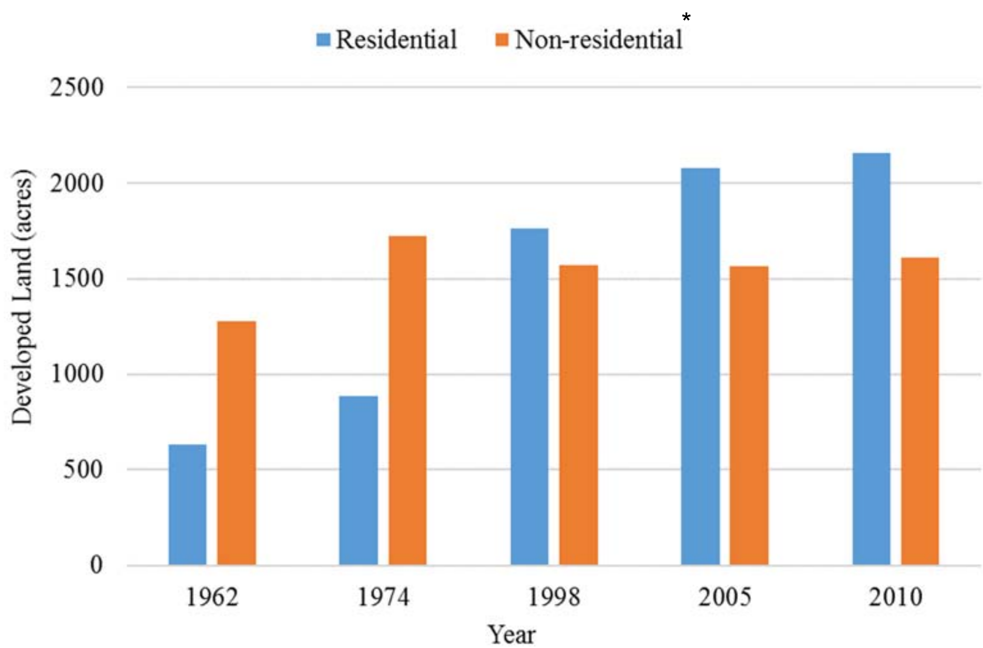


Figure 16. Estimated Historic Population in Winnicut River Watershed

Historic land use changes for the years 1962, 1974, 1998, 2005 and 2010, available through GRANIT, were analyzed to show the trends in developed land. Developed land was categorized by residential and non-residential land uses. Non-residential developed land includes commercial, industrial, transportation, outdoor recreation, cemeteries, and communications facilities. Figure 17 presents the historic land use changes in the watershed for both residential and non-residential development. The average annual increase in residential development is 3 percent over the 48 year period, whereas non-residential change is 1 percent. Non-residential development shows a decrease from a reported peak in 1974, whereas residential development shows an increasing trend. However, discrepancies in these values could be attributed to improvements in the resolution of data over time due to changes in mapping, and GIS technology. As a result, older available data may over-estimate non-residential land development prior to 1998.



** Non-residential: commercial, industrial, transportation, outdoor recreation, cemeteries and communication facilities*

Figure 17. Historic Developed Land Changes in Winnicut River Watershed

3.7.2 Future Population Projections

Estimates of future population growth through 2040 for the watershed's towns were compiled from the New Hampshire Office of Energy and Planning (NHOEP) population projections (NHOEP, 2016). Similar to the historic population values, future population estimates were scaled based on the percentage of town area within the watershed. Figure 18 presents the historic and the projected future population within the Winnicut River watershed. Population is projected to increase annually by 0.4 percent between 2020 and 2040, resulting in an estimated total increase of 7 percent over that period.

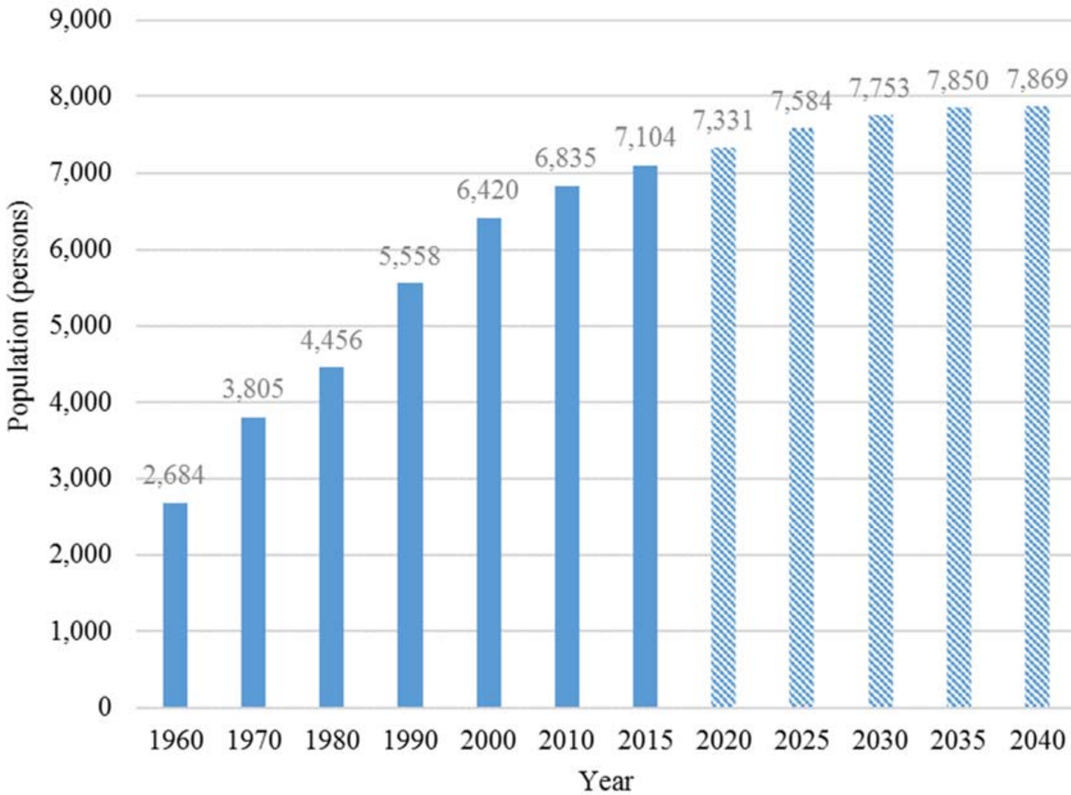


Figure 18. Historic and Future Population in the Winnicut River Watershed

3.7.3 Future Developed Land Projections

Traditional Zoning

With population growth comes changes in land use (undeveloped to developed). To understand the impacts of population growth on developed land under current "traditional" zoning, two development scenarios were analyzed based on: (1) projection of developed land historic trends; and (2) historic population and developed land trends.

Under the first scenario, projected developed land was forecast based on the percent change per year of historic residential and non-residential trends from Section 3.7.1. This projection assumes no changes in zoning and that land is developed in similar patterns. Using the FORECAST function in Microsoft Excel, residential development and non-residential development was projected to year 2040 based on the historic rate of growth. Figure 19 presents the projected developed land areas through 2040. Based on this projection, total developed land area would increase by 31 percent from 3,770 acres in 2010 to 4,930 acres in 2040.

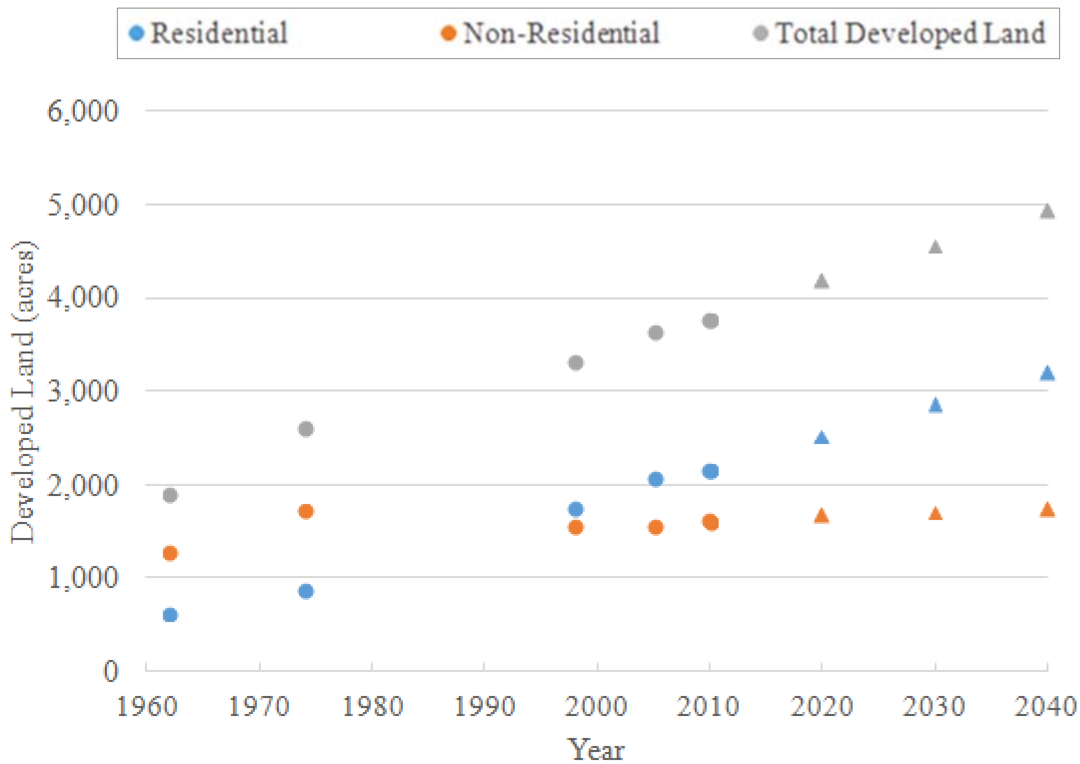


Figure 19. Historic and Projected Land Use Trends

Under the second analysis, historic population was compared to historic developed land and an acreage per person was calculated. The average acreage per person in the watershed between 1962 and 2010 is 0.59. This considers both residential and non-residential developed land growth and does not distinguish the differences. Using the 0.59 acres per person estimate, future developed land was estimated based on the projected population growth. Figure 20 presents the historic and projected developed land in the Winnicut River watershed compared to the estimated watershed population. Approximately 4,620 acres would be developed based on these projections, which would increase the percentage of developed land in the watershed from 33 percent in 2010 to 41 percent in 2040. Similar to the previous scenario, this scenario assumes that zoning and development patterns would be consistent with historic trends.

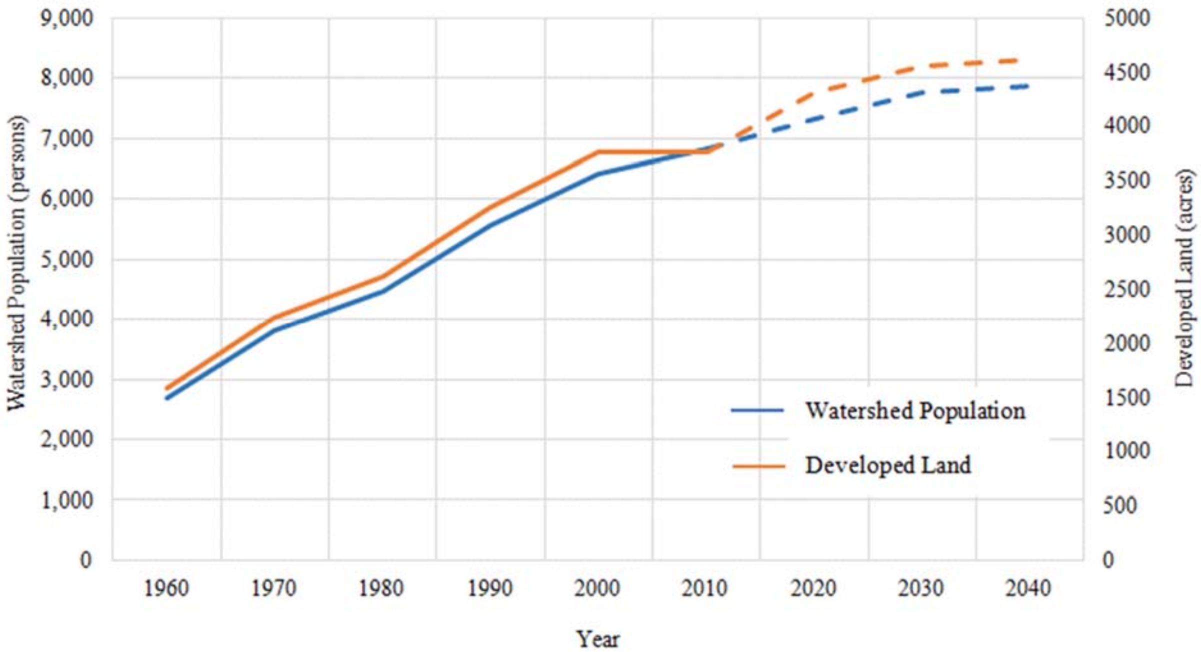


Figure 20. Historic and Projected Population and Developed Land

When comparing the two scenarios presented above, the first scenario is predicts a higher rate of future land development. As a result, the first scenario provides a more conservative estimate for planning purposes to project the future load under a traditional zoning scenario.

Low Impact Development Zoning

Low impact development (LID) zoning aims to preserve open space, conserve lot coverage and critical resources such as wetlands, floodplains and riparian corridors, and to minimize the overall land disturbance and impervious surfaces associated with a development. Traditional zoning tends to require a minimum lot size for a residential or commercial parcel and often results in complete disturbance of the lot. One approach to LID zoning focuses on requirements for preservation of undeveloped land and reduced lot coverage, also known Natural Resource Protection Zoning. For example, as shown in Figure 21, a 100-acre wooded site is being considered for development. Under a traditional zoning (middle image) with two-acre zoning, 34 lots or homes would be developed with no preservation of open space. The traditional zoning scenario would involve earth work on the entire 100-acre lot. Alternatively, under LID zoning with a land preservation requirement, the same 100-acre parcel would preserve approximately 75% of the parcel and result in the development of 14 lots.

Figure 21. Impacts of Traditional Zoning and LID Zoning

Another approach to LID zoning encourages development of the same number of units, but with a smaller minimum lot size that results in a smaller development footprint and reduction in lot coverage resulting in preservation of open space. For example, under traditional zoning with a one-acre minimum lot size, a 20-acre subdivision would result in 20 homes and disturbance of the entire 20 acres. Under LID zoning with the minimum lot size reduced to 0.5 acres, the same number of units (20 homes) could be built, disturbing 10 acres and preserving the remaining 10 acres as open space.

Table 25. Elements of LID Zoning

Characteristics	Potential Benefits	Financial Considerations
➢ Streamlined permitting process ➢ Regulatory consistency between local boards, departments and agencies ➢ Link density bonuses to watershed and community goals ➢ Link open space to watershed and community goals ➢ Openness to flexible design that allows for various lot sizes, frontages and setbacks	➢ Concentrated development ➢ Mixed use ➢ Reduced impervious cover ➢ Reduce impacts to water quality ➢ Protection of land and ecosystem ➢ Aquifer protection ➢ Expansion of housing opportunities ➢ Reduced lot coverage	➢ Decreasing costs for installation and maintenance of conventional infrastructure ➢ Cost savings with reduced clearing and grading ➢ Increased value due to preservation of valuable open space and proximity to recreational area

To understand the potential water quality benefits of LID zoning in the Winnicut River watershed on future development three zoning scenarios were evaluated. These scenarios focus on variable lot size per home; however, it is assumed that with reduction of lot size comes preservation of open space, reduced impervious cover, reduction in overall lot coverage, and less sprawl. The three scenarios are as follows:

- 1 acre lots;
- ½ acre lots; and
- ¼ acre lots

Based on the 2010 residential land use and population, the estimated developed land per person was approximately 0.59 acres. According to the 2010 US Census, 2.4 persons occupied each household, which means that the developed land per household is approximately 1.4 acres. The traditional (1.4 acres) is compared to the LID scenarios in Table 26.

Table 26 presents the developed and undeveloped acres in years 2010, 2020, 2030 and 2040 based on future growth conforming to LID zoning, which for analysis purposes assumes that all new growth between 2010 and 2040 would conform to the minimum lot size, as described. When compared to traditional zoning, developed area in 2040 is reduced by 15 percent for 1-acre lots, 19 percent for ½-acre lots and 21 percent for ¼-acre lots.

Table 26. Developed Land for Low Impact Development Zoning* Alternatives

Year		Developed Land (Acres)			
		Traditional Zoning (1.4 AC Lots)	LID (1 AC Lots)	LID (1/2 AC Lots)	LID (1/4 AC Lots)
2010	Residential	2,159	-	-	-
	Non-residential	1,610	-	-	-
	Undeveloped	7,445	-	-	-
2020	Residential	2,520	2,395	2,333	2,302
	Non-residential	1,663	1,581	1,540	1,519
	Undeveloped	7,031	7,238	7,342	7,393
2030	Residential	2,856	2,602	2,482	2,422
	Non-residential	1,700	1,549	1,478	1,442
	Undeveloped	6,657	7,063	7,254	7,350
2040	Residential	3,193	2,720	2,580	2,510
	Non-residential	1,737	1,480	1,404	1,366
	Undeveloped	6,284	7,014	7,230	7,337
Developed Area Reduced by Year 2040 (Ac)			**731**	**946**	**1,054**
Percent Reduced			**15%**	**19%**	**21%**

** LID Zoning results in overall reduction in lot coverage and preservation of open space*

3.7.4 Projected Future Stormwater Load

For each of the zoning scenarios, traditional and LID, the projected total nitrogen and total phosphorus stormwater load from the watershed was estimated to determine the future impact of development on the watershed. The 2010 pollutant load estimates were used to determine the average pollutant load export rates for residential and non-residential developed land as well as undeveloped land including pervious and impervious land cover. Residential developed land was estimated to export an average of 2.47 pounds of nitrogen per acre per year, non-residential an average of 5.31 pounds of nitrogen per acre per year and undeveloped 1.63 pounds of nitrogen per acre per year.

For the three LID zoning scenarios, the estimated developed land for each year was multiplied by the percent residential and non-residential ratio from the traditional zoning scenario, which provides the area of residential and non-residential in each of the LID zoning scenarios. The undeveloped area is the total watershed area subtracted from the estimated developed area. Similar to the estimated traditional zoning load, the areas of residential, non-residential and undeveloped were multiplied by the pollutant load export rates to calculate an unattenuated load. The unattenuated load was multiplied by the attenuation factor (0.87) to get the attenuated total nitrogen load in 2020, 2030 and 2040, as presented in Table 27.

Table 27 presents the future projected total nitrogen load from the watershed per year for the three LID zoning scenarios compared to the traditional zoning scenario. The future (2040) load is reduced by 5 percent by reducing lot size from 1.4 acres to 1.0 acres, by 6 percent with ½-acre lots, and by 7 percent with ¼-acre lots.

Table 27. Projected Future Total Nitrogen Attenuated Stormwater Load by Zoning Scenario and Year

Year	Total Attenuated Nitrogen (lbs/Yr)			
	Traditional Zoning (1.4 ac Lots)	LID (1 ac Lots)	LID (1/2 ac Lots)	LID (1/4 ac Lots)
2010	22,564	-	-	-
2020	23,101	22,746	22,569	22,481
2030	23,465	22,796	22,480	22,323
2040	23,829	22,661	22,316	22,144
2040 Load Reduced (lbs/yr)		1,168	1,512	1,684
Percent Reduced		5%	6%	7%

To estimate the total phosphorus load, similar procedures were used including estimating the pollutant load export rates for residential, non-residential and undeveloped lands using the 2010 pollutant load estimates. Based on the 2010 values, residential developed land was estimated to export an average of 0.24 pounds of phosphorus per acre per year, non-residential an average of 0.48 pounds of phosphorus per acre per year and undeveloped 0.14 pounds of phosphorus per acre per year. For the three LID zoning scenarios, the estimated residential, non-residential and undeveloped land was multiplied by the average pollutant load export rates to get the total phosphorus unattenuated load.

Table 28 presents the future projected total phosphorus unattenuated load from the watershed per year for the three LID zoning scenarios compared to the traditional zoning scenario. The future (2040) load is reduced by 6 percent by reducing lot size from 1.4 acres to 1.0 acres, by 7 percent with ½-acre lots, and by 8 percent with ¼-acre lots.

Table 28. Projected Future Total Phosphorus Unattenuated Stormwater Load by Zoning Scenario and Year

Year	Total Attenuated Phosphorus (lbs/Yr)			
	Traditional Zoning (1.4 ac Lots)	LID (1 ac Lots)	LID (1/2 ac Lots)	LID (1/4 ac Lots)
2010	2,284	-	-	-
2020	2,348	2,308	2,287	2,277
2030	2,395	2,318	2,282	2,263
2040	2,442	2,307	2,267	2,247
2040 Load Reduced (lbs/yr)		136	176	196
Percent Reduced		6%	7%	8%

Based on these projected load reductions, it is clear that implementing zoning which preserves open space, protects ecological resources and decreases the development footprint provides a reduction in water quality impacts and should be considered when managing the Winnicut River watershed.

Section 4. Watershed Management

This section of the Winnicut River WRMP presents recommended best management practices according to the following categories:

- Structural Best Management Practices (Section 4.1)
- Wastewater Management (Section 4.2)
- Non-structural Best Management Practices (Section 4.3)

Section 4.4 provides tables that summarize and provide a prioritization ranking of the recommended BMPs based on BMP categories. These tables allow for comparison of recommended BMPs within each category, and includes a description of prioritization ranking factors for each category.

4.1 STRUCTURAL BEST MANAGEMENT PRACTICES

4.1.1 Field Watershed Investigation

Engineers from Geosyntec and Wright-Pierce (Team) conducted a watershed field investigation on November 2 and November 10 of 2016 to identify locations where structural BMPs could be constructed to reduce pollutant loads within the Winnicut River Watershed. Priority culvert upgrade opportunities were identified based on a review of existing culvert inventory and assessments conducted by the Rockingham Planning Commission and The Nature Conservancy (TNC, 2009) and visual observations during the watershed field reconnaissance.

The Team conducted both on the ground reconnaissance throughout the watershed. The Team identified potential structural BMP locations based on the following factors:

- Connectivity to the Winnicut River, its tributaries and wetlands;
- Existing “available” space (i.e., land without buildings or other structures);
- Parking lot configuration/traffic flow (i.e., how much parking is currently provided?; are there paved medians?; would improvement impact or alter traffic patterns?);
- Entrances to the site and buildings (i.e., highly visible areas);
- Below-ground infrastructure/utilities as well as groundwater elevations;
- Site drainage patterns and proximity to existing inlets to enable overflow drainage;
- Potential for disconnecting and routing roof drains/headers or other catchment areas to structures;
- Locations with existing infrastructure in poor condition where strategic improvements can be made to serve dual benefits (e.g., replace crumbling walkway or asphalt with permeable pavement);
- Constructability concerns (proximity to foundations, overhead utilities, wetland resource areas and other permitting constraints, etc.); and
- Proximity to cultural/historical areas that may require special conditions.

The potential structural BMP locations described in this section are not intended to be an all-inclusive listing of potential structural retrofit improvements possible within the watershed. Figure 22 shows the location of each proposed structural BMP location. Attachment A presents the cost estimates and nutrient (nitrogen and phosphorus) loading reduction estimate calculations for each proposed site.

BMP Recommendations

The structural BMP locations described on the following pages were identified during the Team's field investigations. A design objective for each proposed BMP should be to size the BMP to treat and potentially infiltrate the water quality volume (WQV) to the maximum extent practicable. The WQV is the minimum amount of stormwater runoff from a rainfall event that should be captured and treated to remove the majority of stormwater pollutants on an average annual basis. The WQV is defined in the New Hampshire Stormwater Manual (NH DES, 2008) as the volume of runoff associated with the first one-inch of rainfall, which is equivalent to capturing and treating the runoff from the 90th percentile of all rainfall. However, each proposed BMP should be designed to get the most treatment that is practical given the size and constraints of each site.

Each BMP site description includes:

- A site summary that describes the current conditions and stormwater drainage patterns;
- A description of proposed structural BMP(s);
- Estimated costs;
- Estimated annual phosphorus and nitrogen load reduction for the proposed structural BMP, assuming that the practice is properly designed, installed, maintained according to guidelines provided in the New Hampshire Stormwater Handbook (NHDES, 2008); and
- Recommended priority for BMP implementation (low, medium or high). As presented in Section 4.4, priority ranking is based on factors including 20-year life-cycle cost, annual N and P load reduction, cost per pound of N and P load reduction, public visibility (i.e., potential education/outreach value), and construction feasibility.

Methodology

Costs and pollutant load reductions were calculated for each structural BMP and culvert using the following assumptions and methodology:

- **Estimated Costs (Structural Stormwater BMPs):** A present day value life cycle cost for each structural BMP was estimated using capital construction costs, engineering and design costs, and operation and maintenance (O/M) costs over a 20-year service life. The majority of capital construction costs were based on installed unit prices using information from EPA, 2016 (e.g., $10 per cubic foot bioretention). Capital construction costs for catch basins, outlet protection, revegetation, culvert daylighting, and educational kiosks were taken from recent 2016/17 Geosyntec project data. Engineering and design costs were calculated based on 35-percent of the capital construction cost. These costs represent approximate costs for engineering design and analysis, survey, design drawing preparation, permitting and bid support. Operation and maintenance costs were derived based on a percentage of the mean capital construction costs using percentages published in EPA, 1999. Mean percentage of capital construction costs include bioretention (6%), infiltration facility (5.5%) and gravel wetland (2%). Present day life cycle costs were calculated by taking the sum of capital construction costs plus engineering design costs, plus the annual operation and maintenance costs times 20 years.

- **Estimated Costs (Culvert Improvements):** A present day value life cycle cost for each culvert was estimated using capital construction costs, engineering and design costs, and operation and maintenance costs over a 20-year service life. Capital construction costs were estimated using information presented in 2010 LD1725 Cost Models from Maine Department of Transportation (Maine DOT, 2010).

Replacement culvert sizes are conceptual and based on the New Hampshire Stream Crossing Guidelines (UNH, 2009) recommendation that culverts should be a minimum of 1.2 times the bankfull width plus 2 feet. Stream bankfull dimensions were obtained from the TNC report or estimated by Geosyntec during site reconnaissance. Additional hydraulic modeling and engineering analysis is required to accurately size a replacement culvert prior to permitting and construction. Engineering and design costs were calculated based on 35-percent of the capital construction cost. These costs represent approximate costs for engineering design and analysis, survey, design drawing preparation, permitting and bid support. Operation and maintenance costs were derived based on a percentage 1% of the mean capital construction cost. Present day life cycle costs were calculated by taking the sum of capital construction costs plus engineering design costs, plus the annual operation and maintenance costs times 20 years.

- **Pollutant Loading Estimates:** Pollutant loading estimates associated with each structural BMP were calculated using the water quality volume for each structural BMP based on the anticipated area and depth of each BMP. It was assumed that each BMP was properly designed and maintained and would adequately treat this water quality volume to achieve the pollutant load removal efficiencies presented in the New Hampshire Stormwater Handbook (NHDES, 2008). This percent removal was applied to the water quality volume to estimate the mass of pollutant removed in pounds per year. This value was converted into a range of pollutant load removal using a 10% factor of safety (i.e., 0.9 to 1.1). The mean of this range was also used to estimate the cost per pollutant load divided by the mean pollutant load removed. This metric was used in the evaluation of ranking the structural BMPs.

- **Pollutant Load Unit Cost ($/lb pollutant)**: Pollutant load unit costs were developed for each structural BMP as one metric to compare and rank recommended structural BMPs. The pollutant load unit cost was estimated by dividing the estimated present-day value life cycle cost (in U.S. dollars, USD) by the BMP service life (i.e., 20 years) and the annual pollutant load (in pounds of pollutant per year). The resulting unit cost is USD per pound of pollutant removed, assuming that the BMP is properly designed and maintained.

