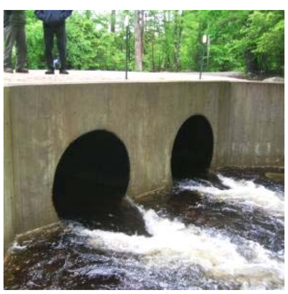
Pawtuckaway Lake
Storm Water Management Assessment

MAY 2007

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1. INTRODUCTION

1.1 Summary of Scope

Geosyntec Consultants, Inc. (Geosyntec) was contracted by the New Hampshire Department of Environmental Services (NHDES) to conduct a document review, field investigations and model pollutant loading to provide a preliminary assessment of potential storm water management improvements within the Pawtuckaway Lake watershed (Watershed). The Watershed is located in the town of Nottingham, NH and includes Pawtuckaway Lake State Park.

Geosyntec reviewed Watershed-related reports that were provided by the NHDES and Pawtuckaway Lake Association (PLA) to help identify sources of phosphorus pollution within the Watershed. Sources of sediment were also considered as studies have shown that there is a strong correlation between sediment and phosphorus levels in storm water runoff. The relevant findings of the reports are summarized in Section 1.1 below.

Bob Hartzel (Senior Water Resources Scientist) and Daniel Bourdeau (Water Resources Engineer) of Geosyntec conducted a field investigation of the Watershed on 8 June 2006. A follow up field investigation was performed by Mr. Hartzel on 13 October 2006. During the field investigations, Geosyntec identified several sites that were potential sources of pollutants and potential sites for implementing storm water best management practices (BMPs) and improvements. A description of the sites identified during field investigations and recommended improvements are presented in Section 3.0. Generic descriptions of recommended BMP improvements that may be implemented at specific sites within the Watershed are provided in Section 2. An aerial orthophoto map of the Watershed with the locations of sites described in Section 3.0 is provided as Exhibit A. A topographical map of the Watershed with subwatershed boundaries is provided as Exhibit B.

Geosyntec also conducted land-use based phosphorus export modeling for fifteen subwatersheds within the Watershed (Exhibit B). The land-use based modeling included an evaluation of phosphorus export from on-site sanitary septic systems located within the Watershed. The results of the land-use export modeling were used to prioritize watershed improvements based on areas with the highest predicted P export. For example, a subwatershed that is adjacent to the Lake and has a high predicted phosphorus export would be a high priority subwatershed for improvement. Conversely, a subwatershed that has a lower phosphorus export and is not adjacent to the lake would be a low priority subwatershed for improvement. In addition, land-use-based export models were used to evaluate the total load of phosphorus expected to be removed by each recommended BMP or improvement. These modeling results were also used to prioritize the sites based on which BMPs or improvements would have high expected removal rates. A summary of the land-use based modeling is provided in Section 2. The combined field investigations and modeling results were used to prioritize the sites described in Section 3.

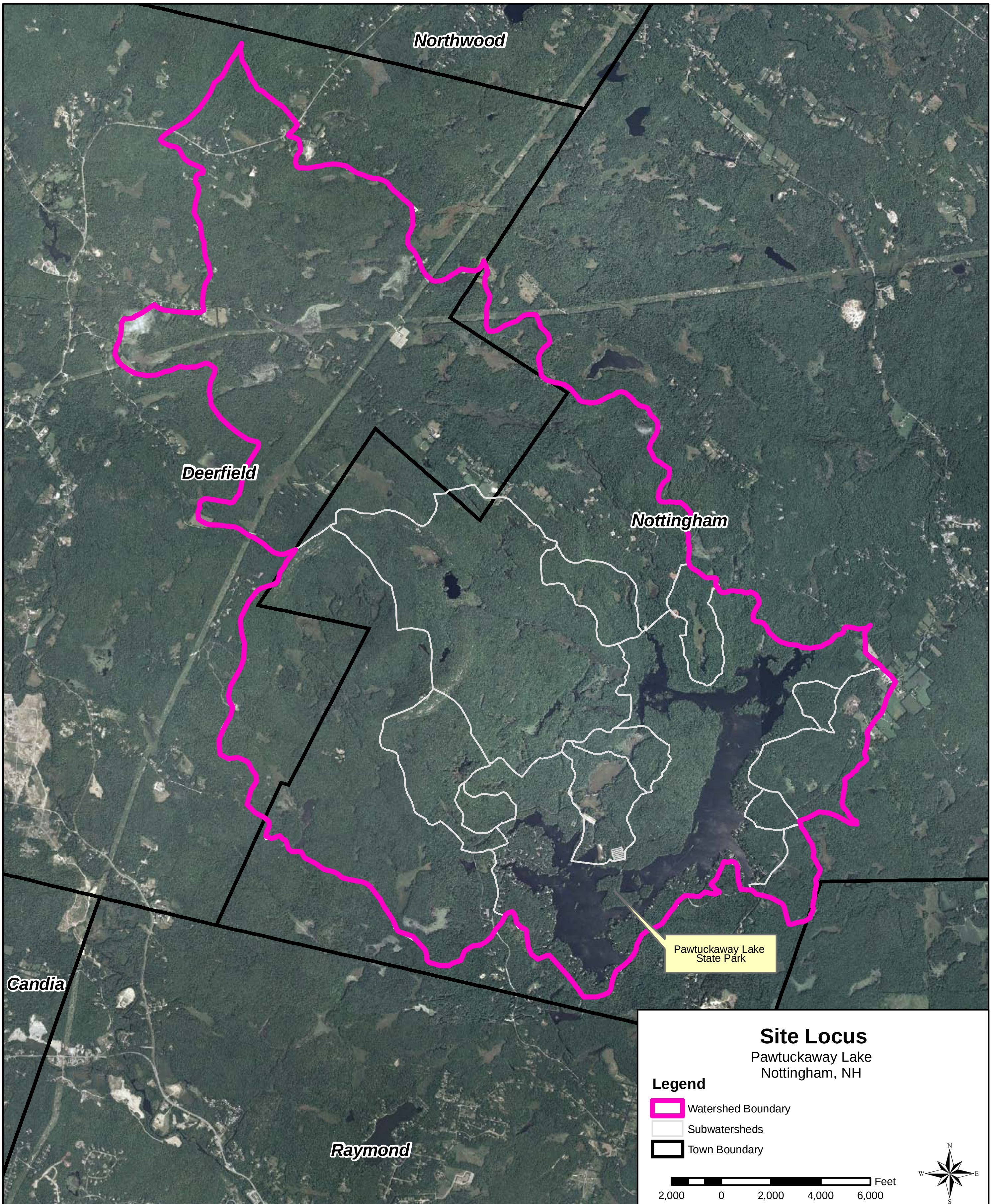
1.2 Document Review Summary

The following documents were reviewed and a summary of findings and recommendations relative to phosphorus and sediment loading to Pawtuckaway Lake and tributaries are presented below.

- New Hampshire Department of Environmental Services, Volunteer Lake Assessment Program, 2003 Biennial Report for Pawtuckaway Lake, Nottingham.
    - The most critical factor in measuring the water quality of New Hampshire lakes is the amount of phosphorous in the water.
    - Decreasing the amount of phosphorous in a lake will also decrease the alga that naturally grows in the lake.
    - When in-lake phosphorous levels increase, the possibility of algal blooms and unnecessarily high plant growth also increases.
    - Some possible sources of phosphorous near a lake may be septic systems, waste from animals, run-off from lawns around the lake (especially when fertilizers are used), erosion from unpaved roads, construction site runoff and natural wetlands.
    - Increased phosphorous levels in a lake may also be caused by a release of insoluble phosphorus to the water column from lake bed sediments during very low in-lake dissolved oxygen levels (i.e., anoxic conditions).
    - Volunteer Lake Assessment Program recommended that one of the keys to reducing the amount of phosphorous loading to a lake is to educate the residents of the watershed about the sources of phosphorous and that increasingly the amount of phosphorus in a lake can result in negative ecological effects and reduce the value of the lake and adjacent properties.

- New Hampshire Department of Environmental Services, Water Supply and Pollution Control Division, Pawtuckaway Lake Diagnostic/Feasibility Study, Final Report, June 1995.
    - The purpose of the diagnostic study was to determine sources of phosphorous and identify the paths entering Pawtuckaway Lake.
    - The purpose of the feasibility study was to assess watershed BMPs that could decrease the phosphorous loading into the lake and any possible lake restoration techniques that could be implemented to mitigate degraded lake quality.
    - The study identified Pawtuckaway Lake as a typical dimictic lake exhibiting thermal stratification into three layers during the summer months and mixing completely during the spring and fall overturns each year. The study also identified that during the summer months, the hypolimnion exhibited anoxic or very low dissolved oxygen conditions. Total phosphorus concentrations were elevated in the hypolimnion and increased as the summer progressed, indicating internal phosphorus loading occurs in the lake.
    - Trophic state models concluded that Pawtuckaway Lake could be classified as being in the oligotrophic/mesotrophic state.

- Water quality sampling concluded that the hypolimnion in the north portion of the lake exhibited the highest in-lake total phosphorous concentrations.
- The study identified that tributaries contribute the greatest inflow to the lake and represent 74.5% of Pawtuckaway's inputs of the hydrologic budget.
- This study determined that tributaries were the largest contributor of phosphorous loading representing 45% of the total phosphorus load to the lake. The primary tributaries that contribute the majority of this load are Back Creek B representing 33%, Mountain Cove Brook representing 24%, and Round Pond Brook representing 16% of the total phosphorous loading from tributaries. The study indicated that Fernalds Brook A is not a significant source of the hydrologic budget to the lake, however, represents 11% of the phosphorus loading from tributaries.
- Maximum seasonal tributary phosphorus concentrations were recorded in Fernalds Brook A during the winter, spring, summer and fall.
- The amount of phosphorous loading estimated from septic systems located adjacent to the lake was determined through concentrations measured in the groundwater phosphorous. The study concluded that 48% of the septic systems surrounding Pawtuckaway Lake require repair and may be a contributor to phosphorus loading to the lake.
- The study identified that other sources of phosphorous to the lake include direct surface runoff from areas immediately adjacent to the lake contributing 21%, septic system leachate/groundwater recharge contributing 20%, and atmospheric inputs (i.e., wind transport and deposition) representing 14% of the total external phosphorus load.



