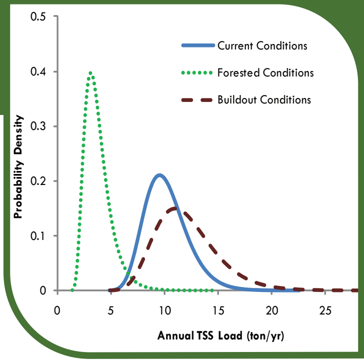
Final Project Report
September 21, 2012

Rust Pond

North Inlet and Route 28 Boat Launch Subwatershed Assessment



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Funding for this project was provided by a grant from the New Hampshire Department of Environmental Services with funding from the United States Environmental Protection Agency under Section 319 of the Clean Water Act.

Cover photo courtesy of the Rust Pond Association.

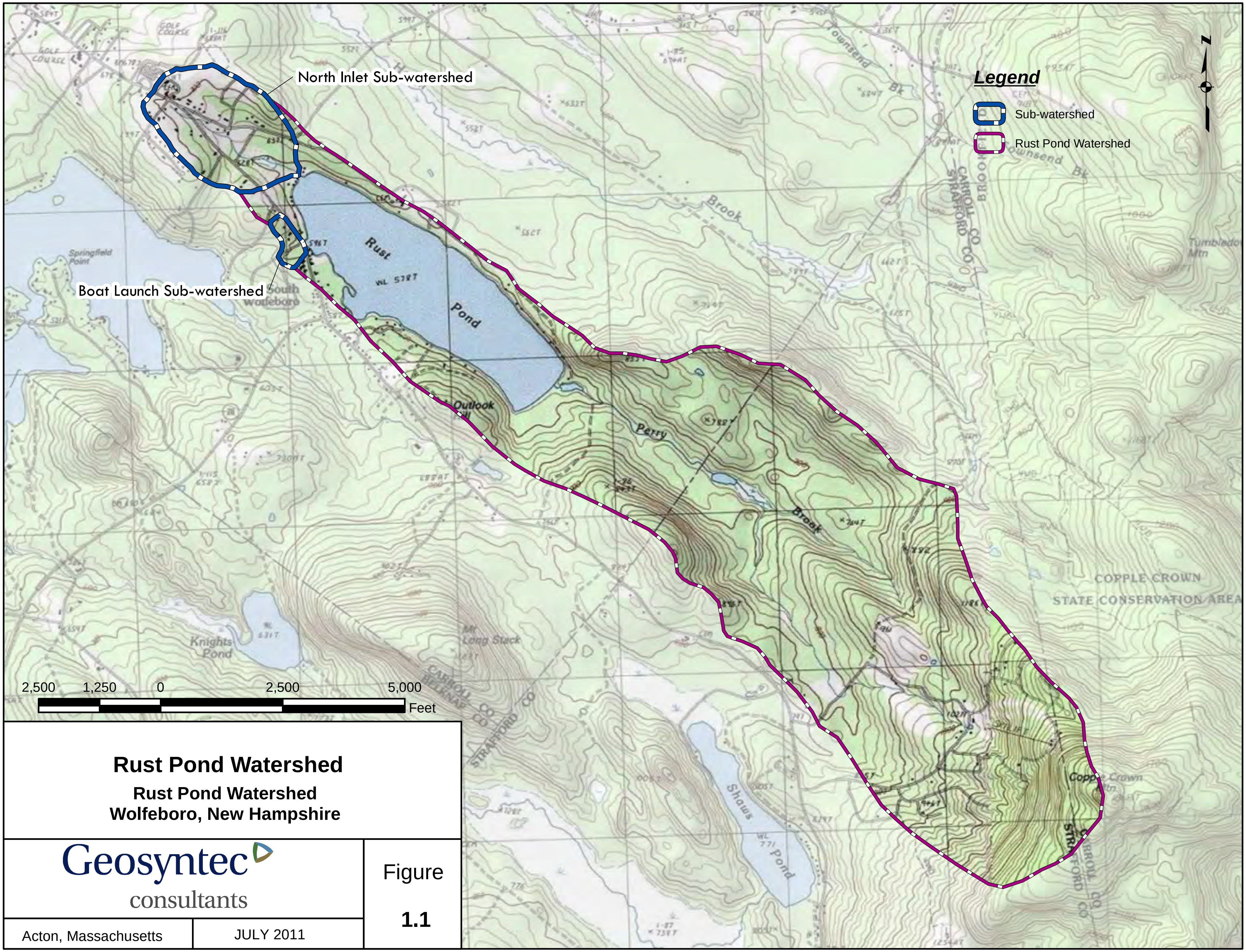
1. INTRODUCTION

Rust Pond is a 210-acre waterbody located in Wolfeboro, NH, within the Merrimack River watershed. The pond's 1,651-acre watershed is located in Wolfeboro and New Durham, New Hampshire. Two locations in the pond watershed, the North Inlet and Route 28 boat launch, have been identified by NHDES as contributing excessive sediment loading to the pond (for more information see Rust Pond - Pond and Watershed Diagnostic Study, prepared by NHDES, 2007).

Sediment loads from the North Inlet subwatershed have reduced water depths at the north end of the pond to the point where recreational use of some docks has been become either impossible or significantly impaired. Based on the 2007 NHDES study referenced above, the primary factors causing the impairment are sediment loads from land uses, channel erosion and incision from upstream hydromodification and streambank modification and destabilization. Excessive sediment loading at this location has been noted since 1999. The sediment delta at this location is estimated to be between 740-1,100 cubic yards of material. At the Route 28 boat launch, runoff from Route 28 onto the unstabilized boat launch surface results in additional erosion and sediment discharge to the pond.

This watershed management report provides the following information:

1. An identification of both point and non-point sources of sediment in the North Inlet subwatershed and an estimate of the sediment load that these sources contribute;
2. A discussion of the Rust Pond water quality goal, and the methods by which the goal was developed;
3. A list of potential best management practices (BMP's) to be implemented in the watershed to achieve the water quality goal;
4. A summary of the technical and financial support needed to implement the proposed management activities;
5. A general schedule and important milestones to track management implementation; and
6. A discussion of monitoring activities and evaluation criteria that can be used to determine if the implemented management practices are having the desired effect on the water quality of Rust Pond.



Rust Pond Watershed

Rust Pond Watershed
Wolfeboro, New Hampshire

Geosyntec consultants

Figure **1.1**

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2. RUST POND SEDIMENT BUDGET

2.1 Model Methodology

Geosyntec performed a Monte Carlo (MC) analysis to determine likely ranges of TSS loading from the North Inlet watershed under three scenarios: (1) forested conditions that likely existed in the past, (2) current conditions, and (3) future buildout conditions. The MC analysis utilized the Simple Method, described in the New Hampshire Stormwater Manual. Rather than using a single value for each of the input parameters (such as precipitation depth and Event Mean Concentration), the MC analysis repeatedly selects random parameter values from statistical distributions. The MC analysis calculates the loading from individual runoff events; the annual load is then calculated as the sum of all runoff events in a given year.

The TSS load from a single event is calculated using the formula:

$$TSS_i = \sum_{j=1}^{n} A_j \cdot P_i \cdot F_p \cdot (0.05 + 0.9 \cdot I_j) \cdot EMC_j$$

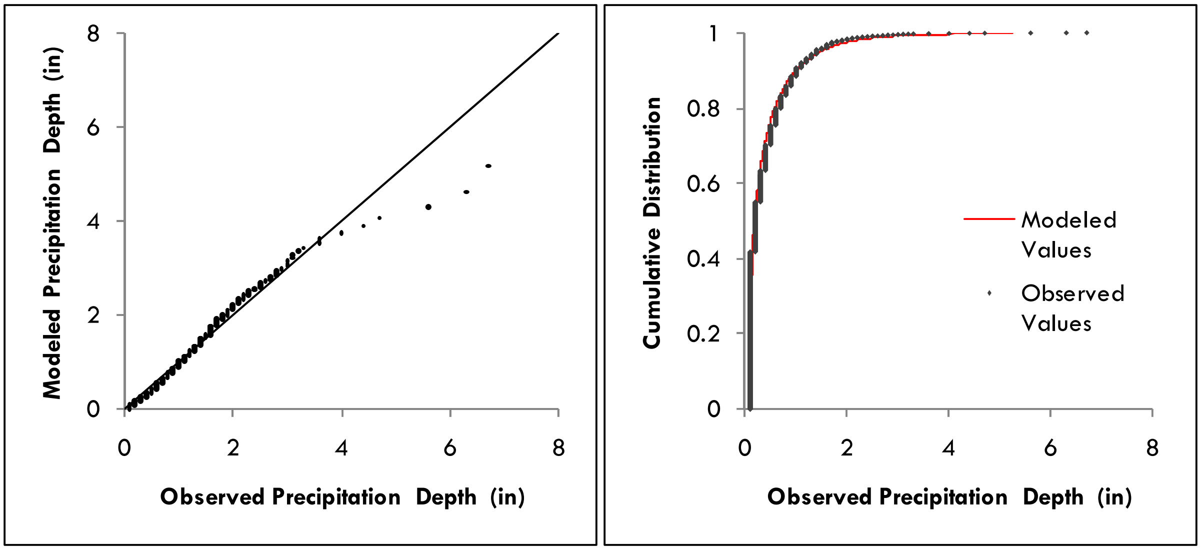
Where TSS_i is the loading from event i, n is the number of different land uses within the watershed, A_j is the area of land use j, P_i is the precipitation depth of event i, F_p is the fraction of precipitation contributing to runoff (0.9), I_j is the impervious surface percentage of land use j, and EMC_j is the Event Mean Concentration of TSS for land use j. Variables A_j and I_j are properties of the watershed and are not varied statistically in the MC analysis. The precipitation depth, P_i, and EMC_j are selected from distributions in the MC analysis. The statistical properties of these two parameters are discussed in the following sections.

2.1.1 Precipitation Statistics

The MC analysis utilizes two properties of precipitation records to generate a synthetic rainfall record; precipitation event depth (P_i), and inter-event time (IET_i). For this analysis, an event was defined as any period of precipitation preceded and followed by at least 6 hours of dry weather. Precipitation statistics were obtained from the precipitation of the nearby Bristol NCDC station, which included 15 minute precipitation totals from 1973 to 2008, with 72% coverage. Geosyntec identified 2,630 precipitation events in this record. The distribution of these precipitation event depths was approximated using a gamma distribution, where the cumulative probability function is represented by:

$$F(x;\alpha,\beta) = \frac{\gamma\left(\alpha, \frac{x}{\beta}\right)}{\Gamma(\alpha)}$$

Where γ is the incomplete gamma function and Γ is the gamma function, and α and β are shape and scale parameters, respectively. The distribution of precipitation depths was fit to a gamma distribution with $\alpha = 0.39$ and $\beta = 0.88$. Figures 2.1 and 2.2 show the observed and modeled data plotted on a line with slope 1:1, and the observed and modeled cumulative distribution. The modeled and observed data had a correlation coefficient of 0.99.

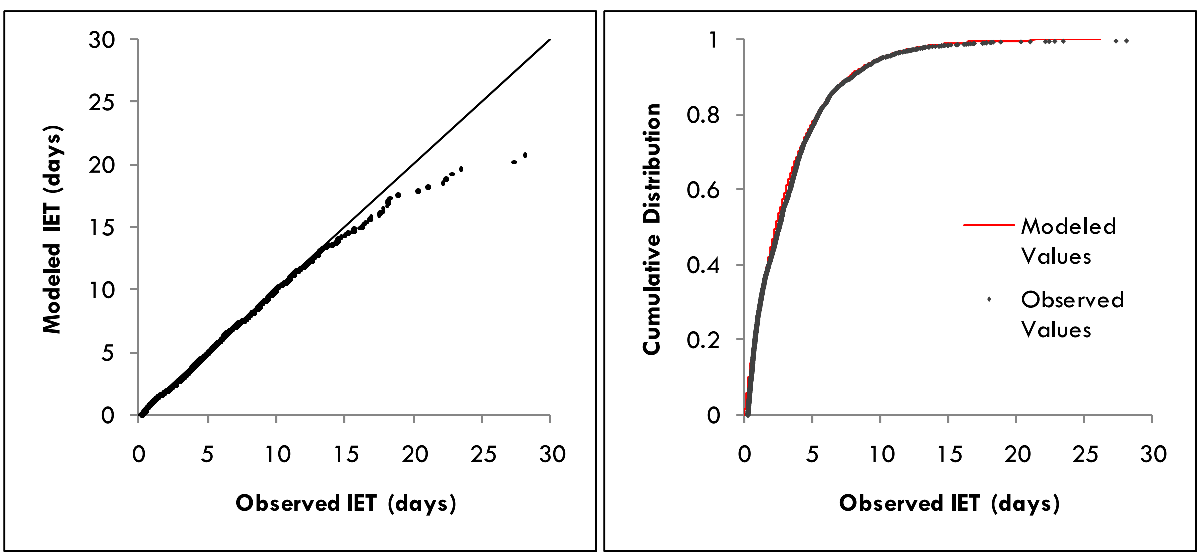


Figures 2.1, 2.2. Observed vs. Modeled precipitation event depths, and observed and modeled precipitation event depth CDF. (Note that the events greater than 4 inches were not well described by the model. This represents 0.3% of the observed precipitation events).

In the same precipitation record, Geosyntec identified 2,553 inter-event time (IET) periods, which was the time between the start of one event and the start of the following event. The distribution of IETs was estimated using an exponential distribution, where the cumulative distribution function is described by:

$$F(x;\lambda) = 1 - e^{-\lambda x}$$

The IET data were fit to an exponential distribution with λ=0.3. Figures 2.3 and 2.4 show the observed and modeled data plotted on a line with slope 1:1, and the observed and modeled cumulative distribution. The modeled and observed data had a correlation coefficient of 0.96.



Figures 2.3, 2.4. Observed vs. Modeled IETs, and observed and IET CDF. (Note that the events greater than 18 days were not well described by the model. This represents 0.5% of the observed IETs).

The utility of these distributions was verified by using them to calculate two hundred years of precipitation data. Assuming that the two distributions (event depth and IET) are sufficient to describe a realistic precipitation record, the distribution of actual annual precipitation should be similar to that of the synthetically derived annual precipitation. In Figure 2.5 below, the distribution of modeled annual precipitation totals is compared to the distribution of New Hampshire average precipitation. The mean and standard deviation for Annual Precipitation in New Hampshire is 43.05 and 5.84, respectively, while the mean and standard deviation of the synthetic annual precipitation was 45.23 and 6.80, respectively.

