Environment

Prepared for:
Granite Lake Association

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Belmont, NH
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January 2011

Granite Lake
Watershed Management Plan

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Executive Summary

A watershed management plan was prepared for Granite Lake, New Hampshire. Granite Lake is a high quality lake but has experienced a cyanobacteria bloom in recent years. This effort included the construction of a nutrient budget and setting a target value for phosphorus that would not cause algal blooms and preserve the lake in the pristine state it has been in historically. Limiting phosphorus concentrations and associated algal growth should be sufficient to maintain water quality throughout the lake. The phosphorus loads are allocated among sources of phosphorus such that in-lake phosphorus concentrations meet the target and Granite Lake supports its designated uses. The analysis suggests that the current loads of phosphorus to Granite Lake should be reduced by 6.5% overall in order to maintain the target in-lake phosphorus value of 5 μg/L and the short-term goal of 4.75 μg/L and allow for some future increases. The plan puts primary emphasis on reducing watershed phosphorus sources over other sources due to the relative load contribution from the watershed and practical implementation considerations. It is expected that these reductions would be phased in over a period of several years. Successful implementation of this watershed management plan will be based on maintenance of in lake total phosphorus concentrations at or below the phosphorus target. Specific targeted measures to control phosphorus inputs to the lake are presented and discussed. Guidance for obtaining additional Clean Water Act (Section 319) funding for nonpoint source control is presented in Section 11.0. Suggestions for enhancement of the current monitoring program to monitor progress and effectiveness of control measures are provided.

1.0 Introduction

Granite Lake is a 228 acre lake with a watershed of about 2,432 acres entirely within the towns of Nelson and Stoddard (NHDES 2009). Characteristics of Granite Lake are presented in Table 1-1. The watershed to lake area ratio is 11:1. Lakes with watershed ratios greater than 10:1 can experience low water clarity, high phosphorus and obnoxious algal blooms when the watershed is highly developed or has high export of nutrients. Furthermore, the amount of impervious cover (i.e., development) within a watershed is correlated with water quality. Poor water quality and significant changes in hydrology are typically experienced in watersheds where impervious cover is at or greater than 10% of the total area (CWP 2003). In areas where impervious cover is greater than 25% (CWP 2003) waters are typically of poor quality and may not support such uses as swimming, and drinking. Although the Granite Lake watershed is below the 10% threshold, localized, short-term or periodic water quality problems may be still be observed. The recent cyanobacteria bloom in Granite Lake is likely a reaction to a short term loading episode.

Table 1-1: Characteristics of Granite Lake, Nelson and Stoddard, NH[1]

Parameter	Value
Lake Area (acres)	228
Lake Volume (m^3)	11,525,000
Watershed Area (acres)	2,432
Watershed/Lake Area	11
Mean Depth (m)	9.8
Max Depth (m)	28.9
Flushing Rate (yr^{-1})	0.72
Epilimnetic TP (*u*g/L mean, range)	4.9, 2.5-12.0
Hypolimnetic TP (*u*g/L mean, range)	5.3, 2.5-10.0
Epilimnion TN:TP Ratio	26

[1]Water quality statistics are calculated from 2003-2009 data

Recent water quality data from the New Hampshire Volunteer Lake Assessment Program website were reviewed in the 2008 VLAP report (NHDES 2009). Total phosphorus (TP) and chlorophyll a (a measure of the amount of algae) concentrations have shown considerable variability over years but a review of the data suggests that mean concentrations are low and have not changed significantly over time. A blue-green alga, anabaena, was found to be the dominant species in July 2006. This species was also dominant in 2002. Blue-green algae can release toxins that can be potentially harmful to animals and humans. In contrast to recent increases in TP and chlorophyll a is water clarity, which appears to be increasing with time. This may be an artifact of sample methodology, however, as explained in the Volunteer Lake Assessment Reports. There is considerable variation in water clarity over the years as well. The lake is quite deep relative to its size, with a mean and maximum depth of 9.8 and 28.9 meters (NHDES 2007a, Figure 1-1). Deep lakes in the northern temperate region typically undergo thermal stratification . During stratification, oxygen in bottom waters can get depleted by organic matter decomposition processes. In the absence of oxygen, phosphorus can be released from iron in the bottom sediments and be circulated into the water column becoming available for algal uptake. Figure 1-2 shows temperature and dissolved oxygen concentrations from profiles conducted in 2004, 2005 and 2006. Oxygen concentrations were high at all depths sampled with the exception of locations very close to the bottom and mid water column depths during August of 2004. Oxygen concentrations in the deep zones of lakes are typically at a minimum just before fall turnover which typically occurs in late September or early October. The latest dissolved oxygen data available are from August so it is possible that concentrations in Granite Lake get lower prior to turnover. The mid-depth dissolved oxygen minima observed in August 2004 may be due to an accumulation of dying algal cells in the metalimnion and upper hypolimnion.

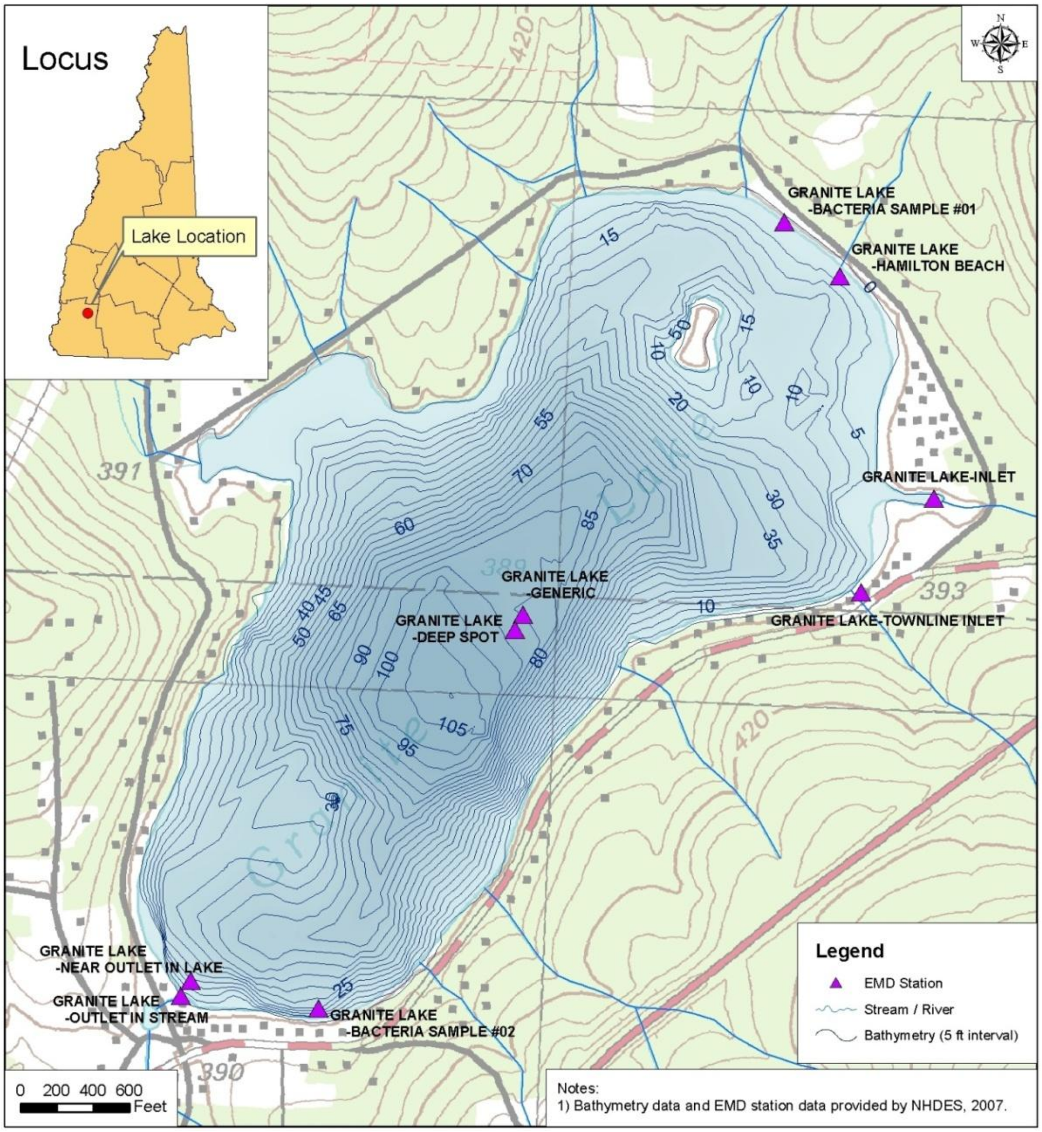


Figure 1-1: Granite Lake Location and Bathymetry

Granite Lake supports a cold water fishery as well as a number of warm water fish species. According to New Hampshire Fish and Game (2010) the lake supports rainbow trout (stocked), lake trout, smallmouth bass, rock bass, chain pickerel and hornpout.

Cyanobacteria (anabaena) were reported in Granite Lake in 2007 (NHDES 2007a). Cyanobacteria and other algal species typically increase in numbers in response to nutrient enrichment. Phosphorus is the primary limiting nutrient in northern temperate lakes, hence algal growth is likely directly related to phosphorus concentrations. Nitrogen can also play a role in determining the type of algae present and the amount of algal growth in a waterbody since some cyanobacteria (blue-green algae) can fix nitrogen from the atmosphere. An examination of water quality data from 2003 to 2009 shows a total nitrogen to total phosphorus ratio of 26. This ratio suggests that algal growth in Granite Lake is limited by phosphorus, making control of phosphorus the primary focus of watershed management efforts. Additionally, phosphorus is typically more easily controlled than nitrogen. A watershed management plan for total phosphorus (TP) as a surrogate for chl a and cyanobacteria has been prepared for Granite Lake and the results are presented in this report. Chloride (from road salt) has also been identified as a potential issue in the lake and watershed. A discussion of chloride loading is also presented.

The New Hampshire Department of Environmental Services (NH DES) conducted water quality monitoring of Granite Lake in 1985-86, 1996-97, and 2006-07 for Lake Trophic Studies (NHDES 1986, NHDES 1997, NHDES 2007a). Granite Lake has participated in the Volunteer Lake Assessment Program (VLAP) since 1989 (NH DES 2009). Granite Lake also participates in the Lake Host program (NHDES 2009) to educate boaters and examine boats and trailers for exotic plants entering or leaving lakes.

The mean, median and range of selected water quality parameters from each sampling location from the most recent data available (2003-2009) are summarized in Table 1-2. Secchi disk transparencies (SDT), a measure of water clarity, are high, ranging from 6.1 to 14.0 m with a mean of 9.8 m. Chlorophyll a (chl a) concentrations, a measure of algal productivity, are low over this time period ranging from 0.5 to 2.7 μg/L. TP concentrations (the primary nutrient for algal growth) in the epilimnion range from 2.5 to 12 μg/L with a mean of 4.9 μg/L. Hypolimnetic TP concentrations are similar to epilimnetic concentrations ranging from 2.5 to 10 μg/L with a mean of 5.3 μg/L. Similar surface and bottom concentrations during the summer stratification period suggest that there is currently little to no sediment release of TP. NHDES (2009) concluded through a visual inspection of water quality data collected since 1989 that summer composite chl a concentrations and TP concentrations have not changed and that Secchi transparencies have increased. All of these measures showed that Granite Lake water quality was much better than the typical NH lake and better than most similar high quality lakes.

Table 1-2: Lake Summer Water Quality Summary Table 2003-2009

Statistic	TP Epi	TP Meta	TP Hypo	TP-Generic	SDT	Chl	TKN-Epi	TKN-Hypo	NO2/NO3-Epi	NO2/NO3-Hypo
Units	µg/L	µg/L	µg/L	µg/L	m	µg/L	mg/L	mg/L	mg/L	mg/L
Count	21	21	21	2	21	21	2	2	2	2
Min	2.5	2.5	2.5	10.0	6.1	0.5	0.125	0.125	0.050	0.050
Mean	4.9	17.4	5.3	12.5	9.8	1.4	0.125	0.125	0.050	0.050
Max	12.0	130.0***	10.0	15.0	14.0	2.7	0.125	0.125	0.050	0.050
Median	5.0	5.0	5.4	12.5	9.9	1.4	0.125	0.125	0.050	0.050

n = number of samples; Epi = epilimnion; Meta = metalimnion; Hypo = hypolimnion; SDT= Secchi Disk Transparency, Chl a= Chlorophyll a, DO= Dissolved Oxygen
* Uncorrected for phaeophytin
** DO values are from each discrete observation in the data set regardless of depth
*** Data suspected to be invalid, not used in calculations.

Granite Lake has numerous tributaries and direct stormwater inputs (Figure 1-2). A summary of the data from the tributaries is presented in Appendix G, Table G-1. Water quality entering the lake from these points could be improved. Conductivity, an indirect measure of charged ions in water, in the lake and within tributaries has increased over time (NHDES 2009). A major source of these ions in many New Hampshire lakes is road salt. In addition, tributary TP and turbidity were elevated at the primary inlet. Specific stormwater improvements have been suggested by the New Hampshire Department of Environmental Services (NHDES) in Granite Lake Stoddard/Nelson Stormwater Drainage for North Shore and West Shore Roads (NHDES 2007c, Appendix F). We suggest several additional best management practices (both structural and non-structural to lower loads of phosphorus to Granite Lake.

These data, together with suggested management recommendations, provide a basis for the development of a Watershed Management Plan for Granite Lake. Outreach and education will be an important aspect of this project. A Site Specific Project Plan (SSPP) detailing the steps to be undertaken in development of the plan was presented to NHDES in the fall of 2009 and approved.

The purpose of the Granite Lake watershed plan is to establish TP loading targets, a plan to meet those targets and a means for measuring progress. Once completed and implemented, the plan should protect the pristine nature of Granite Lake. Water quality that is consistent with state standards is, a priori, expected to protect designated uses. This plan recognizes the unique nature of Granite Lake as a high quality water and sets targets and goals well beyond what would be required to protect designated uses. AECOM prepared this watershed plan according to the United States Environmental Protection Agency's (US EPA) guidance (US EPA, 2008). The main objectives of this watershed plan include the following 9 elements from the EPA guidance:

1. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant

subcategory level along with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).

2. An estimate of the load reductions expected from management measures.
3. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in paragraph 2, and a description of the critical areas in which those measures will be needed to implement this plan.
4. Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.
5. An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.
6. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.
7. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.
8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.
9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item 8 immediately above.

This watershed management plan is expected to fulfill the nine requirements for a watershed management plan required to qualify a project for Section 319 restoration funding.

2.0 Phosphorus Target

2.1 Numeric Water Quality Target

To develop a watershed management plan, it is necessary to derive a numeric TP target values (e.g., in-lake concentration) for determining acceptable nutrient loads. The suggested TP values are described in the following paragraphs.

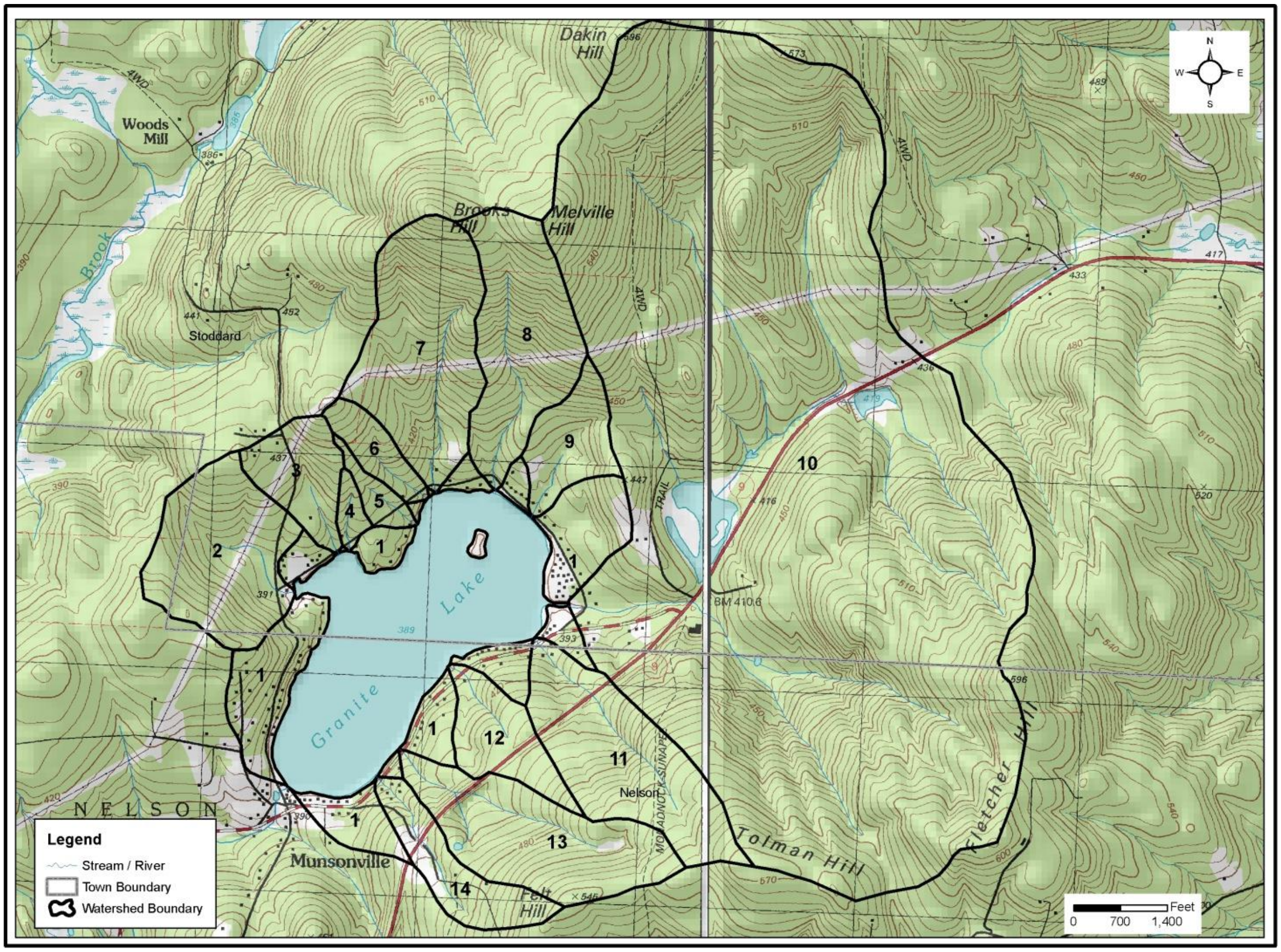


Figure 2-1: Granite Lake Drainage Basins

Determining the nutrient load that a lake can assimilate without degrading or exceeding water quality standards is challenging and complex. First, many lakes receive a high proportion of their nutrient loading from non-point sources, which are highly variable and are difficult to quantify. Secondly, lakes demonstrate nutrient loading on a seasonal scale, not a daily basis. Loading during the winter months may have little effect on summer algal densities. Finally, variability in loading may be very high in response to weather patterns, and the forms in which nutrients enter lakes may cause increased variability in response. Therefore, it is usually considered most appropriate to quantify a lake nutrient budget as an annual load and evaluate the results of that annual load on mid-summer conditions that are most critical to supporting recreational uses. Accordingly, the nutrient loading capacity of lakes is typically determined through water quality modeling, which is usually expressed on an annual basis. Thus, while a single value may be chosen as the target load for each nutrient, it represents a range of loads with a probability distribution for associated water quality problems (such as algal blooms). Uncertainty is likely to be very high, and the resulting target load should be viewed as a nutrient-loading goal that helps set the direction and magnitude of management, not as a rigid standard that must be achieved to protect against eutrophication. While data from individual sampling dates and seasons are important to understanding the nutrient loading dynamics of Granite Lake, the annual mean load should be given primacy when developing and evaluating the effectiveness of nutrient loading reduction strategies.

Numerical water quality criteria for TP in oligotrophic lakes were recently developed by the State of New Hampshire. For Granite Lake, an oligotrophic lake, the criteria is set at < 8 µg/L. This criteria is 60% higher than the current summer epilimnetic concentration of TP (5.0 µg/L) and 27% higher than the current annual average TP concentration (6.3 µg/L). Best professional judgment of AECOM, NH DES, and the Granite Lake Association was employed to select a quantitative target in-lake TP concentration that will protect water quality. Review of existing data and modeling of current conditions suggested that the current phosphorus concentrations in the lake would result in acceptable water quality going forward. This point is bolstered by the fact that water quality as measured by chl a and TP has not changed appreciably in recent years. However, it was acknowledged that short-term phenomenon had the potential to cause periodic water quality problems like the bloom experienced in 2006 and the anecdotal evidence that nearshore water quality may be declining. It was further recognized that there would be future development in the watershed.

A meeting was convened on December 3, 2009 with NHDES, AECOM and the Town of Nelson to present target options and come to a consensus on an acceptable target for Granite Lake. Using the conceptual assimilative capacity approach and a criteria of 8 ug/L as the cutoff point between oligotropic and mesotrophic lakes, the target for Granite Lake could be set at 0.5 ug/L higher than existing conditions allowing for a 10% reserve and using 20% of the remaining assimilative capacity. It was agreed that this target was too high for Granite Lake given that periodic water quality problems had been experienced at current levels of phosphorus despite the fact that the annual average TP and chlor a concentration has been steady in recent years. Meeting attendees reached consensus that the water quality target should be set at current conditions mean summer in-lake total phosphorus concentrations of approximately 5.0 µg/L, but that a short term mean summer goal of 4.75 µg/L should be established to reduce the watershed phosphorus load as much as practical with Best Management Practices (BMPs) recognizing that future development was likely in the watershed. The short term mean summer epilimnetic goal (4.75 µg/L) corresponds to a spring overturn value of 5.9 µg/L. This is compared to a current spring overturn value of 6.3 µg/L. This target and short term goal were then presented to the Town of Stoddard who agreed with the recommendation. Load reduction through BMP’s is discussed further in Section 9 of the report.

The numeric (in-lake) water quality target for TP for Granite Lake is 5.0 µg/L for a summer epilimnetic mean concentration which equates to a spring overturn TP concentration of 6.3 µg/l because mean annual TP concentrations are usually higher than summer epilimnetic concentrations (Nurnberg 1996, 1998. The target number is supported by evaluation of the Trophic State Indices (TSI) developed by Carlson (1977) and a probabilistic assessment of the likelihood of blooms (Walker 1984, 2000) discussed below. The “weight of evidence” suggests that 5 µg/L is an appropriate target that will allow Granite Lake to remain in its current pristine state. Possible reductions to move Granite Lake below this target to a short term goal in lake summer mean concentration of 4.75 µg/L to allow for future increases in TP are discussed in Section 7 below. This equates to a spring overturn concentration of 5.9 µg/L The target concentration corresponds to non-bloom conditions, as reflected in suitable measures of both SDT and chl a.

3.0 ENSR-LRM Model of Current Conditions

Current TP loading was assessed using the ENSR-LRM methodology, which is a land use export coefficient model developed by AECOM for use in New England and modified for New Hampshire lakes by incorporating New Hampshire land use TP export coefficients when available and adding septic system loading into the model (CT DEP and ENSR, 2004). Documentation for ENSR-LLRM is provided in Appendix B. Both STEPL and AVGWLF were also run for the Granite Lake watershed. While all three approaches gave similar results, the scale of AVGWLF made it inappropriate for further consideration. It is designed for very large river watersheds and uses very coarse land cover data. STEPL provided similar results to ENSR LLRM and had the additional benefit of incorporating BMP effectiveness tables but the shortcoming of not including a lake response model like ENSR LLRM. AECOM incorporated the BMP effectiveness tables from STEPL into ENSR LLRM for this application and therefore got the best attributes of both models.

The major direct and indirect nonpoint sources of TP to Granite Lake include:

- Atmospheric deposition (direct precipitation to the lake)
- Surface water base flow (dry weather tributary flows, including any groundwater seepage into streams from groundwater)
- Stormwater runoff (runoff draining to tributaries or directly to the lake)
- Waterfowl (direct input from resident and migrating birds)
- Direct groundwater seepage including septic system inputs from shorefront residences

Although the lake stratifies in the summer the mean summer epilimnion and hypolimnion TP are similar so, internal loading is not expected be a major TP source to Granite Lake. Internal loading therefore was not calculated in the current conditions model.

There are no permitted point source discharges of nutrients in this watershed. However, construction activities in the watershed that disturb greater than one acre of land and convey stormwater through pipes, ditches, swales, roads or channels to surface water require a federal General Permit for Stormwater Discharge from Construction Activities. However, construction discharges are not incorporated in the model due to their variability and short-term impacts.

The watershed of Granite Lake contains one major tributary draining the eastern wetland complex as well as a number of smaller tributary streams. In addition, there are numerous area of the watershed near the lake that are considered Direct Drainage (Figure 1-2). TP loads were estimated based on runoff and groundwater land use export coefficients. The TP loads were then attenuated as necessary to match tributary monitoring data, if available. If no tributary data were available or current, then the attenuation factor was based on the slope, soils, and wetland attenuation. Loads from the watershed as well as direct sources were then used to predict in-lake concentrations of TP, chl a, SDT, and algal bloom probability. The estimated load and in-lake predictions were then compared to in-lake concentrations recognizing that the data were primarily from the summer and that the predicted concentrations were spring overturn values. The monitored summer epilimnetic values were assumed to be 20% lower than spring values as discussed in Nurnberg (1996 and 1998) so the in-lake concentration predicted by the calibrated model is higher than the mean of the monitoring data. The attenuation factors were used as calibration tools to achieve a close agreement between predicted in-lake TP and observed mean/median TP. However, perfect agreement between modeled concentrations and monitoring data were not expected as monitoring data are limited for some locations and are biased towards summer conditions when TP concentrations are expected to be lower than the annual mean predicted by the loading model.

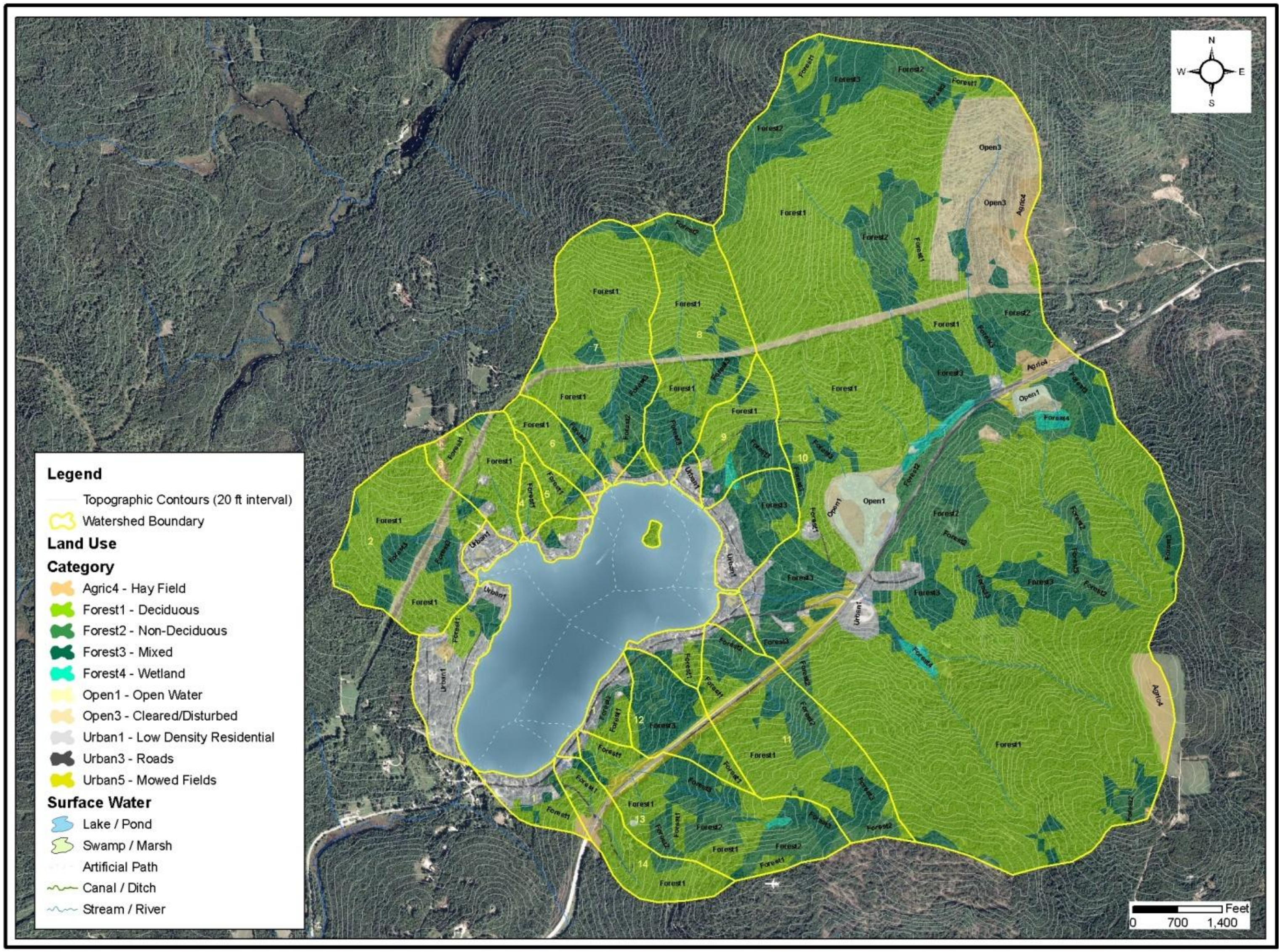


Figure 3-1: Granite Lake Watershed Land Use

3.1 Hydrologic Inputs and Water Loading

Calculating TP loads to Granite Lake requires estimation of the sources of water to the lake. The three primary sources of water are: 1) atmospheric direct precipitation; 2) runoff, which includes all overland flow to the tributaries and direct drainage to the lake; and 3) baseflow, which includes all precipitation that infiltrates and is then subsequently released to surface water in the tributaries or directly to the lake (i.e., groundwater). Baseflow is roughly analogous to dry weather flows in streams and direct groundwater discharge to the lake. The water budget is broken down into its components in Table 3-1.

- Precipitation - Mean annual precipitation was assumed to be representative of a typical hydrologic period for the watershed. The annual precipitation value was derived from the USGS publication: Open File Report 96-395, "Mean Annual Precipitation and Evaporation - Plate 2", (USGS 1996) and confirmed with precipitation data from weather station in Concord. For the Granite Lake watershed, 1.06 m (40.94 in) of annual precipitation was used.
- Runoff - For each landuse category, annual runoff was calculated by multiplying mean annual precipitation by basin area and a land use specific runoff fraction. The runoff fraction represents the portion of rainfall converted to overland flow. This was compared to the standard water yield for this area.
- Baseflow - The baseflow calculation was calculated in a manner similar to runoff. However, a baseflow fraction was used in place of a runoff fraction for each land use. The baseflow fraction represents the portion of rainfall converted to baseflow.

Runoff and baseflow fractions from Dunn and Leopold (1978) were altered slightly to be representative for the generally steeper slopes in the Granite Lake watershed (i.e. less infiltration to baseflow and more runoff). The fractions are listed in Tables G-3 in Appendix G. The hydrologic budget was calibrated to a representative standard water yield for New England (Sopper and Lull, 1970; Higgins and Colonell 1971, verified by assessment of yield from various New England USGS flow gauging stations). More detail on the methodology for hydrologic budget estimation and calibration is presented in Appendix B.

Table 3-1: Granite Lake Water Budget

WATER BUDGET	M^3/YR
Atmospheric	1,010,392
Watershed Runoff	2,084,688
Watershed Baseflow	5,271,087
Total	8,366,167

3.2 Nutrient Inputs

Land Use Export

The Granite Lake watershed boundary was delineated using NH DES delineations and corrected with USGS topographic maps when necessary (NH DES, 2007). Land uses within the watershed were determined using several sources of information including: (1) Geographic Information System (GIS) data, (2) analysis of aerial photographs and (3) ground truthing (when appropriate).

The TP load for the watershed was calculated using export coefficients for each land use type. The watershed loading was adjusted based upon proximity to the lake, soil type, presence of wetlands, and attenuation provided by Best Management Practices (BMPs) for water or nutrient export mitigation. The watershed load (baseflow and runoff) was combined with direct loads (atmospheric, septic system, and waterfowl) to calculate TP loading. The generated load to the lake was then input into a series of empirical models that provided predictions of in-lake TP concentrations, chl a concentrations, algal bloom frequency and water clarity. Details on model input parameters and major assumptions used to estimate the baseline loading (i.e., existing conditions) for Granite Lake are described below.

- Areal land use estimates were generated from land use and land cover GIS data layers from NH GRANIT. For Granite Lake, data sources are: 2001 NH Land Cover Assessment layer © Complex Systems Research Center, University of New Hampshire, and National Wetland Inventory (1971-1992). A Land Use data layer was not available for Nelson or Stoddard, NH although partial parcel data were available and used where appropriate. Land use categories were matched with the ENSR-LRM land use categories and their respective TP export coefficients. Table G-2 lists ENSR-LRM land use categories in which the GRANIT categories were matched. Land cover data and aerial photographs were used to determine certain land use classifications, such as agriculture and forest types. Selected land uses were confirmed on the ground during a watershed survey. Watershed land use is presented spatially in Figure 3-1 and summarized in Table 3-2.
- TP export coefficient ranges were derived from values summarized by Reckhow et al. (1980), Dudley et al. (1997) as cited in ME DEP (2003) and Schloss and Connor (2000). Table G-2 provides ranges for export coefficients and Table G-3 provides the runoff and baseflow export coefficient for each land use category in Granite Lake and the sources for each export coefficient. Residential areas were designated as Urban 1 (Low Density Residential). The export coefficient for Urban 1 was set at 0.5 kg/ha/yr. A University of New Hampshire study also found a TP runoff export coefficient of 0.35 kg/ha/yr to be at the lower end of the range and 0.9 kg/ha/yr to be a moderate export coefficient for urban land use in the Flints Pond watershed (Schloss and Connor, 2000). The land use distribution in the Flints Pond watershed of denser residential along the shoreline and low density non-shoreline residential found is also found in the Granite Lake watershed (AECOM, 2009).
- Areal loading estimates were attenuated within the model based on natural features such as porous soils, wetlands or by anthropogenic sources, such as implemented physical BMPs that would decrease loading. The Granite Lake watershed has relatively steep, shallow, highly permeable soils. Granite Lake also has wetland complexes in the watershed, particularly along the Inlet tributary. These wetlands are expected to spread the flow and encourage water infiltration, settling and adsorption of TP. Little Granite Lake and the wetland complex on the Inlet, which are east of Granite Lake, likely retain a large amount of the TP originating upgradient of them. A TP attenuation factor of 60% was applied to the Granite Lake Direct Drainage and the Inlet, meaning that 40% of the generated TP load from these areas is actually delivered to the lake.
- Annual areal loading of TP from the watershed is estimated to be 66.9 kg/yr, which represents 61% of the total load to the lake.

Table 3-2. Land Use Categories by Granite Lake Subwatershed.

Land Use	Area (Hectares)													
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	BASIN 11	BASIN 12	BASIN 13	BASIN 14
	Direct Drainage	North Shore End	Foxweldon	Unnamed	Warren Drive	431 N. Shore	395 N. Shore	305 N. Shore	210 N. Shore	Inlet	Town Inlet	668 GLR	603 GLR	586 GLR
Urban 1 (Low Density Residential)	39.2	1.4	1.2	0.4	0.3	0.4	0.3	0.4	0.7	10.9	0.3	0.0	0.3	0.5
Urban 2 (Mid-Density Residential/Commercial)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 3 (Roads)	2.7	0.3	0.2	0.1	0.1	0.1	0.0	0.1	0.2	5.3	0.8	0.5	0.6	0.8
Urban 4 (Industrial)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urban 5 (Mowed Fields)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	1.7	1.1	2.0	0.4
Agric 1 (Cvr Crop)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 2 (Row Crop)	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agric 4 (Hayfield)	0.0	0.0	0.8	0.0	0.0	0.0	0.3	0.0	0.0	12.8	0.0	0.0	0.0	0.8
Forest 1 (Deciduous)	14.4	28.2	13.2	3.1	4.4	7.6	38.3	28.6	8.2	349.7	24.8	4.3	18.6	14.9
Forest 2 (Non-deciduous)	4.6	0.8	0.0	0.0	0.0	0.0	2.6	3.6	0.5	69.8	11.1	2.6	12.9	1.0
Forest 3 (Mixed)	13.2	8.8	0.9	0.0	0.4	1.3	10.2	10.3	7.1	89.3	9.1	10.0	10.7	0.8
Forest 4 (Wetland)	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	4.7	0.0	0.0	0.4	0.0
Open 1 (Wetland/Lake)	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.2	0.0	0.0	0.1	0.0
Open 2 (Meadow)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Open 3 (Excavation)	0.2	3.2	1.4	0.0	0.0	0.0	1.6	1.3	0.0	38.0	0.0	0.0	0.0	0.0
TOTAL	75.5	42.7	17.8	3.5	5.2	9.3	53.4	44.2	17.4	598.5	47.7	18.5	45.6	19.3

Atmospheric Deposition

Nutrient inputs from atmospheric deposition were estimated based on a TP coefficient for direct precipitation. The atmospheric load of 0.25 kg/ha/yr includes both the mass of TP in rainfall and the mass in dryfall (Wetzel, 2001). The sum of these masses is carried by rainfall. The concentration calculated for use in the loading estimate 24 μg/L is roughly equivalent to the mean concentration (25 μg/L) observed in rainfall in Concord, NH (NH DES, 2008 Unpublished Data). The coefficient was then multiplied by the lake area (ha) in order to obtain an annual atmospheric deposition TP load. The contribution of atmospheric deposition to the annual TP load to Granite Lake was estimated to be 23.8 kg/yr or 22% of the total load.

Septic systems

TP export loading from residential septic systems was estimated within the 125 ft shoreline zone. The 125 ft zone is the minimum distance from lakes that new septic systems are allowed in New Hampshire with rapid groundwater movement through gravel soils. A shoreline survey using GIS ortho-photographs determined the number of residencies within the 125 ft zone. It was assumed that if the dwelling was within the 125 ft zone that the septic system was also within the 125 ft zone. The TP load was calculated by multiplying a TP export coefficient (based on literature values for wastewater TP concentrations and expected water use), the number of dwellings, the mean number of people per dwelling, the number of days occupied per year, and an attenuation coefficient of 90% for new systems and 80% for old systems meaning that 10% and 20% of the phosphorus load from these systems reached the lake, respectively. In Granite Lake, the TP loading from shoreline septic systems was estimated to be 16.4 kg/yr, which is 15% of the TP load to Granite Lake. A more detailed septic survey or groundwater monitoring as suggested in Section 8.0 may yield more precise estimates of septic loading. In particular, the area near the inlet (Sandy Beach) was not included in the septic load estimate because houses in this neighborhood are set back from the lake by more than 125 feet. However, this area is just above lake level with shallow depth to groundwater, sandy soils and dense development with individual septic systems. The septic load should be revised if further investigation indicates that a significant TP load is migrating to the lake from this area. A study for further evaluating this area is outlined in Section 10.The following assumptions were used in estimating the TP load from septic systems.

- It was estimated that 87 residences are seasonal (40 new systems and 47 old systems) and 38 residences are year round (19 new systems and 19 old systems) (Baybutt 2009).
- Two and a half people were estimated to reside in each dwelling. It was estimated that each resident uses 65 gallons per day for 365 days per year for year round residents and 90 days for seasonal residents.
- The TP coefficients were calculated based on mean TP concentration in domestic wastewater of 8 mg/L and mean household water uses (Metcalf & Eddy, 1991).
- All septic loads to Granite Lake from new systems were attenuated 90% (Dudley and Stephenson, 1973; Brown and Associates, 1980) to account for TP uptake in the soil between the septic systems and the lake (10% of TP gets to the lake). Septic loads from old systems were attenuated 80% (20% of TP gets to the lake). Available watershed reports suggest that the majority of the soils underlying the developed area immediately adjacent to Granite Lake have poor suitability for septic systems (NH Office of State Planning 1972).

Waterfowl

Total phosphorus load from waterfowl was estimated using a TP export coefficient and an estimate of annual mean waterfowl population. It was estimated that 10 waterfowl reside on the pond. The TP export coefficient for waterfowl of 0.2 kg/waterfowl/yr was multiplied by the number of waterfowl in order to obtain a TP load of 2 kg/yr. This equates to 2% of the total TP load.

3.3 Phosphorus Loading Assessment Summary

The current TP load to Granite Lake was estimated to be 109.1 kg/yr from all sources. The TP load according to source is presented in Table 3-3.

Loading from the watershed was overwhelmingly the largest source at 66.9 kg/yr (61% of the TP load. Direct precipitation provides approximately 21% of the annual TP load or 23.8 kg/yr while waterfowl contribute only 2.0 kg/yr or 2% of the annual TP load. Septic systems contribute 16.4 kg/yr or 15% of the annual TP budget.

Table 3-2: Granite Lake Phosphorous Loading Summary

TP INPUTS	**Modeled Current TP Loading (kg/yr)**	**% of Total Load**
Atmospheric	23.8	22
Waterfowl	2.0	2
Septic System	16.4	15
Watershed Load- Direct Drainage	66.9	61
Total	**109.1**	**100**

3.4 Phosphorus Loading Assessment Limitations

While the analysis presented above provides a reasonable accounting of sources of TP loading to Granite Lake, there are several limitations to the analysis:

- Precipitation varies among years and hence hydrologic loading will vary. This may greatly influence TP loads in any given year, given the importance of runoff to loading.
- Spatial analysis has innate limitations related to the resolution and timeliness of the underlying data. In places, local knowledge was used to ensure the land use distribution in the ENSR-LRM model was reasonably accurate, but data layers were not 100% verified on the ground. In addition, land uses were aggregated into classes which were then assigned export coefficients; variability in export within classes was not evaluated or expressed.
- TP export coefficients as well as runoff/baseflow exports were representative but also had limitations as they were not calculated for the study water body, but rather are regional estimates.
- The TP loading estimate from septic systems was limited by the assumptions associated with this calculation described above in the “Septic Systems” subsection.
- Water quality data for Granite Lake are limited, restricting calibration of the model.

3.5 Lake Response to Current Phosphorus Loads

TP load outputs from the ENSR-LRM Methodology were used to predict in-lake TP concentrations using five empirical models. The models include: Kirchner-Dillon (1975), Vollenweider (1975), Reckhow (1977), Larsen-Mercier (1976), and Jones-Bachmann (1976). These empirical models estimate TP from system features, such as depth and detention time of the waterbody. The load generated from the export portion of ENSR-LRM was used in these equations to predict in-lake TP. The mean predicted TP concentration from these models was compared to measured (observed) values. Input factors in the export portion of the model, such as export coefficients and attenuation, were adjusted to yield an acceptable agreement between measured and average predicted TP. Because these empirical models account for a degree of TP loss to the lake sediments, the in-lake concentrations predicted by the empirical models are lower than those predicted by a straight mass-balance (13.1 μg/L) where the mass of TP entering the lake is equal to the mass exiting the lake without any retention. Also, the empirical models are based on relationships derived from many other lakes. As such, they may not apply accurately to any one lake, but provide an approximation of predicted in-lake TP concentrations and a reasonable estimate of the direction and magnitude of change that might be expected if loading is altered. These empirical modeling results are presented in Table 3-4.

The TP load estimated using ENSR-LRM methodology translates to predicted mean in-lake concentrations ranging from 5.2 to 8.0 μg/L. The mean in-lake TP concentration of the five empirical models was 6.3 μg/L. The mean and median epilimnetic TP concentration from observed in-lake data from 2003 to 2009 were 4.9 and 5.0 μg/L, respectively. The disagreement between the model results and the in-lake data is likely attributable to the time of year of sampling. Nearly all of the monitoring data are from the summer, a time when epilimnetic concentrations are typically lower than mean annual concentrations. The empirical models all predict mean annual TP concentrations assuming fully mixed spring overturn conditions. Nurnberg (1996) shows summer epilimnetic concentrations as 14% lower than annual concentrations using a dataset of 82 dimictic lakes while Nurnberg (1998) shows a difference of 40% using a dataset of 127 stratified lakes. The mean (4.9 μg/L) and median (5.0 μg/L) observed concentrations in Granite Lake are approximately 20% lower than the predicted concentration (6.3 μg/L), which is within the range reported in the two Nurnberg studies.

Table 3-3: Predicted In-Lake Total Phosphorous Concentration using Empirical Models

Empirical Equation	Equation	3.6 Predicted TP at spring overturn (*u*g/L)[1]
Mass Balance	TP=L/(Z(F))*1000	13.1
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	6.3
Vollenweider 1975	TP=L/(Z(S+F))*1000	8.0
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	6.0
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	5.8
Reckhow General 1977	TP=L/(11.6+1.2(Z(F)))*1000	5.2
Average of Above 5 Model Values		***6.3***
Observed Summer Epilimnion Mean (2003-2009)		***4.9***
Observed Summer Epilimnion Median (2003-2009)		***5.0***

Variable	Description	Units	Equation
L	Phosphorus Load to Lake	g P/m2/yr	
Z	Mean Depth	m	Volume/area
F	Flushing Rate	flushings/yr	Inflow/volume
S	Suspended Fraction	no units	Effluent TP/Influent TP
Qs	Areal Water Load	m/yr	Z(F)
Vs	Settling Velocity	m	Z(S)
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)

[1]Note that the annual average TP concentrations (spring overturn) equate to a summer epilimnetic concentration that is 20% lower.