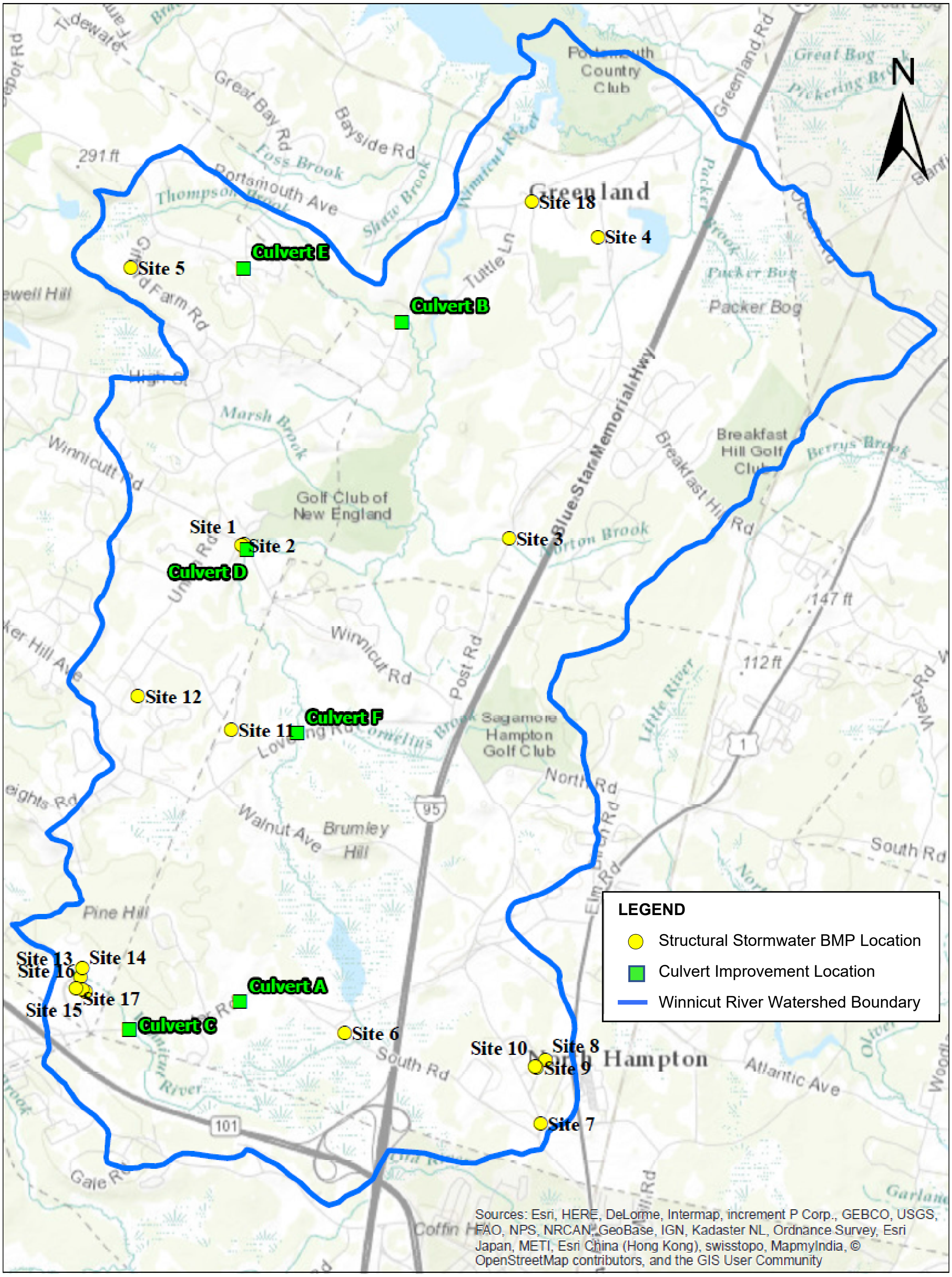


Figure 22. Proposed Structural BMP Locations

STRUCTURAL STORMWATER BMP SITES

Site 1: North Side of Winnicutt Road between Arnold Palmer Dr. and former gristmill, Stratham, NH

Site Summary:

Drainage along the north side of Winnicutt Road discharges to a catch basin inlet at the intersection of Arnold Palmer Drive and Winnicutt Road (Photo 1-1). Drainage from the catch basin flows under Arnold Palmer Drive through a culvert (Photo 1-2) that daylights upgradient of the Winnicut River Bridge at the location of the old gristmill. At the time of the site reconnaissance, the culvert was approximately 50% full of sediment. Erosion and sediment deposition (Photos 1-3 and 1-4) was observed from the outlet of the culvert and ultimately to the Winnicut River, where a channel has formed due to erosive flows from the culvert. Erosion along the banks of this channel could be contributing sediment and nutrient load to the Winnicut River.

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvement:

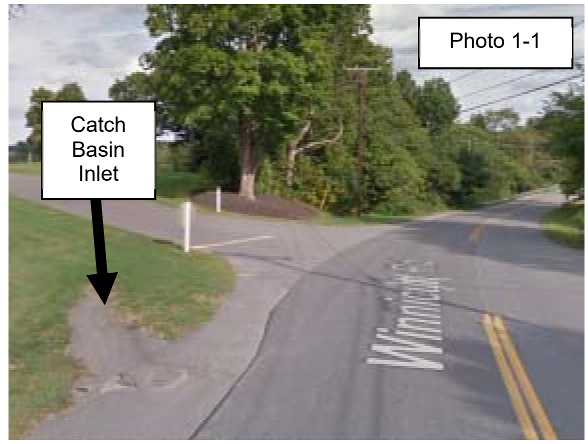
Clean catch basin and remove accumulated sediment from the culvert under Arnold Palmer Drive.

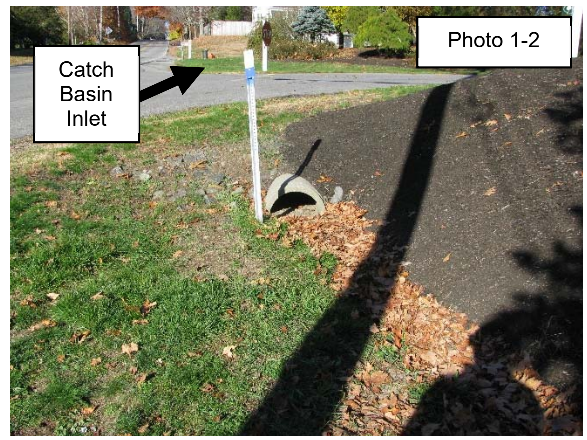
Install culvert outlet protection and vegetated swale (30 ft by 4 ft) (Photo 1-5) along existing flow path from the culvert.

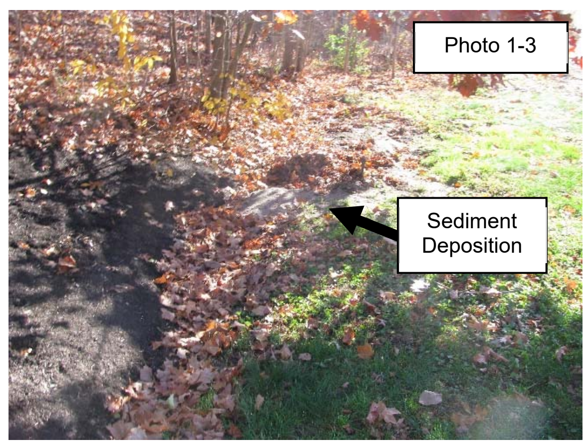
Install a bioretention cell (450 sq. ft.) adjacent to Winnicutt Road to intercept and infiltrate water from the proposed vegetated swale before discharging into the wooded area and ultimately to the Winnicut River (Photo 1-5). The bioretention cell should be planted with non-woody vegetation, as observations indicate that woody vegetation along the road in this location has been removed and/or mowed. At the outlet of the bioretention cell, the existing eroded channel should be repaired and lined with stable material (i.e., rock or rip-rap) to reduce future erosion and migration of sediment to the river.

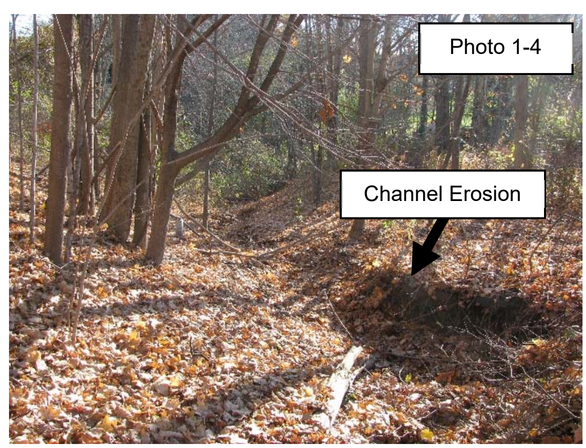
Estimated Costs:

- Capital Costs (Engineering Design and Construction): $21,300 - $30,800
- Annual O/M: $1,150/yr
- 20-Year Life Cycle Cost: $49,050





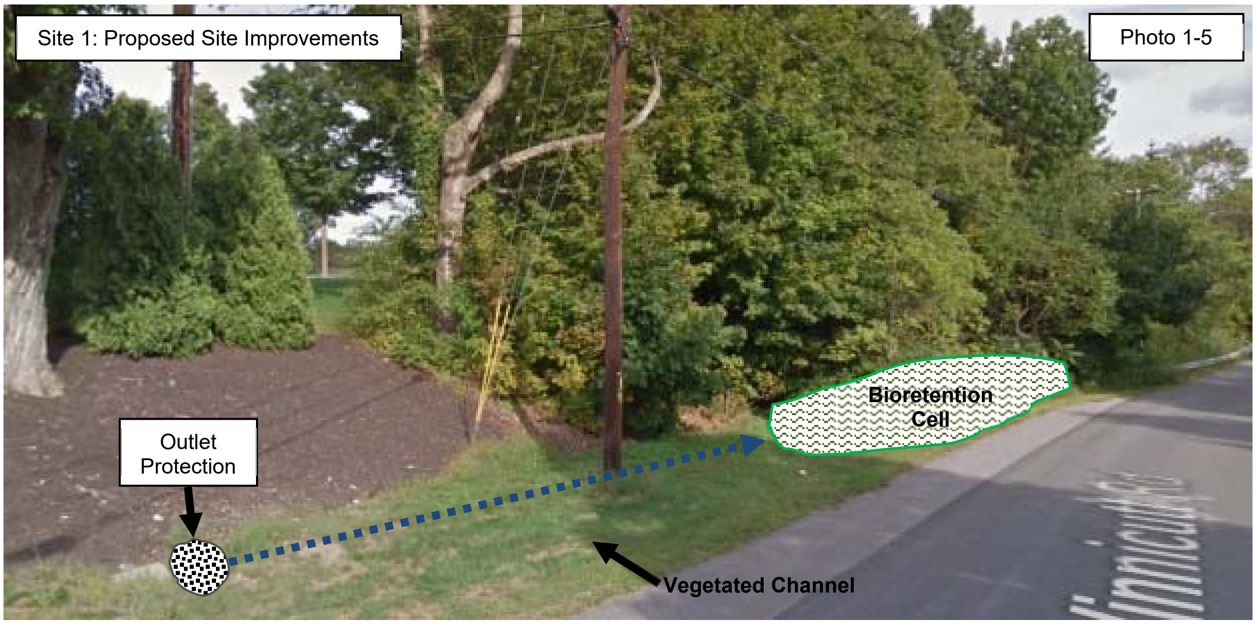


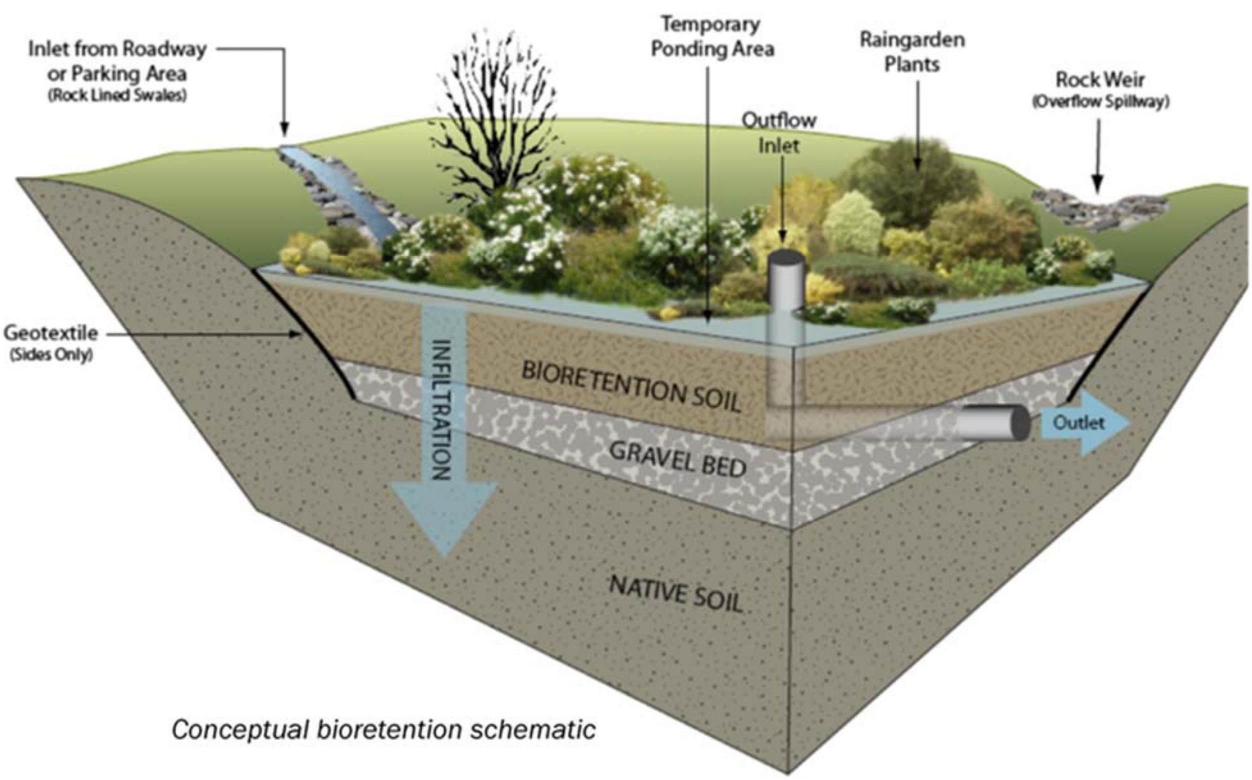


Estimated Nutrient Load Reduction:

- Phosphorus: 0.4 – 0.5 lb P/yr
- Nitrogen: 3.0 – 3.4 lb N/yr
- Cost per lb. of P and N Reduction per Year: $5,500 (P); $800 (N)

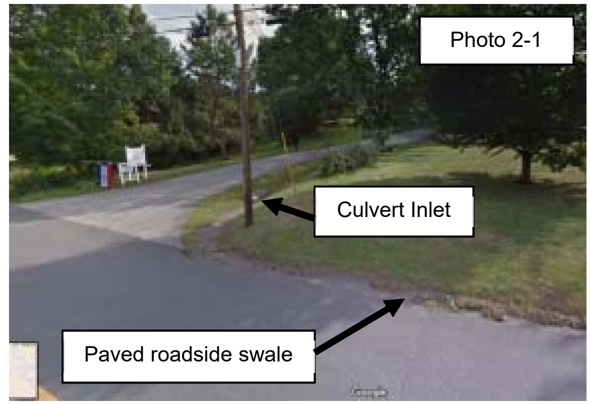
Priority: **Medium**

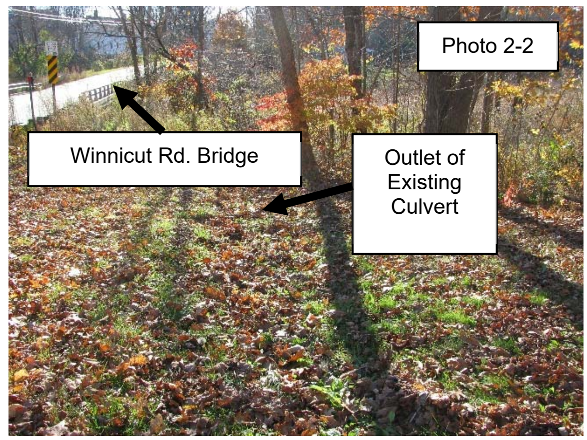




Conceptual bioretention schematic

Site 2: South Side of Winnicutt Road across from Arnold Palmer Dr., Stratham, NH





Site Summary:

Drainage along the south side of Winnicutt Road drains from a paved roadside swale to a culvert which flows under a driveway (Photo 2-1) and daylights to a vegetated area (Photos 2-2 and 2-3) adjacent to the Winnicutt Road bridge and ultimately to the Winnicut River. Erosion was observed at the outlet of the existing culvert as well as along the banks of the Winnicut River at the culvert outlet.

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvement:

Daylight the existing pipe approximately 30 to 40 feet (ft) further upstream and create a stabilized outlet which discharges to an approximate 20 ft. by 15 ft. bioretention cell with a stabilized outlet prior to discharging to the Winnicut River (Photo 2-4). The bioretention cell should be planted with non-woody vegetation, as visual observations indicate that vegetation along the road in this location has been removed and/or mowed. The downstream channel should be stabilized with rip-rap, as needed.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $11,900 - $17,100
- Annual O/M: $650/yr
- 20-year Life Cycle Cost: $27,500

Estimated Nutrient Load Reduction:

- Phosphorus: 0.3 lb P/yr
- Nitrogen: 2.0 – 2.2 lb N/yr
- Cost per lb. of P and N Reduction per Year: $4,600 (P); $700 (N)

Priority: **Medium**


Site 2: Proposed Site Improvements
Photo 2-4
Proposed
Bioretention Cell
Proposed
culvert daylight

Site 3: 682 Post Road adjacent to Norton Brook crossing, Greenland, NH

Site Summary:

Stormwater flows (blue arrows) along the edge of pavement on Post Road (Photo 3-1) and ultimately to a catch basin (Photo 3-2) which discharges untreated stormwater directly into Norton Brook, which ultimately discharges to the Winnicut River. Norton Brook discharges into a pond (Photo 3-2 and Photo 3-3) which is hydraulically connected to the Winnicut River and adjacent to a farm and agricultural land.

Soils in the vicinity of the site are characterized as Eldridge fine sandy loam, which is a moderately well drained soil that is not rated for a HSG. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvement:

Install a catch basin along the east and west sides of Post Road. The catch basin on the east side should discharge to the catch basin on the west side. The west catch basin should discharge, via a subsurface pipe, to a bioretention cell (480 sq. ft.) in the grassed island in the driveway of 682 Post Road. The bioretention cell could include either grass vegetation or woody vegetation depending on stakeholder input during the design phase. The catch basins should include deep sumps and hoods to provide pre-treatment to minimize operation and maintenance in the bioretention cell.

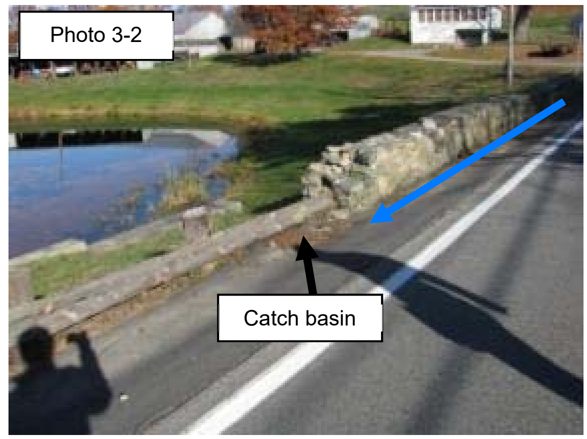
Estimated Costs:

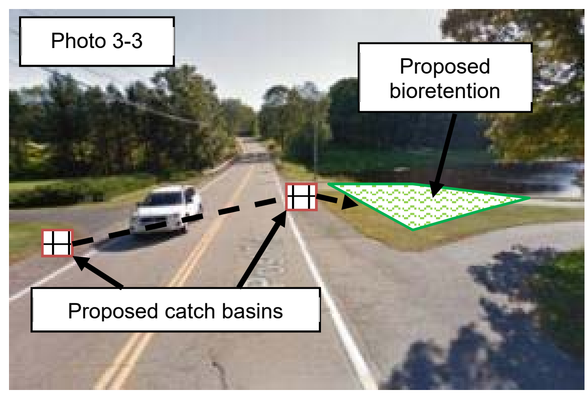
- Capital Costs (Engineering Design and Construction):$50,500 – 73,000
- Annual O/M: $2,750/yr
- 20-year Life Cycle Cost: $116,750

Estimated Nutrient Load Reduction:

- Phosphorus: 0.4 – 0.5 lb P/yr
- Nitrogen: 3.2 – 3.6 lb N/yr
- Cost per lb. of P and N Reduction per Year: $13,000 (P); $1,800 (N)

Priority: Low





Site 4: Greenland Central School, Greenland, NH

Site Summary:

The Greenland Central School located at 70 Post Road (Photo 4-1) has a large parking lot (Photo 4-2) to serve the school and associated administrative buildings. Drainage from the parking area consists of sheet and overland flow to Post Road or to pervious areas.

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).

Working with students at the Greenland Central School, design and install a 400 sq. ft. raingarden demonstration project to educate students on stormwater management and water quality. An example of a raingarden is provided in Photo 4-3. An educational kiosk should also be installed to educate the public.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $3,900 - $5,700
- Annual O/M: $200/yr
- 20-year Life Cycle Cost: $8,800

Estimated Nutrient Load Reduction:

- Phosphorus: 0.2 lb P/yr
- Nitrogen: 1.3 – 1.5 lb N/yr
- Cost per lb. of P and N Reduction per Year: $2,200 (P); $400 (N)

Priority: High

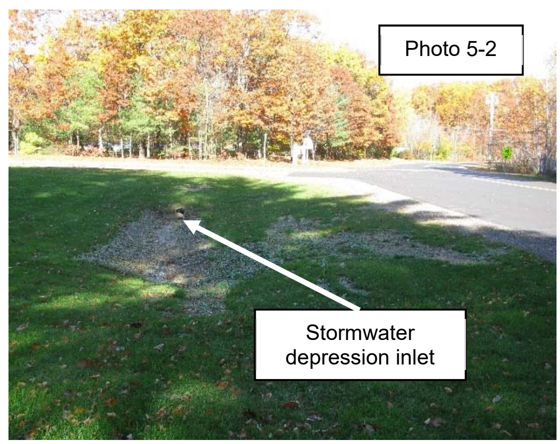
Example of newly planted raingarden with shrub planting scheme (Tuftonboro, NH)

Site 5: Stratham Memorial School, 39 Gifford Farm Road, Stratham, NH

Site Summary:

Stormwater runoff from Griffin Road and a portion of the Stratham Memorial School discharge through a culvert under the school entrance. Stormwater flows from the culvert to a stormwater depression which ultimately discharges under Griffin Farm Road to the wooded area across the street (Photo 5-1).

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).



Proposed Improvements:

Retrofit the existing stormwater depression along Gifford Farm Road to provide water quality treatment. The retrofit could consist of a water quality low flow swale (800 sq. ft.) to treat stormwater runoff and provide infiltration (depending on subsurface soils and depth to groundwater). An educational kiosk could also be installed to educate students and the public.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $26,100 - $37,700
- Annual O/M: $1,400/yr
- 20-year Life Cycle Cost: $59,900

Estimated Nutrient Load Reduction:

- Phosphorus: 0.2 – 0.3 lb P/yr
- Nitrogen: 2.1 – 2.3 lb N/yr
- Cost per lb. of P and N Reduction per Year: $12,200 (P); $400 (N)

Priority: **Low**

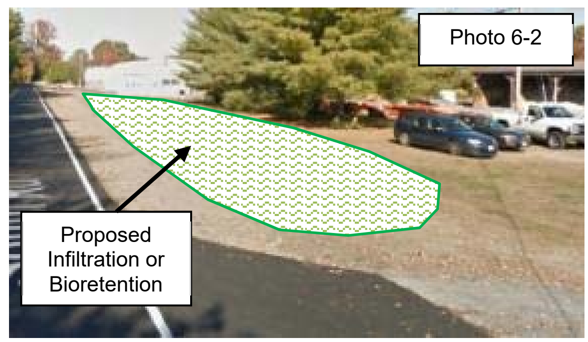
Site 6: NHDOT Facility, 174 South Road, North Hampton, NH

Site Summary:

A NHDOT Facility is located at 174 South Road (Photo 6-1). The facility has a partial paved and partial gravel lot where transportation related materials and equipment are stored. The Winnicut River is located immediately downstream of the property. A well-established forested and vegetated buffer exists along the edge of the lot.

Soils in the vicinity of the site are characterized as disturbed Scitico silt loam, which is a poorly drained HSG C/D soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:



Install an infiltration practice (i.e., 2,800 sq. ft.) infiltrating swale) in the existing grassed island on NHDOT property along the edge of 174 South Road (Photo 6-2), if depth the groundwater and soils are adequate. The area appears to collect stormwater runoff from South Road and diversions could be installed to increase the capture of stormwater to this proposed infiltrating structural BMP. If subsurface soils are not amenable to infiltration, a bioretention facility could be used at this location. The bioretention cell could include either grass vegetation or woody vegetation depending on stakeholder input during the design phase. A catch basin could be used as the diversion and should include a deep sump and hood to provide pre-treatment to minimize operation and maintenance in the infiltration or bioretention cell. Utilities should be confirmed prior to design.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $51,200 – 74,000
- Annual O/M Costs: $2,800/yr
- 20-year Life Cycle Cost: $118,600

Estimated Nutrient Load Reduction:

- Phosphorus: 1.2 – 1.5 lb P/yr
- Nitrogen: 9.5 – 10.5 lb N/yr
- Cost per lb. of P and N Reduction per Year: $4,400 (P); $600 (N)

Priority: **Medium**

Site 7: Grassed Island at Intersection of Post Road and Fern Road (across from 31 Post Road), North Hampton, NH

Site Summary:

Stormwater runoff from impervious road surfaces at the intersection of Fern Road and Post Road drain via overland flow to a grassed island (Photo 7-1). A storm drain culvert leaves the island (Photo 7-2) and discharges into an unnamed tributary to the Winnicut River.

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:

Retrofit existing grassed island with a 600 sq. ft. bioretention cell to capture and treat road runoff prior to discharging into an existing culvert inlet at this grassed island.

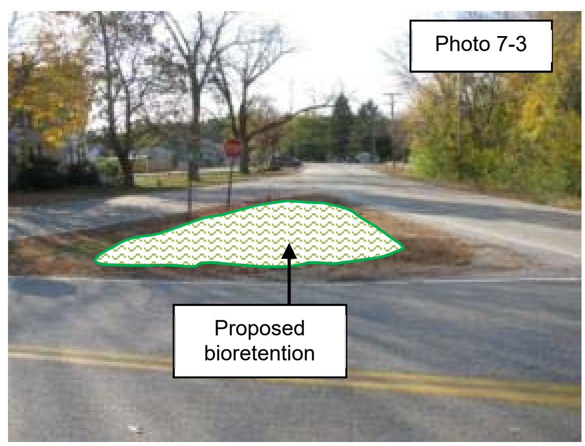
Estimated Costs:

- Capital Costs (Engineering Design and Construction): $18,900 - $27,400
- Annual O/M: $1,050/yr
- 20-year Life Cycle Cost: $44,150

Estimated Nutrient Load Reduction:

- Phosphorus: 0.5 – 0.6 lb P/yr
- Nitrogen: 4.0 – 4.5 lb N/yr
- Cost per lb. of P and N Reduction per Year: $4,100 (P); $600 (N)

Priority: **Medium**



Site 8:
Adjacent to 72 Meadow Fox Road, North Hampton, NH

Site Summary:

Stormwater flows from the Sylvan Road and Meadow Fox Road discharge through a series of catch basins and ultimately to a wooded lot adjacent to 72 Meadow Fox Road (Photo 8-1). Erosion at the outfall was observed during the field reconnaissance (Photo 8-2).

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:

A 3,200 sq. ft. infiltration basin could be installed between the catch basin and the outfall to reduce stormwater volume and discharge rate and reduce erosion at the outlet. In addition, depending on site soils and depth to groundwater, an infiltration basin could provide recharge to the groundwater which supports base flows in the Winnicut River watershed.