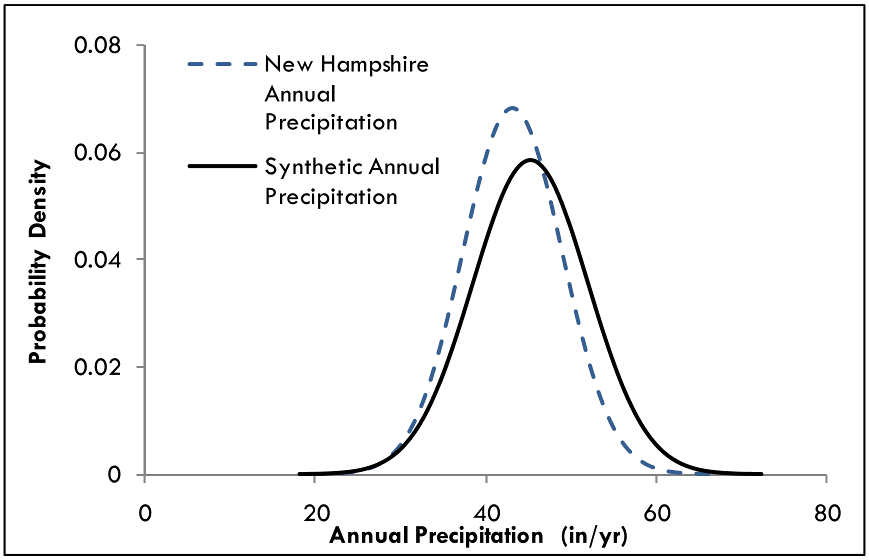


Figure 2.5. Synthetic rainfall data compared to New Hampshire annual precipitation data.

2.1.2 Event Mean Concentration (EMC) Statistics

TSS Event mean concentration data was obtained from the National Stormwater Quality Database (NSQD). Data was obtained for four land use categories: Residential, Transportation, Open Space/Forest, and Institutional. The EMC data were assumed to be lognormally distributed. The cumulative distribution function of the lognormal distribution is described by the equation:

$$F(x;\mu,\sigma) = \Phi\left(\frac{\ln(x)-\mu}{\sigma}\right)$$

Where μ and σ are the mean and standard deviation of the natural logarithms of the data, and Φ denotes the standard normal cumulative distribution. Figure 2.6 shows lognormal probability plots displaying the fit of the data to a lognormal distribution, along with the estimated parameters μ and σ (the closer the data points fall along the straight line, the better they are described using the lognormal distribution).

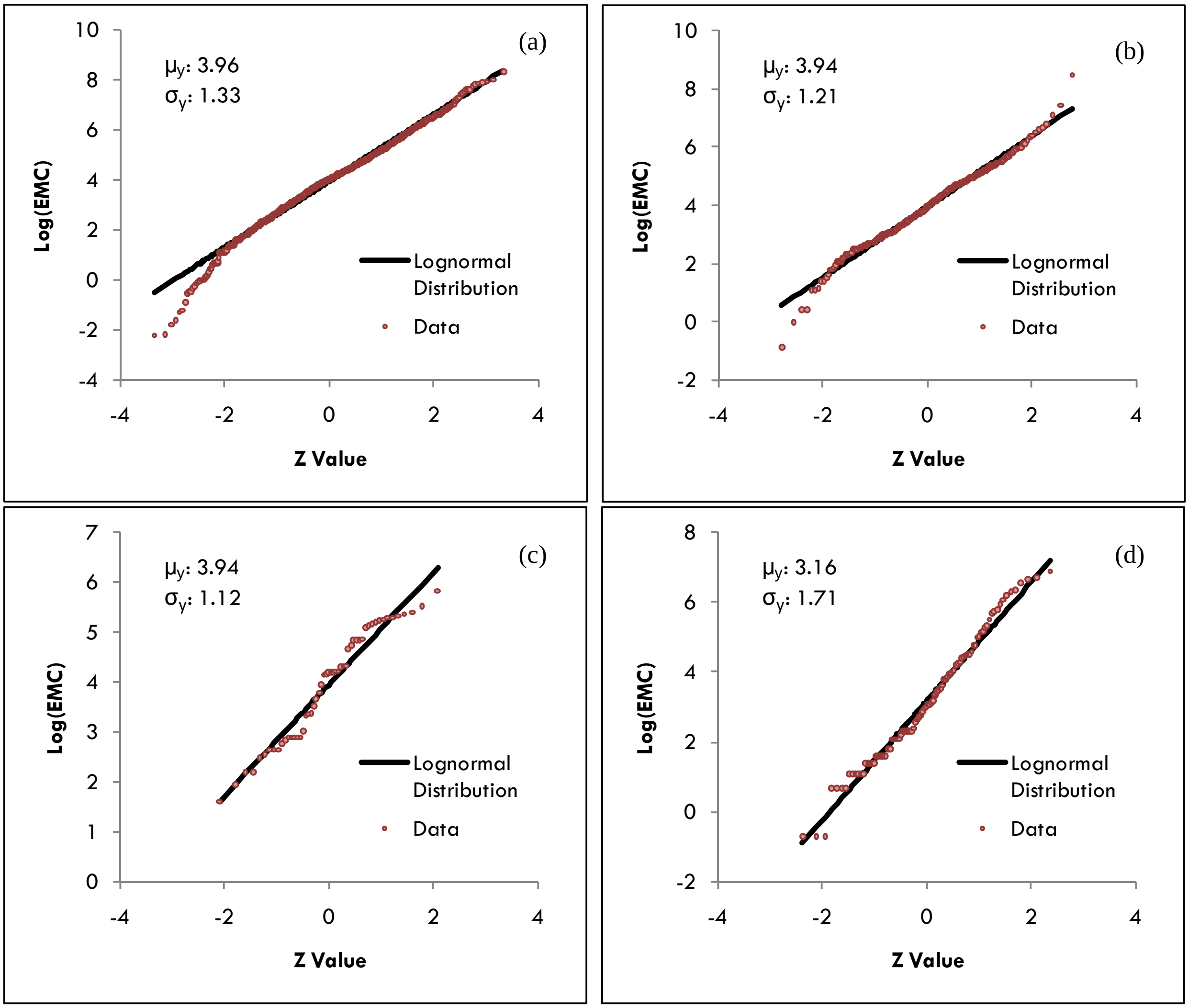


Figure 2.6. Lognormal distribution of (a) Residential EMCs, (b) Transportation EMCs, (c) Institutional EMCs, and (d) Open Space/Forest EMCs

2.2 Model Results

The Monte Carlo Analysis was run for three scenarios:

1. **Forested Condition:** All land area is simulated as forest to represent the "pristine" TSS load;
2. **Current Condition:** Represents an estimate of TSS load based on existing land uses; and
3. **Buildout Condition:** Uses a range of buildout conditions, as described in section 2.2.3, to represent a likely future TSS load.

For each scenario, the MC analysis was run until a total of 5000 annual TSS loads (iterations) was calculated. In each iteration, the model parameters (precipitation depth, inter-event time, EMC from each land use) for single precipitation events were randomly selected until the inter-event times summed to one year, at which point the load from all events was summed and a new iteration was begun.

2.2.1 *Forested Condition*

The 5000 annual loads calculated in the MC analysis for the forested condition followed a lognormal distribution with a mean and standard deviation of the log of TSS load being 0.97 and 0.42, respectively. This translates to an actual predicted average TSS load under the forested condition of 2.64 tons/yr. The MC analysis for forested conditions indicates that 50% of the possible annual loading outcomes will fall between 1.99 and 3.49 tons/yr.

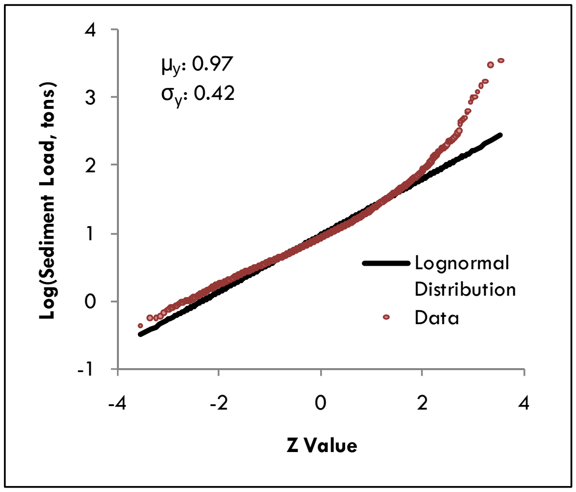


Figure 2.7. Lognormal Distribution of Monte Carlo results for Forested Conditons.

2.2.2 *Current Condition*

Current conditions were modeled by assigning the following land uses and EMC types to the watershed:

Table 2.1. Land Uses in North Inlet subwatershed and assigned EMC's.

LAND USE	AREA (acres)	EMC Type
Forest	37.6	Open
Open	14.2	Open
Residential	51.8	Residential
Road	6.8	Transportation
School	11.0	Institutional
Wetland	5.0	Open
TOTAL	126.4	

The 5000 annual loads calculated in the MC analysis for the current condition followed a lognormal distribution with a mean and standard deviation of the log of TSS load being 2.15 and 0.23, respectively. This translates to an actual predicted average TSS load of 8.63 tons/yr. The MC analysis for current conditions indicates that 50% of the possible annual loading outcomes will fall between 7.41 and 10.05 tons/yr.

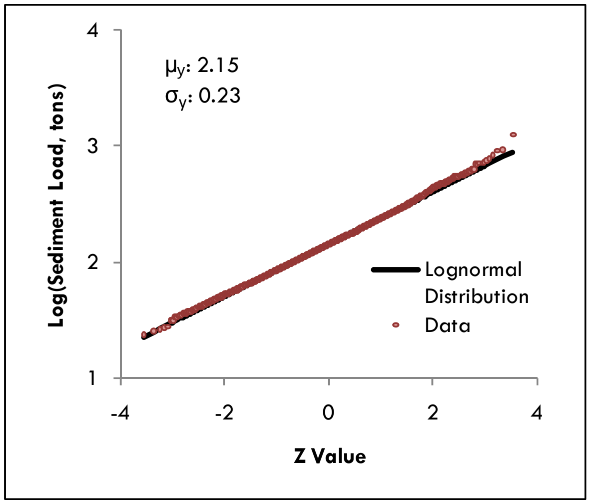


Figure 2.8. Lognormal Distribution of Monte Carlo results for Current Conditions.

2.2.3 Buildout Conditions

The buildout condition was modeled similarly to the current condition with a modification to adjust the areas associated with each land use. This buildout factor (BF) was assumed to vary linearly between three values:

- At a minimum, no further buildout occurs (current conditions persist into the future);
- A "most likely" amount of buildout occurs, based on population projections for the Town of Wolfeboro;
- Maximum buildout occurs, converting all forested/open land into "developed" (residential/road) land.

The "most likely" amount of buildout was calculated using a 24.8% population increase projection for Wolfeboro by 2030 (Lakes Region Planning Commission). The watershed currently has an estimated 45 homes. Assuming 2.3 persons/household, the watershed population is approximately 105 persons. A 24.8% increase would lead to an additional 26 persons, and 11 additional homes. The minimum lot size for Wolfeboro Zoning Class R is 1 acre, meaning 11 additional acres of residential land will be converted from forest/open land under the "most likely" buildout scenario.

It was assumed that under any buildout scenario, the ratio of residential land area to road area would remain the same (1 acre of road for every 7.6 acres of residential land).

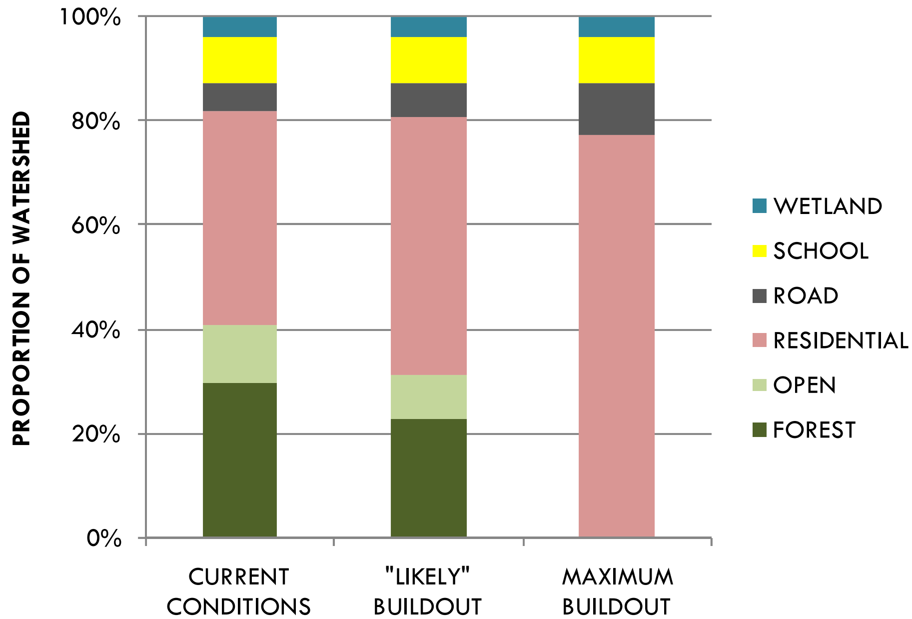


Figure 2.9. Variation in Land Use for buildout scenarios.

The 5000 annual loads calculated in the MC analysis for the buildout condition followed a lognormal distribution with a mean and standard deviation of the log of TSS load being 2.33 and 0.26, respectively. This translates to an actual predicted average TSS load under the buildout condition of 10.32 tons/yr. The MC analysis for buildout conditions indicates that 50% of the possible annual loading outcomes will fall between 8.61 and 12.36 tons/yr.

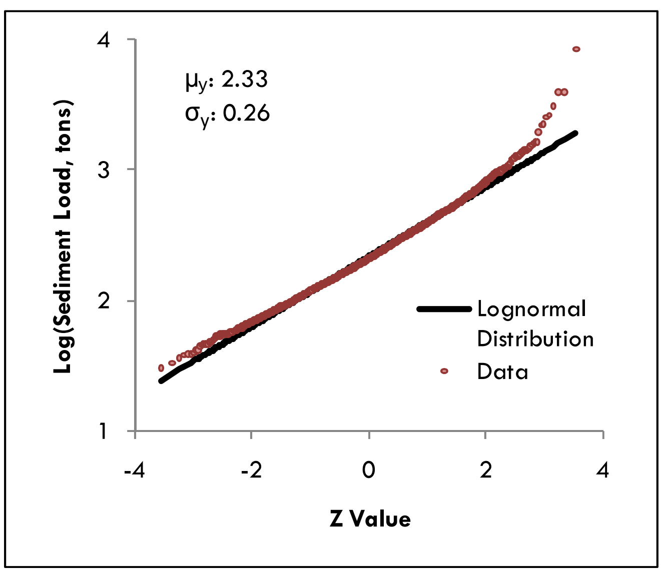


Figure 2.10. Lognormal Distribution of Monte Carlo results for Buildout Conditions.