Once TP estimates were derived, annual mean chl a and SDT can be predicted based on another set of empirical equations: Carlson (1977), Dillon and Rigler (1974), Jones and Bachman (1976), Oglesby and Schaffner (1978), Vollenweider (1982), and Jones, Rast and Lee (1979). Bloom frequency was also calculated based on equations developed by Walker (1984, 2000) using a natural log mean chl a standard deviation of 0.5. These predictions are presented in Table 3-5. Predicted mean chl a concentrations (Table 3-5) are similar to those observed in the monitoring data. Predicted Secchi transparencies are substantially lower than observed which may be a reflection of the minimal amount of dissolved color in Granite Lake and a general lack of non-algal turbidity.

Table 3-4: Predicted In-Lake Chlorophyll a and Secchi Disk Transparency Predictions based on an Annual Average In-Lake Phosphorous Concentration of 12 μg/L

Empirical Equation	Equation	Predicted Value
Mean Chlorophyll		***u*g/L**
Carlson 1977	Chl=0.087*(Pred TP)^1.45	1.2
Dillon and Rigler 1974	Chl=10^(1.449*LOG(Pred TP)-1.136)	1.0
Jones and Bachmann 1976	Chl=10^(1.46*LOG(Pred TP)-1.09)	1.2
Oglesby and Schaffner 1978	Chl=0.574*(Pred TP)-2.9	0.7
Modified Vollenweider 1982	Chl=2*0.28*(Pred TP)^0.96	3.3
Average of Model Values		**1.5**
Observed Summer Mean		***1.4***
Peak Chlorophyll		***u*g/L**
Modified Vollenweider (TP) 1982	Chl=2*0.64*(Pred TP)^1.05	8.8
Vollenweider (CHL) 1982	Chl=2.6*(AVERAGE(Pred Chl))^1.06	4.0
Modified Jones, Rast and Lee 1979	Chl=2*1.7*(AVERAGE(Pred Chl))+0.2	5.3
Average of Model Values		**6.0**
Observed Summer Maximum*		***2.7***
Bloom Probability		***% of Summer***
Probability of Chl >10 *u*g/L	See Walker 1984 & 2000	0.00%
Secchi Transparency	***check***	***m***
Mean: Oglesby and Schaffner 1978	SDT=10^(1.36-0.764*LOG(Pred TP))	5.6
Max: Modified Vollenweider 1982	SDT=9.77*Pred TP^-0.28	5.8
Observed Summer Mean		***9.8***
Observed Summer Maximum		***14***
Variable	**Description**	**Units**
"Pred TP"	The average TP calculated from the 5 predictive equation models in Table 3-4	*u*g/L
"Pred Chl"	The average of the 3 predictive equations calculating mean chlorophyll	*u*g/L

*The observed summer maximum is based on n=21 and is not necessarily the peak chlorophyll

3.7 Future Development

Since the human population within a watershed may continue to grow and contribute additional TP to the impaired lakes, watershed plans should allow for growth and associated future TP loading. For example, in Maine, target TP loading from anticipated future development is set to allow a 1.0 μg/L change in in-lake TP concentration (Dennis et al., 1992). It should be recognized that the NH DES has no mechanism for regulation/enforcement of TP export from future developments of single house lots that do not require a Section 401 Water Quality Certification or fall under the thresholds for alteration of terrain permits (100,000 square feet of disturbance or 50,000 square feet within 250 feet of a lake). Municipalities can, however, regulate such development by revising their land use ordinances/regulations to require no additional loading of TP from new development. Increases in future loads were anticipated in this plan by incorporating a short term goal of reduction of loading and in-lake concentrations below the target. A build out scenario was developed to form the upper bound for development potential and is presented in Section 4.

3.8 Critical Conditions

Critical conditions in Granite Lake typically occur during the summertime, when the potential (both occurrence and frequency) for nuisance algal blooms are greatest. The loading capacity for TP was set to achieve desired water quality standards during this critical time period and also provide adequate protection for designated uses throughout the year. This was accomplished by using a target concentration based on summer epilimnetic data and applying it as a mean annual concentration in the predictive models used to establish the mean annual maximum load. Since mean summer epilimnetic values are typically about 20% less than mean annual concentrations (Nurnberg 1996, 1998), an annual load allocation based on mean annual concentrations will be sufficiently low to protect designated uses impacted by TP in the critical summer period.

3.9 Seasonal Variation

As explained in Section 3.7, the Granite Lake model takes into account seasonal variations because the target annual load is developed to be protective of the most sensitive (i.e., biologically responsive) time of year (summer), when conditions most favor the growth of algae.

3.10 Reduction Needed

Current TP loading and in-lake concentrations are adequate to support designated uses and preserve high quality water. However, this plan incorporates a short-term goal of reduction of phosphorus loading below the target to accommodate future development. The degree of TP load reduction required to meet the target over the long term is calculated by subtracting the load associated with the short term goal (Section 4) from the existing load estimated with ENSR-LRM (Section 3.3). In order to achieve an in-lake concentration of 4.75 µg/L (short term goal), phosphorus loading must be reduced from the current level of 109.1 kg/yr to 102 kg/yr for a reduction of 7.1 kg/yr or 6.5%.

As some sources are less controllable than others, the actual reduction to be applied to achieve this goal will vary by source (see Sections 6 and 7). A 7% reduction from manageable watershed sources and a 13% reduction from septic systems (Table 3-6) would be required to achieve the 4.75 µg/L short-term goal TP concentration. Loading reduction strategies are discussed further in Section 7 below.

Table 3-5: Granite Lake Total Phosphorous Load at Short Term Goal of 4.75 μg/L

TP INPUTS	Modeled TP Load to Attain 4.75 *u*g/L short term goal (kg/yr)	Modeled Current TP Load (kg/yr)	Reduction (%)
Atmospheric	23.8	23.8	0
Waterfowl	2.0	2.0	0
Septic System	14.2	16.4	13
Watershed Load	62.0	66.9	7.3
TOTAL	**102**	**109.1**	6.5

3.11 Loading Model Development Summary

The relationship between TP and algal biomass is well documented in scientific literature. This assessment was developed for TP and is designed to protect Granite Lake and its designated uses impacted by excessive chl a concentrations.

In conclusion, water quality was linked to TP loading by:

- Choosing a preliminary target in-lake TP level, based on historic state-wide and in-lake water quality data, best professional judgment, and through consultation with NH DES, Nelson and Stoddard sufficient to attain water quality standards and support designated uses. The preliminary in-lake TP concentration target is 5 μg/L.
- Recognizing that future development may increase future loading a short term goal of an in-lake concentration of 4.75 μg/L was set.
- Using the mean of five empirical models that link in-lake TP concentration and load, calibrated to lake-specific conditions, to estimate the load responsible for observed in-lake TP concentrations.
- Determining the overall mean annual in-lake TP concentration from those models, given that the observed in-lake concentrations may represent only a portion of the year or a specific location within the lake.
- Using the predicted mean annual in-lake TP concentration to predict Secchi disk transparency, chl a concentration and algal bloom frequency.
- Using the aforementioned empirical models to determine the TP load reduction needed to meet the numeric concentration target.
- Using a GIS-based spreadsheet model to provide a relative estimate of loads from watershed land areas and uses under current and various projected scenarios to assist stakeholders in developing TP reduction strategies.

Documentation of the model approach is presented in Appendix B. This approach is viewed as combining an appropriate level of modeling with the available water quality and watershed data to generate a reasonably reliable estimate of TP loading and concentration under historic, current, and potential future conditions. It offers a rational estimate of the direction and magnitude of change necessary to support the designated uses protected by New Hampshire.

4.0 Evaluation of Alternative Loading Scenarios

The ENSR-LRM model was used to evaluate a number of alternative loading scenarios and the probable lake response to these loadings. These scenarios included:

- Current Loading
- Natural Environmental Background Loading
- Build-out of Watershed
- Route 9 Construction
- Removal of Septic Load
- Reduction of Watershed Loads to Meet 4.75 μg/L short term goal

The current loading scenario is discussed above in Section 3.0. Each scenario described below represents a change from the current loading scenario. The discussion of each scenario includes only the portions of the current loading scenario that were altered for the specific simulation. A comparison of the results of each of the alternative scenarios is presented in Tables 4-1 and 4 -2. More detailed model output can be found in Appendix G.

Table 4-1: Comparison of Phosphorous Loading Scenarios for Granite Lake

Inputs	**Current Load (kg/yr)**	**Natural Environmental Background (kg/yr)**	**Build Out Analysis (kg/yr)**	**Current Load without Septic Load (kg/yr)**	**Maximum Route 9 Construction (kg/yr)**	**Short-term Goal to Obtain 4.75 *u*g/L Summer In-lake Concentration (kg/yr)**
Atmospheric	23.8	23.8	23.8	23.8	23.8	23.8
Waterfowl	2.0	2.0	2.0	2.0	2.0	2.0
Septic System	16.4	0.0	16.4	0.0	16.4	14.2
Watershed Load	66.9	45.9	163.8	66.9	143.4	62.0
Total Load	109.1	71.7	206.0	92.7	185.6	102
Total Overall Load Change from Current Load (kg/yr)	-	-37.4	96.9	-16.4	76.5	-7.1
Percent Overall Change (%)	-	-34%	89%	-15%	70%	-6.5%

Table 4-2: Lake Water Quality Response to Different Loading Scenarios for Granite Lake

Parameters	**Current Load**	**Natural Environmental Background**	**Build Out Analysis**	**Current Load without Septic Load**	**Maximum Route 9 Construction**	**Short-term goal to Obtain 4.75 *u*g/L Summer In-lake Concentration**
TP Load (kg/yr)	109.1	71.7	206.0	92.7	185.6	102.0
Mean Annual TP (*u*g/L)[1]	6.3	4.1	11.4	5.2	10.5	5.9
Summer Epilimnetic TP *(ug/L)*	5.0	3.3	9.1	4.2	8.4	4.8
Mean Secchi Disk Transparency (m)	5.6	7.8	3.6	**6.5**	3.8	5.9
Mean Chlorophyll *a* (*u*g/L)	1.5	0.7	3.5	1.1	3.2	1.33
Peak Chlorophyll *a* (*u*g/L)	6.0	3.3	12.9	4.7	11.7	5.5
Probability of Summer Bloom (Chl *a* > 10 *u*g/L)	0.0%	0.0%	1.0%	0.0%	0.6%	0.0%

[1]Note that the annual average TP concentrations (spring overturn) equate to a summer epilimnetic concentration that is 20% lower.

[2]Actual value of 4.75 was rounded up to 4.8 for consistency in presentation.

4.1 Natural Environmental Background Phosphorus Loading

Natural environmental background levels of TP in the lake were evaluated using the ENSR-LRM model. Natural background was defined as background TP loading from non-anthropogenic sources. Hence, land uses in the watershed were set to its assumed “natural” state of forests and wetlands. Loading was then calculated using the ENSR-LRM model as described above. This estimate is useful as it sets a realistic lower bound of TP loading and in-lake concentrations possible for Granite Lake. Loadings and target concentrations below these levels are very unlikely to be achieved.

The septic loads were removed and all developed land was converted to forests. The developed land was split into mixed, deciduous, and coniferous forest categories in the same percentages as the current watershed forest composition. Waterfowl loading was not reduced as the waterfowl population is currently low and it is assumed natural. Wetland areas were not changed because it was assumed no wetland had been lost due to development. Background TP loads under this scenario were 71.7 kg/yr total with a watershed load of 45.9 kg/yr. Table 4-1 compares loads for possible scenarios. The calculated background loading of TP to Granite Lake would result in mean in-lake TP concentration of 4.1 µg/L, a summer epilimnetic TP concentration of 3.3 µg/L, a mean Secchi Disk transparency of 7.8 m, and a bloom probability of chl a > 10 µg/L of 0.0%. Estimated TP loading to the lake under this scenario is 34% lower than current loads to the lake (Table 4-1). The lake would support designated uses and be viewed as pristine under this scenario as in-lake predicted TP concentration (4.1 µg/L) is well below the target value (5 µg/L) and the short-term goal (4.75 µg/L) . This scenario provides the lower limit of phosphorus concentrations for Granite Lake.

4.2 Build Out Analysis

The build out scenario was developed to assess the impact of complete development of the watershed. This scenario involved converting all existing forested and agricultural land not currently in conservation to low density residential land within the watershed. This did not include wetland areas or conservation areas but did include areas with insufficient road frontage under the current conditions assuming that more roads could be built to serve these areas. It was assumed that all future building would retain similar characteristics as current building in the watershed and similar levels of best management practices. This was designed as a worst case scenario. In reality, some level of best management practices could be expected for future development so the actual increases in loading might be lower than those projected. It should also be noted that development could include more intensive uses which would tend to increase the loading estimates. Under this scenario, loading would be expected to increase 89% over current levels to a total of 206.0 kg/yr (Table 4-1). This would result in an in lake average TP concentration of 11.4 µg/L (summer epilimnetic mean of 9.1 µg/L), a transparency of 3.6m which is roughly half of the current transparency and a probability of a bloom greater than 10 µg/L of 1% or 3-4 day per year (Table 4-2). Clearly, this is a scenario that would produce unacceptable water quality in Granite Lake.

4.3 Septic System Load Removal

This scenario involved removal of the septic loads only. It is a reasonable approximation of what would occur if the lake were sewered, all septic systems were moved back away from the lake or all existing septic systems exported TP at a negligible concentration. Under this scenario, total loading is decreased by 15% over current loading (Table 4-1) and would likely support designated uses because the predicted average annual in-lake concentration at this scenario is 5.2 µg/L (4.2 µg/L summer epilimnetic mean), which is below the target of 6.3 µg/L (5.0 µg/L summer) (Table 4-2). Removal of all septic sources would likely be costly and not be feasible. Also, note that our analysis did not account for actively failing septic systems, so the load may be underestimated. Such systems may have localized impacts on TP and should be addressed as they are discovered. It is recommended that a detailed septic survey be conducted in order to refine the septic system loading estimate in this model before widescale reduction measures are implemented. An upgrade program is suggested in Section 7 and detailed in Section 8.

4.4 Maximum Route 9 Construction

This scenario attempts to estimate the maximum possible influence of the construction of Route 9 on Granite Lake. It is only intended to represent the period of actual construction of the road. The influence of the road, as constructed, is incorporated in the current conditions scenario. This scenario was developed by converting the entire footprint of the road, shoulder and corridor to open land (bare soil). This predictive scenario has limitations because the actual sequencing of the construction is unknown and would have had to have been present in a disturbed state for well over a year to be completely reflected in the lake nutrient concentrations. However, it is helpful in explaining periodic water quality problems that may have originated from the construction activity. It is likely that sediments in the stream channels down gradient of Route 9 deposited during the construction period are still migrating towards the lake although likely at much lower rates than during the construction activity. This influence will likely continue to decline in the future. Under this scenario, loading is predicted to have increased to 185.6 kg/yr or by 70% over current conditions (Table 4-1). This results in an annual mean in-lake TP concentration of 10.5 µg/L (8.4 µg/L summer epilimnetic mean) and a probability of an algal bloom greater than 10 µg/L chlorophyll a of 0.6 % (Table 4-2). Clearly a construction project of this magnitude has the potential, likely did and probably continues to influence the water quality of Granite Lake.

4.5 Reduction of Loads to Meet In-lake Short-Term TP Goal of 4.75 μg/L Summer In-Lake Concentration

This scenario involves the focus of resources on the largest source of TP to Granite Lake, the watershed load as well as some other smaller loads. Under this scenario, watershed TP loads were iteratively reduced until predicted in-lake concentrations met the 4.75 μg/L short-term goal. A reduction of 7.3% of the loads from the watershed and 13% of the load from septic systems would be required to meet the annual load of 102 kg/yr related to this scenario. There are other combinations of alternatives that could also meet the short-term goal. Water quality under this scenario would be improved over current conditions but it should be recognized that current conditions are the target and this scenario allows some level of future development to be accommodated. Options for meeting this short-term goal are presented in the management section of this document (Section 7).

5.0 Additional Watershed Concerns

5.1 Road Salt

Road salt has been identified as a concern by the Granite Lake Association. As a part of the watershed planning effort AECOM evaluated historic data on specific conductance (a measure of the amount of dissolved ions in a water and used as an indicator of the present of salt) in Granite Lake and modeled road salt concentrations to predict specific conductance in the tributaries and in Granite Lake that can be attributed to road salt inputs.

Road salt is a concern to lakes for several reasons. First at very high concentrations, road salt or more specifically chloride can be toxic to aquatic organisms. Fortunately, the concentrations observed in Granite lake are well below that threshold. The second potential impact of road salt is related to the greater density of water with dissolved salt as compared to fresh water with little salt. If road salt loading is excessive in a lake, it can result in formation of a dense layer of saline water at the bottom of the lake. In some cases, the density difference between the saline water and fresher water above is so great that the lake does not turn over completely in the spring and/or the fall. The "stranded" waters near the bottom do not get reoxygenated and can form an anoxic zone at the bottom of the lake where most aquatic life cannot survive. In addition, phosphorus is released from the sediments under anoxic conditions so the potential for addition of phosphorus to the lake from the sediments is greatly increased when a lake does not mix. Fortunately, there is little evidence in the data of the buildup of saline water in the deeper portions of the lake and on most sampling dates specific conductance readings are similar throughout the water column. However, a look at historic specific conductance (a measure of the dissolved ions in the lake and an indicator of the amount of salt) data from Granite Lake suggests that salt loading increased significantly through the mid 1990's (Figure 5-1) from values in between 40 and 50 to values between 60 and 70. Conductivity appeared to peak in the early 2000's at around 80 umhos/cm. In recent years, values have returned to values between 55 and 70. These data suggest that while Granite Lake is no doubt influenced by road salt, levels have stabilized or declined in recent years and are below levels that would be a concern in the lake from either a toxicity or stratification standpoint.

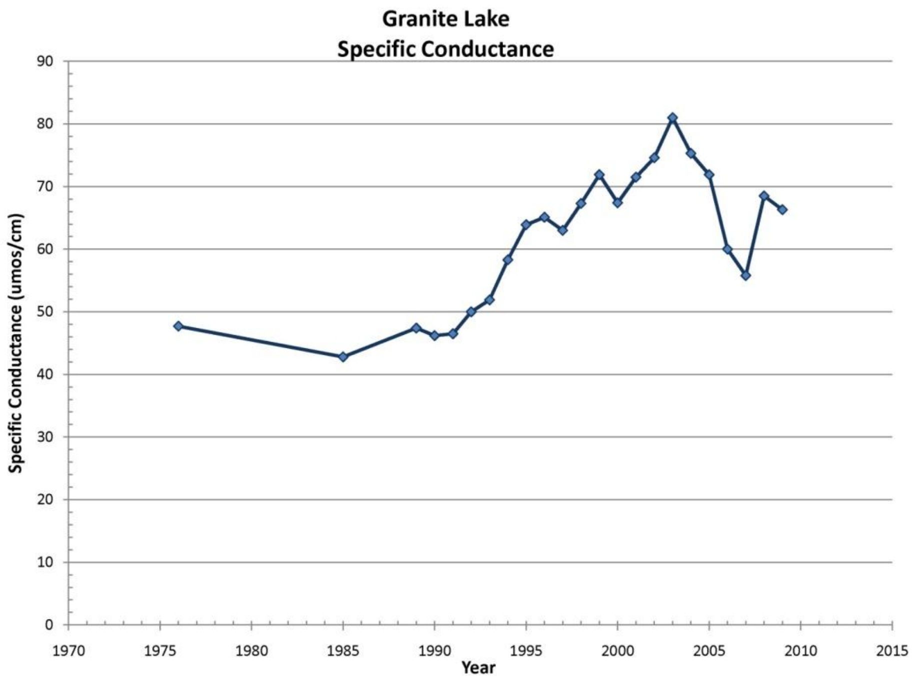


Figure 5-1: Specific Conductance in Granite Lake (1976-2009)

There may be localized areas in tributary stream where chloride concentrations are elevated during snowmelt to levels that cause aquatic toxicity but there are currently not sufficient data to confirm this. The stations at the Inlet, Town Inlet, 603 GLR, 668 GLR and 586 GLR would be good candidates for additional data collection of chloride and/or specific conductance.

AECOM estimated the contribution of road salt to Granite Lake. The load of sodium and chloride, the constituents of salt, were calculated using water input data for each subwatershed from the ENSR LLRM model and the mass of road salt added by NH DOT and the state road agents per lane mile per winter. NH DOT provided an average of the salt used per lane mile for the winters of 1995-2009. The salt contribution from Granite Lake Road was estimated using a usage rate of 250 lbs/lane mile/storm and an average of 27 storms per winter (Town of Nelson Road Agent, personal communication). AECOM calculated the mileage for the paved roads salted in the winter using Geographic Information Systems (GIS) distance tools. It was assumed that only the paved roads in the watershed were salted in the winter, Granite Lake Road and NH Route 9, and that salt was applied to two lanes per road. In-lake conductivity originating from road salt was calculated using the total mass of road salt contributed annually divided by the total annual volume of water (volume times flushing rate) in Granite Lake and converted to conductivity. The analysis assumed that all of the salt applied made it to the lake each year. While there is some storage of salt in the soils near roadways, salt is highly soluble and mobile so it is reasonable to expect that over the long term all salt applied would eventually reach Granite Lake. The results of the modeling effort are presented in Table 5-1. As expected, the basins with the largest percentage of paved area contributed the largest amount of road salt to Granite Lake. The road salt currently applied to the Granite Lake watershed based on the assumptions described above current accounts for 6 umhos/cm of the observed conductivity of Granite Lake.

Table 5-1: Salt Load by Basin to Granite Lake (note that other basins had no salt load)

	BASIN 10 Inlet	BASIN 11 Town Inlet	BASIN 12 668 GLR	BASIN 13 603 GLR	BASIN 14 586 GLR
Salt Load (kg/yr)	12,358	2,427	1,627	1,888	1,385

5.2 Water Level Management

Water level management at Granite Lake has been listed as a concern with respect to the water quality of the lake. As in many lakes, there is equal support for higher and lower water levels depending on the specific site conditions at each resident's property. This discussion focuses only on the water quality implications of higher or lower water levels in Granite Lake.

In the Northeast, lakes without dams or naturally fluctuating lakes typically reach a maximum level each year in the late spring or early summer. Levels typically decline from that maximum level throughout the summer and early fall reaching a minimum level around September. Once the trees lose their leaves in the fall, evapotranspiration of water from the watershed decreases resulting in an increase in tributary flow and that plus fall storms result in a rebound of lake levels through the fall.

Granite Lake, like many lakes with dams, has been managed at full pond throughout the summer period for the convenience of shorefront property owners. Because this has been going on for many years, the shoreline has become “acclimated” to this water level management regime and buildings, septic systems and other infrastructure have been built with the current water level regime in mind. The undeveloped shoreline acclimates to a given water level by gradually eroding fine grained soil from the immediate shoreline leaving larger boulders or cobbles to armor the shore or stable beaches where sand naturally occurs along the shore. Vegetation and trees along the shore establish based on the water level and their relative tolerance for water in the root zone. A change in water level management has the potential to expose erodible materials on the land side under higher water levels or soft sediments on the low side. A large increase in water level may result in soil erosion from the base of trees and other vegetation and formerly stable banks erode and slump. A major decrease in water level puts the wave line in contact with sediments that were deposited under higher water levels and may cause them to be resuspended in the water column. Lower water also exposes a rim around lake that is not stabilized by vegetation in the short term. This rim can erode from rainfall and runoff further suspending soil particles in the water column. Eventually the shoreline will stabilize at the new level (higher or lower) but it may take many years to decades.

Similar to the concerns with the natural aspects of the shoreline, the built aspects of the shoreline are also affected by increases or decreases in water level. Buildings at the edge of the lake may experience structural damage related to erosion and septic systems in low lying areas may not perform as well as the distance from septic disposal fields to groundwater is reduced.

The magnitude of changes under consideration in recent years (2-6 inches increase in summer level) were evaluated using the water quality model. Because the lake is so deep relative to its surface area, a change of this magnitude has very little effect on the lake volume (<1 %) and a similar small effect on the flushing rate of the lake. Because of this negligible change in volume and flushing rate, changes in the overall lake response to nutrients related to this water level change is expected to be minimal. The shoreline should be monitored for changes in erosion patterns related to a higher water level and consideration should be given to returning to the historic lake levels if problems are observed. Likewise, consideration should be made to upgrading septic systems that are too close to the groundwater table. These systems will be closer to the water table with a higher lake.

Periodically, Granite Lake is subject to a larger fall/winter drawdown for the convenience of the lake residents wishing to conduct work on their waterfront. While such a drawdown is not beneficial to aquatic life that use the nearshore areas of the lake, the impacts can be reduced by timing the drawdown to reach a minimum level by late September or early October in order to protect of mussels, invertebrates and amphibians. Later drawdowns run the risk of dewatering and freezing organisms that have burrowed into the bottom in shallow water zones for the winter. Native aquatic plants are often reduced in abundance after significant drawdowns and plants with a tolerance for dewatering are favored. As discussed above, erosion of soft sediments not normally exposed could occur during large drawdowns. Once eroded, these sediments are redistributed throughout the water column or moved deeper in the lake. While it is realized that occasional larger winter drawdowns are often desired for maintenance reasons, they should not be conducted any more often than is necessary.

5.3 Near Shore Septic Survey

AECOM conducted a near shore survey of Granite Lake on August 6, 2009. The purpose of the investigation was to evaluate if there were any actively failing septic systems around Granite Lake. A conductivity meter with a probe mounted on a pole was used to evaluate water quality in waters shallower than could be traversed by a boat. Septic effluent typically has much higher specific conductance than is found in a lake. Gross failure of a septic system would be detected by observing a spike in specific conductance in the vicinity of the septic discharge to the lake. Specific conductance throughout the lake was generally consistent at around 64 µmhos/cm. These values are very similar to recent values reported by the VLAP monitoring in the lake (Figure 5-1). A very slight increase in specific conductance (66 µmhos/cm) was observed in the vicinity of Town Line Inlet. It is likely that this increase is due to road salt application in the watershed. A portion of the salt applied in the winter is stored in the soil and slowly leaches out throughout the year. No areas of active septic failure were uncovered although it should be noted that unless the systems are in use at the time of the survey, failure may not be detected.

During the course of the septic survey sparse stand of native aquatic plants were observed. Some of the more commonly encountered ones included pipewort, native milfoil, pond weed, pond lily and pickerel weed. Several areas were observed to have sparse green algae on the bottom.

5.4 Near-shore Groundwater Sampling Training

A set of well points was purchased for the Granite Lake Association in order to assist in quantification of near-shore shallow groundwater quality. Training was given in the installation of these well points and retrieval of samples from the well points using the methods outlined in Mitchell et. al (1989). Data obtained using near shore groundwater sampling should help confirm movement of nutrients from poorly performing septic systems to the lake.

6.0 Implementation Plan

The following TP control implementation plan provides recommendations for future BMP work and necessary water quality improvements. The recommendations are intended to provide options of potential watershed and lake management strategies that can improve water quality to meet target loads. Note that providing a comprehensive diagnostic/feasibility study is beyond the scope of this report, but we have attempted to narrow the range of management options in accordance with known loading issues and desired loading reductions.

The successful implementation of this watershed plan will be based on maintaining the TP target and attaining the short-term goal for reductions in TP loading to Granite Lake. It is anticipated that TP reductions associated with this plan will be conducted in phases.

As discussed in Section 3, watershed TP loading is the predominant source (61%) of TP to Granite Lake. Septic systems also contribute to the total load, but if this source were removed completely which is impractical, the annual TP load would be reduced only by 15% (Section 4). Implementing BMPs, some septic upgrades and public education and outreach to reduce the watershed load are the primary strategy to reduce the TP loading into Granite Lake in order to attain an in-lake TP concentration of 4.75 μg/L, which represents the short-term goal for Granite Lake.

Experience suggests that aggressive implementation of watershed BMPs may result in a maximum practical TP loading reduction of 60-70%. Greater reductions are possible, but consideration of costs, space requirements, and legal ramifications (e.g., land acquisitions, jurisdictional issues), limit attainment of such reductions. Most techniques applied in a practical manner do not yield >60% reductions in TP loads (Center of Watershed Protection, 2000). Better results may be possible with widespread application of low impact development techniques, as these reduce post-development volume of runoff as well as improve its quality, but there is not enough of a track record yet to generalize attainable results on a watershed basis.

The actual reduction in watershed loading necessary to meet the 4.75 μg/L short-term goal is 7%, and it is assumed that this reduction would be obtained mainly from the runoff portion of the load. This level of reduction is well within the practical maximum suggested by Center of Watershed Protection (2000), and should be achievable. Implementation will be phased in over a period of several years, with monitoring and adjustment as necessary. Coupled with this watershed reduction is a septic system reduction of 26%.

There are a number of BMPs that could appropriately be implemented in the Granite Lake watershed (Table 6-1). BMPs fall into three main functional groups: 1) Recharge / Infiltration Practices, 2) Low Impact Development Practices, and 3) Extended Detention Practices. The table lists the practices, the pollutants typically removed and the degree of effectiveness for each type of BMP. Specific information on the BMPs is well summarized by the Center for Watershed Protection (2000).

Some of these practices may be directly applicable to the Granite Lake watershed. The natural wetlands in the Inlet watershed and several other watersheds naturally function to slow runoff water thereby encouraging infiltration of water and removal of TP through settling, soil adsorption and plant uptake. These functions should be preserved.

Maintaining buffers between lawn areas and Granite Lake and its tributary streams and encouraging minimal or no use of fertilizers is recommended. If fertilizer must be used, low or no TP fertilizer is recommended for lake protection.

Detention and infiltration practices can improve the quality of storm water originating from the highways and developments in the Granite Lake watershed. Route 9, Granite Lake Road and several town roads are close to the shoreline of Granite Lake. Designing and installing BMPs that encourage infiltration or stormwater detention would reduce channel erosion and reduce TP concentrations by settling and contact with the soil prior to entry to the lake.

Retrofitting developed land with low impact designs is a highly desirable option, especially near the lake. Numerous homes are very close to the lake and provide no vegetated buffer. Educational programs can help raise the awareness of homeowners and inform them how they can alter drainage on their property to reduce nutrients entering the lake. Another option to engage the community is through technical assistance programs, such as BMP training for municipal officials and septic system inspection programs. Guidelines for evaluating TP export to lakes are found in “Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development” (Dennis et al., 1992). Recent guidance for low impact living on the shoreline, “Landscaping at the Waters Edge: An Ecological Approach”, has been developed by UNH Cooperative Extension (2007).

Section 319 of the Clean Water Act was established to assist states in nonpoint source control efforts. Under Section 319, grant money can be used for technical assistance, financial assistance, education training, technology transfer, load reduction projects and monitoring to assess the success of specific nonpoint source implementation projects,

This watershed plan was written to meet the criteria of the nine elements required by EPA to be a part of watershed plans (Section 1) Application materials and instructions for 319 funding can be obtained through:

Nonpoint Coordinator
New Hampshire Department of Environmental Services
29 Hazen Drive
P.O. Box 95
Concord, NH 03302
www.des.state.nh.us/wmb/was/grants.htm

Proactive planning can preserve lake water quality. However, past resistance to zoning regulations creates difficulties for proactive planning. The watershed planning process is intended to give a direction and goal for planning and watershed management. As the lake improves towards the short-term goal, the implementation strategy should be re-evaluated using current data and modeling and the plan for further load reduction adapted accordingly.

Table 6-1: Best Management Practices Selection Matrix

Key:
- Adverse Impact
- Moderate Mitigation
- Good Mitigation
- Minimal Mitigation
- Moderately Suited
- Well Suited
- Not Applicable

Management Practice	Ability to Mitigate																Applicability							Notes
	Runoff Volume (↑)	Peak Flow Rates (↑)	Bankfull Flow (↑)	Baseflow (↓)	Mod. Sed. Transport	Channel Morph. Changes[1]	In-Stream Temp. (↑)	Sediment conc. (↑)	Nutrient conc. (↑)	Metal Conc. (↑)	Hydrocarbon Conc. (↑)	Bacteria/Pathogens (↑)	Organic carbon Conc. (↑)	MTBE Conc. (↑)	Pesticide conc. (↑)	Deicer conc. (↑)	New Development	Retrofit	Urban	Sub-Urban	Residential Sub-Division	Commercial	Industrial	
Recharge / Infiltration Practices[2]																								
Infiltration Swale	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Permeable site soils required. Pre-treatment recommended.
Infiltration Trench/Galley	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Permeable site soils required. Pre-treatment recommended.
Retention/Infiltration Basin	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Permeable site soils required. Pre-treatment recommended.
Low Impact Development Practices																								
Bioretention	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Disconnecting Impervious Area	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Flow Path Practices	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well Suited	Not Applicable	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Includes increasing roughness, sheet flow, flow path length, and flattenting slopes.
Green Roof	Good	Good	Good	Minimal	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well Suited	Moderately Suited	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	
Minimize Disturbance Area	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well Suited	Not Applicable	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Used as a component of LID site design.
Minimize Site Imperviousness	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well Suited	Not Applicable	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Includes imiting use of sidewalks, and reducing road/driveway length/width.
Porous Pavement	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Preserve Infiltratable Soils	Good	Moderate	Moderate	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well Suited	Not Applicable	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Used as a component of LID site design.
Preserve Natural Depression Areas	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well Suited	Not Applicable	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Used as a component of LID site design.
Rain Barrels/Cisterns	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Rain Garden	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Good	Good	Good	Good	Good	Good	Good	Moderate	Good	Moderate	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Soil Amendment	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Moderately Suited	Moderately Suited	Used as a component of LID site design.
Vegetated Filter Strip	Good	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Minimal	Minimal	Well Suited	Well Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Vegetation Preservation	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Well Suited	Not Applicable	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Used as a component of LID site design.
Extended Detention Practices																								
Created Wetland/Biofilter Detention	Moderate	Good	Moderate	Minimal	Moderate	Moderate	Adverse	Moderate	Moderate	Moderate	Moderate	Minimal	Moderate	Moderate	Moderate	Moderate	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Extended Detention Pond	Minimal	Good	Moderate	Minimal	Moderate	Moderate	Adverse	Moderate	Moderate	Moderate	Good	Moderate	Moderate	Minimal	Moderate	Minimal	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Wet Detention	Minimal	Good	Moderate	Minimal	Moderate	Moderate	Adverse	Moderate	Moderate	Moderate	Good	Adverse	Moderate	Minimal	Moderate	Minimal	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Other Best Management Practices																								
Deep Sump Catch Basins	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Pre-treatment prior to infiltration BMPs
Sand/Organic Filter	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	
Swale	Moderate	Good	Moderate	Minimal	Moderate	Moderate	Minimal	Moderate	Moderate	Moderate	Good	Moderate	Moderate	Minimal	Moderate	Minimal	Well Suited	Moderately Suited	Moderately Suited	Well Suited	Well Suited	Well Suited	Well Suited	Dry swale with some infiltration.
Water Quality Inlet	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Moderate	Minimal	Minimal	Moderate	Minimal	Minimal	Minimal	Minimal	Minimal	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Well Suited	Includes proprietary hydrodynamic devices. Pre-treatment prior to exfiltration BMPs.

[1] *Impacts include channel enlargement/incision/embededness, changes in pool/riffle structure, and reduced channel sinousity.*

[2] *Recharge and infiltration measures require permeable soils and pre-treatment is recommended. See specific BMP descriptions for more information.*

7.0 Options for Managing Phosphorus Loading to Granite Lake

This section describes non-point sources of phosphorus within the Granite Lake Watershed and outlines methods that could be employed to control their transport into Granite Lake. These management practices could provide reductions in current loading rates and should be considered along with other management options as the Granite Lake watershed becomes more developed and the need to manage loads becomes more critical to the preservation of Granite Lake water quality.

7.1 Land Development

As natural undisturbed land is developed, impervious areas and the potential for phosphorus export are typically increased. Increased volume and rates of runoff from impervious roofs, driveways, and compacted soils causes greater potential for the transport of phosphorus to the lake. If not properly managed, these increased flows can cause substantial erosion of land that previously had not conveyed water as well as along existing drainage channels. The sediment load from such erosion can be a major source of phosphorus as the available phosphorus is dissolved in the water and transported to the lake.

Specific sources of phosphorus introduced with development include lawn and garden fertilizers, septic systems, and pet and livestock/fowl waste. Without proper erosion controls, a considerable amount of phosphorus and sediment can be transported during construction activities.

Based on the land use data used in this study, there is currently 168 acres of developed residential land in the Granite Lake Watershed. This is 6.8 percent of the total watershed area. The area that drains directly to the lake (Basin 1) has the greatest percentage (56%) of development, and Basin 7 has the least (0.7%). The close proximity and the high percentage developed land near the lake make this area a high priority for application of management measures to control the potential phosphorus loading from development activities.

7.1.1 Existing Protection for Land Development

Development regulations pertaining to the Granite Lake watershed are under the jurisdiction of the federal government, the State of New Hampshire and the Towns of Nelson and Stoddard. While this is not intended to be an exhaustive review of those regulations, it highlights important provisions of each of the jurisdictions regulations that have relevance to water quality in the Granite Lake watershed. Any specific development project should do a complete review of requirements prior to any action.

Federal Requirements

- Dredge and fill permit. – Under section 404 of the Clean Water Act dredging and filling of waters of the United States is regulated. A permit is required for dredging or filling water. This included many activities on the waterfront or in wetlands including construction of beaches, break walls and boat houses.
- Stormwater Permit – A federal stormwater permit (NPDES – Phase II Construction Permit) is required for any land disturbance of greater than 1 acre.

State Requirements

- Site Specific Permit – A Site Specific Permit is required when disturbing more than 100,000 square feet of land or more than 50,000 square feet of land in the Shoreland zone (within 250 feet of a lake or tributary).
- State Septic Permit – A permit for on-site wastewater disposal is required for new construction or expansion of current use of a structure to include additional bedrooms.
- Shoreland Protection Act – Requires a permit for many activities in the 250 foot zone from a lake or tributary

Nelson Requirements

- Subdivision Regulations (adopted by Planning Board April 20, 2005)
  - Defers to state Shoreland Protection Act and federal stormwater permits
  - Primarily deals with stormwater quantity (rates and volumes) not quality (loading or concentrations)
  - Erosion control and sedimentation plans are required for construction no standards for runoff quality after development are included.
- Zoning Ordinance (amended March 13, 2007)
  - Granite Lake is within a lake district
  - 2 acre zoning for new construction
  - 150 feet of frontage required for lakefront lots
  - 100 foot setback for septic on lakefront
  - Open space or conservation subdivisions allowed with planning board approval

Stoddard Requirements

- Subdivision Regulations (amended January 17, 2005)
  - Primarily deals with stormwater quantity (rates and volumes) not quality (loading or concentrations)
  - Erosion control plan may be requested by planning board
  - 100 foot setback for septic systems near surface water
- Community Planning Ordinance (as amended in 2003)
  - Lakeside district (500 feet from lakes) except in residential areas
  - 1 acre lot size in lakeside district (within 500 feet of lake)
  - 50 feet of lake frontage per lakefront dwelling unit
  - 400 square feet of beach area per lakefront dwelling
  - 200 square feet of parking per lakefront dwelling
  - Defer to NH DES septic setbacks of 75 feet from lake
  - 50 foot natural vegetation buffer around wetlands and surface water

– Planned developments allowed on parcels greater than 25 acres at underlying zoning density

Towns in New Hampshire have the authority to develop and enforce ordinances to protect designated resources of the town such as Granite Lake. The statute authority is granted under RSA 674:35 and 674:43 to regulate subdivisions, and nonresidential and multi-family residential site development, respectively. The requirements associated with the development of a town master plan are stated in RSA 674:1-4. Authority for developing and enforcing zoning ordinances are specified in 674:17-20, and the application of innovative land use controls are described in RSA 674:21.

7.1.2 Considerations for Management of Land Development

Water quality impacts associated with development activities can be mitigated through zoning and planning ordinances and measures including:

- Removing the potential for development: If a land owner is willing, a conservation organization or the town can either remove the development rights from a property through a conservation easement, or through deeded ownership of the land. Land owners may donate conservation easements in exchange for tax deductions, or request financial compensation. Approximately 25.3% of the Granite Lake watershed is currently under conservation protection. These conservation lands are primarily located northeast of the lake in subwatersheds 7, 8, and 10. Approximately 2.2% of the conservation lands are located to the southeast of the lake in subwaterhes 13 and 14. Additional increases in the amount of land protected from development would reduce the potential for future increases in TP export to Granite Lake from the watershed. As presented in the discussion of buildout (Section 4.2), development of all land that could currently be developed in the Granite Lake watershed would result in an increase in phosphorus loading to Granite Lake of of 89%. Additional protection of lands from development would result in a direct decrease in the maximum potential increase in TP loading related to future development. A search of January 2011 real estate listings suggest that land without water access in Nelson and Stoddard can be purchased for approximately $5,000 – $6,000 per acre. Shorefront or lake access parcels range from $50,000 to $200,000 per acre. Purchasing conservation easements on property would be less expensive than deeded ownership. Based on the analysis conducted in Section 4, the removal of the development potential from currently undeveloped land in the Granite Lake watershed will eliminate potential future increases in loads of 0.063 kg TP/acre (0.155 kg TP/ha) of land protected.
- General Ordinances
  - Local or regional bans on phosphorus in lawn fertilizer
- New Development / Construction Ordinances
  - Incorporate low impact development (LID) requirements
  - Minimize disturbed areas
  - Maintain natural buffers
  - Maximize setbacks from lakes and tributaries
  - Minimize impervious cover
  - Minimize construction footprint
  - Pervious pavers / pavement

- Minimize soil compaction during construction
- Provide drainage management for impervious areas (gravel & paved driveways, and roofs)
- Dry wells
- Infiltration trenches
- Bioretention Systems (“rain gardens”)
- Rain Barrels

- Enforcement of Ordinances

Any of the above provisions could be codified in the Nelson of Stoddard Planning or Zoning regulations.

7.2 Roads and Stormwater Management

There are approximately 7.4 miles of road within the Granite Lake Watershed. Of these, 3.6 miles (48.6%) are gravel roads and 3.8 miles (51.4%) are paved. The paved roads consist of 2.1 miles of Route 9, 1.3 miles of Granite Lake Road (old Route 9), approximately 0.2 miles of Nye Road, and approximately 0.1 miles of West Shore Rd. North Shore Road and the majority of West Shore Road are gravel roads that access the northern and western portions of the lake; respectively.

Old Route 9, Granite Lake Road, passes within 50 feet of Granite Lake for nearly 500 feet. The drainage along this portion of Granite Lake Road is primarily via sheet flow across the road shoulder to the lake, and across the road to the drainage swales on the upslope side of the road. There are three catch basins that convey stormwater from steep portions of the road to the lake.

Along West Shore Road there are many culverts that convey stormwater that flows from upslope mostly undeveloped areas and from this gravel road. Management of runoff along this road is challenging due to limited shoulder areas and some steep slopes. All of the drainage along this road is considered part of the direct drainage (Basin 1) North Shore Road is primarily flat with some hills and areas of somewhat dense camp and residential development. The northwest portion of this road crosses six perennial streams (Basins 2 through 7). The northeastern portion of this road crosses three perennial streams (Basins 8 through 10). See Section 7.7 for a detailed review of the drainage along these roads.

7.2.1 Road Maintenance

To minimize sediment and phosphorus transport from roadways into Granite Lake and its tributaries, physical treatment practices should be employed and routine maintenance of the roads and drainage systems should be performed.

A primary mechanism for the transport of phosphorus from paved roads is sheet flow washing of sediments. Sand that is applied in winter to paved roads is a major source of sediment load to down gradient streams and lakes. Best management practices for minimizing the sediment and phosphorus load from paved roads are:

- Minimize use of sand and salt during the winter;
- Remove sand from the streets prior to spring rain and ground thaw;
- Routine monitoring of and removal of sediments in stormwater catch basins.

Gravel roads are essentially impervious so precipitation water quickly pools and flows to the edge of the road where it either infiltrates into surrounding soils or becomes channelized and flows along a roadside drainage ditch to the nearest surface water or topographic low point. The slope of the road and abutting land, the infiltration capacity and ground cover of the surrounding soil, and the intensity of the storm event are factors that determine the amount of sediment that is transported from gravel roads. Unfortunately these factors are generally established by the location and layout of the road. Through proper road maintenance and the incorporation of a system for treating the drainage, sediment loads associated with runoff from gravel roads can be managed.