Estimated Costs:

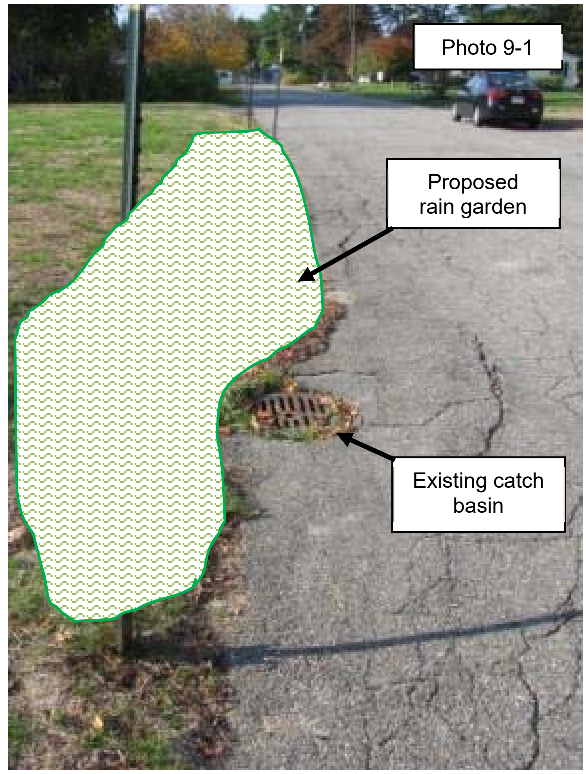
- Capital Costs (Engineering Design and Construction): $121,400 - $175,200
- Annual O/M: $6,050/yr
- 20-year Life Cycle Cost: $269,300

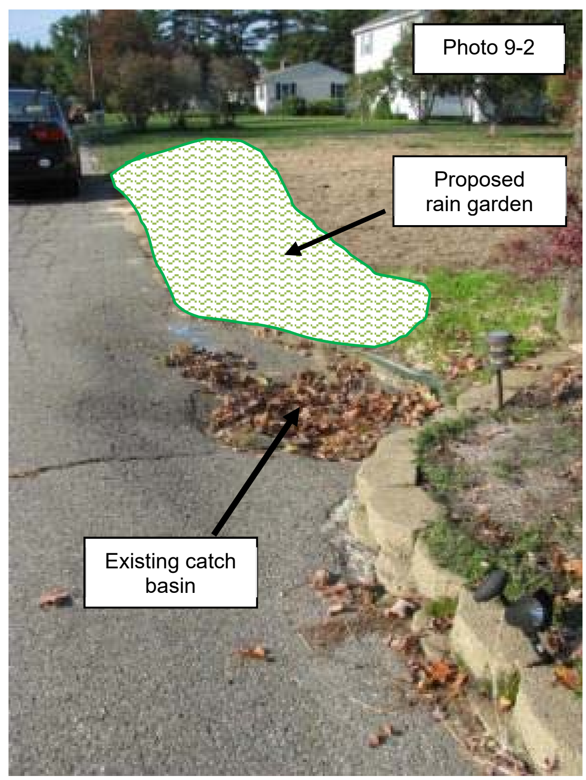
Estimated Nutrient Load Reduction:

- Phosphorus: 5.5 – 6.7 lb P/yr
- Nitrogen: 39.7 – 44.1 lb N/yr
- Cost per lb. of P and N Reduction per Year: $2,300 (P); $400 (N)

Priority: **High**

Sites 9 and 10:
10 and 12 Sylvan Road, North Hampton, NH





Site Summary:

Drainage from Sylvan Road is conveyed via sheet and overland flow to a series of catch basins, prior to discharging untreated stormwater to Site 9.

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:

Install two 100 sq. ft. rain gardens on properties located at 10 (Photo 9-1) and 12 Sylvan Road (Photo 9-2) to provide treatment to property and road runoff prior to discharging into the drain network for the development.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $1,600 - $2,300
- Annual O/M: $100/yr
- 20-year Life Cycle Cost: $3,950

Estimated Nutrient Load Reduction:

- Phosphorus: 0.1 lb P/yr
- Nitrogen: 0.7 – 0.8 lb N/yr
- Cost per lb. of P and N Reduction per Year: $2,000 (P); $300 (N)

Priority: **High**

Site 11: 8 Winterberry Lane, Stratham, NH

Site Summary:

Retrofit the existing dry detention basin to provide water quality treatment within the Winterberry Lane subdivision (Photo 11-1). As currently designed, the detention basin manages the storm volume and peak discharge. The detention basin manages runoff from the impervious areas associated with the development. The basin appears to provide little water quality treatment prior to discharge.

Soils in the vicinity of the site are characterized as Chatfield-Hollis-Canton complex (coarse loamy material), which is a well-drained HSG B soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:

Retrofit the existing dry detention basin (Photo 11-2) with a 1,000 sq. ft. micropool to temporarily store and release the water quality volume. The micropool enhances pollutant removal and prevents resuspension of sediment. In addition, depending on site soil and groundwater levels, the micropool could be designed to infiltrate the water quality volume.

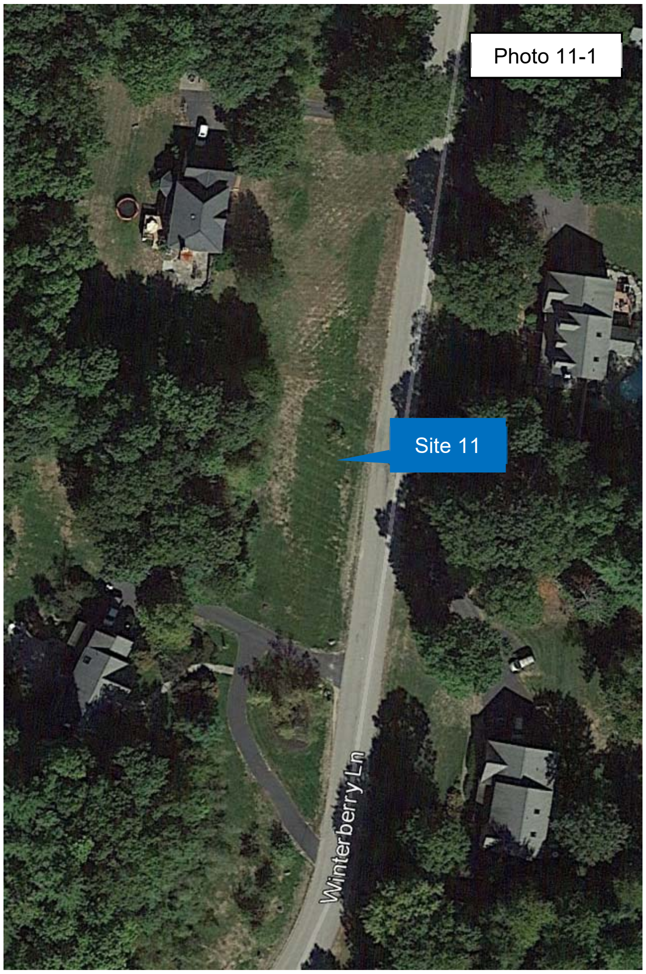
Estimated Costs:

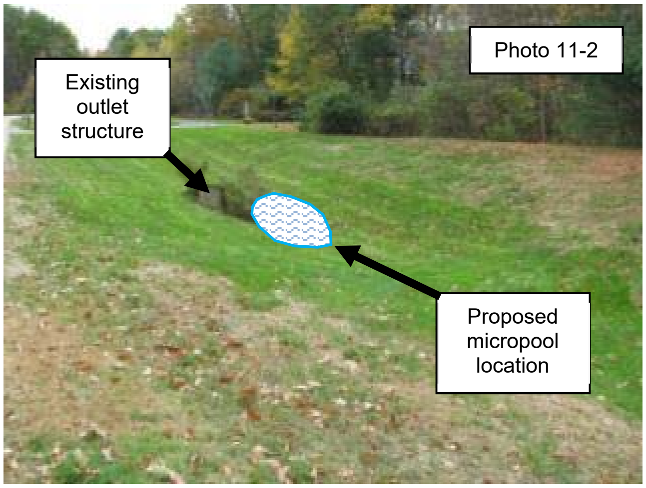
- Capital Costs (Engineering Design and Construction): $21,300 - $30,800
- Annual O/M: $1,150/yr
- 20-year Life Cycle Cost: $49,050

Estimated Nutrient Load Reduction:

- Phosphorus: 0.2 lb P/yr
- Nitrogen: 1.4 – 1.6 lb N/yr
- Cost per lb. of P and N Reduction per Year: $12,300 (P); $1,700 (N)

Priority: Low



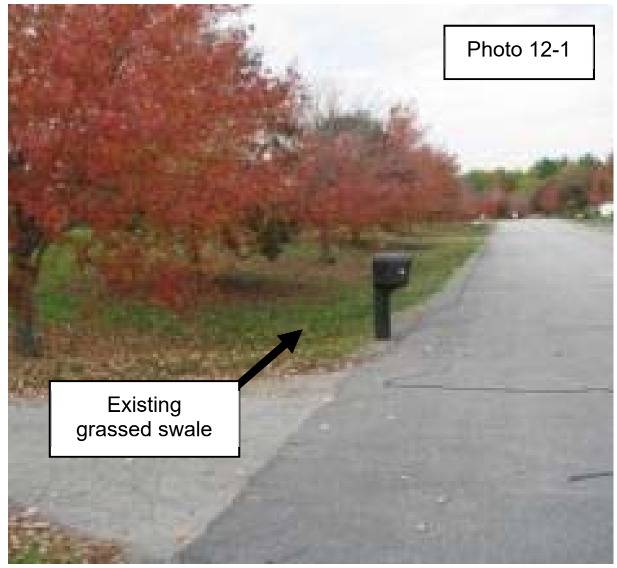


Site 12: 11 and 12 Strawberry Lane, Stratham, NH

Site Summary:

Two existing grassed swales convey runoff from the Strawberry Lane subdivision (Photo 12-1) to an unnamed tributary of the Winnicut River. The swales appeared to be maintained as lawn and appear to primarily function for conveyance.

Soils in the vicinity of the site are characterized as Hoosic gravelly fine sandy loam, which is a well-drained HSG A soil. (https://websoilsurvey.nrcs.usda.gov).



Proposed Improvements:

Retrofit existing grassed swales into treatment swales (400 linear feet of 4 ft. wide water quality swale) (Figure 23). Treatment swales are designed to hold water for a longer period of time to provide higher pollutant removal efficiencies; whereas grassed swales are designed primarily for conveyance. The proposed treatment swales will discharge to the same location as the existing grass swales, to an unnamed tributary of the Winnicut River.

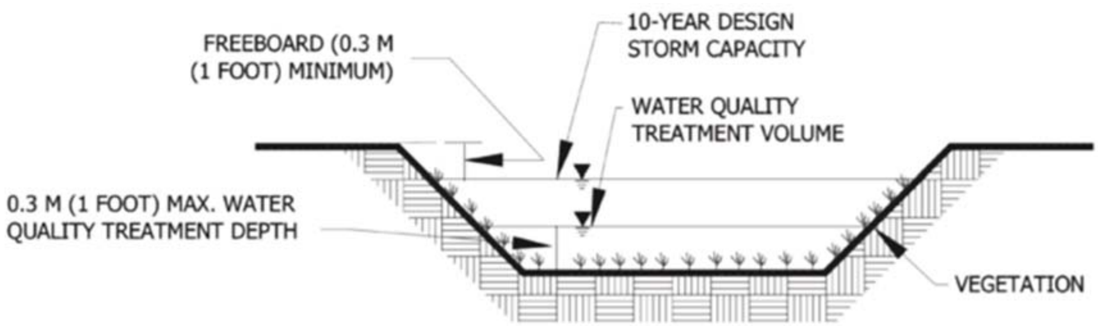


Figure 23. Treatment Swale Cross-Section Detail (Source: NH Stormwater Manual, Volume 2, 2008)

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $20,300 - $29,200
- Annual O/M: $1,100/yr
- 20-year Life Cycle Cost: $46,750

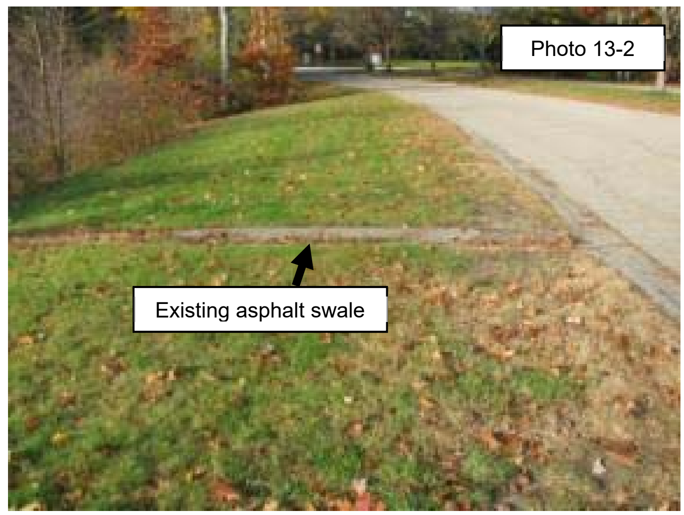
Estimated Nutrient Load Reduction:

- Phosphorus: 0.2 – 0.3 lb P/yr
- Nitrogen: 2.1 – 2.3 lb N/yr
- Cost per lb. of P and N Reduction per Year: $9,500 (P); $1,100 (N)

Priority: **Medium**

Site 13: Domain Drive at Timberland Entrance, Stratham, NH

Site Summary:



Road runoff at the entrance to the Timberland Facility on Domain Drive (Photo 13-1) is collected in a series of asphalt lined swales (Photo 13-2) prior to discharging to an existing flood storage basin. This basin discharges with limited treatment directly to an unnamed tributary of Winnicut River. The basin inlet and outlet are large diameter culverts and the outlet is located in close proximity and directly across from the inlet likely resulting in short circuiting and reduced water quality treatment. There appears to be limited pretreatment for pollutant removal prior to the basin.

Soils in the vicinity of the site are characterized as disturbed Scitico silt loam, which is a poorly drained HSG C/D soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:

Reconstruct existing asphalt swale into a treatment swale (60 linear feet, 4 ft. wide) (see Figure 23), to provide treatment prior to discharge into the flood storage basin. Pre-treatment facilities (e.g., forebays) should be included in the design to pre-treat stormwater runoff and allow for long-term maintenance.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $3,000 - $4,300
- Annual O/M: $150/yr
- 20-year Life Cycle Cost: $6,650

Estimated Nutrient Load Reduction:

- Phosphorus: 0.03 – 0.04 lb P/yr
- Nitrogen: 0.3 – 0.4 lb N/yr
- Cost per lb. of P and N Reduction per Year: $9,500 (P); $1,000 (N)

Priority: **Medium**

Site 14: Cul-de-sac at the end of Marin Way, Stratham, NH

Site Summary:

The existing grassed cul-de-sac at this site collects road runoff and has apparent erosion along the banked road edge. Runoff from this area discharges to a culvert and ultimately to an unnamed stream.

Soils in the vicinity of the site are characterized as Boxford silt loam, which is a moderately well drained soil that is not rated for a HSG. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:

Retrofit the grassed area with a 1,200 sq. ft. bioretention cell which uses the culvert as an overflow structure.

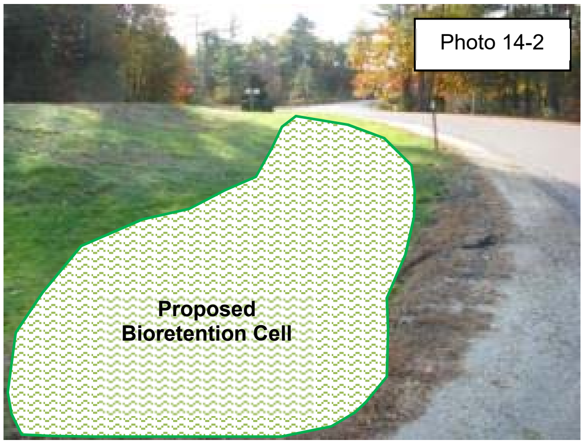
Estimated Costs:

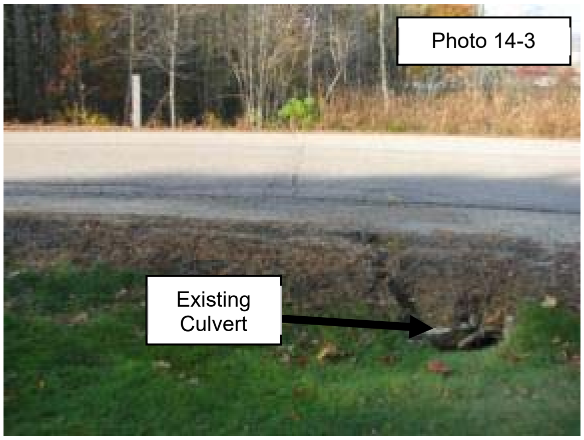
- Capital Costs (Engineering Design and Construction): $37,900 - $54,800
- Annual O/M: $2,050/yr
- 20-year Life Cycle Cost: $87,350

Estimated Nutrient Load Reduction:

- Phosphorus: 1.0 – 1.3 lb P/yr
- Nitrogen: 8.1 – 9.0 lb N/yr
- Cost per lb. of P and N Reduction per Year: $3,900 (P); $600 (N)

Priority: High





Site 15: 8 Marin Way, Stratham, NH

Site Summary:

Existing grassed area collects runoff from adjacent road and parking area which discharges to an existing catch basin before discharging to an on-site stormwater pond (Photo 15-1). The stormwater pond appears to function as a flood control basin and is not intended to provide water quality treatment.

Soils in the vicinity of the site are characterized as Canton fine sandy loam, which is a well-drained HSG B soil. (https://websoilsurvey.nrcs.usda.gov).

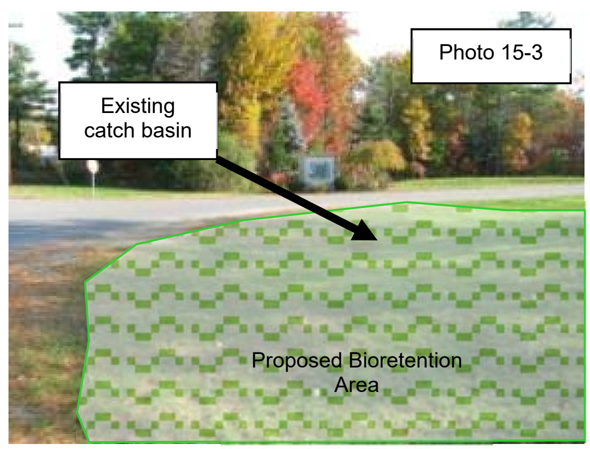
Proposed Improvements:

Install a 1,400 sq. ft. bioretention cell in the existing grassed area adjacent to the catch basin and use the existing catch basin (Photos 15-2 and 15-3) as an overflow structure. The bioretention cell will provide water quality treatment of impervious cover. Forebay features should be included to provide pretreatment prior to flow entering the bioretention cell.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $44,300 - $63,900
- Annual O/M: $2,400/yr
- 20-year Life Cycle Cost: $102,100

Estimated Nutrient Load Reduction:



- Phosphorus: 1.2 – 1.5 lb P/yr
- Nitrogen: 9.4 – 10.5 lb N/yr
- Cost per lb. of P and N Reduction per Year: $3,900 (P); $600 (N)

Priority: **High**

Site 16: Across from 8 Marin Way adjacent to Timberland parking area, Stratham, NH

Site Summary:

Two existing grassed swales, along the tree line (Photo 16-1), collect runoff from Marin Way and the adjacent parking lot, with these flows draining into a nearby flood storage basin.

Soils in the vicinity of the site are characterized as Canton fine sandy loam, which is a well-drained HSG B soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements: Retrofit the existing swales as treatment swales (400 linear ft.) to provide treatment prior to discharge into the flood storage basin. Pre-treatment facilities (e.g., forebays) should be included in the design to pre-treat stormwater runoff and allow for long term maintenance.

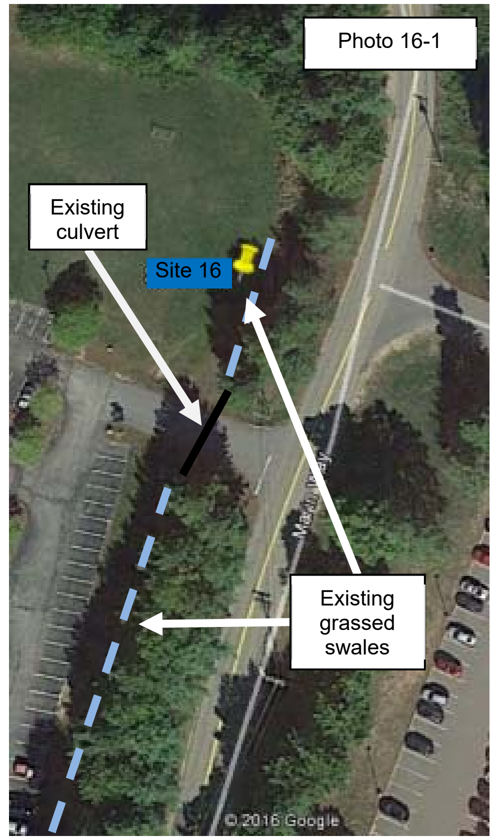
Estimated Costs:

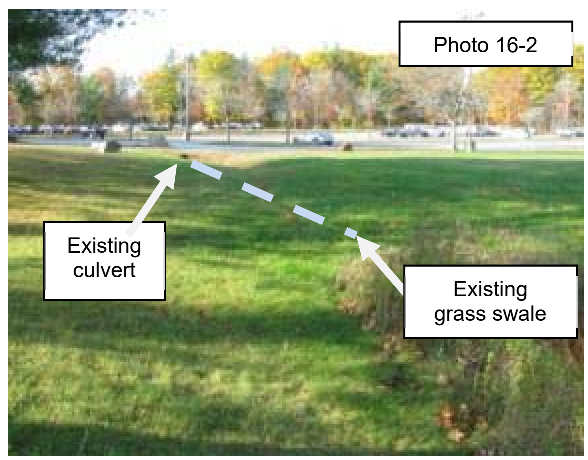
- Capital Costs (Engineering Design and Construction): $20,300 - $29,200
- Annual O/M: $1,100/yr
- 20-year Life Cycle Cost: $46,750

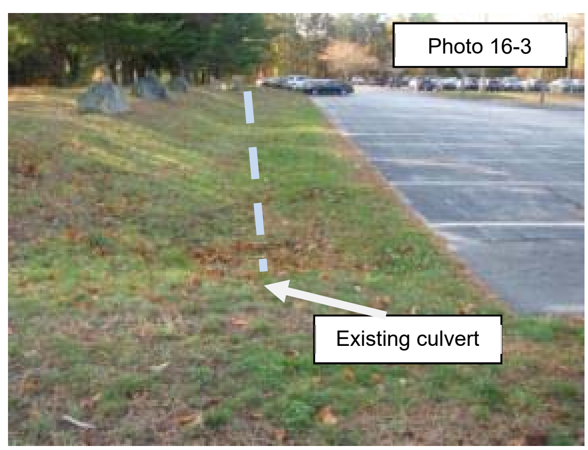
Estimated Nutrient Load Reduction:

- Phosphorus: 0.2 – 0.3 lb P/yr
- Nitrogen: 2.1 – 2.3 lb N/yr
- Cost per lb. of P and N Reduction per Year: $9,500 (P); $1,100 (N)

Priority: **Medium**







Site 17: Timberland Parking Lot, across from 8 Marin Way, Stratham, NH

Site Summary:

A catch basin with an asphalt apron collects runoff from a large parking area for the Timberland company (Photos 17-1 and 17-2). Drainage from the catch basin discharges into a stormwater pond adjacent to outdoor playing fields. The stormwater pond appears to function as a flood control basin and is not intended to provide water quality treatment.

Soils in the vicinity of the site are characterized as Canton fine sandy loam, which is a well-drained HSG B soil. (https://websoilsurvey.nrcs.usda.gov).

Proposed Improvements:

Retrofit the asphalt apron of the catch basin into a 400 sq. ft. bioretention cell while using the catch basin as an overflow structure (Photo 17-3). The bioretention cell with provide groundwater recharge and enhanced water quality treatment. Pre-treatment facilities (e.g., forebays) should be included in the design to pre-treat stormwater runoff and allow for long term maintenance.

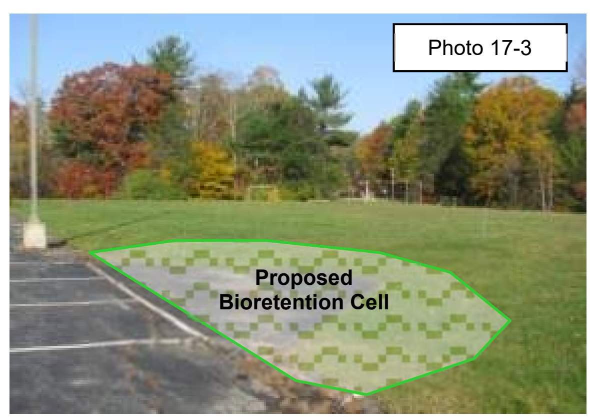
Estimated Costs:

- Capital Costs (Engineering Design and Construction): $12,700 - $18,200
- Annual O/M: $700/yr
- 20-year Life Cycle Cost: $29,450

Estimated Nutrient Load Reduction:

- Phosphorus: 0.3 – 0.4 lb P/yr
- Nitrogen: 2.7 – 3.0 lb N/yr
- Cost per lb. of P and N Reduction per Year: $3,900 (P); $600 (N)

Priority: **Medium**



Site 18: 588 Portsmouth Avenue, Greenland, NH

Site Summary:

A depressed grassed area collects road drainage at the intersection of Portsmouth Avenue and Route 33 (Photo 18-1), prior to discharging into the tidal reach of the Winnicut River. The depressed area appears to function as a limited flood control basin and is not intended to provide water quality treatment.

Soils in the vicinity of the site are characterized as Squamscott fine sandy loam, which is a poorly drained soil that is not rated for a HSG (https://websoilsurvey.nrcs.usda.gov).

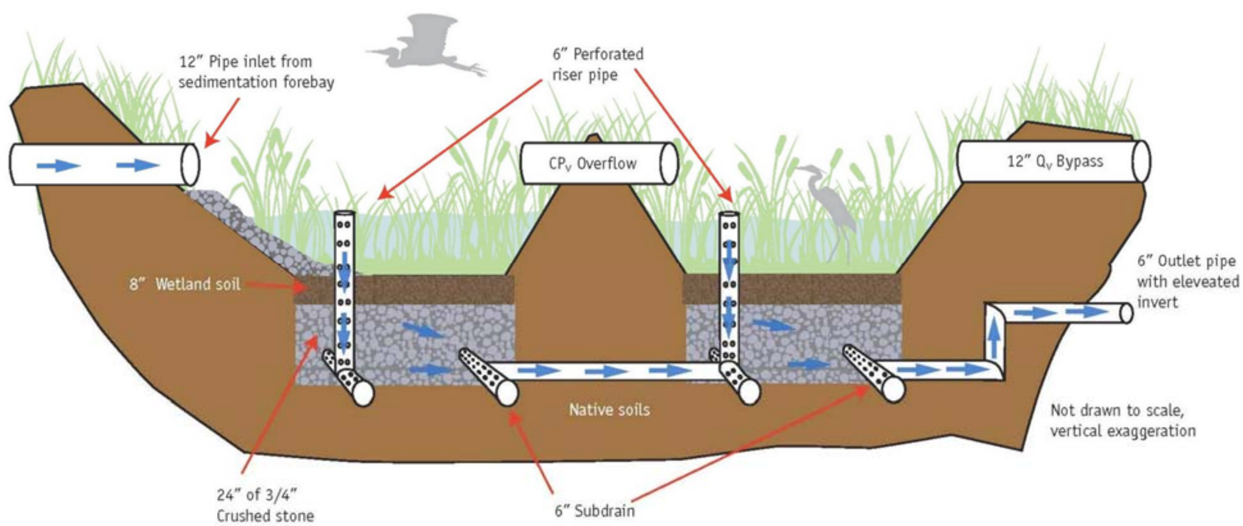


Figure 24. Gravel Wetland Cross-Section Detail (Source: UNH Stormwater Center)

Proposed Improvements:

Retrofit the grassed area with a 10,000 sq. ft. gravel wetland (Figure 24) to provide enhanced water quality treatment prior to discharging to the Winnicut River. The gravel wetland could also provide flood control during larger flows and provide significant water quality treatment during smaller, more frequent storm events.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $252,700 - $365,000
- Annual O/M: $4,600/yr
- 20-year Life Cycle Cost: $400,850

Estimated Nutrient Load Reduction:

- Phosphorus: 8.4 – 10.3 lb P/yr
- Nitrogen: 88 – 98 lb N/yr
- Cost per lb. of P and N Reduction per Year: $2,200 (P); $300 (N)

Priority: High

CULVERT IMPROVEMENT SITES

Priority culvert upgrade opportunities were identified based on a review of an existing culvert inventory and assessments conducted by the Rockingham Planning Commission and The Nature Conservancy (TNC, 2009), and observations during Geosyntec's watershed field reconnaissance.