Site Locus
Pawtuckaway Lake
Nottingham, NH

Legend
Watershed Boundary
Subwatersheds
Town Boundary

Feet
2,000 0 2,000 4,000 6,000

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ACTON, MASSACHUSETTS

FIGURE NO. 1	
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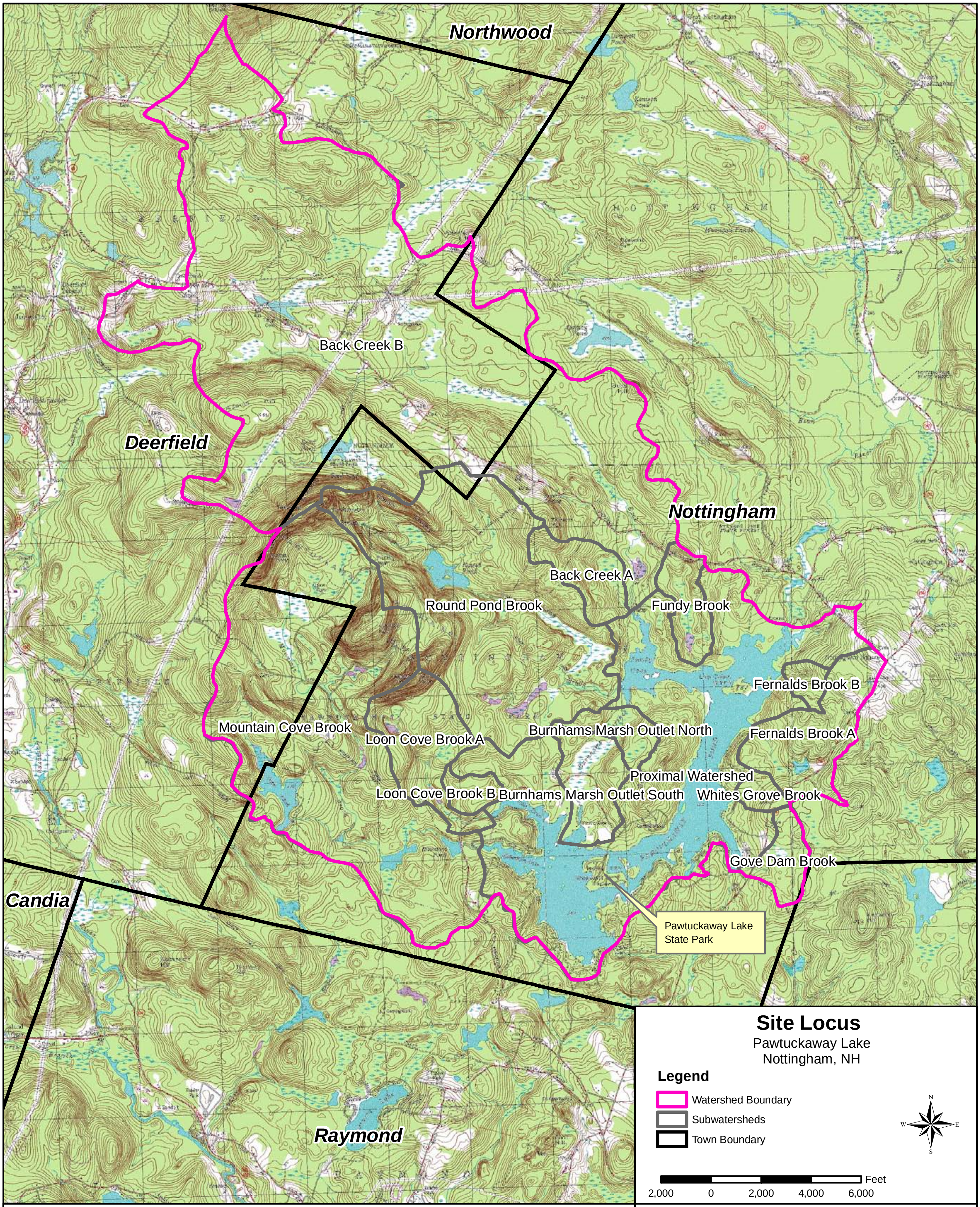

Site Locus

Pawtuckaway Lake
Nottingham, NH

Legend

- Watershed Boundary
- Subwatersheds
- Town Boundary

Feet: 2,000 0 2,000 4,000 6,000

Geosyntec consultants
ACTON, MASSACHUSETTS

FIGURE NO. 2	
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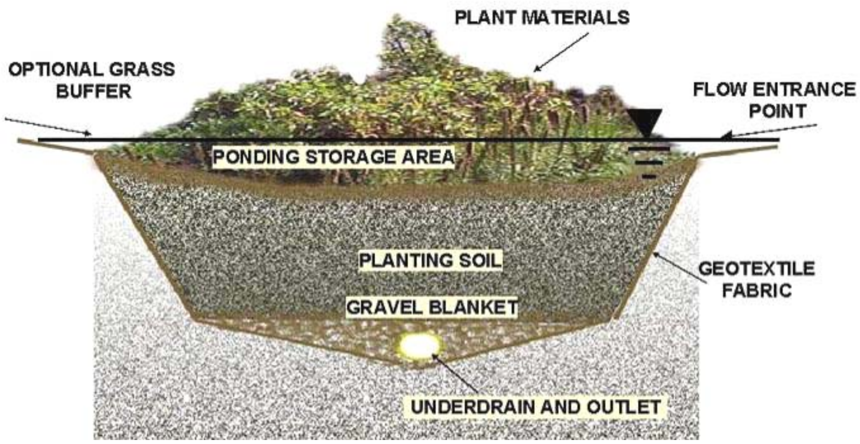
2. DESCRIPTION OF STORM WATER BEST MANAGEMENT PRACTICES

Storm water best management practices (BMPs), including Low-Impact Development (LID) techniques, are management approaches that reduce storm water impacts through a variety of small-scale techniques that are distributed throughout a watershed. LID techniques aim to *mimic pre-development hydrology* by using small-scale practices that infiltrate, evaporate and transpire storm water. Examples of LID techniques include bioretention cells, rain gardens, and vegetated filter strips. These techniques can be incorporated directly into the design of new developments, or can be retrofit into existing developed areas, often replacing or enhancing direct pipe discharges to water bodies such as Pawtuckaway Lake. Examples of other storm water management BMPs include unpaved road management and stabilization techniques. The sections below provide a general description of BMPs and LID improvements that are recommended for use at specific sites within the Watershed as described in Section 3.0.

2.1 Bioretention Cells/Rain Gardens

Bioretention cells are shallow landscaped depressions that incorporate plantings and an engineered soil mixture with a high infiltration rate. Bioretention cells are used to: control storm water runoff volume by providing storage capacity; reduce peak discharge by increasing the travel time of storm water through a watershed; and remove pollutants through physical, chemical and biological processes that occur in the plants and soil media. Storm water that drains into a bioretention cell accumulates in a shallow depression and then infiltrates the engineered soil mixture. Bioretention cells are typically designed to provide an infiltration rate approximately equal to the peak discharge rate associated with the 10-year, 24-hour design storm event. Infiltration rates are enhanced during the growing season by uptake from vegetation (i.e., evapotranspiration) within the cell.



A cross-section of a typical bioretention cell.

Installed costs for engineering, materials and construction of a typical bioretention cell are estimated between $3,000 (for a small individual shallow cell) up to $30,000 (for a large retrofit cell that involves significant earth work). The installed costs also depend on site-specific requirements. Pre-fabricated bioretention cells (e.g., Filterra™) can treat storm water runoff from an area up to 0.25-acres and cost approximately $7,000 each (installed cost).

Rain gardens are small-scale bioretention cells. Rain gardens are shallow vegetated depressions designed to capture and infiltrate storm water runoff. Rain gardens are often appropriate for residential developments, to treat storm water from impervious areas associated with individual lots. The total installed cost of a typical rain garden is approximately $2,000 to $4,000, depending on garden size, soil conditions, type of plantings used, and other site-specific requirements.

A rain garden installed on a residential property.

2.2 Unpaved Road Best Management Practices

Unpaved roads, if not properly managed, can be a significant contributor of non-point source pollution. Structural BMP techniques and preventative maintenance practices can reduce unpaved road erosion and improve downstream water quality while potentially reducing the cost of road maintenance. Storm water or surface water accumulated on or adjacent to unpaved roads can create an unstable road bed, resulting in rutting, potholes, shoulder erosion, washouts, and clogged culverts. Poor drainage can also result in sediment deposits at culverts and in ditches and cause flooding. In addition, erosion of unpaved roads can result in sediment loads to downstream receiving waters. Unpaved road BMPs and preventative maintenance practices include:

- **Surface Grading** is one of the most important aspects of maintaining a gravel road surface. Surface grading is conducted to preserve and maintain a proper road crown for good drainage. When grading, maintain a safe distance (minimum one foot) from the ditch so that vegetation or rock ditch stabilization is not disturbed.

- **Shoulder Maintenance** is an important unpaved road management practice to maintain proper drainage of storm water from the traveled portion of the road to the side slope and into ditches. The shoulder should help separate the traveled way from the side slopes and ditches. The shoulder should be kept clear of vegetation so that water can freely drain from traveled portions into adjacent ditches.

- **Storm Water Ditches** are used to convey storm water runoff from the shoulders to an outlet without causing erosion or sedimentation. Ditches should be properly lined (e.g., rock or vegetation) to prevent erosion. Regular maintenance should be performed to keep ditches clear and stable, and maintain the original capacity.

- **Culverts** are closed conduits (e.g., pipes) typically used to convey storm water across unpaved roads. Culverts are important in preserving the road base by draining water from road side ditches and thereby keeping the road sub-base dry. Culverts should be inspected on a regular basis. The inlets and outlets of culverts should be protected by marking their location, stabilizing, and maintaining ditch linings (both up gradient and down gradient of culverts) to prevent erosion and clogging.

- **Bank Stabilization** is the vegetative or structural means used to prevent erosion and failure of any side slope or bank. Unpaved road banks should be carefully evaluated before selecting stabilization techniques. Vegetation should be used whenever possible as a cost-effective way to stabilize banks. Additionally, recently stabilized banks should be regularly maintained and inspected to ensure that adequate stabilization is established.

2.3 Stone Infiltration Trenches

Infiltration trenches are typically deep stone filled trenches lined with a non-woven geotextile. The base of the trench can be stepped to maximize storage capacity and promote infiltration. Infiltration trenches are used to: control storm water runoff volume by providing storage capacity; promote infiltration; and remove sediment and associated pollutants through filtration. Storm water that drains to an infiltration trench either infiltrates the stone immediately or flows on the stone surface a short distance before infiltrating. Storm water then filters through the stone and percolates to the base. The storm water then infiltrates the existing subsurface and recharges the aquifer.