As is the case for most potential pollution sources, control at the source is typically the easiest and most cost effective. The following best management practices address gravel roads as the source of sediment loads through on-going maintenance:

- Evaluate and maintain the best cross-road pitch as is appropriate for the drainage conditions. It is important to pitch gravel roads to minimize runoff flow velocity and contact time, ponding, and erosion. A road center crown is appropriate when surrounding topography is flat enough to infiltrate sheet flow or roadside drainage ditches/swales exist that are adequate for the expected flow. Where possible, it is ideal to maintain a road grade and pitch that causes sheet flow to the area abutting the road where it can infiltrate in undisturbed soils. Pitching the road toward the upslope edge should be considered where downslope erosion is a concern. The ditch/swale along the upslope roadside must be adequately sized and reinforced to manage the concentrated channelized flow and the discharge at the low topographic point must be capable of handling and treating the expected flow.
- Re-surface gravel roads as is needed to maintain the cross-road pitch, remove pot-holes, and maintain the road elevation as is needed for proper drainage. Crushed bank-run gravel or similar angular-grained material should be used for a re-surfacing.
- When plowing, care must be taken to ensure the gravel is not disturbed.
- The edge of gravel roads must be graded such that water can freely flow to the abutting ditch/swale or ground surface. Gravel that falls into drainage ditches and swales must be removed.
- Schedule maintenance to minimize potential erosion. Top coating should be performed after spring thaw and at a time when no or very little rain is predicted.

As runoff is channelized along roadside ditches, its potential to cause erosion and suspend sediment greatly increases. In order to minimize the sediment loads associated with drainage conveyance, it is important to understand the size and characteristics of the area draining to channel and properly engineer the channel and treatment practice for predicted storm volumes and peak rates.

Routine inspections of the drainage along gravel roads are important for the identification of potential problems. Some problems with simple solutions such as a clogged culvert could cause major damage to a gravel road.

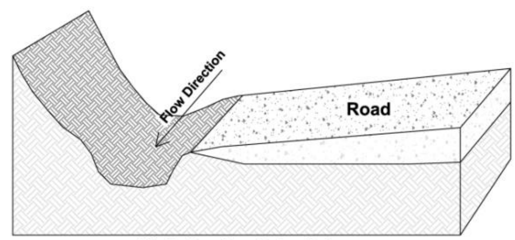
7.2.2 Stormwater Management Practices

Paved and gravel roads are essentially impervious so during rain events water rapidly collects and flows to the nearest water conveyance channel or area where it can infiltrate to the ground. Road-side ditches have historically been built or were naturally created to rapidly drain stormwater to the nearest waterbody, but due to increased flooding, erosion, and contaminant transport associated with this practice, alternative techniques for managing road runoff are recommended. Minimizing the accumulation of channelized flow is the initial step toward controlling stormwater. This is accomplished by directing runoff to areas near the point of generation that are capable of naturally infiltration. As greater amounts of runoff accumulates, the complexity of capturing, slowing, and treating the stormwater increases along with the costs. The New Hampshire Stormwater Manual (NHDES, 2008) is a comprehensive resource for stormwater best management practices. As residential development, and road and driveway construction takes place in the Granite Lake Watershed, it will be important that stormwater controls are implemented in accordance with this guidance document.

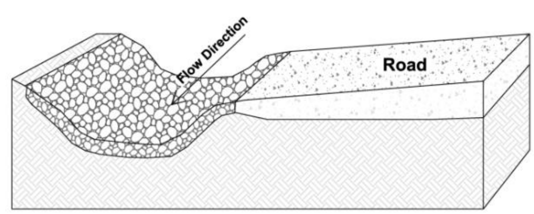
The following stormwater management practices are presented as examples of measures that could be employed at the sites in the Granite Lake watershed. These measures, as well as others that are listed in Table 7-1 and described in the NH Stormwater Manual should be considered for existing sites and those that are discovered or developed in the future.

Swales

Swales convey stormwater along roadsides to prevent water from ponding on, or flowing over the road. In many cases, road-side swales are ditches that have been created by channelized stormwater eroding a path of least resistance. The sediment and nutrient load associated with this type of drainage is considerable, as is the potential damage to the road integrity and abutting property. Properly designed swales provide a channel that is capable of conveying expected storm flow rates without erosion. Factors that need to be considered in the design of a road-side swale include topographic slope, drainage area, expected storm flow, swale dimensions, outlet control, base material and vegetation.



High Erosion Potential
Narrow Roadside Ditch with Steep Side-Slope



Low Erosion Potential
Riprap Reinforced Swale
Widened with Lowered Side-Slopes

The performance of swales can improved and their potential contribution to sediment and nutrient loading reduced by increasing their depth and width, reinforcing with appropriately sized riprap, installing check dams (riprap) and step pools, and reducing their slope (cross-section and profile). Where feasible, infiltration trenches should be considered in place of conveyance swales. Opportunities for swales to turn-out into areas with excess infiltration capacity should be assessed and utilized to convert channelized swale flow to sheet flow and infiltration.

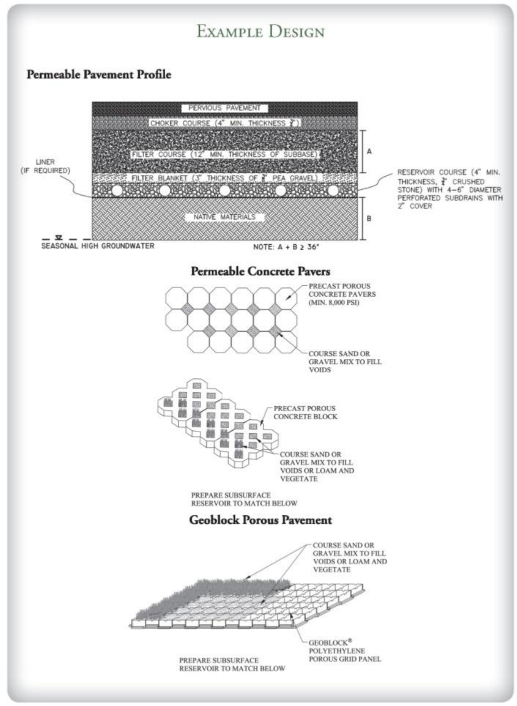
Culvert Inlet and Outlet Scour Protection

To reduce sediment and nutrient loading associated with erosion at culvert inlets and outlets, loose sediments should be routinely removed, the inlet and outlet pools should be reinforced with appropriately sized riprap, and headwalls should be installed. Inlet and outlet culvert areas are subject to concentrated flow velocities so the potential for erosion at these locations is considerable. By installing an energy dissipation/settling pool at these locations where scour is likely due to high flow velocities, erosion can be mitigated. These pools are intended for use at the low point of swales and intermittent streams and stormwater drainage culverts, not perennial streams. The size of this type of pool is dependent upon the expected flow rates and the site conditions. At the locations in the Granite Lake watershed that are identified as potential sites for these pools, their sizes could range from four to eight feet in diameter and two to three feet in depth.

In some cases the installation of a deep-sump catch basin is appropriate for capturing runoff and reducing potential erosion associated with culvert designs. The area around the catch basin inlets should be reinforced with riprap to minimize sediment loading from the concentrated areas of flow immediately surrounding the basin.

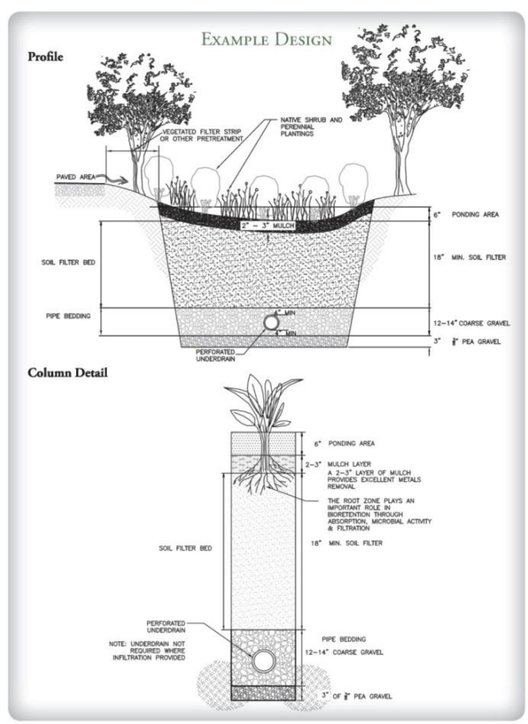
Drop Inlet Catch Basin

To reduce the potential for catch basins to be a source of sediment and nutrient loading it is important that sediments are routinely removed. The land cover immediately around catch basin inlets should be stable and sloped at grades that minimize the transport of sediments. In areas with high potential for sediment loads, the installation of a hydrodynamic separator should be considered. Catch basins with perforated bases should be considered for use as dry wells in areas with sufficient depth to groundwater and suitable soil permeability.



Pervious Pavement / Pavers

Properly designed and constructed pervious asphalt pavement and pervious concrete pavers result in no direct runoff from these areas. The installation of pervious pavement/pavers is ideal where land area for runoff treatment is insufficient and the ability to infiltrate runoff before it channelizes is limited. Factors that control the feasibility of this stormwater control option include the depth to groundwater, depth to bedrock, native soil permeability, topographic limitations, and expected traffic load. For optimal performance it is essential that pervious pavement / pavers are constructed in accordance with current design standards (http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pa_spec_10_09.pdf). Example design shown here is from the NH Stormwater Manual, 2008, Volume 2.



Bioretention System

Bioretention systems are shallow basins designed to infiltrate runoff thorough an engineered highly permeable soil material. Water treated with a bioretention system either infiltrates to the groundwater or discharges via an underdrain system. Bioretention systems are vegetated to assist with the uptake of pollutants and to blend in with landscape aesthetics. Typically these systems are designed with a treatment capacity of the 10-year 24-hour storm. Pretreatment to remove settleable solids is required, as is a means to bypass flows greater than the design storm. Design criteria are specified in the NH Stormwater Manual, 2008, Volume 2 (http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-08-20b.pdf). Example design shown here is from the NH Stormwater Manual.

Total suspended solids and total phosphorus removal from properly designed and installed bioretention systems is reported to be approximately 90% and 65%, respectively (NH Stormwater Manual). Installed costs for bioretention systems vary widely based on their size and site complexity. Systems could cost from $3,000 for very small simple systems, to over $35,000 for large systems.

7.3 In-Lake and Shoreland Management

Shoreland activities can significantly contribute to sediment and nutrient loading to surface waters. To minimize the impact of shoreland development and associated near-lake and in-lake activities the following practices should be employed:

- Shoreland buffers should be maintained as specified in the NH Comprehensive Shoreland Protection Act. (Appendix C)
  - Maintain a minimum of 50 foot buffer of natural vegetation along the shoreline;
  - No beach construction – filling along shoreline
  - Incorporate infiltration step designs on pathways to the water as specified in A Shoreland Homeowner’s Guide to Stormwater Management, NHDES (Appendix C)
- Lawn/Yard Maintenance;
  - No dumping of grass clippings in or near water
  - No phosphorus fertilizer
- Minimize impervious surfaces (roofs, driveways, etc…) and incorporate storm water controls to minimize runoff from impervious surfaces.
  - Rain Barrels
  - Dripline Trenches
  - Dry Wells
- Remove pet waste from shoreline areas;
- Minimize disturbance of lake sediments (avoid sediment churning from boat motors).

Many of the practices listed above are covered in detail in a recent publication entitled “Landscaping at the Water’s Edge: An Ecological Approach” (UNH Cooperative Extension 2007).

7.4 Septic System Inventory, Maintenance, and Upgrades

Septic systems contribute approximately 15% of the total phosphorus to Granite Lake based upon the nutrient loading model used for this management plan. The phosphorus load from septic systems accounts for approximately 44% of the total phosphorus load increase over the undeveloped conditions as modeled, so it is important to assess and actively manage this potential source. In order to manage the load from septic systems, it is important to understand the conditions of the existing systems and their respective potential for contributing to the phosphorus load to Granite Lake.

A Septic System Management Plan should be prepared that identifies the goal of reducing phosphorus loading to Granite Lake and explains the methods that will be used to meet this goal. The following elements should be included in the plan:

a) Method of collecting and compiling septic system information (See Section 8 for inventory questions)
b) Shallow groundwater sampling plan including sample locations and frequency
c) Data management system description
d) Method for prioritizing systems for upgrade/replacement
e) Guidelines for septic system maintenance and general residential system awareness fact sheets
f) Summary of potential funding sources (grant, tax, etc…)
g) Options for rebates/discounts for pumping, inspections, and maintenance
h) Roles and responsibilities for association members involved in project

Shallow groundwater sampling as discussed in Section 8.1 should be performed to refine the phosphorus removal potential with septic upgrades. The results of this sampling program may also help direct the management efforts toward specific areas where phosphorus loading reductions may be more achievable.

The option to replace existing systems with a community system that has less potential to contribute phosphorus to the lake should be considered upon the review groundwater sample results and septic system inventories. The densely developed area on the loop road in the northeastern lakeshore area (Sandy Beach) is an area that may have some potential for reducing septic system loading by converting the systems to a new combined community system. The soils in this area are Naumburg loamy fine sand which is described in the USDA Natural Resources Conservation Service Soils database as having very limited potential for septic tank absorption fields. This limitation is primarily due to the high water table in this soil unit. Unfortunately the soils adjacent to this area, Peru Fine Sandy Loam and Marlow Fine Sandy Loam, also are described as having very limited potential for septic tank absorption fields. Upon further assessment of the status of the septic systems in this community, decisions can be made regarding the most effective method of reducing the phosphorus load from this potential source. Recommendations for further study of this area are presented in Section 8.1.Using the LLRM to estimate where phosphorus load reductions could be achieved to attain the target in-lake concentration, an estimated 4.2 kg of phosphorus could be reduced from the septic system contribution. Assumptions for the estimated loading from septic systems are detailed in Section 3.2. Based on these assumptions, 75% of the systems that are currently considered old systems (i.e., phosphorus removal is 80%) would need to be upgraded (to 90% removal) to achieve this reduction in load. Based on available estimates, this equates to 14 year-round residences and 37 summer residences, assuming an equal percentage division of upgrades. Since there is limited information about the existing septic systems, this approach for determining potential phosphorus loading reductions from septic systems is only an example of the measures that could be employed. Upon further investigation of the existing systems, the discovery of a few failing systems, old systems within 75 feet of the lake, or direct discharges may be able to account for a considerable amount of the overall septic load to the lake, thus the scope of the upgrades may be considerably less than this scenario.

7.5 Timber Harvesting

Timber harvesting operations have considerable potential to cause soil erosion, runoff, and sediment and nutrient loading. The document, Best Management Practices for Erosion Control on Timber Harvesting Operations, 2004, published by the New Hampshire Department of Resources and Economic Development, Division of Forests and Lands is available on-line at: http://www.nhdfl.org/library/pdf/Publications/BMPs/erosion/control/2004.pdf

Loggers should be made aware by Town officials that erosion control BMPs shall be followed during timber harvesting operations. Inspections by town officials or commission members should be performed to ensure BMPs are practiced and disturbance of soils, wetlands, and waterways are properly minimized. Hiring a forester or environmental consultant with a working knowledge of forestry BMPs to conduct routine inspections during logging operations is an effective approach to control soil erosion, storm water runoff, and wetland disturbances.

7.6 Agriculture

Agriculture is not currently a significant source of phosphorus in the Granite Lake watershed. Nutrient loading from agricultural land can be managed through many methods including runoff controls and treatment, grazing area restrictions and setbacks, and manure application timing and buffers. Considerable information is available to assist with the management of nutrient loads from agricultural lands. The US Environmental Protection Agency has published a series of Nonpoint Source Management Fact Sheets (http://www.epa.gov/owow/nps/pubs.html#ag).

7.7 Granite Lake - Site-Specific, Non-Point Source Management Measures

This section identifies specific areas in the Granite Lake watershed that are probable sources of sediment and nutrient load to the lake currently and proposes Best Management Practices (BMPs) that could be employed to reduce the loading from these areas. Many of these areas along West Shore Road and North Shore Road are also addressed in the report Stormwater Drainage for North Shore and West Shore Roads, NHDES, 2007 (Appendix F). The BMP site numbers in this report references the NHDES report where appropriate (Table 7-1). Locations of the proposed BMPs are presented on Figure 7-1. The predicted reductions from the management practices are estimates based upon literature values and best professional judgment. Removal efficiencies and associated construction costs are provided in Table 7-1.

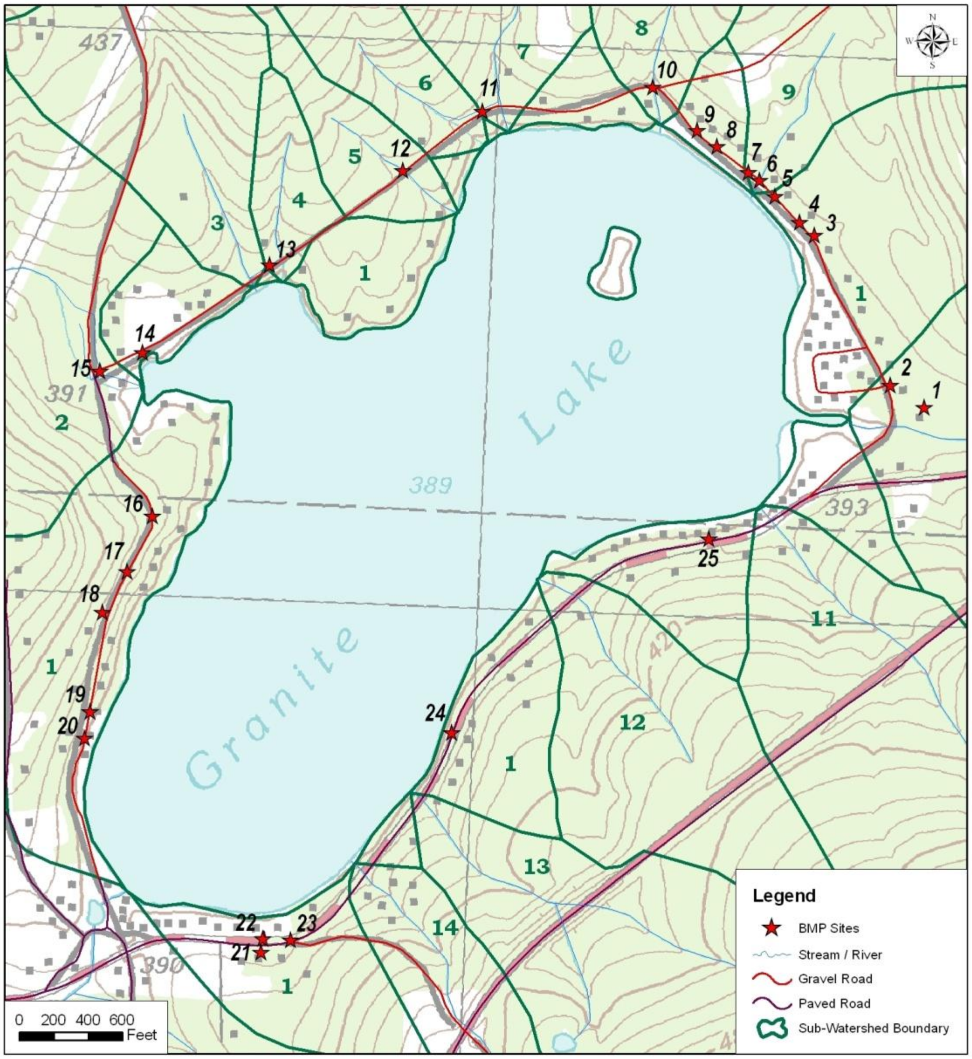


Figure 7-1: Sites for Best Management Practice Implementation

7.7.1 North Shore Road Catch Basins, Culverts, and Swales

The eastern portion of North Shore Road has little topographic relief and is the most densely populated area along Granite Lake. Groundwater is shallow along the eastern portion of North Shore Road and road drainage has apparently been a challenge based upon the presence of multiple catch basins and culverts. During site visits in March and June 2010 many of the catch basins were either filled with sediment or water. Due to the close proximity of the road to the lake many of the culverts discharge nearly directly into the lake, thus little to no opportunities exist for adding end-of-pipe treatment measures. Efforts should be made to document the catch basins' and culverts' specifications and integrity. Alternatives to catch basin drainage should be investigated by performing test pits at locations along North Shore Road where infiltration trenches or dry well catch basins may be feasible. It is likely that the groundwater table is too high in many locations to render these options feasible, but if possible, infiltration would be the best solution for removal of the sediment and phosphorus load from this area's runoff.

Through education and/or an incentive program, property owners along North Shore Road could evaluate and potentially address runoff from driveways and other impervious surfaces through on-site infiltration practices prior to its accumulation and runoff to road-side catch basins and the lake.

Additional sediment capture could potentially be gained by replacing the existing catch basins with deep-sump basins. Hydrodynamic separators could also be considered if other management measures do not provide adequate sediment removal.

At a minimum, the sediment in the existing catch basins should be removed regularly (as needed so no more than half of the sump depth contains sediment). The gravel area surrounding the catch basin inlets (approximately two feet from perimeter by six to twelve inches deep) should be replaced with large cobble or riprap). The swales approaching the catch basin should be deepened and reinforced with riprap as needed to maintain stability, provide some storage and infiltration potential and prevent ditch erosion.

7.7.2 West Shore Road / North Shore Road Intersection Culverts and Swales

Runoff from Basin 2 discharges through two 24-inch plastic culvert at the intersection of West Shore Road, North Shore Road and Aten Road. Erosion along the banks of the outlet channels from these culverts is evident. To reduce peak flow through these culverts, opportunities to infiltrate road runoff should be investigated. Infiltration trenches or road-side ditch turn-outs could potentially reduce the runoff volume from Aten Road. Headwalls should be constructed at the culvert inlets and outlets. Upon further study of the stream dynamics in this area, measures for reducing the stream bank erosion could be identified. They may include simple stream bed placement of riprap, or more extensive re-grading, sloping and reinforcement of channel banks.

The drainage ditches that discharge to the inlet side of culvert C19 (BMP Site 15) should be reinforced with riprap and an energy dissipation/settling pool should be constructed to minimize erosion at the culvert inlet.

7.7.3 West Shore Road Culverts and Swales

West Shore Road is a gravel road with steep side slopes. Ditches on the upslope roadside convey water from natural undeveloped areas as well as some low-density residential areas to culverts that discharge immediately down-slope from the road. Along the southern portion of West Shore Road the culverts discharge directly into the lake and along the middle and northern portions of West Shore Road the discharge from the culverts flow through eroded channels to the lake.

The roadside ditches convey sediment and nutrients from the gravel road surface and are sources of sediment and nutrients as they erode during high runoff events. Proper maintenance of gravel road surfaces will help reduce loading from them, but in many cases additional measures need to be taken to prevent further erosion from the ditches and culverts.

Most culverts around Granite Lake do not have headwalls; the inlets consist of the pipe end surrounded by filled gravel or crude stone backfill. During storm events, runoff pools in front of the pipe inlets and has the potential to scour and erode the bank and re-suspend settled material in the pooled area. Headwalls help to prevent further erosion at these inlet areas. Pre-fabricated or poured in-place headwalls are simple solutions to minimize the sediment and nutrient loads generated by these points of potential erosion.

The stability of roadside swales is primarily dependent upon their slope, cross-section dimensions, and bottom base materials/vegetation. To reduce or prevent erosion of roadside drainage ditches they need to have sufficiently wide bottom channels and have slopes that are mild enough to convey expected storm flows at rates without disturbance of the base material. Most of the ditches along West Shore Road are narrow channels on fairly steep slopes with somewhat vegetated native soils and gravel as their base material. The following site-specific measures are recommended to reduce erosion of the ditches by reinforcing the base material, stabilizing areas with high potential for scour, and slowing the flow rates. They are presented as examples of the road drainage improvement measures that are recommended in this plan.

Culverts along the middle and northern portion of West Shore Road (BMP Site 16, 17, & 18) do not have headwalls and their inlet pools have loose sand sediments. Headwalls should be constructed on the inlets and outlets of these culverts. The inlet pools should be dredged as is feasible and the bottoms reinforced with adequately sized riprap ($D_{50} \geq 6$”). An energy dissipation/settling pool should be installed at the outlet of culvert C24 (BMP Site 18) to reduce the flow velocity through the outlet channel. The outlet channel from C24 also should be reinforced with riprap, as significant erosion is evident in the downstream channel.

Culvert at BMP Site 18

Culvert at BMP Site 18 Outlet Channel

The southern portion of West Shore Road (BMP Site 20 on Figure 7-1) is relatively flat. Headwalls should be installed and culvert inlet pools should be cleaned and reinforced with riprap (D50≥4”). The base material in some of these roadside swales is mostly loose gravel that may migrate into the lake during large storm events and spring thaw. The swales should be improved by removing loose gravel, widening as is possible, and placing riprap to reinforce the swale bottom and side slopes.

Swale at BMP Site 20

The culvert at BMP Site 19 has a vertical pipe inlet in an area with loose roadside gravel. This inlet could be improved by replacing some gravel and soil around the pipe inlet with riprap. This will cause some slight ponding of runoff prior to flowing into the drop pipe to allow for some sediment to settle or be trapped in the riprap.

7.7.4 Nelson Fire Station Parking Lot

The Town of Nelson’s Fire Station is located across Granite Lake Road from the boat ramp on the southern side of the lake. The driveway area in front of the fire station is approximately 3,400 square feet of gravel that is sloped toward the road. Runoff from the driveway appears to drain toward the western corner where it flows into a roadside swale and catch basin. A culvert runs from this catch basin, under the fire station driveway to a ditch/pit near the eastern corner of the driveway. Runoff during high-intensity storms may flow

Nelson Fire Station Driveway (BMP Site 21)

across Granite Lake Road to the boat ramp. Storm water discharges from the ditch/pit in the northern corner through a culvert under Granite Lake Road to a catch basin in the boat ramp area. This catch basin discharges to Granite Lake on the northeastern side of the boat ramp. Based on the land use coefficients used in LLRM, this area contributes approximately 0.1 kg-P/year to the lake.

Due to lack of available land around the fire station driveway, the options available to control the migration of sediment and associated nutrients from this area are limited. The source of the sediment could be removed by replacing the gravel driveway with either pervious pavement or concrete pavers. To determine the feasibility of this option, the permeability of subsurface material would need to be tested and the durability of the material evaluated with respect to the truck loads.

To minimize erosion and re-suspension of sediment in the pit/ditch on the eastern side of the driveway, the pit bottom should either be deepened and reinforced with riprap ($D_{50} \geq 6$”), or a deep-sump catch basin installed in-place of the pit.

Some additional sediment and nutrient removal from this drainage may be achieved through the drainage measures taken for the boat ramp (see below). The measures at the boat ramp and the fire station need to be considered together to ensure the storm water controls are adequately sized.

7.7.5 Granite Lake Boat Ramp

The Granite Lake boat ramp is a point of direct drainage from the currently degraded asphalt pavement on the ramp, the abutting portion of Granite Lake Road, and the fire station driveway. A catch basin near the road discharges into the lake on the western side of the boat ramp. The boat ramp is approximately 40 feet wide and 100 feet long. Based on the land use coefficients used in LLRM, the boat ramp area contributes a phosphorus load of approximately 0.06 kg/year; however given the slope, proximity to the lake, and nature of the activities at the boat ramp this load is more likely between 0.1 and 0.3 kg/year

Catch Basin at Boat Ramp (BMP Site 22)

The boat ramp should be reconstructed to minimize the sediment and nutrient loading from direct runoff. Pervious asphalt or concrete could be considered, but fine sand and silt and organic matter from overhanging trees, boats and trailers may cause the pores to clog and the pavement to ultimately fail. The construction of a treatment swale with a porous sand and gravel base and riprap surface along the western side of the boat ramp could provide some sediment and phosphorus removal from the road and ramp runoff. The ramp would need to be pitched toward the swale. A poured concrete ramp with a grooved surface could help direct the runoff toward the swale. A proper design would need to include an evaluation of the permeability of the subsurface material and the typical high groundwater level. The discharge from the swale could pass through a vegetated buffer along the lake shoreline, or through the riprap before entering the lake. The side slope of the swale should be very shallow so that vehicles that mistakenly drive off the pavement can recover.

The amount of sediment and phosphorus removal from a swale in this location is highly dependent upon the design. If sufficient depth to water exists to allow for some infiltration of the runoff, better removal could be achieved than if only surface flow through the riprap was possible.

7.7.6 Granite Lake Road Catch Basins and Direct Drainage

Catch basins along the northern portion of Granite Lake Road convey stormwater from sections of the lake side of the road toward the lake. The majority Granite Lake Road drains to roadside swales and natural undeveloped areas along the road. To minimize sediment and phosphorus loading from the road area drained by the catch basins, routine removal of sediments in the basin should be performed. If samples from the catch basin discharges yield high phosphorus concentrations, measures to treat the discharge through infiltration techniques should be considered.

Along the section of Granite Lake Road that passes within 50 feet of Granite Lake for a distance of nearly 500 feet, road runoff apparently flows directly over the shoulder of the road into Granite Lake (BMP Site 24, Figure 7-1). The roadway shoulder along this section consists of sand and gravel. In order to minimize the amount of sediment that migrates from the roadway shoulder into the lake, the shoulder should be stabilized with vegetation where possible and reinforced with riprap where vegetation cannot be established. This will require the removal of some of the existing sand and gravel, which will need to be performed with precautions to prevent sediment from falling into the lake.

Approximately 200 feet northeast of the boat ramp, at 558 Granite Lake Road (BMP Site 23), runoff from two paved driveways and surface water runoff from a swale that abuts an old road (Boys Camp Road) flows into a catch basin that discharges to an open area that slopes toward Granite Lake. It is apparent that stormwater flows overland from the catch basin outlet pipe to Granite Lake. Based on phosphorus loading coefficients used in the LRM, this drainage contributes approximately 0.4 kg of phosphorus per year to the lake. If samples from this drainage yield phosphorus levels that support the implementation of treatment, the site where the runoff flows overland appears to have an adequate area for the installation of a bioretention system. The property at this site is privately owned, so this might limit the feasibility of this option or increase the cost if easements must be purchased. The depth to the seasonal high water table would need to be determined and the native soil permeability would need to be tested to properly design the system. The contributing drainage area, roughly estimated as 0.5 acres, would need to be determined to properly size the system and design the bypass control. Given the potential phosphorus removal efficiency of 65%, approximately 0.26 kg of phosphorus could be removed per year from this system.

Catch Basin at BMP Site 23

7.7.7 Route 9, Nye Road, and NH DOT Storage Area

Stormwater drainage from Route 9 within the Granite Lake watershed is conveyed through grass swales. It appears most runoff from Route 9 infiltrates within the swales and large storm events may produce some runoff that flows to established stream channels. The portion of Route 9 that is located near the NH Department of Transportation storage shed and the Nye Road intersection has some drainage systems that could be improved.

A swale located near the intersection of Route 9 and Granite Lake Road conveys runoff from a portion of Route 9 (BMP Site 26) to a culvert that discharges into the tributary drainage from Basin 10. The topography and the open area at the swale location appear favorable for the installation of a treatment measure such as a bioretention system or a shallow wetland. Based on the phosphorus load coefficients used in LRM, the area draining through this swale contributes approximately 0.29 kg of phosphorus per year. A treatment wetland with a removal efficiency of 45% would result in a calculated load reduction from the Basin 10 drainage of 0.13 kg/year.

Nye Road is a paved road with a drainage swale that discharges into a catch basin with a direct discharge into the Basin 10 tributary stream (Figure 7-2). Loose sand and gravel have built up in the swale and appear to have been washed into the catch basin. The swale should be reinforced with riprap and the soil/gravel around the catch basin inlet should be replaced with riprap.

Runoff from the NH DOT storage facility flows through a swale into a catch basin near the entrance gate. The catch basin discharges into a constructed shallow wetland along the access road. The wetland discharges through a culvert directly into the Basin 10 tributary stream. The swale and slopes around the wetland have eroded and gravel from the road surface has been transported into portions of these stormwater management systems. The size of the constructed wetland is too small given the apparent drainage area to function as a treatment wetland.

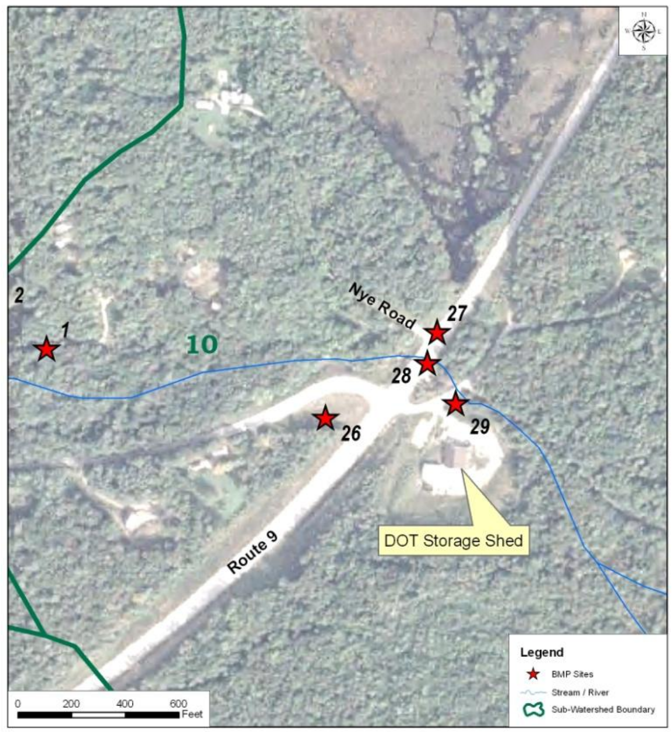


Figure 7-2: Sites for BMP Implementation Near Route 9 Bridge

Nye Road Catch Basin (BMP Site 27)

NH DOT Storage Facility Swale (BMP Site 29)

Slopes around the wetland and along the drainage swales should be reinforced with riprap or reduced to prevent further erosion. The volume and if possible, the area of the wetland should be increased to better treat the runoff from this site. Alternatively, an additional wetland or bioretention system could be constructed in the swale area or further upgradient in the facility.

8.0 Phosphorus Management Summary and Implementation Schedule

The measures recommended for the management of phosphorus loading to Granite Lake are prioritized with cost estimates and predicted phosphorus removal in Tables 8-1, 8-2, and 8-3. The BMP Sites referenced in this table refer to locations on Figures 7-1 and 7-2, and the Stormwater Drainage report prepared by NHDES in 2007 (Appendix F). The recommended measures are summarized below in priority order and in Table 8-4 with a proposed implementation schedule.

The cost estimates are rough approximations based on best professional judgment and available cost information. Some of the recommended measures will require technical assistance with preliminary investigations and designs to develop more accurate cost estimates. The measures are prioritized with respect to their associated load and potential for overall load reduction. Table 8-4 is presented as a general guide to help direct watershed management efforts in a manner that is most cost effect with respect to the goal of reducing phosphorus loading to Granite Lake.

8.1 Septic System Survey and Shallow Groundwater Sampling

To assess the potential phosphorus loading from septic systems within the Granite Lake Shoreland Zone, an inventory of system information should be compiled. The following steps could be performed by volunteers or a hired consultant.

1) Prepare and mail an inventory form and cover letter to all residence along West Shore Road, North Shore Road, and Granite Lake Road that requests specific information about their septic system and notifies them that someone will be visiting to locate their leach field with a GPS receiver (and detailed aerial photo map). The inventory form can be a paper form that can be returned to GLA and/or an online web-page where information can be electronically submitted. Information that should be requested includes:
    a. What year was the existing system installed?
    b. Is the existing system the original system or a replacement?
    c. What is the type of septic system? (tank/stone leach bed; cesspool tank; proprietary system (manufacturer name?); other?)
    d. What is the design capacity of existing system (# of bedrooms)?
    e. How many bedrooms are currently in the house associated with this system?
    f. What are the geographic coordinates of the leach field (NAD83)?
    g. Where is the leach field relative to the front door of the house?
    h. Approximately how many feet is the leach field from the lake or tributary stream?
    i. Has the septic system ever failed?
    j. Has water from the septic tank or leach field ever appeared at the ground surface?
    k. When was the last time the septic tank was pumped out? Inspected?
    l. How often have you historically had the septic tank pumped out?

2) Compile information in spreadsheet, including residences that did not respond that may require follow-up phone calls or letter.

3) Obtain geographic coordinates of leach fields/disposal locations with a GPS receiver and pace distances from these locations to the lake or tributary stream. Personal visits with homeowners can be used to distribute information about septic system maintenance as well as shoreland BMPs for storm water controls and landscaping.

4) Evaluate the compiled septic system information with respect to their potential to contribute elevated phosphorus to the lake. A ranking system can be used to prioritize systems for follow-up actions. Factors to consider in the ranking include distance from the lake or tributary, age of system, type of system, historic system failures, and capacity of system (vs. existing discharge to system).

To assess the potential phosphorus loading to the lake from shallow groundwater that may convey septic discharges, groundwater samples from shallow well points should be collected and analyzed. Well points should be installed on land within 50 feet of the shoreline and where the groundwater is likely to be less than three feet below the ground surface. Areas where there is a high density of residences and the soil is known to have limitations for septic system installations should be targeted for this assessment. The well screen should be installed within the top three feet of groundwater. Documentation of the screen length, well location, and the ease/difficulty of the installation should be maintained for future reference. Prior to collecting a sample from the well point, at least three volumes of water should be discarded from the well to ensure the sample is representative of the surrounding groundwater. Samples should be collected during high water levels (spring or early summer) when septic systems are most likely to be in direct contact with the groundwater table, and during low-water levels (late fall or early winter) when the highest gradient exists between the near-shore groundwater levels and the lake-water level. Samples should be analyzed for total phosphorus and nitrates. The analytical results from samples should be compiled and maintained by GLA and provided to NHDES for their interpretation.

The Sandy Beach area is one area that should be targeted for more intensive study. As discussed in Section 3.2, this area is just above lake level with shallow depth to groundwater, sandy soils and dense development with individual septic systems. In addition administering the septic survey described above to all of the residences of Sandy Beach Road, a sampling plan should be implemented to evaluate potential movement of nutrients from onsite septic systems to the lake in this area. A minimum of one shallow groundwater sampling location per 100 feet of lakefront should be established to characterize groundwater in this area. In addition, samples should be collected each 100 feet along the shoreline of the inlet to characterize potential inputs of groundwater. It is estimated that this will result in a total of 8-10 monitoring locations to be monitored during both high and low water level periods as well as following periods of high use. A late spring, post 4th of July weekend and post Labor Day sampling schedule could meet all of the criteria. Two additional groundwater monitoring locations should be sampled along an undeveloped reference area of shoreline. The shoreline to the south of the inlet and the south side of the inlet stream may be good candidates for a reference sites. Surface water should be sampled in conjunction with lakefront groundwater samples during each event. Locations for surface water sampling should include a station in the inlet upstream of the North Shore Road, in the inlet at Granite Lake, in the lake 25 feet from the shoreline in front of the Sandy Beach waterfront and mid-lake at the deep spot. All samples should be analyzed for total and dissolved phosphorus, nitrates, specific conductance and dissolved oxygen at a minimum.

If high concentrations of nitrates and/or phosphorus are encountered in the shallow groundwater samples, additional investigation should be conducted to determine if the origin of the elevated concentrations are from specific septic systems in this area. This may include the addition of sampling locations between the lake/inlet front stations and the houses to isolate the origin of the nutrients or inspection of individual septic systems that are suspected of inadequately removing nutrients.

The results from these assessments could be used to modify the current phosphorus loading model and assist with the targeting of further phosphorus loading management measures. The results may identify specific septic systems or general areas where phosphorus loading from septic systems is greater than expected. Measures for reducing loads from these sources could range in scope from residential incentives for upgrading septic systems to the design and installation of a community system(s). Shoreland Protection and Education Programs

Considerable reductions in lake impacts from residential property within the shoreland protection zone can be achieved through education and outreach programs. Section 9 outlines suggested activities and programs to elevate the dialogue with property owners that could participate in the management of lake water quality. With volunteer efforts and/or funding, shoreland improvement projects could be conducted and used to promote various techniques for managing land along the lake. Shoreland property owners that are willing to use their land for demonstration projects should be identified along with a variety of shoreland management techniques.

Watershed Protection Districts should be established in the Towns of Stoddard and Nelson that codify specific development and land management requirements to protect lake water quality. The NH Comprehensive Shoreland Protection Act provides protections for near-lake development which can be incorporated into the Town ordinance. Additional protections from shoreland activities can be incorporated in the District rules such as requirements for use of only no- or low- phosphorus fertilizers, and setbacks for livestock grazing or housing structures. A Watershed Protection District ordinance should also address issues such as storm-water management (both quality and quantity controls) and erosion potential from proposed property subdivision development, hazardous chemical storage, septic system setbacks, and.other buffers and setbacks associated with surface-water quality protection.

8.2 Road Maintenance and Storm Water Drainage Improvements

The BMP’s for reducing phosphorus loading from storm-water runoff are prioritized in Tables 8-1 and 8-2 by their estimated removal potential. Most of these BMP’s result in minor reductions individually, so their potential for load reductions should be considered in terms of an overall road maintenance and storm water control program. The estimated cost for the High, Medium, and Low priority BMP’s total $125,580, $62,760, and $39,540; respectively. Some of the BMP’s may not be feasible due to property ownership issues, thus efforts to implement these BMP’s may need to adjust accordingly. The effort associated with the implementation these BMP’s was not considered in this ranking, so for example, performing all of the riprap and settling/energy dissipation pool installations may be more cost effective if they are done at the same time even though they are not all prioritized equally in terms of their removal potential. The BMP’s are also categorized in Table 8-2 by the type of construction required. The estimated cost for the BMP’s that involve swale modifications and riprap installation (SWL), and culvert headwall (HW) installation is $51,560. The estimated cost for the replacement and investigation of catch basins (CB) is $15,450. The estimated costs for the remainder of the drainage BMP’s, all which will require project-specific materials and construction plans is $160,870.

Road maintenance and storm-water drainage improvements are costly given the predicted phosphorus removal from these BMPs; however, they are specific sources that can be addressed with structural measures. This is unlike the more abstract removal potentials predicted from watershed-based ordinances and education programs.

Table 8-1: Recommended Measures to Manage Phosphorous Loading to Granite Lake – Load Reduction Estimates for Road Drainage Improvements

Source	Site Location	Basin	Estimate Drainage Length (ft)	Estimated Drainage Width (ft)	Estimated Contributing Drainage Area (ha)	Estimated Annual Phosphorus Load (kg/yr)	Treatment Measure[1]	Removal Efficiency[1]	Estimated Load Reduction (kg/yr)
Road Runoff & Swale Erosion	Jackson Road	10	200	50	0.09	0.19	Re-grade road away from stream; construct riprap-reinforced sediment pool at culvert outlet	80%	0.15
	Eastern End of North Shore Road	10	300	20	0.06	0.11	Perform pipe integrity inspection (replace pipe if necessary); clean catch basins	80%	0.09
	North Shore Road	1	100	20	0.02	0.04	Replace CB with deep-sump CB or if sufficiently low groundwater exists replace with a dry well CB; reinforce area surrounding CB with stable vegetation or 4-inch riprap	80%	0.03
	North Shore Road	1	20	20	0.00	0.01	Replace inlet and outlet headwalls	80%	0.01
	North Shore Road	1	20	20	0.00	0.01	Replace inlet and outlet headwalls	80%	0.01
	North Shore Road	9	20	20	0.00	0.01	Replace inlet and outlet headwalls	80%	0.01
	North Shore Road	1	150	20	0.03	0.06	Replace CB's with deep-sump CB's or if sufficiently low groundwater exists, replace with dry well CB's; reinforce area surrounding CB's and drainage swales with stable vegetation or 4-inch riprap.	80%	0.04
	North Shore Road	1	150	30	0.04	0.08	Replace CB with deep-sump CB or if sufficiently low groundwater exists replace with a dry well CB; trench(1' deep x 3' wide) and reinforce swales and area surrounding CB with stable vegetation or 4-inch riprap; investigate outlet pipe integrity and replace if needed.	80%	0.07
	North Shore Road	1	100	15	0.01	0.03	Replace CB with deep-sump CB or if sufficiently low groundwater exists replace with a dry well CB; reinforce area surrounding CB and swales with stable vegetation or 4-inch riprap; incorporate infiltration trench if subsurface is suitable.	80%	0.02
	North Shore Road	8	200	15	0.03	0.06	Widen and reinforce swale with 4-inch riprap; install check dams/energy dissipators in swales at the stream edge.	80%	0.04
	North Shore Road	7	300	15	0.04	0.08	Install turn-out to divert runoff from ditch vegetated area on the north side of the road. Grade outlet from turn-out to disperse water evenly across native vegetation. Widen, deepen and reinforce the lower portion of the drainage swale with 4-inch riprap (10-inch thickness min.). Minimize the slope of the swale to reduce erosion potential. Install a riprap dam across swale to dissipate energy prior to discharge in the stream.	80%	0.07
	Warren Drive	5	100	12	0.01	0.02	Widen and reinforce swale with 4-inch riprap; install check dams/energy dissipators in swales at the stream edge.	80%	0.02
	Near 534 North Shore Road	3	180	24	0.04	0.08	Widen and reinforce swales; install check dams/ and settling pool at inlet of C15	80%	0.06
	North Shore / West Shore Intersection	1	20	20	0.00	0.01	Install headwall at culvert outlet; reinforce bank with vegetated buffer	80%	0.01
	North Shore / West Shore Intersection	2	100	20	0.02	0.04	Reinforce inlet to western culvert (C19) with riprap and install energy dissipation/settling pools to reduce erosion at culvert inlet. Engineering services required to calculate anticipated storm flow rates and design reinforcement structures for outlet channels - costs for materials and labor for outlet channels not included in this estimate.	80%	0.03

NOTE:

[1] Load reductions from road drainage improvements are based on areas subject to erosion near BMP sites, and the removal efficiencies are considered as a result of preventing erosion, not necessarily removal efficiency as rated for treatment processes.