Upstream side of Winnicut River at Lovering Road culvert

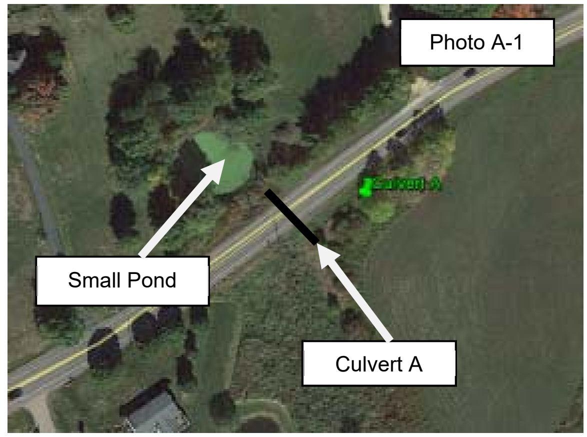
Where applicable, sizing for recommended culvert improvements has been based on estimates of bankfull width and the New Hampshire Code of Administrative Rules Chapter Env-Wt 900 (Stream Crossings). Env-Wt 904.05 states that "*New tier 2 stream crossings, replacement tier 2 stream crossings that do not meet the requirements of Env-Wt 904.07, and new and replacement tier 3 stream crossings shall be designed and constructed: (a) In accordance with the New Hampshire Stream Crossing Guidelines, University of New Hampshire, May 2009…*". For such stream crossings, the NH Stream Crossing Guidelines generally recommends that culverts should be a minimum of 1.2 times the bankfull width plus 2 feet, as stated in the excerpt below:

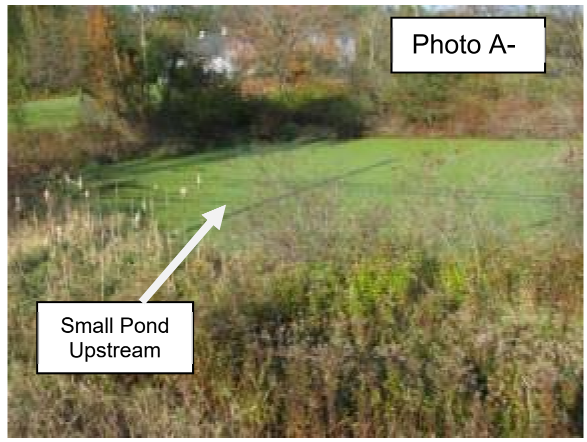
vii. Structure Width *(from New Hampshire Stream Crossing Guidelines, UNH, May 2009)*

The width of a stream crossing structure should be appropriate to provide for the adequate passage of water, sediment, aquatic biota, and organic matter at all flow levels. Because of the high variability of stream channel types in New Hampshire, it is recognized that a single standardized numeric value for the size of crossing structures based on any metric for all streams is unrealistic and may actually lead to long-term erosion or sedimentation problems at the crossings or obstruction of aquatic organism passage, consequences that this guidance document is intended to prevent. A stream crossing structure should be wide enough to accommodate the geomorphic characteristics of a stream without impacting the balance of sediment erosion and deposition that occurs naturally at the site. In all cases, to ensure aquatic organism passage for the long-term, it is critical to avoid channel constriction during typical bankfull flows, as these are the channel forming flows. A numeric standard that has been used to determine the appropriate width of the streambed inside the proposed structure is 1.2 times the bankfull width plus 2 feet (and also see other guidance documents in the "Examples of Other Agency Stream Crossing Guidelines" section at the end of this document, many of which also suggest that a minimum of 1.2 times bankfull width be used as a minimum). Barnard (2003) concluded that culverts that were built to this specification and included a stream simulation design within them (i.e., contained a designed and constructed streambed within the culvert), and had a culvert slope/channel slope ratio <1.25, did create similar fish passage conditions compared to the adjoining channel. The streams in this study were relatively small and steep, likely all Rosgen Type A and B channels, with bankfull channel widths ranging from 6.3 to 15 feet and channel slopes ranging from 2% to 17%, with most greater than 4%, and had been in place for only several years.

Therefore, although this information is useful, it should be used with an understanding of the limitations of the dataset and the conclusions drawn from the analysis. Simply applying this as a numeric standard for all crossings is not recommended given the amount of geomorphic variability in New Hampshire streams and rivers; however, this numeric value may be useful to those designing and constructing crossings and to those involved with reviewing applications for stream crossings.

Culvert A: Adjacent to 93 Exeter Road, North Hampton, NH





Site Summary:

Culvert A consists of a stone box culvert in poor condition, which drains a small pond in the headwaters of the Winnicut River (Photo A-1). The pond was covered in green algae at the time of the field reconnaissance, likely caused by lack of flushing and high nutrient load. Downstream of the culvert is a wetland system which drains directly to the Winnicut River. The upstream end of the culvert appeared to be blocked by a deteriorated headwall and appeared to limit discharge. TNC (2009) identified this crossing (Crossing ID #38) as a minor barrier to fish passage. TNC did not report a bankfull width for this culvert. The inlet of the culvert functions as the outlet of the pond. The culvert outlet appeared to be buried at the time of the reconnaissance and downstream of the culvert is generally characterized as heavy wetland vegetation.

Bankfull width immediately downstream of the culvert was estimated to be 3 feet (1.2 x bankfull width + 2 feet = 5.6 feet).

Proposed Improvements:

Reconnect 0.04 miles of the Winnicut River by replacing the stone box culvert with a reinforced concrete box culvert (assume one 6-foot wide by 3-foot tall box culvert for costing purposes), with an imbedded bottom, restoring full connectivity to the stream and reducing flood risk.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $93,800 – $123,800
- Annual O/M: $800/year
- 20-year Life Cycle Cost: $124,800
- Cost per mile of restored stream connectivity: $3,120,000 (0.04 miles)

Other Factors:

- Fish Passage Improvement: Minor
- Potential to Reduce Flood Risk: Low

Priority: **Low**

Culvert B: Thompson Brook at Winnicut Road, Greenland, NH

Site Summary:

Photo B-1

A 6-foot diameter culvert under Winnicut Road, between Meaghan Way and Spring Hill Road, conveys Thompson Brook to the Winnicut River. The culvert was identified by TNC (2009) (Crossing ID #2) as perched, limiting migration for fish passage, and showed some signs of corrosion and rusting. TNC identified this project as a priority project for future structural improvements to enhance fish passage. Further, grant funding through the NHDES Coastal Resilience Technical Assistance Project was sought by Trout Unlimited, Inc. Great Bay Chapter to replace this culvert with a bridge to provide greater connectivity within the river system.

Bankfull width reported by TNC for this culvert is 10.6 feet (1.2 x bankfull width + 2 feet = 14.7 feet).

Photo B-2

Proposed Improvements:

Reconnect 1.17 miles of Thompson Brook, a tributary of the Winnicut River, by replacing an undersized, perched metal culvert with a reinforced concrete box culvert (assume two 8 ft wide by 4 ft tall box culverts for costing purposes), restoring full connectivity to the stream and reducing flood risk. Species that would benefit from this project include Eastern brook trout, river herring (blueback and alewife), American eel and sea lamprey. The culvert location is only 0.54 miles from the tidal water of the Great Bay estuary, making this a good location to improve infrastructure in a coastal zone, reduce flood risk, and restore impaired hydrologic connectivity and associated stream ecological functions.

Estimated Costs[3]:

- Capital Costs (Engineering Design and Construction): $187,500 - $247,500
- Annual O/M: $1,500/yr
- 20-year Life Cycle Cost: $247,500
- Cost per mile of restored stream connectivity: $212,000

Other Factors:

- Fish Passage Improvement: Moderate
- Potential to Reduce Flood Risk: Moderate

Priority: **Medium**

3 Estimated costs based on the NH Coastal Resilience Technical Assistance Funding Proposal Request (2014).

Culvert C: Between 128 and 132 Exeter Road, North Hampton, NH

Site Summary:

At this location in the headwaters of the Winnicut River, a corrugated metal pipe conveys flows under Exeter Road (Route 111) (Photo C-1). Erosion along the roadside and bank failure was observed at the time of the site reconnaissance, blocking the outlet of the culvert on the downstream side. TNC (2009) identified this culvert (crossing ID #39) as a moderate barrier to fish passage. TNC did not report a bankfull width for this culvert.

Bankfull width immediately downstream of the culvert was estimated to be 8 feet (1.2 x bankfull width + 2 feet = 11.6 feet).


Photo C-1


Photo C-2

Proposed Improvement:

Reconnect 0.05 miles of the Winnicut River by replacing the metal culvert with an open bottom culvert crossing (assume one 12-foot wide by 2-foot tall three-sided culvert for costing purposes), restoring full connectivity to the stream.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $125,000 - $165,000
- Annual O/M: $1,000/year
- 20-year Life Cycle Cost: $165,000
- Cost per mile of restored stream connectivity: $3,300,000 (0.05 miles)

Other Factors:

- Fish Passage Improvement: Moderate
- Potential to Reduce Flood Risk: Low

Priority: Low

Culvert D: Winnicut Pond Dam at Winnicutt Road, Stratham, NH

Site Summary:

Three 20-foot by 10-foot bridge spans convey the Winnicut River under Winnicut Road (Photo D-1) in Stratham. Remnants of the former Winnicut Pond dam remain immediately downstream of Winnicut Road (Photo D-2) are hydraulic restrictions to flow and serve as impediments to fish passage, as identified by TNC (2009) (Crossing ID #12).

Photo D-1


Photo D-2

Proposed Improvement:

Reconnect 4.14 miles of the Winnicut River, by removing the remaining remnants of the former Winnicut Pond dam to restore full connectivity to the river.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $156,300 - $206,300
- Annual O/M: $1,300/year
- 20-year Life Cycle Cost: $207,300
- Cost per mile of restored stream connectivity: $50,000 (4.14 miles)

Other Factors:

- Fish Passage Improvement: Moderate
- Potential to Reduce Flood Risk: Moderate

Priority: High

Culvert E: Willow Brook at Willowbrook Avenue, Greenland, NH

Site Summary:

A 36-inch corrugated metal pipe conveys Willow Brook under Willowbrook Avenue (Photo E-1). The outlet of the pipe is perched, which is typically representative of an undersized culvert, and is restricting the natural width of the channel.

Approximately 2 feet of the pipe at the outlet is deteriorated. TNC (2009) ranked this crossing as a moderate barrier to fish passage (Crossing ID #5).

The bankfull width reported by TNC for this culvert is 10 feet (1.2 x bankfull width + 2 feet = 14 feet).

Proposed Improvements:

Reconnect 0.88 miles upstream of Willow Brook, by replacing the undersized, perched metal culvert with a concrete box culvert (assume one 14-foot wide by 2-foot tall box culvert for costing purposes), restoring full connectivity to the stream and reducing flood risk.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $187,500 - $247,500
- Annual O/M: $ 1,500/year
- 20-year Life Cycle Cost: $247,500
- Cost per mile of restored stream connectivity: $281,300 (0.88 miles)

Other Factors:

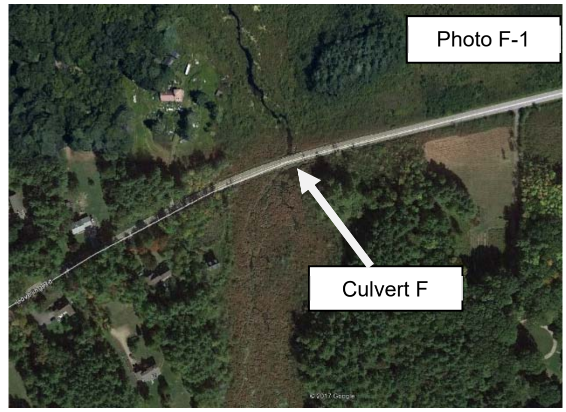
- Fish Passage Improvement: Moderate
- Potential to Reduce Flood Risk: Moderate

Priority: **Medium**

Culvert F: Lovering Road, North Hampton, NH

Site Summary:

Culvert A consists of an existing 2-foot diameter corrugated metal pipe which conveys the Winnicut River (Photo F-1) under Lovering Road. The culvert connects two large wetland floodplain areas of the Winnicut River. TNC (2009) identified this crossing (Crossing ID #20) as a moderate barrier to fish passage.



The bankfull width dimension for this site was not reported by TNC. Geosyntec estimated the bankfull width downstream of the culvert to be 15 feet (1.2 x bankfull width + 2 feet = 20 feet).

Proposed Improvements:

Reconnect 1.06 miles of the Winnicut River by replacing the existing 2 ft. dia. culvert with multiple box culvert spans (assume two 10-foot wide by 2-foot tall box culverts for costing purposes), restoring hydraulic capacity and full connectivity to the stream and reducing flood risk.

Estimated Costs:

- Capital Costs (Engineering Design and Construction): $281,300 - $371,300
- Annual O/M: $2,300/yr
- 20-year Life Cycle Cost: $372,300
- Cost per mile of restored stream connectivity: $351,200 (1.06 miles)

Other Factors:

- Fish Passage Improvement: Moderate
- Potential to Reduce Flood Risk: Moderate

Priority: Medium

4.1.2 Linear Optimization Model for Structural Stormwater Management Practices

Section 4.1.1 presents recommended structural stormwater BMPs and culvert upgrades based on opportunities identified during field investigations and practical considerations such as available space, site drainage patterns, constructability, proximity and connectivity to the Winnicut River and its tributaries, etc. In addition to this practical, field-based approach to BMP siting, the project Team also prepared a linear optimization (LO) model to identify cost-effective structural stormwater BMPs and associated land use combinations to achieve the greatest nitrogen and phosphorus load reduction to meet target water quality goals. To identify these practices, a LO model developed as part of the Water Integration for the Squamscott Exeter River Watershed project (WISE; Geosyntec, 2015) was used. The results of the LO model investigation are presented as Appendix B.

The LO model demonstrates that a 20 percent reduction in annual stormwater nitrogen load could be achieved through the implementation of structural stormwater BMPs, at an estimated cost of $651 per pound of nitrogen removal. To achieve this nitrogen load reduction, treatment of nearly all of the imperious cover within the watershed would be required, which is likely to be impracticable. Achieving a 25 percent annual load reduction in phosphorus would require the treatment of 96 percent of the total impervious cover in the watershed, at an estimated cost of $16,720 per pound of phosphorus removal. Additional strategies, such as non-structural stormwater BMPs (e.g., public education programs, land conservation, fertilizer reduction, street sweeping, catch basin maintenance, improved buffer zones, regulatory tools such as municipal ordinances, etc.), are likely to be important components of a comprehensive approach to reducing nutrient loads in the watershed to meet water quality targets. Recommended nonstructural practices for the Winnicut River Watershed are presented in Section 4.3.

4.2 WASTEWATER MANAGEMENT

This section provides an assessment and recommendations related to priority areas for potential subsurface wastewater management upgrades and wastewater alternative treatment strategies within the Winnicut River Watershed. As described in Section 3.4, the watershed's population is served entirely by on-site septic systems, which represents approximately 50% of the contributing load of nitrogen load to the watershed. Estimated phosphorus load from septic systems was not calculated as part of this project.

4.2.1 Background

Subsurface wastewater disposal septic systems provide a cost effective and efficient way of disposing of domestic waste. However, even properly designed, installed, and maintained septic systems provide inadequate treatment for nitrogen and phosphorus. Treatment of wastewater effluent is essential for the protection of ground and surface waters.

A conventional septic system includes a septic tank that collects the effluent from a home or business and a drainfield that disperses the effluent to the subsurface (Figure 25). Septic systems receive effluent from a variety of sources including toilet flushing, sink and shower drains, and washing machines. The treatment between the septic tank and the edge of the drainfield is attributed to ammonia volatilization and settling of nitrogen solids in the septic tank.

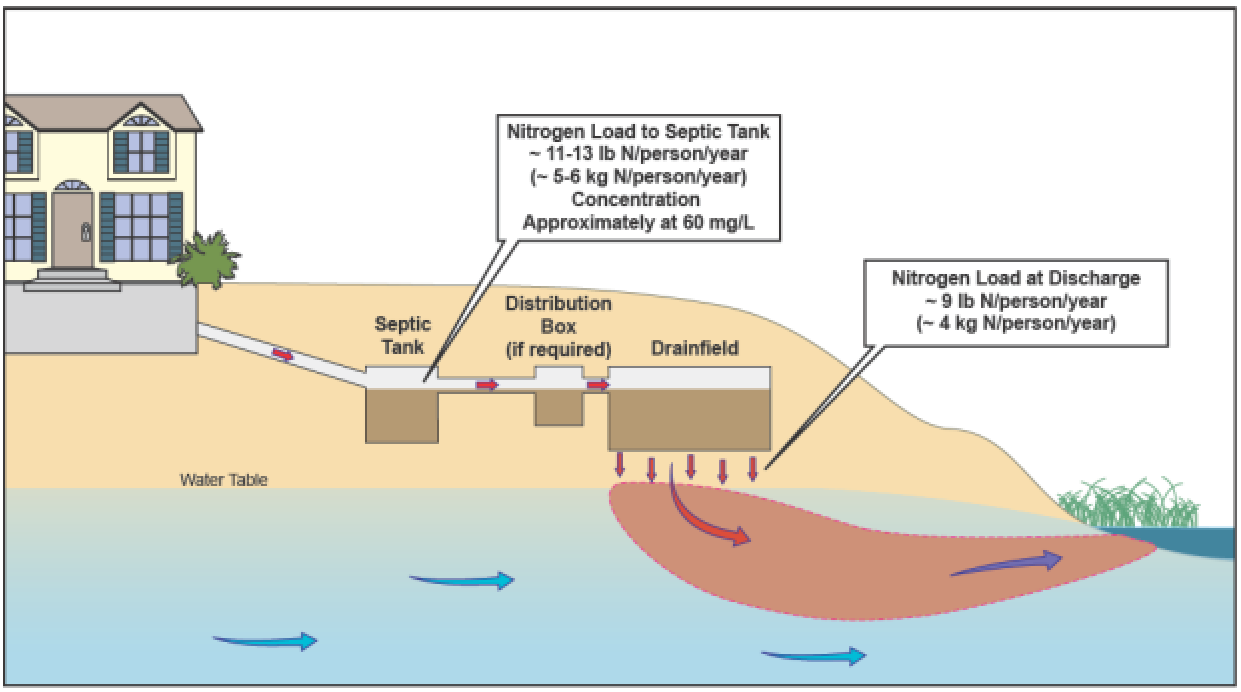
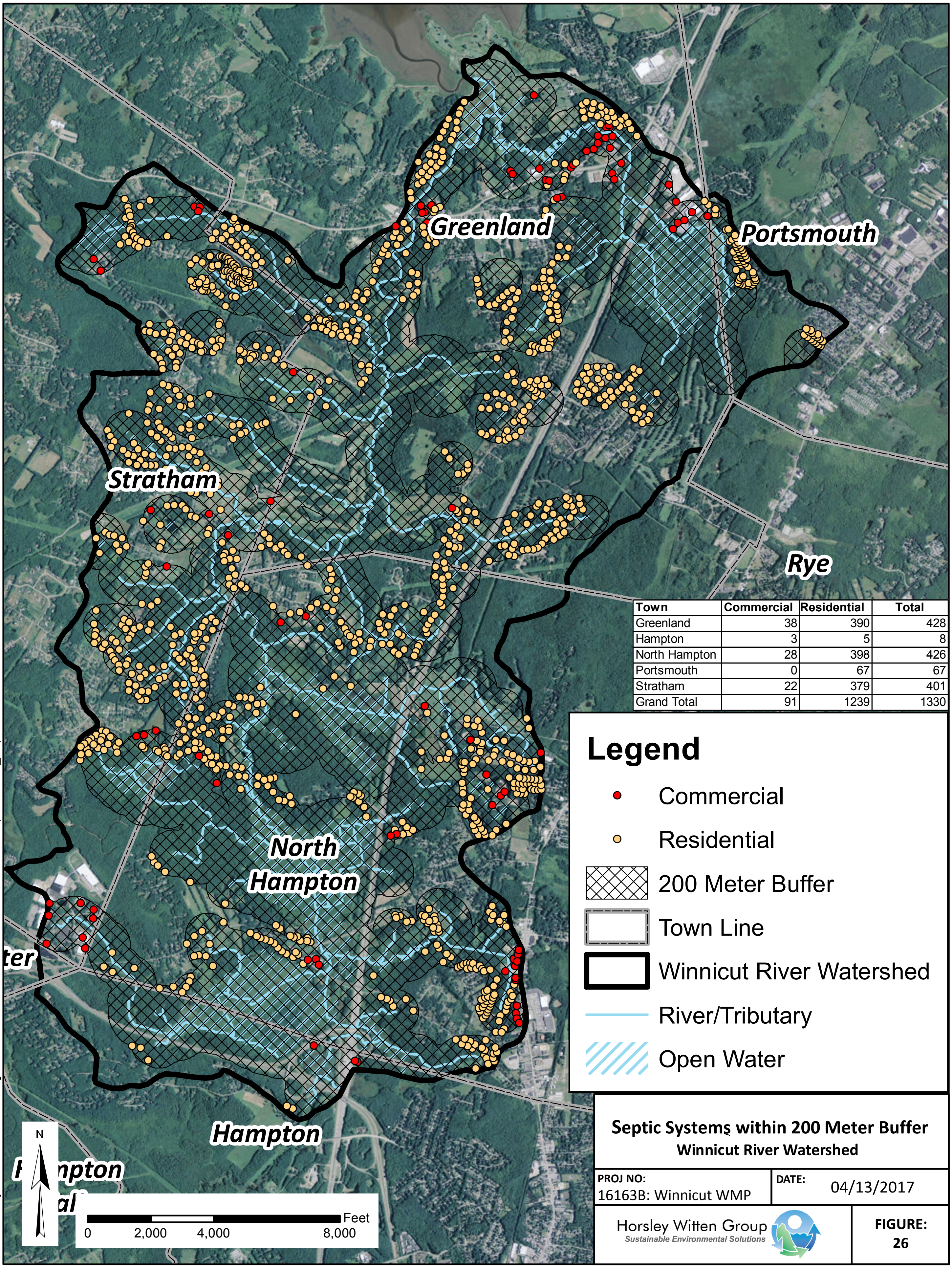


Figure 25. Conventional Onsite Septic System (Source: EPA, 2013)

Once effluent has discharged from the drainfield, the GBNNPSS assumes 60% of this load actually reaches the receiving water through groundwater transport for systems within 200 meters (640 feet) of an estuary and 26% of the load for systems outside the 200-meter buffer. The remaining load that does not reach water bodies is assumed to be lost to attenuation through denitrification in anaerobic saturated soils, at the groundwater-surface water interface, through plant uptake, or in the lower-order streams before reaching the simulated river reach (EPA, 2010).

Figure 26 depicts parcels within 200 meters of the Winnicut River and its tributaries with septic systems. The dots do not represent the actual location of the septic system on the parcel.



Town	Commercial	Residential	Total
Greenland	38	390	428
Hampton	3	5	8
North Hampton	28	398	426
Portsmouth	0	67	67
Stratham	22	379	401
Grand Total	91	1239	1330

Septic Systems within 200 Meter Buffer
Winnicut River Watershed

PROJ NO: 16163B: Winnicut WMP

DATE: 04/13/2017

Horsley Witten Group
Sustainable Environmental Solutions

FIGURE: 26

TAH H:\Projects\2016\16163 Wright-Pierce\16163B Winnicut River WBP\GIS\Maps\170327_Septic GW.mxd

4.2.2 Alternative Treatment Systems

Alternative systems are typically upgraded from traditional septic systems by adding a component that reduces nitrogen concentrations from the effluent before it is discharged to the ground. They are installed at an individual home, or cluster of homes, and usually cost more to operate and maintain than a traditional septic system. The increased O/M costs are due to power needs for the system (e.g., pumps, aerators), required water quality sampling, and other elements that are not needed for a traditional onsite system.

Advanced Onsite Treatment

Alternative treatment components can be added to a conventional system, often between the septic tank and the drainfield, to provide advanced treatment of nitrogen (Figure 27). Most of these systems can reduce nitrogen effluent concentrations and associated loads from conventional systems by approximately 50% relative to the 9 lbs N/person/yr loading rate (EPA, 2013). Many alternative systems provide a treated effluent with a total nitrogen concentration of approximately 20 mg/L or a load reduction of 4 lbs N/person/yr. Some systems have a combination of treatment components that can treat to a final concentration of 10 mg/L (EPA, 2010b; Rich, 2005) resulting in even greater load reductions. Table 29 summarizes the nitrogen load reductions available through advanced treatment.

An advanced treatment system refers to a system that includes a septic tank, an aeration system, and a recirculation system in the septic tank. Some systems may also have an additional component for advanced denitrification.

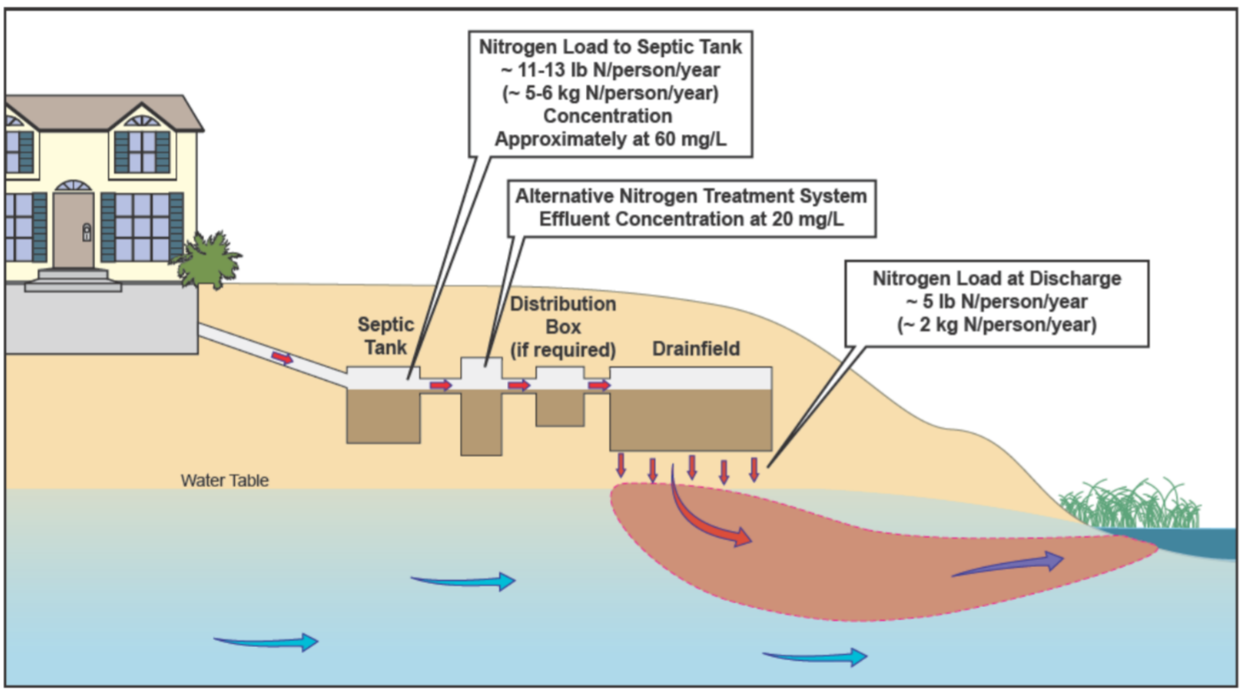


Figure 27. Alternative Onsite System with Nitrogen Treatment (Source: EPA, 2013)

Table 29. Examples of Nitrogen Load Reductions Achievable Through Advanced Treatment (Source: EPA, 2013)

Type of System	Nitrogen Discharge[1] Concentration (mg/L)	Load Reduction Provided	Nitrogen Reduction (lb per person/yr)	Treatment Cost for Upgrading System
Conventional System	39	0%	0	-
Advanced Treatment[2]	20	49%	4	$4,000 - $10,000
Advanced Treatment with Denitrification[3]	10	74%	7	$10,000 - $15,000

[1] This is the concentration of wastewater effluent as it enters the drainfield.

[2] "Advanced treatment system" refers to a system that includes a septic tank, an aeration system, and a recirculation system into the septic tank, or equivalent.

[3] "Advanced treatment system with denitrification" refers to a septic tank, an aeration system, and an anoxic environment separate from the septic tank, or equivalent.

Alternative Toilets

Composting toilet systems offer a different solution to wastewater by eliminating much of the liquid waste. On a basic level, composting toilets retain solid and liquid excrement in a contained unit that facilitates the natural breakdown of material, or composting. Whether done completely within the eco-toilet unit, or transported and completed offsite, this process results in 'finished' compost free of pathogens and disease, with the potential to serve as a soil amendment. There are many different types of composting systems that range in cost, size, and maintenance requirements.

The types of composting toilets include large bin, batch composting, self-contained, urine diversion, and hybrid composting toilets. According to the Cape Cod Eco-Toilet Center, reported N removal rates for composting toilets range from 70 to 88% (EPA, 2013). Assuming a 70% N removal, upgrading a household to composting toilets would result in a 10 lb N reduction for a single property.

The cost of upgrading a residential property to alternative toilets varies greatly and is based on a number of factors including: number of bathrooms, extent of remodeling work required, greywater management (i.e., hand and dish washing, showers, laundry, etc.), permitting requirements, and the type of system. Table 30 summarizes the potential cost range of these factors.

Table 30. Estimated Alternative Toilet Cost (Source: EPA, 2013)

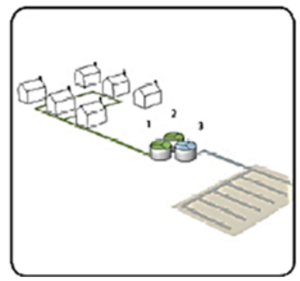
Cost Element	Cost Range
Materials	$2,000 - $10,000
Design and Installation	$2,000 - $4,000
Greywater Management	$1,000 - $5,000
Permitting	$1,000 - $3,000

Connection to Wastewater Treatment Facilities

Towns within the Winnicut River Watershed could consider the possibility and cost to connect to a local wastewater treatment facility. The City of Portsmouth (i.e., Pease Plant) and Towns of Exeter and Newington are the closest communities with wastewater treatment facilities (WWTF). USEPA and NHDES currently require a nitrogen effluent limit of 3 mg/L for WWTF permits to communities that discharge to the Great Bay and its tributaries. Since the Pease, Newington and Exeter plants are located outside of the Winnicut River Watershed, connection would result in an equivalent concentration of 0 mg/L from effluent discharge to the watershed for each residential or commercial unit connected.