A stone-filled infiltration trench constructed to intercept runoff from the adjacent road.

Infiltration trenches are typically designed to provide an infiltration rate approximately equal to the peak discharge rate associated with the 10-year, 24-hour design storm event. Infiltration trenches typically include a maintenance stone layer at the top of the trench that can be easily removed, cleaned and replaced.

The installed cost for engineering, materials and construction of a typical infiltration trench is estimated between $200 to $800 per linear foot of trench, depending on trench size, material and site-specific requirements.

3. WATERSHED ASSESSMENT AND RECOMMENDATIONS

Geosyntec conducted an assessment of the Watershed including modeling and field investigations to identify potential sites for storm water improvements. Modeling was done using a land-use based pollutant model and included estimating subwatershed pollutant loads, phosphorus load due to on-site septic systems and BMP load reductions. The modeling results were used in conjunction with observations made during the site investigation to identify potential sites for storm water improvements. These results were also used to prioritize the proposed improvements. Below is a description of the modeling, field investigation and site prioritization.

3.1 Land-Use Based Pollutant Modeling

Geosyntec conducted land-use based modeling to estimate annual phosphorus export from fifteen subwatersheds within the Watershed (Exhibit B). The National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land-use data was used to represent the current Watershed's land-use condition. C-CAP data was the most recently published land-use data available for public use. Land-use pollutant export coefficients (represented in lbs/acre-yr) were derived from New Hampshire GIS data (GRANIT) information.

Table 1: Phosphorus Export Coefficients by Land Use Category

C-CAP Land Use Code	Cover Type	Phosphorus Export Coefficient (lbs/ac-yr)
2	High-Intensity Developed	0.446
3	Low-Intensity Developed	0.446
4	Cultivated Land	0.535
5	Grassland	0.535
6	Deciduous Forest	0.178
7	Evergreen Forest	0.178
9	Scrub/Shrub	0.178
10	Palustrine Forested Wetland	0.045
11	Palustrine Scrub/Shrub Wetland	0.045
12	Palustrine Emergent Wetland	0.045
13	Estuarine Forested Wetland	0.045
14	Estuarine Scrub/Shrub Wetland	0.045
15	Estuarine Emergent Wetland	0.045
17	Bare Land	0.446
18	Water	0.000
19	Palustrine Aquatic Bed	0.000
20	Estuarine Aquatic Bed	0.000
21	Tundra	0.000

Land use based exports are an average measure of pollutant export and are typically reported for specific land use categories. These data were used in a land-use based pollutant model to predict annual phosphorus loading from the Watershed. The area of each land cover type is shown below in Table 2. A table summarizing the results of the land-use loading model is provided in Table 3 below.

Table 2: Subwatershed Land Cover Areas (all values in acres)

	Proximal Watershed	Burnham's Marsh Outlet South	Loon Cove Brook B	Burnham's Marsh Outlet North	Fundy Brook	Fernalds Brook B	Gove Dam Brook	Mountain Cove Brook	Back Creek B	Whites Grove Brook	Round Pond Brook	Fernalds Brook A	Loon Cove Brook A	Back Creek A
High-Intensity Development	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Low-Intensity Developed	0.3	2.8	0.0	0.0	0.0	0.0	0.0	1.1	6.1	0.0	0.0	0.8	0.0	0.0
Cultivated Land	5.9	1.1	0.0	0.0	0.0	0.0	0.1	2.4	21.2	0.0	0.0	1.5	0.1	0.0
Grassland	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.8	0.0	0.0	0.0	0.0	0.0
Deciduous Forest	3.6	0.0	0.0	0.0	0.0	0.0	0.0	2.0	26.7	0.0	0.0	2.1	0.0	0.0
Evergreen Forest	8.2	2.2	0.0	0.7	0.4	0.0	1.2	6.0	260.9	0.0	15.6	37.9	1.4	0.4
Mixed Forest	1.8	0.0	0.0	0.0	0.4	0.0	0.0	1.8	20.2	0.0	0.4	0.7	117.1	0.4
Scrub/Shrub	299.5	7.2	7.4	10.8	19.1	8.2	20.3	429.6	656.9	13.2	413.9	62.5	126.3	71.9
Palustrine Forested Wetland	623.0	97.9	24.2	37.3	57.3	13.1	27.5	824.0	1163.6	7.0	449.1	89.2	94.3	33.1
Palustrine Scrub/Shrub Wetland	565.3	65.5	33.1	41.5	59.3	33.4	68.2	844.8	2322.5	32.7	632.3	159.8	3.7	76.6
Palustrine Emergent Wetland	40.9	6.2	0.0	2.7	3.6	0.0	2.1	58.8	202.9	0.0	35.6	10.3	4.5	2.1
Estuarine Forested Wetland	28.5	0.9	4.3	7.6	8.9	0.0	1.9	28.3	161.7	0.9	27.0	7.9	1.5	3.0
Estuarine Scrub/Shrub Wetland	10.0	32.7	0.0	3.5	4.4	0.0	5.0	33.2	78.8	0.0	24.9	0.4	2.4	0.4
Estuarine Emergent Wetland	9.5	1.5	0.0	3.1	0.4	0.0	0.0	40.3	46.6	0.0	15.9	0.4	0.0	0.0
Bare Land	1.0	0.7	0.0	0.9	0.0	0.0	0.2	0.4	3.6	0.0	0.0	0.2	0.0	0.0
Water	0.9	0.4	0.0	0.4	0.0	0.0	0.4	3.3	17.6	0.0	2.9	1.6	3.3	0.0
Palustrine Aquatic Bed	753.2	10.4	0.0	3.9	1.1	0.0	0.0	25.5	41.1	0.0	22.4	1.1	0.0	0.0
Estuarine Aquatic Bed	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0
Tundra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0

Table 3: Subwatershed Pollutant Loading Summary

Subwatershed	**Area** (acres)	**Estimated Annual Phosphorus Load** (lbs/yr)		**Estimated Annual Phosphorus Load** (kg/yr)	
		Total	**Per Acre**	**Total**	**Per ha**
Back Creek A	188	18	0.10	8	0.11
Loon Cove Brook A	355	32	0.09	14	0.10
Round Pond Brook	1640	130	0.08	59	0.09
Fernalds Brook A	376	32	0.08	14	0.09
Whites Grove Brook	54	4	0.08	2	0.09
Back Creek B	5033	366	0.07	166	0.08
Mountain Cove Brook	2302	162	0.07	74	0.08
Gove Dam Brook	127	9	0.07	4	0.08
Burnham's Marsh Outlet South	233	15	0.06	7	0.07
Fundy Brook	155	10	0.06	4	0.07
Burnham's Marsh Outlet North	112	7	0.06	3	0.07
Loon Cove Brook B	69	4	0.06	2	0.07
Fernalds Brook B	55	10	0.06	2	0.07
Proximal Watershed	2354	118	0.05	53	0.06
Pawtuckaway Lake Watershed	13053	908	0.07	412	0.08

The land-use based pollutant loading model provides a tool for estimating and comparing (1) total annual pollutant loads (in pounds per year and kilograms per year) and (2) annual pollutant load rates normalized to the watershed area (in pounds per acre per year and kilograms per hectare per year) for each subwatershed within the Watershed. This type of land-use model cannot be used to accurately predict in-lake conditions (e.g., in-lake total phosphorus concentrations) because it does not reflect site-specific land management practices or other variables such as internal nutrient recycling, lake volume, etc. However, the land-use pollutant loading model estimates do provide a useful comparative measure of the relative impact that each subwatershed has on lake water quality, and therefore are a useful tool to prioritize sites for watershed improvements.

A brief summary of the land-use pollutant loading model results for each of the subwatersheds is provided below:

Back Creek A: The 188 acre Back Creek A subwatershed is located to the north of Fundy Cove. The primary tributary, Back Creek, drains into Fundy Cove. The majority of the subwatershed does not border the Lake. The subwatershed is entirely comprised of wetland and forest. The predicted annual phosphorus load for the subwatershed is 0.10 lbs P/acre/year (0.11 kg P/ha/yr), the highest of all predicted loads. Because of the small subwatershed area, this accounts for only 2% of the Lake's total predicted phosphorus load.

Loon Cove Brook A: The Loon Cove Brook A subwatershed is located northwest of the Lake and drains into Neals Cove. This subwatershed comprises 3% of the Lake's entire watershed area and is primarily characterized as undeveloped scrub-shrub and wetland. The predicted annual phosphorus load for the subwatershed is 0.09 lbs P/acre/year (0.10 kg P/ha/yr), accounting for approximately 3% of the Lake's total predicted phosphorus load.

Round Pond Brook: The 1,640 acre Round Pond Brook subwatershed is the fourth largest subwatershed and is located to the north of the Lake in the center of the Watershed. The primary tributary, Round Pond Brook, drains into the west portion of Fundy Cove. However, the majority of the subwatershed does not border the Lake. The subwatershed is entirely characterized as undeveloped wetland and forest. The predicted annual phosphorus load for the subwatershed is 0.08 lbs P/acre/year (0.09 kg P/ha/yr) and represents 14% of the Lake's total predicted phosphorus load.

Fernalds Brook A: The Fernalds Brook A subwatershed is approximately 376 acres and is located to the east of the Lake. Although Fernalds Brook drains into the eastern portion of the Lake. Most of the subwatershed does not border the Lake. The subwatershed is primarily characterized by undeveloped forest and wetland with less than 1% of the land-use area comprised of low-density development and cultivated land. The cultivated land area is a portion of Fernalds Farm. The predicted annual phosphorus load for the subwatershed is 0.08 lbs P/acre/year (0.09 kg P/ha/yr) and accounts for approximately 3% of the Lake's total predicted phosphorus load.

Whites Grove Brook: The 54-acre Whites Grove Brook subwatershed is one of the smallest subwatersheds and is located immediately adjacent to the south side of the Lake. The subwatershed is primarily characterized by undeveloped forest and wetland. The predicted annual phosphorus load for the subwatershed is 0.08 lbs P/acre/year (0.09 kg P/ha/yr). However, due to the small subwatershed area, it accounts for less than 1% of the Lake's total predicted phosphorus load.