Table 8-1 Recommended Measures to Manage Phosphorus Loading to Granite Lake – Load Reduction Estimates for Road Drainage Improvements (Continued)

Source	Site Location	Basin	Estimated Drainage Length (ft)	Estimate Drainage Width (ft)	Estimated Contributing Drainage Area (ha)	Estimated Annual Phosphorus Load (kg/yr)	Treatment Measure[1]	Removal Efficiency[1]	Estimated Load Reduction (kg/yr)
Road Runoff & Swale Erosion	West Shore Road	1	75	10	0.01	0.01	Install culvert headwall, reinforce pool at culvert inlet with 6-inch riprap	80%	0.01
	West Shore Road	1	50	12	0.01	0.01	Install culvert headwall at inlet; install and reinforce pool at culvert inlet with riprap; widen inlet swale and vegetate; ensure adequate riprap is in place at outlet to prevent bank erosion above CB next to garage	80%	0.01
	West Shore Road	1	100	20	0.02	0.04	Deepen, widen, and vegetate swale on north side of driveway; deepen pool at culvert inlet and reinforce with 6-inch riprap; install inlet and outlet headwalls; construct plunge pool with outlet check dam with 6-inch riprap	80%	0.03
	West Shore Road	1	75	10	0.01	0.01	Widen and deepen swale to reduce channel slope; install riprap pool around inlet stand pipe; vegetate ditch; vegetate roadside edge/slope to swale	80%	0.01
	West Shore Road	1	700	28	0.18	0.36	Install headwalls; reduce drainage channel slopes as possible	80%	0.29
	Nelson Fire Station	1	54	65	0.03	0.08	Install pervious pavement / pavers. Engineering services required for design.	65%	0.05
	Boat Ramp	1	130	45	0.05	0.16	Construct treatment swale & resurface ramp. Engineering services and subsurface investigation required for design.	65%	0.11
	558 Granite Lake Road	1	300	100	0.28	0.42	Construct bioretention system or an infiltration swale. Engineering services and subsurface investigation required (cost estimated under Professional Services). Samples of runoff from this drainage would help to determine whether the P-load justifies the expense for this measure.	65%	0.27
	Granite Lake Road	1	500	12	0.06	0.17	Reinforce shoulder with riprap	65%	0.11
	Granite Lake Road Catch Basins	1	200	12	0.02	0.07	Annual catch basin cleaning	50%	0.03
	Route 9 Drainage	10	500	210	0.98	0.29	Construct bioretention system or shallow wetland to treat Route 9 runoff. Current swale discharges directly to stream. Engineering services and subsurface investigation required for design. Property ownership may influence the feasibility of this BMP.	45%	0.13
	Nye Road Drainage	10	200	20	0.04	0.07	Reinforce swale and area around catch basin with riprap.	80%	0.06
	Route 9 Bridge Drainage	10	100	40	0.04	0.04	Pipe bridge scuppers to infiltration trench or bioretention system. Engineering services and subsurface investigation required for design. Cost estimate only for engineering consulting services.	65%	0.03
	Shallow wetland treatment at DOT storage facility	10	660	50	0.31	0.34	Improve efficiency: clean forebay, reinforce basin slopes, install outlet check dam, reinforce swale at CB inlet, maintain vegetation along roadway. Engineering services required to assess existing system efficiency and design additional storage and treatment if feasible. Property ownership may influence the feasibility of this BMP.	45%	0.15
							Total Phosphorus Reduction from Road Drainage BMPs:		**1.95**

NOTE:

[1] Load reductions from road drainage improvements are based on areas subject to erosion near BMP sites, and the removal efficiencies are considered as a result of preventing erosion, not necessarily removal efficiency as rated for treatment processes.

Table 8-2: Recommended Measures to Manage Phosphorus Loading to Granite Lake – Cost Estimates for Road Drainage Improvements

Source	BMP Site ID	Drainage swale improvement (length)	Drainage swale improvement (width)	Sediment/energy-dissipation pool diameter (ft)	Sediment/energy-dissipation pool finished depth (ft)	Riprap estimate (tons)	Filter fabric area (ft^2)	Pre-cast concrete headwall (#)	Materials Cost Estimate ($)	Labor Cost Estimate ($)	Professional Services Cost Estimate ($) (Engineering, Permitting, etc…)	Total Cost Estimate	Low Cost Estimate (-15%)[2]	High Cost Estimate (+15%)[2]	Total Estimated Cost/gram P-Reduction	Priority (Based on P-Removal Estimates)	BMP Category For Installation Prioritization
Road Runoff & Swale Erosion	1			4.0	1.5	1.2	20		$240	$850		$1,090	$900	$1,300	$7	High	Unique
	2								$286	$1,260	$2,080	$3,630	$3,100	$4,200	$41	High	Unique
	3	20	4			3.3	80		$868	$2,100		$2,970	$2,500	$3,400	$100	Medium	CB
	4							2	$1,200	$560		$1,760	$1,500	$2,000	$197	Low	HW
	5							2	$1,200	$560		$1,760	$1,500	$2,000	$197	Low	HW
	6							2	$1,200	$560		$1,760	$1,500	$2,000	$197	Low	HW
	7	20	4			3.3	80		$1,660	$3,500		$5,160	$4,400	$5,900	$116	Medium	CB
	8	50	4			8.3	200		$1,770	$2,240		$4,010	$3,400	$4,600	$60	Medium	CB
	9	30	4			13.0	360		$1,070	$2,240		$3,310	$2,800	$3,800	$148	Low	CB
	10	100	6			25.0	840		$534	$560		$1,090	$900	$1,300	$25	Medium	SWL
	11	150	6	6.0	2.0	38.9	900		$790	$1,360		$2,150	$1,800	$2,500	$32	Medium	SWL
	12	100	6	4.0	1.5	26.3	625		$535	$1,360		$1,900	$1,600	$2,200	$106	Low	SWL
	13	150	6	6.0	2.0	38.9	928		$793	$1,360		$2,150	$1,800	$2,500	$34	Medium	SWL
	14							1	$850	$1,360	$1,040	$3,250	$2,800	$3,700	$547	Low	HW
	15	40	6	6.0	2.0	11.4	268		$232	$1,360	$13,000	$14,590	$12,400	$16,800	$491	Medium	HW

NOTE:

[2] Cost estimates are order-of-magnitute approximations based on estimated labor, materials, consulting costs, and best professional judgement. Cost are intended for general prioritzation of measure implementation. More accurate cost estimates will require additional designs, assessments of site condition, and feasibility evaluations.

Table 8-2: Recommended Measures to Manage Phosphorus Loading to Granite Lake – Cost Estimates for Road Drainage Improvements (Continued)

Source	BMP Site ID	Drainage swale improvement (length)	Drainage swale improvement (width)	Sediment/energy-dissipation pool diameter (ft)	Sediment/energy-dissipation pool finished depth (ft)	Riprap estimate (tons)	Filter fabric area (ft^2)	Pre-cast concrete headwall (#)	Materials Cost Estimate ($)	Labor Cost Estimate ($)	Professional Services Cost Estimate ($) (Engineering, Permitting, etc...)	Total Cost Estimate	Low Cost Estimate (-15%)[2]	High Cost Estimate (+15%)[2]	Total Estimated Cost/gram P-Reduction	Priority (Based on P-Removal Estimates)	BMP Category For Installation Prioritization
Road Runoff & Swale Erosion	16	20	6	6.0	2.0	6.4	148	1	$730	$1,120		$1,850	$1,600	$2,100	$166	Low	HW
	17	20	6	4.0	1.5	5.6	133	1	$715	$1,120		$1,830	$1,600	$2,100	$206	Low	HW & SWL
	18	30	6	10.0	3.0	11.4	293	4	$2,635	$2,720		$5,350	$4,600	$6,200	$180	Medium	HW &SWL
	19	75	6	6.0	2.0	28.4	529		$639	$680		$1,320	$1,100	$1,500	$118	Low	SWL
	20	300	6			50	1800	8	$5,880	$2,240		$8,120	$6,900	$9,300	$28	High	HW & SWL
	21								$10,530	$8,400	$3,120	$22,050	$18,700	$25,400	$416	Medium	Unique
	22					90	1500		$14,210	$5,600	$7,800	$27,610	$23,500	$31,800	$261	High	Unique
	23					30	2500	1	$8,481	$8,400	$10,400	$27,280	$23,200	$31,400	$100	High	Unique
	24					200	3000		$4,131	$3,400		$7,530	$6,400	$8,700	$69	High	Unique
	25									$560		$560	$500	$600	$17	Medium	Unique
	26								$15,000	$13,600	$15,600	$44,200	$37,600	$50,800	$336	High	Unique
	27	100	10			50	1000		$1,000	$1,680		$2,680	$2,300	$3,100	$45	Medium	SWL
	28										$20,800	$20,800	$17,700	$23,900	$783	Low	Unique
	29	60	8	8.0	2.0	27	530		$715	$2,800	$2,600	$6,120	$5,200	$7,000	$40	High	Unique

NOTE:

[2] Cost estimates are order-of-magnitute approximations based on estimated labor, materials, consulting costs, and best professional judgement. Cost are intended for general prioritzation of measure implementation. More accurate cost estimates will require additional designs, assessments of site condition, and feasibility evaluations.

Table 8-3: Recommended Measures to Reduce Phosphorus Loading to Granite Lake - Septic and Land Management Practices

Source	Site Location	Basin	Contributing Drainage Area (ha)	Estimated Annual Phosphorus Load (kg/yr)	Treatment Measure[1]	Removal Efficiency[1]	Estimated Load Reduction (kg/yr)	Materials Cost Estimate ($)	Labor Cost Estimate ($)	Total Cost Estimate[2]	Low Cost Estimate (-15%)[2]	High Cost Estimate (+15%)[2]	Total Estimated Cost/g P-Reduction	Priority
Septic Systems[3]	Shoreland Zone (250 feet)	1		16.4	Septic System Management Plan / Implementation			$200	$8,250	$8,450	$7,200	$9,700		High
	Shoreland Zone (125 feet)				Septic System Upgrades (assumed upgrade of 75% of existing year-round and seasonal systems that were modeled as old systems, and upgrade reduced load by 50%). Cost estimates based on 51 upgraded systems. Phosphorus load reduction estimates will need to be adjusted based on inventory and groundwater samples conducted under "Septic System Management Plan/ Implementation"	Loading reduced by 50% in 75% of the old systems	4.2			$408,000	$346,800	$469,200	$97	Medium
	Sandy Beach Area				Shallow Groundwater Sampling and Assessment. Study consisting of well-point installations and multiple sampling events as detailed in Section 8.1. Information will assist with the prioritization of septic improvements and refinement of the lake loading model.			$6,500	$33,500	$40,000	$34,000	$46,000	Unknown	High
Timber Harvesting[4]				14	Enforcement of Forestry BMPs	5%	0.7			$5,000	$4,250	$5,750	$7	High
Managing Developed Areas[5]	Designated Watersheds	1	39.2	7.8	Watershed Protection District / Zoning Ordinance (phosphorus limitations, buffer zones ,stormwater controls, impervious cover limits, etc…)	10%	0.8							High
	Shoreland Zone (250 feet)	1	8.2	9.0	Shoreland Protection (Education and Incentive Programs). Phosphorus loading reductions estimated from following public engagement and outreach activities.	20%	1.8						$4	High
					Demonstration Shoreland Management BMP (per project)			$1,000	$2,400	$3,400	$2,900	$3,300		
					Distribution of Shoreland Management BMP Information			$50	$2,800	$2,850	$2,400	$2,800		
					Kiosk construction and installation			$500	$800	$1,300	$1,100	$1,300		
					Fund Raising Lake Awareness Programs					$0	$0	$0		
Protecting Undeveloped Areas	Undeveloped Areas				Land Conservation	Estimated to protect against future phosphorus load increases of approximately 0.155 kg TP/ha.		Cost for conservation land purchase based on current real estate sales vary from $5,000 - $6,000/acre (non-waterfront) to between $50,000 and $200,000 /acre (waterfront). Conservation sale of development rights may be a cost effective alternative, though highly dependent upon the land characteristics.					Not Applicable	Medium
					Watershed Protection District / Zoning Ordinance (buffers, setbacks, undisturbed area requirements, etc…)								Unknown	Medium

Total Estimated Phosphorus Load Reduction from Septic System and Land Management Practices (kg/yr): 7.5

TOTAL ESTIMATED PHOSPHORUS REDUCTION (KG/YR)= 9.4

NOTES:

[2] Cost estimates are order-of-magnitute approximations based on estimated labor, materials, consulting costs, and best professional judgement. Cost are intended for general prioritzation of measure implementation. More accurate cost estimates will require additional designs, assessments of site condition, and feasibility evaluations.

[3] Septic system reductions are assumed to be derived by upgrading old systems that produce twice the amount of phosphorus load as new systems. Proximity to the lake, depth to water, depth to bedrock, specific system conditions are not accounted for in this assessment.

[4] Potential load reductions from timber harvesting operations is based on the modeled load assumed from recent timber cut. Costs based on part time inspector assuming ~80 hours/year.

[5] Developed area management assumes loads based on loading coefficients from developed areas.

Table 8-4: Implementation Schedule

Management Practice	Implementation Schedule	Estimated Cost*
Septic System Upgrades		
1) Septic System Management Plan	1) Year 1	1) $2,700 - $9,700
2) Septic System Upgrades	2) Year 2 – Year 10	2) $347K - $470K
3) Sandy Beach GW and Septic Evaluation	3) Year 1-2	3) 34K – 46K
Shoreland Protection and Education Programs		
1) Shoreland Management Demonstration Project (Year1)	1) Year 1	1) $1,100 - $7,400
Distribution of Shoreland Management Information		
Lake Host Program		
Kiosk Construction & Installation		
2) Watershed Protection District Ordinance	2) Year 2	
3) Land Protection (Acquisition/Easement)	3) Year 1 – Year 10	
Road Drainage Improvement		
1) High Priority Sites	1) Year 1 – Year 2	1) $106,800 - $144,500
2) Medium Priority Sites	2) Year 3 – Year 4	2) $53,300 - $72,300
3) Low Priority Sites	3) Year 4 – Year 5	3) $33,700 - $45,300

*Cost estimates are preliminary approximations for planning purposes

9.0 Public Outreach and Education

The centerpiece of efforts to control phosphorus loading to Granite Lake is public outreach and education. In addition to educating individual homeowners on the implications of their actions on phosphorus export to the lake and the impact of that phosphorus on lake water quality, the secondary purpose to education and outreach is to educate decision makers at the town level so that phosphorus management becomes part of the criteria evaluated as decisions are made on zoning, planning, public works, recreation and site development issues.

Granite Lake is fortunate to have a great deal of public awareness of these issues at present due to the work of the lake association but there is room for improvement as there are numerous instances of green lawns close to the lake, inadequate shoreline buffers and old septic systems. In order to further public education, we recommend a program with the following elements that will add to the existing program.

An initial survey of residents and public officials to determine the current state of knowledge on topics like shoreland protection, phosphorus fertilizers, road maintenance and septic system maintenance is suggested. The survey can be formulated as a web based survey or as a mailed survey to accompany the newsletter. It could also be filled out at the annual meeting or picnic. The results of this survey can be used to target materials and programs towards particular topics. It is recommended that this survey be fairly short and easy to fill out.

As critical components of the public outreach plan are completed, perform a follow–up survey to assess progress. The pre and post implementation surveys will provide a quantifiable measure of progress as is required by EPA.

The current public awareness and outreach program at Granite Lake has several key elements. Below each element are suggestions of ways to enhance the program:

1) Newsletter

Current Program - A newsletter that summarizes Granite Lake Association news, events and provides popular interest articles on water quality.

Suggested Enhancements - Provide space in the newsletter for a guest article on water quality or watershed issues. Topics for these articles can either come from areas highlighted by survey results as lacking in understanding or emerging topics.

2) Web site

Current Program - A website (www.granitelake.org) that provides a clearinghouse for information.

Suggested Enhancements

a) Provide a list of documents that would be useful to lake and watershed residents. This watershed plan which incorporates many relevant activities and documents would be a good choice for one of the documents. Other potential documents include; planning and zoning documents, NHDES fact sheets, popular articles on water quality and watersheds, forms and permit applications, lists of native plants etc.

b) Increase traffic to the web site. The web site is only useful if people visit it. The single most viewed feature of many lake association web sites is a live web-cam image. These can be installed and maintained fairly easily and provide a place for residents who are "away" to see their lake and, in the process, visit the web page. A related feature is the ability to post pictures in a variety of categories. An example of a web site with a web cam and picture forums maintained by volunteers can be found at www.lwa.org. Largely because of the web cam and forums, the LWA website receives 50-100 visits a day. An up-to-date posting of lake level and lake temperature can also be an attractor to a lake association web site.

c) Consider addition of a forum specifically for water quality and watershed questions.

3) Annual Meeting

Current Program - An annual meeting that is a forum for information on the lake and discussion of lake issues. This program is successful and currently quite well attended.

Suggested Enhancements

a) Consider the inclusion of additional speakers or special outdoor sessions to address specific topics. Examples could include specific information from a vendor who presents information on specific BMPs or a seminar on Shoreland Protection and landscaping that could feature NHDES Shoreland Protection outreach specialists, UNH cooperative extension specialist, staff from the New Hampshire Lakes Association or a local nursery staff member to talk about local, low maintenance native plants for landscaping with no fertilizer requirements.

b) Consider a perpetual award to be given annually to the person or organization that shows outstanding stewardship of the watershed resources or implements a particularly unique and effective project.

4) Lake Host

Current Program - Participation in the NH Lakes Lake Host program. This program is also currently quite successful.

Suggested Enhancements – Consider provision of information to the Lake Host on watershed issues of at least inform the lake host on current initiatives on the lake so that information can be shared with users of the boat ramp. One particularly valuable opportunity will occur if the boat ramp is retrofitted as suggested in this plan. The lake host can explain the features of the newly configured site and explain why it has been reworked.

5) Other Lake Gatherings

Current Program - The Granite Lake Picnic. This is also a successful event.

Suggested Enhancements – Consider ways of getting more and broader participation at the picnic or sponsor other stand-alone events. A few types of activities that have been successful elsewhere include; a race/walk around the lake (prior to the picnic), kids events including games like kayak/canoe relays or a scavenger hunt, a lake/roadway cleanup, an ecology lecture at the edge of the lake, or a kids fishing derby.

6) Published and Posted Materials

Current Program: Signage and public education posters at the boat launch.

Suggested Enhancements – a) Build a kiosk to better present watershed and water quality information. b) stencil or put signs near storm drains in the watershed, particularly along Granite Lake Road with a message that says: " Drains to Granite Lake, do not dump" or equivalent." c) prepare and distribute flyers or information sheets on specific issues related to septic systems, phosphorus in fertilizer, shoreland protection and native plantings etc. d) Present materials at local schools to engage young people. e) Provide information related to successful BMP installation. This could range from a guided or self tour of completed BMP projects to a seminar on shorefront landscaping that features a property that does an exceptionally good job at incorporating measures to reduce phosphorus export to the lake and is aesthetically pleasing. f) Provide information and/or sponsor training courses for loggers, developers or public works officials on BMPs for phosphorus reduction.

10.0 Monitoring Plan

NH DES most recently conducted water quality monitoring on Granite Lake in 2007 for Lake Trophic Studies. The Volunteer Lake Assessment Program (VLAP) began in 1989 and continues to the present day (NH DES 2009). The deepest site in the center of the lake is the primary sampling location in Granite Lake (Figure 1-1). Water quality samples collected during summer stratification are tested for epilimnetic, metalimnetic and hypolimnetic TP. In addition, a composite sample of the water column to the depth of the thermocline is tested for chl a. A DO profile from top to bottom is conducted and a Secchi disk transparency measurement is taken. A tributary monitoring program was initiated in 2008 and includes monitoring points at the lower end of nearly all of the subwatersheds around Granite Lake. In addition, sampling has been conducted throughout the Inlet tributary to attempt to bracket locations where the bulk of the TP is entering the tributary and to further assess the influence of the wetland complex on TP concentration in this tributary. This data collection should continue. Tributary samples should be collected during both wet and dry periods and multiple samples should be collected during long storm events. Flow measurements associated with the sample collection would allow direct calculation of loads rather than estimation through modeling. This can be accomplished by installing staff gages in the tributary streams and developing stage/discharge relationships for each gage to relate specific gage readings with specific flows. If specific tributaries show consistently high concentrations or flows, visual investigation and/or additional monitoring points upstream should be considered to isolate the cause.

An ideal tributary sampling period might include a spring snowmelt/rain sampling event prior to leaf-out, 2 wet and 2 dry summer events and a fall rain event after leaf fall. A minimum of ½ inch of rain forecast over a six hour period provides a target for a wet weather event (with the exception of a snowmelt event). A dry event would be best represented by sampling after a minimum of 72 hours with no rainfall or runoff.

It is recommended that VLAP sampling be continued to document the in-lake response, trends, and compliance with water quality criteria following implementation of TP reduction measures. As discussed in the previous section, successful implementation of this watershed management plan will be based on attaining the target and short-term goal for TP in Granite Lake. Data collected by VLAP which includes DO, conductivity, transparency, planktonic chl a and the reporting of cyanobacteria scums should continue. NH DES staff will continue to sample and document the extent and severity of any potential future reported cyanobacteria blooms through microscopic identification, cell counts and toxicity tests.

To help prioritize implementation of TP reduction measures in the watersheds, it will be instructive for volunteer monitors to continue to collect dry and wet weather TP samples (along with estimates of flow) in some of the tributaries draining suspected sources such as subwatersheds with a high percentage of the gravel roads in the overall watershed. The TP loads should be calculated using concentration and flow data. Tributaries impacted by humans (i.e., not natural) with the highest TP load would be the target of initial efforts to reduce TP.

Septic systems are an additional source of TP loading. A detailed survey of septic systems would help confirm model input, including the assumption that there are no failed septic systems and guide efforts to deal with this potential source. Collection of nearshore groundwater data will help to verify areas where septic systems are contributing nutrients to the lake. A plan for monitoring shallow groundwater is outlined in Section 8.

With respect to implementation of specific BMPs throughout the watershed, the existing tributary monitoring program should be augmented with site specific monitoring immediately below and above the sites of proposed BMP implementation. This monitoring should commence prior to the installation of each BMP and continue through construction and after construction to document that estimated removal efficiencies are obtained. At a minimum, TP should be assessed but the addition of other parameters such as total suspended solids and flow should be considered.

In order to evaluate the effectiveness of the public outreach and education efforts to be conducted as a part of this plan, a survey that evaluates the current state of knowledge about fertilizer, shoreland protection, septic system maintenance and stormwater management. Use the results of the survey to target specific topics and individuals for educational efforts. After implementation of the public education components of the watershed plan, conduct a follow up survey to test the effectiveness of the program by repeating the initial survey. The increase in awareness will be used as a metric to measure the effectiveness of the program. If deficiencies are still noted in the knowledge of watershed residents, the public outreach and education program can be modified to provide the appropriate information.

11.0 Potential Sources of Funding

Improvements and management techniques described in Section 7 above will require funding to install and complete. There are several primary sources of funding for non point source projects in New Hampshire. These include, but are not limited to, Section 319 funding and NHDES Small Outreach and Education Grants and several other programs detailed below. Alternative funding may be in the form of donated labor from the Nelson and Stoddard 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.

Conservation License Plate Program: To promote natural resource related programs throughout NH. Conservation Districts, Cooperative Extension, conservation commissions, schools, groups, and other non-profits can apply for funding. http://www.nh.gov/nhdhr/grants/moose/

Land and Water Conservation Program: UNH Cooperative Extension helps New Hampshire communities and conservation groups with land and water conservation planning projects. Land & Water Conservation Program staff provide technical assistance, facilitation and guidance to communities interested in conserving their natural resources, prioritizing areas for protection, and working with local landowners to conserve land. Extension assistance is limited to project guidance and training, and does not include specific involvement in completing project tasks. http://extension.unh.edu/CommDev/CCAP.htm

Transportation Enhancement (TE) Program: The 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) called for a ten percent designated share of all Surface Transportation Program funds to be used for Transportation Enhancement Activities. The intent of the program is to afford an opportunity to develop "livable communities" by selecting projects that preserve the historic culture of the transportation system and/or enhance the operation of the system for its users. The 1998 Transportation Equity Act for the 21st Century (TEA-21) continued the Transportation Enhancement Program and expanded the eligible use of funds. One of the categories of projects eligible for funding is "Environmental mitigation to address water pollution due to highway runoff or reduce vehicle-caused wildlife mortality while maintaining habitat connectivity." http://www.nh.gov/dot/org/projectdevelopment/planning/tecmaq/index.htm or http://www.enhancements.org/profile/new_profile_search.php

Wetlands Reserve Program: The Wetlands Reserve Program is a voluntary program offering landowners the opportunity to protect, restore, and enhance wetlands on their property. The USDA Natural Resources Conservation Service (NRCS) provides technical and financial support to help landowners with their wetland restoration efforts. The NRCS goal is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. This program offers landowners an opportunity to establish long-term conservation and wildlife practices and protection. http://www.nrcs.usda.gov/Programs/wrp/

Forest legacy Program: The Forest Legacy Program helps protect environmentally important private forestlands threatened with conversion to non-forest uses. The Secretary of Agriculture is responsible for the development and administration of the Forest Legacy Program. The US Forest Service in cooperation with States and other units of government is responsible for the implementation of the program. States have been granted the authority to establish criteria for their programs within the framework of the national program to help address specific needs and goals of their state.

To help maintain the integrity and traditional uses of private forest lands, the Forest Legacy Program promotes the use of conservation easements, legally binding agreements transferring a negotiated set of property rights from one party to another. Participation in the program is entirely voluntary. http://www.nhdfl.org/land-conservation/forest-legacy-program.aspx

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Appendix A

Granite Water Quality Target Discussion Minutes December 3, 2009

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Meeting Minutes

Client:	Granite Lake Watershed Association
Project Name:	Granite Lake Watershed Management Plan
AECOM Environment Project Number:	60133416
Date:	December 3, 2009
Location:	NH DES, Concord NH
Meeting Purpose:	Granite Lake Water Quality Target Discussion
Prepared By:	Sarah MacDougall

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Action Item Number	Action Item	Responsibility
0001	Converse with Stoddard Select Board informing them about the December 3rd meeting & get their "buy-in" on an anti-degradation target and watershed phosphorus load reduction.	GLA
0002	Draft e-mail for Stoddard Select Board with consultant support of the anti-degradation target and watershed phosphorus load reduction goal.	AECOM

Summary
Don Kretchmer and Sarah MacDougall of AECOM presented a brief background on the Granite Lake project, water quality summary tables, and preliminary phosphorus modeling results. Stakeholders expressed concerns about the impact of the 1995 Route 9 construction, logging practices not employing Best Management Practices, erosion of gravel roads into the lake, lake level changes, and the salt storage at NH DOT State Shed. These concerns will be addressed in the Granite Lake Watershed Management Plan. Don Kretchmer began the water quality target discussion by introducing the proposed NH DES nutrient criteria threshold between oligotrophic (nutrient poor) and mesotrophic (moderately enriched) lakes of 8.0 *u*g/L Granite Lake Association and Nelson stakeholders expressed concern over degrading the water quality as Granite Lake qualifies as a Tier 2- High Quality Water. Meeting attendees reached consensus that the water quality target should be set at current conditions (mean summer in-lake total phosphorus concentrations of 4.9 *u*g/L- median of 5.0 *u*g/L), but have a short term goal should be set to reduce the watershed phosphorus load as much as practical with Best Management Practices. AECOM will model phosphorus loading reduction scenarios to determine a realistic phosphorus reduction in the watershed. The short term goal of reducing the watershed phosphorus load will allow for future development loading while maintaining current water quality.

Appendix B

ENSR LRM Documentation

APPENDIX B:
LLRM – Lake Loading Response Model Users Guide (also called SHEDMOD or ENSR-LRM)

Model Overview

The Lake Loading Response Model, or LLRM, originated as a teaching tool in a college course on watershed management, where it was called SHEDMOD. This model has also been historically called ENSR-LRM. The intent was to provide a spreadsheet program that students could use to evaluate potential consequences of watershed management for a target lake, with the goal of achieving desirable levels of phosphorus (TP), nitrogen (N), chlorophyll a (Chl) and Secchi disk transparency (SDT). For the NH Lake TMDLs only TP, Chl and SDT were simulated. As all cells in the spreadsheet are visible, the effect of actions could be traced throughout the calculations and an understanding of the processes and relationships could be developed.

LLRM remains spreadsheet based, but has been enhanced over the years for use in watershed management projects aimed at improving lake conditions. It is still a highly transparent model, but various functions have been added and some variables have been refined as new literature has been published and experience has been gained. It is adaptable to specific circumstances as data and expertise permit, but requires far less of each than more complex models such as SWAT or BASINS. This manual provides a basis for proper use of LLRM.

Model Platform

LLRM runs within Microsoft Excel. It consists of three numerically focused worksheets within a spreadsheet:

1. Reference Variables – Provides values for hydrologic, export and concentration variables that must be entered for the model to function. Those shown are applicable to the northeastern USA, and some would need to be changed to apply to other regions.
2. Calculations – Uses input data to generate estimates of water, N and TP loads to the lake. All cells shaded in blue must have entries if the corresponding input or process applies to the watershed and lake. If site-specific values are unavailable, one typically uses the median value from the Reference Variables sheet.
3. Predictions – Uses the lake area and inputs calculated in the Calculations sheet to predict the long-term, steady state concentration of N, TP and Chl in the lake, plus the corresponding SDT. This sheet applies multiple empirical models and provides average final results from them, but with knowledge of the system or empirical models, one can eliminate models used in generating those averages to get the best fit for the targeted system.

Watershed Schematic

Generation of a schematic representation of the watershed is essential to the model. It is not a visible part of the model, but is embodied in the routing of water and nutrients performed by the model and it is a critical step. For the example provided here, the lake and watershed shown in Figure 1 is modeled. It consists of a land area of 496.5 hectares (ha) and a lake with an area of 40 ha. There are two defined areas of direct drainage (F and G), from which water reaches the lake by overland sheetflow, piped or ditched stormwater drainage, or groundwater seepage (there are no tributaries in these two drainage basins). There is also a tributary (Trib 1) that is interrupted by a small pond, such that the corresponding watershed might best be represented as two parts, upstream and downstream of that pond, which will provide some detention and nutrient removal functions. There is another tributary (Trib 2) that consists of two streams that combine to form one that then enters the lake, the classic "Y' drainage pattern. With differing land uses associated with each of the upper parts of the Y and available data for each near the confluence, this part of the watershed is best subdivided into three drainage areas. As shown in Figure 2, the watershed of Figure 1 is represented as the lake with two direct drainage units, a tributary with an upper and lower drainage unit, and a tributary with two upper and one lower drainage units. The ordering is important on several levels, most notably as whatever nutrient loading attenuation occurs in the two lower tributary basins will apply to loads generated in the corresponding upper basins. Loads are generated and may be managed in any of the drainage basins, but how they affect the lake will be determined by how those loads are processed on the way to the lake. LLRM is designed to provide flexibility when testing management scenarios, based on watershed configuration and the representation of associated processes.

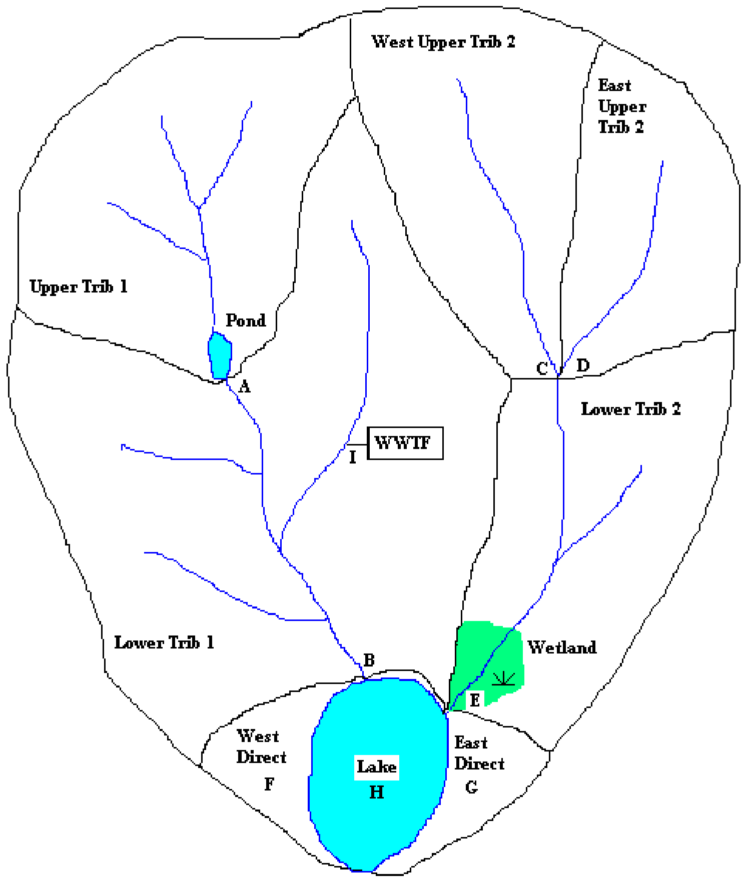


Figure 1. Watershed Map for Example System

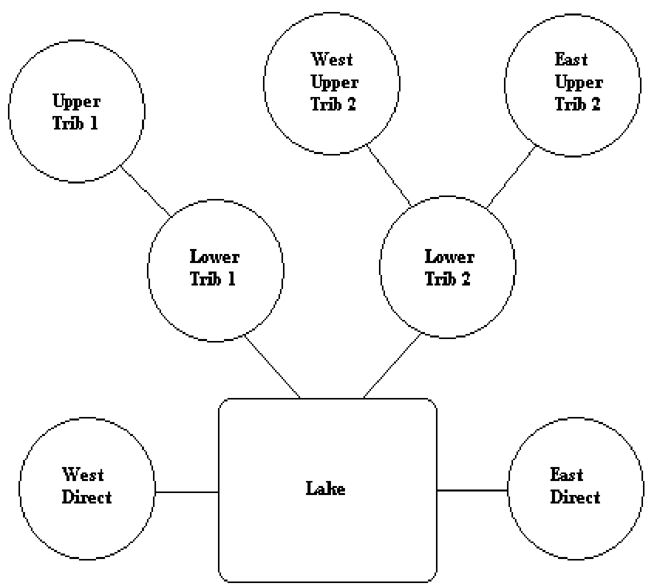


Figure 2. Watershed Schematic for Example System

Model Elements

There are three main types of inputs necessary to run LLRM:

1. Hydrology inputs – These factors govern how much water lands on the watershed and what portion is converted to runoff or baseflow. The determination of how much precipitation becomes runoff vs. baseflow vs. deep groundwater not involved in the hydrology of the target system vs. loss to evapotranspiration is very important, and requires some knowledge of the system. All precipitation must be accounted for, but all precipitation will not end up in the lake. In the northeast, runoff and baseflow may typically account for one to two thirds of precipitation, the remainder lost to evapotranspiration or deep groundwater that may feed surface waters elsewhere, but not in the system being modeled. As impervious surface increases as a percent of total watershed area, more precipitation will be directed to runoff and less to baseflow. There are two routines in the model to allow "reality checks" on resultant flow derivations, one using a standard areal water yield based on decades of data for the region or calculated from nearby stream gauge data, and the other applying actual measures of flow to check derived estimates.
2. Nutrient yields – Export coefficients for N and TP determine how much of each is generated by each designated land use in the watershed. These export values apply to all like land use designations; one cannot assign a higher export coefficient to a land use in one basin than to the same land use in another basin. Differences are addressed through attenuation. This is a model constraint, and is imposed partly for simplicity and partly to prevent varied export assignment without justification. Where differing export really does exist for the same land uses in different basins of the watershed, attenuation can be applied to adjust what actually reaches the lake. Nutrient export coefficients abound in the literature, and ranges, means and medians are supplied in the Reference Variables sheet. These are best applied with some local knowledge of export coefficients, which can be calculated from land area, flow and nutrient concentration data. However, values calculated from actual data will include attenuation on the way to the point of measurement. As attenuation is treated separately in this model, one must determine the pre-attenuation export coefficients for entry to initiate the model. The model provides a calculation of the export coefficient for the "delivered" load that allows more direct comparison with any exports directly calculated from data later in the process.
3. Other nutrient inputs – five other sources of N and TP are recognized in the model:
    a. Atmospheric deposition – both wet and dry deposition occur and have been well documented in the literature. The area of deposition should be the entire lake area. Choice of an export coefficient can be adjusted if real data for precipitation and nutrient concentrations is available.
    b. Internal loading – loads can be generated within the lake from direct release from the sediment (dissolved TP, ammonium N), resuspension of sediment (particulate TP or N) with possible dissociation from particles, or from macrophytes ("leakage" or scenescence). All of these modes have been studied and can be estimated with a range, but site specific data for surface vs. hypolimnetic concentrations, pre-stratification whole water column vs. late summer hypolimnetic concentrations, changes over time during dry periods (limited inflow), or direct sediment measures can be very helpful when selecting export coefficients.
    c. Waterfowl and other wildlife – Inputs from various bird species and other water dependent wildlife (e.g., beavers, muskrats, mink or otter) have been evaluated in the literature. Site specific data on how many animals use the lake for how long is necessary to generate a reliable estimate.
    d. Point sources – LLRM allows for up to three point sources, specific input points for discharges with known quantity and quality. The annual volume, average concentration, and basin where the input occurs must be specified.
    e. On-site wastewater disposal (septic) systems – Septic system inputs in non-direct drainage basins is accounted for in baseflow export coefficients, but a separate process is provided for direct drainage areas where dense housing may contribute disproportionately. The number of houses in two zones (closer and farther away, represented here as <100 ft and 100-300 ft from the lake) can be specified, with occupancy set at either seasonal (90 days) or year round (365 days). For the NH lake nutrient TMDLs, one zone of 125 feet from the lake was used. The number of people per household, water use per person per day, and N and TP concentrations and attenuation factors must be specified. Alternatively, these inputs can be accounted for in the baseflow export coefficient for direct drainage areas if appropriate data are available, but this module allows estimation from what is often perceived as a potentially large source of nutrients.

LLRM then uses the input information to make calculations that can be examined in each corresponding cell, yielding wet and dry weather inputs from each defined basin, a combined total for the watershed, a summary of other direct inputs, and total loads of TP and N to the lake, with an overall average concentration for each as an input level. Several constraining factors are input to govern processes, such as attenuation, and places to compare actual data to derived estimates are provided. Ultimately, the lake area and loading values are transferred to the Prediction sheet where, with the addition of an outflow TP concentration and lake volume, estimation of average in-lake TP, N, Chl and SDT is performed. The model is best illustrated through an example, which is represented by the watershed in Figures 1 and 2. Associated tables are directly cut and pasted from the example model runs.

Hydrology

Water is processed separately from TP and N in LLRM. While loading of water and nutrients are certainly linked in real situations, the model addresses them separately, then recombines water and nutrient loads later in the calculations. This allows processes that affect water and nutrient loads differently (e.g., many BMPs) to be handled effectively in the model.

Water Yield

Where a cell is shaded, an entry must be made if the corresponding portion of the model is to work. For the example watershed, the standard yield from years of data for a nearby river, to which the example lake eventually drains, is 1.6 cubic feet per square mile (cfsm) as shown below. That is, one can expect that in the long term, each square mile of watershed will generate 1.6 cubic feet per second (cfs). This provides a valuable check on flow values derived from water export from various land uses later in the model.

COEFFICIENTS	
STD. WATER YIELD (CFSM)	1.6
PRECIPITATION (METERS)	1.21

Precipitation

The precipitation landing on the lake and watershed, based on years of data collected at a nearby airport, is 1.21 m (4 ft, or 48 inches) per year, as shown above. Certainly there will be drier and wetter years, but this model addresses the steady state condition of the lake over the longer term.

Runoff and Baseflow Coefficients

Partitioning coefficients for water for each land use type have been selected from literature values and experience working in this area. Studies in several of the drainage basins to the example lake and for nearby tributaries outside this example system support the applied values with real data. It is expected that the sum of export coefficients for runoff and baseflow will be <1.0; some portion of the precipitation will be lost to deep groundwater or evapotranspiration.

	RUNOFF EXPORT COEFF.			BASEFLOW EXPORT COEFF.		
	Precip Coefficient	P Export Coefficient	N Export Coefficient	Precip Coefficient	P Export Coefficient	N Export Coefficient
LAND USE	(Fraction)	(kg/ha/yr)	(kg/ha/yr)	(Fraction)	(kg/ha/yr)	(kg/ha/yr)
Urban 1 (Residential)	0.30	0.65	5.50	0.15	0.010	5.00
Urban 2 (Roads)	0.40	0.75	5.50	0.10	0.010	5.00
Urban 3 (Mixed Urban/Commercial)	0.60	0.80	5.50	0.05	0.010	5.00
Urban 4 (Industrial)	0.50	0.70	5.50	0.05	0.010	5.00
Urban 5 (Parks, Recreation Fields, Institutional)	0.10	0.80	5.50	0.05	0.010	5.00
Agric 1 (Cover Crop)	0.15	0.80	6.08	0.30	0.010	2.50
Agric 2 (Row Crop)	0.30	1.00	9.00	0.30	0.010	2.50
Agric 3 (Grazing)	0.30	0.40	5.19	0.30	0.010	5.00
Agric 4 (Feedlot)	0.45	224.00	2923.20	0.30	0.010	25.00
Forest 1 (Upland)	0.10	0.20	2.86	0.40	0.005	1.00
Forest 2 (Wetland)	0.05	0.10	2.86	0.40	0.005	1.00
Open 1 (Wetland/Lake)	0.05	0.10	2.46	0.40	0.005	0.50
Open 2 (Meadow)	0.05	0.10	2.46	0.30	0.005	0.50
Open 3 (Excavation)	0.40	0.80	5.19	0.20	0.005	0.50
Other 1	0.10	0.20	2.46	0.40	0.050	0.50
Other 2	0.35	1.10	5.50	0.25	0.050	5.00
Other 3	0.60	2.20	9.00	0.05	0.050	20.00

Setting export coefficients for the division of precipitation between baseflow, runoff and other components (deep groundwater, evapotranspiration) that do not figure into this model is probably the hardest part of model set-up. Site specific data are very helpful, but a working knowledge of area hydrology and texts on the subject is often sufficient. This is an area where sensitivity testing is strongly urged, as some uncertainly around these values is to be expected. There is more often dry weather data available for tributary streams than wet weather data, and some empirical derivation of baseflow coefficients is recommended. Still, values are being assigned per land use category, and most basins will have mixed land use, so clear empirical validation is elusive. As noted, sensitivity testing by varying these coefficients is advised to determine the effect on the model of the uncertainty associated with this difficult component of the model.

Nutrient Yields for Land Uses

Phosphorus and Nitrogen in Runoff

The values applied in the table above are not necessarily the medians from the Reference Variables sheet, since there are data to support different values being used here. There may be variation across basins that is not captured in the table below, as the same values are applied to each land use in each basin; that is a model constraint. Values for “Other” land uses are inconsequential in this case, as all land uses are accounted for in this example watershed without creating any special land use categories. Yet if a land use was known to have strong variation among basins within the watershed, the use of an “Other” land use class for the strongly differing land use in one or another basin could incorporate this variability.

Phosphorus and Nitrogen in Baseflow

Baseflow coefficients are handled the same way as for runoff coefficients above. While much of the water is likely to be delivered with baseflow, a smaller portion of the TP and N loads will be delivered during dry weather, as the associated water first passes through soil. In particular, TP is removed effectively by many soils, and transformation of nitrogen among common forms is to be expected.

The table above is commonly adjusted to calibrate the model, but it is important to justify all changes. Initial use of the median TP export value for a land use may be based on a lack of data or familiarity with the system, and when the results strongly over- or under-predict actual in-lake concentrations, it may be necessary to adjust the export value for one or more land use categories to achieve acceptable agreement. However, this should not be done without a clear understanding of why the value is probably higher or lower than represented by the median; the model should not be blindly calibrated, and field examination of conditions that affect export values is strongly recommended.

Other Nutrient Inputs

Atmospheric Deposition

Both wet and dry deposition nutrient inputs are covered by the chosen values, and are often simple literature value selections. Where empirical data for wet or dry fall are available, coefficients should be adjusted accordingly. Regional data are often available and can be used as a reality check on chosen values. Choices of atmospheric export coefficients are often based on dominant land use in the contributory area (see Reference Variables sheet), but as the airshed for a lake is usually much larger than the watershed, it is not appropriate to use land use from the watershed as the sole criterion for selecting atmospheric export coefficients. Fortunately, except where the lake is large and the watershed is small, atmospheric inputs tend not to have much influence on the final concentrations of TP or N in the lake, so this is not a portion of the model on which extreme investigation is usually necessary.

For the example system, a 40 ha lake is assumed to receive 0.2 kg TP/ha/yr and 6.5 kg N/ha/yr, the median values from the Reference Variables sheet. The model then calculates the loads in kg/yr to the lake and uses them later in the summary.