2.2.4 Additional Loads

In addition to the TSS loading estimated by the MC analysis, loads from various forms of streambank erosion was calculated and added to each of the three scenarios discussed above. The streambank erosion method is discussed in further detail below

<u>Normal Streambank Erosion</u>

A TSS load from streambank erosion that is expected to occur in streams with normal flow and generally stable bank conditions was estimated using the Lateral Erosion Rate (LER) method discussed in the AVGWLF (Arc View General Watershed Loading Function) model developed by Penn State University. For more detail on the LER method, see the AVGWLF user documentation.
For this calculation, the following parameters were assumed:

- 55% developed land
- 0 livestock per hectare
- Average curve number of 74
- Soil erodability factor of 0.17 (obtained from NRCS Soil Data Mart, for Champlain Loamy Sand, 3 to 8 percent slope)
- Mean topographic slope of 4%
- Soil bulk density of 1.4 g/cm^3
- Stream length of 470 m
- Bank height of 0.6 m
- Monthly discharge of 29,920 m^3/month (obtained from NHDES Report: "Rust Pond: Pond and Watershed Diagnostic Study")

The resulting LER TSS load was 0.95 tons/yr. This load was added to the results of the Monte Carlo Analyses for each of the three scenarios.

<u>Impaired Streambank Erosion</u>

A stretch of the North Inlet tributary that was adjacent to a former beaver dam contains actively eroding banks. The additional erosion caused by these bank segments is addressed using the "Impaired Streambank" tool included with the USEPA STEP-L (Spreadsheet Tool for Estimating Pollutant Loads) worksheet. The Impaired Streambank load was estimated to be 0.43 tons/yr, assuming a gully approximately 6 feet deep, 10 feet wide, and 40 feet long, experiencing a "severe" rate of lateral recession (for comparison, this load is 17 times higher than the typical streambank erosion when normalized for length). This load was added to the results of the Monte Carlo Analyses for the current and buildout conditions.

Extreme Erosion Events

A known recent source of sediment contributing to the North Inlet delta is the severely eroded streambank adjacent to the beaver dam. As stated previously, continued erosion from this bank is estimated at approximately 0.43 tons/yr. However, our understanding is that the erosion that led to the current state of the streambank may have occurred rapidly and contributed a load in the past. Using the STEP-L Gully Erosion tool and the dimensions provided above, and assuming that the gully formed over 5 years, the annual TSS load from this source in the past is estimated to be 8.4 tons/yr. This source could have contributed approximately 26 cubic yards of sediment to the delta over the 5 years that it formed. This would account for approximately 3% of the estimated sediment delta volume of 920 cubic yards.

2.3 Summary of Results

Table 2.2 below summarizes the results of the three buildout scenarios. Figure 2.11 displays the probability density curves for the three scenarios.

Table 2.2. Summary of Sediment Loading Results

MODEL SCENARIO	MONTE CARLO AVERAGE LOADING (tons/yr)	NORMAL STREAMBANK EROSION (tons/yr)	IMPARED STREAMBANK EROSION (tons/yr)	**TOTAL (tons/yr)**
Forested	2.64	0.95	0.0	3.6
Current	8.63	0.95	0.43	10.0
Buildout	10.32	0.95	0.43	11.7

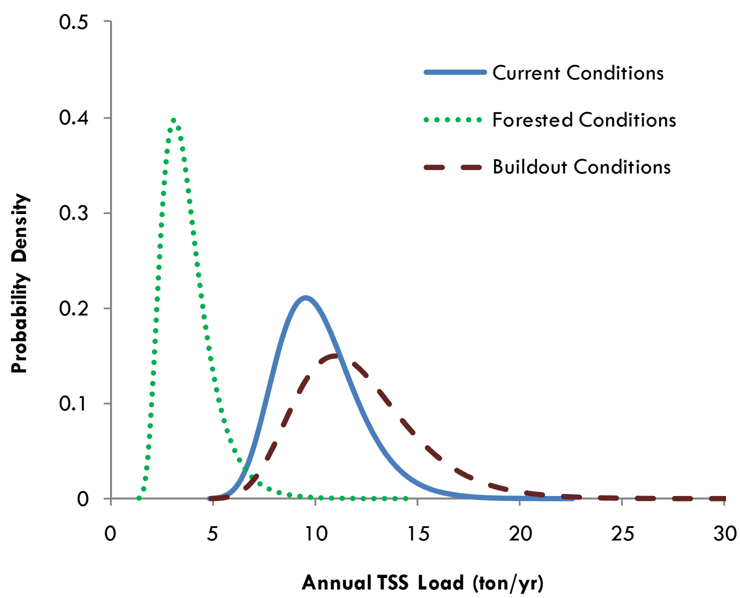


Figure 2.11. Lognormal "bell curve" distributions of model results.

2.4 Comparison to Other Estimates

Geosyntec used an alternate method of calculating sediment load. This method uses export coefficients, which are presented in terms of pounds per acre per year. These export coefficients are multiplied by the area of each land use to determine a total load for a watershed. Table 2.3 presents annual TSS loading results calculated from export coefficients presented in (1) the USEPA Region 5 Model, and in (2) Massachusetts Geographic Information System.

Table 2.3. Export Coefficient Estimates of Sediment Load for Current Conditions

		EPA REGION 5 MODEL			MASSGIS		
LAND USE	AREA (acres)	EXPORT CO. (LB/AC/YR)	EXPORT (LB/YR)		EXPORT CO. (LB/AC/YR)	EXPORT (LB/YR)	
FOREST	37.6	20	752		21	789	
OPEN	14.2	20	284		13	184	
RESIDENTIAL	51.8	154	7977		346	17922	
ROAD	6.8	1330	9044		866	5888	
SCHOOL	11.0	790	8690		346	3806	
WETLAND	5.0	20	100		47	235	
TOTAL	126.4	TOTAL	26847	lb/yr	TOTAL	28826	lb/yr
			13.4	Tons/yr		14.4	Tons/yr

A comparison of all sediment load estimates is presented if Figure 2.12 below, including the loads presented in Table 2.2, the export coefficient results, watershed sediment load results from the STEP-L model, and an estimate provided by NHDES in the memo entitled "Rust Pond Impairment at the North Inlet."

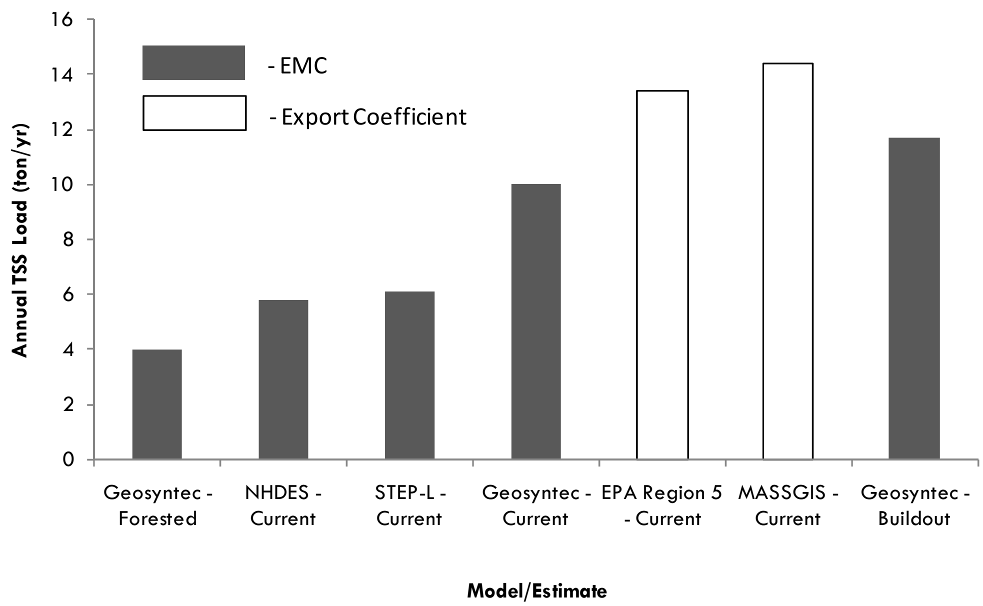


Figure 2.12. Comparison of sediment load estimates.

As shown in the comparison, Geosyntec's estimate of current conditions falls between the two methods, STEP-L and export coefficients (EPA Region 5 and MASSGIS). Additionally, the distribution resulting from the Monte Carlo analysis includes the other estimates within its range. These two facts lend credibility to the estimate of 10.0 tons/yr.

3. WATER QUALITY GOAL

A memo entitled "Rust Pond Impairment at the North Inlet" (NHDES, 2007), provides an estimate of the sediment volume in the delta that has formed at the North Inlet. The volume estimate is approximately 920 cubic yards of sand and sediment, based on the NHDES estimated range of 740-1100 cubic yards.

Assuming a typical "silty sand" porosity of 0.28 (Das, 1999) and a solids density of 2.65 g/cm^3, the estimated solids density of wet sediment is:

$$D_{sed} = (1-\sigma)(\rho_{sed}) = (1-0.28)\left(2.65\ \frac{g}{cm^3}\right) = 1.9\ \frac{g}{cm^3}$$

$$\left(1.9\ \frac{g}{cm^3}\right)\left(\frac{lb}{453.592\ g}\right)\left(\frac{ton}{2000\ lb}\right)\left(\frac{1\times 10^6\ cm^3}{m^3}\right)\left(\frac{1\ m^3}{1.308\ cy}\right) = 1.6\ ton/cy$$

Under current conditions, with an estimated average TSS loading of 10.0 tons/yr, approximately 6.25 cy/yr is expected to be delivered to the North Inlet delta. This means that if the current 920 cy delta is dredged, it would take roughly 150 years for a similar delta to accumulate.

A water quality goal for Rust Pond was determined during a series of conference calls between Geosyntec and project stakeholders, including NHDES and the Town of Wolfeboro. The water quality goal for sediment loading in Rust Pond's North Inlet subwatershed will be to have no decrease in the timeframe for delta reformation. In other words, **the current loading of 10.0 tons/yr would be maintained and any sediment loading increases projected due to future development would be prevented/offset via the implementation of stormwater best management practices (BMP's)**.

The average difference between average current loads and average projected future loads is 1.7 tons/yr. At a minimum, a suite of best management practices should be implemented such that their combined load reduction equals 1.7 tons/yr. However, as shown by the Monte Carlo analysis above, the range of projected future estimates is large relative to forested and current conditions estimates. With that in mind, a conservative management strategy may consider additional implementation of BMP's, which will only further decrease potential future loading and improve the water quality of Rust Pond.

4. OPTIONS FOR REDUCING SEDIMENT LOADING TO RUST POND

4.1 Field Watershed Investigation

Daniel Bourdeau (Water Resources Engineer, P.E.) and Renee Fitsik (Water Resources Engineer) of Geosyntec conducted a field watershed investigation on November 4, 2010 and an assessment of the North Inlet tributary on April 28, 2011. Based on the results of this field investigation and assessment, the following pages provide a discussion of potential sediment reduction best management practices (BMPs) and restoration practices that relate to storm water management and sediment load reduction in the North Inlet and Route 28 Boat Launch subwatersheds.

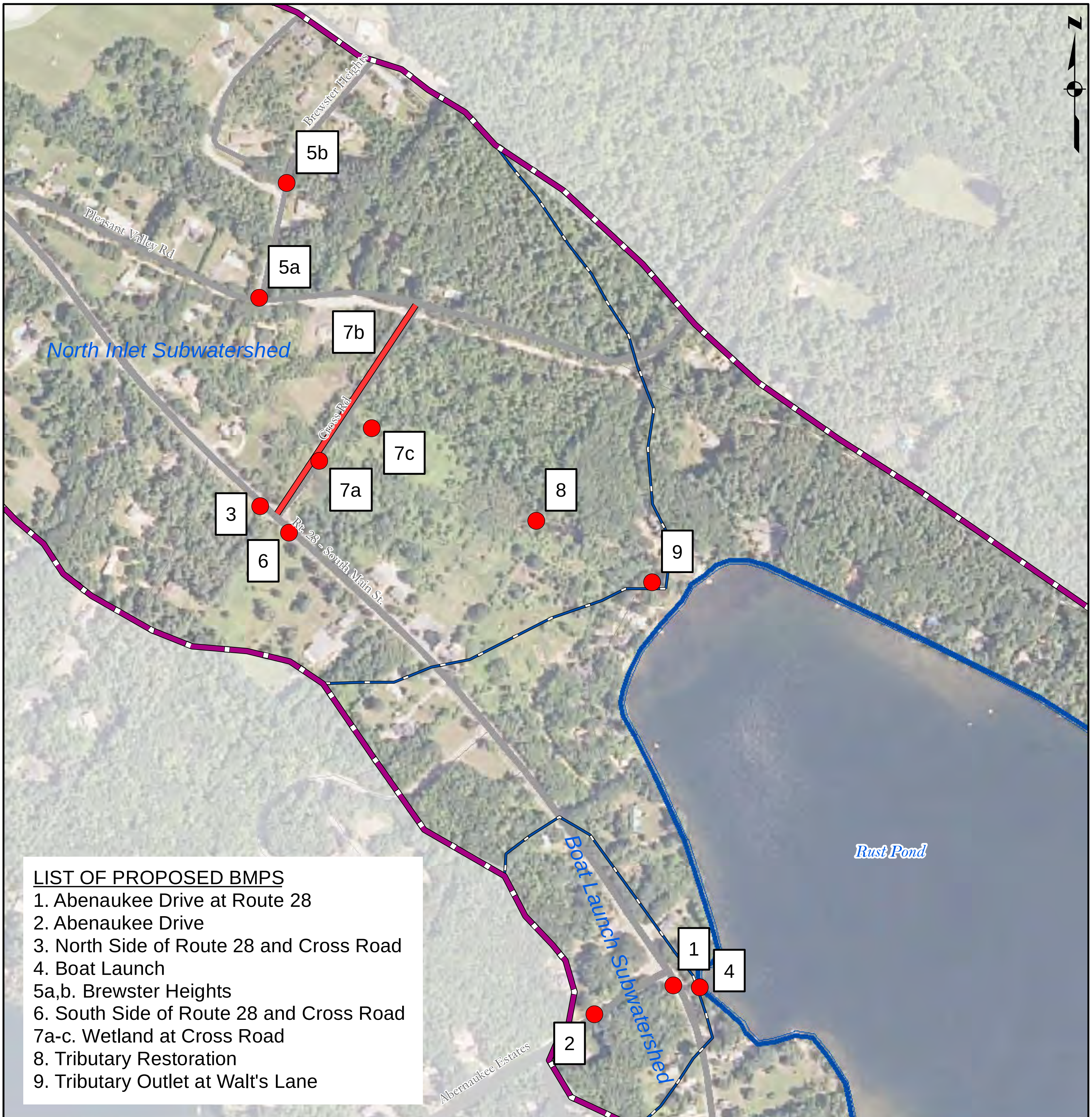
When considering sediment loading and future stormwater improvements in the North Inlet subwatershed, recent (2010) improvements to the Kingswood School Complex should also be considered. These improvements included building renovations, parking expansion, storm water management system improvements, and renovations to the sports field complex. Renovations to the sports field complex included installation of a new underdrain system and decommissioning of the previous underdrain system that discharged directly to the headwater wetland of the North Inlet tributary. The previous underdrain system was reported to discharge sediment-laden water into the wetland and North Inlet tributary. The previous system was also reported to discharge large volumes of water into this wetland, contributing to (1) elevated peak flow volumes and velocities and (2) stream bank erosion in the tributary, specifically at an existing beaver dam located in the North Inlet tributary just upstream of Walt's Lane. The new underdrain system discharges directly into the storm water management basin at the southwest corner of the sports fields, allowing for settling of sediment and reduction in peak flow volume and velocity.