Back Creek B: The 5,033 acre Back Creek B subwatershed is the largest subwatershed and represents the majority of the northern portion of the Watershed. Although Back Creek drains into Fundy Cove, the majority of the subwatershed does not border the Lake. The subwatershed is primarily characterized as undeveloped wetland and forest, with less than 1% of the land-use area comprised of low-density development and cultivated land. The predicted annual phosphorus load for the subwatershed is 0.07 lbs P/acre/year (0.08 kg P/ha/yr) and represents 40% of the Lake's total predicted phosphorus load.

Mountain Cove Brook: The Mountain Brook Cove subwatershed is the third largest subwatershed and is in the western portion of the Watershed. The subwatershed includes Deer Pond as well as several unnamed impounded areas. The primary tributary, Mountain Brook, drains into the west end of the Lake. The subwatershed is primarily characterized by undeveloped scrub-shrub and wetland with less than 1% being characterized as low-intensity developed land use. The predicted annual phosphorus load for the subwatershed is 0.07 lbs P/acre/year (0.08 kg P/ha/yr), accounting for approximately 18% of the Lake's total predicted phosphorus load.

Gove Dam Brook: The Gove Dam Brook subwatershed is approximately 127 acres in area and is located to the south of the Lake in the southernmost portion of the watershed. The primary tributary is Gove Brook which drains into the southern portion of the Lake. However, the majority of the subwatershed is not located adjacent to the Lake. The subwatershed is primarily characterized by undeveloped wetland. The predicted annual phosphorus load for the subwatershed is 0.07 lbs P/acre/year (0.08 kg P/ha/yr), accounting for approximately 1% of the Lake's total predicted phosphorus load.

Burnham's Marsh Outlet South: The Burnham's Marsh Outlet South subwatershed is located immediately adjacent to the north side of the Lake. The subwatershed includes the majority of Burnham's Marsh as well as portions of the State Park. It comprises 2% of the Lake's entire watershed area and is primarily characterized as undeveloped wetland with less than 1% of the area characterized as low-intensity developed land use. The predicted annual phosphorus load for the subwatershed is 0.06 lbs P/acre/year (0.07 kg P/ha/yr), accounting for approximately 2% of the Lake's total predicted phosphorus load.

Fundy Brook: The 155 acre Fundy Brook subwatershed is located to the east of Fundy Cove. The primary tributary, Fundy Brook, drains into the east portion of Fundy Cove. However, the majority of the subwatershed does not border the Lake. The subwatershed is entirely characterized as undeveloped wetland and forest. The predicted annual phosphorus load for the subwatershed is 0.06 lbs P/acre/year (0.07 kg P/ha/yr) and represents 1% of the Lake's total predicted phosphorus load.

Burnham's Marsh Outlet North: The 112 acre Burnham's Marsh Outlet North subwatershed is located to the north of the Lake immediately south of Fundy Cove. It comprises 1% of the Lake's entire watershed area and is entirely characterized as undeveloped forest and wetland. The predicted annual phosphorus load for the subwatershed is 0.06 lbs P/acre/year (0.07 kg P/ha/yr), accounting for approximately 1% of the Lake's total predicted phosphorus load.

Loon Cove Brook B: The Loon Cove Brook B subwatershed is located adjacent to the west end of the Lake. This subwatershed comprises 1% of the Lake's entire watershed area and is primarily characterized as undeveloped wetland. The predicted annual phosphorus load for the subwatershed is 0.06 lbs P/acre/year (0.07 kg P/ha/yr), accounting for less than 1% of the Lake's total predicted phosphorus load.

Fernalds Brook B: The Fernalds Brook B subwatershed is one of the smallest subwatersheds (55 acres) and is located adjacent to the east side of the Lake. Fernalds Brook drains into the eastern portion of the Lake. The subwatershed is entirely characterized by undeveloped forest and wetland. The predicted annual phosphorus load for the subwatershed is 0.06 lbs P/acre/year (0.07 kg P/ha/yr). Due to the subwatershed's small area, it accounts for less than 1% of the Lake's total predicted phosphorus load.

Proximal Subwatershed: The proximal subwatershed is the second largest subwatershed and includes the areas directly adjacent to the Lake, including the Tuckaway Shores beach, Nottingham town beach, portions of Pawtuckaway Lake State Park and the Lakeview Drive. The proximal watershed does not have a primary tributary and generally drains via overland flow or through storm water drainage systems directly into the Lake. The subwatershed is primarily characterized by undeveloped scrub-shrub and wetland with less than 1% being characterized as low-intensity developed land use. The predicted annual phosphorus load for the subwatershed is 0.05 lbs P/acre/year (0.06 kg P/ha/yr), the lowest predicted for the entire Watershed. However, because the proximal subwatershed is the largest subwatershed, the predicted pollutant load represents 13% of the Lake's total load.

3.2 Pollutant Loading from On-site Sanitary Systems

3.2.1 Estimated Total Phosphorus Load From On-site Sanitary Systems

Geosyntec conducted an assessment to estimate phosphorus loads from on-site sanitary systems located in developed areas around the Lake. The model and assumptions used for this assessment were adapted from the Pawtuckaway Lake Diagnostic/Feasibility Study, June 1995. On-site sanitary systems considered in the analysis include septic tanks with leaching fields, septic tanks with chambers, cesspools, holding tanks, chemical toilets, dry-wells, and outhouses. The Nottingham Zoning Board reported that there are currently 309 residential properties around the Lake, with an estimated 2.83 persons per residence. For the purpose of this analysis, all of the 309 residential properties were assumed to be serviced by a septic systems as the best available information indicated that there were no shared sanitary sewer systems within the proximity of the Lake. In order to account for seasonal residences, the loading from septic systems was estimated based on an assumption that each of the 309 residences was occupied for 9 months out of the year.

The estimated phosphorus load to the Lake from on-site sanitary systems was 361 lbs P/yr (164 kg P/yr), as calculated using the following equation:

$$M=(E_S)(\#\ \text{Capita Years})(1-S_R)$$

Where:

M is the predicted phosphorus loading;

E_s is the phosphorus export coefficient of 1.1 lbs P/capita-year;

 # Capita Years is the product of the number of parcels (309 parcels) multiplied by the average number of residents per parcel (2.83 residents/parcel) and the average occupancy (9 of 12 months or 0.75);

S_R is the soil retention coefficient (0.5). E_S was determined based on literature published by the US Geological Survey and the University of Delaware extension program. The soil retention coefficient used is the same soil retention coefficient used in the 1995 Pawtuckaway Lake Diagnostic Feasibility Study.

The estimated total phosphorus load from septic systems represents approximately 28% of the total annual estimated phosphorus load to the Lake. This estimate is approximately 20% less than the field-sampling based estimate of 455 lbs P/yr (207 kg P/yr) described in the Pawtuckaway Lake Diagnostic/Feasibility Study (June 1995).

3.2.2 Potential Community Septic System Locations

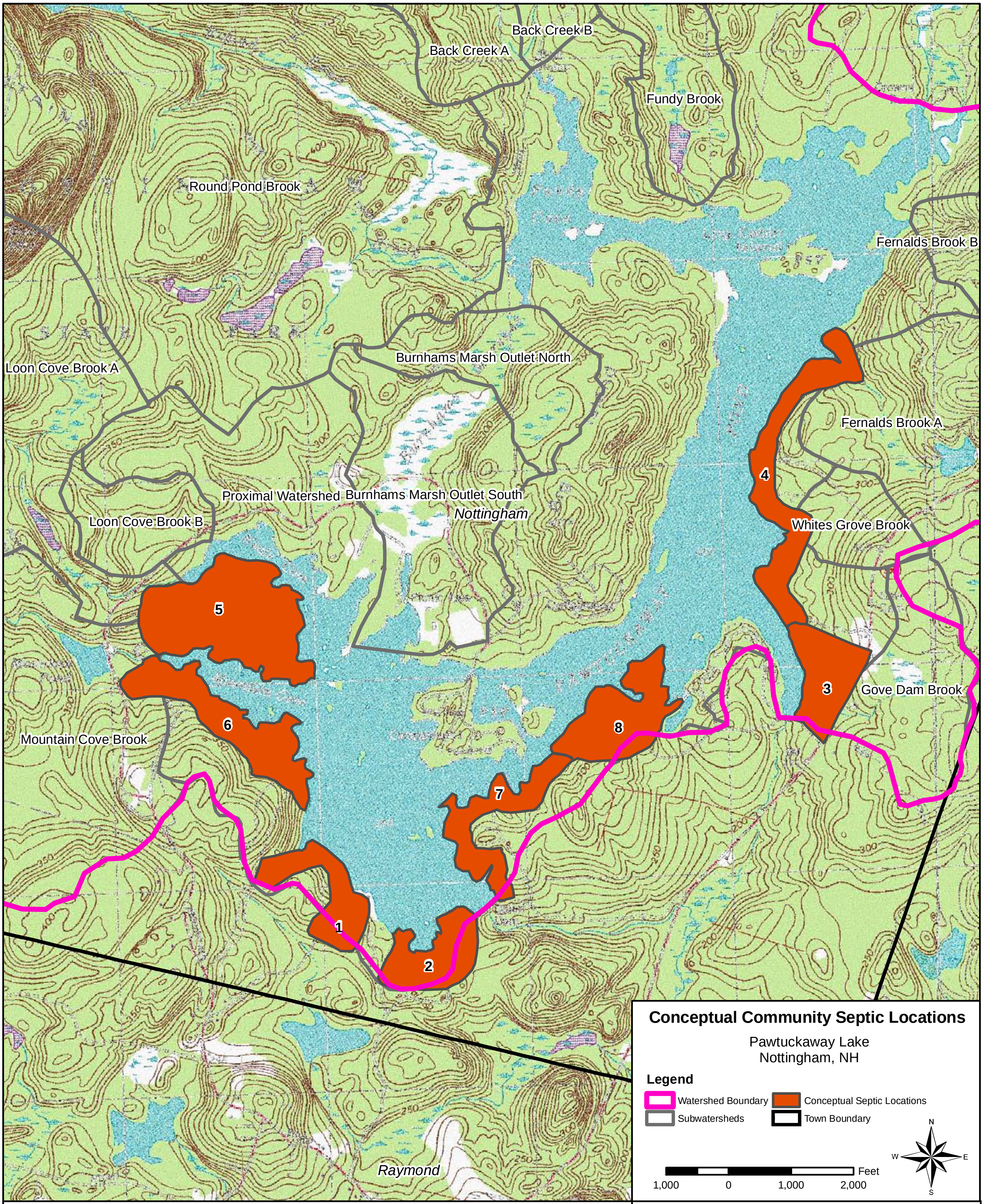
Geosyntec conducted a preliminary review to identify potential areas for community septic systems. The review was based on (1) the density of existing homes in close proximity to the Lake and tributaries and (2) data on soil types and soil drainage classes in the areas surrounding the Lake. An orthophoto map with existing soils information and the locations of the eight potential sites for community septic systems are shown below in Figure 3. The majority of the soils surrounding the Lake are characterized as a well-drained Chatfield-Hollis-Canton Complex soil, which tend to be suitable for siting wastewater treatment facilities. The drainage characteristics of Pawtuckaway Lake soils are shown below in Figure 4.