AREAL SOURCES									
	Affected Lake Area (ha)	P Export Coefficient (kg/ha/yr)	N Export Coefficient (kg/ha/yr)	P Load (from coeff) (kg/yr)	N Load (from coeff) (kg/yr)	Period of Release (days)	P Rate of Release (mg/m2/day)	N Rate of Release (mg/m2/day)	P (fro (k
Direct Atmospheric Deposition	40	0.20	6.50	8	260				
Internal Loading	20	2.00	5.00	40	100	100	2.00	5.00	

Internal Loading

Internal release of TP or N is generally described as a release rate per square meter per day. It can be a function of direct dissolution release, sediment resuspension with some dissociation of available nutrients, or release from rooted plants. The release rate is entered as shown in the table above, along with the affected portion of the lake, in this case half of the 40 ha area, or 20 ha. The period of release must also be specified, usually corresponding to the period of deepwater anoxia or the plant growing season. The model then calculates a release rate as kg/ha/yr and a total annual load as shown in the table above.

For the NH lake nutrient TMDLs, the release rate from internal loading was calculated using water quality data (pre-stratification vs. late summer hypolimnetic TP concentrations or late summer hypolimnetic vs. late summer epilimnetic TP concentrations) and dividing by the anoxic area of the lake.

Waterfowl or Other Wildlife

Waterfowl or other wildlife inputs are calculated as a direct product of the number of animal-years on the lake (e.g., 100 geese spending half a year = 50 bird-years) and a chosen input rate in kg/animal/yr, as shown in the table below. Input rates are from the literature as shown in the Reference Variables sheet, while animal-years must be estimated for the lake.

NON-AREAL SOURCES									
	Number of Source Units	Volume (cu.m/yr)	P Load/Unit (kg/unit/yr)	N Load/Unit (kg/unit/yr)	P Conc. (ppm)	N Conc. (ppm)	P Load (kg/yr)	N Load (kg/yr)	
Waterfowl	50		0.20	0.95			10	47.5	
Point Sources									
PS-1		45000			3.00	12.00	135	540	
PS-2		0			3.00	12.00	0	0	
PS-3		0			3.00	12.00	0	0	
Basin in which Point Source occurs (0=NO 1=YES)									
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9
PS-1	0	0	0	1	0	0	0	0	0
PS-2	0	0	0	0	0	0	0	0	0
PS-3	0	0	0	0	0	0	0	0	0

Point Source Discharges

LLRM allows for three point source discharges. While some storm water discharges are legally considered point sources, the point sources in LLRM are intended to be daily discharge sources, such as wastewater treatment facility or cooling water discharges. The annual volume of the discharge must be entered as well as the average concentration for TP and TN, as shown in the table above. The model then calculates the input of TP and TN. It is also essential to note which basin receives the discharge, denoted by a 1 in the appropriate column. As shown in the table above, the example system has a discharge in Basin 4, and no discharges in any other basin (denoted by 0).

On-Site Wastewater Disposal Systems

While the input from septic systems in the direct drainage areas around the lake can be addressed through the baseflow export coefficient, separation of that influence is desirable where it may be large enough to warrant management consideration. In such cases, the existing systems are divided into those within 100 ft of the lake and those between 100 and 300 ft of the lake, each zone receiving potentially different attenuation factors. For the NH lake TMDLs, a single 125 foot zone was used. A further subdivision between dwelling occupied all year vs. those used only seasonally is made. The number of people per dwelling and the water use per person per day are specified, along with the expected concentrations of TP and TN in septic system effluent, as shown in the table below. The model then calculates the input of water, TP and TN from each septic system grouping. If data are insufficient to subdivide systems along distance or use gradients, a single line of this module can be used with average values entered.

DIRECT SEPTIC SYSTEM LOAD										
Septic System Grouping (by occupancy or location)	Days of Occupancy/Yr	Distance from Lake (ft)	Number of Dwellings	Number of People per Dwelling	Water per Person per Day (cu.m)	P Conc. (ppm)	N Conc. (ppm)	P Attenuation Factor	N Attenuation Factor	Water Loa (cu.m/yr
Group 1 Septic Systems	365	<100	25	2.5	0.25	8	20	0.2	0.9	57
Group 2 Septic Systems	365	100 - 300	75	2.5	0.25	8	20	0.1	0.8	171
Group 3 Septic Systems	90	<100	50	2.5	0.25	8	20	0.2	0.9	28
Group 4 Septic Systems	90	100 - 300	100	2.5	0.25	8	20	0.1	0.8	56
Total Septic System Loading										312

Subwatershed Functions

The next set of calculations addresses inputs from each defined basin within the system. Basins can be left as labeled, 1, 2, 3, etc., or the blank line between Basin # and Area (Ha) can be used to enter an identifying name. In this case, basins have been identified as the East Direct drainage, the West Direct drainage, Upper Tributary #1, Lower Tributary #1, East Upper Tributary #2, West Upper Tributary #2, and Lower Tributary #2, matching the watershed and schematic maps in Figures 1 and 2.

Land Uses

The area of each defined basin associated with each defined land use category is entered, creating the table below. The model is set up to address up to 10 basins; in this case there are only seven defined basins, so the other three columns are left blank and do not figure in to the calculations. The total area per land use and per basin is summed along the right and bottom of the table. Three “Other” land use lines are provided, in the event that the standard land uses provided are inadequate to address all land uses identified in a watershed. It is also possible to split a standard land use category using one of the “Other” lines, where there is variation in export coefficients within a land use that can be documented and warrants separation.

Land use data is often readily available in GIS formats. It is always advisable to ground truth land use designation, especially in rapidly developing watersheds. The date on the land use maps used as sources should be as recent as possible.

BASIN AREAS											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
LAND USE	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (HA)	AREA (H
Urban 1 (Residential)	12.0	8.5	8.4	47.4	6.7	4.5	18.1				10
Urban 2 (Roads)	3.7	5.5	0.0	5.9	0.8	0.6	2.3				1
Urban 3 (Mixed Urban/Commercial)	3.6	5.8	0.0	5.9	0.8	0.6	2.3				1
Urban 4 (Industrial)	0.0	0.0	0.0	23.5	0.0	0.0	0.0				2
Urban 5 (Parks, Recreation Fields, Institutional)	0.0	3.2	0.0	0.0	0.0	0.0	0.0				
Agric 1 (Cover Crop)	0.0	0.0	0.0	0.8	12.3	0.0	0.0				1
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	16.2	0.0	0.0				1
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	4.0	0.0	0.0				
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.5	0.0	0.0				
Forest 1 (Upland)	7.7	17.5	50.3	90.3	9.2	32.0	33.6				24
Forest 2 (Wetland)	0.0	0.2	0.0	14.5	0.0	0.0	1.9				1
Open 1 (Wetland/Lake)	2.5	0.6	2.0	0.1	0.0	0.1	14.2				1
Open 2 (Meadow)	2.0	1.3	0.0	10.2	0.1	0.0	0.2				1
Open 3 (Excavation)	0.1	0.1	0.0	2.3	0.0	0.0	0.0				
Other 1											
Other 2											
Other 3											
TOTAL	31.6	42.6	60.7	200.9	50.6	37.7	72.4	0	0		49

Load Generation

At this point, the model will perform a number of calculations before any further input is needed. These are represented by a series of tables with no shaded cells, and include calculation of water, TP and TN loads from runoff and baseflow as shown below. These loads are intermediate products, not subject to attenuation or routing, and have little utility as individual values. They are the precursors of the actual loads delivered to the lake, which require some additional input information.

WATER LOAD GENERATION: RUNOFF											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
LAND USE	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
Urban 1 (Residential)	43560	30855	30492	172056	24182	16277	65563	0	0	0	382985
Urban 2 (Roads)	18005	26457	0	28676	4030	2713	10927	0	0	0	90808
Urban 3 (Mixed Urban/Commercial)	26136	42108	0	43014	6045	4069	16391	0	0	0	137763
Urban 4 (Industrial)	0	0	0	142175	0	0	0	0	0	0	142175
Urban 5 (Parks, Recreation Fields, Institutional)	0	3872	0	0	0	0	0	0	0	0	3872
Agric 1 (Cover Crop)	0	0	0	1387	22325	0	0	0	0	0	23712
Agric 2 (Row Crop)	0	0	0	0	58806	0	0	0	0	0	58806
Agric 3 (Grazing)	0	0	0	0	14520	0	0	0	0	0	14520
Agric 4 (Feedlot)	0	0	0	0	2723	0	0	0	0	0	2723
Forest 1 (Upland)	9325	21175	60863	109263	11126	38720	40600	0	0	0	291073
Forest 2 (Wetland)	0	150	0	8746	0	0	1153	0	0	0	10049
Open 1 (Wetland/Lake)	1494	334	1210	56	0	37	8591	0	0	0	11722
Open 2 (Meadow)	1210	768	0	6199	38	0	122	0	0	0	8336
Open 3 (Excavation)	593	454	0	10991	0	0	0	0	0	0	12038
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
TOTAL (CU.M/YR)	100323	126173	92565	522564	143794	61816	143347	0	0	0	1190582
TOTAL (CFS)	0.11	0.14	0.10	0.59	0.16	0.07	0.16	0.00	0.00	0.00	1.33

WATER LOAD GENERATION: BASEFLOW											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
Urban 1 (Residential)	21780	15428	15246	86028	12091	8139	32781	0	0	0	191492
Urban 2 (Roads)	4501	6614	0	7169	1008	678	2732	0	0	0	22702
Urban 3 (Mixed Urban/Commercial)	2178	3509	0	3585	504	339	1366	0	0	0	11480
Urban 4 (Industrial)	0	0	0	14218	0	0	0	0	0	0	14218
Urban 5 (Parks, Recreation Fields, Institutional)	0	1936	0	0	0	0	0	0	0	0	1936
Agric 1 (Cover Crop)	0	0	0	2775	44649	0	0	0	0	0	47424
Agric 2 (Row Crop)	0	0	0	0	58806	0	0	0	0	0	58806
Agric 3 (Grazing)	0	0	0	0	14520	0	0	0	0	0	14520
Agric 4 (Feedlot)	0	0	0	0	1815	0	0	0	0	0	1815
Forest 1 (Upland)	37301	84700	243452	437052	44504	154880	162402	0	0	0	1164291
Forest 2 (Wetland)	0	1203	0	69969	0	0	9220	0	0	0	80393
Open 1 (Wetland/Lake)	11953	2672	9680	450	0	294	68728	0	0	0	93777
Open 2 (Meadow)	7260	4605	0	37192	226	0	732	0	0	0	50016
Open 3 (Excavation)	297	227	0	5496	0	0	0	0	0	0	6019
Other 1	0	0	0	0	0	0	0	0	0	0	0
Other 2	0	0	0	0	0	0	0	0	0	0	0
Other 3	0	0	0	0	0	0	0	0	0	0	0
Point Source #1	0	0	0	45000	0	0	0	0	0	0	45000
Point Source #2	0	0	0	0	0	0	0	0	0	0	0
Point Source #3	0	0	0	0	0	0	0	0	0	0	0
TOTAL (CU.M/YR)	85270	120894	268378	708932	178122	164330	277961	0	0	0	1803888
TOTAL (CFS)	0.10	0.14	0.30	0.79	0.20	0.18	0.31	0.00	0.00	0.000	2.02

LOAD GENERATION: RUNOFF P											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (Residential)	7.8	5.5	5.5	30.8	4.3	2.9	11.7	0.0	0.0	0.0	68.6
Urban 2 (Roads)	2.8	4.1	0.0	4.4	0.6	0.4	1.7	0.0	0.0	0.0	14.1
Urban 3 (Mixed Urban/Commercial)	2.9	4.6	0.0	4.7	0.7	0.4	1.8	0.0	0.0	0.0	15.2
Urban 4 (Industrial)	0.0	0.0	0.0	16.5	0.0	0.0	0.0	0.0	0.0	0.0	16.5
Urban 5 (Parks, Recreation Fields, Institutional)	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6
Agric 1 (Cover Crop)	0.0	0.0	0.0	0.6	9.8	0.0	0.0	0.0	0.0	0.0	10.5
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	16.2	0.0	0.0	0.0	0.0	0.0	16.2
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.0	1.6
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	112.0	0.0	0.0	0.0	0.0	0.0	112.0
Forest 1 (Upland)	1.5	3.5	10.1	18.1	1.8	6.4	6.7	0.0	0.0	0.0	48.1
Forest 2 (Wetland)	0.0	0.0	0.0	1.4	0.0	0.0	0.2	0.0	0.0	0.0	1.7
Open 1 (Wetland/Lake)	0.2	0.1	0.2	0.0	0.0	0.0	1.4	0.0	0.0	0.0	1.9
Open 2 (Meadow)	0.2	0.1	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
Open 3 (Excavation)	0.1	0.1	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	2.0
Other 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	15.6	20.6	15.7	79.4	147.1	10.2	23.6	0.0	0.0	0.0	312.2

LOAD GENERATION: RUNOFF N											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (Residential)	66.0	46.8	46.2	260.7	36.6	24.7	99.3	0.0	0.0	0.0	580.3
Urban 2 (Roads)	20.5	30.1	0.0	32.6	4.6	3.1	12.4	0.0	0.0	0.0	103.2
Urban 3 (Mixed Urban/Commercial)	19.8	31.9	0.0	32.6	4.6	3.1	12.4	0.0	0.0	0.0	104.4
Urban 4 (Industrial)	0.0	0.0	0.0	129.3	0.0	0.0	0.0	0.0	0.0	0.0	129.3
Urban 5 (Parks, Recreation Fields, Institutional)	0.0	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.6
Agric 1 (Cover Crop)	0.0	0.0	0.0	4.6	74.8	0.0	0.0	0.0	0.0	0.0	79.4
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	145.8	0.0	0.0	0.0	0.0	0.0	145.8
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	20.8	0.0	0.0	0.0	0.0	0.0	20.8
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	1461.6	0.0	0.0	0.0	0.0	0.0	1461.6
Forest 1 (Upland)	22.0	50.1	143.9	258.3	26.3	91.5	96.0	0.0	0.0	0.0	688.0
Forest 2 (Wetland)	0.0	0.7	0.0	41.3	0.0	0.0	5.4	0.0	0.0	0.0	47.5
Open 1 (Wetland/Lake)	6.1	1.4	4.9	0.2	0.0	0.1	34.9	0.0	0.0	0.0	47.7
Open 2 (Meadow)	4.9	3.1	0.0	25.2	0.2	0.0	0.5	0.0	0.0	0.0	33.9
Open 3 (Excavation)	0.6	0.5	0.0	11.8	0.0	0.0	0.0	0.0	0.0	0.0	12.9
Other 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	139.9	182.0	195.0	796.6	1775.2	122.5	261.0	0.0	0.0	0.0	3472.2

LOAD GENERATION: BASEFLOW P											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (Residential)	0.12	0.09	0.08	0.47	0.07	0.04	0.18	0.00	0.00	0.00	1.06
Urban 2 (Roads)	0.04	0.05	0.00	0.06	0.01	0.01	0.02	0.00	0.00	0.00	0.19
Urban 3 (Mixed Urban/Commercial)	0.04	0.06	0.00	0.06	0.01	0.01	0.02	0.00	0.00	0.00	0.19
Urban 4 (Industrial)	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.24
Urban 5 (Parks, Recreation Fields, Institutional)	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Agric 1 (Cover Crop)	0.00	0.00	0.00	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.13
Agric 2 (Row Crop)	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.16
Agric 3 (Grazing)	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.04
Agric 4 (Feedlot)	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Forest 1 (Upland)	0.04	0.09	0.25	0.45	0.05	0.16	0.17	0.00	0.00	0.00	1.20
Forest 2 (Wetland)	0.00	0.00	0.00	0.07	0.00	0.00	0.01	0.00	0.00	0.00	0.08
Open 1 (Wetland/Lake)	0.01	0.00	0.01	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.10
Open 2 (Meadow)	0.01	0.01	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Open 3 (Excavation)	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Other 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #1	0.00	0.00	0.00	135.00	0.00	0.00	0.00	0.00	0.00	0.00	135.00
Point Source #2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	0.25	0.33	0.35	136.42	0.46	0.22	0.48	0.00	0.00	0.00	138.50

LOAD GENERATION: BASEFLOW N											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	TOTAL
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
LAND USE	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
Urban 1 (Residential)	60.00	42.50	42.00	236.99	33.31	22.42	90.31	0.00	0.00	0.00	527.53
Urban 2 (Roads)	18.60	27.33	0.00	29.62	4.16	2.80	11.29	0.00	0.00	0.00	93.81
Urban 3 (Mixed Urban/Commercial)	18.00	29.00	0.00	29.62	4.16	2.80	11.29	0.00	0.00	0.00	94.88
Urban 4 (Industrial)	0.00	0.00	0.00	117.50	0.00	0.00	0.00	0.00	0.00	0.00	117.50
Urban 5 (Parks, Recreation Fields, Institutional)	0.00	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00
Agric 1 (Cover Crop)	0.00	0.00	0.00	1.91	30.75	0.00	0.00	0.00	0.00	0.00	32.66
Agric 2 (Row Crop)	0.00	0.00	0.00	0.00	40.50	0.00	0.00	0.00	0.00	0.00	40.50
Agric 3 (Grazing)	0.00	0.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00	20.00
Agric 4 (Feedlot)	0.00	0.00	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00	12.50
Forest 1 (Upland)	7.71	17.50	50.30	90.30	9.20	32.00	33.55	0.00	0.00	0.00	240.56
Forest 2 (Wetland)	0.00	0.25	0.00	14.46	0.00	0.00	1.91	0.00	0.00	0.00	16.61
Open 1 (Wetland/Lake)	1.23	0.28	1.00	0.05	0.00	0.03	7.10	0.00	0.00	0.00	9.69
Open 2 (Meadow)	1.00	0.63	0.00	5.12	0.03	0.00	0.10	0.00	0.00	0.00	6.89
Open 3 (Excavation)	0.06	0.05	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	1.24
Other 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #1	0.00	0.00	0.00	540.00	0.00	0.00	0.00	0.00	0.00	0.00	540.00
Point Source #2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Point Source #3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	106.60	133.54	93.30	1066.71	154.61	60.06	155.54	0.00	0.00	0.00	1770.36

Load Routing Pattern

The model must be told how to route all inputs of water, TP and TN before they reach the lake. Since attenuation in an upstream basin can affect inputs in an upstream basin that passes through the downstream basin, the model must be directed as to where to apply attenuation factors and additive effects. In the table below, each basin listed on the lines labeled on the left that passes through another basin labeled by column is denoted with a 1 in the column of the basin through which it passes. Otherwise, a 0 appears in each shaded cell. All basins pass through themselves, so the first line has a 1 in each cell. Basins 1 and 2 go direct to the lake, and so all other cells on the corresponding lines have 0 entries. Basin 3 passes through Basin 4 (see Figure 2), and so the line for Basin 3 has a 1 in the column for Basin 4. Likewise, Basins 5 and 6 pass through Basin 7, so the corresponding lines have a 1 entered in the column for Basin 7.

ROUTING PATTERN										
	(Basin in left hand column passes through basin in column below if indicated by a 1)									
1=YES 0=NO XXX=BLANK	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2			
	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
INDIVIDUAL BASIN	1	1	1	1	1	1	1	1	1	1
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0
BASIN 3 OUTPUT	0	0	XXX	1	0	0	0	0	0	0
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0
BASIN 5 OUTPUT	0	0	0	0	XXX	0	1	0	0	0
BASIN 6 OUTPUT	0	0	0	0	0	XXX	1	0	0	0
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX

CUMULATIVE DRAINAGE AREAS										
	(Total land area associated with routed water and nutrients)									
1=YES 0=NO XXX=BLANK	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2			
	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
INDIVIDUAL BASIN	31.6	42.6	60.7	200.9	50.6	37.7	72.4	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	60.7	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	50.6	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	37.7	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
TOTALS	31.6	42.6	60.7	261.6	50.6	37.7	160.7	0.0	0.0	0.0

The model then combines the appropriate watershed areas as shown above, generating larger sub-watersheds that are used later to calculate overall export coefficients, comparative water yields, and related checks for model accuracy.

Load Routing and Attenuation

With the loads calculated previously for each basin under wet and dry conditions and the routing of those loads specified, the model can then combine those loads and apply attenuation values chosen to reflect expected losses of water, TP or TN while the generated loads are on their way to the lake.

Water

Water is attenuated mostly by evapotranspiration losses. Some depression storage is expected, seepage into the ground is possible, and wetlands can remove considerable water on the way to the lake. In general, a 5% loss is to be expected in nearly all cases, and greater losses are plausible with lower gradient or wetland dominated landscapes. In the example system, only the lower portion of Tributary 2 is expected to have more than a 5% loss, with a 15% loss linked to the wetland associated with this drainage area and tributary (see Figure 1).

WATER ROUTING AND ATTENUATION										
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2			
SOURCE	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)	(CU.M/YR)
INDIVIDUAL BASIN	185594	247067	362153	1231497	321916	226145	421308	0	0	0
BASIN 1 OUTPUT	XXX	0	0	0	0	0	0	0	0	0
BASIN 2 OUTPUT	0	XXX	0	0	0	0	0	0	0	0
BASIN 3 OUTPUT	0	0	XXX	344045	0	0	0	0	0	0
BASIN 4 OUTPUT	0	0	0	XXX	0	0	0	0	0	0
BASIN 5 OUTPUT	0	0	0	0	XXX	0	305820	0	0	0
BASIN 6 OUTPUT	0	0	0	0	0	XXX	214838	0	0	0
BASIN 7 OUTPUT	0	0	0	0	0	0	XXX	0	0	0
BASIN 8 OUTPUT	0	0	0	0	0	0	0	XXX	0	0
BASIN 9 OUTPUT	0	0	0	0	0	0	0	0	XXX	0
BASIN 10 OUTPUT	0	0	0	0	0	0	0	0	0	XXX
CUMULATIVE TOTAL	185594	247067	362153	1575542	321916	226145	941966	0	0	0
BASIN ATTENUATION	0.95	0.95	0.95	0.95	0.95	0.95	0.85	1.00	1.00	1.00
OUTPUT VOLUME	176314	234714	344045	1496765	305820	214838	800671	0.0	0.0	0.0
Reality Check from Flow Data				1500000.0			800000.0			
Calculated Flow/Measured Flow	#DIV/0!	#DIV/0!	#DIV/0!	0.998	#DIV/0!	#DIV/0!	1.001	#DIV/0!	#DIV/0!	#DIV/0!
Reality Check from Areal Yield X Basin Area	174638.7	235450.8	335258.2	1444750.2	279386.8	208035.3	887509.1	0.0	0.0	0.0
Calculated Flow/Flow from Areal Yield	1.010	0.997	1.026	1.036	1.095	1.033	0.902	#DIV/0!	#DIV/0!	#DIV/0!

The resulting output volume for each basin is calculated in the table below, and two reality check opportunities are provided. First any actual data can be added for direct comparison; average flows are available for only two points, the inlets of the two tributaries, but these are useful. In many cases no flow data may be available. The model therefore generates an estimate of the expected average flow as a function of all contributing upstream watershed area and the water yield provided near the top of the Calculations sheet (covered previously). While this flow estimate is approximate, it should not vary from the modeled flow by more than about 20% unless there are unusual circumstances.

In the example, the ratio of the calculated flow from the complete model generation and routing to the estimated yield from the contributing drainage area ranges from 0.902 to 1.095, suggesting fairly close agreement. As some ratios are lower than 1 and others are higher than 1, no model-wide adjustment is likely to bring the values into closer agreement. Slight changes in attenuation for each basin could be applied, but are not necessary when the values agree this closely.

Phosphorus

The same approach applied to attenuation of water is applied to the phosphorus load, as shown in the table below. Here attenuation can range from 0 to 1.0, with the value shown representing the portion of the load that reaches the terminus of the basin. With natural or human enhanced removal processes, it is unusual for all of the load to pass through a basin, but it is also unusual for more than 60 to 70% of it to be removed. What value to pick depends on professional judgment regarding the nature of removal processes in each basin. Infiltration, filtration, detention and uptake will lower the attenuation value entered below, and knowledge of the literature on Best Management Practices is needed to make reliable judgments on attenuation values.

LOAD ROUTING AND ATTENUATION: PHOSPHORUS										
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2			
	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
BASIN 1 INDIVIDUAL	15.8	20.9	16.3	215.8	147.6	10.4	24.1	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	12.2	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	118.1	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	7.8	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	15.8	20.9	16.3	228.0	147.6	10.4	149.9	0.0	0.0	0.0
BASIN ATTENUATION	0.90	0.90	0.75	0.85	0.80	0.75	0.70	1.00	1.00	1.00
OUTPUT LOAD	14.2	18.8	12.2	193.8	118.1	7.8	104.9	0.0	0.0	0.0

In the example system, the direct drainage basins were assigned values of 0.90, representing a small amount of removal mainly by infiltration processes. Upper Tributary #1 has a small pond and was accorded a value of 0.75 (25% removal); a larger pond might have suggested a value closer to 0.5. Lower Tributary #1 has an assigned value of 0.85 based on channel processes that favor uptake and adsorption. West and East Upper Tributary #2 have value based on drainage basin features as evaluated in the field, while the wetland associated with Lower Tributary #2 garners it the lowest load pass-through at 0.7. A more extensive wetland with greater sheet flow might have earned a value near 0.5. Resulting output loads are then calculated.

Nitrogen

The same process used with water and TP attenuation applies to TN, but attenuation of TN is rarely identical to that for TP. Nitrogen moves more readily through soil, and while transformations occur in the stream, losses due to denitrification require slower flows and low oxygen levels not commonly encountered in steeper, rockier channels. However, losses from uptake and possibly denitrification are possible in wetland areas, such as that associated with Lower Tributary #2. Accordingly, attenuation values are assigned as shown in the table below, with generally lower losses for TN than for TP. As with TP attenuation, choosing appropriate values does require some professional judgment.

LOAD ROUTING AND ATTENUATION: NITROGEN										
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2			
	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)	(KG/YR)
BASIN 1 INDIVIDUAL	246.5	315.6	290.1	1863.3	1929.8	182.6	416.6	0.0	0.0	0.0
BASIN 1 OUTPUT	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 2 OUTPUT	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 3 OUTPUT	0.0	0.0	XXX	232.1	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 4 OUTPUT	0.0	0.0	0.0	XXX	0.0	0.0	0.0	0.0	0.0	0.0
BASIN 5 OUTPUT	0.0	0.0	0.0	0.0	XXX	0.0	1543.8	0.0	0.0	0.0
BASIN 6 OUTPUT	0.0	0.0	0.0	0.0	0.0	XXX	146.0	0.0	0.0	0.0
BASIN 7 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0	0.0
BASIN 8 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0	0.0
BASIN 9 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX	0.0
BASIN 10 OUTPUT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	XXX
CUMULATIVE TOTAL	246.5	315.6	290.1	2095.4	1929.8	182.6	2106.4	0.0	0.0	0.0
BASIN ATTENUATION	0.95	0.95	0.80	0.90	0.80	0.80	0.75	1.00	1.00	1.00
OUTPUT LOAD	234.2	299.8	232.1	1885.8	1543.8	146.0	1579.8	0.0	0.0	0.0

Load and Concentration Summary

Water

Water loads were handled to the extent necessary in the previous loading calculations, and are used in this section only to allow calculation of expected TP and TN concentrations, facilitating reality checks with actual data.

Phosphorus

Using the calculated load of TP for each basin and the corresponding water volume, an average expected concentration can be derived, as shown in the table below. Where sampling provides actual data, values can be compared to determine how well the model represents known reality. Sufficient sampling is needed to make the reality check values reliable; it is not appropriate to assume that either the data or the model is necessarily accurate when the values disagree. However, with enough data to adequately characterize the concentrations observed in the stream, the model can be adjusted to produce a better match. Estimated and actual concentrations are used to generate a ratio for easy comparison.

The TP loads previously calculated represent the load passing through each basin, but do not represent what reaches the lake, as not all basins are terminal input sources. The model must be told which basins actually drain directly to the lake, and for which the exiting load is part of the total load to the lake.

LOAD AND CONCENTRATION SUMMARY: PHOSPHORUS											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
OUTPUT (CU.M/YR)	176314	234714	344045	1496765	305820	214838	800671	0	0	0	
OUTPUT (KG/YR)	14.2	18.8	12.2	193.8	118.1	7.8	104.9	0.0	0.0	0.0	
OUTPUT (MG/L)	0.081	0.080	0.035	0.129	0.386	0.036	0.131	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC. (FROM DATA)	0.078	0.076	0.040	0.150	0.325	0.035	0.125				
CALCULATED CONC./MEASURED CONC.	1.035	1.056	0.886	0.863	1.188	1.038	1.049	#DIV/0!	#DIV/0!	#DIV/0!	
BASIN EXPORT COEFFICIENT	0.45	0.44	0.20	0.74	2.33	0.21	0.65	#DIV/0!	#DIV/0!	#DIV/0!	
TERMINAL DISCHARGE?	1	1	0	1	0	0	1	1	1	1	
(1=YES 2=NO)											
LOAD TO RESOURCE											TOTAL
WATER (CU.M/YR)	176314	234714	0	1496765	0	0	800671	0	0	0	2708464
PHOSPHORUS (KG/YR)	14.2	18.8	0.0	193.8	0.0	0.0	104.9	0.0	0.0	0.0	331.8
PHOSPHORUS (MG/L)	0.081	0.080	0.000	0.129	0.000	0.000	0.131	#DIV/0!	#DIV/0!	#DIV/0!	0.123

For the example system, the ratio of the calculated concentration to average actual values derived from substantial sampling (typically on the order of 10 or more samples representing the range of dry to wet conditions) ranges from 0.886 to 1.188, or from 11% low to 19% high, within a generally acceptable range of $\pm$20%. This is not a strict threshold, especially with lower TP concentrations where detection limits and intervals of expression for methods can produce higher percent deviation with very small absolute differences. Yet in general, <20% difference between observed and expected watershed basin output values is considered reasonable for a model at this level of sophistication.

That some values are higher than expected and others lower suggests that now model-wide adjustment will improve agreement (such as an export coefficient change), but attenuation values for individual basins could be adjusted if there is justification.

For the example system, Basins 1, 2, 4 and 7 contribute directly to the lake, and are so denoted by a 1 in their respective columns on the line for terminal discharge. These loads will be summed to derive a watershed load of TP to the lake.

Nitrogen

The model process followed for TN is identical to that applied to TP loads from basins. For TN in the example system, comparison of expected vs. observed values yields a range of ratios from 0.929 to 1.188, representing 7% low to 19% high. Only one out of seven values is lower than 1, so perhaps some adjustment of the TN export coefficients is in order, but most individual basin values are within 8% of each other, so without clear justification, the judgment exercised in the original choices for export coefficients and attenuation is not generally overridden. The same basins denoted as terminal discharges for TP are so noted for TN, allowing calculation of the total watershed load of TN to the lake.

LOAD AND CONCENTRATION SUMMARY: NITROGEN											
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10	
	E. Direct	W. Direct	Upper T1	Lower T1	W. Upper T2	E. Upper T2	Lower T2				
OUTPUT (CU.M/YR)	176314	234714	344045	1496765	305820	214838	800671	0	0	0	
OUTPUT (KG/YR)	234.2	299.8	232.1	1885.8	1543.8	146.0	1579.8	0.0	0.0	0.0	
OUTPUT MG/L	1.328	1.277	0.675	1.260	5.048	0.680	1.973	#DIV/0!	#DIV/0!	#DIV/0!	
REALITY CHECK CONC. (FROM DATA)	1.430	1.240	0.650	1.180	4.250	0.650	1.830				
CALCULATED CONC./MEASURED CONC.	0.929	1.030	1.038	1.068	1.188	1.046	1.078	#DIV/0!	#DIV/0!	#DIV/0!	
BASIN EXPORT COEFFICIENT	7.41	7.03	3.82	7.21	30.52	3.88	9.83	#DIV/0!	#DIV/0!	#DIV/0!	
TERMINAL DISCHARGE?	1	1	0	1	0	0	1	1	1	1	
(1=YES 2=NO)											
LOAD TO RESOURCE											TOTAL
WATER (CU.M/YR)	176314	234714	0	1496765	0	0	800671	0	0	0	2708464
NITROGEN (KG/YR)	234.2	299.8	0.0	1885.8	0.0	0.0	1579.8	0.0	0.0	0.0	3999.7
NITROGEN (MG/L)	1.328	1.277	0.000	1.260	0.000	0.000	1.973	#DIV/0!	#DIV/0!	#DIV/0!	1.477

Grand Totals

The final portion of the Calculation sheet is a summary of all loads to the lake and a grand total load with associated concentrations for TP and TN, as shown below. The breakdown of sources is provided for later consideration in both overall target setting and in consideration of BMPs. For the example system, the watershed load is clearly dominant, and would need to be addressed if substantial reductions in loading were considered necessary. The loads of water, TP and TN are then transferred automatically to the Prediction sheet to facilitate estimation of in-lake concentrations of TP, TN and Chl and a value for SDT. The derived overall input concentration for TP is also transferred; the in-lake predictive models for TN do not require that overall input concentration, but the comparison of TP and TN input levels can be insightful when considering what types of algae are likely to dominate the lake phytoplankton.

LOAD SUMMARY			
DIRECT LOADS TO LAKE	P (KG/YR)	N (KG/YR)	WATER (CU.M/YR)
ATMOSPHERIC	8.0	260.0	484000
INTERNAL	40.0	100.0	0
WATERFOWL	10.0	47.5	0
SEPTIC SYSTEM	31.8	517.0	31250
WATERSHED LOAD	331.7	3998.4	2707372
TOTAL LOAD TO LAKE	421.5	4922.9	3222622
(Watershed + direct loads)			
TOTAL INPUT CONC. (MG/L)	0.131	1.528	

Water Quality Predictions

Prediction of TP, TN, Chl and SDT is based on empirical equations from the literature, nearly all pertaining to North American systems. Only a few additional pieces of information are needed to run the model; most of the needed input data are automatically transferred from the Calculations sheet. As shown below, only the concentration of TP leaving the lake and the lake volume must be entered on the Prediction sheet. If the outflow TP level is not known, the in-lake surface concentration is normally used. If the volume is not specifically known, an average depth can be multiplied by the lake area to derive an input volume, which will then recalculate the average depth one cell below. The nature of the TN prediction models does not require any TN concentration input.

IN-LAKE MODELS FOR PREDICTING CONCENTRATIONS: Current Conditions					
THE TERMS					
	PHOSPHORUS				
SYMBOL	**PARAMETER**	**UNITS**	**DERIVATION**	**VALUE**	
TP	Lake Total Phosphorus Conc.	ppb	From in-lake models	To Be Predicted	
KG	Phosphorus Load to Lake	kg/yr	From export model	422	
L	Phosphorus Load to Lake	g P/m2/yr	KG*1000/A	1.054	
TPin	Influent (Inflow) Total Phosphorus	ppb	From export model	131	
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data, if available	75	Enter Value (TP out)
I	Inflow	m3/yr	From export model	3222622	
A	Lake Area	m2	From data	400000	
V	Lake Volume	m3	From data	1625300	Enter Value (V)
Z	Mean Depth	m	Volume/area	4.063	
F	Flushing Rate	flushings/yr	Inflow/volume	1.983	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.573	
Qs	Areal Water Load	m/yr	Z(F)	8.057	
Vs	Settling Velocity	m	Z(S)	2.330	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.491	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.415	
	NITROGEN				
SYMBOL	**PARAMETER**	**UNITS**	**DERIVATION**	**VALUE**	
TN	Lake Total Nitrogen Conc.	ppb	From in-lake models	To Be Predicted	
KG	Nitrogen Load to Lake	kg/yr	From export model	4923	
L1	Nitrogen Load to Lake	g N/m2/yr	KG*1000/A	12.31	
L2	Nitrogen Load to Lake	mg N/m2/yr	KG*1000000/A	12307	
C1	Coefficient of Attenuation, from F	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	1.01	
C2	Coefficient of Attenuation, from L	fraction/yr	2.7183^(0.71(ln(L2))-6.426)	1.30	
C3	Coefficient of Attenuation, from L/Z	fraction/yr	2.7183^(0.594(ln(L2/Z))-4.144)	1.85	

Phosphorus Concentration

TP concentration is predicted from the equations shown below. The mass balance calculation is simply the TP load divided by the water load, and assumes no losses to settling within the lake. Virtually all lakes have settling losses, but the other equations derive that settling coefficient in different ways, providing a range of possible TP concentration values. Where there is knowledge of the components of the settling calculations, a model might be selected as most representative or models might be eliminated as inapplicable, but otherwise the average of the five empirical models (excluding the mass balance calculation) is accepted as the predicted TP value for the lake.

THE MODELS				
	PHOSPHORUS	PRED.	PERMIS.	CRITICAL
		CONC.	CONC.	CONC.
NAME	FORMULA	(ppb)	(ppb)	(ppb)
Mass Balance	TP=L/(Z(F))*1000	131		
(Maximum Conc.)				
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	67	18	36
(K-D)				
Vollenweider 1975	TP=L/(Z(S+F))*1000	101	27	55
(V)				
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	76	21	41
(L-M)				
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	83	22	45
(J-B)				
Reckhow General (1977)	TP=L/(11.6+1.2(Z(F)))*1000	50	13	27
(Rg)				
Average of Model Values		75	20	41
(without mass balance)				
Measured Value		75		
(mean, median, other)				
From Vollenweider 1968				
Permissible Load (g/m2/yr)	Lp=10^(0.501503(log(Z(F)))-1.0018)	0.28		
Critical Load (g/m2/yr)	Lc=2(Cp)	0.57		

The predicted in-lake TP concentration can be compared to actual data (an average value is entered in the shaded cell as a reality check) and to calculation of the permissible and critical concentrations as derived from Vollenweider's 1968 work. For the example lake, the predicted TP level of 75 ug/L is an exact match for the measured value of 75 ug/L, but both are well above the critical concentration.

The permissible concentration is the value above which algal blooms are to be expected on a potentially unacceptable frequency, while the critical concentration is the level above which unacceptable algal growths are to be expected, barring extreme flushing, toxic events, or light limitation from suspended sediment.

Use of the range of values derived from these empirical equations provides some sense for the uncertainty in the analysis. Changing input loads, lake volume, or other key variables allows for sensitivity analysis.

Nitrogen Concentration

Prediction of TN is based on three separate empirical equations from the same work, each calculating settling losses differently. A mass balance equation is applied as well, as with the prediction of TP. An actual mean value is normally entered in the shaded cell as a reality check. For the example system, the actual mean TN value is within the range of predicted values, but is about 5.6% lower than the average of predicted values. One might consider adjusting export coefficients or attenuation rates in the Calculations sheet, to bring these values closer together, but the discrepancy is relatively minor.

	NITROGEN	
Mass Balance	TN=L/(Z(F))*1000	1528
(Maximum Conc.)		
Bachmann 1980	TN=L/(Z(C1+F))*1000	1011
Bachmann 1980	TN=L/(Z(C2+F))*1000	923
Bachmann 1980	TN=L/(Z(C3+F))*1000	789
Average of Model Values		908
(without mass balance)		
Measured Value		860
(mean, median, other)		

Chlorophyll Concentration, Water Clarity and Bloom Probability

Once an average in-lake TP concentration has been established, the Predictions sheet derives corresponding Chl and SDT values, as shown below. Five different equations are used to derive a predicted Chl value, and an average is derived. Peak Chl is estimated with three equations, with an average generated. Average and maximum expected SDT are estimated as well. Bloom frequency is based on the relationship of mean Chl to other threshold levels from other studies, and the portion of time that Chl is expected to exceed 10, 15, 20, 30 and 40 ug/L is derived.

A set of shaded cells are provided for entry of known measured values for comparison. For the example lake, the average and peak Chl levels predicted from the model are slightly higher than actual measured values, while the average and maximum SDT from the model are slightly lower than observed values, consistent with the Chl results. Agreement is generally high, however, with differences between 10 and 20%. There were not enough data to construct a dependable actual distribution of Chl over the range of thresholds provided for the example lake.

There are other factors besides nutrients that can strongly affect the standing crop of algae and resulting Chl levels, including low light from suspended sediment, grazing by zooplankton, presence of heterotrophic algae, and flushing effects from high flows. Consequently, close agreement between predicted and actual Chl will be harder to achieve than for predicted and actual TP. Knowledge of those other potentially important influences can help determine if model calibration is off, or if closer agreement is not rationally achievable.

PREDICTED CHL AND WATER CLARITY			
MODEL	**Value**	**Mean**	**Measured**
Mean Chlorophyll (ug/L)			
Carlson 1977	45.9		
Dillon and Rigler 1974	38.4		
Jones and Bachmann 1976	44.7		
Oglesby and Schaffner 1978	40.4		
Modified Vollenweider 1982	35.5	41.0	37.5
Peak Chlorophyll (ug/L)			
Modified Vollenweider (TP) 1982	119.7		
Vollenweider (CHL) 1982	133.1		
Modified Jones, Rast and Lee 1979	139.5	130.8	118.1
Secchi Transparency (M)			
Oglesby and Schaffner 1978 **(Avg)**	0.8		1.0
Modified Vollenweider 1982 **(Max)**	2.9		3.1
Bloom Probability			
Probability of Chl >10 ug/L **(% of time)**	99.5%		
Probability of Chl >15 ug/L **(% of time)**	96.1%		
Probability of Chl >20 ug/L **(% of time)**	88.2%		
Probability of Chl >30 ug/L **(% of time)**	64.6%		
Probability of Chl >40 ug/L **(% of time)**	42.0%		

Evaluating Initial Results

LLRM is not meant to be a “black box” model. One can look at any cell and discern which steps are most important to final results in any give case. Several quality control processes are recommended in each application.

Checking Values

Many numerical entries must be made to run LLRM. Be sure to double check the values entered. Simple entry errors can cause major discrepancies between predictions and reality. Where an export coefficient is large, most notably with Agric4, feedlot area, it is essential that the land use actually associated with that activity be accurately assessed and entered.

Following Loads

For any individually identified load that represents a substantial portion of the total load (certainly >25%, perhaps as small a portion as 10%), it is appropriate to follow that load from generation through delivery to the lake, observing the losses and transformations along the way. Sometimes the path will be very short, and sometimes there may be multiple points where attenuation is applied. Consider dry vs. wet weather inputs and determine if the ratio is reasonable in light of actual data or field observations. Are calculated concentrations at points of measurement consistent with the actual measurements? Are watershed processes being adequately represented? One limitation of the model involves application of attenuation for all loads within a defined basin; loads may enter at the distal or proximal ends of the basin, and attenuation may not apply equally to all sources. Where loading and attenuation are not being properly represented, consider subdividing the basin to work with drainages of the most meaningful sizes.

Reality Checks

LLRM can be run with minimal actual water quality data, but to gain confidence in the predictions it is necessary to compare results with sufficient amounts of actual data for key points in the modeled system. Ideally, water quality will be tested at all identified nodes, including the output points for all basins, any point source discharges, any direct discharge pipes to the lake, and in the lake itself. Wet and dry weather sampling should be conducted. Flow values are highly desirable, but without a longer term record, considerable uncertainty will remain; variability in flow is often extreme, necessitating large data sets to get representative statistical representation. Where there are multiple measurement points, compare not just how close predicted values are to observed values, but the pattern. Are observed values consistently over- or underpredicted? A rough threshold of ±20% is recommended as a starting point, with a mix of values in the + or – categories.

Sensitivity Testing
The sensitivity of LLRM can be evaluated by altering individual features and observing the effect on results. For any variable for which the value is rather uncertain, enter the maximum value conceivable, and record model results. Then repeat the process with the minimum plausible value, and compare to ascertain how much variation can be induced by error in that variable. Which variables seem to have the greatest impact on results? Those variables should receive the most attention in reality checking, ground truthing, and future monitoring, and would also be the most likely candidates for adjustment in model calibration, unless the initially entered values are very certain.

For example, the runoff coefficients for TP from the various land uses were set below the median literature values, based on knowledge of loads for some drainage areas from actual data for flow and concentration. However, it is possible that the actual load generated from various land uses is higher than initially assumed, and it is the attenuation that should be adjusted to achieve a predicted in-lake concentration that matches actual data. If the median TP export for runoff is entered into the Calculations sheet, substituting the unshaded values for the shaded values in the table below, the resulting in-lake TP prediction is 89 ug/L, much higher than the 75 ug/L from real data.

LAND USE	Original P Export Coefficient (kg/ha/yr)	New P Export Coefficient (kg/ha/yr)
Urban 1 (Residential)	0.65	1.10
Urban 2 (Roads)	0.75	1.10
Urban 3 (Mixed Urban/Commercial)	0.80	1.10
Urban 4 (Industrial)	0.70	1.10
Urban 5 (Parks, Recreation Fields, Institutional)	0.80	1.10
Agric 1 (Cover Crop)	0.80	0.80
Agric 2 (Row Crop)	1.00	2.20
Agric 3 (Grazing)	0.40	0.80
Agric 4 (Feedlot)	224.00	224.00
Forest 1 (Upland)	0.20	0.20
Forest 2 (Wetland)	0.10	0.20
Open 1 (Wetland/Lake)	0.10	0.20
Open 2 (Meadow)	0.10	0.20
Open 3 (Excavation)	0.80	0.80
Other 1	0.20	0.20
Other 2	1.10	1.10
Other 3	2.20	2.20

To get a closer match for the known in-lake value, attenuation would have to be adjusted (reduction in the portion of the generated load that reaches the lake) by about 0.1 units (10%), as shown below. This would result in a predicted in-lake TP concentration of 77 ug/L, not far above the measured 75 ug/L. It is apparent that choice of export coefficients is fairly important, but that error in those choices can be compensated by adjustments in attenuation that are not too extreme to be believed. Yet those choices will affect the results of management scenario testing, and should be made carefully. The intent is to properly represent watershed processes, both loading and attenuation, not just the product of the two.