Connection to area treatment plants typically requires substantial capital and infrastructure and most often is more expensive that advanced onsite treatment. For a preliminary study completed for the City of Rochester, New Hampshire, the average cost per household to connect to the local sewer system was between $20,000 and $45,000, which does not include the additional operation and maintenance costs per year around $800-$1,200 per household.

Cluster or Neighborhood Treatment Systems



Cluster or shared systems provide an opportunity for cost savings in both the construction and operation of the system. Building and operating one larger system is often less expensive than operating many small individual systems unless the homes using the system are far apart and the costs to connect them by sewer are high. Cluster systems also provide an opportunity to offset nitrogen discharges from other systems where upgrades are less feasible.

While cluster systems can be easily implemented for new development, retrofitting an existing area to a cluster system may pose both financial and engineering challenges. For example, the cost of piping the wastewater from each individual property to the cluster system could be a significant expense, particularly in low density areas. The construction of new collection systems and the availability of land for cluster systems also pose engineering challenges. Dense areas or areas with historical failures might provide the most opportunities for retrofitting conventional systems to cluster systems.

The cost for implementation of a cluster system to meet the current state-of-the-practice is approximately $35,000 to $48,000 per property served (HW, 2015; CCC, 2013) and $52,000 per property served if optimized for nitrogen (CCC, 2013). These cost estimates are highly dependent on site-specific factors.

Permeable Reactive Barriers

Permeable reactive barriers (PRBs; Figure 28) treat nitrogen contained in shallow groundwater. They can be installed downgradient of a single drainfield, or downgradient of a cluster of closely spaced onsite systems. They can be installed as long, narrow trenches perpendicular to groundwater flow in an area that will capture nitrogen rich groundwater.

PRBs constructed downgradient from septic systems have shown significant nitrogen removal in the groundwater flowing through the barrier (HW, 2015). Those barriers are typically constructed using wood chips, because the wood provides a carbon source promoting denitrification. Nitrogen removal rates as high as 90% have been observed for these types of structures, but their siting and construction can be a challenge, because their effectiveness depends on the amount of contaminant traveling through the barrier (HW, 2015). If sited too high, or too low, the barrier may not intercept the plume, or may only treat part of it. In addition, after some time, the carbon source needs to be replaced, and the trench needs to be reopened.

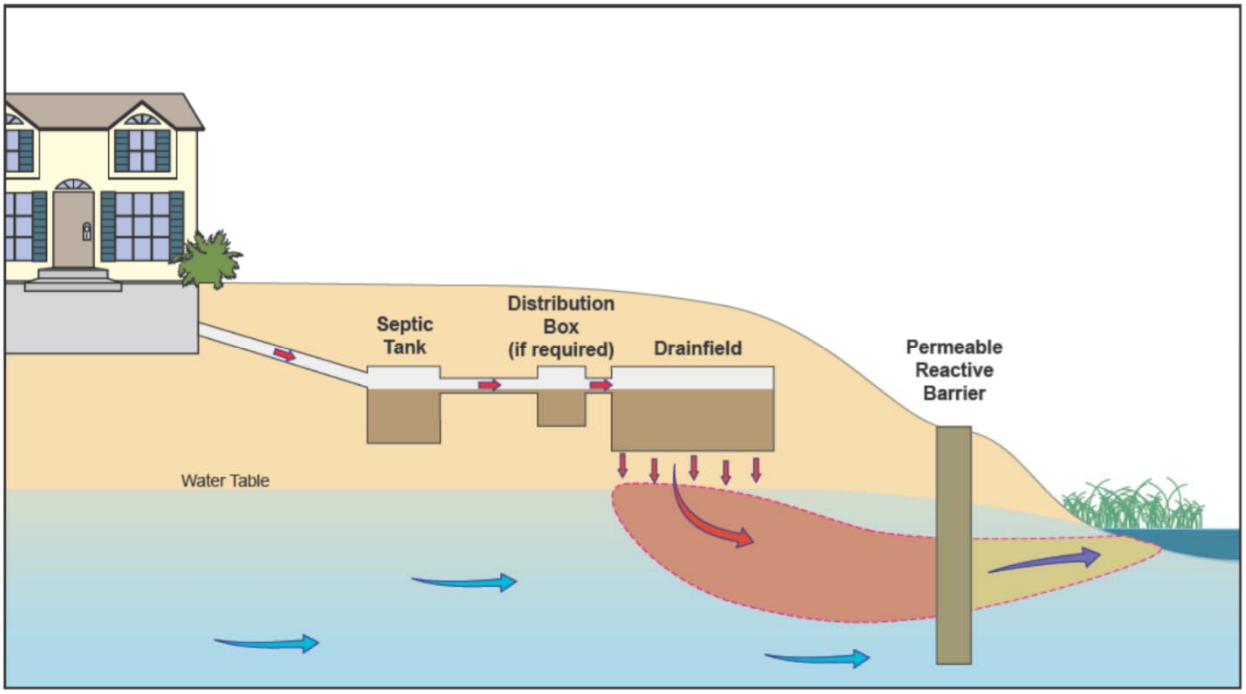


Figure 28. Permeable Reactive Barrier Schematic (Source: EPA, 2013)

Alternatively, a series of injection wells could be drilled in a line perpendicular to the direction of flow. A carbon source would be injected into each well, and the wells would be spaced such that the carbon source injected in each well overlaps with the carbon source injected in the two neighboring wells. This would create a horizontal carbon-based barrier capable of denitrification and nitrogen removal.

Construction of PRB's costs on average $1,000 - $1,500 per linear foot (HW, 2015). For a site located in Brewster, MA the cost to install a total of 150 to 250 wells for a horizontal PRB along 3,000 to 5,000 feet would vary from $2.5 to $3.5 million, which does not include the cost for injection of the carbon source (HW, 2015).

Irrigation Wells to Capture N and Return it for Beneficial Use

Most golf course and outdoor irrigation systems withdraw water from wells, some of which may have non-negligible concentrations of nitrogen and other nutrients. However, when groundwater high in nutrient content, potentially caused by septic systems, is pumped from an irrigation well and used to irrigate a golf course, or any vegetated area, the nutrients are taken out of the groundwater and potentially absorbed by the irrigated turf. This practice is sometimes called fertigation (i.e., a combination of fertilization and irrigation) (HW, 2015).

It is unclear how irrigation needs are provided on golf courses or outdoor fields within the Winnicut River Watershed. If irrigation is from private wells and not surface ponds, irrigation with groundwater could reduce the need for application of surface fertilizer on these fields and reduce nitrogen loading to groundwater.

Experimental Sawdust Leachfields

Over the past five years researchers in various locations around the country have been investigating whether incorporating sawdust in various configurations while constructing a leachfield can enhance nitrogen removal by supplying this carbon source to support denitrification (BCDHE, 2016b). Three different designs of leachfields that incorporate sawdust have been placed at the Massachusetts Alternative Septic System Test Center (MASSTC). One of the designs being tested, places a saw dust barrier in a horizontal configuration directly below the leaching drainfield to intercept nitrate-laden discharge (Figure 29).

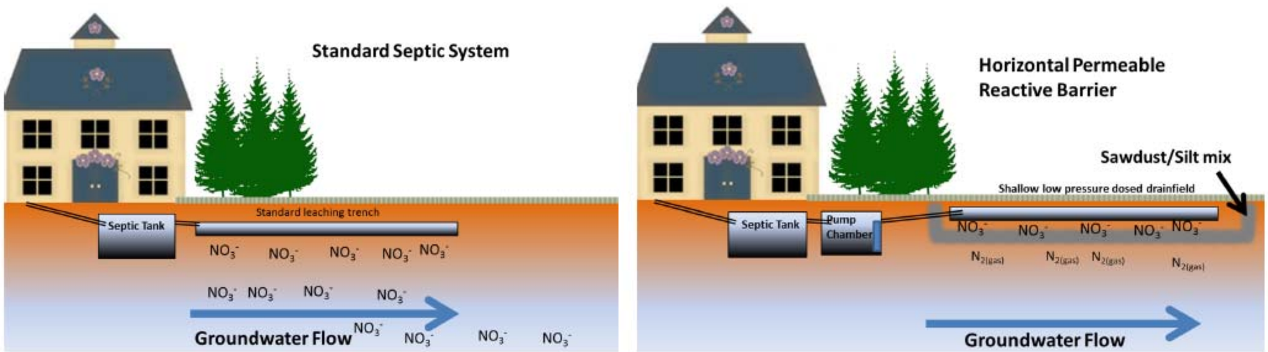


Figure 29. Conventional septic system compared to sawdust PRB (Source: BCDHE, 2016)

This alternative system has an added pump chamber and a timed-dose electric panel. In these alternative systems, the leachfield is placed less than 8 inches below the surface, compared to greater than 5 feet for conventional systems. The leachfield is underlain by sand (60%) and sawdust (40%). When compared to conventional septic systems, the sawdust systems cost an additional $6,000, not including installation. Studies out of the Florida State Department of Health found that these types of systems removed greater than 85% of the nitrate (BCDHE, 2016a).

4.2.3 Recommendations for Wastewater Management

The Winnicut River Watershed population is served entirely by on-site septic systems, which represents approximately 50% of the contributing load of nitrogen load to the watershed. Management strategies associated with septic systems are anticipated to be an important part of the long-term approach to achieving and maintaining the nitrogen concentration goals established as part of this watershed plan. Using the management strategies described above, reduction of the nitrogen load from septic systems is achievable. Septic systems are currently regulated at the State level and alternative treatment practices have not yet been approved. Therefore, regulatory changes at the State level are needed to allow for implementation of alternative treatment practices.

Establishment of a tiered approach to addressing onsite subsurface wastewater systems is recommended, based on system proximity to a waterbody. The GBNNPSS indicates that systems within 200 meters of a waterbody deliver a greater load than those located beyond this distance. Therefore, a distance of 200 meters (640 feet), is recommended as a starting distance for prioritization and implementation of alternative treatment strategies.

The municipalities that comprise the Winnicut River Watershed should consider establishing town regulations which enable and encourage the installation of alternative wastewater treatment systems based on system proximity to a waterbody (i.e., 200 meters) for new development, redevelopment and replacement of failed system.

4.3 NON-STRUCTURAL BEST MANAGEMENT PRACTICES

Unlike structural BMPs, non-structural BMPs do not involve construction of site-specific infrastructure and generally focus on reducing pollutant loads through the following:

1. **Public Information and Education:** Changing behavior and land use patterns through efforts to inform, educate, and engage the public on issues related to protection of water quality and aquatic habitat.
2. **Land Conservation:** Reducing pollutants at the source through natural systems, such as land conservation and protection of sensitive land areas through purchase, easements, etc.;
3. **Regulatory Tools:** Changing behavior and land use patterns through regulation (e.g., state laws, municipal ordinances)
4. **Institutional Practices and Programs:** Reducing pollutant loads through improved institutional practices such as enhanced street sweeping, catch basin cleaning, leaf litter pickup programs, etc.

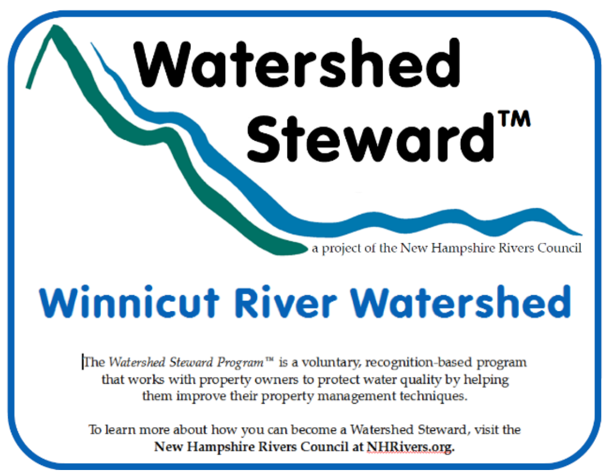
The pollutant load reductions associated with non-structural measures are generally more difficult to estimate than those for structural BMPs. Strategies for reducing pollutant loads in the Winnicut River Watershed through non-structural BMPs are discussed in the sections below.

4.3.1 Public Information and Education

Public information and education (I/E) efforts associated with the Winnicut River WRMP are expected to include the following:

Watershed Steward™ Program

The Watershed Steward™ Program (WSP) will be implemented by the NHRC and its partners to engage local residents and others in watershed outreach and protection activities. The WSP was originally funded in part by NHDES in 1998 and piloted in the Lake Winnipesaukee watershed.



Example Watershed Steward Sign

The WSP provides local groups with a promotional brochure, Water Quality Report Card, a companion booklet, and signage. The WSP includes conducting a homeowner visit to assess land management practices and other personal choices that affect water quality, such as lawn/landscaping fertilizer use, septic system maintenance, and disposal of household chemicals. Recommendations and resources are provided to homeowners. When WSP criteria are met, the homeowner is certified as a Watershed Steward™ for a five-year period and signage is provided. Watershed Stewards are encouraged to work with friends and neighbors to increase program participation in the watershed.

Working with the Conservation Law Foundation, the NHRC has secured funding to re-pilot the WSP effort in the Winnicut watershed and the larger Great Bay watershed, and then to make the program available throughout New Hampshire. NHRC anticipates that WSP outreach activities and homeowner property assessments in the Winnicut watershed will be conducted annually between April and October during the

5-year WRMP planning period. After the initial homeowner visits and WSP certification process, NHRC will provide follow-up communications and visits with homeowners to provide technical assistance on land management practices and promote participation in related programs (e.g., septic system management programs). This process is expected to continue throughout the five-year WRMP planning period.

Workshop: Low Impact Development for Homeowners

The NHRC, in partnership with Geosyntec, will provide a public education workshop geared towards property owners in the Winnicut River watershed. This workshop will focus on the concepts of LID and ways that homeowners can implement LID on their properties, such as raingardens, bioretention, rain barrels, infiltration trenches, low- or no-phosphorus fertilizers, etc. Specific topics addressed during the workshop will include:

- Stormwater and LID concepts
- Why LID? Case study of benefits and costs
- LID Practices (including step-by step instruction on how to design and build a residential raingarden)
- Recommended native plantings
- Tools for estimating cost and pollutant load reductions
- Construction Do’s and Don’ts

Example Residential Raingarden

Municipal Department of Public Works Meetings

The NHRC and its project partners will conduct meetings with the DPWs of the three primary watershed towns (Greenland, North Hampton, and Stratham). These three towns collectively comprise approximately 93% of the land area in the Winnicut River Watershed.

These meetings with DPW staff (and staff of other relevant municipal departments) will be held to discuss each town’s capital improvement plan, other funding opportunities, and strategies for coordinating (e.g., project prioritization, timing, etc.) to implement the recommendations of this WRMP. This series of meetings will allow project resources to focus specifically on setting the stage for plan implementation.

New Hampshire Department of Transportation Meetings

The NHRC and its project partners will attend NHDOT Natural Resource Agency Coordination Meetings to discuss the implementation of the Winnicut WRMP and related projects that involve NHDOT jurisdiction. In advance of these meetings (held monthly in Concord), NHRC will request that the relevant projects are included on the meeting agenda and will prepare materials for advance distribution to the meeting group. These meetings will promote coordination among project proponents, NHDOT, and other state agencies, in the interest of developing support and momentum for plan implementation. As needed, NHRC will also coordinate and meet with NHDOT District 6 staff regarding routine repairs, maintenance, and smaller-scale projects.

4.3.2 Land Conservation

Land conservation efforts can include strategies to protect and limit future development of high sensitive parcels through purchase, donations, conservation easements, deed restrictions, and other real estate legal agreements.

As presented in Section 3.7.3, developed land is projected to increase from 34 percent of the watershed in 2010 to 44 percent in 2040. Under the traditional zoning scenario presented in Section 3.7.4, this increase in development is project to increase the watershed's phosphorus load by 158 lbs/year and nitrogen load by 1,265 lbs/year. Efforts to protect land from future development can contribute to the long-term water quality goals established in this WRMP by reducing these projected load increases associated with land development.

Although the process of prioritizing specific parcels for land conservation is beyond the scope of this WRMP project, there are a variety of resources and that can used as a starting point to pursue, continue, and update such efforts in the future, as summarized below. Using these resources as the basis for developing a land conservation plan that is specific to the Winnicut River Watershed is recommended. This effort should include coordination via planning summit (or series of meetings) with SELT, GBRPP, state and local agency staff, and other local conservation groups to prioritize land conservation goals and target parcels.

- **Land Conservation Plan for New Hampshire's Coastal Watersheds** *(The Nature Conservancy, et al. 2006).* https://www.epa.gov/sites/production/files/2015-09/documents/piscataqua_land_conservation_plan.pdf

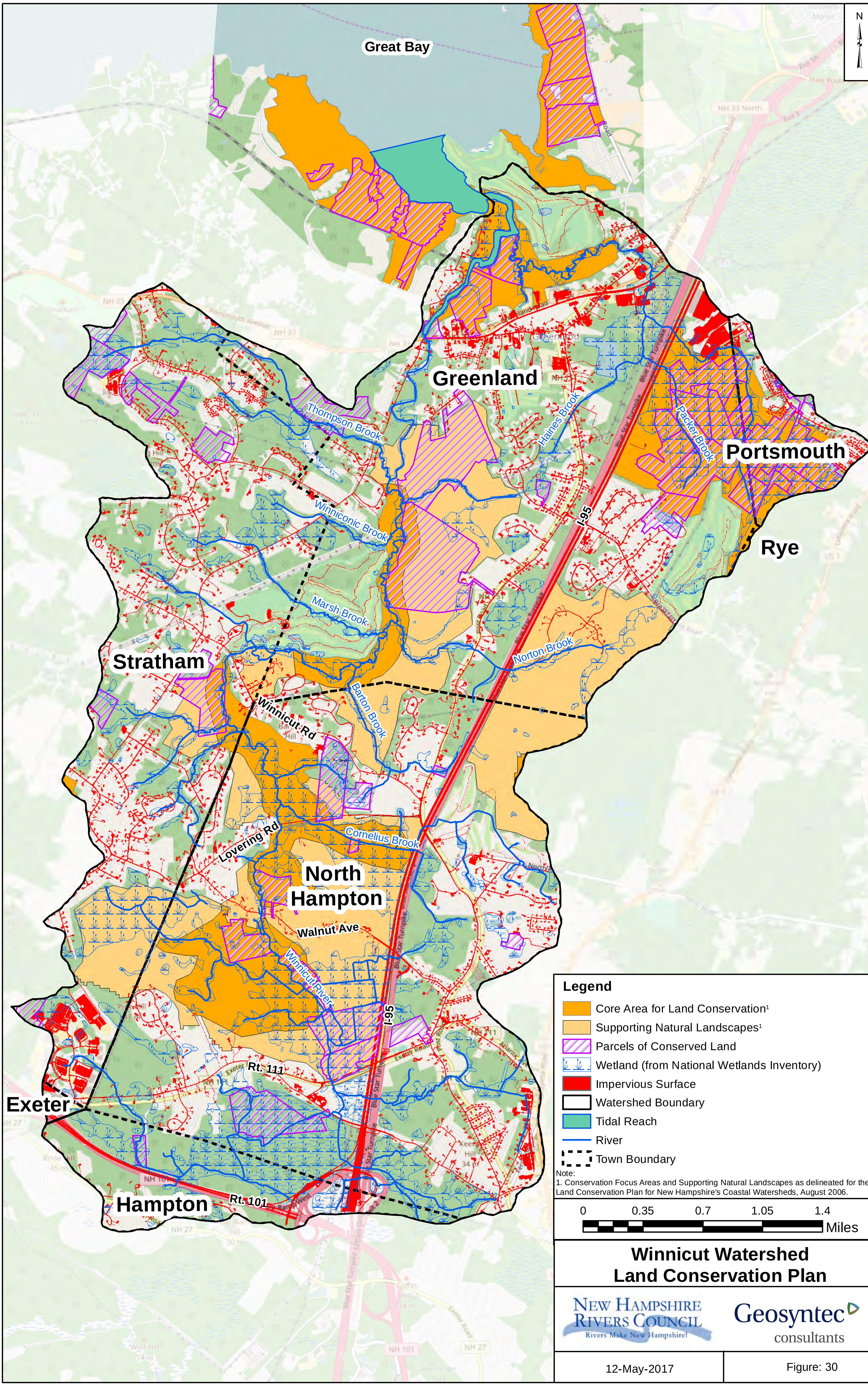
  This report identifies Conservation Focus Areas (CFAs) for New Hampshire's coastal watersheds, including Core Areas for land conservation and associated Supporting Natural Landscapes. As described in the report, CFAs were determined to be "*of exceptional significance for the protection of living resources and water quality in the coastal watersheds*" and generally are located "*where multiple important natural resource features co-occur to an extent that is significant from a whole-watershed perspective*".

  CFAs comprise 32% (3,551 acres) of the 11,151-acre Winnicut River Watershed (14% Core Area and 18% Supporting Natural Landscapes), as depicted in Figure 30. Over half of this area (52%, 1,865 acres) is currently protected from future development either by wetland regulations or as conservation land. Although these protections have limits (e.g., some wetland impacts are allowable with appropriate mitigation), they provide a reasonable screening criteria for a preliminary assessment of remaining "developable" land. Existing roads, buildings, and other impervious cover (IC) comprise an estimated 31.4 acres (<1%) of the Conservation Focus Areas. The remaining CFA lands that are not protected as wetlands or conservation land comprise 15% (1,655 acres) of the watershed, as presented in Figure 30 and Table 31. These areas, 90% of which are in North Hampton and Greenland, provide a starting point for additional analysis to determine remaining developable parcels (i.e., areas that could be further developed, sub-divided, or otherwise built-out under existing zoning and subdivision regulations).

Table 31. Winnicut River Watershed - Conservation Focus Areas[1]

Town	Core Area (ac)	Supporting Natural Landscapes (ac)	Total CFA (ac)	Wetlands and Conservation Land (CL) in CFA (ac)	Impervious Cover in CFA (ac)	Total CFA *minus* Wetlands, CL and IC (ac)
Greenland	755.1	790.0	1545.1	846.7	7.8	690.6
North Hampton	572.2	943.1	1515.3	698.2	21.2	795.9
Stratham	54.1	256.4	310.5	168.6	2.0	139.8
Exeter	0.0	0.0	0.0	0.0	0.0	0.0
Portsmouth	177.9	0.0	177.9	151.5	0.4	26.0
Rye	2.6	0.0	2.6	0.1	0.0	2.4
Hampton	0.0	0.0	0.0	0.0	0.0	0.0
Totals	**1561.9**	**1989.5**	**3551.4**	**1865.2**	**31.4**	**1654.8**

[1] Conservation Focus Areas from Land Conservation Plan for New Hampshire's Coastal Watersheds *(The Nature Conservancy, et al. 2006)*


N
Great Bay
Greenland
Portsmouth
Rye
Stratham
North Hampton
Exeter
Hampton
Thompson Brook
Winniconic Brook
Marsh Brook
Haines Brook
Packer Brook
Norton Brook
Barton Brook
Cornelius Brook
Winnicut River
Winnicut Rd
Lovering Rd
Walnut Ave
Rt. 111
Rt. 101
I-95
Legend
Core Area for Land Conservation[1]
Supporting Natural Landscapes[1]
Parcels of Conserved Land
Wetland (from National Wetlands Inventory)
Impervious Surface
Watershed Boundary
Tidal Reach
River
Town Boundary
Note:
1. Conservation Focus Areas and Supporting Natural Landscapes as delineated for the Land Conservation Plan for New Hampshire's Coastal Watersheds, August 2006.
0
0.35
0.7
1.05
1.4
Miles
Winnicut Watershed
Land Conservation Plan
New Hampshire Rivers Council
Rivers Make New Hampshire!
Geosyntec
consultants
12-May-2017
Figure: 30

- ***New Hampshire Coastal and Estuarine Land Conservation Protection Plan*** *(NHDES, et al.).* https://www.des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-06-43.pdf

  This report identifies priority New Hampshire coastal and estuarine areas with significant ecological, conservation, recreation, historical, or aesthetic values. The plan uses two separate processes to identify target areas for conservation, one for ecological and conservation values and one for recreation, historical, or aesthetic values. The primary building block for this report is the 2006 *Land Conservation Plan for New Hampshire's Coastal Watersheds* described above. The Conservation Focus Areas identified in that plan (as shown in Figure 30) were an important consideration when selecting projects to submit for funding through the national Coastal and Estuarine Land Conservation Program (CELCP) competition.

  Ecological Project Areas: The following areas within the Winnicut River Watershed were identified as (1)unprotected core areas eligible for CELCP funds under the ecological value criteria, and (2) Supporting Natural Landscape areas. (*Note: The areas listed below include both unprotected lands and protected lands*.)

Core Area	Acreage
Lower Winnicut River	229.0
Middle Winnicut River	163.9
Upper Winnicut River	289.6
Winnicut River/Cornelius Brook	329.4
Total Area:	**1011.9**

Supporting Natural Landscapes	Acreage
Middle Winnicut River	614.0
Upper Winnicut River and Winnicut River/Cornelius Brook	920.1
Total Area:	**1534.1**

- ***Great Bay Resource Protection Partnership***: The GBRPP is a collaboration of conservation organizations in the New Hampshire coastal region which promotes land conservation and stewardship. The Partnership works to build consensus among local, regional, state, and federal partners in establishing land conservation priorities and stewardship programs. More detailed information about the Partnership's organizations, land conservation planning efforts, and land stewardship can be found at http://www.greatbaypartnership.org.

- ***Southeast Land Trust of New Hampshire:*** SELT is nonprofit land conservation organization serving 52 communities in southeastern New Hampshire. SELT's focus is on proactively protecting the conservation focus areas described above, with an emphasis on farmland and water resources. Information on SELT's current land conservation efforts and related resources can be found at: http://seltnh.org/

4.3.3 Regulatory Tools

Local ordinances can provide effective protection against nonpoint source pollution. This section provides examples of model ordinances that can be used to regulate and improve the quality of stormwater runoff from developed areas, and a summary of the status of local stormwater regulations in the Winnicut River Watershed.

Zoning

Zoning ordinances are used to specify and regulate land use activities that are permitted in each section of a town, as well as the allowable density of development. Zoning typically applies only to future site development and redevelopment, and does apply to existing land uses. Table 32 provides a list of example zoning ordinances that may be used to protect water resources.

Table 32. Examples of Zoning Ordinances to Protect Water Resources

Example Ordinance	Web Link
Model Stormwater Standards For Coastal Watershed Communities (Southeast Watershed Alliance, 2012, et al.)	www.des.nh.gov/repp/documents/stormwater-ord.pdf
Innovative Land Use and Planning Ordinances (NHDES et, al.)	www.des.nh.gov/repp/innovative_land_use.htm
Watershed Protection Overlay District (Cobbetts Pond and Canobie Lake, Windham, NH; see page 61)	www.windhamnh.gov/sites/default/files/PDF/Ordinances/Zoning/ORDZNG_ZoningOrdinance.pdf
Aquifer Protection: Stratham, NH Aquifer Protection District Ordinance (see page 137)	www.stormwatercenter.net/Model%20Ordinances/Source_Water_Protection/Aquifer%20district%20ordinance.htm
Model Groundwater Protection Ordinance (NHDES/NHOEP)	www.des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-06-41.pdf
Subsurface Wastewater Disposal Regulations (Meredith, NH)	http://www.meredithnh.org/sites/meredithnh/files/uploads/septic_regs_.pdf
New Hampshire Model Floodplain Ordinances (NHOEP)	www.nh.gov/oep/planning/programs/fmp/regulations.htm
Coastal Floodplain Management Model Bylaw (Woods Hole Sea Grant Program, et al.)	www.floods.org/ace-files/documentlibrary/State_Local%20Resources%20and%20Tools/Best%20Practices/Sea_Grant_Coastal_Floodplain_Bylaw_Model_12_14_09.pdf
Impervious Surface Zoning Bylaw (Based on Town of Mashpee, MA zoning bylaw)	www.mass.gov/eea/agencies/massdep/water/drinking/sample-impervious-surface-zoning-bylaw.html
Open Space Design / Natural Resource Protection Zoning Bylaw (MA Smart Growth/Smart Energy Toolkit)	www.mass.gov/envir/smart_growth_toolkit/bylaws/model-osd-nrpz-zoning-final.pdf
Additional Related Resources	
Limiting Impervious Surface Cover and Protecting Water Resources through Better Site Design and Planning (Rockingham Planning Commission)	http://scholars.unh.edu/cgi/viewcontent.cgi?article=1198&context=prep
Innovative Land Use Planning Techniques: A Handbook For Sustainable Development (NHDES, et al.)	www.des.nh.gov/repp/documents/ilupt_complete_handbook.pdf
Massachusetts Citizen Planner Training Collaborative	http://masscptc.org/documents/publications.html

Table 32 includes the *Model Stormwater Standards for Coastal Watershed Communities,* developed in 2012 by the Southeast Watershed Alliance (SWA) in cooperation with the UNH Stormwater Center and Rockingham Planning Commission. These model stormwater standards were developed to help guide the development stormwater standards for New Hampshire coastal communities.