Geosyntec identified the eight areas described below as potential sites for community septic systems. Four High Priority sites were identified based on parcel density, proximity to the Lake, and the presence of an existing community association structure (e.g. Tuckaway Shores).

Table 4: Potential Community Septic System Locations

Area	Location	Priority
Tuckaway Shores Area	This area is a private community association at the southern end of the Lake.	High
Lakeview Drive Area	This area is located on the western side and includes all properties on Lakeview Drive and Lookout Point Lane.	High
Barderry Lane Area (north of Gove Cove)	This area is located north of Gove Cove in the northeastern portion of the Lake. The northern portion of this area is bounded to the east by Barderry Lane. The southern portion is bounded to the north by White's Grove Road.	High
Lamprey Drive/ Shore Drive Area	This area is located at the southeastern end of the Lake. This area includes properties to the west of Lamprey Drive and along the southern portion of Shore Drive.	High
Mooers Road/ South Road Area	Located at the southern end of the Lake, this area includes the lakefront properties on Mooers Road and all properties in the South Road area.	Medium
Highland Avenue Area	This area is located along the eastern side of Gove Cove. The area is bounded on the east by Raymond Road and includes all properties along Highland Avenue.	Medium
Area South of Mountain Brook Cove	This area is located in the western portion of the Lake to the south of Mountain Brook Cove. This area includes all properties along Head Road and lakefront properties in the northern portions of Sach's Road and Jampsa Trail.	Medium
Lake Shore Drive/ Cahill Lane Area	This area is located in the eastern portion of the Lake and includes the properties along the northern portion of Shore Drive and along Cahill Drive.	Medium

The installed cost for a community septic system can vary widely depending on site specific conditions such as soils, slopes, piping distances, etc. In general, the cost of a community system per household will decrease significantly as the number of homes sharing the system increases. For general costing purposes, a cluster mound system servicing 25 homes will cost about $400,000 to install ($16,000 per house). This cost includes $150,000 to install the system and $250,000 to install piping connections, assuming an average of 100 feet of small diameter pipe per home at $10 per linear foot. Annual Operation and Maintenance costs for this type of system are estimated to be $5,000 ($200 annually per home).



Geosyntec consultants

ACTON, MASSACHUSETTS

FIGURE NO. 3

PROJECT NO. BW0085

DATE: 05/02/07

Pawtuckaway_SepticLoc.mxd

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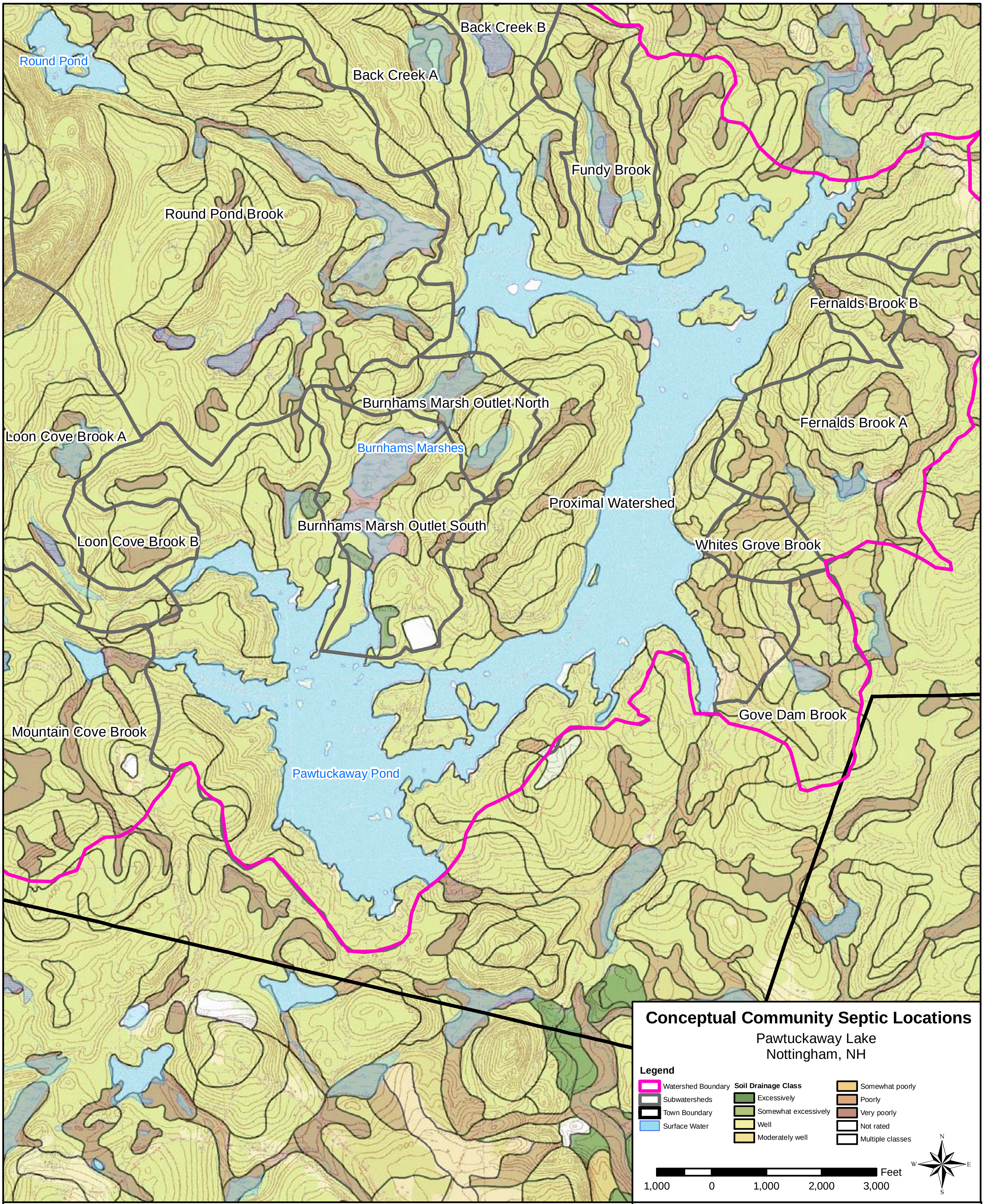

Geosyntec consultants

ACTON, MASSACHUSETTS

FIGURE NO. 4

PROJECT NO. BW0085

DATE: 05/02/07

Pawtuckaway_Soils.mxd

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3.3 Field Watershed Investigation

Bob Hartzel (Senior Water Resources Scientist) and Daniel Bourdeau (Water Resource Engineer) of Geosyntec conducted a field Watershed investigation on 8 June 2006. Mr. Hartzel and Mr. Bourdeau are both Certified Professionals in Sediment and Erosion Control (CPESC). A CPESC is a recognized specialist in soil erosion and sediment control, with certification by the Soil and Water Conservation Society and the International Erosion Control Association.

The field investigation was conducted during a rain event that occurred on 7 and 8 June 2006 that resulted in a 24-hour accumulation of 1.3 and 0.2 inches of rain, respectively. During the field investigation, Geosyntec identified several sites that were potential sources of pollutants and potential sites for implementing storm water BMPs and LID improvements.

The following pages provide descriptions of the sites identified on the 8 June 2006 field investigation and recommended improvements. The sites are presented in decreasing order of priority (i.e., 1 is highest and 8 is lowest) based on the observed field conditions and observed storm water runoff rates and apparent visual quality of the storm water runoff; the subwatershed in which the site is located; and the estimated pollutant load reduction for each BMP or improvement as discussed below.

SITE #1: #99 LAKEVIEW DRIVE

Site Summary:

Storm water run-off from the area of #99 Lakeview Drive collects in small topographical depressions in the gutter line of the unpaved road (Photo 1-1). The accumulated storm water drains into a drop inlet structure located adjacent to Lakeview Drive. Accumulated leaf litter was observed on the grate and sediment was observed in the sump of the drop inlet structure (Photo 1-2). The drop inlet structure apparently discharges via two 4-inch diameter PVC culverts directly into Neals Cove (Photo 1-3).

Photo # 1-1

Proposed Improvement:

A <u>bioretention cell</u> is recommended at this drop inlet structure to reduce pollutant discharges directly to Neals Cove. The retrofit may include:

- A trenched ring around the device that would be lined with stone overlain by a bioretention soil mixture with plantings. The cell would provide filtration and promote infiltration.
- In addition, improvements may include cleaning and increasing the structure's sump to provide additional sediment capture. Bioretention cells are described in Section 2.0.

Photo # 1-2

Estimated Cost: $3,000 to $4,000

Estimated Pollutant Load Reduction: 0.4 lbs P/yr (0.2 kg P/yr)

Photo # 1-3

SITE #2: FERNALD'S CREEK CROSSING AT BARDERRY LANE

Site Summary:

Storm water runoff from Barderry Lane in the area of Fernalds Creek drains via a road side ditch (Photo 2-1) toward the Creek. The ditch drains from Barderry Lane into the area adjacent to Fernalds Creek, transporting sediment from the unpaved road surface to the Creek (Photo 2-2). Accumulated sediment was observed in this area adjacent to Fernalds Creek (Photo 2-3).

Photo # 2-1

Proposed Improvement:

Structural bank stabilization is recommended along the west side of Barderry Lane. The wall would be constructed from stone-filled gabion baskets in combination with coir fiber rolls. Gabion basket walls provide cost effective bank stabilization while also providing stone media for storm water filtration.

Photo # 2-2

The gabion basket retaining wall would include:

- Coir fiber rolls along the exterior toe that will promote vegetation growth. The vegetation will provide additional treatment of storm water runoff that filters through the stone filled gabion baskets.
- The gabion baskets will also establish a defined road edge and will provide both a channel to control storm water and a boundary for road maintenance activities.