	BASIN 1 E. Direct	BASIN 2 W. Direct	BASIN 3 Upper T1	BASIN 4 Lower T1	BASIN 5 W. Upper T2	BASIN 6 E. Upper T2	BASIN 7 Lower T2
ORIGINAL BASIN ATTENUATION	0.90	0.90	0.75	0.85	0.80	0.75	0.70
NEW BASIN ATTENUATION	0.80	0.80	0.65	0.75	0.70	0.65	0.60

Aside from changes in all export coefficients, one might consider the impact of changing a single value. As that value applies to all areas given for the corresponding land use, its impact will be proportional to the magnitude of that area relative to other land uses. A change in forested land use exports may be very influential if most of the watershed is forested. A much larger change would be necessary to cause similar impact for a land use that represents a small portion of the watershed.

Model Calibration

Actual adjustment of LLRM to get predicted results in reasonable agreement with actual data can be achieved by altering any of the input data. The key to proper calibration is to change values that have some uncertainty, and to change them in a way that makes sense in light of knowledge of the target watershed and lake. One would not change entered land use areas believed to be correct just to get the predictions to match actual data. Rather, one would adjust the export coefficients for land uses within the plausible range (see Reference Variables sheet), and in accordance with values that could be derived for selected drainage areas (within the target system or nearby) from actual data. Or one could adjust attenuation, determining that a detention area, wetland, or other landscape feature had somewhat greater or lesser attenuation capacity that initially estimated. Justification for all changes should be provided; model adjustment should be transparent and amenable to scrutiny.

For the example system, it may be appropriate to adjust either TN export coefficients or attenuation to get the average of the three empirical equation results for TN (see Predictions sheet) to match the observed average more closely. In the example, a predicted TN concentration of 908 ug/L was derived, while the average of quite a few in-lake samples was 860 ug/L. With a difference of <6%, this is not a major issue, but since all but one of the individual basin predictions for TN concentration were also overpredictions, adjustment can be justified.

If all the TN export coefficients in the Calculations sheet are reduced by 10%, an entirely plausible situation, the new TN prediction for the lake becomes 861 ug/L, a very close match for the observed 860 ug/L. Export coefficients were not changed selectively by land use; all were simply adjusted down a small amount, well within the range of possible variation in this system. Alternatively, if the TN attenuation coefficient for each basin is reduced in the Calculations sheet by 0.05 (representing 5% more loss of TN on the way to the lake), the new predicted in-lake TN concentration becomes 842 ug/L, not far below the observed 860 ug/L. Attenuation in each basin was adjusted the same way, showing no bias. Either of these adjustments (export coefficients or attenuation values) would be reasonable within the constraints of the model and knowledge of the system.

The only way to change the export coefficient for land use in a single basin is to split off that land use into one of the “Other” categories and have it appear in only the basins where a different export coefficient is justified. This is hardly ever done, and justification should involve supporting data. Likewise, if one basin had a particularly large load and a feature that might affect that load, one might justify changing the attenuation for just that one basin, but justification should be strong to interject this level of individual basin bias.

Model Verification

Proper verification of models involves calibration with one set of data, followed by running the model with different input data leading to different results, with data to verify that those results are appropriate. Where data exist for conditions in a different time period that led to different in-lake conditions, such verification is possible with LLRM, but such opportunities tend to be rare. If the lake level was raised by dam modification, and in-lake data are available for before and after the pool rise, a simple change in the lake volume (entered in the Predictions sheet) can simulate this and allow verification. If in-lake data exist from a time before there was much development in the watershed, this could also allow verification by changing the land use and comparing results to historic TP and TN levels in the lake. However, small changes in watershed land use are not likely to yield sufficiently large changes in in-lake conditions to be detectable with this model. Additionally, as LLRM is a steady state model, testing conditions in one year with wetter conditions against another year with drier conditions, with no change in land use, is really not a valid approach.

Model verification is a function of data availability for at least two periods of multiple years in duration with different conditions that can be represented by the model. Where available, use of these data to verify model performance is strongly advised. If predictions under the second set of conditions do not reasonably match the available data, adjustments in export coefficients, attenuation, or other features of the model may be needed. Understanding why conditions are not being properly represented is an important aspect of modeling, even when it is not possible to bring the model into complete agreement with available data.

Scenario Testing

LLRM is meant to be useful for evaluating possible consequences of land use conversions, changes in discharges, various management options, and related alterations of the watershed or lake. The primary purpose of this model is to allow the user to project possible consequences of actions and aid management and policy decision processes. Testing a conceived scenario involves changing appropriate input data and observing the results. Common scenario testing includes determining the likely "original" or "pre-settlement" condition of the lake, termed "Background Condition" here, and forecasting the benefit from possible Best Management Practices (BMPs).

Background Conditions

Simulation of Background Conditions is most often accomplished by changing all developed land uses to forest, wetland or water, whichever is most appropriate based on old land use maps or other sources of knowledge about watershed features prior to development of roads, towns, industry, and related human features. Default export coefficients for undeveloped land use types are virtually the same, so the distinction is not critical if records are sparse.

For the example system, all developed land uses were converted to forested upland, although it is entirely possible that some wetlands were filled for development before regulations to protect wetlands were promulgated, and some may even have been filled more recently. The resulting land use table, shown below, replaces that in the original model representing current conditions. The watershed area is the same, although in some cases diversions may change this aspect as well. Many lakes have been created by human action, such that setting all land uses to an undeveloped state would correspond to not having a lake present, but the assumption applied here is that the user is interested in the condition of the lake as it currently exists, but in the absence of human influences.

BASIN AREAS

LAND USE	BASIN 1 E. Direct AREA (HA)	BASIN 2 W. Direct AREA (HA)	BASIN 3 Upper T1 AREA (HA)	BASIN 4 Lower T1 AREA (HA)	BASIN 5 W. Upper T2 AREA (HA)	BASIN 6 E. Upper T2 AREA (HA)	BASIN 7 Lower T2 AREA (HA)	BASIN 8 AREA (HA)	BASIN 9 AREA (HA)	BASIN 10 AREA (HA)	TOTAL AREA (HA)
Urban 1 (Residential)											0.0
Urban 2 (Roads)											0.0
Urban 3 (Mixed Urban/Commercial)											0.0
Urban 4 (Industrial)											0.0
Urban 5 (Parks, Recreation Fields, Institutional)											0.0
Agric 1 (Cover Crop)											0.0
Agric 2 (Row Crop)											0.0
Agric 3 (Grazing)											0.0
Agric 4 (Feedlot)											0.0
Forest 1 (Upland)	27.1	40.6	60.7	176.0	50.5	37.6	56.2				448.7
Forest 2 (Wetland)	0.0	0.2	0.0	14.5	0.0	0.0	1.9				16.6
Open 1 (Wetland/Lake)	2.5	0.6	0.0	0.1	0.0	0.1	14.2				17.5
Open 2 (Meadow)	2.0	1.3	0.0	10.2	0.1	0.0	0.2				13.8
Open 3 (Excavation)											0.0
Other 1											0.0
Other 2											0.0
Other 3											0.0
TOTAL	31.6	42.7	60.7	200.8	50.6	37.7	72.5	0	0		496.6

Also altered in this example, but not shown explicitly here, are the internal load (reduced to typical background levels of 0.5 mg TP/m2/d and 2.0 mg TN/m2/d), point source (removed), septic system inputs (removed), and attenuation of TP and TN (values in cells lowered by10%, representing lesser transport to the lake through the natural landscape).

Resulting in-lake conditions, as indicated in the column of the table below labeled “Background Conditions,” include a TP concentration of 16 ug/L and a TN level of 366 ug/L. Average Chl is predicted at 5.7 ug/L, leading to a mean SDT of 2.7 m. Bloom frequency is expected to be 8.6% for Chl >10 ug/L and 1.5% for Chl >15 ug/L, with values >20 ug/L very rare. While the example lake appears to have never had extremely high water clarity, it was probably much more attractive and useable than it is now, based on comparison with current conditions in the table. If this lake was in an ecoregion with a target TP level of <16 ug/L, it is expected that meeting that limit would be very difficult, given apparent natural influences.

SUMMARY TABLE FOR SCENARIO TESTING	Existing Conditions		Background Conditions	Complete Build-out	WWTF Enhanced	Feasible BMPs
	Calibrated Model Value	Actual Data	Model Value	Model Value	Model Value	Model Value
Phosphorus (ppb)	75	75	16	83	49	24
Nitrogen (ppb)	861	860	366	965	745	540
Mean Chlorophyll (ug/L)	40.7	37.5	5.7	46.7	23.3	9.3
Peak Chlorophyll (ug/L)	130.0	118.1	20.1	148.5	76.1	31.6
Mean Secchi (m)	0.8	1.0	2.7	0.8	1.2	2.0
Peak Secchi (m)	2.9	3.1	4.5	2.8	3.3	4.0
Bloom Probability						
Probability of Chl >10 ug/L	99.5%		8.6%	99.8%	92.6%	34.4%
Probability of Chl >15 ug/L	96.0%		1.5%	97.8%	73.6%	11.3%
Probability of Chl >20 ug/L	87.9%		0.3%	92.6%	52.3%	3.7%
Probability of Chl >30 ug/L	64.1%		0.0%	73.8%	22.5%	0.5%
Probability of Chl >40 ug/L	41.5%		0.0%	52.5%	9.2%	0.1%

Changes in Land Use

Another common scenario to be tested involves changes in land use. How much worse might conditions become if all buildable land became developed? For the example system, with current zoning and protection of some undeveloped areas, a substantial fraction of currently forested areas could still become low density residential housing. Adjusting the land uses in the corresponding input table to reflect a conversion of forest to low density urban development, as shown below, and adding 28 septic systems to that portion of the loading analysis (not shown here) an increase in TP, TN and Chl is derived, and a decrease in SDT are observed (see summary table above). TP rises to 83 ug/L and TN to 965 ug/L, but the change in Chl and SDT are not large, as the lake would already be hypereutrophic.

BASIN AREAS

LAND USE	BASIN 1 E. Direct AREA (HA)	BASIN 2 W. Direct AREA (HA)	BASIN 3 Upper T1 AREA (HA)	BASIN 4 Lower T1 AREA (HA)	BASIN 5 W. Upper T2 AREA (HA)	BASIN 6 E. Upper T2 AREA (HA)	BASIN 7 Lower T2 AREA (HA)	BASIN 8 AREA (HA)	BASIN 9 AREA (HA)	BASIN 10 AREA (HA)	TOTAL AREA (HA)
Urban 1 (Residential)	16.0	18.5	23.4	87.4	6.7	12.5	38.6				203.1
Orginal Urban 1	12.0	8.5	8.4	47.4	6.7	4.5	18.1				
Urban 2 (Roads)	3.7	5.5	0.0	5.9	0.8	0.6	2.3				18.8
Urban 3 (Mixed Urban/Commercial)	3.6	5.8	0.0	5.9	0.8	0.6	2.3				19.0
Urban 4 (Industrial)	0.0	0.0	0.0	23.5	0.0	0.0	0.0				23.5
Urban 5 (Parks, Recreation Fields, Institutional)	0.0	3.2	0.0	0.0	0.0	0.0	0.0				3.2
Agric 1 (Cover Crop)	0.0	0.0	0.0	0.8	12.3	0.0	0.0				13.1
Agric 2 (Row Crop)	0.0	0.0	0.0	0.0	16.2	0.0	0.0				16.2
Agric 3 (Grazing)	0.0	0.0	0.0	0.0	4.0	0.0	0.0				4.0
Agric 4 (Feedlot)	0.0	0.0	0.0	0.0	0.5	0.0	0.0				0.5
Forest 1 (Upland)	3.7	7.5	35.3	50.3	9.2	24.0	13.0				143.0
Original Forest 1	7.7	17.5	50.3	90.3	9.2	32.0	33.6				240.6
Forest 2 (Wetland)	0.0	0.2	0.0	14.5	0.0	0.0	1.9				16.6
Open 1 (Wetland/Lake)	2.5	0.6	2.0	0.1	0.0	0.1	14.2				19.5
Open 2 (Meadow)	2.0	1.3	0.0	10.2	0.1	0.0	0.2				13.8
Open 3 (Excavation)	0.1	0.1	0.0	2.3	0.0	0.0	0.0				2.5
Other 1											0.0
Other 2											0.0
Other 3											0.0
TOTAL	31.6	42.7	60.7	200.9	50.6	37.8	72.5				496.8

Changes in Wastewater Management

Managing wastewater is often a need in lake communities. In LLRM, wastewater treatment facilities (WWTF) are represented as point sources, with flow and concentration provided. On-site wastewater disposal (septic) systems are part of the baseflow of drainage areas with tributaries, and can be represented that way for direct drainage areas as well, but the option exists to account separately for septic systems in the direct drainage area. Changes to point sources or septic systems can be made in LLRM to simulate possible management actions.

In the example system, there is one small WWTF that discharges into Lower Tributary #1 and 250 residential units that contribute to septic system inputs in the two defined direct drainage areas (see Figure 1). If the units now served by septic systems were tied into the WWTF via a pumping station, the flow through the WWTF would increase from 45,000 cu.m/yr under current conditions to 71,953 cu.m/yr, the amount of wastewater calculated to be generated by those 250 residential units. If WWTF effluent limits for TP and TN were established at 0.1 and 3.0 mg/L, respectively, the concentration in the discharge would be reduced from 3.0 and 12.0 mg/L (current values from monitoring) to the new effluent limits. The result would be a higher flow from the WWTF with lower TP and TN levels, and an elimination of septic system inputs in the model, both simple changes to make, as shown in the table below.

NON-AREAL SOURCES												
	Number of Source Units	Volume (cu.m/yr)	P Load/Unit (kg/unit/yr)	N Load/Unit (kg/unit/yr)	P Conc. (ppm)	N Conc. (ppm)	P Load (kg/yr)	N Load (kg/yr)				
Waterfowl	50		0.20	0.95			10	47.5				
Point Sources												
PS-1		71953			0.10	3.00	7.2	215.9				
PS-2		0			3.00	12.00	0	0				
PS-3		0			3.00	12.00	0	0				
Basin in which Point Source occurs (0=NO 1=YES)												
	BASIN 1	BASIN 2	BASIN 3	BASIN 4	BASIN 5	BASIN 6	BASIN 7	BASIN 8	BASIN 9	BASIN 10		
PS-1	0	0	0	1	0	0	0	0	0	0		
PS-2	0	0	0	0	0	0	0	0	0	0		
PS-3	0	0	0	0	0	0	0	0	0	0		
DIRECT SEPTIC SYSTEM LOAD												
Septic System Grouping (by occupancy or location)	Days of Occupancy/Yr	Distance from Lake (ft)	Number of Dwellings	Number of People per Dwelling	Water per Person per Day (cu.m)	P Conc. (ppm)	N Conc. (ppm)	P Attenuation Factor	N Attenuation Factor	Water Load (cu.m/yr)	P Load (kg/yr)	N Load (kg/yr)
Group 1 Septic Systems	365	<100	0	2.5	0.25	8	20	0.2	0.9	0	0.0	0.0
Group 2 Septic Systems	365	100 - 300	0	2.5	0.25	8	20	0.1	0.8	0	0.0	0.0
Group 3 Septic Systems	90	<100	0	2.5	0.25	8	20	0.2	0.9	0	0.0	0.0
Group 4 Septic Systems	90	100 - 300	0	2.5	0.25	8	20	0.1	0.8	0	0.0	0.0
Total Septic System Loading										0	0.0	0.0

The result, shown in the summary table for scenario testing above, is an in-lake TP concentration of 49 ug/L and a new TN level of 745 ug/L. These are both substantial reductions from the current levels, but continued elevated Chl (mean = 23.3 ug/L, peak = 76.1 ug/L) and a high probability of algal blooms is expected. Water clarity improves slightly (from 0.8 to 1.2 m on average), but at the cost of the sewerage and treatment, this is unlikely to produce a success story.

Best Management Practices
The application of BMPs is generally regarded as the backbone of non-point source pollution management in watershed programs. Considerable effort has been devoted to assessing the percent removal for various pollutants that can be attained and sustained by various BMPs. BMPs tend to fall into one of two categories: source controls and pollutant trapping. Source controls limit the generation of TP and TN and include actions like bans on lawn fertilizers containing TP or requirements for post-development infiltration to equal pre-development conditions, and would be most likely addressed in LLRM by a change in export coefficient. Pollutant trapping limits the delivery of generated loads to the lake and includes such methods as detention, infiltration, and buffer strips, and is most often addressed in LLRM by changes in attenuation values.

There are limits on what individual BMPs can accomplish. While some site specific knowledge and sizing considerations help modify general guidelines, the following table provides a sense for the level of removal achievable with common BMPs.

Range and Median for Expected Removal (%) for Key Pollutants by Selected Management Methods, Compiled from Literature Sources for Actual Projects and Best Professional Judgment Upon Data Review.

	TSS	Total P	Soluble P	Total N	Soluble N	Metals
Street sweeping	5-20	5-20	<5	5-20	<5	5-20
Catch basin cleaning	5-10	<10	<1	<10	<1	5-10
Buffer strips	40-95 (50)	20-90 (30)	10-80 (20)	20-60 (30)	0-20 (5)	20-60 (30)
Conventional catch basins (Some sump capacity)	1-20 (5)	0-10 (2)	0-1 (0)	0-10 (2)	0-1 (0)	1-20 (5)
Modified catch basins (deep sumps and hoods)	25 (25)	0-20 (5)	0-1 (0)	0-20 (5)	0-1 (0)	20 (20)
Advanced catch basins (sediment/floatables traps)	25-90 (50)	0-19 (10)	0-21 (0)	0-20 (10)	0-6 (0)	10-30 (20)
Porous Pavement	40-80 (60)	28-85 (52)	0-25 (10)	40-95 (62)	-10-5 (0)	40-90 (60)
Vegetated swale	60-90 (70)	0-63 (30)	5-71 (35)	0-40 (25)	-25-31 (0)	50-90 (70)
Infiltration trench/chamber	75-90 (80)	40-70 (60)	20-60 (50)	40-80 (60)	0-40 (10)	50-90 (80)
Infiltration basin	75-80 (80)	40-100 (65)	25-100 (55)	35-80 (51)	0-82 (15)	50-90 (80)
Sand filtration system	80-85 (80)	38-85 (62)	35-90 (60)	22-73 (52)	-20-45 (13)	50-70 (60)
Organic filtration system	80-90 (80)	21-95 (58)	-17-40 (22)	19-55 (35)	-87-0 (-50)	60-90 (70)
Dry detention basin	14-87 (70)	23-99 (65)	5-76 (40)	29-65 (46)	-20-10 (0)	0-66 (36)
Wet detention basin	32-99 (70)	13-56 (27)	-20-5 (-5)	10-60 (31)	0-52 (10)	13-96 (63)

Constructed wetland	14-98 (70)	12-91 (49)	8-90 (63)	6-85 (34)	0-97 (43)	0-82 (54)
Pond/Wetland Combination	20-96 (76)	0-97 (55)	0-65 (30)	23-60 (39)	1-95 (49)	6-90 (58)
Chemical treatment	30-90 (70)	24-92 (63)	1-80 (42)	0-83 (38)	9-70 (34)	30-90 (65)

While BMPs in series can improve removal, the result is rarely multiplicative; that is, application of two BMPs expected to remove 50% of TP are unlikely to result in 0.5 X 0.5 = 0.25 of the load remaining (75% removal) unless each BMP operates on a different fraction of TP (particulates vs. soluble, for example). This is where judgment and experience become critical to the modeling process. In general, BMPs rarely remove more than 2/3 of the load of P or N, and on average can be expected to remove around 50% of the P and 40% of the N unless very carefully designed, built and maintained. The luxury of space is not often affordable, forcing creativity or greater expense to achieve higher removal rates.

In the example system, setting attenuation for all basins to 0.5 for P and 0.6 for N is viewed as a practical level of BMP application for a first cut at what BMPs might be able to do for the lake. Careful consideration of which BMPs will be applied where in which basins is in order in the final analysis, but to set a reasonable approximation of what can be achieved, these are supportable attenuation values. Note that values are not set at 0.5 or 0.6 of the value in place in the calibrated model, but rather a low end of 0.5 or 0.6. If, as with Basin 7 (Lower Tributary #2) in the example system, the attenuation values for P and N under current conditions are 0.70 and 0.75, the practical BMP values of 0.5 and 0.6, respectively, represent less of a decline through BMPs than for the direct drainage areas, which have current condition attenuation values of 0.9 for P and 0.95 for N.

In addition to setting P attenuation at 0.5 for P in all basins and 0.6 for N in all basins in the example system, the WWTF has been routed to a regional WWTF out of the watershed, and the all areas within 300 ft of the lake have been sewered, with that waste also going to the regional WWTF. Consequently, the WWTF and direct drainage septic system inputs have been eliminated. Finally, internal loading has been reduced to 0.5 mg P/m/day and 2.0 mg N/m^2/day, achievable with nutrient inactivation and lowered inputs over time.

The results, as indicated in the summary table for scenario testing above, include an in-lake P concentration of 24 ug/L and an N level of 540 ug/L. The predicted mean Chl is 9.3 ug/L, with a peak of 31.6 ug/L. SDT would be expected to average 2.0 m and have a maximum of 4.0 m. While much improved over current conditions, these are marginal values for supporting the range of lake uses, particularly contact recreation and potable water supply. As a first cut assessment of what BMPs might do for the system, it suggests that more extreme measures will be needed, or that in-lake maintenance should be planned as well, since algal blooms would still be expected. Further scenario testing with the model, combined with cost estimation for potential BMPs, may shed light on the cost effectiveness of rehabilitating the example lake.

Appendix C

NHDES Shoreland Fact Sheets

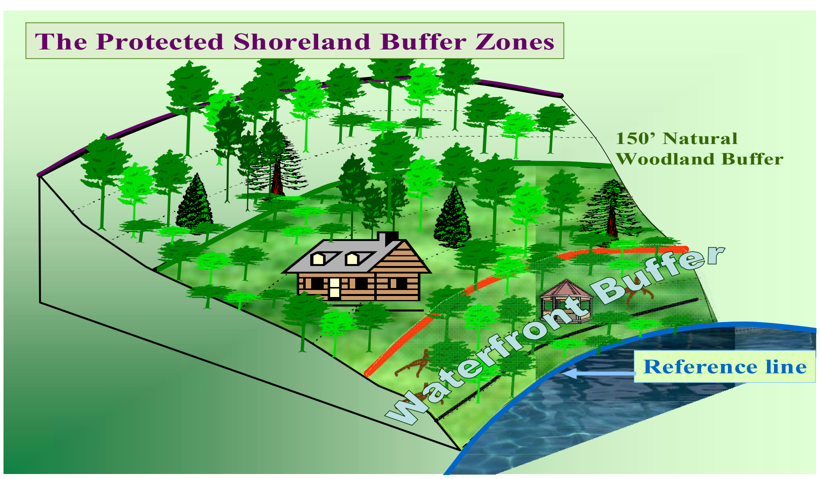
ENVIRONMENTAL
Fact Sheet
NEW HAMPSHIRE DEPARTMENT OF Environmental Services
29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

WD-SP-5 2010

Vegetation Maintenance within the Protected Shoreland

Vegetation is a key component in preserving the integrity of public waters and is also a critical element of wildlife habitat. The NH Comprehensive Shoreland Protection Act (CSPA), RSA 483-B, has protected a 150-foot wide natural woodland buffer adjacent to public waters since July 1, 1994. For the purposes of the CSPA, public waters are defined as lakes, ponds and artificial impoundments greater than 10 acres, rivers and streams that are 4th order or higher, designated rivers and all tidal waters. A shoreland impact permit is *not* required to remove vegetation within the protected shoreland but, property owners must operate in accordance with the guidelines below.

Changes to the CSPA in 2008 modified the way the CSPA protects vegetation. These changes established a new waterfront buffer zone within the larger natural woodland buffer zone. The natural woodland buffer extends 150 feet from the reference line but, the first 50 feet extending landward from the reference line is now considered the waterfront buffer.



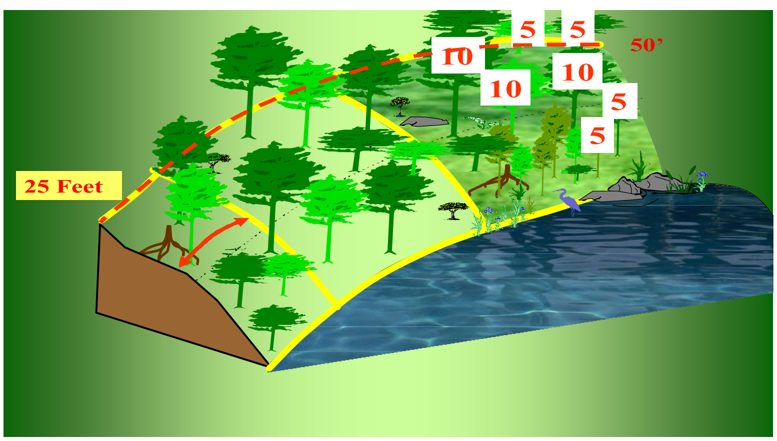
Example: Waterfront Buffer within the Natural Woodland Buffer Zone

Vegetation Maintenance within the Waterfront Buffer

Within the waterfront buffer, branches may be trimmed, pruned, and thinned to the extent necessary to protect structures, maintain clearances and provide views. Limbing of branches for the purpose of providing views is limited to the bottom half of trees and saplings to help ensure the health of the tree or sapling. Owners of lots that were legally developed prior to July 1, 2008 that have cleared areas within the waterfront buffer such as existing lawns or beaches are not required to replant or restore these areas. Owners may continue to maintain these areas as they have in the past but, may not enlarge them, with the exception of beaches provided the Wetlands Bureau issues a permit for the expansion.

Ground cover is protected within the waterfront buffer. Vegetation generally less than three feet in height, rocks, stumps and their root systems must be left intact in the ground however, clearing ground cover for a six-foot wide foot path to the water body is allowed provided the path is designed in such a way not to concentrate storm water runoff or contribute to erosion.

Live trees and saplings may be removed provided certain criteria are met. Starting from the northerly or easterly boundary of the property, and working along the shoreline, divide the waterfront buffer into 50 foot x 50 foot segments. Within each segment a minimum combined tree and sapling score of at least 50 points must be maintained. If for any reason there is insufficient area for a full segment, the number of points required to be maintained is proportional to the requirement of a full segment. For instance, a segment that measures 25 feet x 50 feet , would only need to maintain at least 25 points worth of trees and saplings.



Example: Lot with two full grid segments and one partial grid segment.

To determine if trees and saplings may be removed, the owner must first verify that at least the minimum tree and sapling score will remain within the affected grid segment. To accomplish this, at a height of 4 ½ feet above the ground, on the uphill side, measure the tree and sapling diameter within each grid segment and score in accordance with the table below. Once the tree and sapling score reaches the minimum point score required to remain within a grid segment, then trees and saplings beyond the minimum score may be removed from the grid segment. If the score within a grid segment is less than 50 points or below the minimum score to remain within a partial grid segment, then trees and saplings may not be removed. The stumps of felled trees and saplings may be ground flush to the ground surface but the stump and root systems must remain in the ground and care must be taken to avoid removal of surrounding ground cover.

Calculating the tree and sapling score within a 50 foot by 50 foot segment:

Determine each tree and sapling circumference 4½ feet above the ground, uphill side and score as follows:

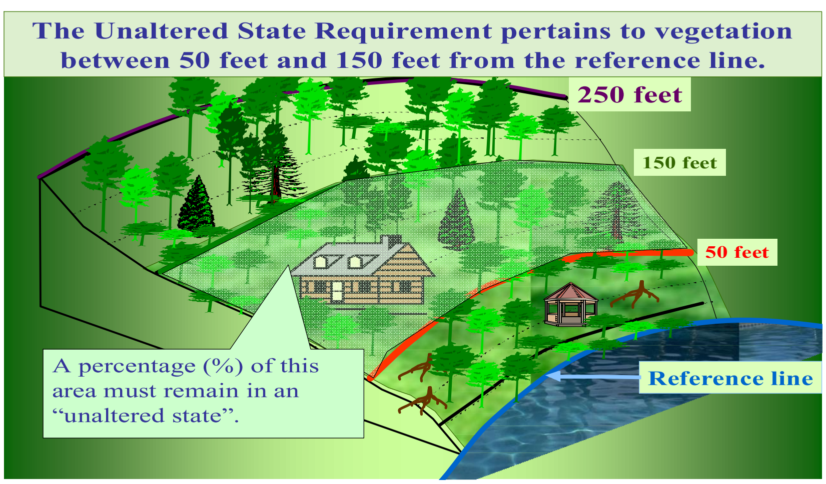
Diameter of Tree or Sapling	Score
1 inch to 6 inches	1 pt
6 inches to 12 inches	5 pts
Greater than 12 inches	10 pts

If possible, owners are encouraged to retain dead trees as they provide valuable wildlife habitat and nesting opportunities. However, dead, diseased or unsafe trees are not included in the scoring and may be removed provided no damage occurs to surrounding trees and saplings, damage to the groundcover is minimized and erosion and sedimentation to the waterbody is prevented.

No fertilizer, except limestone, can be used within 25 feet of the reference line. From 25 feet to 250 feet, low-phosphate, slow-release nitrogen fertilizer may be used on vegetated areas.

Vegetation Maintenance within the Natural Woodland Buffer

Within the Natural Woodland Buffer a percentage of vegetated area must be left in an unaltered state. "Unaltered state" means native vegetation that is allowed to grow without cutting, limbing, trimming, pruning, mowing, or other similar activities. Lawns are modified surfaces and are considered altered areas. This does not prevent raking of existing lawns, the removal of non-native or invasive species, or the removal of dead vegetation. The percentage of area to remain in an unaltered state within the natural woodland buffer is determined by the size of the lot 150 feet from the reference line.



For lots having a half-acre (21,780 sq ft) or less within 150 feet of the reference line, the area to remain in an unaltered state is 25 percent of the area of the lot between 50 feet and 150 feet from the reference line.

For lots having greater than a half-acre within 150 feet of the reference line, the area to remain in an unaltered state is 50 percent of the area of the lot between 50 feet and 150 feet from the reference line exclusive of impervious surfaces. The area to remain in an unaltered state is calculated by first subtracting the area of impervious surfaces located between 50 feet and 150 feet of the reference line from the total area of the lot between 50 feet and 150 feet from the reference line. 50 percent of the area within 50feet and 150feet, not covered by impervious surfaces, must remain in an unaltered state. If additional impervious areas are constructed at a later date, then additional areas may be altered as well.

Dead, diseased, or unsafe trees, limbs, saplings or shrubs that pose an imminent hazard to structures or have the ability to cause personal injury may be removed from the natural woodland buffer, even areas that are to remain in an unaltered state. However, preservation of dead and living trees that provide dens and nesting places for wildlife is encouraged.

Properties that were developed prior to July 1, 2008 may not have enough unaltered area remaining to meet the minimum requirements of the CSPA. Owners of these properties are not required to restore areas or let them revert into a natural state. Owners may continue to maintain these areas as they have in the past.

For more information

For more information about the Comprehensive Shoreland Protection Act and the DES Shoreland Program, please go to http://des.nh.gov/organization/divisions/water/wetlands/cspa/index.htm or contact the program at (603) 271-2147 or shoreland@des.nh.gov .

ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

SP-2 1997

Proper Lawn Care In the Protected Shoreland the Comprehensive Shoreland Protection Act

Helping the Environment Starts in Your Own Backyard

How you care for your lawn can have a dramatic impact on the ecosystem in and around your waterbody, not to mention the demands upon your time and resources.

The following describes both the restrictions on fertilizer use imposed by the New Hampshire Comprehensive Shoreland Protection Act (CSPA), and many tips on how to maintain a healthy and yet low impact (and low maintenance) lawn.

Fertilizers and The Comprehensive Shoreland Protection Act

Fertilizers can contaminate surface and groundwater. The phosphorus and nitrogen in fertilizers are nutrients that not only promote grass growth but also promote excessive growth of algae in surface waters. This reduces clarity of the water and ultimately threatens survival of fish and other aquatic life (see **WD-BB-3 *Lake Eutrophication***). Since phosphorus is the nutrient which can most adversely effect New Hampshire's waterbodies and coastal areas, proper use and application of fertilizer is extremely important.

The Act prohibits the use of all fertilizers except limestone within 25 feet of the reference line of public waters . Twenty-five feet beyond the reference line, low phosphate, slow release nitrogen fertilizer or limestone may be used (see fact sheet **WD-SP-4** for *Shorelands Under the Jurisdiction of the Comprehensive Shoreland Protection Act*).

Common Lawn Care Mistakes

Water: Grass does need water, but improper watering can cause problems for a lawn such as diseases and shallow root structure. A shallow root structure may not be able to hold on to the soil during runoff and is liable to cause an ongoing erosion problem. A healthy lawn requires one good soaking of up to an inch of water per week.

Fertilizer: Quick release fertilizers and pesticides can produce a green lawn in a short time. They may also, however, disturb the natural chemical and biological balance of the lawn. The Act only allows for the use of slow release, low phosphate fertilizer within the protected shoreland.

Mowing: One of the most neglected components of an otherwise healthy lawn is the lawn mower. If the tips of the grass have a jagged or uneven tip after mowing, the lawn mower blade is dull and must be sharpened.

Thatch: Grass clippings do not contribute to thatch accumulation. Thatch is a layer of undecomposed stems and roots that accumulates near the soil surface. According to a study by the University of Michigan, the rate at which thatch accumulates is determined by the type and vigor of the grass in the lawn. A thatch-prone bluegrass sod given abundant water and fertilizer, forms thatch more rapidly than other grasses given less care. Cutting back on fertilizer and watering less frequently may reduce thatch.

Proper Lawn Care in Protected Shoreland

1. Aerate the soil. Soil can naturally contain clay or be packed down. In these circumstances it is difficult for water and air to penetrate the soil. The best method of aerating utilizes a machine that removes small cylindrical cores of soil from the lawn allowing it to receive proper amounts of water and nutrients.

2. Test the pH of your soil. Plants are happiest and grow the best with a soil pH between 5 and 7. You can have your soil tested by UNH soils lab for a small fee. They will explain how to properly balance your soil pH.

3. Leave the grass clippings on the lawn. This is the best and most efficient way to fertilize your lawn. It will cut your mowing time by an average of 38 percent and reduces the amount of solid waste in landfills. It also naturally adds nutrients like nitrogen and potassium.

4. A single application of slow release, low phosphate fertilizer at the beginning of fall is adequate in most cases. Fertilizer may be applied no closer than 25 feet from the reference line.

5. Maintain your grass at 2 inches or more of height. The longer the grass, the deeper the roots. Deeper roots enable the grass to tap into a large volume of nutrients and moisture. Also the longer grass will shade and discourage weeds and helps a lawn survive heat and drought. Never cut more than one third of the height of the grass.

6. Keep a healthy well distributed stand of trees to keep grass from the full heat of the sun for too long. Seed mixes are available that are tolerant of lower light conditions. A shaded lawn requires less watering because grass is shielded from the sun's heat and will resist drying during the summer.

Alternative: Use ground cover as an alternative to grass. Ground cover can be hardier than grass, usually has a longer root system, and often stays green without the use of fertilizers.

ENVIRONMENTAL Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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WD-SP-1 2010

Erosion Control for Construction within the Protected Shoreland

EROSION IS A SERIOUS PROBLEM

Erosion is the process by which soil is carried by water or wind. When water carries soil into a waterbody, it not only fills in the waterbody, it contributes significant amounts of harmful nutrients as well. When vegetation and natural ground cover is removed or disturbed, erosion accelerates, overloading the waterbody with nutrients and sediments. This often contributes to excessive algae and aquatic weed growth resulting in dramatic reductions in water clarity and quality.

Erosion at construction sites is a leading cause of water quality problems in New Hampshire's waterbodies. Soils become vulnerable to erosion when construction activity removes or disturbs vegetative cover. These vegetative covers shield soil surface from the impact of rain, reduce the velocity of runoff, maintain the soil's capacity to absorb water, and hold soil particles in place. By limiting and phasing vegetation removal during construction, soil erosion can be significantly reduced.

The New Hampshire Comprehensive Shoreland Protection Act (CSPA, RSA 483-B) was established to protect New Hampshire's lakes, ponds, rivers, and estuaries. The CSPA requires that all excavation, earth moving and filling activities within the protected shoreland (250 feet from the waters edge) must have appropriate erosion and sedimentation controls in accordance with the Alteration of Terrain Program (RSA 485-A:17 and Env-Wq 1500). This fact sheet explains some methods to limit erosion during construction within the protected shoreland.

Problems caused by sediments and nutrients include:

- **Lower Property Values**: Property values may decline when a lake, pond or stream fills with sediment. Shallow areas encourage weed growth and create boating hazards.
- **Poor Fishing**: Sediments and nutrients reduce fish populations by clouding the water, covering spawning beds, increasing unwanted aquatic plant growth and decreasing the quantity of oxygen in the water critical for fish survival.
- **Nuisance Growth of Weeds and Algae**: Sediments carry nutrients that feed algae and aquatic weeds including exotic species such as milfoil.
- **Loss of Tourism**: Shallow, mucky lakes, ponds and streams are not attractive to tourists or local residents.
- **Local Tax Impacts**: Cleaning up sediment in streets, sewers and ditches adds extra costs to local government budgets.

PREVENTING EROSION IS EASY

- Erosion control is important to protect the quality of New Hampshire's public waters. The materials needed are easy to find and are relatively inexpensive: hay bales or silt fence, stakes, mulch, gravel, and grass seed.
- Putting these materials to use is a straight forward process. Only a few controls are needed on most sites.
- **Silt Fence or Hay Bales**: These are used to trap sediment on the down slope side of the lot. Proper installation is the key to success.
- **Hay/Straw Mulch**: This is used to cover disturbed soil and prevent erosion, promotes seed growth.
- **Temporary Diversions**: These structures route clean water from up slope areas around the site.
- **Soil Pile Location**: Locate erodable materials away from any roads or waterways.
- **Gravel Drive**: Use gravel to limit the tracking of mud onto streets. Use of geotextiles under gravel stops pumping of gravel into underlying sediment and saves on maintenance.
- **Cleanup**: Reclaim sediments that are carried off site by vehicles or storms.
- **Downspout Extenders**: These prevent erosion from roof runoff and safe outlets to prevent scour. Vegetation, stone basins, and level spreaders are useful in outlet protection.
- **Vegetation**: Preserve existing trees, vegetation and natural ground cover where possible to prevent erosion.
- **Revegetation**: Replant and seed sites as soon as possible with natural or native species. Do not underestimate the success of frost seeding and mulch as an alternative to leaving a slope bare until spring planting season.

HAY BALE OR SILT FENCE

- Put up before any other work is done.
- Install on down slope side(s) of site with ends extended up side slopes a short distance.
- Place parallel to the contour of the land to allow water to pond behind the fence.
- Entrench 4 inches deep (see back page). Stake (2 stakes per hay bale or 1 stake every 3 feet for silt fence).
- Leave no gaps between hay bales or sections of silt fence.
- Inspect and repair once a week and after every ½ inch rain. Remove sediment if deposits reach half the fence height.
- Maintain until lawn is established or soil is stable.

HAY/STRAW MULCH

- Place sufficient amount on disturbed soils as soon as possible so that surface of soil is not visible.
- On small areas hold mulch by wetting, stakes, or string.
- Required for seeding outside normal seeding season.

TEMPORARY DIVERSION OF RUNOFF

- Install diversion upslope of disturbed areas where runoff is coming onto property from upslope areas.
- Should be 1 to 2 feet deep with 1 foot bottom width and 3:1 side slope.
- Do not use to intercept intermittent or perennial streams or dam wetland areas.
- Stabilize with erosion control matting prior to use.

- Install diversions that divert runoff into vegetated areas.

SOIL PILES

- Locate away from steep slopes, any down-slope street, driveway, stream, lake, wetland, ditch, or drainage way.
- Temporary mulch seed such as annual rye, oats, or winter (cereal rye) is recommended for topsoil piles.
- Slash piles are not allowed within 50 feet of the reference line of any waterbody.

GRAVEL DRIVE

- Install a single access drive using 2 to 3 inch aggregate.
- Lay gravel 6 inches deep and 7 feet wide from the foundation to the street (or 50 feet if less).
- Use to prevent tracking dirt onto the road by all vehicles.
- Maintain throughout construction.

SEDIMENT CLEANUP

By the end of each work day or after a storm, sweep or scrape up soil tracked onto the road or use a gravel buffer strip between construction site and paved road.

DOWNSPOUT EXTENDERS

- Ground gutters (lined outlets on the ground under the dripeaves) work well also.
- Highly recommended for sites with steep slopes.
- The key to either system is an adequately protected outlet.
- Install as soon as gutters and downspouts are completed.
- Route water to a vegetated area.
- Maintain until lawn is established or soil is stable.

REVEGETATION

- Seed, sod or mulch bare soil as soon as possible.
- Replant with native or naturalized species.
- If using light mulch (prone to wind movement), use a tuckifier or krimp by tracking with a bulldozer to keep mulch in place.
- Erosion control blankets, although more costly, are extremely effective and can be purchased already impregnated with seed.

SEEDING AND MULCHING

- Spread 6 inches of topsoil.
- Fertilizer cannot be used within 25 feet of public waters. Plant natural vegetated buffers that does not require fertilizers.
- Twenty-five feet beyond the reference line, low phosphate, slow release nitrogen fertilizer or limestone, may be used on lawns or areas with grass.

TIMING IS CRUCIAL

- Fertilization should not be done until vegetation has germinated. If site is fertilized in winter and planted in spring, all value of fertilizer will have leached by the time of planting.
- Seed with an appropriate mix for the site (see table).
- Rake lightly to cover seed with 1/4" of soil. Roll lightly.
- Mulch with hay or straw (70-90 lb. or one bale per 1000 sq. ft.).Tack mulch if prone to wind erosion.
- Anchor mulch by punching 2 inches into the soil with a dull, weighted disk or by using netting or other measures on steep slopes.
- Water gently every day or two to keep soil moist. Less watering is needed once grass is 2 inches tall. (This is when fertilizer should be applied.)

SODDING

- Spread 6 inches of topsoil and lightly water the soil.
- Lay sod. Tamp or roll lightly.
- On slopes, lay sod starting at the bottom and work toward the top. Peg each piece down in several places.
- Initial watering should wet soil 6 inches deep (or until water stands 1 inch deep in a straight-sided container). Then water lightly every day or two for 2 weeks.
- If construction is completed after September 15, seeding or sodding may be delayed. Applying mulch or temporary seed (such as rye or winter rye) is recommended if weather permits. Hay bales or silt fences must be maintained until final seeding or sodding is completed in the spring (by June 1) or until all soils are stable.

PRESERVING EXISTING VEGETATION

- Wherever possible, preserve existing trees, shrubs, and other vegetation.
- To prevent root damage, do not grade, place soil piles, or park vehicles near trees marked for preservation.
- Use top diameter of canopy as guideline to root width.
- Under the Shoreland Protection Act, stumps cannot be removed within 50 feet of the reference line.
- Place plastic mesh or snow fence barriers around trees to protect the trees and the area directly below their branches-using canopy diameter as the guideline for distance from the trunk needing protection.

Seed	Seeding Rates (Lbs./1000sq.ft.)	Seeding Rates (Lbs/Ac.)	Recommended Seeding Dates
Winter Rye	2.6	112(2.0bu)	8/15-10/1 (FALL)
Oats	2	80(2.5bu)	4/1-7/1 8/15-9/15
Annual Ryegrass	1	40(1.0bu)	4/1-6/1
Perennial Ryegrass	0.7	30(1.5bu)	4/1-6/1 8/15-9/15

For more information, contact NHDES Wetlands Bureau, Shoreland Protection Program (603) 271-2147, or go to www.des.nh.gov and search in the A to Z List for “Shoreland Protection.”

Information taken, in part, from a publication of the University of Wisconsin-Extension, in cooperation with the Wisconsin Department of Natural Resources. May 1997

A Shoreland Homeowner's Guide to Stormwater Management

~ *protecting your home & environment* ~

NH Department of Environmental Services
29 Hazen Drive, Concord, NH 03301 • 603.271.3503 • www.des.nh.gov

Introduction

The recently revised Comprehensive Shoreland Protection Act (CSPA), which was enacted to help protect the state's surface waters, includes limits on development that contribute to stormwater runoff. If you are a shoreland homeowner, your property may produce stormwater runoff that directly impacts the quality of our public waters. However, you can reduce or prevent polluted stormwater runoff. This guide provides several simple and cost effective practices that shoreland homeowners can install to address stormwater runoff from roofs, patios, lawns and driveways. These practices can be used to meet the provisions of the CSPA. The guide also includes general information about what state environmental permits, if any, are necessary for incorporating these practices.