The locus map (Figure 4.1) on the following page shows the location of potential improvement sites in the North Inlet subwatershed that have been identified by Geosyntec. Table 4.1 presents a cost estimate and sediment loading reduction estimate calculations for each proposed improvement. A USDA-NRCS soil survey map identifying soil classes in the North Inlet subwatershed is provided as Figure 4.2.

4.2 BMP Recommendations

The BMP sites described on the following pages were identified during Geosyntec's field investigations. Each BMP site description includes:

1. A site summary that describes the current conditions and stormwater drainage patterns;
2. A description of proposed improvements;
3. Estimated costs including installed contractor construction costs, engineering and permitting costs;
4. Sediment load reduction predicted for the proposed BMP, provided the practice is properly installed and maintained;
5. Typical annual operation and maintenance costs for the proposed BMP practice; and
6. Recommended priority for BMP implementation (low, medium or high). The priority level is based on factors including cost, sediment load reduction, constructability, location, ease of maintenance and best professional judgment.



Legend

- Location of Proposed Improvement
- Rust Pond Watershed
- Sub-Watershed
- Rust Pond

500 250 0 500 1,000 Feet

Locations of Proposed Stormwater Improvements

Rust Pond Watershed
Wolfeboro, New Hampshire

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Figure 4.1

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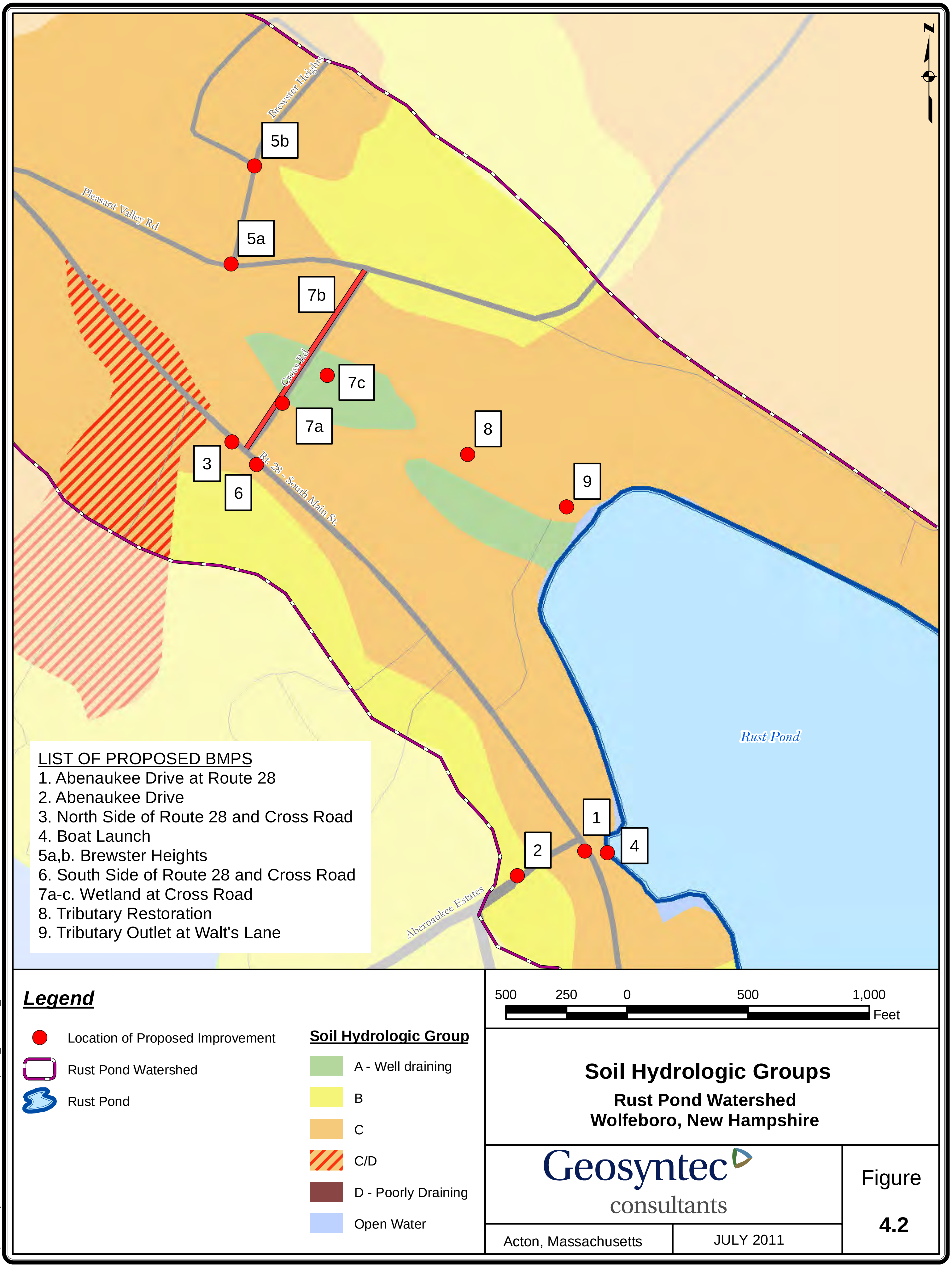

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TABLE 4.1: BMP CONSTRUCTION COST ESTIMATES

SITE	BMP / STORMWATER IMPROVEMENT	COMPONENT	QUANTITY	UNIT PRICE	COMPONENT COST	TOTAL COST[5]	TSS LOAD[6] (ton/yr)	PERCENT REDUCTION	TSS LOAD REDUCTION (ton/yr)
1a	Abenaukee Drive at Route 28- Hydrodynamic Separator & Bioretention					$9,477 - $11,583	0.38	94%	0.32 - 0.39
		Hydrodynamic Separator Device [2]	1	$6,000 ea	$6,000				
		Flow Splitter [2]	1	$1,000 ea	$1,000				
		Bioretention [1]	100 sf	$11 sf	$1,100				
1b	Abenaukee Drive at Route 28- Channel Stabilization					$2,246 - $2,746	0.09	100%	0.08 - 0.10
		Outfall Energy Dissipation [2]	150 sf	$8 sf	$1,200				
		Channel Stabilization [2]	30 lf	$24 lf	$720				
2	Abenaukee Drive					$2,750 - $3,361	0.016	90%	0.013 - 0.016
		Bioretention Cell [1]	150 sf	$11 sf	$1,650				
		Underdrain (including excavation/bedding) [3]	20 lf	$35 lf	$700				
3	North Side of Rt. 28 and Cross Road					$2,633 - $3,218	1.2	82%	0.89 - 1.08
		Sediment Forebay [2]	200 sf	$6 sf	$1,200				
		Vegetative Channel [1]	50 lf	$21 lf	$1,050				
4	Rust Pond Boat Launch					$1,316 - $1,609	0.002	70%	0.001 - 0.002
		Stabilization/Revegetation [2]	375 sf	$3 sf	$1,125				
5a	Brewster Heights Bioretention/Sediment Trap					$2,574 - $3,146	0.4	82%	0.30 - 0.36
		Bioretention [2]	200 sf	$11 sf	$2,200				
5b	Brewster Heights Channel Diversions					$2,340 - $2,860	0.9	25%	0.20 - 0.25
		Earthen Flow Diversion [2]	2	$1,000 ea	$2,000				
6	South Side of Rt. 28 and Cross Street					$2,808 - $3,432	0.6	82%	0.44 - 0.54
		Sediment Forebay [2]	400 sf	$6 sf	$2,400				
7a	Wetland at Cross Road - Culvert Replacement					$13,860 - $16,940	-	-	
		Concrete Headwall [3]	2	$3,000 ea	$6,000				
		24" HDPE culvert [3]	60 lf	$29 lf	$1,740				
		Excavation [3]	65 cy	$8 cy	$520				
		Backfill [3]	58 cy	$37 cy	$2,146				
		Asphalt pavement [2]	360 sf	$4 sf	$1,440				
7b	Channel Stabilization	Vegetative Channel [1]	700 lf	$21 lf	$14,700	$17,199 - $21,021	Channel Stabilization (erosion prevention)		
							1.3	100%	1.17 - 1.43
							Stormwater TSS load reduction (without other watershed BMPs at sites 3, 5a, 5b, 6)		
							6	21%	1.13 - 1.39
							Stormwater TSS load reduction (with other watershed BMPs at sites 3, 5a, 5b, 6)		
							2.2	63%	1.24 - 1.51
7c	Wetland at Cross Road - Wetlands Rehabilitation					$41,535 - $50,765	Without other watershed BMPs (Sites 3, 6)		
							6.6	78%	4.63 - 5.66
		Sediment Excavation [2]	150 cy	$70 cy	$10,500		With other watershed BMPs (Sites 3, 6)		
		Wetland Replication [1]	20000 sf	$1.25 sf	$25,000		4.98	78%	3.50 - 4.27
8	Tributary Restoration					$9,945 - $12,155	0.43	90%	0.35 - 0.43
		Impoundment Removal and Import Fill	100	$70 cy	$7,000				
		Biostabilization	300 sf	$5 sf	$1,500				
9	Tributary Outlet at Walt's Lane					$5,288 - $6,464	Without other watershed BMPs (Sites 3, 6, 7 and 8)		
		Sediment Excavation [2]	15 cy	$70 cy	$1,050		6.6	82%	4.87 - 5.95
		Native Shrub Planting [4]	320 sf	$1.50 sf	$480		With other watershed BMP's (Sites 3, 6, 7 and 8)		
		Emergent Aquatic Planting [4]	100 sf	$1.40 sf	$140		0.50	82%	0.37 - 0.45
		Bank/Cover Improvement [4]	1	$1,500 ea	$1,500				
		Debris/Fascines [4]	75 lf	$18 lf	$1,350				

Notes:
1. Unit costs from Charles River Watershed Association.
2. Unit costs based on past Geosyntec projects and contractor estimates.
3. Unit costs estimated from R.S. Means
4. Stream restoration costs from "Stream Restoration: The costs of engineered and bio-engineered alternatives," USEPA
5. Cost includes additional 30% to reflect mobilization, erosion and sediment controls, contingency, etc.
6. BMP TSS (sediment) loading calculated using Spreadsheet Tool for Estimating Pollutant Loads (STEPL), provided by USEPA

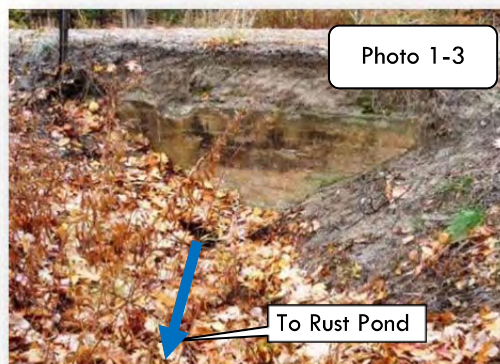
SITE 1: ABENAUKEE DRIVE AT ROUTE 28

Site Summary:

A series of catch basins collect runoff from the intersection of Abenaukee Drive and Route 28. These catch basins and drain pipes include newer structures starting just south of the 569 South Main Street driveway, on the west side of Route 28. One of the catch basin in this series (Photo 1-1) collects runoff from the area of Abenaukee Drive and Route 28 (drainage area for the proposed BMP). In addition to this storm drain system, a wetland west of Route 28 also drains through the culvert under Route 28 (Photo 1-2). The culvert discharges to Rust Pond via an unstabilized channel (Photo 1-3).

Proposed Improvement:

- Install a flow splitter in the catch which would divert low flows to a hydrodynamic separator and high flows would discharge directly to the culvert and ultimately to Rust Pond. The hydrodynamic separator would discharge to a bioretention cell, approximately 20 feet long by 5 feet wide, and provide treatment (i.e., settling of suspended sediments). Photo 1-4 is a rendering of the area surrounding the catch basin. Image 1-5 is a cross section of a typical bioretention cell.
- Stabilize the existing culvert outfall (Photo 1-3) with an energy-dissipation device and stabilize the existing 30-feet of drainage channel with natural stone.



Estimated Cost:

Design and Permitting: $3,000 - $5,000

Construction:

- Hydrodynamic Separator and Bioretention Cell: $9,480 - $11,580
- Channel Stabilization: $2,250 - $2,750

Estimated Sediment Reduction:

- Hydrodynamic Separator & Bioretention Cell: 0.32 – 0.39 ton/yr
- Channel Stabilization: 0.08 – 0.10 ton/yr

Estimated O&M Costs: $50 - $100/yr; remove accumulated sediment annually from the particle separator device, remove sediment from bioretention cell every two years, and replace plants as needed every two years.

Priority: High
SITE 1: ABENAUKEE DRIVE AT ROUTE 28 *(continued)*

Photo 1-4 shows proposed BMP locations in the area just downgradient of the catch basin.