Photo # 2-3

Estimated Cost: $12,000 to $16,000

Estimated Pollutant Load Reduction: 8.4 lbs P/yr (3.8 kg P/yr)

Example of gabion basket wall

SITE #3: CORNER OF LAKEVIEW DRIVE/LOOKOUT POINT

Site Summary:

Storm water runoff from paved portions of Lakeview Drive drain via overland flow onto the unpaved Lookout Point (Photo #3-1). These flows concentrate along the unpaved eastern side of Lakeview Drive in an undefined road ditch. The undefined ditch apparently drains along a paved driveway toward Mountain Brook Cove (Photo #3-2). Accumulated sediment was observed at the down gradient end of the paved driveway, adjacent to Mountain Brook Cove (Photo #3-3).


Photo # 3-1

Proposed Improvement:

A stone drainage channel is recommended to be installed along the eastern side of Lakeview Drive/Lookout Point and continued along the paved driveway shown in Photo3-2. The drainage channel would ultimately discharge to Mountain Brook Cove and consist of:


Photo # 3-2

- A deep rock-lined trench that would provide a well defined storm water conveyance to provide filtration and promote infiltration.
- The trench would function to capture storm water runoff from the paved portions of Lakeview Drive and either infiltrate these flows or convey flows in a controlled, non-erosive manner to Mountain Brook Cove.

Estimated Cost: $10,000 to $12,000

Estimated Pollutant Load Reduction: 0.7 lbs P/yr (0.3 kg P/yr)


Photo # 3-3

SITE #4: JASPER TRAIL

Site Summary:

Jasper Trail is an unpaved road as shown in Photo #4-1. Storm water runoff from Jasper Trail drains into undefined ditches along both sides of the Trail. In addition, a small unnamed tributary drains from Sax Hill toward Jasper Trail. The stream drains across the road via a 12" diameter culvert. The culvert apparently has caused flooding that has resulted in Jasper Trail being eroded (i.e., washed-out). The culvert inlet (Photo #4-2) is not protected and sediment from the unpaved road run-off has accumulated at the culvert inlet, thereby reducing the capacity of the culvert. In addition, accumulated sediment was observed immediately down gradient of the culvert outlet (Photo #4-3). The stream discharges from the culvert and drains south along Jasper Trail and then east toward Pawtuckaway Lake.

Photo # 4-1

Photo # 4-2

Photo # 4-3

Proposed Improvement:

Recommended storm water improvements in the area of the Jasper Trail culvert include:

- Improvements to the inlet and outlet of the culvert as well as stream channel improvements of the unnamed tributary.
- Outlet improvements would include a gabion basket headwall and grading a rock lined channel to convey flows from the culvert along Jasper Trail to the existing stream channel.
- Inlet improvements include stabilizing the channel up gradient of the culvert and constructing stone or coir fiber roll check dams to reduce flow velocities and trap sediment.
- Additionally, a headwall may be constructed at the culvert inlet to reduce erosion and provide hydraulic control at the inlet.

Estimated Cost: $8,000 to $10,000

Estimated Pollutant Load Reduction: 0.4 lbs P/yr (0.2 kg P/yr)

SITE #5: # 105 LAKEVIEW DRIVE

Site Summary:

Storm water runoff from the paved portions of Lakeview Drive in the area of #105 Lakeview Drive drain via a 12" diameter culvert located on the north side of the road (Photo #5-1). The area adjacent to the culvert inlet was not stabilized and rills were observed in adjacent side slopes (Photo #5-2). The culvert apparently drains into one of two catch basin structures that captures storm water runoff from the paved driveway of #105 Lakeview Drive (Photo #5-3). These catch basin structures appear to discharge to Neals Cove via a culvert through private property.

Photo # 5-1

Photo # 5-2

Photo # 5-3

Proposed Improvement:

Recommended storm water controls in the area of #105 Lakeview Drive include retrofit LID technologies to improve storm water quality discharging to Neals Cove. Recommended improvements include:

- Constructing a bioretention cell at the exiting culvert inlet. This would provide stabilization to the area as well as filtration and storm water treatment prior to discharging through the culvert.
- A pre-manufactured bioretention cell (i.e., Filterra) installed with the homeowner's approval at the northernmost catch basin structure.
- The combination of bioretention units would provide a multiple barrier approach to treat storm water runoff prior to discharging to Neals Cove.

Estimated Cost: $12,000 to $18,000

Estimated Pollutant Load Reduction: 0.2 lbs P/yr (0.1 kg P/yr)

SITE #6: #47 LAKEVIEW DRIVE

Site Summary:

Storm water runoff in the area of #47 Lakeview Drive apparently accumulates and can cause flooding of Lakeview Drive (Photo #6-1). The accumulated storm water discharges across Lakeview Drive. These flows discharge from the pavement onto unstabilized side slopes before draining overland toward Mountain Brook Cove. Evidence of erosion was observed in the unstabilized areas down gradient of the pavement (Photo #6-2). These flows then drain overland to a series of topographical depressions and eventually drain into Mountain Brook Cove (Photo #6-3).

Photo # 6-1

Proposed Improvement

Storm water runoff in the area of #46 Lakeview should be controlled to reduce flooding and erosion caused by flow over unstabilized surfaces within close proximity to the lake. Recommended controls and improvements include:

- Installing a conveyance such as a culvert across Lakeview Drive to drain accumulated storm water.
- Clean the flooding area of accumulated tree/yard debris that has apparently been dumped in the area and is a potential source of pollutants (i.e., nutrients).
- Installing a bioretention cell along the west side of Lakeview Drive in the area of flooding to provide storm water runoff storage and promote infiltration.
- Additional recommended improvements include installation of an energy dissipation device and level spreader at the proposed culvert outlet to reduce flow velocities and promote non-erosive flows to drain overland through the forested area before discharging into Mountain Brook Cove.

Photo # 6-2

Photo # 6-3

Estimated Cost: $8,000 to $12,000

Estimated Pollutant Load Reduction: 0.3 lbs P/yr (0.1 kg P/yr)

SITE #7: BARDERRY LANE

Site Summary:

Barderry Lane is an unpaved road that crosses a wetland complex that drains toward Gove Cove. The wetland along the east side of Barderry Lane drains west via several culverts. However, grading activities associated with unpaved road maintenance have apparently caused sediment to accumulate and block the inlets of at least one culvert (Photo #7-1). Flooding occurs in the area up gradient of the blocked culvert.

Photo # 7-1

Proposed Improvement:

Approximately 500 linear feet of Barberry Lane in the area of the blocked culverts should be maintained according to unpaved road BMPs and improvements including:

- Maintaining this are of Barberry Lane so that sediment is not transported to adjacent storm water controls (e.g., ditches, culverts).
- Cleaning the accumulated sediment that has clogged the culverts along this portion of road.
- Installing culvert headwalls to define the locations of culverts and provide stabilization to the road in these areas.
- Installing a well-defined ditch along the approximate 500 linear feet of Barberry Lane.
- Stabilizing ditches with rock or installing a deep rock-lined trench, to define the road boundary as well as treat and infiltrate storm water runoff. The trench would either infiltrate storm water runoff or convey these flows to one of the exiting culverts that drain west toward Gove Cove.

Photo # 7-2

Estimated Cost: $8,000 to $12,000

Estimated Pollutant Load Reduction: 1.1 lbs P/yr
(0.5 kg P/yr)

Photo # 7-3

SITE #8: PAWTUCKAWAY LAKE STATE PARK

Site Summary:

Pawtuckaway Lake State Park is located along the west shore of the Lake, to the north of Neals Cove. There is a grassed picnic area located to the south of the main beach of the Park (Photo #8-1). Storm water runoff from this grassed area either infiltrates or drains via overland flow toward the Lake. Two catch basin structures capture the runoff and apparently discharge these flows to the Lake. The catch basin structures appear to not properly drain and flooding was observed in the area of both structures (Photo #8-2).

The Park's secondary parking lot is located to the east of the main beach. Storm water runoff from the paved parking lot either drains into catch basins or discharges from the southeast corner of the parking lot via a paved spillway (Photo #8-3). The spillway discharges into an unstabilized channel and erosion was observed immediately down gradient of the spillway.

Photo # 8-1

Photo # 8-2

Photo # 8-3

Proposed Improvement:

Recommended for the State Park include:

- Install bioretention cell at each of the drop inlet structures located to the south of the grassed picnic area. The bioretention cells would provide storm water filtration and storage capacity while promoting infiltration.
- Install an energy dissipation and level spreader device at the paved spillway at the southeast corner of the secondary parking lot. The energy dissipation device will reduce flow velocities prior to discharging runoff in a non-erosive manner to the unstabilized channel.
- Stabilize the existing channel down gradient of the paved spillway located in the southeast corner of the secondary parking area.

Estimated Cost: $8,000 to $12,000

Estimated Pollutant Load Reduction: 0.4 lbs P/yr (0.2 kg P/yr)

SITE #9: TUCKAWAY SHORES BEACH AREA

Photo # 9-1

Site Summary:

The unpaved road adjacent to the Tuckaway Shores beach area appears to be a source of sediment loading to the lake. Road grading had been conducted several days before Geosyntec's site visit on 13 October 2006, resulting in roadside berms and a road surface of relatively fine-grained and erodible material (Photo # 9-1). Sediment transported along the road by storm water collects in an area between the road and the beach area fencing (Photo #9-2). From this area, storm water and associated sediment are directed to the lake via a paved flume (Photo # 9-3).

Photo # 9-2

Proposed Improvement:

Proposed improvements for this area include:

- Surface the road section proximal to the beach area with either pavement or a specification hard-pack.
- In conjunction with any road surfacing improvement, construct rock-lined infiltration trenches to define the road boundary and infiltrate storm water runoff. The trench would either infiltrate storm water runoff or convey flows to the sediment trap and vegetated swale described below.
- Construct a stone-lined sediment trap in the roughly triangular area between the paved flume and the roadway. Regular maintenance will be required to remove fine-grained sediment as it accumulates in the sediment trap.
- Replace the paved flume with a densely vegetated water quality swale.

Photo # 9-3

Estimated Cost: $10,000 - $12,000

Estimated Pollutant Load Reduction: 0.5 lbs P/yr (0.2 kg P/yr)

3.4 Estimated BMP Pollutant Load Reduction

Pollutant load reductions were estimated for each of the proposed improvements described above in Section 2. The reduction rates, presented in lbs P/year and kg P/year, were estimated using published pollutant reduction rates for BMPs as follows: The predicted phosphorus load entering each BMP was estimated based on the land cover in the drainage area contributing flows through the BMP. Each BMP drainage area was delineated based on United States Geological Survey (USGS) topography maps. Next, land use categories were interpreted from aerial maps and assigned to the drainage area. An annual pollutant load was estimated for each catchment using the land-use based model as described in Section 3.1. This pre-BMP annual pollutant load represents the amount of pollutant expected to enter the Lake if the BMP was not in-place. Next, published BMP reduction values were used to estimate the total amount of pollutant (in lbs P/yr and kg P/yr) which is expected to be removed (provided that the improvement is properly installed and maintained). The post-BMP pollutant load represents the pollutant load predicted to enter the Lake if the BMP was installed. The results of the land-use loading model are provided in Table 5 below.