What is Stormwater Runoff?

Stormwater runoff describes the flow of rainwater or meltwater from snow or ice over the land's surface.

Polluted stormwater runoff flowing into a storm drain.

On undisturbed sites, much of the stormwater is intercepted by natural ground cover or is absorbed into the ground. Land clearing and development reduces the capacity of the land to absorb rainwater and snowmelt, which leads to more water flowing over the land and into surface waters.

As water flows over the land, it picks up exposed soil as well as any chemicals, fertilizers or pollutants that are present. Stormwater carries these polluting substances over impervious surfaces and through storm drains and drainage ditches. Impervious surfaces are surfaces that cannot effectively absorb and infiltrate water. Examples of impervious surfaces include, but are not limited to, roofs, decks, patios and paved, gravel or crushed stone driveways, parking areas and walkways unless designed to effectively absorb and infiltrate water. This flow of stormwater eventually reaches a body of water, where the sediments, nutrients and pollutants are deposited.

10 in One!

Please note that this document is actually 10 articles in one: an introductory document and nine guidance sheets, which may be printed out altogether or separately. They are:

Alteration of Terrain Permits

The Alteration of Terrain (AoT) permit protects New Hampshire surface waters, drinking water supplies, and groundwater by controlling soil erosion and managing stormwater runoff from developed areas. This permitting program applies to earth moving operations, such as industrial, commercial, and residential developments as well as sand pits, gravel pits, and rock quarries.

Permits are issued by DES after a technical review of the application, which includes the project plans and supporting documents. An AoT permit is required whenever a project proposes to disturb more than 100,000 square feet of contiguous terrain (50,000 square feet, if any portion of the project is within the Protected Shoreland) or disturbs an area having a grade of 25 percent or greater within 50 feet of any surface water. In addition to these larger disturbances, the AoT General Permit by Rule applies to smaller sites.

To determine if an AoT permit may be necessary for the work that you plan to conduct, contact the AoT Program at (603) 271-3434. For more information, please click on the program's name in the "A to Z List" at www.des.nh.gov.

STATE OF NEW HAMPSHIRE
American Recovery and Reinvestment Act
NHRECOVERY

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NHDES-WD-10-8

How Does Stormwater Runoff Affect Surface Waters?

As stormwater flows overland as runoff, it picks up and carries a load of sediment, nutrients and pollutants. The faster and more concentrated the flow, the greater the load that stormwater runoff can carry.

Stormwater runoff from developed areas may carry pollutants such as exposed soil, sediment and organic matter; chemicals, fertilizers and herbicides from lawns; animal wastes, cigarette butts and other litter; road salt, chemicals and oil from paved surfaces; and grass clippings, leaves and other yard waste. Stormwater carries these substances through pipes, drains and ditches and eventually into lakes, ponds, rivers and streams. Stormwater slows down after entering a waterbody and deposits the load of nutrients, bacteria, toxic substances, sediment, and other pollutants into the surface water.

Stormwater runoff can cause water quality declines in the following ways:

1. NUTRIENTS: Runoff from fertilized lawns, landscaped yards and agricultural fields into waterbodies contributes large quantities of nutrients to waterbodies. Sewer systems as well as pet and wildlife waste can also contribute excess nutrients. These nutrients accelerate algal and cyanobacteria blooms and fuel the increased growth of aquatic plants, which promotes declines in water clarity and dissolved oxygen which can impact aquatic species and cold water fisheries in particular.

2. BACTERIA: Bacteria from human and animal waste can contaminate surface waters and lead to beach closures, shellfish bed closures and other measures to protect public health.

3. TOXIC SUBSTANCES: Industrial and agricultural pollutants, including ammonia, metals, organic compounds, pesticides, nitrates and salts, can harm wildlife and also pose a contamination threat for groundwater and public drinking water supplies.

4. SEDIMENT: Heavy loads of eroded sediment deposited into waterbodies can smother aquatic habitat, decrease water clarity, increase water temperature and cause the depletion of dissolved oxygen in the water column.

Protecting Water Quality through the Comprehensive Shoreland Protection Act

The Comprehensive Shoreland Protection Act (CSPA), RSA 483-B, was enacted to protect the water quality of New Hampshire's surface waters by managing the disturbance of shoreland areas.

To reduce the transport of nutrients, sediments and other pollutants into the State's surface waters, the CSPA seeks to maintain a shoreland buffer of natural vegetation to protect against the potentially harmful effects of stormwater runoff.

The CSPA applies to all fourth order and greater streams, designated rivers, tidal waters and lakes, ponds and impoundments over 10 acres in size. DES maintains an inventory of these waterbodies in the Consolidated List of Water Bodies subject to RSA 483-B, which may be found at http://des.nh.gov/organization/divisions/water/wetlands/cspa/water_bodies.htm.

Around these waterbodies, the CSPA applies to development and land use activities within 250 feet of the water's edge or high water mark, called the reference line. This area is referred to as the "Protected Shoreland." Within the Protected Shoreland, the CSPA requires:

- A waterfront buffer with minimal disturbance to natural vegetation and natural groundcover within 50 feet of the Reference Line.
- A natural woodland buffer retaining a certain percentage of vegetation in an unaltered state between 50 and 150 feet of the Reference Line.
- Limitations on impervious surfaces, lot subdivision, excavation and filling within 250 feet of the Reference Line.

According to the CSPA, lots within the Protected Shoreland may not have greater than 30 percent impervious surface coverage. If a project within the Protected Shoreland proposes an impervious surface coverage of more than 20 percent, then a stormwater management system must be implemented and maintained to

Wetlands Permits

If you plan to conduct work in the state's surface waters or in the bank of a lake, pond or river, you need to secure a Wetlands Permit prior to starting the activity. The bank is the transitional slope immediately adjacent to the edge of a surface water body, the upper limit of which is usually defined by a break in slope. RSA 482-A authorizes DES to protect wetlands and surface waters by requiring a permit for dredge, fill or construction in wetlands and waterbodies. A Wetlands Permit is required for any alteration of tidal or non-tidal wetlands. Permits are issued by the Wetlands Bureau after a technical review of the application and confirmation that the proposed activities meet the statutory requirements. The applicant must demonstrate that potential impacts have been avoided to the maximum extent practicable and that any unavoidable impacts have been minimized. Impacts that are specifically covered by a Wetlands Permit or a Wetlands Permit by Notification will not need a Shoreland Permit.

Most of the small-scale stormwater management structures included in this guide would be installed above the top of the bank; however, if you plan to install infiltration steps or a path or walkway, these structures may be installed in the bank.

To determine if your plan requires a Wetlands Permit, contact the Wetlands Program at (603) 271-2147, or click on the program's name in the "A to Z List" at www.des.nh.gov.

Shoreland Permits

The DES Shoreland Program implements RSA 483-B, the Comprehensive Shoreland Protection Act (CSPA). The CSPA establishes minimum standards for activities within the Protected Shoreland that are designated to protect the water quality of the state's larger water bodies and to fulfill the state's role as a trustee of those waters. The Shoreland Program provides multiple services to the public. Permitting staff review shoreland permit, waiver and variance requests for compliance with the CSPA. The review process is designed to provide a level of oversight for construction, fill and excavation activities to ensure that projects are carried out in a manner that protects water quality.

New construction or construction that modifies the footprint of existing impervious surfaces on a lot within the protected shoreland, using mechanized equipment to either excavate, remove or form a cavity within the ground with the protected shoreland and filling any area within the protected shoreland with rocks, soil, gravel or sand requires a shoreland permit. None of the practices included in this guide would require a permit if they are installed using hand tools and are located above the bank of the lake or river.

To determine if your work plan will require a Shoreland Permit, contact the Shoreland Protection at (603) 271-2147 or shoreland@des.nh.gov. For more information, please click on the program's name in the "A to Z List" at www.des.nh.gov.

effectively absorb and infiltrate the post-construction stormwater that would occur as a result of the new impervious surfaces. A "stormwater management system" includes stormwater treatment prcatices, stormwater conveyences and groundwater recharge practices.

When to Use Stormwater Management Practices

If you plan to expand existing structures, construct new structures or develop a previously undeveloped lot within the Protected Shoreland, employing the stormwater management practices included in this guide may be an effective means of satisfying the statutory requirement for projects that exceed 20 percent impervious surface coverage. For example, if a property owner wishes to construct a new garage and upon completion of the project the total area of imperviousness of the lot within the Protected Shoreland exceeds 20 percent, the CSPA requires the implementation of a stormwater management system. The management system must be constructed and maintained to allow the infiltration of stormwater that would result from the additional impervious area.

It is important to note that many of the stormwater practices discussed in this guide such as the walkways and infiltration trenches are considered pervious surfaces and are not taken into consideration when determining the total area of imperviousness of the lot within the Protected Shoreland.

For new or undeveloped parcels, the practices included in this guide could be installed so as to not exceed the 20 percent impervious surface area or they could be used in a stormwater management system thereby allowing the property owner to cover up to 30 percent of the lot with impervious surfaces.

What Permits are Necessary?

When planning to install one of the stormwater management practices described in this guide, homeowners should consult with their municipal planning department, building inspector or code enforcement officer to determine if local permits are necessary.

At the state level, there are three DES programs with overlapping jurisdictions, the Alteration of Terrain Program (AoT) (RSA 485-A:17), the Wetlands Program (RSA 482-A), and the Shoreland Program (RSA 483-B). See side bars for information on permits.

This document was prepared by the DES Shoreland Protection Program and the Lakes Management and Protection Program in partnership with the Upper Valley Lake Sunapee Regional Planning Commission.

DRIPLINE TRENCH

~ managing roof runoff on homes without gutters ~



Purpose

Dripline trenches collect and infiltrate stormwater, and control erosive runoff from the rooftop. The trenches collect roof runoff and store it until it soaks into the soil. These systems also minimize wear on your house by reducing back splash.

Also known as a roof dripline trench and an infiltration trench.

Materials

Crushed stone and non-woven geotextile fabric. Other geotextiles, including landscaping weed barrier, can be substituted for smaller projects.

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

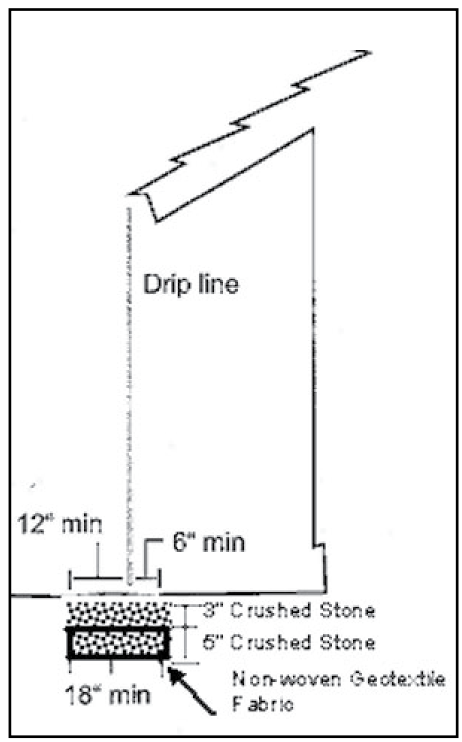
Funding provided by the American Recovery and Reinvestment Act under Section 604(b) of the Clean Water Act. Guidance sheets used with permission from the Maine Department of Environmental Protection.

Installation

1. Dig a trench that is 18" wide and at least 8" deep along the drip line. Slope the bottom away from the house so that water will drain away from the foundation. Make sure to dispose of the soil in a flat area where it cannot be washed into lakes and streams. The front and sides of the trench may be edged with stone or with pressure-treated lumber to hold the stones in place.

2. Extend the life of the dripline trench by lining the sides with non-woven geotextile fabric.

3. Fill the trench with ½" -1½" crushed stone and to within 3" of the ground level. Fold a flap of non-woven geotextile fabric over the top of the trench and top off with additional stone.



Note: Dripline trenches work best in sand and gravel soils that can quickly disperse a large volume of water. They should not be used on structures with improperly sealed foundations, as flooding may result.

Maintenance

To maintain these structures, periodically remove accumulated debris and weeds from the surface. Trenches lined with non-woven geotextile fabric will require less frequent maintenance, however, they will still clog over time and the stone will need to be removed and washed to clean out the accumulated sediment and debris.

DRYWELLS

~ managing roof runoff on homes with gutters ~

Purpose

Drywells collect and infiltrate runoff at gutter downspouts and other places where large quantities of concentrated water flow off rooftops. These systems help control erosive runoff on your property, and reduce wear on your house by minimizing back splash.

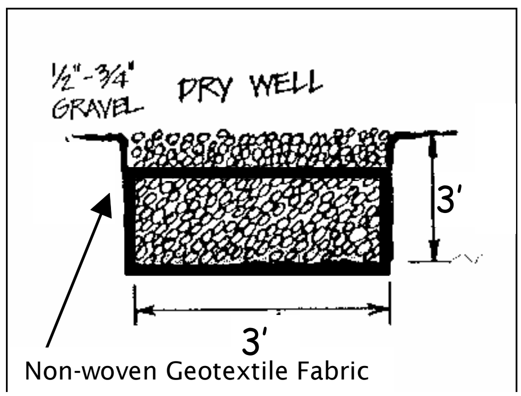
Materials

Crushed stone and non-woven geotextile fabric. Other geotextiles, including landscaping weed barrier, can be substituted for smaller projects.

Installation

1. Drywells should measure about 3’ x 3’ x 3’, be lined with non-woven geotextile fabric and back-filled with 1/2” to 1½” crushed stone.

2. Slope the bottom of the drywell away from the house so that water does not drain towards the foundation. Make sure to dispose of the removed soil in areas where it will not wash into lakes and streams.



3. Extend the life of the dry well by lining the sides with non-woven geotextile fabric and filling to within 3” of the ground level with stone. Fold a flap of filter fabric over the top of the dry well and top off with additional stone.

4. Direct gutter downspout to the drywell.

Note: Drywells work best in sand and gravelly soils that can quickly disperse a large volume of water. They should not be used on structures with improperly sealed foundations, as flooding may result. If flooding is of concern, place the drywell 6’ away from the base of the foundation.

Maintenance

To maintain these structures, periodically remove accumulated debris and weeds from the surface. Non-woven geotextile fabric will extend the life of these structures, however, they will eventually clog over time and the stone will need to be removed and washed to clean out the accumulated sediment and debris.

New Hampshire Department of Environmental Services

Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

Funding provided by the American Recovery and Reinvestment Act under Section 604(b) of the Clean Water Act. Guidance sheets used with permission from the Maine Department of Environmental Protection.

INFILTRATION STEPS – new
~ controlling erosion on steep paths ~

Purpose

Infiltration steps use crushed stone to slow down and infiltrate runoff; they're built with timbers and filled with crushed stone or pea stone. They are effective on moderate slopes, but consider building wooden stairways on 1:1 slopes (45˚) or areas where rocks or surface roots make it difficult to set infiltration steps in the ground.

Materials

Crushed stone and pea stone; non-woven geotextile fabric. Other geotextiles, including landscaping weed barrier, can be substituted for smaller projects. Pressure treated timbers, cedar landscape timbers and steel rebar.

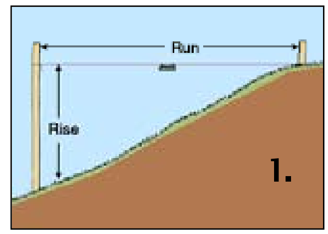
Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

Funding provided by the American Recovery and Reinvestment Act under Section 604(b) of the Clean Water Act. Guidance sheets used with permission from the Maine Department of Environmental Protection.

Installation

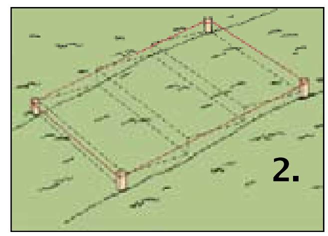
1. Calculate the Rise and Run of Each Step

First, measure the overall rise and run of your steps in inches. The step height is determined by the 6" thickness of the timber. Divide the rise by 6 and round off to the nearest whole number to determine the number of steps. Divide the run by the number of steps to determine step width. A comfortable width will be at least 15".



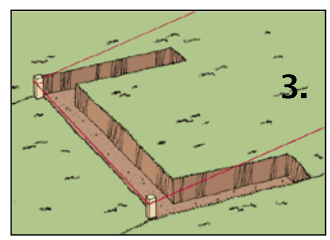
2. Stake Out the Steps

Figure out the step width. A 4' width is comfortable for one person. Paths must no more than 6' wide in the waterfront buffer. Drive stakes at each corner of the stairway and stretch string between them to outline the steps. Spray paint or sprinkle sand or flour on the ground to mark the outline.



3. Excavate the First Step

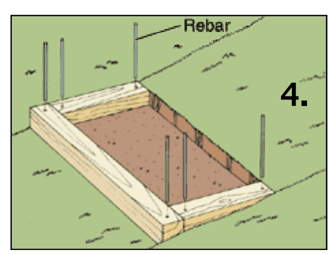
Starting at the bottom, dig a trench for the first timber (this will be little more than a shallow groove in the ground). Next, dig trenches for the side timbers, which need to be long enough to extend 6" past the next step's riser. Check to make sure the trenches are level.



Note: Infiltration steps may not require side timbers, especially if the steps are in an eroded pathway where the surrounding land is higher. In this case, extend the timbers into the adjacent banks so water will not go around the steps.

4. Cut the Timbers

Cut the riser timber to length, then measure and cut the side timbers. Drill ½" diameter holes 6" from the ends of each timber. Position the step, then remove or add soil as needed to level it. Anchor the step by driving 18" long pieces of ½" diameter steel rebar through the holes and into the ground. Make sure the rebar

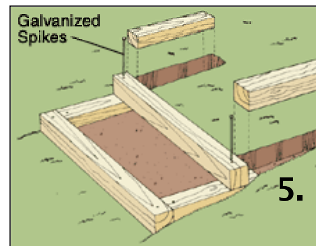


Continued on back

is flush or slightly recessed since the edges may be sharp. Set the side timbers in place, and level and anchor them.

Shovel out the soil inside the step to create a surface roughly level with the bottom of the timbers. Additional soil can be removed to provide more area for infiltration. Make sure to dispose of excavated soil in a place where it will not wash into lakes or streams.

5. Build the Next Step



Measure from the front of the first riser to precisely locate the second riser. Dig a trench for the riser, and trench back into the hill for the sides, as before. Set the riser roughly in place with the ends resting on the side timbers below. The riser is attached to the side timbers below it with 12” galvanized spikes. Drill a pilot hole about 5” into the riser, and spike the riser into the side timbers below. Set the side timbers, drill ½” holes and pound in 18” rebar pieces into the ground as with the first step.

Excavate between the sides, as before. Continue up the hillside in this fashion. When installing the top step, cut the side timbers 6” shorter than the ones on the lower steps - these timbers do not need the extra length since no stairs will rest on them.

6. Lay Down Geotextile Fabric and Backfill with Stone

Line the area inside each set of timbers with non-woven geotextile fabric. This felt-like fabric will allow water to percolate through but will separate the stone from the underlying soil. Make sure the fabric is long enough to extend a few inches up the sides of the timbers.

Fill each step with ¾” crushed stone or pea stone until it is about 1” below the top of the timber. This lip will break up water flow and encourage infiltration. Pea stone is comfortable for bare feet but may be more expensive and more difficult to find. Paving stones can also be set into crushed stone to provide a smooth surface for bare feet - as long as ample crushed stone is exposed to allow infiltration.

Seed and/or mulch bare soil adjacent to the steps. Planting areas adjacent to the steps with shrubs and groundcover plants soften the edges and help prevent erosion.

Maintenance

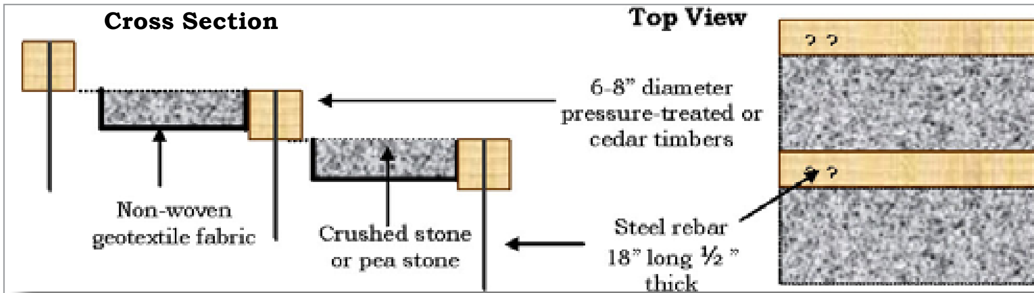
Replace rotten timbers. If the crushed stone or pea stone becomes filled up with sediment over time, remove, clean out sediment and replace.

INFILTRATION STEPS – retrofit

~ retrofitting steps to control erosion on paths ~

Purpose

Infiltration steps use crushed stone to slow down and infiltrate run-off. They are effective on moderate slopes, but consider building wooden stairways on 1:1 slopes (45˚) or areas where rocks or surface roots make it difficult to set infiltration steps into the ground.



Materials

Crushed stone and pea stone can be purchased from gravel pits. Other geotextiles, including landscaping weed barrier, can be substituted for smaller projects. Pressure treated timbers, cedar landscape timbers and steel rebar can be purchased from lumber and hardware stores. Some stores will cut rebar to the specified length for a small fee. Otherwise, rebar can be cut with a hack saw.

Installation

Infiltration steps are steps built with timbers and backfilled with crushed stone or pea stone to help water soak into the ground. Many existing timber steps can be retrofitted to create infiltration steps by making the following changes.

1. Remove several inches of soil from behind each step. Dispose of excavated soil in a place where it will not wash into lakes or streams.

2. Line the bottom and sides of the excavated area with non-woven geotextile fabric. This felt-like fabric allows water to infiltrate but will separate the stone from the underlying soil.

3. Backfill the hole with washed ¾" crushed stone or pea stone so that the tread is level or it just slightly slopes up to meet the above step. Pea stone is comfortable on bare feet but also usually more expensive. Paving stones can also be set into crushed stone to provide a smooth surface for bare feet - as long as ample crushed stone is exposed to allow infiltration.

4. If the timbers are not firmly secured, drill ½" diameter holes, 6" from the ends of each timber. Drive ½" diameter, 18" long steel rebar through the holes with a sledge hammer. For gentle slopes, wooden stakes or large rocks can also secure the timbers.

Maintenance

Replace rotten timbers. If the crushed stone or pea stone becomes filled up with sediment over time, remove, clean out sediment and replace.

Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

Funding provided by the American Recovery and Reinvestment Act under Section 604(b) of the Clean Water Act. Guidance sheets used with permission from the Maine Department of Environmental Protection.

INFILTRATION TRENCH
~ retrofitting steps to control erosion on paths ~

Purpose

Infiltration trenches collect and infiltrate runoff from paved driveways, rooftops and other areas, and work best in well-drained soils like sands and gravels. Also, they can only effectively handle smaller rainfall events, so are not well suited for areas that receive large amounts of sediment (e.g., gravel driveways) as they will fill in quickly.

Materials

Crushed stone can be purchased at your local gravel pit. Contact your local Soil and Water Conservation District for suppliers of non-woven geotextile fabric. Other geotextiles, including landscaping weed barrier, can be substituted for smaller projects.

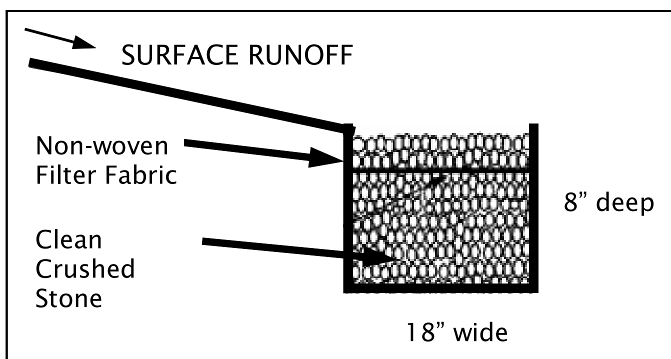
Installation

1. Dig a trench that is 18" wide and at least 8" deep. Make sure to dispose of the soil in a flat area where it cannot be washed into lakes or streams. The front and sides of the trench may be edged with stone or lumber to hold the stones in place.

2. Extend the life of the infiltration trench by lining the sides with non-woven geotextile fabric.

3. Fill to within 3" of the ground level with ½" to 1½" crushed stone.

4. Fold a flap of non-woven geotextile fabric over the top of the trench and top off with additional stone.



Maintenance

To maintain these structures, periodically remove accumulated debris and weeds from the surface. Non-woven geotextile fabric will extend the life of these structures, however, they will eventually clog over time and the stone will need to be removed and washed to clean out the accumulated sediment and debris.

New Hampshire Department of Environmental Services

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PATHS & WALKWAYS

~ managing foot traffic for lake protection ~

Purpose

Properly designed pathways direct foot traffic, absorb water, reduce the rate of flow, and protect soil. Pathways can also reduce the potential for erosion, and minimize the amount of pollutants flowing from your property into local streams and lakes.

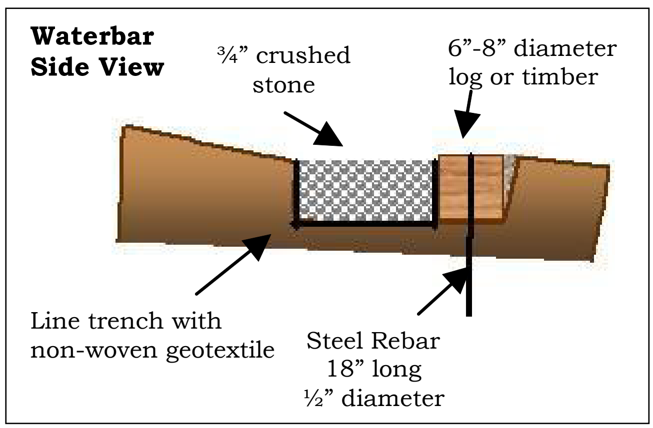
Materials

A mix of wood fibers, soil and gravel, which holds up to runoff and has a natural look. One option for pathway materials includes setting stepping stones into a crushed stone base. The crushed stone allows runoff to infiltrate, and the stepping stones are comfortable for bare feet.

Installation

Install narrow, meandering pathways in high-use areas. Reroute paths that go directly down steep slopes or install steps or water bars to break up the slope.

- Ideally, paths should be no more than 3'-4' wide. In the waterfront buffer, new paths can be no more than 6' wide.
- The walking surface should be covered with 3"-4" of material such as an erosion control mix, pine needles, bark mulch, crushed stone, wood chips, or other material. This will define the path, guide foot traffic, and reduce soil erosion.
- Paths should be meandering, depending on the slope, to provide opportunities for runoff to disperse into adjacent vegetation.



- New paths can be clearly marked with strategic plantings, stones, solar lights, etc. along the edges.
- Install waterbar "speed bumps" to break up the slope and keep water from concentrating on a pathway. Fill behind with crushed stone to help runoff soak into the ground and direct water into vegetated areas. Extend logs or timbers past the outside edge of both sides of the path and install at a 30-degree angle. Secure the waterbar with large stones on the downhill side and/or pound in with pieces of rebar steel.

Maintenance

To maintain these structures, periodically remove accumulated debris from the surface. Mulched pathways may need to be re-shaped and additional material may be needed to replace what has washed or worn away. Using non-woven geotextile fabric below stone pathways will extend their life.

New Hampshire Department of Environmental Services

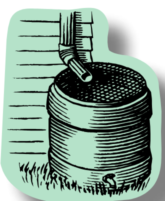
Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

Funding provided by the American Recovery and Reinvestment Act under Section 604(b) of the Clean Water Act. Guidance sheets used with permission from the Maine Department of Environmental Protection.

RAIN BARRELS
~ managing roof runoff in your backyard ~

Purpose

Rain barrels provide an innovative way to capture rainwater from your roof, and store it for later use. Water collected from rain barrels can be used to water lawns, gardens and indoor plants. This water would otherwise run off your roof or through downspouts and become stormwater, picking up pollutants on its way to a storm drain, stream or lake. You can lower your water bill, conserve well water in the dry season, and reduce polluted stormwater runoff.



Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

Funding provided by the American Recovery and Reinvestment Act under Section 604(b) of the Clean Water Act. Guidance sheets used with permission from the Maine Department of Environmental Protection.

Materials

Rain barrels are available in many sizes and styles, and range in price from $80 to over $200. Contact your local hardware store, garden center or nursery, or order a rain barrel on-line.

Building your own rain barrel is usually the least expensive option. Several web sites exist with material lists and clear directions.

Finally, you can simply use an open barrel to collect rainwater. However, you should use the water within two weeks before mosquitos have an opportunity to hatch.

Installation

1. Place rain barrel on a level surface. If you have gutters, place the rain barrel beneath the downspout so the water flows onto the screen on top of the barrel. You may need to have your downspout cut to an appropriate height above your rain barrel. If you do not have gutters, find a location where water concentrates from your roof and place the rain barrel where it will capture this steady stream of water during rain storms.

2. Elevate your rain barrel by placing it on cinder blocks or a sturdy wooden frame. Raising the barrel allows the barrel to drain properly, and you can easily fit a watering can underneath the spout or attach a hose to the spout. Soaker hoses attached to rain barrels will slowly release water into gardens and recharge groundwater.

Maintenance

Gutters and downspouts should be clean of debris. Leaves and pine needles can clog gutters and prevent water from reaching the rain barrel. Furthermore, check the screen on the rain barrel after each storm event and remove debris that has plugged the screen.

Freezing water can damage your barrel. Rain barrels should be drained and stored before freezing weather sets in to prevent ice damage. They can be stored outside if they are turned upside down and the faucet is covered. Be sure to put something heavy on your rain barrel so it doesn't roll away. Rain barrels can also be stored inside a garage or other protected area.

WATER BARS

~ diverting water off paths and trails ~

Purpose

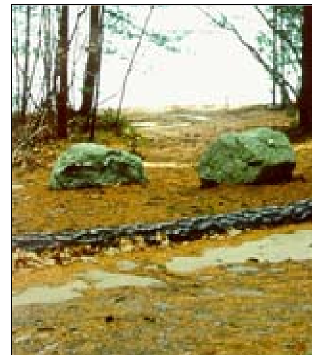
A water bar intercepts water traveling down footpaths, trails and other areas and diverts it into stable vegetated areas.

Materials

Fallen rot-resistant timbers can often be found on site. Pressure treated timbers, cedar landscape timbers and steel rebar can be purchased from lumber and hardware stores.

Contact your local soil and water conservation district for suppliers of non-woven geotextile fabric. Other geotextiles, including landscaping weed barrier, can be substituted for smaller projects.

Installation



Install water bars on moderately steep paths with concentrated flows. Select a location where the water bar outlet can drain to a stable, vegetated area. Install multiple water bars as needed and space closer together on steeper slopes as directed in Table 1.

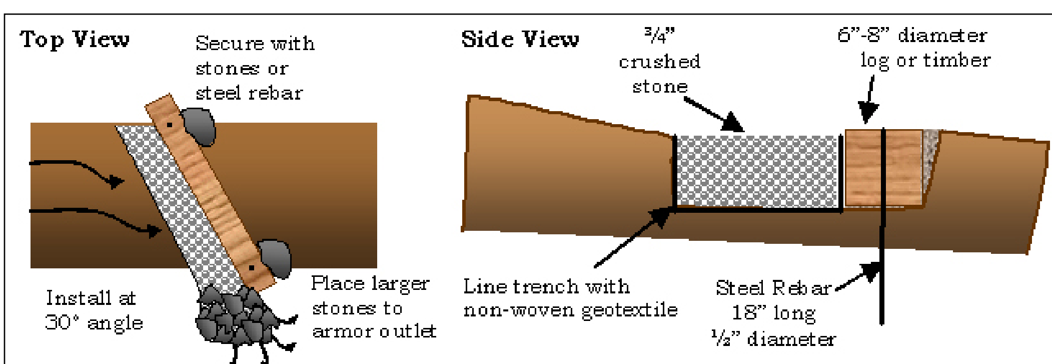
Any rot-resistant type of wood, such as cedar, spruce, fir or hemlock logs can be used. For logs, the diameter should be at least 8" at the small end. 6" to 8" diameter, pressure treated or cedar timbers can also be used. The length should extend past the edge of the path on both sides. Install water bars as follows:

Table 1. Water Bar Spacing

% Grade	Spacing Between Water Bars (in feet)
2	250
5	130
10	80
15	50
25+	40

1. Dig the trench – First, dig a trench for the wood that is a 30° angle across the path. Be sure the trench and the water bar extends off both sides of the path. The trench should be deep enough so the top of the log will be almost flush with the trail on its downhill side once in place. Soil and rock excavated from the trench should be heaped on the trail below the water bar to be used later as backfill.

2. Install the log or timber – Place the log or timber in the trench. The log should fit snugly in the trench with no high point or voids under the log. Secure the water bar with large stones, rebar pins or wooden stakes. If using stones, partially bury on downhill side. If using rebar, drill ½" holes 6" in from each edge and pound in 18" pieces of ½" rebar so that the rebar is flush or slightly recessed with the top.



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Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

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WATER BARS
~ continued ~

3. Backfill around the water bar – Dig a 12" wide and 6" deep trench along the up-hill side of the bar. Fill the trench with crushed stone, leaving a few inches of the timber exposed. Place a flared apron of stones to armor the water bar outlet. Pack soil and gravel up against the downhill side of the water bar so that the top of it is flush with the trail. Cover all disturbed soil with seed and mulch or leaf litter.

Maintenance

Water bars should be checked periodically and after storm events to ensure that material is not eroding behind the structure or at the outlet. Any needed repairs should be made as soon as possible. Periodically remove accumulated leaves and debris from behind the water bar.

RAIN GARDENS

~ managing roof runoff in your backyard ~

Purpose

Rain gardens are attractive and functional landscaped areas that are designed to capture and filter stormwater from roofs, driveways, and other hard surfaces. They collect water in bowl-shaped, vegetated areas, and allow it to slowly soak into the ground. This reduces the potential for erosion and minimizes the amount of pollutants flowing from your lawn into streams and lakes.

Materials

Mulches and erosion control mix are available from local garden centers. Native plants can be purchased from your local nursery; select species that thrive in wet soil.

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Look for more homeowner guidance to stormwater management online at www.des.nh.gov.

Funding provided by the American Recovery and Reinvestment Act under Section 604(b) of the Clean Water Act. Guidance sheets used with permission from the Maine Department of Environmental Protection.

Installation

Rain gardens sizing depends on the area draining to the garden. To calculate the area needed for your rain garden:

1. Determine the size of the drainage area.

2. Determine the type of soil at the rain garden site:
   - Sandy soil – very gritty; does not roll into a ball
   - Silty soil – smooth and fine; does not roll into a ball
   - Clay soil – very fine, sticky when wet; rolls into a ball

3. Multiply the drainage area by the soil sizing factor listed below: Sandy soil – 0.03; Silty soil – 0.06; Clay soil – 0.10. The resulting number is the area needed for your rain garden.

Designing

The garden should be bowl-shaped, with the lowest point of the garden no more than 6” below the surrounding land.

The sides should be gently sloping towards the center to prevent sudden drop-offs that could lead to erosion problems or walking hazards. Rain gardens are often placed in a preexisting or created depression within a lawn, or in a location that receives roof runoff from a downspout.

To avoid flooding improperly sealed foundations, build your rain garden 10’ away from existing structures, and direct water into the garden with a grassy swale, infiltration trench, gutter extension or other device.

Rain gardens can be placed in sunny or shady regions of your lawn, but plants should be chosen accordingly, with the lowest point planted with wet-tolerant species, the sides closest to the center planted with moist-tolerant species, and the edges of the rain garden should be planted with sub-xeric (moist to dry) or xeric (dry) tolerant plants. After construction of the garden is complete, the entire area should be covered with a thick layer of mulch, preferably an erosion control mix.

Maintenance

Please note that fertilizer use is restricted within the Protected Shoreland. Fertilizer cannot be used within 25 feet of the reference line. From 25 feet to 250 feet, low phosphate, slow release nitrogen fertilizer may be used on vegetated areas.

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

RSA 483-B
Comprehensive Shoreland Protection Act (CSPA)
A Summary of the Standards

A STATE SHORELAND PERMIT is required for most new construction, excavation and filling activities within the Protected Shoreland. (*See definitions below*) Forest management not associated with shoreland development or land conversion and conducted in compliance with RSA 227-J:9 and agricultural activities and operations defined in RSA 21:34-a and governed by RSA 430 are exempt from the provisions of the CSPA. Projects that receive a permit under RSA 482-A, e.g., beaches and retaining walls do not require a shoreland permit. A complete list of activities that ***do not*** require a shoreland permit can be found on the Shoreland Program Page by visiting www.des.nh.gov.

250 feet from Reference Line — THE PROTECTED SHORELAND:

Impervious Surface Area Limitation. No greater than 30% of the area of a lot within the protected shoreland may be composed of impervious surfaces. If a homeowner or developer wishes to exceed 20%, a stormwater management plan must be implemented to infiltrate increased stormwater from development and if any grid segment within the waterfront buffer does not meet the minimum required 50 point tree and sapling score, each deficient grid segment must be planted with additional vegetation to at least achieve the minimum required score.

Other Restrictions/ Notes:

- No establishment/expansion of salt storage yards, auto junk yards, solid waste and hazardous waste facilities.
- All new lots, including those in excess of 5 acres are subject to subdivision approval by DES.
- Setback requirements for all new septic systems are determined by soil characteristics.
  - 75 feet for rivers and areas where the there is no restrictive layer within 18 inches and where the soil down gradient is not porous sand and gravel (perc>2 min.).
  - 100 feet for soils with a restrictive layer within 18 inches of the natural soil surface.
  - 125 feet where the soil down gradient of the leachfield is porous sand and gravel (perc rate equal to or faster than 2min/in.).
- In accordance with RSA 485-A, when selling developed waterfront property, a *Site Assessment Study* is required for all properties with on-site septic that are contiguous to or within 200 feet of waterbodies jurisdiction under the CSPA. For more information relative to site assessments, contact the NH Subsurface Systems Bureau at (603) 271-3711.
- In accordance with RSA 485-A:17, an Alteration of Terrain Permit is required for any project that proposes to disturb more than 50,000 sq ft of contiguous terrain if any portion of the project is within the protected shoreland or disturbs an area having a grade of 25% or greater within 50 feet of any surface water.

150 feet from Reference Line — NATURAL WOODLAND BUFFER LIMITATIONS:

- For lots that are ½ acre or more in size between the reference line and 150 feet from the reference line, at least 50 percent of the area between 50 feet and 150 feet from the reference line, exclusive of impervious surfaces, must be maintained in an unaltered state.
- For lots that are less than ½ acre between the reference line and 150 feet from the reference line, at least 25 percent of the area between 50 feet and 150 feet from the reference line must remain in an unaltered state.

50 feet from Reference Line — WATERFRONT BUFFER and PRIMARY BUILDING SETBACK:

- All primary structures must be set back at least 50 feet from the reference line. Towns may maintain or enact greater setbacks.
- Within 50 feet from the reference line, a waterfront buffer must be maintained. Within the waterfront buffer, tree coverage is managed with a 50 x 50 foot grid and point system. Trees and saplings may be cut provided the sum score of the remaining trees and saplings within the grid segment is at least 50 points. (see Vegetation Maintenance within the Protected Shoreland FACT SHEET)
- No natural ground cover shall be removed except for a footpath to the water that does not exceed 6 feet in width and does not concentrate stormwater or contribute to erosion.
- Natural ground cover, including the duff layer, must remain intact. No cutting or removal of vegetation below 3 feet in height (excluding previously existing lawns and landscaped areas). Stumps, roots, and rocks must remain intact in and on the ground.
- Pesticide and herbicide applications can be applied by a licensed applicator only.
- Only low phosphorus, slow release nitrogen fertilizer can be used beyond 25 feet of the reference line. Only limestone may be used within 25 feet of the reference line.

"REFERENCE LINE"- The reference line is the point from which setbacks are determined. For ***coastal waters*** it is the highest observable tide line; for ***rivers*** it is the ordinary high water mark and for ***lakes and ponds*** it is the surface elevation listed on the Consolidated List of Waterbodies subject to the CSPA.

"CONSTRUCTION"- Erecting, reconstructing or altering any structure(s) that result in an increase in impervious area.

"EXCAVATION" - To dig, remove, or form a cavity or hole within the ground with mechanized equipment.

"FILL" - To place or deposit materials such as rocks, soil, gravel, sand or other such materials.

"UNALTERED STATE" - Native vegetation, including grown cover, allowed to grow without cutting, limbing, trimming, pruning or mowing or other similar activities except as needed to maintain the health of the vegetation.


The Protected Shoreland
250' from Reference Line
Natural Woodland Buffer
150'
Waterfront Buffer
50'
Reference Line
Primary Building Setback
50' from reference line

Appendix D

NHDES Watershed Management of Fact Sheets

ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

29 Hazen Drive, Concord, New Hampshire 03301 • (603) 271-3503 • www.des.nh.gov

WD-WMB-19 2006

Why Watersheds Are Important to Protect

What is a Watershed?

A watershed can be defined as an area of land that drains down slope until it reaches a common point. "Watershed" is synonymous with other terms you may have heard such as "drainage basin" and "catchment area." Perhaps a simpler way of defining a watershed is by saying that it is an area of land where all of the water that falls in it ends up in the same place. All precipitation that falls within a watershed, but is not used by existing vegetation, will ultimately seek the lowest points. These low points are bodies of water such as rivers, lakes, and finally the ocean. This means that every stream, brook, tributary, and river that we see will eventually reach a larger body of water within its associated watershed. Even groundwater that we cannot see moves towards a common low point. One way to picture it is as a giant funnel that catches and directs all of the water that falls into it towards the bottom. On a topographical map, a watershed can be determined by connecting all of the points of highest elevation around a lake.

Who lives in watersheds?

Everyone lives in a watershed! No matter where we live we will always be part of a watershed. Major watersheds span across county, state and national boundaries. Therefore, a resident of New Hampshire can affect a lake in Massachusetts, Maine or Vermont and vice versa. It doesn't matter if the lake is in your front yard or miles away. Pollution anywhere within the watershed has the potential to affect all waterbodies located downstream from it.

How significant are watersheds?

Watersheds are *extremely* important. Watersheds provide many of us with our drinking water supply, plus recreational opportunities and aesthetic beauty. Unfortunately, the replacement of vegetation by impervious surfaces like roads, parking lots and rooftops has a negative impact on watersheds. This increases the velocity and amount of runoff flowing into surface waters and causes erosion, turbidity and degraded wildlife habitats. Not only that, but this runoff carries pollutants such as oil, bacteria, nutrients, sediment and metals into surface waters along with it. Forested areas play a very important role in the health of a watershed. The plant cover and leaf litter absorb moisture and help maintain soil structure, while root masses keep soil permeable and stable so moisture can move into it for storage. This is more desirable, because it allows water to be filtered and released slowly into the stream system rather than rapidly running overland.

Want help locating the watershed that you call home?

An easy way to locate your watershed is via the U.S. Environmental Protection Agency's website at cfpub.epa.gov/surf/locate/index.cfm, or at the U.S. Geological Survey website at water.usgs.gov/wsc.

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WMB-16 2005

Watershed Districts and Ordinances

What are Watershed Districts and Ordinances?
Watershed district and ordinances are methods of zoning that recognize watershed boundaries instead of political boundaries, as a means of regulating land uses that may affect surface water quality. A watershed district or ordinance may set rules or regulations that restrict certain activities within the watershed in order to protect surface water resources, such as lakes, ponds and rivers. Regulations could include setback requirements, buffer requirements, land use restrictions, implementation of best management practices (BMP) and implementation of low impact development (LID) techniques. Typically, a watershed district or ordinance is proposed by a town or city planning board and must be approved by the voters. Often, the ordinance or district modifies or amends zoning regulations already in place in the towns or cities involved. Watershed districts and ordinances may vary by town and can be tailored to suit the needs of the particular watershed.

How Can Watershed Districts and Ordinances Protect New Hampshire Lakes and Ponds?
This approach to watershed management is beneficial to New Hampshire's surface waters, especially those with expansive watersheds. Within a watershed district or ordinance, towns work together to protect their common water resource(s). A watershed district or ordinance may decrease sedimentation, and nutrient loading to surface waters by taking measures to reduce or eliminate stormwater runoff. In addition, reduction or elimination of the use of hazardous materials within the watershed may prevent dangerous substances from reaching lakes and ponds. In densely developed watersheds, this approach may help to improve water quality. In relatively undeveloped watersheds, this approach may help to protect water quality in the face of future development.

How To Form a Watershed District or Ordinance in Your Community
Forming a watershed district or ordinance involves bringing a lot of different groups together under a shared goal. Often, DES will work with the interested communities and provide as much assistance as possible throughout the process. The first step is to determine which towns are included in the lake or pond's watershed. Town planning boards and conservation commissions should be included in the planning process. Watershed districts and ordinances formed to protect lakes and ponds often involve local lake associations as well. These groups, as well as any other interested groups or individuals, determine what activities will be regulated. Regulated activities may include agriculture, forestry and construction, as well as standards for septic systems. Standards for wetlands and surface water protection may be included as well. Regulations or standards are set for the watershed district or ordinance, and put to a vote within each town. Once the voters of each town in the watershed accept the regulations and standards, the ordinance or district may go into effect.