A summary of the status (as of May 2017) of efforts to adopt these standards in the three primary towns that comprise the Winnicut River Watershed (North Hampton, Greenland, and Stratham) is as follows:

Greenland

Between August 2015 and October 2016, the Town of Greenland worked with the RPC on a stormwater management regulation update. Funding for this effort was from a Piscataqua Region Environmental Planning Assessment (PREPA) grant.

Status: On May 18, 2017, the Greenland planning consultant (Mark Fougere of Fougere Planning and Development, Inc.) confirmed that draft stormwater regulations had been completed and were pending review by the Planning Board. Mr. Fougere stated that a vote by the Planning Board on the proposed regulations is anticipated in June 2017.

North Hampton

Between September 2015 and September 2016, the Town of North Hampton worked with the RPC on a PREPA grant-funded effort to develop to develop stormwater management regulations based on the 2012 model stormwater standards developed by SWA.

Status: On May 18, 2017, the North Hampton Planning Board voted to incorporate the model stormwater regulations into the town's Site Plan Review Regulations. The adopted regulations are very similar to the SWA 2012 model stormwater standards.

Stratham

Between August 2015 and December 2015, the Town of Stratham worked on a PREPA grant-funded effort to adopt model stormwater regulations and a variety of other regulations and ordinances to improve water resource protection.

Status: The 2015-2016 PREPA Grant Final Report states "Whereas a*t the start of the project there was a willingness to revise stormwater and wetland regulations, after the demonstrated stakeholder concern, the Selectmen instructed the town staff not to proceed on the stormwater regulation revisions in the absence of a current need."*

SWA is currently (as of June 2017) updating the 2012 model stormwater standards. Continued municipal efforts to develop and adopt stormwater regulations based on the latest SWA model are recommended. Table 33 summarizes several key sections of the new SWA draft standards and a comparison to current regulations in Greenland, North Hampton, and Stratham. This table is provided only to allow for a quick overview and comparison. For more detailed information, see the following documents in their entirety:

- Greenland Zoning Ordinance; Subdivision Regulations: https://www.greenland-nh.com/planning-board
- North Hampton Site Plan Review Regulations: http://www.northhampton-nh.gov/planning-zoning-department/pages/ordinances-regulations-and-fees
- Stratham Zoning Ordinance; Subdivision Regulations: http://www.strathamnh.gov/town-administration/pages/town-ordinances
- Southeast Watershed Alliance Post Construction Stormwater Management Standards (Draft 2017 Standards, *pending availability*): http://swa.thirstproductions.com/southeast-watershed-alliance-home/southeast-watershed-alliance-important-links/

Table 33. Comparison of Selected SWA Draft 2017 Post-Construction Stormwater Standards to Current Town Stormwater Regulations

	Has Town Adopted Stormwater Regulations?	Minimum Thresholds for Applicability	Exemption Threshold	Treatment of Runoff from Impervious Surfaces (IC)	LID Design Requirements	Post-Development Peak Runoff Standards
Draft 2017 Post-Construction Stormwater Standards (SWA)	**N/A**	Any development or redevelopment subject to Site Plan Review that disturbs **more than 5,000 square feet** or disturbs more than **2,500 square feet** within 100 feet of a surface water body.	For disturbances **< 5,000 square feet**, Town may grant an exemption if total site impervious cover created does not exceed **1,000 square feet** (*Note: must meet performance standards*)	Runoff from IC shall be treated to achieve **≥ 80%** TSS removal and **≥ 60%** removal of both total nitrogen and total phosphorus	LID design strategies **must be used to the maximum extent practicable** to reduce runoff volumes, protect water quality, and maintain predevelopment site hydrology.	Control post-development peak runoff rate to not exceed pre-development runoff. Drainage calculations shall compare pre- and post-development stormwater runoff rates and volumes for the **1-inch rainstorm and 2-year, 10-year, 25-year, and 50-year 24-hour storm events**.
North Hampton	**YES** Updated Site Plan Review Regulations based on 2012 SWA Model (adopted May 2017)	Standards apply to all projects requiring Planning Board review and approval under Section V.A. of Site Plan Review Regulations	Planning Board may grant a waiver for projects that: disturb **< *15,000* square feet**; create **< *5,000* square feet** of new impervious surface; and do not disturb land within 100 feet of a surface water or wetland. (*Note: must meet performance standards*)	Runoff from IC shall be treated to achieve **≥ 80%** TSS removal and **≥ 50%** removal of both total nitrogen and total phosphorus	LID design **must be used to the maximum extent practicable** to reduce stormwater runoff volume for new development and redevelopment. Applicants must document why LID strategies are not appropriate if not used to manage stormwater.	Measures shall be taken to control the post-development peak rate runoff so that it does not exceed pre-development runoff for the **2-year, 10-year and 25-year, 24-hour storm events**.
Greenland	**PENDING** Draft regulations pending Planning Board review, vote anticipated in June 2017. (*Information in columns to the right based on the draft regulations*)	Any new development that disturbs **more than 5,000 square feet** or redevelopment that disturbs more than **10,000 square feet**.	For disturbances **< 5,000 square feet**	No numeric performance standard. Within Aquifer Protection District, runoff from IC "*shall be recharged on the site, and diverted toward areas covered with vegetation for surface infiltration to the extent possible*."	Wetland Protection Ordinance goal to "*require use of best management practices and* ***LID in and adjacent to wetland areas***."	Measures shall be taken to control post-development runoff so that it does not exceed pre-development runoff for the **2-year, 10-year, and 25-year, 24-hour storm event.** (Subdivision Regulations, Design Standards)
Stratham	**NO** Selectmen instructed town staff not to proceed with regulation revisions "in the absence of a current need".	No relevant standard	No relevant standard	No numeric performance standard. Within Aquifer Protection District, IC shall not exceed 20%. To the extent feasible, runoff from IC shall be recharged on-site.	Implementation of LID techniques is **strongly encouraged**. (Zoning Ordinance)	Measures shall be taken to control post-development runoff so that it does not exceed pre-development runoff for the **2-year, 10-year, and 25-year, 24-hour storm event.** (Subdivision Regulations, Addendum C)

Lawn Fertilizer Reduction Regulations and Programs

Landscaping fertilizers can be a significant source of phosphorus and nitrogen from areas of residential development and other areas where turf grass lawns are maintained (e.g., golf courses, office parks, schools, sports fields, etc.). The towns that comprise the Winnicut River Watershed could develop municipal landscaping fertilizer ordinances to reduce the use of fertilizers or restrict the use of fertilizer in sensitive areas. There are numerous successful regulations that limit the use fertilizer on lawns, including statewide programs in Maine and Minnesota and county programs in Dane County (WI), Muskegon County (MI), and Ottawa County (MI). Several New England examples include:

- 2016 zoning regulations adopted by Exeter, NH. These regulations incorporated fertilizer prohibition zones into the town's Shoreland Protection District and Aquifer Protection District, with these zones varying from 150-300 feet depending on the water body. http://exeternh.gov/sites/default/files/fileattachments/building/page/13081/2016_final.pdf
- Town of Orleans, MA *Fertilizer Nitrogen and Phosphorus Control Bylaw* http://ecode360.com/28460572.

In addition to using regulatory tools, public education programs can also play an important role in curbing nutrient loads from landscaping fertilizers. Fertilizers are often over-applied in areas where soils naturally have adequate nutrient content to support landscaping needs. Education and outreach efforts such as the Watershed Steward Program described in Section 4.3.1 are recommended as part of the long-term approach to reducing this source of pollutants.

New Hampshire Rivers Management and Protection Program (RMPP)

The NHDES RMPP protects and provides a planning framework for rivers that receive state status as a **Designated River** for their outstanding natural and cultural resources, pursuant to New Hampshire RSA 483. The process for nominating a river to become Designated River is detailed in A Guide to River Nominations (NHDES, May 2015) and summarized below.

Submitting a nomination for the Winnicut River and attaining Designated River status is recommended as important step to achieving the long-term goals of this WRMP. The sponsoring organization for this effort could be the NHRC or a regional organization such as the Rockingham Planning Commission.

Nominating a river requires an individual or organization to submit a River Nomination that presents the river's values and characteristics. The nomination must include documentation of support for designation from local municipal officials and riverfront community residents. If approved by NHDES, the nomination must then receive approval from the NH General Court and signature from the Governor, at which point RSA 483 is amended to include the river for protection under the RMPP.

Upon designation, a Local River Management Advisory Committee (LAC) is formed to develop and implement a River Management Plan (RMP) that provides ongoing regional coordination of activities affecting the river. NHDES assists with development and implementation of the RMP and enforces regulations concerning the quality and quantity of flow in protected river segments.

4.3.4 *Institutional Practices and Programs*

Several institutional practices and programs that could be implemented in the Winnicut River Watershed to reduce pollutant loading are summarized below.

Catch Basin Cleaning

Catch basin cleaning is an infrastructure maintenance practice that can used to reduce pollutant discharge to receiving waters. Frequent clean-out can retain the volume in the catch basin sump available for capture of suspended sediments and treatment of stormwater flows. At a minimum, catch basins should be cleaned once or twice per year. Increasing the frequency of clean-out can improve the performance of catch basins, particularly in industrial or commercial areas. Although literature on this topic is relatively scarce, a frequently cited study of the benefits of catch basin cleaning (Mineart, P. and S. Singh. 1994. *Storm Inlet Pilot Study*) found that monthly cleaning yielded the best results in terms of pollutant removal per cleaning. This study concluded that the pollutant removal benefit of more frequent clean outs should be balanced against the associated increases in municipal costs.

By working with local DPWs, Highway Departments, and NHDOT, a more frequent catch basin cleaning schedule could be implemented. Local residents can contribute by clearing catch basin grates of debris and sediment after large storm events. To maintain sump capacity for proper catch basin performance, it is preferable to clean catch basins before they have accumulated sediment to half of capacity.

If contracted out to a private firm, catch basin cleaning will typically cost an estimated average of $30 per catch basin. A planning-level cost estimate for increased catch basin cleaning is $4,500 per year, based on 2 extra cleanings per year for 75 catch basins in North Hampton, Greenland and Stratham. Based on this estimate, the cost would be $1,500 annually per town for 25 catch basins each.

The water quality benefits (i.e., pollutant reduction) of catch basin cleaning will vary considerably, depending on site-specific conditions such as land use, the size of the drainage area contributing to each basin, catch basin sump volume, extent of localized erosion, time elapsed since last cleaning, etc. As a reference, the 2017 New Hampshire Small MS4 General Permit (Appendix F, Attachment 2) provides a method for calculating phosphorus and nitrogen reduction credits for catch basin cleaning, as follows:

$$\text{Credit}_{P\ CB} = IA_{CB} \times PLER_{IC\text{-land use}} \times PRF_{CB}$$

$$\text{Credit}_{N\ CB} = IA_{CB} \times NLER_{IC\text{-land use}} \times PRF_{CB}$$

Where

Credit_{CB} = Amount of phosphorus load removed by catch basin cleaning (lb/year)

IA_{CB} = Impervious drainage area to catch basins (acres)

$PLER_{IC\text{-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-1**)

$NLER_{IC\text{-land use}}$ = Nitrogen Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-2**)

PRF_{CB} = Phosphorus Reduction Factor for catch basin cleaning *(see Table 2-4*)*

NRF_{CB} = Nitrogen Reduction Factor for catch basin cleaning (see Table 2-4*)

** Table references are to Appendix F, Attachment 2 of 2017 NH MS4 General Permit*

Enhanced Street /Pavement Cleaning Programs

Street sweeping can be a very effective practice to reduce watershed nutrient loading. Street sweeping provides cleanup and removal of solids, including organic debris (leaves, pine needles), sand, and fines that accumulate on roadways. In absence of street sweeping, these materials contribute nutrients and other pollutants such as salt to receiving waters, and increase the frequency of maintenance required to maintain performance of catch basins and other storm water infrastructure.

Enhancements to municipal and NHDOT street sweeping programs are recommended, with a focus on increased frequency in the spring and summer months when buildup of organic materials on roads tends to be highest. The benefits of increased street sweeping will also be greatest in areas with highest tree canopy cover, as these areas produce the most leaves that can contribute nutrient to surface waters through decomposition. Specific target areas and sweeping frequencies should be established based on coordination with municipal DPWs, Highway Departments, and NHDOT.

As a reference, the 2017 New Hampshire Small MS4 General Permit (Appendix F, Attachment 2) provides a method for calculating phosphorus and nitrogen reduction credit for enhanced street sweeping, as follows:

The credit shall be calculated by using the following equations:

$$\text{Phosphorus Credit}_{\text{sweeping}} = \text{IA}_{\text{swept}} \times \text{PLER}_{\text{IC-land use}} \times \text{PRF}_{\text{sweeping}} \times \text{AF}$$

$$\text{Nitrogen Credit}_{\text{sweeping}} = \text{IA}_{\text{swept}} \times \text{NPLER}_{\text{IC-land use}} \times \text{NRF}_{\text{sweeping}} \times \text{AF}$$

Where

$\text{Credit}_{\text{sweeping}}$ = Amount of phosphorus load removed by enhanced sweeping program (lb/year)

IA_{swept} = Area of impervious surface that is swept under the enhanced sweeping program (ac)

$\text{PLER}_{\text{IC-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-1**)

$\text{NLER}_{\text{IC-land use}}$ = Nitrogen Load Export Rate for impervious cover and specified land use (lb/acre/yr) (*see Table 2-2**)

$\text{PRF}_{\text{sweeping}}$ = Phosphorus Reduction Factor for sweeping based on sweeper type and frequency. (*see Table 2-4)*

AF = Annual Frequency of sweeping. For example, if sweeping does not occur in Dec/Jan/Feb, the AF would be 9 mo./12 mo. = 0.75. For year-round sweeping, AF=1.0

** Table references are to Appendix F, Attachment 2 of 2017 NH MS4 General Permit*

Enhanced Organic Waste and Leaf Litter Collection Programs

Enhanced organic waste and leaf litter collection programs are similar and complementary to street sweeping programs, in that they remove organic material that can decompose and contribute soluble nutrients and other pollutants to surface waters. These programs typically include regular gathering, removal, and disposal of landscaping wastes, organic debris, and leaf litter from roadways and parking lots. The primary watershed towns of Greenland, North

Hampton, and Stratham do not currently have programs to collect organic waste and leaf litter, and the development of such programs is recommended.

As a reference, the 2017 New Hampshire Small MS4 General Permit (Appendix F, Attachment 2) provides a method for calculating phosphorus and nitrogen reduction credits for enhanced organic waste and leaf litter collection programs. The credit formula below applies to programs that collect organic waste and leaf litter at least once per week during the period of September 1 to December 1 of each year:

$$\text{Credit P}_{\text{leaf litter}} = (\text{IA}_{\text{leaf litter}}) \times (\text{PLER}_{\text{IC-land use}}) \times (0.05)$$

$$\text{Credit N}_{\text{leaf litter}} = (\text{IA}_{\text{leaf litter}}) \times (\text{NLER}_{\text{IC-land use}}) \times (0.05)$$

Where

$\text{Credit}_{\text{leaf litter}}$ = Amount of nutrient load reduction credit for organic waste and leaf litter collection program (lb. /year)

$\text{IA}_{\text{leaf litter}}$ = Impervious area (acre) in applicable watersheds that are subject to enhanced organic waste and leaf litter collection program

$\text{PLER}_{\text{IC-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lbs./acre/yr.) (*see Table 2-1*)

$\text{NLER}_{\text{IC-land use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lbs./acre/yr.) (*see Table 2-1*)

0.05 = 5% nutrient reduction factor for organic waste and leaf litter collection program in the applicable watershed

** Table references are to Appendix F, Attachment 2 of 2017 NH MS4 General Permit*

4.4 RECOMMENDED BMP SUMMARY TABLES

Table 34 on the following pages presents a summary and prioritization ranking of the recommended BMPs discussed in Sections 4.1 – 4.3.

Table 34. BMP Prioritization Summary

BMP Priority Ranking Factors*

L = Low	M = Medium	H = High

** For cost factors, lower cost = higher priority*

A. Structural Stormwater BMPs

Site #	Location	BMP Description	Relevant Authorities	Capital Costs[1] (Engineering Design and Construction)	20 -Year Life Cycle Cost[2]	Annual Nutrient Load Reduction (lbs. of P and N)[3]	$ per Pound of P and N Load Reduction per Year[4]	Public Visibility/ Outreach[5]	Feasibility to Construct[6]	SITE PRIORITY
1	Winnicutt Road near Arnold Palmer Dr., north side (Stratham)	Catch basin maintenance; Install outlet protection, vegetated swale, and bioretention.	NHDOT; property owner	$21,300 - $30,800	$49,050	P: 0.5 lb/yr N: 3.2 lb/yr	$5,500 (P) $800 (N)	L	M	**Medium**
2	Winnicutt Road near Arnold Palmer Dr, south side (Stratham)	Daylight culvert pipe and stabilize outlet; Install bioretention cell with a stabilized outlet.	NHDOT; property owner	$11,900 - $17,100	$27,500	P: 0.3 lb/yr N: 2.1 lb/yr	$4,600 (P) $700 (N)	L	M	**Medium**
3	682 Post Road at Norton Brook crossing (Greenland)	Divert low flows from road into bioretention swale via level spreader/vegetated filter strip. Install catch basins on both sides of road; discharge to bioretention in grassed island.	Greenland Highway Department; property owner	$50,500 – 73,000	$116,750	P: 0.5 lb/yr N: 3.4 lb/yr	$13,000 (P) $1,800 (N)	L	M	**Low**
4	Greenland Central School (Greenland)	Raingarden demonstration project with educational kiosk	Greenland School Department; Greenland DPW	$3,900 - $5,700	$8,800	P: 0.2 lb/yr N: 1.4 lb/yr	$2,200 (P) $400 (N)	H	H	**High**
5	Stratham Memorial School, 39 Gifford Farm Rd. (Stratham)	Retrofit existing depression/swale with a meandering flow path, vegetation and engineered soil media to treat stormwater runoff and provide infiltration; Install educational kiosk.	Stratham School Department; Stratham Highway Department	$26,100 - $37,700	$59,900	P: 0.3 lb/yr N: 2.1 lb/yr	$12,200 (P) $1,400 (N)	H	H	**Low**
6	NHDOT Facility, 174 South Road (North Hampton)	Install an infiltration bed or infiltrating swale in grassed island on NHDOT property; Install diversions to increase BMP's stormwater capture.	NHDOT	$51,200 – 74,000	$118,600	P: 1.4 lb/yr N: 10 lb/yr	$4,400 (P) $600 (N)	L	H	**Medium**
7	Intersection of Post Road and Fern Road (North Hampton)	Retrofit grassed island with a bioretention cell to capture and treat road runoff prior to discharging into an existing culvert inlet.	North Hampton DPW	$18,900 - $27,400	$44,150	P: 0.6 lb/yr N: 4.3 lb/yr	$4,100 (P) $600 (N)	L	M	**Medium**
8	72 Meadow Fox Road (North Hampton)	Install infiltration basin to reduce erosion and provide water quality treatment.	North Hampton DPW; property owner	$121,400 - $175,200	$269,300	P: 6.1 lb/yr N: 42 lb/yr	$2,300 (P) $400 (N)	L	H	**High**
9-10	10 and 12 Sylvan Road (North Hampton)	Install two rain gardens on properties located at 10 and 12 Sylvan Road to provide treatment to property and road runoff prior to discharging into the storm drain network	Property owners	$1,600 - $2,300	$3,950	P: 0.1 lb/yr N: 0.7 lb/yr	$2,000 (P) $300 (N)	M	H	**High**
11	8 Winterberry Lane (Stratham)	Retrofit dry detention basin with micropool to enhance pollutant removal and prevent sediment resuspension.	Property owner (Winterberry Lane subdivision); Stratham Highway Dept. (potential)	$21,300 - $30,800	$49,050	P: 0.2 lb/yr N: 1.5 lb/yr	$12,300 (P) $1,700 (N)	L	M	**Low**
12	11 and 12 Strawberry Lane (Stratham)	Retrofit grassed swales into treatment swales designed to hold water for a longer period and provide higher pollutant removal efficiencies.	Stratham Highway Dept.; property owners	$20,300 - $29,200	$46,750	P: 0.3 lb/yr N: 2.2 lb/yr	$9,500 (P) $1,100 (N)	M	H	**Medium**
13	Domain Drive at Timberland Entrance (Stratham)	Reconstruct asphalt swale into a treatment swale with forebay, to provide treatment prior to discharge to existing the flood storage basin.	Timberland Inc. (property owner)	$3,000 - $4,300	$6,650	P: 0.04 lb/yr N: 0.3 lb/yr	$9,500 (P) $1,000 (N)	L	H	**Medium**
14	Cul-de-sac at the end of Marin Way (Stratham)	Retrofit grassed area with bioretention cell which uses the culvert as an overflow structure.	Property owner (corporate park area)	$37,900 - $54,800	$87,350	P: 1.1 lb/yr N: 8.5 lb/yr	$3,900 (P) $600 (N)	L	H	**High**
15	8 Marin Way (Stratham)	Install bioretention cell in grassed area; Use existing catch basin as an overflow structure.	Property owner (corporate park area)	$44,300 - $63,900	$102,100	P: 1.3 lb/yr N: 9.9 lb/yr	$3,900 (P) $600 N)	M	H	**High**
16	Adjacent to Timberland Parking Lot off Marin Way (Stratham)	Retrofit existing swales as treatment swales with pre-treatment forebays, to provide treatment prior to discharge to flood storage basin.	Timberland Inc. (property owner)	$20,300 - $29,200	$46,750	P: 0.3 lb/yr N: 2.2 lb/yr	$9,500 (P) $1,100 (N)	H	H	**Medium**
17	Timberland Parking Lot off Marin Way (Stratham)	Retrofit asphalt apron of catch basin into a bioretention cell, using catch basin for overflow.		$12,700 - $18,200	$29,450	P: 0.4 lb/yr N: 2.8 lb/yr	$3,900 (P) $600 (N)	L	H	**Medium**
18	588 Portsmouth Avenue (Greenland)	Retrofit the grassed area with a gravel wetland to provide enhanced water quality treatment prior to discharging to the Winnicut River.	Property owner; Greenland PW	$252,700 - $365,000	$400,850	P: 9.4 lb/yr N: 93 lb/yr	$2,200 (P) $300 (N)	H	M	**High**

[1] Capital Cost priority rank is based on the following for median costs (engineering design and construction): <$5,000: High; $5,000-$30,000: Medium; and >$30,000: Low.

[2] 20-year life cycle costs are based on medians of the ranges of engineering and construction costs plus annual O/M over a 20-year design life, presented as present-day value. Priority rank is based on the following for median costs:

[3] Priority rank is based on the following ranges for P load reduction (the load reduction of N trends with P load reduction): [0.0 - <0.5 lb P/yr]: Low; [0.5 - 1.0 lb P/yr]: Medium; and [1.0+ P/yr]: High.

[4] Dollar ($) per Pound (lb) of P and N load reduction per year are based on the median ranges presented in Appendix A. Priority rank is assigned based on the following ranges for P load reduction: <$4,000: High; $4,000-$10,000: Medium; and >$10,000: Low.

[4] Public visibility/outreach priority based on: Location in recreational area or school, high population density = High; Location receives some pedestrian or vehicle traffic = Medium; Location receives very little pedestrian or vehicle traffic= Low

[6] Feasibility to construct priority ranking based on: ample construction access and space, on public property, few construction traffic impacts, no tree removal = High; Adequate construction access and available space, potential for some tree removal, medium traffic impact, nearby underground utilities = Medium; Potential underground utilities, location on private property, permitting challenges = Low

BMP Priority Ranking Factors*

L = Low	M = Medium	H = High

** For cost factors, lower cost = higher priority*

Table 34. BMP Prioritization Summary *(continued)*

B. Culvert Improvement BMPs

Site #	Location	BMP Description	Relevant Authorities	Capital Costs[7] (Engineering Design and Construction)	20-Year Life Cycle Cost[8]	Restore Stream Connectivity[9]	$ per Mile of Restored Stream Connectivity[10]	Fish Passage Improvement[11]	Reduced Flood Risk[12]	SITE PRIORITY
Culvert A	Adjacent to 93 Exeter Road (North Hampton)	Reconnect 0.04 miles of the Winnicut River by replacing the stone box culvert with a reinforced concrete box culvert (assume one 6 ft wide by 3 ft tall box for costing purposes), with an imbedded bottom, restoring full connectivity to the stream and reducing flood risk.	NHDOT, NHDES	$93,800 - $123,800	$124,800	0.04 Miles of Winnicut River	$3,120,000	L	L	**Low**
Culvert B	Thompson Brook at Winnicut Road (Greenland)	Reconnect 1.17 miles of Thompson Brook, a lower tributary of the Winnicut River, by replacing an undersized, perched metal culvert with a reinforced concrete box culvert (assume two 8 ft wide by 4 ft tall box for costing purposes), restoring full connectivity to the stream and reducing flood risk.	Greenland DPW, NHDES	$187,500 - $247,500	$247,500	1.17 Miles of Thompson Brook	$212,000	M	M	**Medium**
Culvert C	Between 128 and 132 Exeter Road (North Hampton)	Reconnect 0.05 miles of the Winnicut River by replacing the metal culvert with an open bottom culvert crossing (assume one 12 ft wide by 2 ft tall three-sided culvert for costing purposes), restoring full connectivity to the stream	NHDOT, NHDES	$125,000 - $165,000	$165,000	0.05 Miles of Winnicut River headwaters	$3,300,000	M	L	**Low**
Culvert D	Winnicut River at Winnicutt Road (Stratham)	Reconnect 4.14 miles of the Winnicut River, by removing the remaining remnants of the former Winnicut Pond dam to restore full connectivity to the river.	NHDOT, NHDES	$156,300 - $206,300	$207,300	4.14 Miles of Winnicut River	$50,000	M	M	**High**
Culvert E	Willow Brook at Willowbrook Avenue (Greenland)	Reconnect 0.88 miles upstream of Willow Brook, by replacing the undersized, perched metal culvert with a concrete box culvert (assume one 14 ft wide by 2 ft tall box for costing purposes), restoring full connectivity to the stream and reducing flood risk.	Greenland DPW, NHDES	$187,500 - $247,500	$247,500	0.88 Miles of Willow Brook	$281,300	M	M	**Medium**
Culvert F	Lovering Road at Winnicut River (North Hampton)	Reconnect 1.06 miles of the Winnicut River by replacing the existing 2 ft. dia. culvert with multiple box culvert spans (assume two 10 ft wide by 2 ft tall box for costing purposes), restoring hydraulic capacity and full connectivity to the stream and reducing flood risk.	NHDOT, NHDES	$281,300 - $371,300	$372,300	1.06 Miles of Winnicut River	$351,200	M	M	**Medium**

[7] Capital Cost priority rank is based on the following for median costs (engineering design and construction): <$100,000: High; $100,00-$200,000: Medium; and >$200,000: Low.

[8] 20-year life cycle costs are based on medians of engineering and construction cost ranges plus annual O/M over 20-year design life, presented as present-day value (see Appendix A). Priority rank is based on the following ranges: <$120,000: High; $120,000-$240,000: Medium; and >$240,000: Low.

[9] Stream connectivity restoration priorities are based on the potential to improve connectivity as reported in *Assessment of Road Crossings for Improving Migratory Fish Passage in the Winnicut River Watershed* (TNC, 2009). Priority rank is based on the following ranges: < 0.25 miles: Low; 0.25 – 1.0 miles: medium; > 1.0 miles: High

[10] Priority rank for $ per Mile of Restored Stream Connectivity is based on the following ranges: <$200,000/mile: High; $200,000/mile-$400,000/mile: Medium; and >400,000/mile: Low.

[11] Priority ranking for fish passage improvement is based on barrier assessment, spatial analysis, and practical considerations as described in the *Assessment of Road Crossings for Improving Migratory Fish Passage in the Winnicut River Watershed* (TNC, 2009).

[12] Priority ranking for reduced flood risk is based on barrier assessment, extent of stream fragmentation, and practical considerations as described in the *Assessment of Road Crossings for Improving Migratory Fish Passage in the Winnicut River Watershed* (TNC, 2009).