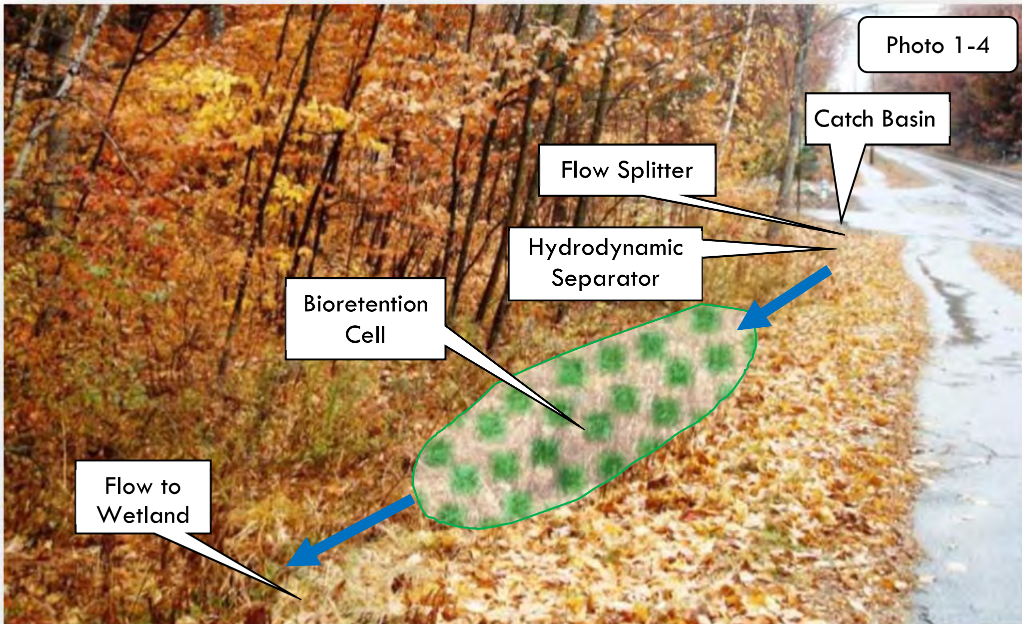
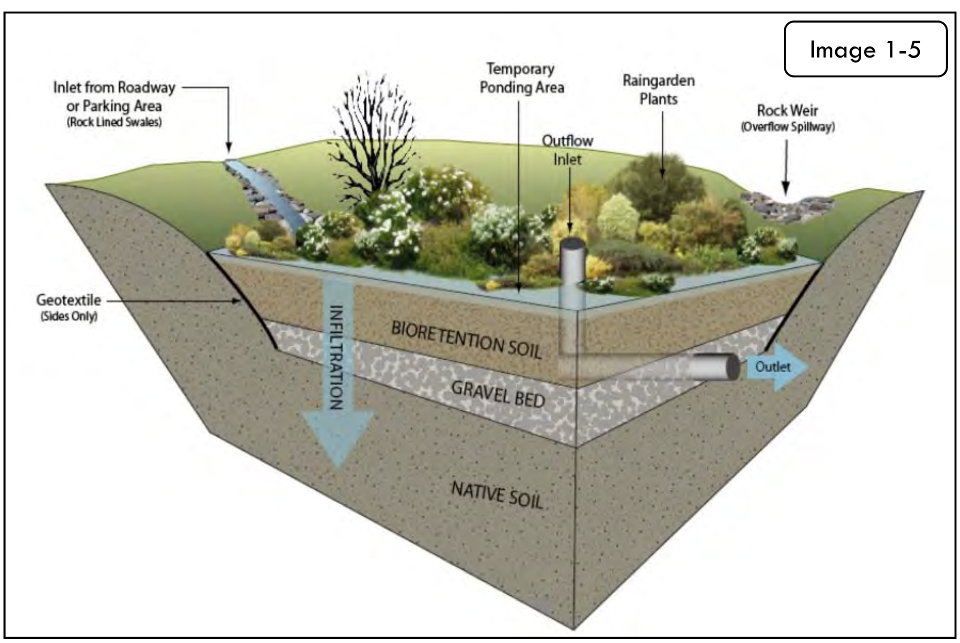


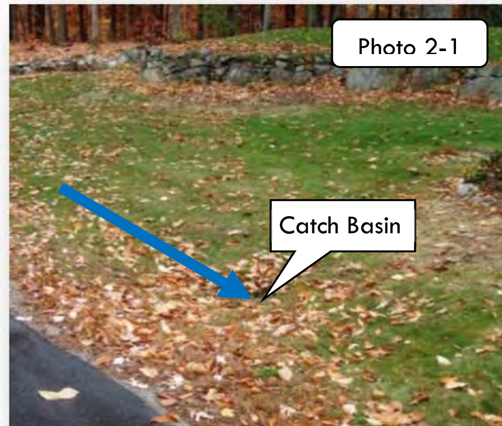
Image 1-5 is a cross section schematic of a typical bioretention cell. Bioretention cells are shallow landscaped depressions that incorporate plantings and engineered soil with a high porosity and infiltration capacity. Bioretention cells control stormwater runoff volume by providing storage, reducing peak discharge, and removing pollutants through physical, chemical, and biological processes occurring in plants and soil.



SITE 2: ABENAUKEE DRIVE

Site Summary:

An existing catch basin in the area of 2 Abenaukee Drive (Photo 2-1) collects runoff from the adjacent road (Photo 2-2). This catch basin drains via storm drain to the catch basin described in Site 1.



Proposed Improvement:

Install a bioretention cell approximately 150 square feet in size in the area surrounding the catch basin. The bioretention cell would be sized to treat (i.e., filter out sediment) and infiltrate storm water runoff volume. The existing catch basin would be used to provide overflow protection during larger storm events, which exceed the storage capacity of the bioretention cell.

Estimated Cost:

Design and Permitting: $1,000 - $1,500

Construction: $2,750 - $3,360

Estimated Sediment Reduction: 0.013 – 0.016 tons/yr (26 - 32 lb/yr)

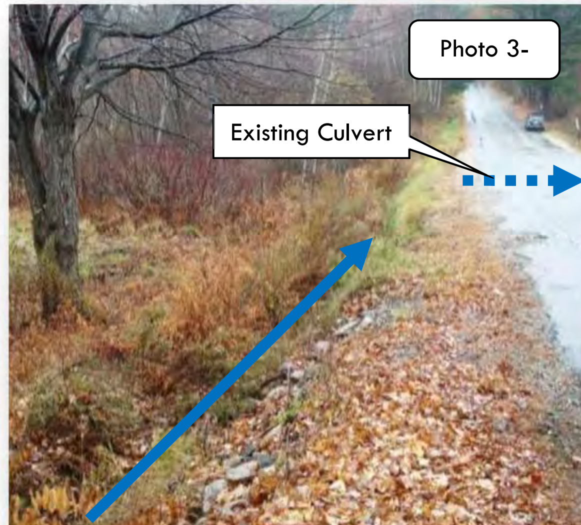
Estimated O&M Costs: $50 - $100/yr (could be a cost incurred by home owner) to remove accumulated sediment from raingarden annually and replace plants as needed every two years.

Priority: Low

SITE 3: NORTH SIDE OF ROUTE 28 AND CROSS ROAD

Site Summary:

Stormwater runoff from the intersection of Cross Road and Route 28 drains into a series of catch basins which discharge to an unstabilized ditch along the northern side of Cross Road (Photo 3-1). This ditch drains into a culvert and ultimately to the wetland described as Site 4.



Proposed Improvements:

- Install a sediment trap at the outlet of the catch basin. The sediment trap would be approximately 50 feet long by 4 feet wide, extending from the catch basin outlet parallel with Cross Road. The sediment trap would collect suspended solids from road runoff.
- Stabilize approximately 50 feet of the ditch (between the outfall of the proposed sediment trap and the proposed Cross Road culvert) with erosion control blanket and vegetation to reduce erosion.

Estimated Cost:

Design and Permitting: $1,500 - $2,000

Construction: $2,630 - $3,220

Estimated Sediment Reduction: 0.89 – 1.08 ton/yr

Estimated O&M Costs: $100 - $200/yr; remove accumulated sediment from the sediment trap annually, repair and revegetate ditches as needed every two years.

Priority: Medium

SITE 4: RUST POND BOAT LAUNCH

Site Summary:

The Route 28 boat launch (across from Abenaukee Drive) provides access to the lake for local residents. The dirt and gravel launch is steep, shows signs of erosion and is located along a busy route with little area for motorized vehicles to park, turn and access the launch.

Proposed Improvement:

The use of this area for a public boat launch is not recommended and consideration should be given to discontinue the use of this area as an access point for boaters. According to the National Park Service Logical Lasting Launches Guide (2004) and the State Organization for Boating Access Design Handbook for Recreational Boating and Fishing Facilities (2006), accessible launches should meet the following design guidelines:

- Width – 6' to 12'
- Length – at least 25'
- Slope – shall not exceed 15%
- Support – provide handrails or other structures to allow boaters balance when putting-in and taking-out boats
- Location – ideally in areas without heavy flow, erosion, exposure to the elements, heavy boat traffic or fragile reptile habitats
- ADA accessible
- Adequate parking
- Adequate layout for maneuvering trailers

The current boat launch layout exceeds the maximum slope recommendations and is located in an area with potential for heavy flows during storm events resulting in erosion. In addition, the current layout does not accommodate parking, ADA accessibility, adequate traffic turning lanes, trailer turning radius requirements or traffic safety.

If discontinued as a boat launch, the area should be re-graded and stabilized with vegetation, including shrubs. Install at wood guard rail or move existing boulders along the shoulder of Route 28 to prevent use of this area by motorized vehicles.

Estimated Cost:

Design and Permitting: < $1,000

Construction: $1,320 - $1,610

Estimated Sediment Reduction: 0.001 – 0.002 ton/yr (2 – 4 lbs/yr)

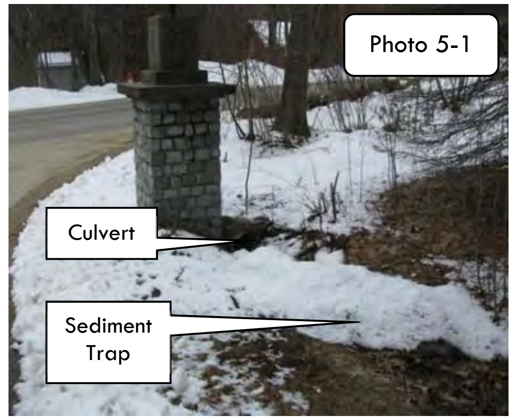
Estimated O&M Costs: < $50/yr; replace dead vegetation each year for first two to three years.

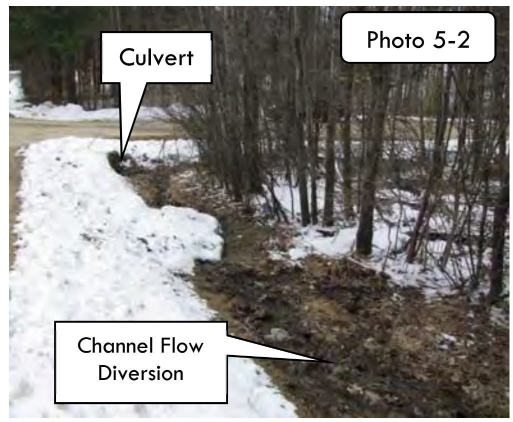
Priority: Medium

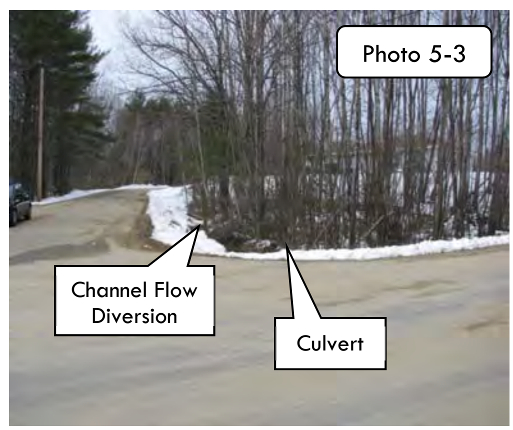
SITE 5: BREWSTER HEIGHTS

Site Summary:

Brewster Heights is a cul-de-sac subdivision north of Rust Pond. Runoff from this development discharges to a series of wetlands and drainage ditches and ultimately to the North Inlet Wetland (Site 7) and Tributary (Site 8). A drainage ditch at the entrance of Brewster Heights collects road runoff prior to discharging into a culvert (Photo 5-1). Two channels convey runoff from the cul-de-sac to a culvert (Photos 5-2 and 5-3).







Proposed Improvements:

- **5a:** Install a bioretention swale/sediment trap near the entrance of Brewster Heights at Pleasant valley Road, to allow for filtering and settling of sediment from the road prior to discharging into a culvert, which drains to a catch basin along Pleasant Valley Road (Photo 5-1).
- **5b:** Install flow diversions in the two channels adjacent to the cul-de-sac, which will direct flow into the existing forested area to increase the flow path, reduce velocity and allow for settling of sediment prior to entering the culvert, which ultimately discharges into a wetland at the entrance of the subdivision (Photos 5-2 and 5-3).

Estimated Cost:

Design and Permitting: $2,200 - $3,200

Construction:

- 5a: Bioretention Swale/Sediment Trap:
  $2,570 - $3,150
- 5b: Flow Diversions: $2,340-$2,860

Estimated Sediment Reduction:

- 5a: Bioretention Swale/Sediment Trap: 0.30 – 0.36 tons/yr
- 5b: Flow Diversions: 0.20 – 0.25 tons/yr

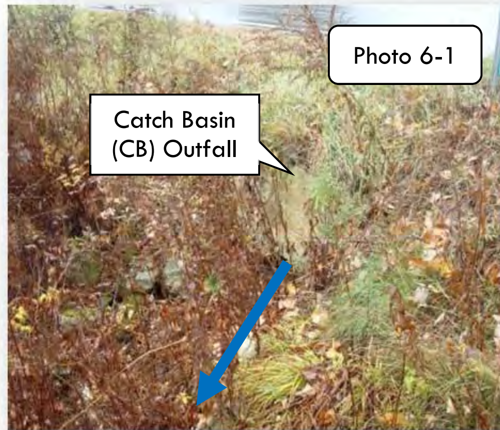
Estimated O&M Costs: $100 - $150/yr; remove sediment from the trap annually, remove sediment and replace channel vegetation as needed every two years.

Priority: Medium

SITE 6: SOUTH SIDE OF ROUTE 28 / CROSS ROAD

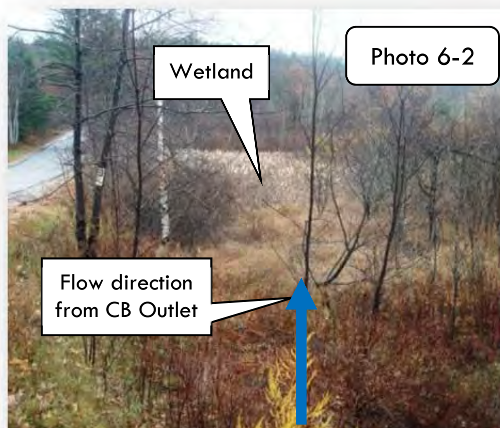
Site Summary:

A portion of the stormwater runoff from the intersection of Cross Road and Route 28 drains into a series of catch basins which outlet into a ditch and vegetated area along the south side of Cross Road (Photo 6-1 and 6-2). This vegetated area drains to the wetland described in Site 7 (Photo 6-2).