Table 5: Estimated phosphorus removal by BMP.

Site Number	Site Description	Drainage Area (acres)	Annual Export (lbs/yr)	Annual Export (kg/yr)	BMP Type/Category	BMP Reduction (% Capture)	Estimated Phosphorus Removal (lbs/yr)	Estimated Phosphorus Removal (kg/yr)
1	99 Lakeview Drive	2.8	0.6	0.3	Vegetated Filters	75%	**0.4**	**0.2**
2	Fernalds Creek at Barderry Lane	161.6	28.0	12.7	Grassed Swales/Infiltration	30%	**8.4**	**3.8**
3	Lakeview Drive and Lookout Point	2.6	2.3	10.4	Grassed Swales/Infiltration	30%	**0.7**	**0.3**
4	Jasper Trail	13.6	2.8	1.3	Open Channel Vegetated	15%	**0.4**	**0.2**
5	105 Lakeview Drive	2.3	0.5	0.2	Filtration systems	45%	**0.2**	**0.1**
6	47 Lakeview Drive	4.0	0.8	0.4	Filtration system	45%	**0.3**	**0.1**
7	Barderry Lane	29.1	5.4	2.5	Grassed Swales	20%	**1.1**	**0.5**
8	Pawtuckaway Lake State Park							
8.1	*Picnic Area*	18.0	3.6	1.6	Filtration System	45%	**1.3**	**0.6**
8.2	*Parking Area*	5.6	2.5	1.1	Open Channel Vegetated	15%	**0.4**	**0.2**
9	Tuckaway Shores (Beach Area)	4.5	1.1	0.5	Basin/Infiltration	45%	**0.5**	**0.2**
Total Estimated Phosphorus Removal:							**13.7**	**6.4**

3.5 Site Prioritization

Each site improvement was ranked based on five parameters including: (1) the estimated load from each subwatershed, (2) septic system loading, (3) BMP removal rates, (4) field investigation observations, and (5) projected cost. *Priority points* were assigned for each parameter for each site and were used as a measure of priority. A description of each parameter and how it was used to prioritize the sites is described below. Appendix C includes a summary of *priority points* assigned to each site.

Subwatershed Phosphorus Load Ranking: Subwatershed phosphorus load was used to rank the sites based on the results described in Section 3.1. In general, subwatersheds with more intensive land-uses have a higher rate of pollutant export per unit of land area and thus have a higher priority ranking. For example, the primarily forested Back Creek B subwatershed is approximately 5,033 acres and has a low predicted phosphorus loading rate of 0.07 lbs P/acre/year (0.08 kg P/ha/year), compared to the Loon Cove Brook A subwatershed that is approximately 355 acres of mixed land-use and has a predicted phosphorus loading rate of 0.09 lbs P/acre/year (0.10 kg P/ha/year). Generally, subwatersheds that are in close proximity to the Lake and have relatively high predicted loading rates have both a greater need for, and offer better opportunities for watershed improvements to protect lake water quality. Each subwatershed where storm water improvements are being proposed was ranked based on the annual phosphorus loading from largest (1) to smallest (3). The subwatersheds where BMPs are being proposed are the Proximal Subwatershed (6 sites), Fernalds Brook A (1 site), Whites Grove Brook (1 site), and Burnham's Marsh Outlet South (2 sites, both in Pawtuckaway Lake State Park).

Septic System Phosphorus Load Ranking: Phosphorus loads from septic systems were used to rank the sites based on the results described in Section 3.2. *Priority points* were assigned to each site based on the overall number of homes in the subwatershed where improvements were proposed. In general, subwatersheds with more homes and thus more septic systems will have a higher annual pollutant load to the Lake than subwatersheds with fewer homes. Therefore, a binary rank was used based on whether the subwatershed included homes. USGS maps only identified homes in the proximal watershed: As such, this subwatershed was assigned one point and the other subwatersheds without homes were assigned two points.

BMP Pollutant Removal Ranking: BMP removal rates were used to rank the sites based on the results described in Section 3.3. *Priority points* were assigned to each site based on the estimated BMP removal rates as follows: one point for a removal rate of 8.4 lbs P/yr or greater (3.81 kg P/yr), two points for a removal rate between 0.8 and 8.3 lbs P/yr (0.36 and 3.77 kg P/yr), or three points for a removal rate less than 0.7 lbs P/yr (0.32 kg P/yr).

Field Observation Ranking: Field conditions were used to rank the sites based on the findings of the field investigation conducted by Geosyntec described in Section 3.3. High priority sites were assigned one point, medium priority sites were assigned two points, and low priority sites were assigned three points. These priority categories were assigned based on professional judgment, so that non-quantifiable observations made during the field investigations could be included in the ranking process.

Cost Ranking: Preliminary estimated cost for each improvement was also used to rank the sites. *Priority points* were assigned to each site based on estimated costs as follows: one point for costs less than $3,999, two points for costs ranging between $4,000-7,999, three points for costs ranging between $8,000-11,999, and four points for costs over $12,000.

Connectivity to Lake: The connectivity of the proposed BMP location to the lake was used to assign priority points. Sites with a direct connection to the lake (e.g., channel or pipe draining directly into the lake) were assigned a value of one. Sites which drained to the lake via overland flow were assigned a value of two. Sites that were not located within close proximity to the lake were assigned a value of three.

Combined Ranking: *Priority points* assigned to each site were then summed for all parameters to calculate the total number of *priority points* for each site. The lower the sum of the points the higher the priority assigned to a site. A summary of the ranking results is included below in Table 6. In summary, the four highest priority sites include 99 Lakeview Drive, Fernalds Creek at Barderry Lane, Tuckaway Shores (Beach Area) and Lakeview Drive at Lookout Point.

Table 6: Priority Points Summary Table

Site Number	Site Description	Priority Points	Priority
1	99 Lakeview Drive	9	High
2	Fernald's Creek at Barderry Lane	11	High
9	Tuckaway Shores (Beach Area)	11	High
3	Lakeview Drive at Lookout Point	12	High
4	Jasper Trail	13	Medium
5	105 Lakeview Drive	13	Medium
8	Pawtuckaway Lake State Park		
8.1	*Picnic Area*	13	Medium
8.2	*Parking Area*	14	Low
6	47 Lakeview Drive	14	Low
7	Barderry Lane	16	Low

4. SUMMARY OF TECHNICAL AND FINANCIAL SUPPORT

4.1 Technical Support

The majority of storm water improvements described in Section 3.0 will require a moderate to high level of technical support. Moderate to high technical support may include a site topographic survey, preparing existing conditions base plans, and preparing definitive site drawings by an Engineer that would be used for permitting and construction. The sites that require a moderate to high level of technical support include: Site 1 (99 Lakeview Drive), Site 2 (Fernald's Creek Crossing at Barderry Lane), Site 3 (Corner of Lakeview Drive at Lookout Point), Site 5 (105 Lakeview Drive), Site 6 (47 Lakeview Drive), Site 8 (Pawtuckaway Lake State Park), and Site 9 (Tuckaway Shores Beach Area). The remaining sites require a low level of technical support and include Site 4 (Jasper Trail) and Site 7 (Barderry Lane). A low level of technical support includes design-build construction using field manuals. In addition to the technical support described above, construction of some of the projects described in Section 3 may require a Minimum Impact Wetlands Application to the NH DES Wetlands Bureau. Wetlands were not delineated as part of this project. As such, technical support from a New Hampshire certified wetland scientist may be required for wetland delineation and permitting support.

4.2 Financial Support

The storm water improvements and management techniques described in Section 3 above will require funding to install and complete. Sources of funding to be considered shall include, but are not limited to, Section 319 funding, NH DES Small Outreach and Education Grants, NH DES Agricultural Nutrient Management Grant Program, USDA's Environmental Quality Incentives Program and USDA's Conservation Reserve Program. Alternative funding may be in the form of donated labor from the Nottingham Department of Public Works as well as local volunteer groups and contractors from communities around the lake. Brief descriptions of potential funding sources are provided below:

Section 319 Grant Funding: Funds for NH DES Watershed Assistance and Restoration Grants are appropriated through the U.S. Environmental Protection Agency under Section 319 of the Clean Water Act (CWA). Two thirds of the annual funds are available for restoration projects that address impaired waters and implement watershed based plans designed to achieve water quality standards. A project eligible for funds must plan or implement measures that prevent, control, or abate no-point source (NPS) pollution. These projects should: (1) restore or maintain the chemical, physical, and biological integrity of New Hampshire's waters; (2) be directed at encouraging, requiring, or achieving implementation of BMPs to address water quality impacts from land-use; (3) be feasible, practical and cost effective; and (4) provide an informational, educational, and/or technical transfer component. The project must include an appropriate method for verifying project success with respect to the project performance targets, with an emphasis on demonstrated environmental improvement.

Nonprofit organizations registered with the N.H. Secretary of State and governmental subdivisions including municipalities, regional planning commissions, non-profit organizations, county conservation districts, state agencies, watershed associations, and water suppliers are eligible to receive these grants. More information on the NH DES Watershed Assistance and Restoration Grants can be found at: http://www.des.state.nh.us/wmb/was/grants.htm.

Small Outreach and Education Grant: The NHDES provides funding to promote educational and outreach components of water quality improvement projects. This program provides small grants of $200 to $2,000 for outreach and education projects relating to NPS issues that target appropriate audiences with diverse NPS water quality related messages. These small grants are available year round on an ongoing basis, which allows applicants to move forward with outreach and education projects without having to wait for annual application deadlines. The NH DES Watershed Assistance Section administers the grant program using $20,000 each year from the U.S. EPA under Section 319 of the CWA. More information on the Small Outreach and Education Grant can be found at: http://www.des.state.nh.us/wmb/was/grants.htm.