BMP Priority Ranking Factors*

L = Low	M = Medium	H = High

** For cost factors, lower cost = higher priority*

Table 34. BMP Prioritization Summary *(continued)*

C. Non-structural BMPs

Non-structural BMP Category	BMP Description	Relevant Authorities	How BMP Achieves Pollutant Load Reductions or Other WRMP Goals	Pollutant Load Reduction Potential	Anticipated Costs	Feasibility	PRIORITY
Public Information and Education	Watershed Steward Program™ property assessments and related outreach	NHRC, watershed homeowners	Reduces pollutant (P,N, and bacteria) loading by improved land management, such as reduced fertilizer use, improved septic system maintenance, stabilization of eroding areas, pet waste management, etc.	M	H	H	**High**
	Meetings with town staff and NHDOT (Natural Resource Agency Coordination Meetings and District 6 staff) to coordinate WRMP implementation	NHRC, towns, NHDOT, NHDES	Reduces pollutant (P,N, and bacteria) loading by improving coordination with agencies that are critical to BMP implementation. Improves schedule coordination, BMP prioritization, and BMP implementation logistics.	M	H	H	**High**
	Updates to NHRC Winnicut WRMP Project Website	NHRC	Serves as the primary clearinghouse for web-based information on progress to develop, implement, and update the WRMP.	L	H	H	**Medium**
	Conduct LID for Homeowners workshop	NHRC, Geosyntec, watershed homeowners	Reduces pollutant (P and N) loading by educating homeowners and promoting adoption of LID practices such as raingardens, vegetated buffers, etc.	L	H	H	**Medium**
Land Conservation	Coordinate with SELT, GBRPP, and other conservation groups to prioritize land conservation goals/target parcels. (land conservation orgs., RPC, NHRC, NHDES)	NHRC, SELT, GBRPP, town planning staff, and other local land conservation orgs.	Prevents increases in pollutant loading associated with land development.	H	H	H	**High**
Regulatory Tools	Continue efforts to adopt town stormwater regulations based on latest (2017) SWA model.	Greenland, North Hampton, and Stratham Planning Boards and Boards of Selectmen	Reduces future increases in pollutant (P, N, and bacteria) loading associated with land development by improving regulatory performance standards for new development and redevelopment projects.	H	H	M	**High**
	Develop landscaping fertilizer ordinances	Greenland, North Hampton, and Stratham Planning Boards and Boards of Selectmen	Reduces P and N loading from landscaping fertilizer applications.	H	L-M	M	**Medium**
	Develop and submit a nomination for the Winnicut River to attain Designated River status	NHRC, Rockingham County Planning Commission (lead org. TBD); watershed towns; NHDES; NH General Court; NH Governor	Contributes to the long-term water quality goals established in this WRMP through regulatory protection and enhanced planning structure provided by the LAC.	M	L-M	M	**Medium**
	Establish town regulations to enable/promote installation of alternative wastewater treatment systems based on proximity to a waterbody (i.e., 200 meters) for new development, redevelopment and replacement of failed systems.	Greenland, North Hampton, and Stratham Boards of Health and Boards of Selectmen	Reduces nutrient and bacteria loading from wastewater sources.	**H**	**H**	M	**High**
Institutional Practices	Increase frequency of catch basin cleaning (2 additional cleanings per year)	Town DPW/Highway Depts., NHDOT	Reduces P and N load as calculated according to NH Small MS4 General Permit formulas for each practice.	M	L	M	**Medium**
	Develop Enhanced Street/Pavement Cleaning Programs	Town DPW/Highway Depts., NHDOT		M	L-M	M	**Medium**
	Develop Enhanced Organic Waste and Leaf Litter Collection Programs	Town DPW/Highway Depts., NHDOT		M	L-M	M	**Medium**

Section 5. Summary of Technical and Financial Support

5.1 TECHNICAL SUPPORT

The structural BMPs described in Section 5.1 will require varying levels of technical support related to engineering and design. Sites requiring low level of technical support would generally be appropriate for design-build construction using field manuals. Those requiring moderate engineering technical support could potentially be constructed based on concepts designs, schematics, and limited modeling. Sites needing a high level of support would require preparation of definitive site drawings by a Professional Engineer for use in permitting, contractor bidding and construction. Other types of technical support associated with engineering and design include site topographic surveys, preparation of existing conditions base plans, etc. The proposed stormwater improvement sites from Section 5.1 are listed in Table 35 according to estimated level of required technical support.

Table 35. Level of Technical Support Required for Stormwater Structural BMP Sites

LOW	MODERATE	HIGH
Site 4: Greenland Central School (Greenland)	**Site 5:** Stratham Memorial School, 39 Gifford Farm Rd. (Stratham)	**Site 1:** Winnicut Rd. near Arnold Palmer Dr., north side (Stratham)
Sites 9 and 10: 10 and 12 Sylvan Road (North Hampton)	**Site 6:** NHDOT Facility, 174 South Road (North Hampton)	**Site 2:** Winnicut Rd. near Arnold Palmer Drive, south side (Stratham)
Site 13: Domain Drive at Timberland Entrance (Stratham)	**Site 7:** Intersection of Post Road and Fern Road (North Hampton)	**Site 3:** 682 Post Road at Norton Brook crossing (Greenland)
Site 16: Next to Timberland Parking Lot / Marin Way (Stratham)	**Site 11:** 8 Winterberry Lane (Stratham)	**Site 8:** 72 Meadow Fox Road (North Hampton)
Culvert A: Adjacent to 93 Exeter Road (North Hampton	**Site 12:** 11 and 12 Strawberry Lane (Stratham)	**Site 15:** 8 Marin Way (Stratham)
Culvert B: Thompson Brook at Winnicut Road (Greenland)	**Site 14:** Cul-de-sac at end of Marin Way (Stratham)	**Site 18:** 588 Portsmouth Avenue (Greenland)
Culvert C: Between 128 and 132 Exeter Road (North Hampton)	**Site 17:** Timberland Parking Lot off Marin Way (Stratham)	**Culvert D:** Winnicut River at Winnicutt Road (Stratham)
Culvert E: Willow Brook at Willowbrook Avenue (Greenland)		

In addition to the technical support described above, construction of some of the proposed BMPs may require a Minimum Impact Wetlands Application to NHDES. Wetlands were not delineated as part of this WRMP project. As such, technical support from a New Hampshire certified wetland scientist would be required on sites where wetlands are present for wetland delineation and permitting support.

Improvements related to the wastewater management alternatives presented in Section 4 require a high degree of technical support from a wastewater engineering firm. Such support is expected to include a feasibility study with detailed site investigations and recommendations on siting options and costing for the proposed wastewater treatment systems. Detailed engineering plans for the systems would be required.

Other types of technical support that may be required for the nonstructural measures in Section 5.2 include:

- graphic design and printing support for public outreach and educational materials;
- qualified staff to conduct homeowner assessments through the Watershed Steward™ Program;
- septic system inspection services;
- legal assistance for conservation land real estate transactions and development of regulatory language for future municipal ordinances.

5.2 FINANCIAL SUPPORT

Site improvements and management recommendations described in Section 5 will require funding for implementation, including construction and ongoing maintenance. Likely sources of funding include, but are not limited to, federal Section 319 Nonpoint Source Pollution Program funds, which are distributed by NHDES through the Watershed Assistance Grants Program.

Brief descriptions of potential grant funding sources are provided in Table 36, as adapted from a summary of funding programs provided by the NHDES Watershed Assistance Section (dated April 4, 2017). Although NHDES updates this list regularly, please note that funding programs are constantly changing.

Table 36. Summary of Funding Programs (adapted from NHDES summary)

Funding Program	Description
Aquatic Resource Mitigation Fund Program http://des.nh.gov/organization/divisions/water/wetlands/WRMP/index.htm	Focuses on projects to restore natural resources within the context of a proposed land conservation effort. NHDES encourages projects providing connectivity to other protected resources or in close proximity to wetland impacts. Projects to benefit rare resources are viewed favorably.
American Rivers - NOAA Community-Based Restoration Program Partnership http://www.habitat.noaa.gov/restoration/programs/crp.html	Grant funding provided for stream barrier removal projects that help restore riverine ecosystems, enhance public safety and community resilience, and have clear and identifiable benefits to diadromous fish populations.
Center for Land Conservation Assistance www.forestsociety.org	Funds transaction costs for permanent land protection projects within NH's coastal watershed area. Funding level: up to $3,000
Community Grants https://www.timberland.com/responsibility.html	Funds projects that are actively engaged with the ecosystem and that work to increase the understanding of environmental sustainability.
Conservation Grant Program (Moose Plate) http://www.agriculture.nh.gov/divisions/scc/grant-program.htm	Funding focus includes: preservation, protection, and conservation of water quantity and quality; restoration, enhancement, or conservation of wildlife habitat; soil erosion prevention and reduction; flood mitigation; installation of BMPs for agriculture; forestry; stormwater management; and land protection.
Davis Conservation Foundation www.davisfoundations.org	Supports organizations with projects related to wildlife, wildlife habitat, environmental protection, or outdoor recreation. Projects that strengthen volunteer activity and community involvement in these categories are of particular interest. Funding range: $2,000 - $150,000; average $10,000.
Fields Pond Foundation http://www.fieldspond.org/	Funds trail making and other enhancement of public access to conservation lands, land acquisitions for conservation, and establishing funds for stewardship. Funding levels: $25,000 maximum, $2,000 - $10,000 typical.

Land and Community Heritage Investment Program (LCHIP) http://www.lchip.org/index.php	The LCHIP is an independent state authority that makes matching grants to NH communities and non-profits to conserve and preserve New Hampshire's most important natural, cultural and historic resources.
National Fish and Wildlife Foundation *Five Star and Urban Waters Restoration Program* http://www.nfwf.org/fivestar/Pages/home.aspx	Provides funds to local partnerships for wetland, forest, riparian and coastal habitat restoration, with a focus on urban waters and watersheds. Funds approximately $1,500,000 annually, with average grants between $25,000 to $35,000 and 1:1 match requirements.
National Park Service – Rivers and Trails Program www.nps.gov/rtca	Funds projects focused on protection of natural resources and enhancement of outdoor recreational opportunities. Funding level: not listed
Natural Resource Conservation Service (NRCS) http://www.nrcs.usda.gov/wps/portal/nrcs/main/nh/programs/financial/	NRCS offers financial and technical assistance to landowners and agricultural producers to help manage natural resources in a sustainable manner. Eligible projects include efforts to implement conservation practices to address natural resource concerns or opportunities to help save energy, improve soil, water, plant, air, animal and related resources on agricultural lands and non-industrial private forest.
New England Grassroots Environmental Fund www.grassrootsfund.org	Funds projects focused on forestry and trails, with a focus on community-based environmental work. Funding level: $500 - $2,500
New England Forests and Rivers Fund www.nfwf.org/newengland	Dedicated to restoring and sustaining healthy forests and rivers that provide habitat for diverse native bird and freshwater fish populations in New England. Annually awards grants ranging from $50,000 to $200,000 each.
Boston Foundation Fund for the Environment - Open Door Grants www.tbf.org	These grants focus on protection of habitat for birds. The grant program is an open process and responds to the expressed ideas and needs of the community.
Norcross Wildlife Foundation http://www.norcrosswildlife.org/grants-loans/grants/	While the Norcross board has decided to suspend the unsolicited grants program for the foreseeable future, Norcross will continue to support conservation efforts via the land loan program, wildlife sanctuary and through various partnerships with conservation and environmental organizations.
Partners for New Hampshire's Fish and Wildlife http://www.nfwf.org/eversourcepartners/Pages/home.aspx	This partnership of Eversource Energy and the National Fish and Wildlife Foundation is dedicated to restoring and sustaining healthy forests and rivers in New Hampshire. The program invests in restoration projects and applied science, and has awarded grants from $65,000-$200,000.
Profits for the Planet http://www.stonyfield.com/contact-us/donation-request	Stonyfield Farm's Profits for the Planet supports efforts to protect and restore the environment and generate measurable results.

Shared Earth Foundation **Category: Non-Federal** http://www.sharedearth.org/	Funds projects that promote protection and restoration of habitat for the broadest possible biodiversity. Funding level $5,000 - $20,000.
Tom's of Maine- Corporate Giving http://www.tomsofmaine.com/community#giving-for-goodness	Funds projects focused on protection and conservation of natural resources, wildlife and wildlife habitat. Funding level: $500 - $5,000
Trout Unlimited Embrace-A-Stream Grant Program www.tu.org/conservation/watershed-restoration-home-rivers-initiative/embrace-a-stream	Trout Unlimited (TU) accepts grant applications for coldwater fisheries conservation projects that best address the needs of native and wild trout following TUs "protect, reconnect, restore and sustain" conservation model. Funding decisions are made annually in February.
U.S. Fish and Wildlife Service, Division of Bird Habitat Conservation: U.S. Standard Grants https://www.fws.gov/birds/grants.php	This competitive, matching grants program supports public-private partnerships for projects in that further the goals of the North American Wetlands Conservation Act. Projects must involve long-term protection, restoration, and/or enhancement of wetlands and associated uplands habitats for the benefit of all wetlands-associated migratory birds.
NHDES Watershed Assistance Grants http://des.nh.gov/organization/divisions/water/wmb/was/categories/grants.htm	NHDES provides funding appropriated through the USEPA under Section 319 of the Clean Water Act to support local initiatives to restore impaired waters or protect high quality waters. Grant funds are targeted toward implementation of completed watershed-based plans, nitrogen reducing BMPs in the Great Bay watershed, and addressing impairments caused by hydromodification.

Section 6. Schedule and Interim Milestones

The schedule below is based on a five-year planning and implementation period from July 1, 2017 to June 30, 2022.

Table 37. Schedule and Interim Milestones

BMP CATEGORY	TASKS (lead organizations)	Year 1	Year 2	Year 3	Year 4	Year 5	
		2017	2018	2019	2020	2021	2022
Structural Stormwater BMPs and Culvert Upgrades	Select priority sites for structural stormwater BMPs and culvert upgrades (NHRC, towns, NHDOT, NHDES)						
	Prepare application for NHDES Watershed Assistance Grant applications for final design/construction of priority BMP sites (NHRC, towns)						
	Prepare priority BMP sites final designs and permitting (pending grant funding) (NHRC, towns)						
	Construct priority BMP Sites (towns, NHDOT, NHRC)						
	Prepare grant application for design and construction of additional BMP sites (NHRC, towns)						
	Obtain grant funding for additional BMP sites; construct BMPs (NHRC, towns)						
Non-structural BMPs: Public Information and Education	Watershed Steward Program property assessments and related outreach (NHRC, homeowners)						
	Meetings with NHDOT and town staff to coordinate WRMP implementation (NHRC, towns, NHDOT, NHDES)						
	Updates to NHRC Winnicut WRMP Project Website (NHRC)						
	Conduct LID for Homeowners workshop (NHRC, Geosyntec)						
Non-structural BMPs: Land Conservation	Coordinate with SELT, GBRPP, and other conservation groups to prioritize land conservation goals/target parcels. (land conservation orgs., RPC, NHRC)						
Non-structural BMPs: Regulatory Tools	Continue efforts to adopt town stormwater regulations based on latest (2017) SWA model. (Greenland, North Hampton, and Stratham Planning Boards)						
	Develop landscaping fertilizer ordinances (Greenland, North Hampton, and Stratham Planning Boards)						
	Develop and submit a nomination for the Winnicut River to attain Designated River status (Rockingham County Planning Commission, NHRC, towns: *lead org. TBD*)						
	Establish town regulations to enable/promote alternative wastewater treatment systems based on proximity to a waterbody (i.e., 200 meters) for new development, redevelopment and replacement of failed systems.						

Table 37. Schedule and Interim Milestones *(continued)*

BMP CATEGORY	TASKS (lead organizations)	Year 1	Year 2		Year 3	Year 4	Year 5
		2017	2018	2019	2020	2021	2022
Non-structural BMPs: Institutional Practices	Increase frequency of catch basin cleaning (2 additional cleanings per year; Town DPW/Highway Depts., NHDOT)						
	Develop and Implement Enhanced Street/Pavement Cleaning Programs (Town DPW/Highway Depts., NHDOT)						
	Develop and Implement Enhanced Organic Waste and Leaf Litter Collection Programs (Town DPW/Highway Depts.)						
Monitoring	Conduct summit of monitoring orgs. to coordinate on data collection goals, locations, etc. (follow-up in 2020, 2022) (NHRC, NHDES, monitoring orgs.)						
	Conduct annual watershed-scale monitoring (NHDES, monitoring orgs.)						
Adaptive Management	Review progress towards meeting WRMP water quality targets and project-specific goals and update as needed. (NHRC, NHDES)						

Section 7. Evaluation Criteria and Monitoring

This Section of the Winnicut River WRMP addresses Elements H and I of the USEPA requirements for a watershed-based plan, as defined below.

Element H: A set of criteria used to determine (1) if loading reductions are being achieved over time and (2) if progress is being made toward attaining water quality goals. Element H asks "***how will you know if you are making progress towards water quality goals?***" The criteria established to track progress can be direct measurements (e.g., *E. coli* bacteria concentrations) or indirect indicators of load reduction (e.g., number of beach closings related to bacteria).

Element I: A monitoring component to evaluate the effectiveness of implementation efforts over time, as measured against the Element H criteria. Element I asks "***how, when, and where will you conduct monitoring?***"

7.1 EVALUATION CRITERIA

Evaluation criteria (Element H) for the Winnicut River Watershed include the categories presented below.

- **Water Quality Targets:** Section 1.6 of the WRMP presents a summary of existing water quality impairments in the Winnicut River Watershed, and Section 2.3 presents the following water quality targets established by this WRMP:
  - **Dissolved Oxygen:** The upstream/headwaters reaches of the Winnicut River will naturally have DO that is lower than the state Class B standard of 5.0 mg/L. Data collected downstream of Winnicutt Road in Stratham will be used to assess the River in reference to the Class B DO standard, with the specific location of this assessment unit boundary to be determined based on further coordination with NHDES and field investigation.
  - **Nitrogen:** The estuarine N target recommended by NHDES in 2009 for prevention of low DO (0.45 mg/L) was established as a planning target. Based on the 2010 NHDES target N loading of 24.3 tons/year (to prevent low DO) and the estimated current attenuated N load to the river of 30.4 tons/year (see Section 3.4), an estimated load reduction of 6.1 tons N/year (20%) is needed. Since N is not typically the limiting nutrient in fresh water, a target N concentration was not selected for the non-tidal river reaches.
  - **Total Phosphorus:** A target TP concentration of 0.027 mg/L was selected for the non-tidal reached of the Winnicut River. Achieving this target will require a 25% reduction from the current median TP of 0.036 mg/L. Since P is not the limiting nutrient in marine waters, a target P concentration was not selected for the tidal river reach.
- **TMDL Criteria:** Although no TMDLs currently exist in the watershed for the parameters listed above, this WRMP should be updated as needed to reflect TMDL criteria if established in the future.
- **Project-Specific Indicators:** The project-specific performance indicators listed in Table 38 may be used as criteria for activities recommended in this WRMP. These project-specific indicators are generally intended to quantify an activity and, whenever possible, explain how that activity achieve load reductions for targeted pollutants or other WRMP goals (i.e., improved aquatic habitat). In cases where it is not possible to quantify a pollutant load reduction, the project-specific indicator states the target pollutant(s) expected to be reduced as a result of the activity.

Table 38. Project-Specific Indicators for Winnicut River Watershed Restoration and Management Plan

BMP Type	Quantified Activity	How Activity Achieves Pollutant Load Reductions or Other WRMP Goals
Structural Stormwater BMPs and Culvert Upgrades	Number of structural stormwater BMPs implemented; annual P and N load reduced	Pollutant (P and N) load reductions from specific structural BMPs as presented in Section 4.1.
	Number of culvert improvement projects implemented.	Miles of restored stream connectivity for fish and aquatic organism passage (see Section 4.1); Length of restored stream channel
Nonstructural BMPs: **Public Information and Education**	Number of Watershed Steward Program™ property assessments; Number of property owners certified as Watershed Stewards	Reduces pollutant (P,N, and bacteria) loading by improved land management, such as reduced fertilizer use, improved septic system maintenance, stabilization of eroding areas, pet waste management, etc.
	Conduct *LID for Homeowners* Workshop: Number of watershed residents who attended workshop	Reduces pollutant (P and N) loading by educating homeowners and promoting adoption of LID practices such as raingardens, vegetated buffers, etc.
	Meetings with municipal DPW/Highway departments and NHDOT to coordinate WRMP implementation.	Reduces pollutant (P,N, and bacteria) loading by improving coordination with agencies that are critical to BMP implementation. Improves schedule coordination, BMP prioritization, and BMP implementation logistics.
	Project updates posted to NHRC project website: Number of project updates and associated news releases.	Serves as the primary clearinghouse for web-based information on progress to develop, implement, and update the WRMP.
Nonstructural BMPs: **Land Conservation**	Coordination via planning summit (or series of meetings) with SELT, GBRPP, state/local agency staff, and other local conservation groups to prioritize land conservation goals and target parcels.	Contributes to the long-term water quality goals established in this WRMP by reducing pollutant load increases associated with land development, as estimated in Section 3.7.4.
	Acres of land protected through land acquisition, conservation easements, or other real estate conservation tools.	Prevents increases in pollutant loading associated with land development.
Nonstructural BMPs: **Regulatory Tools**	Number of watershed towns with stormwater regulations adopted based on SWA model; Updates to existing stormwater regulations to match updated 2017 SWA model	Reduces future increases in pollutant (P,N, and bacteria) loading associated with land development by improving regulatory performance standards for new development and redevelopment projects.
	Number of municipal fertilizer ordinances drafted and adopted by watershed towns; Quantify area (acres) within in community that is regulated by each ordinance.	Reduces P and N loading from landscaping fertilizer applications.
	Document (1) submittal of nomination and (2) approval of Winnicut River for Designated River status	Contributes to the long-term water quality goals established in this WRMP through regulatory protection and enhanced planning structure provided by the LAC.
	Establish town regulations to enable/promote alternative wastewater treatment systems based on proximity to a waterbody (i.e., 200 meters) for new development, redevelopment and replacement of failed systems.	Reduces nutrient and bacteria loading from wastewater sources.
Nonstructural BMPs: **Institutional Practices**	Number of catch basins included in enhanced catch basin cleaning program, and increase in frequency of cleaning.	Reduces P and N load as calculated according to NH Small MS4 General Permit formulas for each practice.
	Number of road miles where enhanced street sweeping was conducted each year, and increase in frequency.	
	Number of road miles/area covered under enhanced organic waste and leaf litter collection programs.	

7.2 MONITORING

Continued watershed-scale water quality monitoring is recommended to address Element I requirements and help document the extent to WRMP implementation efforts are succeeding. The results and locations of past monitoring efforts are summarized in Section 1 of this WRMP. Past monitoring efforts in the watershed have been conducted by a variety of organizations, including the following:

- NHDES Ambient River Monitoring Program
- New Hampshire Volunteer River Assessment Program
- NHDES Shellfish Program
- Great Bay Coastwatch Water Quality Monitoring Program
- Great Bay Estuary Tidal tributary Monitoring Program
- Various permit and project-specific monitoring

Monitoring Recommendations:

To allow for better future coordination of watershed-wide monitoring, a summit meeting of all monitoring groups is recommended. This meeting will allow all monitoring groups to discuss their goals in reference to those established in this WRMP, and to potentially find opportunities for coordination and greater efficiency in using resources to meet shared goals. It is also recommended that all monitoring groups report their data through the NHDES Environmental Monitoring Database.

In addition to the above watershed-wide monitoring recommendations, the following site-specific actions are recommeded:

- As discussed in greater deatil in Section 1.3, the Portsmouth Country Club sampling location should be used for future bacteria sampling events to allow for continued historical trend analysis and better representation of in-river bacteria conditions within the tidal reach of the Winnicut River.
- Nitrogen sampling is recommended for the existing nontidal sampling locations, including the Portsmouth Country Club location.
- As discussed in Section 2.3, data collected downstream of Winnicutt Road should be used to assess the Winnicut River in reference to the Class B DO standard. The specific location of this assessment unit boundary and associated sampling locations should to be determined based on further coordination with NHDES and field investigation. Specifically, coordination with the NHDES Water Quality Section is recommended to confirm when this watershed will be scheduled for synoptic monitoring events. This type of monitoring provides an opportunity to select the location of future monitoring stations in support of WRMP goals.

7.3 ADAPTIVE MANAGEMENT

If, after 3 years of WRMP management measure implementation, the direct measurements and indirect indicators do not show progress towards meeting the water quality targets established in this WRMP, the management measures and water quality targets should be revisited and modified accordingly.

Section 8. References

[1] Department of Environmental Services. 2014. "Great Bay Nitrogen Non-Point Source Study". Prepared by the Water Division and the Air Resources Division.

[2] New Hampshire Department of Environmental Services. 2010. "Analysis of Nitrogen Loading Reductions for Wastewater Treatment Facilities and Non-Point Sources in the Great Bay Estuary Watershed". Prepared by the Water Division.

[3] New Hampshire Department of Environmental Services. 2009. "Numeric Nutrient Criteria for the Great Bay Estuary". Prepared by Philip Trowbridge, P.E.

[4] U.S. Environmental Protection Agency. 2016. "State Progress Toward Developing Numeric Nutrient Water Quality Criteria for Nitrogen and Phosphorus".

[5] Vermont Department of Environmental Conservation. 2014. "Proposed Nutrient Criteria for Vermont's Inland Lakes and Wadeable Streams". Prepared by the Watershed Management Division.

[6] New Hampshire Department of Environmental Services. 2014. "2014 Surface Water Quality Assessment Viewer".

[7] EPA. (2014a). *Attachment 1- Fact Sheet Massachusetts Small MS4, Charles River Basin Nutrient (Phosphorus) TMDLs, Phosphorus Load Export Rates and BMP Performance.* (http://www3.epa.gov/region1/npdes/stormwater/ma/2014FactSheet-Attachment1.pdf).

[8] EPA. (2014b). *EPA's Methodology to Calculate Baseline Estimates of Impervious Area (IA) and Directly Connected Impervious Area (DCIA) for Massachusetts Communities.* April 2014.

[9] Geosyntec Consultants. 2015. *Water Integration for the Squamscott Exeter (WISE) River Watershed: Pollutant Load Modeling Report.* April 2015.

[10] Natural Resource Conservation Service (NRCS). 2007. *National Engineering Handbook, Part 630, Chapter 7 – Hydrologic Soil Groups*. United States Department of Agriculture (USDA). Issued May 2007.

[11] New Hampshire Office of Energy and Planning (NHOEP). 2016. *State of New Hampshire County Population Projections, By Municipality.*

[11] Barnstable County Department of Health and Environment (BCDHE). 2016a. *Does Sawdust Have a Role in Saving Cape Cod's Bays?*

[12] Barnstable County Department of Health and Environment (BCDHE). 2016b. *Experimental leachfields for nitrogen removal – a homeowner's guide.*

[13] Cape Cod Commission. 2013. Regional Wastewater Management Plan, Understanding the Cost Factors of Wastewater Treatment and Disposal. Cape Cod. March 2013.

[14] Horlsey Witten Group, Inc.. 2015. Pleasant Bay Nitrogen Management Alternatives Analysis Report. Brewster, MA. March 2015.

[16] U.S. Environmental Protection Agency (EPA). 2010. Guidance for Federal Land Management in the Chesapeake Bay Watershed. May 12, 2010. U.S. Environmental Protection Agency

[17] EPA. 2013. A Model Program for Onsite Management in the Chesapeake Bay Watershed*.* Office of Wastewater Management. June 2013.

[18] NHDES. 2008. New Hampshire Stormwater Manual. New Hampshire Department of Environmental Services.

[19] TNC. 2009. Assessment of Road Crossings for Improving Migratory Fish Passage in the Winnicut River Watershed. The Nature Conservancy, New Hampshire Chapter.