Proposed Improvement:

Install a sediment trap at the catch basin outfall, approximately 20 feet long by 20 feet wide. The sediment trap would be equipped with a spillway that would drain to the wetland described in Site 3. A sediment trap is a small depression that is typically installed at the end of a conveyance (e.g. stable channel, culvert, etc.), allowing sediment-laden stormwater to temporarily pool and sediment to settle out. Cleaner stormwater drains via the natural rock spillway. Photo 6-3 is an example of a sediment trap with a natural rock spillway that could be constructed at this location.



Estimated Cost:

Design and Permitting: $1,500 - $2,000

Construction: $2,800 - $3,430

Estimated Sediment Reduction: 0.44 – 0.54 ton/yr

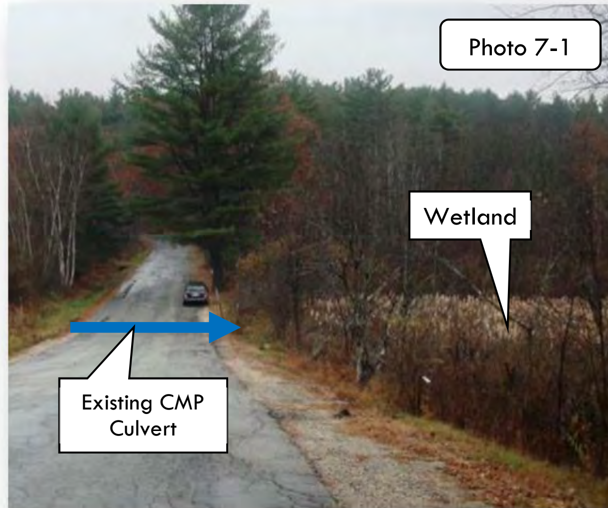
Estimated O&M Costs: $100 - $150/yr; remove accumulated sediment from the sediment trap annually, repair and revegetate ditches as needed every two years.

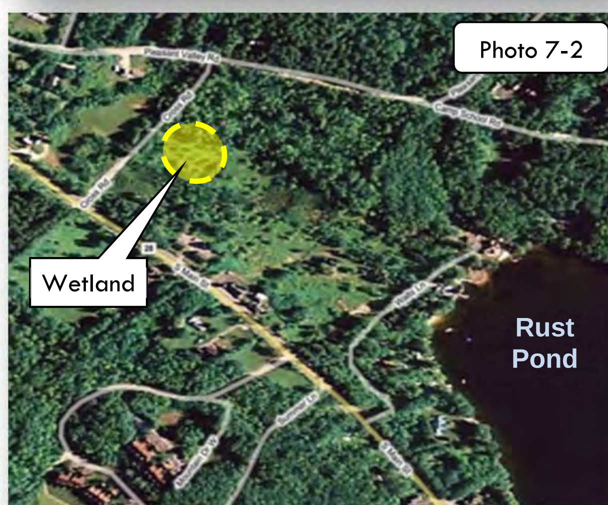
Priority: Medium

SITE 7: WETLAND AT CROSS ROAD

Site Summary:

The wetland adjacent to Cross Road (Photos 7-1 and 7-2) collects stormwater runoff from Cross Road, a portion of Route 28, and a portion of the area between Cross Road and Pleasant Valley Road. A culvert under Cross Road (Photo 7-1) conveys flow from the northern side of Cross Road near the intersection with Route 28, as described in Site 3. A ditch along the south side of Cross Road (near the Route 28 intersection) discharges runoff to the wetland, as described in Site 6. The portion of Cross Road located north of the culvert (towards intersection with Pleasant Valley Road) drains to the wetland via an eroding roadside ditch on the west side of the road. A 2007 NHDES study identified the wetland as impacted by sediment. The accumulated sediment appears to be limiting the hydraulic function of the wetland.





Proposed Improvements:

- **7a:** Replace the existing corrugated metal pipe (CMP) with a 24-inch diameter high-density polyethylene (HDPE) pipe and concrete headwalls. The culvert would be approximately 60 feet long.
- **7b:** Restore the existing roadside ditches along Cross Road with stabilized vegetated swales or other means of stabilization as appropriate for the flow volumes and velocities anticipated in specific areas (*see hydrologic modeling memorandum attached as Appendix A*). This proposed improvement includes all existing ditch areas on the north side of the Cross Road, not including the area already adressed in Site 3. This area comprises approximately 700 linear feet.
- **7c:** Restore the hydraulic function of the existing wetland by (1) constructing a sediment forebay at the outfall of the new culvert, and (2) restoring up to 20,000 square feet of the wetland by removing accumulated sediment, regrading the site, and planting native vegetation. The proposed actions would restore wetland function and reduce sediment load to the tributary that drains into Rust Pond (Site 8). The proposed restoration activities will require a NHDES Wetlands Permit (Standard Dredge and Fill, Major Project). The dredging should be designed not to exceed 20,000 square feet of wetland disturbance, which would exceed the New Hampshire Programmatic General Permit and trigger the requirement for a Section 404 Individual Permit from the U.S. Army Corps of Engineers.

SITE 7: WETLAND AT CROSS ROAD *(continued)*

Estimated Cost:

Design and Permitting: $10,000 - $25,000
Construction:

- Culvert Replacement: $13,860 - $16,940
- Wetland Restoration: $41,540 - $50,770
- Roadside Ditch Improvements: $17,199 – $21,021

Estimated Sediment Reduction:

- Wetland Restoration: Without upstream BMPs (Sites 3, 6): 4.63 – 5.66 ton/yr
  With upstream BMPs (Sites 3, 6): 3.50 – 4.27 ton/yr

- Roadside Ditch Improvements: Without upstream BMPs (Sites 3, 5a, 5b, 6): 2.30 – 2.82 ton/yr
  With upstream BMPs (Sites 3, 5a, 5b, 6): 2.41 – 2.94

Estimated O&M Costs: $400 - $600/yr; remove accumulated sediment from the sediment trap and roadside ditches annually, and replace dead wetland vegetation each year for first two to three years.

Priority: High

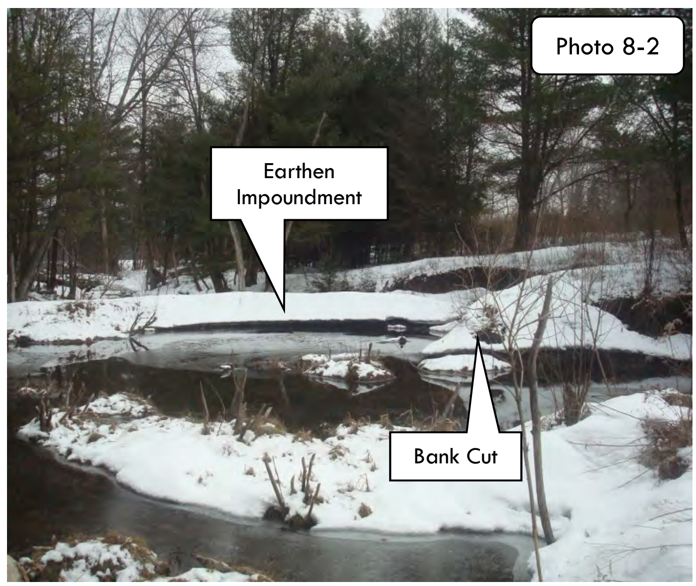
SITE 8: TRIBUTARY RESTORATION

Site Summary:

The North Inlet tributary flows through the wetlands southeast of Cross Road (Site 7) and ultimately discharges to Rust Pond at Walt's Lane (Site 9). An earthen impoundment, likely from previous beaver activity, has caused the tributary to meander out of the natural flow path resulting in bank cutting and erosion (Photo 8-1 and 8-2).

Proposed Improvements:

- Remove a portion of the earthen impoundment at the center of the channel to restore natural flow pattern of the tributary. The portion of the abandoned dam should resemble a v-notch weir.
- Re-grade (i.e., import fill), stabilize tributary banks with biostabilization measures to reduce future erosion.



Estimated Cost:

Design and Permitting: $1,000 - $1,500

Construction: $9,950- $12,160

Estimated Sediment Reduction: 0.35 – 0.43 tons/yr

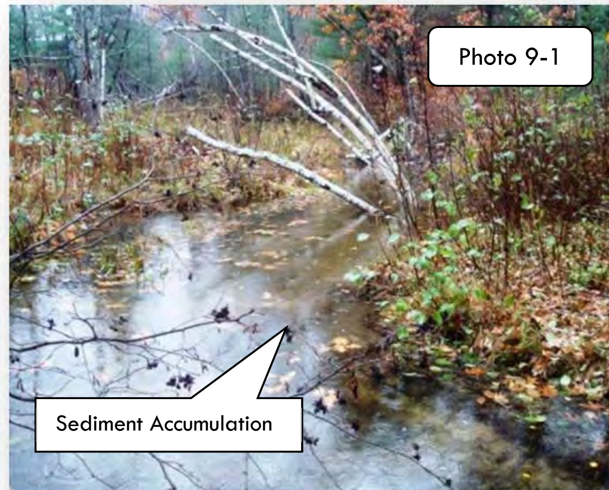
Estimated O&M Costs: < $50/yr; replace dead vegetation each year for first two to three years.

Priority: High

SITE 9: TRIBUTARY OUTLET AT WALT'S LANE

Site Summary:

The North Inlet tributary flows through the wetlands adjacent to Cross Road (Site 7) and discharges to Rust Pond, east of Walt's Lane. An earthen berm restricts open flow at the inlet with approximately an 8-foot break where the tributary drains to the pond. Sediment has accumulated in the area upgradient of the berm (Photos 9-1 and 9-2).



Proposed Improvement:

Restore the hydraulic function of the existing tributary and bordering wetlands by removing approximately 15 cubic yards of accumulated sediment in the area immediately upgradient of the berm. Stabilize the disturbed area with approximately 320 square feet of native shrub and aquatic plantings. Habitat features including woody debris should be incorporated into the restoration. For the purpose of pollutant loading reduction estimates, Geosyntec assumes the additional storage area provided will function similar to a sediment forebay, in that it will provide improved storage capacity for sediment settling and accumulation.

Estimated Cost:

Design and Permitting: $1,500 - $2,500

Construction: $5,300 - $6,470

Estimated Sediment Reduction:

- Without upstream BMP's and Restoration (Sites 3, 6, 7 and 8): 4.87 – 5.95 ton/yr
- With upstream BMP's (Sites 3, 6, 7 and 8): 0.37 – 0.45 ton/yr

Estimated O&M Costs: > $100; replace dead vegetation each year for first two to three years.

Priority: Low (existing vegetation and bank will be disturbed; close proximity to pond)

4.3 Sediment Dredging

Dredging of the existing sediment delta should be considered to further improve the water quality and boating access at the North Inlet. Several methods may be used to accomplish the removal of the accumulated sediment. Based on the sediment delta location and water depths, conventional dry excavation could be feasible if lake level drawdown can be conducted to dewater the delta area. Wet excavation or hydraulic dredging are other alternatives.

- **Dry Excavation** involves draining the lake to the extent possible, dewatering the sediments by gravity and/or pumping and then removing sediments with conventional excavation equipment such as backhoes, bulldozers, or draglines.
- **Wet Excavation**: For this technique, the lake is either not drained or is only partially drawn down to minimize downstream flows. Excavation of sediments is conducted with bucket dredges mounted on cranes or amphibious excavators.
- **Hydraulic Dredging** involves the use of floating equipment, combining the use of a cutter head to loosen sediments and suction to pump sediments out of the lake as a wet slurry. The slurry, which is 80-90% water, must be de-watered outside of the lake, allowing the sediments to dry out for later disposal and the water to drain back to the lake.

Dredging the North Inlet would require the following permits and authorizations:

- Wetlands Dredge and Fill Permit (NHDES);
- Section 401 Water Quality Certification (NHDES);
- Section 404 permit under the Clean Waters Act (Army Corps of Engineers);
- Natural Heritage Bureau (NHB) notification;
- Public notification of drawdown and notice to local city/town and NH Fish and Game Director.

The costs of obtaining the necessary permits, which include preparation of permit applications, permitting plans, wetlands delineations, and other necessary documentation, may total approximately $20,000.

The costs of dredging projects vary significantly depending on the size of the project, the type of material removed, the difficulty of site access, trucking distance to sediment disposal location, etc. Conventional dry dredging may cost up to $70/cy for small-scale projects. Hydraulic dredging costs typically range from $10 - $30/cy, with smaller projects such as the proposed North Inlet dredging normally at the high end of that range (larger projects benefit from economy of scale). The cost of dredging the North Inlet sediment delta, estimated at 920 cy, is to cost approximately between $28,000 - $65,000, depending on the method used. Site access, material handling, sediment and water control, equipment mobilization, etc. will add additional costs based on the particulars of the project.

5. SUMMARY OF TECHNICAL AND FINANCIAL SUPPORT

5.1 Technical Support

Most of the phosphorus loading reduction measures described in Section 6 will require a moderate to high level of technical support. The required types of technical support include site topographic surveys, preparation of existing conditions base plans, and preparation of definitive site drawings by an Engineer that would be used for permitting, contractor bidding and construction. Stormwater improvement sites requiring low level of technical support would generally be appropriate for design-build construction using field manuals. A listing of the stormwater improvement sites according to estimated level of required technical support is as follows:

Level of Technical Support Required for Stormwater BMP Sites

Low	Moderate	High
Site 2: Abenaukee Drive *Site 3*: North Side of Route 28 and Cross Road *Site 6*: South Side of Route 28/Cross Road	*Site 1*: Abenaukee Drive at Route 28 *Site 4*: Rust Pond Boat Launch *Site 5*: Brewster Heights	*Site 7*: Wetland at Cross Road *Site 8*: Tributary Restoration

In addition to the technical support described above, construction of some of the projects described in Section 4 will require wetlands permitting through the NHDES Wetlands Bureau and other permits. Wetlands were not delineated as part of this 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.

5.2 Financial Support

Site improvements and management recommendations described in Section 4 will require funding to install and complete. Likely sources of funding include, but are not limited to, Federal Section 319 grants and Aquatic Resource Mitigation grant funds. Brief descriptions of these grant funding sources are provided below. Alternative funding may be in the form of donated labor from the Town of Wolfeboro, the Rust Pond Association, and local contractors.

Section 319 Watershed Assistance and Restoration Grants:

NHDES Watershed Assistance and Restoration Grants are funded 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 non-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 this grant program can be found at: www.des.state.nh.us/wmb/was/grants.htm.