Agricultural Nutrient Management Grant Program: This grant program seeks to provide financial, educational and technical assistance for livestock and agricultural land operations and related organizations with implementing BMPs and such other measures necessary to prevent or mitigate water pollution. Applicants may apply for cost assistance of up to $2,500 per year. There is no match required, however, in-kind services such as labor provided by the applicant will enhance the application. The majority of funding will be used for on-farm projects that address or prevent water pollution. Funding may also be utilized by organizations for educational projects. This grant program is administered through the N.H. Department of Agriculture, Markets and Food, Bureau of Markets with support from NH DES. Applications are due by June 1 and December 1 each year. More information on the Agricultural Nutrient Management Grant Program can be found at: http://www.des.state.nh.us/wmb/was/grants.htm.

USDA's Environmental Quality Incentives Program: The Environmental Quality Incentives Program (EQIP) was reauthorized in the Farm Security and Rural Investment Act of 2002 (Farm Bill) to provide a voluntary conservation program for farmers and ranchers that promotes agricultural production and environmental quality as compatible national goals. EQIP offers financial and technical help to assist eligible participants install or implement BMPs on eligible agricultural land.

EQIP offers contracts with a minimum term that ends one year after the implementation of the last scheduled practices and a maximum term of ten years. These contracts provide incentive payments and cost-shares to implement conservation practices. Persons who are engaged in livestock or agricultural production on eligible land may participate in the EQIP program. EQIP activities are carried out according to an environmental quality incentives program plan of operations developed in conjunction with the producer that identifies the appropriate conservation practice or practices to address the resource concerns. The practices are subject to NRCS technical standards adapted for local conditions. The local conservation district approves the plan.

EQIP may cost-share up to 75 percent of the costs of certain conservation practices. Incentive payments may be provided for up to three years to encourage producers to carry out management practices they may not otherwise use without the incentive. However, limited resource producers and beginning farmers and ranchers may be eligible for cost-shares up to 90 percent. Farmers and ranchers may elect to use a certified third-party provider for technical assistance. An individual or entity may not receive, directly or indirectly, cost-share or incentive payments that, in the aggregate, exceed $450,000 for all EQIP contracts entered during the term of the Farm Bill. More information on the USDAs EQIP can be found at: http://www.nrcs.usda.gov/Programs/eqip/.

USDA's Conservation Reserve Program: The Conservation Reserve Program (CRP) provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. The program provides assistance to farmers and ranchers in complying with Federal, State, and tribal environmental laws, and encourages environmental enhancement. The program is funded through the Commodity Credit Corporation (CCC). CRP is administered by the Farm Service Agency, with NRCS providing technical land eligibility determinations, conservation planning and practice implementation. The program encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filter strips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract. Cost sharing is provided to establish the vegetative cover practices. More information on the USDAs CRP can be found at: http://www.nrcs.usda.gov/Programs/crp/.

5. PUBLIC INFORMATION AND EDUCATION

Public information and education will be used to enhance public understanding of the storm water improvement projects. Public awareness encourages the use of storm water improvements throughout a watershed. Public information and education about the storm water improvements and BMPs implemented in the watershed are provided via a project webpage and informational brochure. State grants are available, as described above, to assist with public information and education.

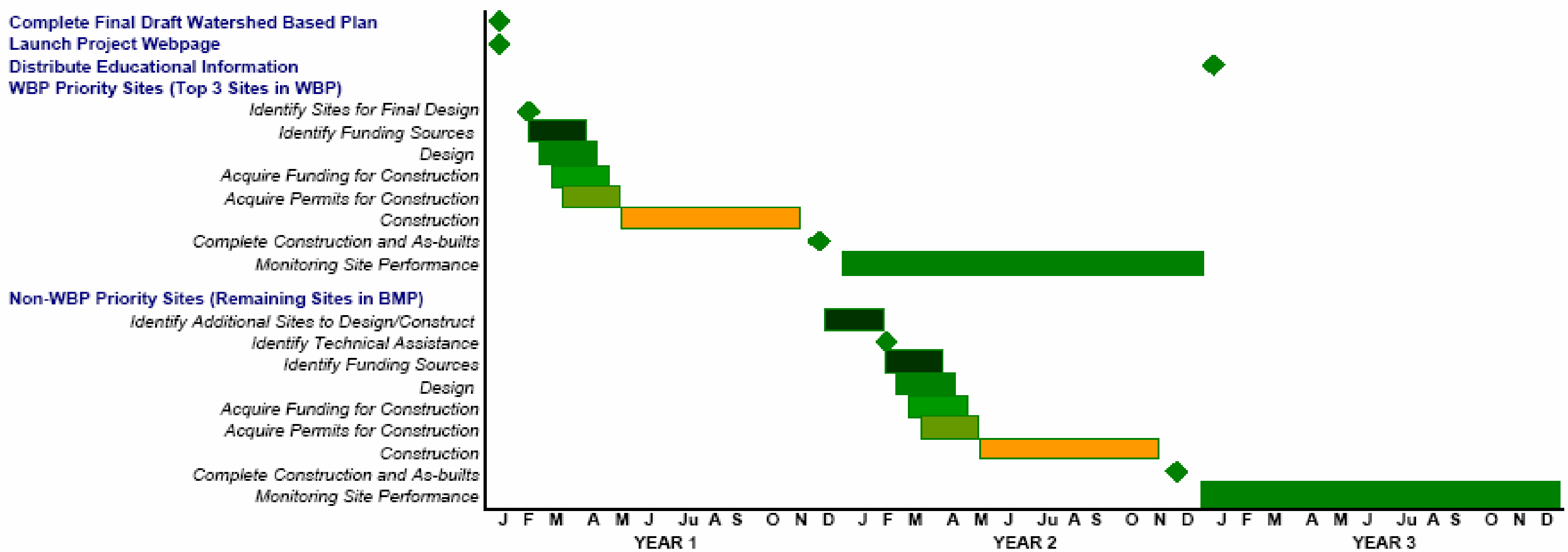
Project Website: A **project web site** is available to provide access to all project-related documents and reports. The website is a convenient method for reviewing and commenting on the draft WBP and other project deliverables as well as provides important feedback to monitor maintenance and improvement in water quality. The project webpage is available at: **http://projects.geosyntec.com/BW0085/**.

Brochure: The NH DES and Geosyntec developed an educational brochure specific to the Pawtuckaway Lake watershed and storm water improvements. A copy of the Pawtuckaway Lake informational brochure is provided in Appendix B to this report.

6. SCHEDULING

The storm water improvements recommended for the Pawtuckaway Lake watershed are ranked in order of priority as described in Section 3.0. Geosyntec recommends the following (as shown in Figure 1) schedule and associated interim milestones to achieve the top priority sites.

FIGURE 1: PLANNING SCHEDULE



APPENDIX A
SITE SUMARY TABLE

APPENDIX A: SITE SUMMARY TABLE

Site	Priority[1]	Proposed Improvements	Estimated Cost [2]
Site #1: #99 Lakeview Drive	High	Install a **bioretention cell** at the drop inlet structure.	$3,000 - $4,000
Site#2: Fernald's Creek crossing at Barderry Lane	High	Install **structural bank stabilization** consisting of stone-filled gabion baskets and coir fiber rolls along the west side of Barderry Lane.	$12,000 - $16,000
Site #3: Corner of Lakeview Drive/ Lookout Point	High	Install a **stone drainage channel** along the eastern side of paved and unpaved portions of Lakeview Drive and continued along a paved driveway, ultimately discharging to Mountain Brook Cove.	$10,000 - $12,000
Site #4: Jasper Trail Culvert	Medium	Improve the inlet and outlet of the culvert under Jasper Trail by installing a **gabion basket headwall** and improve and **stabilize the upstream and downstream channel of the unnamed tributary**.	$8,000 - $10,000
Site #5: #105 Lakeview Drive	Medium	Install a **bioretention cell** at the exiting culvert inlet in the area of #105 Lakeview Drive. Install a **pre-manufactured bioretention cell** (i.e., Filterra) at the northernmost catch basin structure in the # Lakeview Drive driveway.	$12,000 - $18,000
Site #6: #47Lakeview Drive	Medium	Install a **bioretention cell** equipped with a **culvert** that drains across Lakeview Drive. Install **an energy dissipation device and level spreader** at the proposed culvert outlet. Remove the tree and yard debris that has been dumped in this area.	$8,000 - $12,000
Site #7: Barderry Lane	Low	Install a **rock-lined ditch** to define the road boundary. Construct **culvert headwalls** to mark the locations of culverts along this portion of Barberry Lane.	$8,000 - $12,000
Site #8: Pawtuckaway State Park	Medium/ Low	Install **bioretention cells** at each drop inlet structure located to the south of the grassed picnic area. Install an **energy dissipation device and level spreader** at the paved spillway at the southeast corner of the secondary parking lot. **Stabilize** the existing channel immediately downgradient of the paved spillway.	$8,000 - $12,000
Site #9: Tuckaway Shores Beach Area	High	Stabilize road proximal to beach area with pavement or specification hardpack. Install rock-lined roadside infiltration trenches. Install a rock-lined sediment trap between the road and fence for the beach area. Replace the paved flume with a vegetated water quality swale.	$10,000 – $12,000

1. Priority level is assigned as described in Section 3.
2. Estimated ranges in cost are presented in U.S. Dollars, are approximate and represent installed cost where applicable.

APPENDIX B
INFORMATIONAL BROCHURE

APPENDIX C
RANKING SUMMARY TABLE

Site Description	BMP Location (Subwatershed)	Subwatershed Rank	Subwatershed Status Septic P	Phosphorus Removal Ranking	Field Observation Ranking	Cost	Connectivity to Lake	TOTAL Priority Points
99 Lakeview Drive	Proximal Watershed	2	1	3	1	1	1	**9**
Fernald's Creek at Barderry Lane	Fernalds Brook A	1	2	1	1	4	2	**11**
Tuckaway Shores (Beach Area)	Proximal Watershed	2	1	3	1	3	1	**11**
Lakeview Drive and Lookout Point	Proximal Watershed	2	1	3	1	3	2	**12**
Jasper Trail	Proximal Watershed	2	1	3	2	3	2	**13**
105 Lakeview Drive	Proximal Watershed	2	1	3	2	4	1	**13**
Pawtuckaway Lake State Park								
Picnic Area	Burnham's Marsh South	3	2	2	3	2	1	**13**
Parking Area	Burnham's Marsh South	3	2	3	3	2	1	**14**
47 Lakeview Drive	Proximal Watershed	2	1	3	2	3	3	**14**
Barderry Lane	Whites Grove Brook	3	2	2	3	3	3	**16**