APPENDIX A:

Structural BMP Cost Estimate Spreadsheets

A-1: Structural Stormwater BMP Cost and Pollutant Reduction Estimates

A-2: Culvert Improvement Cost Estimates

Appendix A1: Structural Stormwater BMP Cost and Pollutant Reduction Estimates, Winnicut River Watershed Management Plan

SITE	BMP IMPROVEMENT AREA	COMPONENT(S)	QUANTITY	UNIT PRICE	BMP COST	CONSTRUCTION COST[4]	ENGINEERING DESIGN COST[6]	ENGINEERING DESIGN AND CONSTRUCTION COSTS	O&M AS PERCENT OF CAPITAL COST [3]	TOTAL ANNUAL O&M COST	20-YEAR LIFE CYCLE COST (PRESENT DAY VALUE)	PERCENT REDUCTION PHOSPHORUS	PERCENT REDUCTION NITROGEN	ESTIMATED PHOSPHORUS LOAD REDUCTION (lb/yr)	ESTIMATED NITROGEN LOAD REDUCTION (lb/yr)	ESTIMATED P LOAD REDUCTION COSTS ($/lb/yr)	MEAN P REDUCTION COSTS ($/lb/yr)	ESTIMATED NITROGEN LOAD REDUCTION COSTS ($/lb/yr)	MEAN N REDUCTION COSTS ($/lb/yr)
1	North Side of Winnicut Road between Arnold Palmer Drive and former gristmill	Catch basin and culvert cleaning	1 EA	$1,500 LS	$1,500	$15,800 - $22,800	$5,500 - $8,000	$21,300 - $30,800	6%	$1,150	$44,300 - $53,800	65%	65%	0.4 - 0.5	3.0 - 3.4	$ 5,538 - $ 5,380	$ 5,500	$ 732 - $ 800	$ 800
		Culvert outlet protection	1 EA	$500 EA	$500														
		Vegetated Swale (30x4'x1')	120 LF	$8 CF	$960														
		Bioretention Cell (30' x15'x2')	900 CF	$10 CF	$9,000														
		Stabilization/Revegetation	1030 SF	$2 SF	$1,545														
2	South Side of Winnicut Road across from Arnold Palmer Drive	Daylight Existing Pipe	1 LS	$1,000 LS	$1,000	$8,800 - $12,700	$3,100 - $4,400	$11,900 - $17,100	6%	$650	$24,900 - $30,100	65%	65%	0.3 - 0.3	2.0 - 2.2	$ 4,150 - $ 5,017	$ 4,600	$ 617 - $ 671	$ 700
		Culvert Outlet Protection	1 EA	$500 EA	$500														
		Bioretention Cell (20' x15'x2')	600 CF	$10 CF	$6,000														
3	682 Post Road adjacent to Norton Brook crossing, Greeland, NH (across from Site 3)	Catch Basins	2 EA	$10,000 EA	$20,000	$37,400 - $54,100	$13,100 - $18,900	$50,500 - $73,000	6%	$2,750	$105,500 - $128,000	65%	65%	0.4 - 0.5	3.2 - 3.6	$ 13,188 - $ 12,800	$ 13,000	$ 1,634 - $ 1,784	$ 1,800
		Bioretention Cell (40'x12'x2')	960 CF	$10 CF	$9,600														
		Subsurface Pipe	40 LF	$60 LF	$2,400														
4	Greenland Central School, Greenlanc	Raingarden	400 CF	$5 CF	$2,000	$2,900 - $4,200	$1,000 - $1,500	$3,900 - $5,700	6%	$200	$7,900 - $9,700	65%	65%	0.2 - 0.2	1.3 - 1.5	$ 1,975 - $ 2,425	$ 2,200	$ 294 - $ 324	$ 400
		Educational Kiosk	1 EA	$500 EA	$500														
5	Stratham Memorial School, 39 Gifford Farm Road, Stratham, NH	Retrofit Stormwater Swale (20'x40'x2')	1600 CF	$10 CF	$16,000	$19,300 - $27,900	$6,800 - $9,800	$26,100 - $37,700	6%	$1,400	$54,100 - $65,700	20%	25%	0.2 - 0.3	2.1 - 2.3	$ 13,525 - $ 10,950	$ 12,200	$ 1,307 - $ 1,429	$ 1,400
		Educational Kiosk	1 EA	$500 EA	$500														
6	NHDOT Facility, 174 South Road, North Hampton, NH	Infiltrating Swale (140'x20'x1')	2800 CF	$8 CF	$22,400	$37,900 - $54,756	$13,300 - $19,200	$51,200 - $73,956	6%	$2,800	$107,200 - $130,000	65%	65%	1.2 - 1.5	9.4 - 10.5	$ 4,467 - $ 4,333	$ 4,400	$ 569 - $ 621	$ 600
		Stormwater Diversions	1 EA	$10,000 EA	$10,000														
7	Grassed Island at Intersection of Post Road and Fern Road (across from 31 Post Road), North Hampton, NH	Bioretention Cell (30'x20x2")	1200 CF	$10 CF	$12,000	$14,000 - $20,300	$4,900 - $7,100	$18,900 - $27,400	6%	$1,050	$39,900 - $48,400	65%	65%	0.5 - 0.6	4.0 - 4.5	$ 3,990 - $ 4,033	$ 4,100	$ 494 - $ 540	$ 600
8	Adjacent to 72 Meadow Fox Road, North Hampton, NH	Infiltration Basin (80'x40'x4')	12800 CF	$6 CF	$76,800	$89,900 - $129,800	$31,500 - $45,400	$121,400 - $175,200	5.5%	$6,050	$242,400 - $296,200	65%	60%	5.5 - 6.7	39.7 - 44.1	$ 2,204 - $ 2,210	$ 2,300	$ 305 - $ 335	$ 400
9-10	10 & 12 Sylvan Road, North Hampton, NH	Two Raingardens	200 CF	$5 CF	$1,000	$1,200 - $1,700	$400 - $600	$1,600 - $2,300	6%	$100	$3,600 - $4,300	65%	65%	0.1 - 0.1	0.7 - 0.7	$ 1,800 - $ 2,150	$ 2,000	$ 268 - $ 288	$ 300
11	8 Winterberry Lane, Stratham, NH	Vegetative Plantings (1000 SF)	1000 SF	$4 SF	$3,500	$15,800 - $22,800	$5,500 - $8,000	$21,300 - $30,800	6%	$1,150	$44,300 - $53,800	60%	55%	0.2 - 0.2	1.4 - 1.6	$ 11,075 - $ 13,450	$ 12,300	$ 1,557 - $ 1,702	$ 1,700
		Replace Drainage Structure	1 EA	$10,000 EA	$10,000														
12	11 & 12 Strawberry Lane, Stratham, I	Retrofit Existing Swales (400 LF)	1600 CF	$8 CF	$12,800	$15,000 - $21,600	$5,300 - $7,600	$20,300 - $29,200	6%	$1,100	$42,300 - $51,200	20%	25%	0.2 - 0.3	2.1 - 2.3	$ 10,575 - $ 8,533	$ 9,500	$ 1,022 - $ 1,113	$ 1,100
13	Domain Drive at Timberland Entrance, Stratham, NH	Vegetative Swale (60 LF)	240 CF	$8 CF	$1,920	$2,200 - $3,200	$800 - $1,100	$3,000 - $4,300	6%	$150	$6,000 - $7,300	20%	25%	0.03 - 0.04	0.3 0.4	$ 9,484 - $ 9,441	$ 9,500	$ 966 - $ 962	$ 1,000
14	Cul-de-sac at the end of Marin Way, Stratham, NH	Bioretention Cell (1200 SF)	2400 CF	$10 CF	$24,000	$28,100 - $40,600	$9,800 - $14,200	$37,900 - $54,800	6%	$2,050	$78,900 - $95,800	65%	65%	1.0 - 1.3	8.1 - 9.0	$ 3,945 - $ 3,812	$ 3,900	$ 489 - $ 534	$ 600
15	8 Marin Way, Stratham, NH	Bioretention Cell (1400 SF)	2800 CF	$10 CF	$28,000	$32,800 - $47,300	$11,500 - $16,600	$44,300 - $63,900	6%	$2,400	$92,300 - $111,900	65%	65%	1.2 - 1.5	9.4 - 10.5	$ 3,848 - $ 3,817	$ 3,900	$ 490 - $ 535	$ 600
16	Across from 8 Marin Way, adjacent to Timberland parking area, Stratham, NH	Vegetative Swales (400 LF)	1600 CF	$8 CF	$12,800	$15,000 - $21,600	$5,300 - $7,600	$20,300 - $29,200	6%	$1,100	$42,300 - $51,200	20%	25%	0.2 - 0.3	2.1 - 2.3	$ 10,575 - $ 8,533	$ 9,500	$ 1,022 - $ 1,113	$ 1,100
17	Timberland Parking Lot, across from 8 Marin Way, Stratham, NH	Bioretention Cell (20'x20')	800 CF	$10 CF	$8,000	$9,400 - $13,500	$3,300 - $4,700	$12,700 - $18,200	6%	$700	$26,700 - $32,200	65%	65%	0.3 - 0.4	2.7 - 3.0	$ 3,896 - $ 3,844	$ 3,900	$ 496 - $ 539	$ 600
18	588 Portsmouth Ave., Greenland, NH	Gravel Wetland (200'x50')	20000 CF	$8 CF	$160,000	$187,200 - $270,400	$65,500 - $94,600	$252,700 - $365,000	2%	$4,600	$344,700 - $457,000	64%	85%	8.4 - 10.3	88.0 - 97.7	$ 2,043 - $ 2,216	$ 2,200	$ 196 - $ 234	$ 300

Notes:

1. Sizes of structural BMPs based on initial field reconnaissance and may change during additional engineering design and analysis.
2. Unit costs based on past available current sources including Geosyntec projects and the EPA Opti tool (EPA, 2016).
3. O&M costs were estimated as a percentage of the mean construction costs using percentages published in EPA, 1999. Mean percentage of construction costs include bioretention (6%), infiltration facility (5.5%) and gravel wetland (2%).
4. Capital construction cost includes additional 30% to reflect mobilization, erosion and sediment controls, contingency, etc.
5. Estimated Phosphorus and Nitrogen load (hidden columns AD and AE) is based on the treatment volume of the BMP assuming that larger flows do not receive partial treatment.
6. Engineering costs for survey and design are estimated to be 35% of the capital construction cost.

Appendix A-2: Culvert Improvement Cost Estimates, Winnicut River Watershed Management Plan

Culvert	Location	TNC Culvert ID #	Existing Culvert Size: # of Barrels	Dia. (ft)	Width (ft)	Height (ft)	Length (ft)	Proposed Minimum Culvert Parameters(For costing purposes only): Bankfull Width (ft)	1.2xBF + 2' (ft)	# of Barrels	Dia. (ft)	Width (ft)	Height (ft)	Length (ft)	Length of Stream Restored (Miles)	Capital Cost Estimate (USD): Mean	Lower Cost (0.9*Mean)	Upper Cost (1.3*Mean)	Engineering & Permitting Costs (USD)	Range in Engineering and Construction Costs (USD)		Operation & Maintenance Costs (USD)	20-Year Life Cycle Cost (Present Day Value) (USD)	Cost Per Mile Stream Connectivity (USD/Mile)
A	Adjacent to 93 Exeter Rd. (North Hampton)	38	1		2	2	50	3	5.6	1		6	3	50	0.04	$ 75,000	$ 67,500	$ 97,500	$ 26,300	$ 93,800	$ 123,800	$ 800	**$ 124,800**	**$ 3,120,000**
B	Thompson Brook at Winnicut Road (Greenland)	2	1	6			40	10.6	14.72	2		8	4	40	1.17	$ 150,000	$ 135,000	$ 195,000	$ 52,500	$ 187,500	$ 247,500	$ 1,500	**$ 247,500**	**$ 211,538**
C	Between 128 and 132 Exeter Rd. (North Hampton)	39	1	2.5			50	8	11.6	1		12	2	50	0.05	$ 100,000	$ 90,000	$ 130,000	$ 35,000	$ 125,000	$ 165,000	$ 1,000	**$ 165,000**	**$ 3,300,000**
D	Winnicut River at Winnicut Rd. (Stratham)	12	3		20	10	50	No replacement culvert							4.14	$ 125,000	$ 112,500	$ 162,500	$ 43,800	$ 156,300	$ 206,300	$ 1,300	**$ 207,300**	**$ 50,072**
E	Willow Brook at Willowbrook Ave. (Greenland)	5	1	3			50	10	14	1		14	2	50	0.88	$ 150,000	$ 135,000	$ 195,000	$ 52,500	$ 187,500	$ 247,500	$ 1,500	**$ 247,500**	**$ 281,250**
F	Lovering Lane	20	1	2			50	15	20	2		10	2	50	1.06	$ 225,000	$ 202,500	$ 292,500	$ 78,800	$ 281,300	$ 371,300	$ 2,300	**$ 372,300**	**$ 351,226**

Notes:

1. Costs based on 2010 LD1725 Cost Models from Maine DOT and adjusted based on site specific conditions including fill thickness over culvert, culvert diameter, and road width.
2. Life cycle costs are based on 20 year service life.
3. Engineering and permitting costs are based on 35 percent of the mean capital construction cost.
4. Annual O&M costs are based on 1 percent of the construction costs.
5. Culvert sizes used for cost estimate are based on estimates of bankfull width and the New Hampshire Code of Administrative Rules Chapter Env-Wt 900 (Stream Crossings), which typically require a minimum of 1.2 x bankfull width plus 2 feet.

APPENDIX B:

Linear Optimization Model for Cost-Effective Structural Stormwater Management Practices (Task 17), Winnicut River Watershed Restoration and Management Plan

MEMORANDUM

DATE:	June 2, 2017
TO:	Michele L. Tremblay, President, Board of Directors New Hampshire Rivers Council
FROM:	Renee L. Bourdeau, PE, Horsley Witten Daniel H. Bourdeau, PE, Geosyntec
SUBJECT:	Linear Optimization Model for Cost-Effective Structural Stormwater Management Practices (Task 17), Winnicut River Watershed Management Plan

The purpose of this memorandum is to identify cost-effective structural stormwater best management practices (BMP) and associated land use combinations to achieve the greatest nitrogen and phosphorus load reduction to meet target water quality goals. To identify these practices, a linear optimization (LO) model developed as part of the Water Integration for the Squamscott Exeter River Watershed project (WISE; Geosyntec, 2015) was utilized. The WISE LO model evaluated a series of low impact development (LID) structural stormwater best management practices (BMPs) based on their cost and nutrient load reduction to determine the most cost-effective strategies to meet load reduction targets. The WISE LO model and its inputs are based on the most recent and best available region-specific data, and as such are applicable to the Winnicut River Watershed. Model inputs include BMP nitrogen load reductions that were generated using local rainfall data from Durham, New Hampshire. Phosphorus load reductions are based on BMP performance curves developed from USEPA Region 1 research conducted for the Charles River Watershed in Massachusetts and recently (2016) incorporated into the Massachusetts Small MS4 General Permit.

BACKGROUND

A linear optimization model uses a series of linear equations to minimize or maximize a given function. The model consists of the objective function (the mathematical relationship being optimized) and a set of constraints (equations describing the physical limits and/or minimum required performances of the system being modeled). The objective function of the LO model is a function that describes the total cost of a given BMP with the goal of minimizing the cost for the maximum nitrogen and phosphorus load reductions.

Several variables are needed to run the LO model and determine the most cost effective combination of BMPs to provide the maximum nitrogen and phosphorus load reduction. These variables are summarized and presented in Table 1. This analysis focuses on the application of structural stormwater BMPs to treat stormwater runoff from impervious surfaces, which typically generate greater pollutant loads than pervious land cover. Although it is sometimes appropriate to apply structural BMPs to pervious land cover, these areas may be more appropriate for non-structural BMPs such as fertilizer reduction, pet waste programs, street sweeping, catch basin maintenance, improved buffer zones, regulatory tools such as municipal bylaws, etc.

Table 1. Linear Optimization Model Inputs

Variable	Description
Land Use Types	Impervious Cover: Residential, Commercial, Industrial, Institutional, Outdoor, and Transportation
Land Use Area	Area of each land use type within the watershed.
Stormwater Structural BMPs	Permeable Pavement, Sand Filter, Subsurface Infiltration, Tree Box Filter, Bioretention, High Efficiency Bioretention, Infiltration Trench, Wet Pond, Gravel Wetland, Infiltration Trench and Dry Well
BMP Capture Depth	Volume the BMP is sized to capture or treat. Lower bound = 0.25 inches; Upper bound = 1.50 inches; Evaluated at 0.25 inch increments.
BMP Pollutant Load Reduction	Pounds of nitrogen or phosphorus removed by BMP and capture depth. Varies based on literature values.
BMP Cost	Capital cost of BMP based on capture depth.

RESULTS

Nitrogen Results

Figure 1 presents the cost per pound of nitrogen removed by each stormwater structural BMP, which is based on modeling completed as part of the WISE project. The modeling effort consisted of modeling 1-acre representative parcels for each land use type, which generated an annual stormwater nitrogen load based on 20-years of local precipitation data. The representative parcel pollutant load was routed through each combination of structural BMP type (Table 1) and capture depth (Figure 1), designed and sized in accordance with the New Hampshire Stormwater Manual (2008), to determine the pounds of nitrogen removed by the BMP. Costs were estimated based on literature values (RS Means) and engineering judgment. The range in costs in Figure 1 represent the varied capture depths of the BMP, with the lower bound of the bar representing 0.25 inches and the upper bound of the bar representing 1.50 inches. The values range from $305 per pound of nitrogen removed (infiltration trench) to $21,000 per pound removed (sand filter). This figure demonstrates which BMPs are most cost-effective at removing nitrogen.

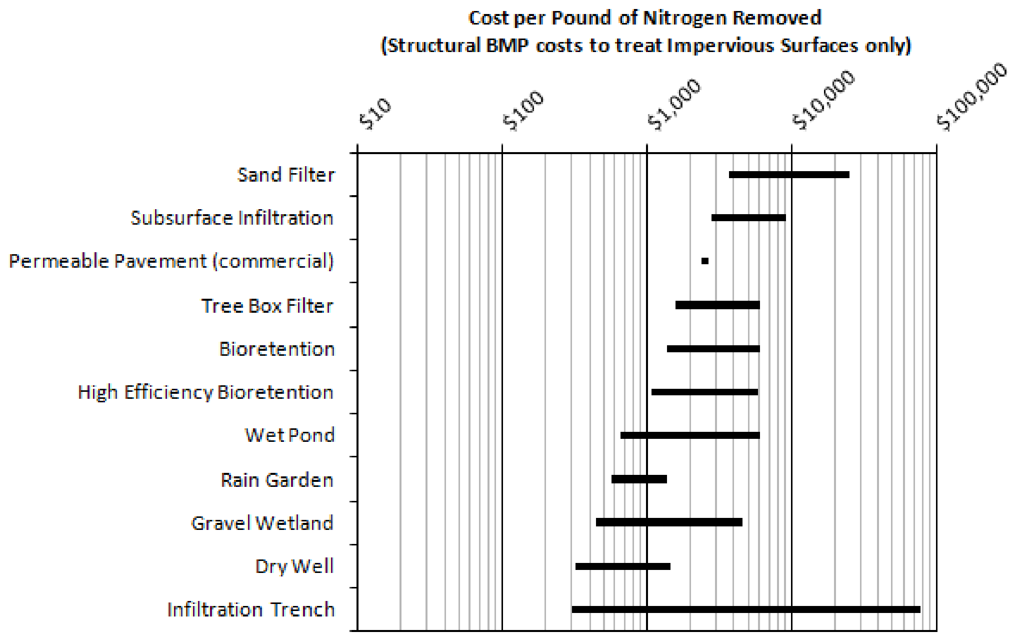


Figure 1. Cost per Pound of Nitrogen Removed by BMP. Length of bar is based on the range in capture depth.

Table 2 presents the most cost effective BMP by impervious land use type, based on modeling completed as part of the WISE project.. These BMP and land use combinations would provide the most cost-effective means to removing nitrogen within the Winnicut River watershed. However, while the smallest BMPs may be the most cost-effective at treating 1-acre, they may not provide enough treatment sufficient to meet water quality goals within the watershed.

Table 2. Most Cost-Effective BMP by Impervious Land Use Type to Remove Nitrogen

Impervious Land Use Type	Structural BMP	Capture Depth (inches)	Nitrogen Removed (lbs/ac)	Cost per Pound N Removed
Residential	Dry Well	0.25	12.5	$319
Commercial	Infiltration Trench	0.25	9.5	$420
Industrial	Infiltration Trench	0.25	9.5	$420
Institutional	Infiltration Trench	0.25	13.1	$305
Outdoor	Infiltration Trench	0.25	8.2	$485
Transportation	Gravel Wetland	0.25	8.5	$693

The LO model was applied to determine the most cost-effective land use and BMP combinations to achieve the Winnicut River annual nitrogen load water quality target of 24.3 tons (48,600 pounds), equivalent to an in-stream concentration of 0.45 mg/L. As presented in Section 3 of the Winnicut River Watershed Management Plan (Geosyntec, 2017), the total current nitrogen load delivered from all watershed sources (i.e., stormwater, septic systems, groundwater) is 30.4 tons (60,800 pounds). To meet the annual nitrogen loading goal of 24.3 tons/year, a total load reduction of 6.1 tons (12,200 pounds) would be needed, which equals a 20 percent reduction. Since the focus of the LO model is on stormwater structural BMPs, a 20 percent reduction in the current stormwater load (22,600 pounds) would be a reduction of approximately 4,520 pounds. The LO model was set up for a target load reduction of 4,520 pounds of nitrogen per year to determine the most cost-effective suite of structural stormwater BMPs to achieve this reduction. Table 3 presents the results of the LO model run. A 4,520 pound/year reduction of nitrogen through implementation of stormwater structural BMPs would require treatment of 94 percent (427 acres) of impervious cover in the watershed. This treatment would have an estimated cost of $2.95 million dollars, or an estimated average cost of $652 per pound of nitrogen removed. This analysis assumes that all 455 acres of impervious cover within the watershed have the ability to be retrofit with a structural BMP and that site conditions are suitable. Because these assumptions do not always hold true, this value should be considered as a planning level value and the cost to implement may be far greater.

Table 3. Linear Optimization Model Most Cost-Effective Structural Stormwater BMPs to Meet Nitrogen Water Quality Target

Impervious Land Use	Total Area (ac)	Suggested Practice and Capture Depth	Treated Area (ac)	Cost to Treat (MIN)**	N Removed (lbs/yr)	% Acres Treated
Commercial	56	Infiltration Trench 0.50"	56	$ 392,000	635	100%
Industrial	10	Infiltration Trench 0.50"	10	$ 71,900	117	100%
Institutional	47	Infiltration Trench 0.50"	47	$ 313,300	649	100%
Outdoor	6	Infiltration Trench 0.25"	6	$ 24,500	50	100%
Residential	81	Drywell 0.75"	81	$ 807,400	1,142	100%
Transportation	255	Gravel Wetland 0.25"	226	$ 1,335,800	1,928	89%
TOTAL	**455**		**427**	**$ 2,944,900**	**4,520**	**94%**

Note: Structural BMPs are limited to the most cost-effective BMP for each impervious land use to meet the treatment target. The most cost-effective BMP was not always chosen, because it did not provide enough treatment to meet the nitrogen load reduction target.

Phosphorus Results

Figure 2 presents the cost per pound of phosphorus removed by each stormwater structural BMP. Similar to Figure 1, the range in costs in Figure 2 represent the varied capture depths of the BMP, with the lower bound of the bar representing 0.25 inches and the upper bound of the bar representing 1.50 inches. The values range from $4,300 per pound of phosphorus removed (dry well) to $163,400 per pound removed (permeable pavement). This figure demonstrates which BMPs are most cost-effective at removing phosphorus.

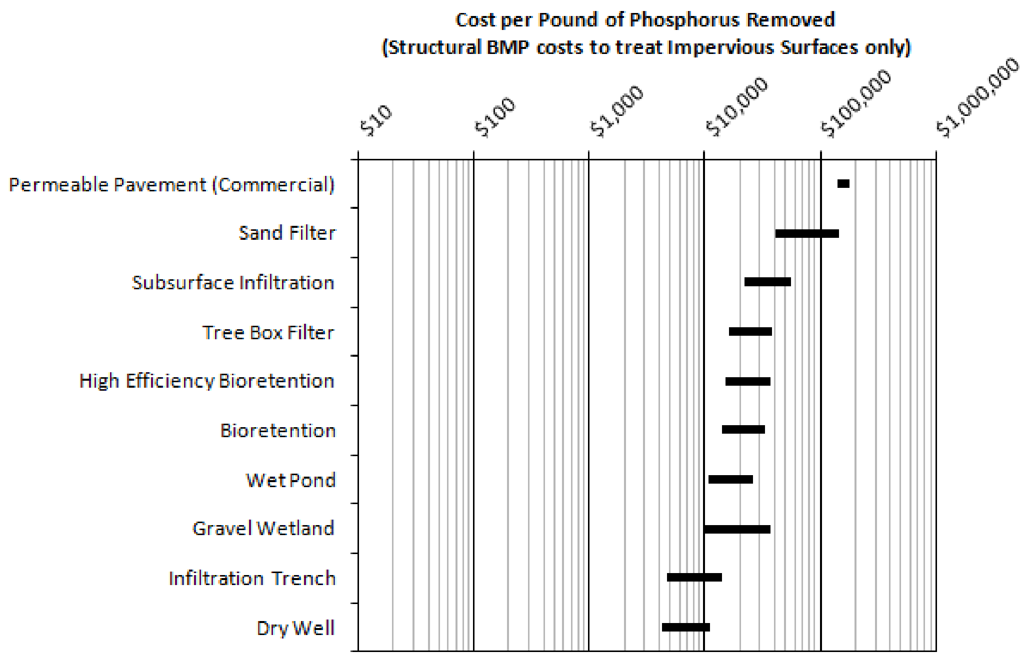


Figure 2. Cost per Pound of Phosphorus Removed by BMP. Length of bar is based on the range in capture depth.

Table 4 presents the most cost effective BMP by impervious land use type for phosphorus removal. These BMP and land use combinations would provide the most cost-effective means to removing phosphorus within the Winnicut River watershed. However, while the smallest BMPs may be the most cost-effective at treating 1-acre, they may not provide enough treatment sufficient to meet water quality goals within the watershed.

Table 4. Most Cost-Effective BMP by Impervious Land Use Type to Remove Phosphorus

Impervious Land Use Type	Structural BMP	Capture Depth (inches)	Phosphorus Removed (lbs/ac)	Cost per Pound P Removed
Residential	Dry Well	0.25	0.9	$4,300
Commercial	Infiltration Trench	0.25	0.9	$4,700
Industrial	Infiltration Trench	0.25	0.9	$4,700
Institutional	Infiltration Trench	0.25	0.9	$4,700
Outdoor	Infiltration Trench	0.25	0.7	$5,500
Transportation	Gravel Wetland	0.25	0.5	$11,500

The LO model was applied to determine the most cost-effective land use and BMP combinations to achieve the selected Winnicut River phosphorus water quality target of 0.027 mg/L. Achieving this target would require a 25 percent reduction from the current median concentration of 0.036 mg/L. As presented in Section 3 of the Winnicut River Watershed Management Plan (Geosyntec, 2017), the total current phosphorus load delivered from stormwater is 2,284 pounds. A 25 percent reduction in the current load would require the removal of approximately 571 pounds of phosphorus through the implementation of structural or non-structural stormwater BMPs. Since the focus of the LO model is on stormwater structural BMPs, the LO model was set up for a target load reduction of 571 pounds of phosphorus per year to determine the most cost-effective suite of structural stormwater BMPs to achieve this reduction. Table 5 presents the results of the LO model run.

Table 5. Linear Optimization Model Most Cost-Effective Structural Stormwater BMPs to Meet Phosphorus Water Quality Target

Impervious Land Use	Total Area (ac)	Suggested Practice and Capture Depth	Treated Area (ac)	Cost to Treat (MIN)**	P Removed (lbs/yr)	% Acres Treated
Commercial	56	Infiltration Trench 1.25"	56	$ 1,079,100	94	100%
Industrial	10	Infiltration Trench 1.25"	10	$ 194,300	17	100%
Institutional	47	Infiltration Trench 1.25"	47	$ 973,100	79	100%
Outdoor	6	Infiltration Trench 1.0"	6	$ 88,400	8	100%
Residential	81	Drywell 1.50"	81	$ 1,611,500	153	100%
Transportation	255	Gravel Wetland 1.0"	238	$ 5,595,600	220	93%
TOTAL	**455**		**438**	**$ 9,542,000**	**571**	**96%**

Note: Structural BMPs are limited to the most cost-effective BMP for each impervious land use to meet the treatment target. The most cost-effective BMP was not always chosen, because it did not provide enough treatment to meet the phosphorus load reduction target.

A 571 pound per year reduction of phosphorus through implementation of stormwater structural BMPs would require treatment of 96 percent (438 acres) of impervious cover in the watershed. This treatment would have an estimated cost of $9.54 million, with an estimated average cost of $16,720 per pound of phosphorus removed. This analysis assumes that all 455 acres of impervious cover within the watershed have the ability to be retrofit with a structural BMP and that site conditions are suitable. Because these assumptions do not always hold true, this value should be considered as a planning level value and the cost to implement may be far greater.

CONCLUSIONS

The LO model demonstrates that a 20 percent reduction in annual stormwater nitrogen load could be achieved through the implementation of structural stormwater BMPs, at an estimated cost of $651 per pound of nitrogen removal. To achieve this nitrogen load reduction, treatment of nearly all of the imperious cover within the watershed would be required, which is likely to be impracticable. Achieving a 25 percent annual load reduction in phosphorus would require the treatment of 96 percent of the total impervious cover in the watershed, at an estimated cost of $16,720 per pound of phosphorus removal. Additional strategies, such as non-structural stormwater BMPs (e.g., fertilizer reduction, pet waste programs, street sweeping, catch basin maintenance, improved buffer zones, regulatory tools such as municipal ordinances, etc.), are likely to be an important components of a comprehensive approach to reducing nutrient loads in the watershed, to meet water quality targets.

REFERENCES

Geosyntec Consultants. 2015. *Water Integration for the Squamscott Exeter (WISE) River Watershed: Pollutant Load Modeling Report.* April 2015.

Geosyntec Consultants. 2017. *Winnicut Watershed Based Plan.* June 2017.