Aquatic Resource Mitigation (ARM) Grant Program

NHDES collects mitigation funds whenever wetlands are impacted by development. This money is held in the Aquatic Resource Mitigation (ARM) Fund and can be granted to projects that will "accomplish long-term environmental results" and that "consider watershed goals and replace or protect wetlands and other aquatic resources functions." Collection and delegation of funds are determined based on the watershed in which the projects are sited. Rust Pond is located in Winnipesaukee River Watershed, which held $255,000 in funding for 2011. Projects suitable for ARM grants include wetlands restoration, stream restoration, and culvert replacement. More information on this grant program can be found at:
http://des.nh.gov/organization/divisions/water/wetlands/wmp/documents/arm_app.pdf

Conservation License Plate Grant Program

Conservation Grants are funded through purchase of the New Hampshire Conservation License Plate ("Moose Plate"). Applicants apply in two groups, grants under $5,000 and grants over $5,000. The Conservation Grant Program's six focus areas include:

- Preserve, protect and conserve water quality and water quantity;
- Planning or implementation of BMPs for agriculture, forestry or storm water management;
- Restore, enhance or conserve wildlife habitat;
- Reduce, prevent and/or mange soil erosion and/or flooding;
- Conservation planning that accomplishes a conservation protection outcome; and
- Permanent land protection through conservation easement or fee purchase.

Eligible grant applicants include:

- County Conservation Grants: County Conservation Districts and County Cooperative Extension Natural Resource Programs; and
- Municipal and Nongovernmental Entity Conservation Grants: municipal conservation agencies engaged in conservation programs; public and private schools, K through 12; scout groups; other nonprofit entities engaged in conservation programs.

Information on the grant program can be found at www.nh.gov/scc/grants/index.htm, and the application form is at www.nh.gov/scc/grants/index.htm.

6. PUBLIC INFORMATION AND EDUCATION

The Town of Wolfeboro, in cooperation with the Rust Pond Association and with support from Geosyntec Consultants, conducted the following activities related to public information and education for this project:

- **Brochure/Kiosk:** In cooperation with the RPA, Geosyntec developed an educational brochure and kiosk poster specific to the Rust Pond watershed and potential improvements and practices to reduce sediment loading to the lake. A copy of the brochure developed through this project is available from the Town.

- ***Field Guide to the Aquatic Plants of Rust Pond*:** Geosyntec developed a *Field Guide to the Aquatic Plants of Rust Pond* based on the results of the 2011 aquatic vegetation survey conducted as part of this project. It is recommended that this field guide be distributed to all lakefront property owners to aid in ongoing volunteer monitoring to prevent the introduction or invasive species to Rust Pond.

- **Public Education Workshop:** Geosyntec provided a public education presentation and workshop at the RPA annual meeting on August 13, 2011 to present the findings of this watershed restoration plan to the RPA members, the Town of Wolfeboro and other watershed stakeholders. The presentation provided an overview of Rust Pond water quality issues related to sediment loading, in addition to specific long-term management options suitable for the pond. Geosyntec also provided educational information on the siting, design and installation of LID landscaping techniques for residential properties. LID techniques presented included raingardens/bioretention, vegetated buffers, and other techniques focused on promoting infiltration and the use of native vegetation to reduce phosphorus loading in lake watersheds.

- **Volunteer Monitoring:** The Rust Pond Association has continued to recruit volunteers and participate in New Hampshire's Volunteer Lake Assessment Program (VLAP). VLAP was established in 1985 and utilizes a network of volunteers to collect and analyze water quality samples at approximately 175 lakes and ponds in New Hampshire.

- **Other Resources:** Homeowners in the Rust Pond watershed are encouraged to review the following educational resources:

  - **Innovative Land Planning Techniques – A Handbook for Sustainable Development:** http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm

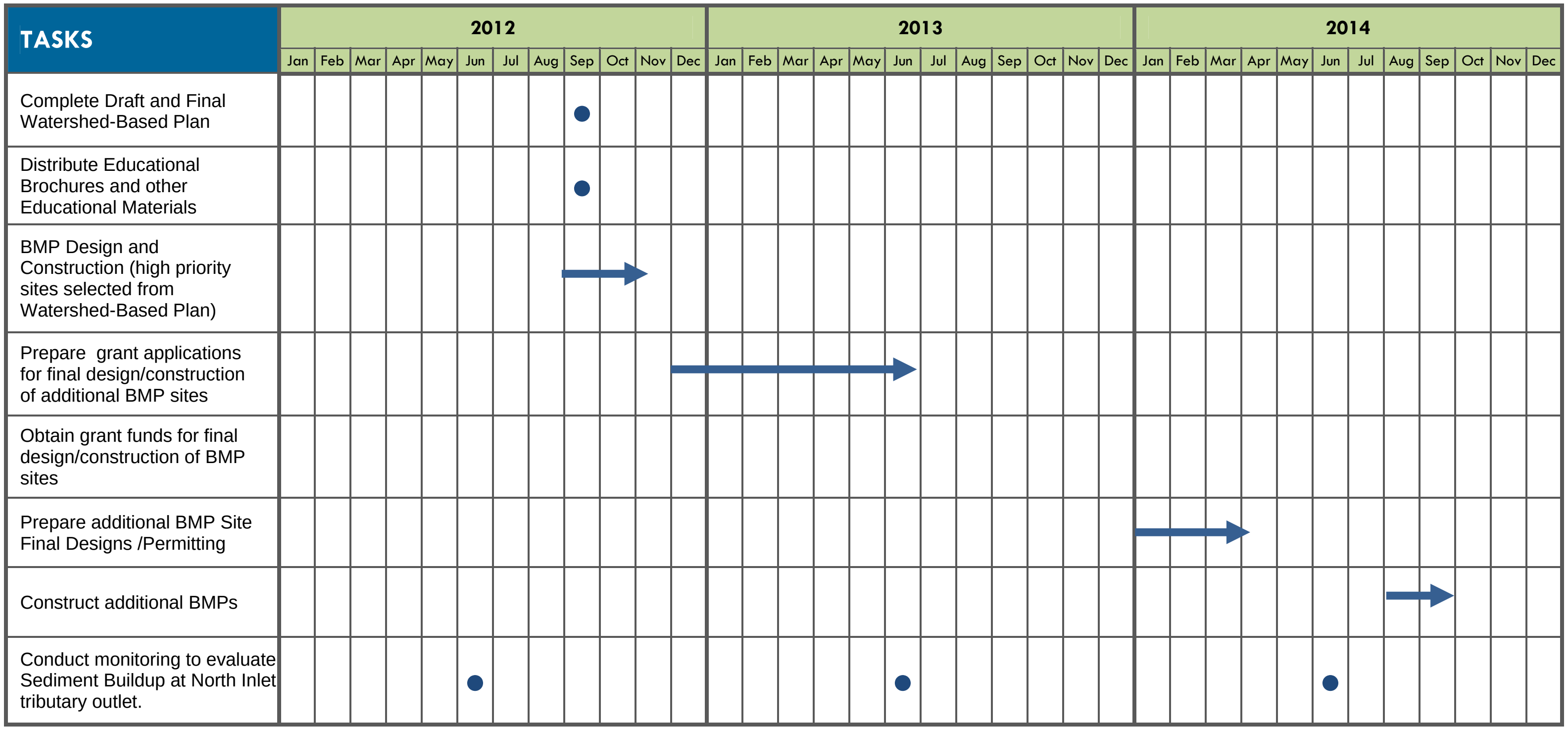
  - **The Vermont Raingarden Manual:** http://nsgl.gso.uri.edu/lcsg/lcsgh09001.pdf

  - **A Shoreland Homeowner's Guide to Stormwater Management** http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/nhdes-wd-10-8.pdf

7. SCHEDULE AND INTERIM MILESTONES

The improvements recommended for Rust Pond and its watershed are ranked in order of priority as described in Section 4 of this report. A proposed schedule and associated interim milestones for these improvements are provided below.

Rust Pond Watershed Restoration Plan - Implementation Schedule and Interim Milestones



8. EVALUATION CRITERIA AND MONITORING

As discussed in Section 3, this watershed restoration plan recommends a maximum annual sediment load from the North Inlet of 10.0 tons/yr. To achieve this load, a minimum of 1.7 tons/yr of sediment must be reduced/prevented via the use of stormwater BMP's. Section 4 of this report describes management measures that may be implemented to achieve this targeted sediment load reduction. Geosyntec recommends the following monitoring and evaluation criteria to determine the effectiveness of these proposed measures in reducing sediment buildup and improving the water quality of Rust Pond.

- **Sediment Deposition Monitoring:** The RPA should continue monitoring in-lake water quality through the NH-VLAP program. In addition, a staff gage can be installed in the area where sediment is currently building up at the North Inlet tributary. The staff gage would be installed at a fixed position and elevation. The gage can be used to determine the rate of sediment buildup, provided that readings from the gage become a regular part of the water quality monitoring program. The current sediment delta is estimated to be approximately 100x100 ft. Based on the estimated sediment densities discussed in Section 3, 10.0 tons/yr spread across the 10,000 ft^2 area equates to approximately 0.2 inches/yr, or 1 inch of sediment accumulation every 5 years. Observed rates of accumulation may vary significantly from this rate depending on the placement of the staff gage, because this estimate assumes uniform sediment deposition over the entire 10,000 ft^2. Therefore, multiple monitoring locations may be necessary to determine a more accurate rate of deposition.

- **Erosion Monitoring:** If the stream restoration activities outlined in Section 4 above are implemented, the RPA should monitor the restored area to ensure that the erosion control activities are functioning as intended. Monitoring activities could include photo-documentation of the restoration site, monitoring vegetation health and growth, and measurement of stream width at the restoration site to document any lateral erosion,

- **Public Outreach, Education and Land Use Activities:** In addition to the monitoring efforts described above, the effectiveness of recommended measures related to public outreach and land use activities can be evaluated with several simple metrics, including:

  - Quantify the number of public education brochures that are distributed to watershed residents;

  - Quantify other watershed improvements initiated by homeowners as a result of outreach and education efforts, such as installation of residential raingardens and other LID practices.

APPENDIX A:

Hydrologic Modeling: Cross Road and South Main Street, Rust Pond North Inlet Subwatershed, Wolfeboro, NH (Geosyntec, 12 July 2012)

Geosyntec consultants

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Memorandum

Date: 12 July 2012

To: David W. Ford, P.E., Director of Public Works and Water & Sewer Utilities, Town of Wolfeboro

From: Daniel Bourdeau, P.E., Geosyntec Consultants
Robert Hartzel, CLM, CPESC, Geosyntec

CC: Andrew Chapman, New Hampshire Department of Environmental Services

Subject: Hydrologic Modeling: Cross Road and South Main Street, Rust Pond North Inlet Subwatershed, Wolfeboro, NH

Introduction

This memorandum summarizes the results of hydrologic modeling performed to determine the design peak discharges at two catch basins located on the south side of the intersection of Cross Road and South Main Street in Wolfeboro, NH. These two catch basins receive runoff via a vegetated roadside swale from the paved surfaces of South Main Street as well as surrounding residential land to the south of the road. The catch basins drain through storm drain pipes under South Main Street and discharge onto the area on the north side South Main Street. Design peak discharge was evaluated for the 2-, 10-, and 25-year, 24 hour design storm events.

Analysis

Contributing subcatchments for the catch basins were delineated using aerial imagery and USGS topographic maps (Figure 1). Each catch basin has two subcatchments; one subcatchment contains the paved road portion as well as the estimated extent of the grass swales south of the road, and the second subcatchment contains the residential land south of South Main Street. The northern catch basin was assumed to receive runoff generated as far north as the intersection of South Main Street and Pleasant Valley Road, while the contributing area of the southern catch basin was extended southward until an apparent watershed divide. Average slopes were estimated using the distance between contours on the USGS topographic map. Land uses types were assigned based on aerial imagery. Hydrologic parameters for each subcatchment are listed in Table 1.

Each catch basin consists of a 2 ft. x 2 ft. storm grate with an 18” dia. corrugated metal pipe (CMP) outlet pipe. The invert of the northern outlet pipe is 3.2 ft. below the grate elevation, while the invert of the southern outlet pipe is 3.5 ft. below the grate elevation. The northern and southern outlet pipes have slopes of 0.038 ft./ft. and 0.027 ft./ft., respectively. The specific inverts, diameters, material, and slopes of the outlet pipes were obtained from a plan titled “Cross Road, Town of Wolfeboro,” prepared by White Mountain Survey and Engineering, Inc., and dated April 19, 2012.

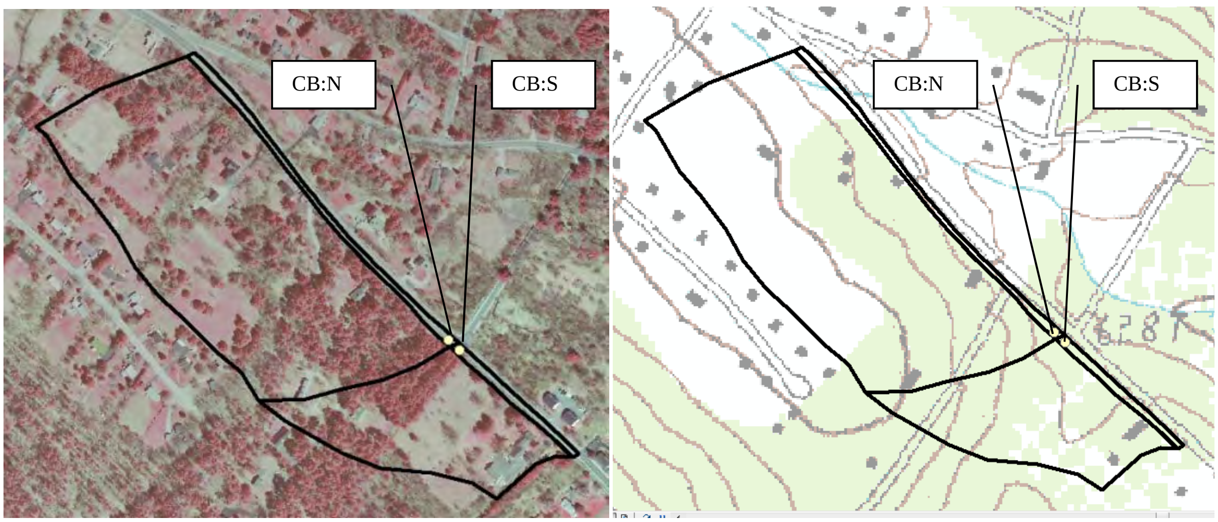


Figure 1. Estimated Contributing Areas, North Catch Basin (CB:N) and South Catch Basin (CB:S)

Table 1. Watershed areas and hydrologic properties.

Subcatchment	Land Use	Area (acres)	Curve Number	Average Slope (ft/ft)
CB:N, Road Portion	Paved	0.41	98	0.021
	Grass, <50%, C soil	0.46	86	
CB:N, Residential Portion	~1 acre residential, C soil	13.8	79	0.037
	Forested	7.7	70	
CB:S, Road Portion	Paved	0.17	98	0.032
	Grass, <50%, C soil	0.27	86	
CB:S, Residential Portion	~1 ac residential, C soil	5.46	79	0.059
	Forested	1.7	70	

Rainfall depths for the 2-, 10-, and 25-year storms were obtained from maps of 24-hour rainfall depth available from National Climate Data Center (NCDC). The depths for these storms are summarized in Table 2. A SCS Type-III 24 hour storm was chosen as the design storm rainfall distribution to which these rainfall depths were applied.

Table 2. Design storm precipitation depth.

Frequency	Precipitation Depth (inches)
2-yr	3.0
10-yr	4.7
25-yr	5.0

HydroCAD, a modeling software program that incorporates the hydrologic computational methods of the NRCS TR-55 rainfall-runoff method, was used to calculate peak runoff at each catch basin for each of the design storms. Table 3 summarizes the peak runoff results.

Table 3. HydroCAD peak runoff results.

Storm Event	Peak Runoff (cfs)	
	CB:N	CB:S
2-yr	28	11
10-yr	65	24
25-yr	72	26

Results provided in Table 3 reflect those peak discharge rates arriving at each catch basin, but do not necessarily reflect the peak discharge rates leaving the outlet pipes north of South Main Street. Discharges that can be expected at the end of these outlet pipes are calculated using the orifice equation. Given that each pipe has an 18 inch diameter, and assuming that the maximum head above the pipe is equal to the elevation difference between the pipe invert and the catch basin grate elevation, the discharge is estimated as follows:

$$Q = C_d A\sqrt{2gh}$$

$$Q_{North} = (0.6)(\pi(0.75')^2)\sqrt{2\cdot\left(32.2\,{}^{ft}/_{s^2}\right)(2.45ft)} = \mathbf{13\ cfs}$$

$$Q_{South} = (0.6)(\pi(0.75')^2)\sqrt{2 \cdot \left(32.2 \, {}^{ft}/_{s^2}\right)(2.72ft)} = \mathbf{14\ cfs}$$

where Q is the discharge based on the orifice equation, Cd is a coefficient of discharge, A is the cross sectional area, g is acceleration due to gravity, and h is the head above the pipe center.

In most cases, the controlling discharge from the orifice equation is less than the peak runoff coming from the contributing subcatchments. As such, some ponding around the catch basins is expected to occur. Ponding/flooding over the catch basin would raise the head above the outflow pipe, thus increasing the discharge through the pipe, but would also cause flow to bypass the catch basin structures. The aforementioned survey lists the rim elevations of the northern and southern grates as 98.8 ft. and 98.3 ft., respectively, and indicates that the road centerline may be between 99 ft. and 100 ft. Assuming that the minimum road elevation that would prevent overtopping is approximately 99.5 ft., the maximum amount of ponding over the catch basins is 0.7 ft. and 1.2 ft. for the northern and southern catch basins, respectively. Adjusting the value of h in the orifice equation raises the peak discharge from the outlet pipes to 15 cfs and 17 cfs for the northern and southern catch basins.

Summary

HydroCAD was used to estimate peak runoff rates for 2-, 10-, and 25-year, 24 hour design storm events to two catch basins at Cross Road and South Main Street in Wolfeboro, NH. In general, the peak runoff rates to the catch basins exceeded the capacity at which the outflow pipes could convey water under South Main Street. As a result, the size of the outflow pipes is the controlling factor that will dictate the peak rate of discharge into stormwater improvements located downstream of these pipes. By assuming a reasonable amount of ponding that could be expected to occur at each catch basin, discharge rates through these pipes were calculated to be 15 and 17 cfs for the northern and southern catch basins, respectively. Given the uncertainty in these calculations, it is recommended that stormwater structures downstream of these catch basins be designed to accommodate flow rates up to 20 cfs.

APPENDIX B:

A Field Guide to the Aquatic Plants of Rust Pond

Field Guide

to the aquatic plants of rust pond

Prepared for:

Town of Wolfeboro, New Hampshire
Department of Planning and Development

Prepared by:

Geosyntec consultants

289 Great Road
Acton, MA 01720
(978) 263-9588

August 2012

This Field Guide to the Aquatic Plants of Rust Pond has been developed to assist in efforts to conduct regular aquatic vegetation monitoring at Rust Pond.

New Hampshire lakes and ponds host a great variety of aquatic plants. If you find a plant in Rust Pond which is not included in this field guide, there are a number of more comprehensive field guides that can be used as a reference for species identification. Some recommended references include the following:

- Aquatic Plants & Algae of New Hampshire's Lakes and Ponds. New Hampshire Department of Environmental Services. (Available online at: www.des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-05-30.pdf)

- G.E. Crow and C.B. Hellquist. 2000. Aquatic and Wetland Plants of Northeastern North America. The University of Wisconsin Press.

- Fassett, N.C. 1940. A Manual of Aquatic Plants. The University of Wisconsin Press.

This field guide is based on the results of an aquatic vegetation survey of Rust Pond conducted by Geosyntec Consultants in August 2011. Emergent wetland plants were recorded only if they were rooted in standing water within the perimeter of Rust Pond. The species identified during the survey are listed in the table on the following page.

Funding for this Field Guide was provided by a grant from the New Hampshire Department of Environmental Services with funding from the US Environmental Protection Agency under Section 319 of the Clean Water Act.

Small Pondweed (Potamogeton pusillis)

This pondweed has narrow leaves (about 2mm wide) with an inner midrib. Stipules are blunt or rounded.

Illustration from: USDA-NRCS PLANTS database.

Ribbonleaf Pondweed (Potamogeton epihydrus)

The floating leaves of this pondweed, when present, are up to 3.5" long and up to 1.75" wide. The submersed leaves look wilted and have a lightly colored stripe down the center.

Illustration from: USDA-NRCS PLANTS Database / USDA NRCS. *Wetland flora: Field office illustrated guide to plant species.*

Snailseed Pondweed (Potamogeton bicupulatus)

This pondweed has submersed and floating leaves that are spirally arranged. The floating leaves, although not always present, have 3-7 veins.

Illustration from: Britton & Brown's Illustrated Flora of the Northern United States and Canada, 2nd ed.

Water Celery (Vallisneria americana)

Wild celery has ribbon-like leaves with bluntly rounded tips. A distinct light green stripe runs down the center of the leaves, which is most visible when the leaf is held up to light.

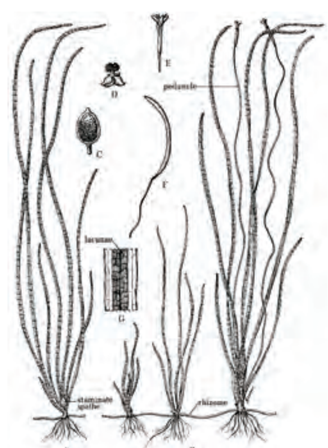
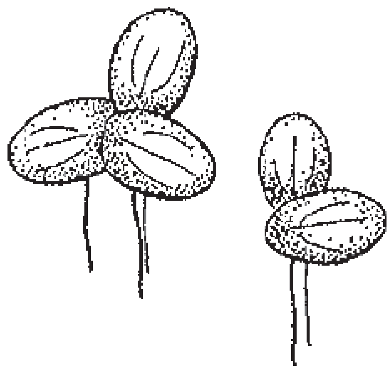


Illustration from: G.E. Crow and C.B. Hellquist. 1982. Aquatic Vascular Plants of New England. New Hampshire Agricultural Experiment Station.

FLOATING LEAF SPECIES

Lesser Duckweed (Lemna minor)

Lesser duckweed is a small (2-3 mm) floating aquatic perennial plant with three veins and a single root. Duckweed can form mats covering areas of slow moving water.



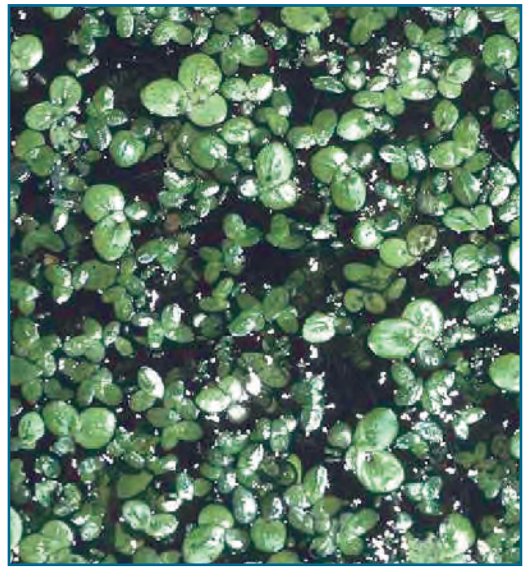


Photo Credit: Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database / USDA NRCS. 1995. Northeast wetland flora: Field office guide to plant species. Northeast National Technical Center, Chester, PA.
Illustration from: Crow, G.E. and Hellquist, C.B. 1982. Aquatic Vascular Plants of New England. New Hampshire Agricultural Experiment Station.

EMERGENT SPECIES

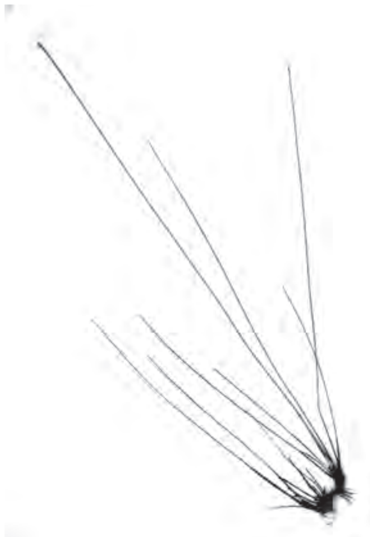
Pipewort (Eriocaulon septangulare)

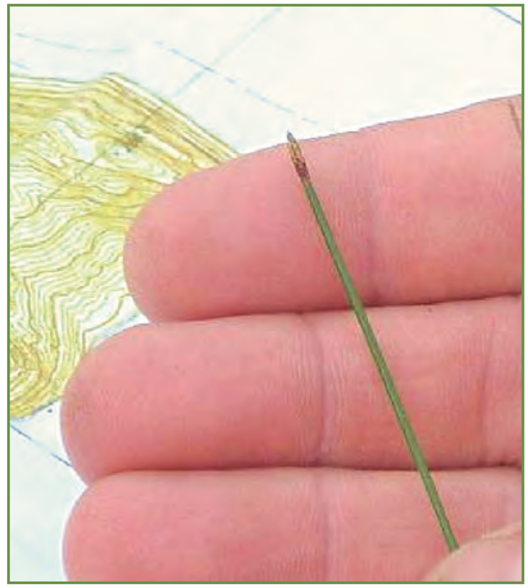
The most prominent feature of this plant is its white roots that have cross lines on them. At the end of the Pipewort's stalk there often is a button-like white flower that emerges.

Illustration from: Crow, G.E. and Hellquist, C.B. 1982. *Aquatic Vascular Plants of New England.* New Hampshire Agricultural Experiment Station.

Spike Rush (Eleocharis robbinsii)

The soft green stems of this plant often grow clumped together with oval shaped spikelets forming at the tips.





Lurid Sedge (Carex lurida)

This emergent wetland plant was found growing in shallow water at the northern tip of Rust Pond. Lurid Sedge reaches a height of 1 to 3 feet. It flowers from May to September and its fruits are yellowish-brown and resemble bottlebrushes.

USDA-NRCS PLANTS Database / Britton, N.L., and A. Brown. 1913. An illustrated flora of the northern United States, Canada and the British Possessions. 3 vols. Charles Scribner's Sons, New York. Vol. 1: 436.

Soft Rush (Juncus effusus)

Soft rush can be recognized by its pale-green stems which are approximately two to five feet tall. Each branch has 30-100 small, greenish-brown flowers which appear to come out of the side of the stem

Illustration from: Crow, G.E. and Hellquist, C.B. 1982. *Aquatic Vascular Plants of New England*. New Hampshire Agricultural Experiment Station.

Water Hemlock (Cicuta maculata)

Water Hemlock is a flowering plant in the carrot family. This plant has a hollow erect stem reaching a maximum height of 1 to 1.5 meters. The alternate compound leaves have lance-shaped leaflets (2-10 cm long) with numerous teeth. The inflorescence is a compound umbel with a many clusters of small white flowers. This plant is highly toxic and may be fatal if eaten.

USDA-NRCS PLANTS Database / USDA NRCS. *Wetland flora: Field office illustrated guide to plant species.* USDA Natural Resources Conservation Service.

Monkey FLower (Mimulus ringens)

Monkey Flower is a perennial flowering plant that grows from 20 centimeters to over a meter tall. Its 4-angled stem is usually erect. The oppositely arranged leaves are lance-shaped to oblong, up to 8 centimeters long, and sometimes joined or nearly so, clasping the stem. The lavender colored flower is 2 to 3 centimeters long and is divided into an upper lip and a larger, swollen lower lip.

Illustration from: Crow, G.E. and Hellquist, C.B. 1982. *Aquatic Vascular Plants of New England*. New Hampshire Agricultural Experiment Station.

Green Bulrush (Scirpus atrovirens)

The stems of this plant are smooth and triangular shaped in an erect position. The leaves are narrowly extended with edges that are rough to the touch.

Illustration from: USDA-NRCS PLANTS Database / USDA NRCS. *Wetland flora: Field office illustrated guide to plant species*.

Broad-leaf Cattail (Typha latifolia)

Cattails are easily identified by their tall, sword-shaped leaves and fruiting spikes. Broad-leaved Cattail is distinguished from Narrow-leaved Cattail by its broader leaves and fruiting spikes that don't have a separation between the male and female sections.

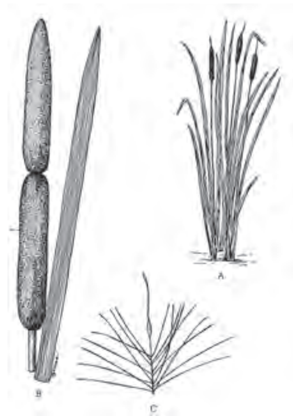


Illustration from: Crow, G.E. and Hellquist, C.B. 1982. *Aquatic Vascular Plants of New England.* New Hampshire Agricultural Experiment Station.

Bur-reed (Sparganium sp.)

Bur-reed is an emergent wetland plant that typically grows up to two feet tall. Its bright green, strap-like leaf blades grow up to 1 inch wide. Its spherical flower heads are green in early season, becoming brown and bur-like later.

Illustration from: Crow, G.E. and Hellquist, C.B. 1982. *Aquatic Vascular Plants of New England.* New Hampshire Agricultural Experiment Station.