For more information, or examples of watershed districts or ordinances that have been implemented in New Hampshire, contact Jody Connor, DES Limnology Center Director, at (603) 271-3414 or jconnor@des.state.nh.us.

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WD-WMB-17 2010

Low Impact Development and Stormwater Management

What is Stormwater
Stormwater is water from rain or melting snow that does not soak into the ground. In a forest, meadow, or other natural environment, stormwater usually soaks into the ground and is naturally filtered. When forests and meadows are developed, they are commonly replaced with residential neighborhoods, shopping centers, and other areas that introduce impervious surfaces such as houses, buildings, and roads and parking lots. Impervious surfaces prevent rain or melting snow from soaking into the ground and create excess stormwater runoff.

Excess stormwater runoff creates problems when stream channels have to accommodate more flow than nature designed them to. When this happens, flooding is more frequent, banks erode, and the groundwater table is lowered. Stormwater can also become polluted with trash and debris, vehicle fluids, pesticides and fertilizers, pet waste, sediment, and other pollutants when it flows over impervious surfaces, lawns, and other developed areas. These pollutants get picked up with the stormwater runoff and eventually flow untreated into nearby lakes, streams and other bodies of water.

Stormwater has been identified as a major source of water pollution in the United States. In New Hampshire, stormwater has been identified as contributing to over 80 percent of the surface water quality impairments in the state. All across New Hampshire, communities, businesses, and property owners are experiencing the challenge of managing stormwater to maintain transportation and storm drainage infrastructures, protect water quality, and to simply keep their driveways and landscaping from washing out each year.

Low impact development can be used to reduce the amount of stormwater that runs off impervious surfaces and protect nearby surface waters from stormwater pollution.

What is Low Impact Development?
Low impact development (LID) is a stormwater management approach. Unlike conventional stormwater management, which focuses on piping stormwater away from a site to large centralized stormwater treatment areas, LID focuses on controlling stormwater by using small, decentralized methods to treat stormwater close to the source. The primary goals of LID are accomplished through LID site planning and LID treatment practices and include:

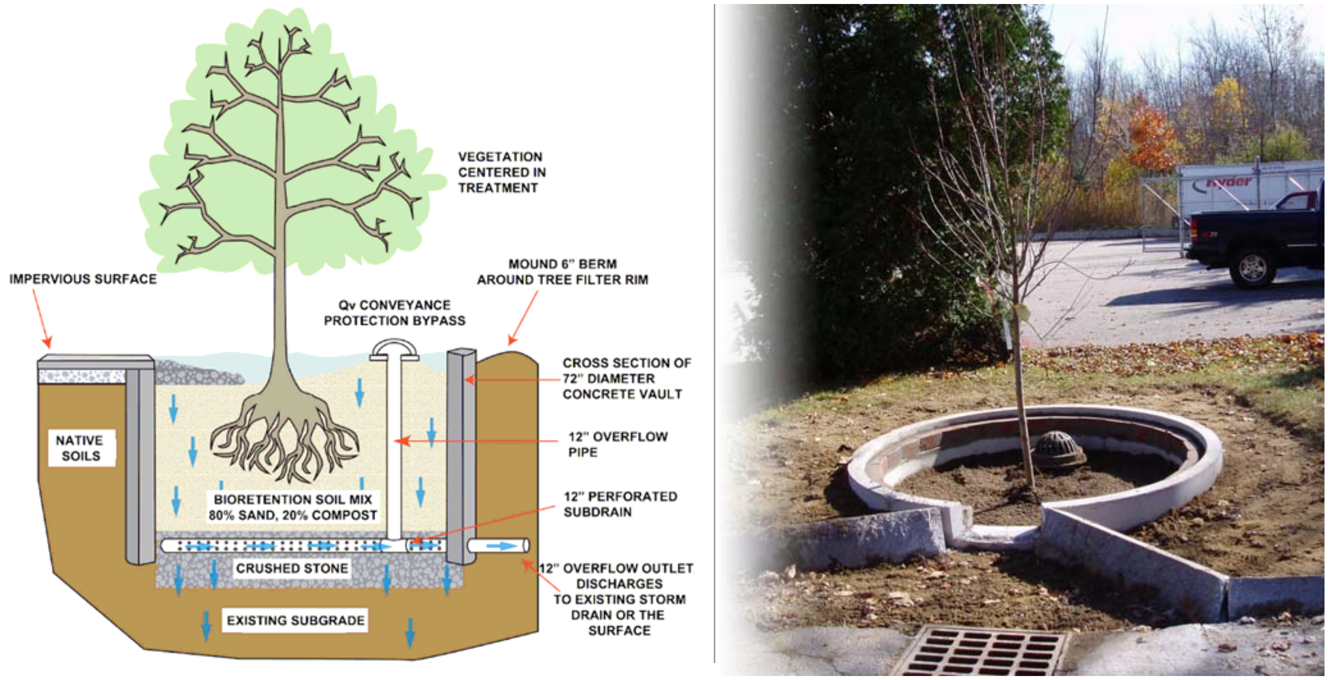
- Lessening the impact of development, and the impact of stormwater resulting from that development, on the natural environment.
- Using the land more efficiently.
- Lowering capital and operating costs associated with development.

LID Site Planning

LID site planning reduces the amount of stormwater generated on a site through source control and protection of the site's existing hydrologic features, such as topography, vegetated buffers, wetlands, floodplains and high-permeability soils. More information on LID site planning can be found in [Chapter 6 of the *New Hampshire Stormwater Manual: Volume 1 Stormwater and Antidegradation*].

Objectives of LID site planning include:

- Minimizing areas of disturbance
- Maintaining and restoring natural buffers
- Minimizing impervious cover
- Disconnecting impervious cover
- Minimizing soil compaction



Example tree box filter design (UNH Stormwater Center 2007a) and installation in the Hodgson Brook Watershed in Portsmouth, NH.

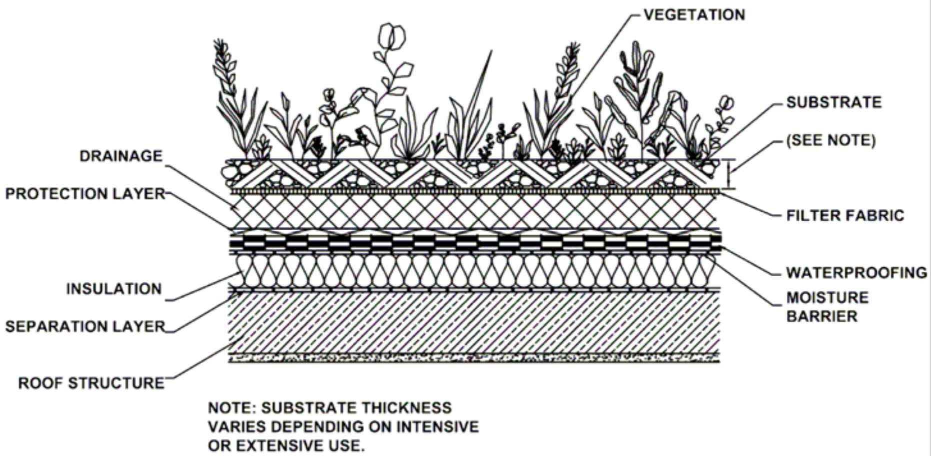
LID Practices

Once LID site planning has been used to minimize the amount of stormwater generated on the site, site-level, decentralized LID treatment practices are used to treat any stormwater runoff that resulted from development. LID treatment practices are typically designed as open, vegetated systems that rely on plants and their root systems as well as permeable soils to slow the flow of water and encourage infiltration and filtration. This reduces both the velocity and volume of stormwater, as well as provides treatment of stormwater pollutants.

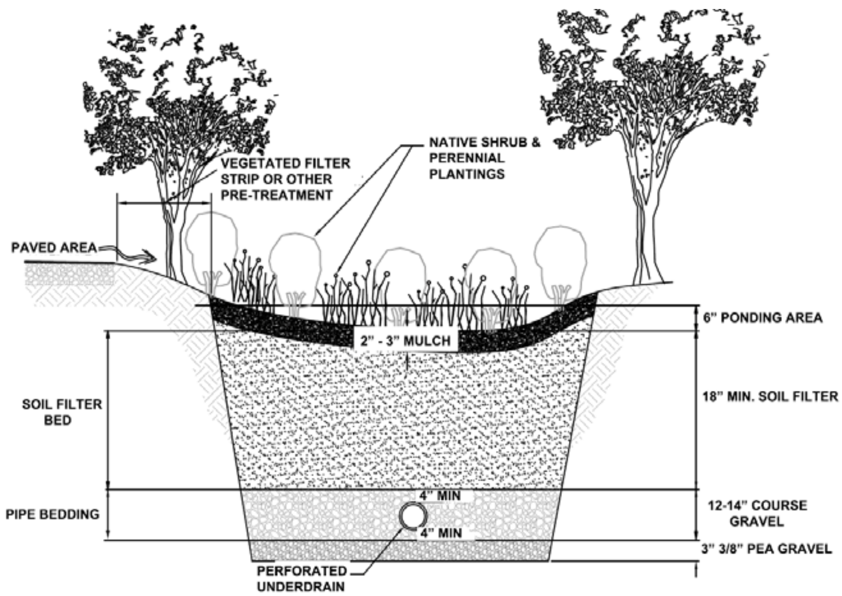
LID treatment practices can be used in existing development and can also be used in redevelopment projects to improve existing stormwater management. In redevelopment situations, LID focuses on minimizing and disconnecting existing impervious surfaces and implementing LID treatment practices for water quality, where feasible. More information on LID treatment practices can be found in [Chapter 4 of the *New Hampshire Stormwater Manual: Volume 2 Post-Construction Best Management Practices Selection & Design*].

Examples of LID treatment practices include:

- Bioretention and Rain Gardens
- Dry Wells
- Rooftop Gardens and Green Roofs
- Vegetated Swales, Buffers, and Strips
- Soil Amendments
- Permeable Pavement
- Tree Box Filters
- Rain Barrels and Cisterns



Example green roof design (Maine DEP 2006, EPA 2006a) and installation at the Mount Washington Hotel, Bretton Woods, NH.



Rain garden and pervious pavement installation in downtown Peterborough, NH.

Barriers to LID

Although LID is not new, it is still considered innovative. Because of this, there are several potential barriers to implementing LID. For example:

- *Cost Concerns* – Many people are deterred from using LID practices because they believe they are more costly than conventional stormwater management practices, when in reality, LID practices can actually cost less than conventional stormwater management due to a reduced need for catch basins and piping. Also, with less infrastructure involved, LID can reduce the long-term cost of operation and maintenance.

- *Conflicting Local Ordinances* – Municipal ordinances and bylaws, such as minimum roadway widths, minimum parking requirements, and curb and gutter conveyance design, can conflict with LID principles. Local regulations can be modified or waivers or variances can be granted to allow for LID, or municipalities can adopt stormwater ordinances that require LID. More information on New Hampshire local ordinances can be found at: des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm
- *Lack of Confidence* – Many people lack confidence in the performance of LID practices. LID has been used successfully in New England and across the country. Specifically, the University of New Hampshire Stormwater Center (UNHSC) has tested several LID practices and has data showing their efficiency in New Hampshire's climate. (www.unh.edu/erg/cstev/)
- *Site Constraints* – There are concerns that LID practices do not work in cold climates or on sites that have poorly draining soils, are close to groundwater, or other site constraints. The UNH Stormwater Center has shown that properly designed and installed LID practices perform well in New Hampshire.
- *Maintenance Concerns* – All best management practices need maintenance. The type of maintenance required for LID practices is often different than conventional systems. Because most LID practices are vegetated, maintenance focuses on maintaining healthy vegetation as well as removing sediment and other debris as necessary. LID practices tend to be smaller and usually do not require the use of heavy equipment to conduct maintenance.

For More Information

Additional information on Low Impact Development can be found in the following resources:

- DES Innovative Land Use Planning Techniques Handbook – http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm
- The University of New Hampshire Stormwater Center – www.unh.edu/erg/cstev/
- EPA's National LID website – www.epa.gov/owow/nps/lid
- EPA New England Stormwater website – www.epa.gov/region1/topics/water/stormwater.html
- Center for Watershed Protection website – www.cwp.org
- Low Impact Development Center website – www.lowimpactdevelopment.org

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WD-WMB-10 2009

Potential Dangers of Cyanobacteria in New Hampshire Waters

What are Cyanobacteria?
Cyanobacteria are bacteria that photosynthesize. Many species of cyanobacteria grow in colonies to form surface water "blooms." Blooms are usually blue-green in color and consist of thousands of individual cells.

Cyanobacteria are some of the earliest inhabitants of our waters, and naturally occur in all of our lakes, often in relatively low numbers. However, research indicates that cyanobacteria abundance increases as lake nutrients increase. As part of the aquatic food web, they can be eaten by various grazers in the lake ecosystem, such as zooplankton and mussels.

Although most often seen when floating near the surface, many cyanobacteria species spend a portion of their life cycle on the lake bottom during the winter months. Increased water temperature and light in the spring promote the upward movement of cyanobacteria through the water column toward the surface where blooms or scums are formed. These scums are often observed in mid to late summer and sometimes well into the fall.

Why are Cyanobacteria a Concern?
Some cyanobacteria produce toxins that adversely affect livestock, domestic animals, and humans. According to the World Health Organization (WHO), toxic cyanobacteria are found worldwide in both inland and coastal waters. The first reports of toxic cyanobacteria in New Hampshire occurred in the 1960s and 1970s. During the summer of 1999, several dogs died after ingesting toxic cyanobacteria from a bloom in Lake Champlain. The WHO has documented acute impacts to humans from cyanobacteria from the US and around the world as far back as 1931. While most human health impacts have resulted from ingestion of contaminated drinking water, cases of illnesses have also been attributed to swimming in cyanobacteria infested waters.

The possible effects of cyanobacteria on the "health" of New Hampshire lakes and their natural inhabitants, such as fish and other aquatic life, are under study at this time. The Center for Freshwater Biology (CFB) at the University of New Hampshire is currently examining the potential impacts of these toxins upon the lake food web. The potential human health hazards via exposure through drinking water and/or during recreational water activities are also a concern to the CFB and the state.

Do Cyanobacteria Exist in New Hampshire Waters?
Yes, they occur in lakes world wide. Cyanobacteria have been found in a majority of lakes in New Hampshire, but most often cyanobacteria numbers present in our lakes are near the minimum level of detection. Four of the most common cyanobacteria found in New Hampshire are: Anabaena, Aphanizomenon, Oscillatoria, and Microcystis. Anabaena and Aphanizomenon produce neurotoxins (nerve toxins) that interfere with nerve function and have almost immediate effects when ingested. Microcystis and Oscillatoria are best known for producing hepatotoxins (liver toxins) known as microcystins. Oscillatoria and Lyngbya (another type of cyanobacteria) also produce dermatotoxins, which cause skin rashes.

Should You be Concerned about Swimming in or Drinking from a New Hampshire Lake?
Both DES and UNH have extensive lake monitoring programs. Generally, the water quality of New Hampshire's lakes is very good. However, the state strongly advises against using lake water for consumption, since neither in-home water treatment systems nor boiling the water will eliminate cyanobacteria toxins if present.

If you observe a well-established cyanobacteria bloom or scum in the water, please comply with the following:

- ✓ Do not wade or swim in the water!
- ✓ Do not drink the water or let children drink the water!
- ✓ Do not let pets or livestock into the water!

Exposure to toxic cyanobacteria scums may cause various symptoms, including nausea, vomiting, diarrhea, mild fever, skin rashes, eye and nose irritations, and general malaise. If anyone comes in contact with a cyanobacteria bloom or scum, they should rinse off with fresh water as soon as possible.

If you observe a cyanobacteria bloom or scum, please call DES at (603) 419-9229. DES will sample the scum and determine if it contains toxin-producing bacteria. An advisory will be posted on the immediate shoreline of a designated beach indicating that the area may not be suitable for swimming. If the affected area extends into water that is not part of a designated beach, DES will issue a warning for the entire lake. DES will continue to monitor the water and will notify the appropriate parties regarding the results of initial and subsequent testing. Public notification occurs through press releases and the DES website. When monitoring indicates that cyanobacteria are no longer present at levels that could harm humans or animals, the advisory or warning will be removed.

Please visit http://des.nh.gov and search term "Beach" to access the most current advisories and warnings.

ENVIRONMENTAL
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WMB-4 1996

Road Salt and Water Quality

Background

The amount of snowfall in northern New England and the necessity of overland travel require the use of plows and de-icing materials to keep highways safe in the winter. Salt, or sodium chloride, is the most commonly used de-icing material in New Hampshire. In general, the purpose of salt is to: 1) reduce adherence of snow to the pavement; 2) keep the snow in a "mealy" condition and thereby permit nearly full removal by plowing; and 3) prevent the formation of ice or snow ice (hard pack).

Sodium chloride can negatively impact drinking water and aquatic life. Sodium is a drinking water concern for individuals restricted to low-sodium diets due to hypertension (high blood pressure), although a review of scientific evidence by the U.S. Environmental Protection Agency showed that the vast amount of sodium ingestion (90 percent) was from food rather than drinking water and that the linkage between sodium and hypertension was still not well documented. Chloride can affect the taste of drinking water, but is not a health concern. If levels of either sodium or chloride approach 250mg/l in drinking water, an alternative source should be found. Chloride ions were found by the U.S. Environmental Protection Agency to be toxic to certain forms of aquatic life at a four-day average concentration of 230 mg/l. Some plant species at the base of the food chain can be impacted at much lower concentrations.

Roadside vegetation is visibly impacted from road salt. Burned grass and shrubs, as well as burned foliage on roadside trees from salt spray are common in New Hampshire.

Road Salt Management Issues

The New Hampshire Department of Transportation's (DOT) winter maintenance goal is to obtain bare and dry pavements on most roads at the earliest practical time following cessation of a storm. Many municipal highway departments have similar goals. Traffic volume, speed, and gradient are the primary factors in determining the level of winter maintenance service for particular roads. When the temperature is 20^{o} F or greater, DOT applies 250-300 lbs. of salt per lane-mile and/or abrasive (sand) as needed. At temperatures below 20º F, DOT uses various combinations of salt, sand, and calcium chloride, depending on road conditions.

Salt storage facilities can have a greater potential for causing water pollution than roadway application. For maximum environmental protection, salt storage facilities should be roofed and paved, with adequate drainage controls to prevent runoff water from contacting salt.

Alternatives to Road Salt

Salt is the most commonly used highway de-icer. Its effectiveness decreases as temperatures drop. Salt is most effective at temperatures above 20º F. Below 10º F, salt cannot dissolve and cannot break the ice-pavement bond.

The second most commonly used de-icing chemical, calcium chloride, is effective in much lower temperatures than salt (as low as 0º F). Liquid calcium chloride can be used to pre-wet salt and sand, which can facilitate de-icing at lower temperatures. The disadvantages to calcium chloride are: 1) it costs more than salt; 2) it is difficult to handle and store; 3) if used alone it may contribute to slippery, black-ice conditions; and 4) the presence of chloride ions makes calcium chloride at least as corrosive to structural materials and toxic to aquatic life as salt.

Sand is sometimes considered an alternative to salt. Sand does provide additional traction in slippery conditions but it cannot melt snow and ice on the road surface. A disadvantage to sand is that great effort must be expended to clean the sand from road surfaces at the end of winter to prevent clogging of roadside ditches and catch basins, and eventually sedimentation in water bodies.

Calcium magnesium acetate (CMA) is another alternative to salt. CMA is made from limestone and acetic acid, the principal ingredient of vinegar. CMA is less damaging to soils, less corrosive to concrete and steel, and non-toxic to aquatic organisms. It is also benign to roadside vegetation. The components of CMA are not harmful to groundwater, although CMA, like salt, has the potential to mobilize trace metals (Fe, Al, Zn, Cu) through cationic exchange reactions in soil. A drawback of CMA is its cost, about $600/ton, compared to about $40/ton for salt. However, a full cost analysis, comparing CMA to salt is needed to determine the full cost of both alternatives. CMA use should lead to longer lasting bridges and cars and less environmental damage. Including avoided costs, CMA may be an economically viable alternative to salt, even though its initial cost is 15 times greater.

DOT Reduced Salt Pilot Program

Chapter 239, Laws of 1994, authorized and required the DOT, in cooperation with the Nashua Regional Planning Commission, to implement a pilot program to minimize salt use during the winters of 1994-95 and 1995-96. Three test sections were found on low traffic volume highways in the Nashua region, public hearings were held, and warning signs were posted on the roads. During the two winters, test sections were treated with approximately one half the amount of salt used on the control sections, which were treated using standard DOT procedures. DOT evaluated road conditions, accidents, costs, environmental benefits, and public acceptance of the pilot program. Monitoring wells were installed along test and control highway sections to measure chloride levels in groundwater.

The results of the pilot program were:

1. While poorer driving conditions were noted on the test sections, safety was not significantly compromised by the reduction in salt use. This was attributed to the absence of curves, hills, and heavy traffic on test sections, as well as the highway signing and public notification of the program.
2. While substantial savings for salt were noted, other costs such as sand and labor were higher. Additional costs were estimated by DOT at $16,774 during the two-year test period for the 8.3 lane-miles in the test sections. It was noted that additional costs could

be incurred due to sand cleanup for lawns, drainage ditches, and culverts. DOT also noted that the higher costs were partially due to the short length of the test sections.

3. Public acceptance of the test was mixed. Very few complaints were from the public, but local police were less than satisfied with road conditions during storms.
4. In each test section chloride levels in monitoring wells were substantially lower than those in corresponding control sections. Application of additional sand in test sections created environmental concerns due to sediment deposition, but these impacts were not measured.

DOT concluded that reduced salt application for winter maintenance is beneficial within very specific parameters. The type of highway to be included in a reduced salt program needs to be carefully considered. The highway must be relatively flat, without hills and curves, and in a low speed/low volume section. Based on the results of the pilot program, DOT will consider conducting other reduced salt programs in communities which request consideration and on roads which meet the specific requirements of the program. Local officials interested in the reduced salt program should contact the DOT Bureau of Highway Maintenance at 271-2693.

Best Management Practices for Road Salt Application

Storage and Handling

- Facilities should be located on flat sites away from surface water and on impervious surfaces that are easily protected from overland runoff.
- Salt should be stored under cover to prevent a loss due to runoff.

Application of Road Salts

- Sensitive areas, such as public water supplies, lakes and ponds, should be identified and made known to salt applicators. Consider de-icing alternatives in sensitive areas.
- Ground-speed controllers should be used for all spreaders.
- Give salt time to work; time plowing operations to allow maximum melting by salt, before snow is plowed off the highway.
- Know when to plow and reapply salt. The need for another salt application can be determined by watching melting snow kicked out behind vehicle tires. If the slush is soft and fans out like water, the salt is still working. Once the slush begins to stiffen and is thrown directly to the rear of vehicle tires, it is time to plow.
- For lesser traveled roads, consider applying salt in a windrow in a four to eight foot strip along the centerline of a two lane road. Less salt is wasted with this pattern and quickly gives vehicles clear pavement under at least two wheels. Traffic will soon move some salt off the centerline and the salt brine will move toward both shoulders for added melting across the entire road width.
- Determine levels of service for all roads in a service area. Salt application rates and frequency should be based on traffic volume, road grade and curvature, intersections, and weather conditions. Sand or sand/salt mix should be used based on the level of service requirements.

Snow Dumping

Dumping plowed snow directly into waterbodies is illegal. For recommended snow dump areas, please see DES Fact Sheet **WD-WMB-3.**

Appendix E

NHDES Septic System Fact Sheets

ENVIRONMENTAL
Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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WD-SSB-2 2010

Care and Maintenance of Your Septic System

What is a septic system?
A septic system is a two part treatment and disposal system designed to condition untreated liquid household waste (sewage) so that it can be readily dispersed and percolated into the subsoil. Percolation through the soil accomplishes much of the final purification of the effluent, including the destruction of disease-producing bacteria.

A septic tank provides the first step in the process by removing larger solid materials, decomposing solids by bacterial action, and storing sludge and scum. The liquid between sludge and scum is then passed along to the leaching area for final treatment and absorption into the ground. Remember: A properly maintained septic system will adequately treat your sewage.

What should I do to maintain my septic system?
Know the location of your septic tank and leaching area.

- Inspect your tank yearly and have the tank pumped as needed and at least every three years.
- Do not flush bulky items such as throw-away diapers or sanitary pads into your system.
- Do not flush toxic materials such as paint thinner, pesticides, or chlorine into your system as they may kill the bacteria in the tank. These bacteria are essential to a properly operating septic system.
- Repair leaking fixtures promptly.
- Be conservative with your water use and use water-reducing fixtures wherever possible.
- Keep deep-rooted trees and shrubs from growing on your leaching area.
- Keep heavy vehicles from driving or parking on your leaching area.

For Further Information

If you have any questions concerning septic systems, contact DES Subsurface at (603) 271-3501, or 29 Hazen Drive, PO Box 95, Concord, NH 03302-0095; Fax: (603) 271-6683; http://des.nh.gov/organization/divisions/water/ssb/index.htm.

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WD-SSB-1 2010

Replacement of A Failed Subsurface Disposal System

What is a Failed Subsurface Disposal System?
New Hampshire RSA 485-A:2 defines failure as "the condition produced when a subsurface sewage or waste disposal system does not properly contain or treat sewage or causes or threatens to cause the discharge of sewage on the ground surface or into adjacent surface or groundwater."

Special Requirements for Replacing a Failed Subsurface Disposal System.
To ensure prompt and effective replacement of a failed subsurface system, the following steps must be taken.

1. The town health officer, or other local official responsible for health code enforcement, must prepare a written statement verifying that the existing system is in failure. This statement must be submitted to DES with the application to replace the existing system.
2. If construction approval is granted, the construction must be completed within 90 days. Failure to complete construction and obtain operational approval of the system within the 90-day period will result in invalidation of DES approval.
3. In the event that your construction approval becomes invalid as a result of exceeding the 90-day construction period, a request for extension must be submitted to the Department of Environmental Services, Subsurface Systems Bureau. DES shall grant one 90-day extension. The request for extension must include all the information required by New Hampshire Administrative Rule Env-Wq 1004.11 (b).

This fact sheet is intended as a basic source of information concerning the replacement of a failed subsurface disposal system; it is not intended to replace the administrative rules contained in Env-Wq 1000. It is also important to remember that some municipalities have additional requirements, and you should check with your local officials before beginning any project.

For Further Information
If you have any questions concerning septic systems, contact DES Subsurface at (603) 271-3501, or 29 Hazen Drive, PO Box 95, Concord, NH 03302-0095; Fax: (603) 271-6683; http://des.nh.gov/organization/divisions/water/ssb/index.htm.

ENVIRONMENTAL Fact Sheet

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

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WD-SSB-12 2010

Approved Technologies for Septic Systems

Over the past several years, the N.H. Department of Environmental Services has approved many new innovative technologies for the treatment and disposal of wastewater to subsurface systems. All new "innovative/alternative" systems for on-site treatment or disposal of wastewater below the ground (usually referred to as "septic systems") need approval from DES under the provisions of NH Administrative Rule Env-Wq 1024, which allows general and provisional approvals. The following is an overview of the various products and technologies that DES has approved to date. But before listing the currently approved systems, we must present these caveats and warnings:

- Systems are listed in random order.
- Mention of a company name, system or device in this list does not constitute DES approval to use that system or device to address any specific problem. Consult a licensed septic system designer to determine what solutions may be appropriate for your problem.
- PUMP OUT YOUR SEPTIC TANK **BEFORE** THERE'S A PROBLEM. Many times, a "technological" solution is not necessary because ordinary maintenance may solve the problem. See Env-Wq 1023 for operating requirements. Also see the other Fact Sheets in DES's SSB series for useful information on septic system operation.
- Where a designer specifies a certain product, such as a brand of septic tank effluent filter, and a different (but similar) brand is used in the actual installation, DES requires the written concurrence of the system designer before approving the tank/septic system for operation.

Leaching Systems

Stone/pipe - field, trench, drywell	"Standard" systems.
Chambers - concrete, plastic	"Standard" systems, but field sizing may be product-specific. See approved design manual.
"Enviro-Septic" system	A "standard" system, field sizing is product-specific. See approved design manual.
"Geo-Flow" system	A "standard" system, field sizing is product-specific. See approved design manual.
Eljen "In-Drain"	A "standard" system, but field sizing is product-specific. See approved design manual. Manufacturer's review for larger commercial systems.
Ruck "A-Fin"	A "standard" system, field sizing is product-specific. See approved design manual. Manufacturer's review required for larger commercial systems.

Mechanical treatment devices , with general DES Approval for leach field reduction:

Norweco "Singulair"	Biological treatment.
Amphidrome Recirculating Batch Reactor	Biological treatment.
Wastewater Alternatives Inc. "The Clean Solution"	Biological treatment.
Jet Package Sewage Treatment Plant	Biological treatment.
Spec Industries AIRR trickling filter	Biological treatment.
SeptiTech Recirculating Trickling Filter	Biological treatment.
BioMicrobics FAST system	Biological treatment.
Zabel SCAT biofilter	Biological treatment.
Orenco AdvanTex system	Biological treatment.
MicoSepTec EnviroServer system	Biological treatment.
CMS ROTORDISK	Biological treatment.
Aeration Systems, LLC, OxyPro system	Biological treatment.
BioClere system	Biological treatment.

Mechanical treatment devices, provisional DES Approval for leach field reduction:

Provisional approval is granted for newer technologies per Env-Wq 1024.06(d) for cases where DES finds that "… there is not sufficient operating history or other valid data to allow general use of the technology …." Provisional approvals are granted for a limited number of applications for a limited period of time. The applicant is required to do performance monitoring of each installation and report the results to DES.

SeptiTech Recirculating Trickling Filter	Biological treatment. The provisional approval is for leach field size reductions beyond that in SeptiTech's General approval.
BioMicrobics FAST System	Biological treatment. The provisional approval is for leach field size reductions beyond that in BioMicrobic's General approval.
WasteTech STM 2000 unit	Physical treatment.

For new construction where a mechanical treatment device with a reduced-size leach field, under a General or Provisional approval, is proposed for use on a lot that was created prior to adoption of DES subdivision rules, the design submitted shall demonstrate sufficient capacity to construct a full sized leaching facility on the lot.

All mechanical systems require on-going professional maintenance. The person doing the maintenance must be a licensed treatment plant operator. See DES fact sheet WD-WEB-2 for information in the licensure program. A Grade 1-OIT license is usually considered sufficient for systems listed here.

Other approved, or approvable, treatment devices and methods:

M.C.C. Inc. "Cajun Aire"	Mechanical unit, approved under Env-Wq 1024.
Cromaglass Sequencing Batch Reactor	Mechanical unit, approved under Env-Wq 1024.
"White Knight," "Pirana"	These are mechanical devices that are inserted into an existing septic tank to provide treatment of the effluent leaving the tank. They are allowed for rehabilitation of failed systems.
Constructed Wetlands	Innovative, has been approved for a few sites. Significant engineering required.
Spray Irrigation	Has been approved for a few sites. Very significant engineering and Groundwater Discharge Permit required. A major issue is control of access to the area where spraying occurs. There are significant public health concerns with coming into contact with partially-treated wastewater.
Sand Filters	Innovative, has been approved for a few sites. Significant engineering required.

Other systems & devices

Septic tank effluent filters	Allowed and encouraged.
Presby "Maze"	Device inserted into septic tank. 30 percent reduced field size allowed for commercial systems.
Holding Tank	Only applicable in very limited circumstances, see Env-Wq 1022.03
Composting toilets	Allowed, but no leach field reduction allowed for the remaining wastewater whenever the building has running water.
"Mini dry well" and privies	Only allowed for buildings with no running water (Env-Wq 1022.01 Prives & Env-Wq1022.02 Mini Drywell).

For more information

For more information about the above list, or to apply for approval of an innovative/alternative product from DES, please contact: Subsurface Systems Bureau, NH Department of Environmental Services, 29 Hazen Drive, PO Box 95, Concord, NH 03302-0095; (603) 271-3501.

Appendix F

NHDES Chapman Stormwater Report

Granite Lake
Stoddard/Nelson

Stormwater Drainage for North Shore and West Shore Roads

Andy Chapman, NH Department of Environmental Services
October 15, 2007

Introduction:

At the request of the Granite Lake Association (GLA), the New Hampshire Department of Environmental Services (DES) met with the GLA, and road agents from Stoddard and Nelson to conduct a site inspection of the stormwater drainage for North Shore and West Shore Roads. The priority goals were to identify drainage improvements for North Shore Road and West Shore Road which will reduce erosion and sediment loading to the lake while minimizing the expense of materials, labor and maintenance to construct those improvements.

Seven sites (Figure 1, Granite Lake Sites A-G) were identified. The information within this report details erosion and sedimentation problem areas and makes recommendations to improve those areas. Most of the Best Management Practice (BMP) recommendations are simple measures targeted to reduce stormwater velocity rates and volumes first being discharged to the roadway itself and second within the ditchline and stormwater drainage system. Beyond the on-site BMPs discussed in this report, DES encourages municipalities to be proactive and address the potential future impacts of stormwater management at the watershed level.

As land use changes from a forested condition to a developed landscape, stormwater runoff rate velocities and volumes increase. If these are not addressed at the planning level, municipalities will inherit managing ever increasing stormwater rates and volumes within the town road right of ways. The concern is that municipalities are not equipped to manage this additional stormwater. As a result, the impact to downstream waters along with public and private property can be detrimental. To find more information on what measures can be taken to properly manage stormwater, the New Hampshire Regional Environmental Planning Program (REPP) is producing a guide with model ordinances and regulations on a number of innovative land use techniques, including stormwater management. The Regional Environmental Planning Program was created within the Department of Environmental Services in recognition of the value of regional planning agencies (RPAs), in addressing environmental issues in New Hampshire. These innovative land use techniques can be found at http://www.des.state.nh.us/REPP/index.asp?go=ilupth or by contacting the DES Watershed Assistance Section at 271-2358 or DES Clean Lakes Program at 603-271-5334.

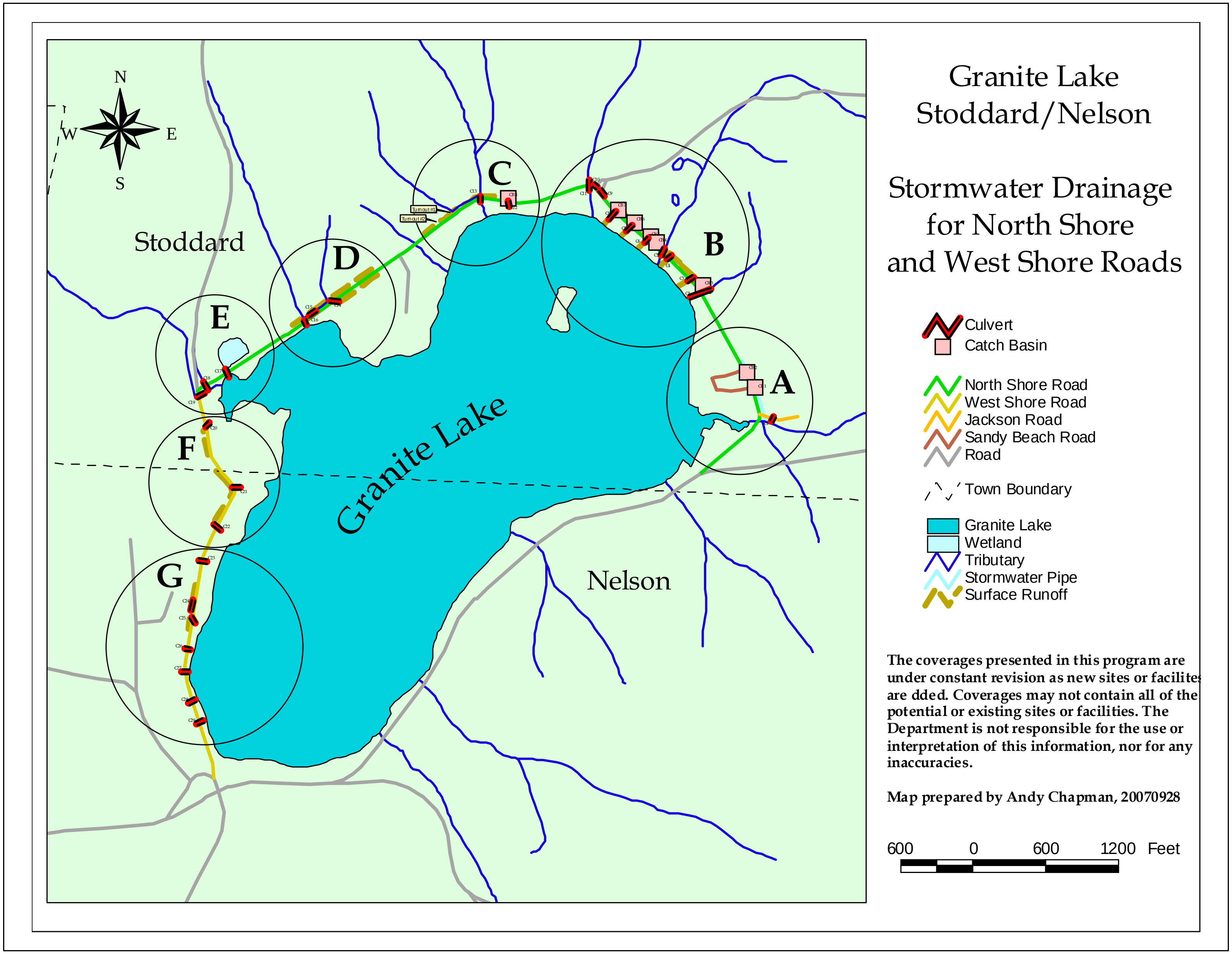

Figure 1: Granite Lake Sites, A-G

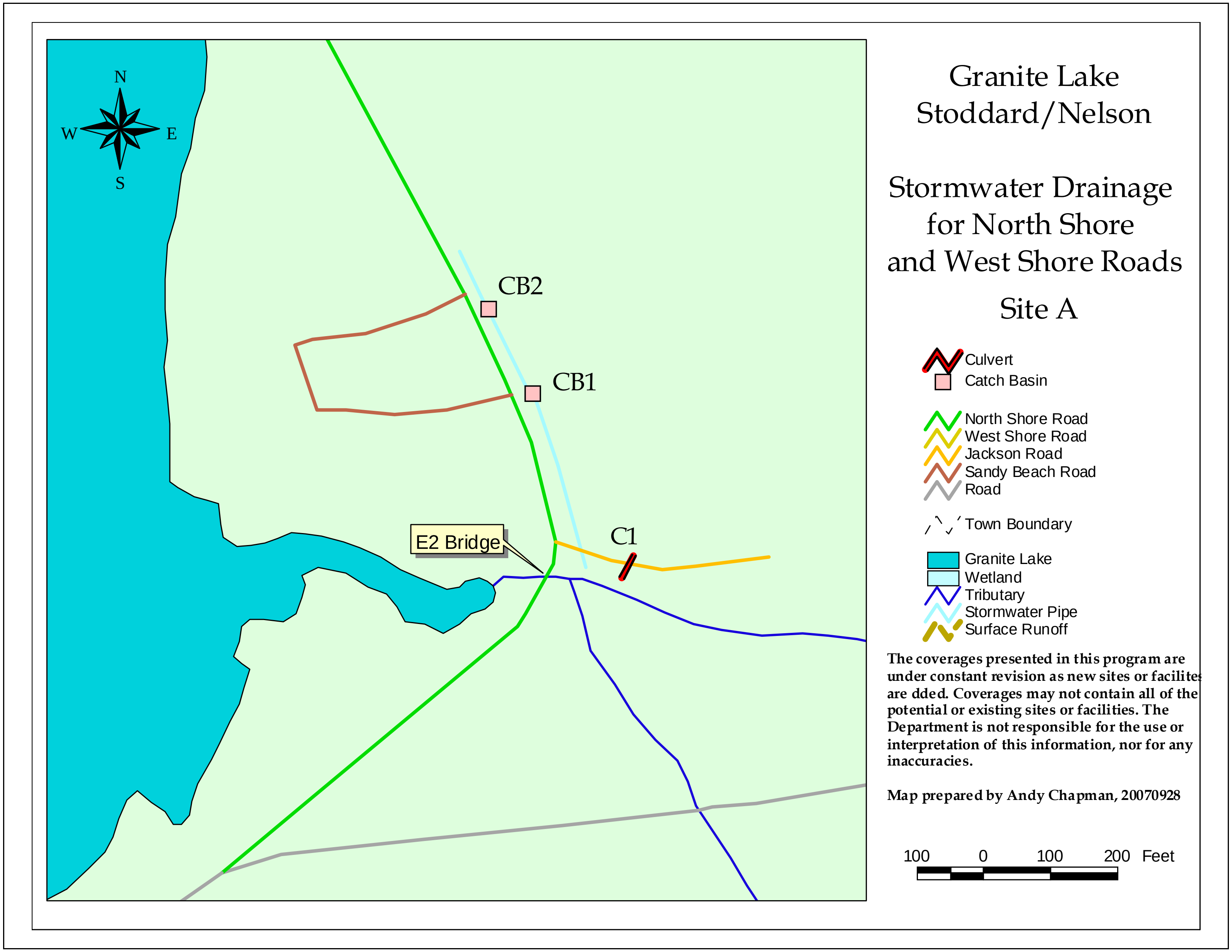

Figure 2: Site A, North Shore Road at Jackson Road and Beach Access Road to house #110

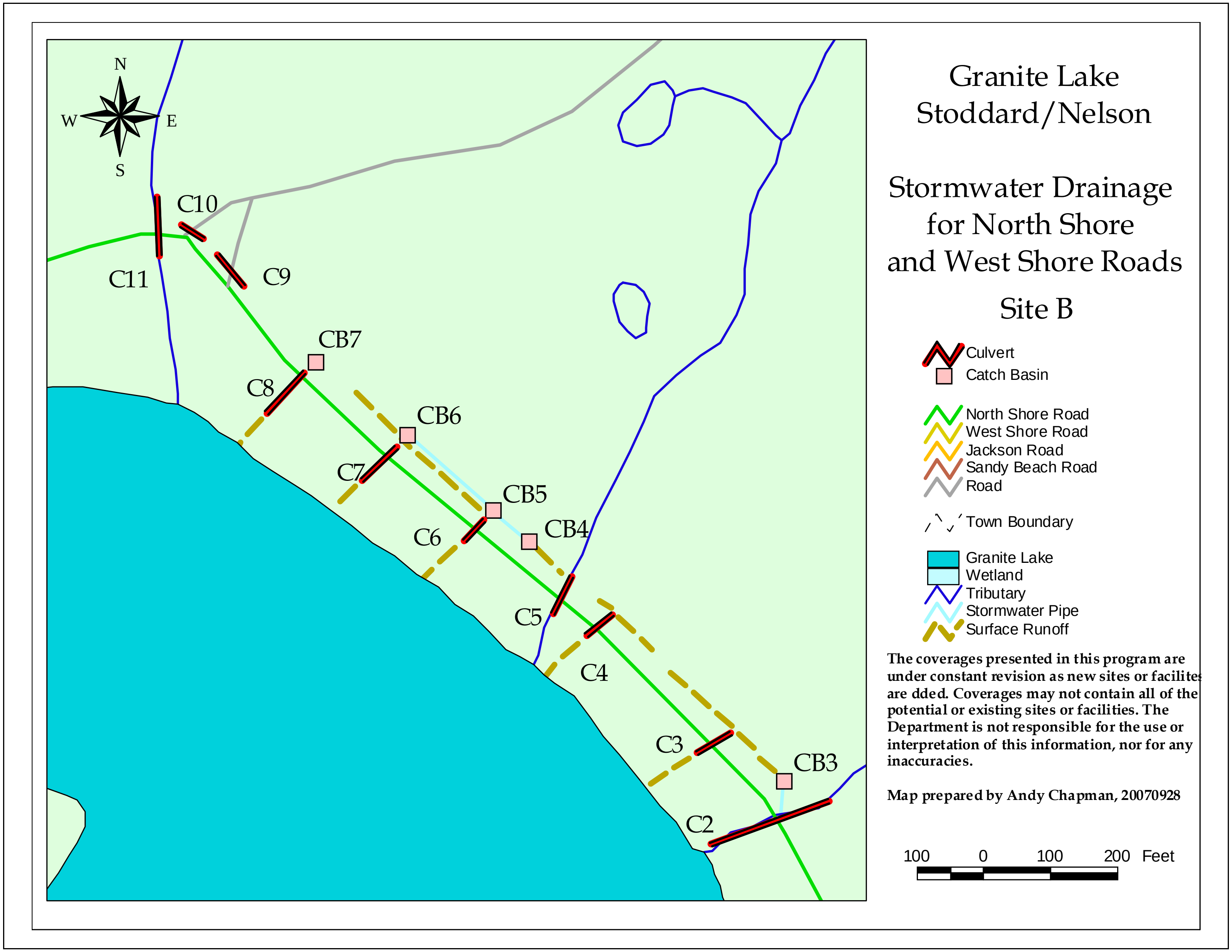

Figure 3: Site B, North Shore Road, house #150 to #305

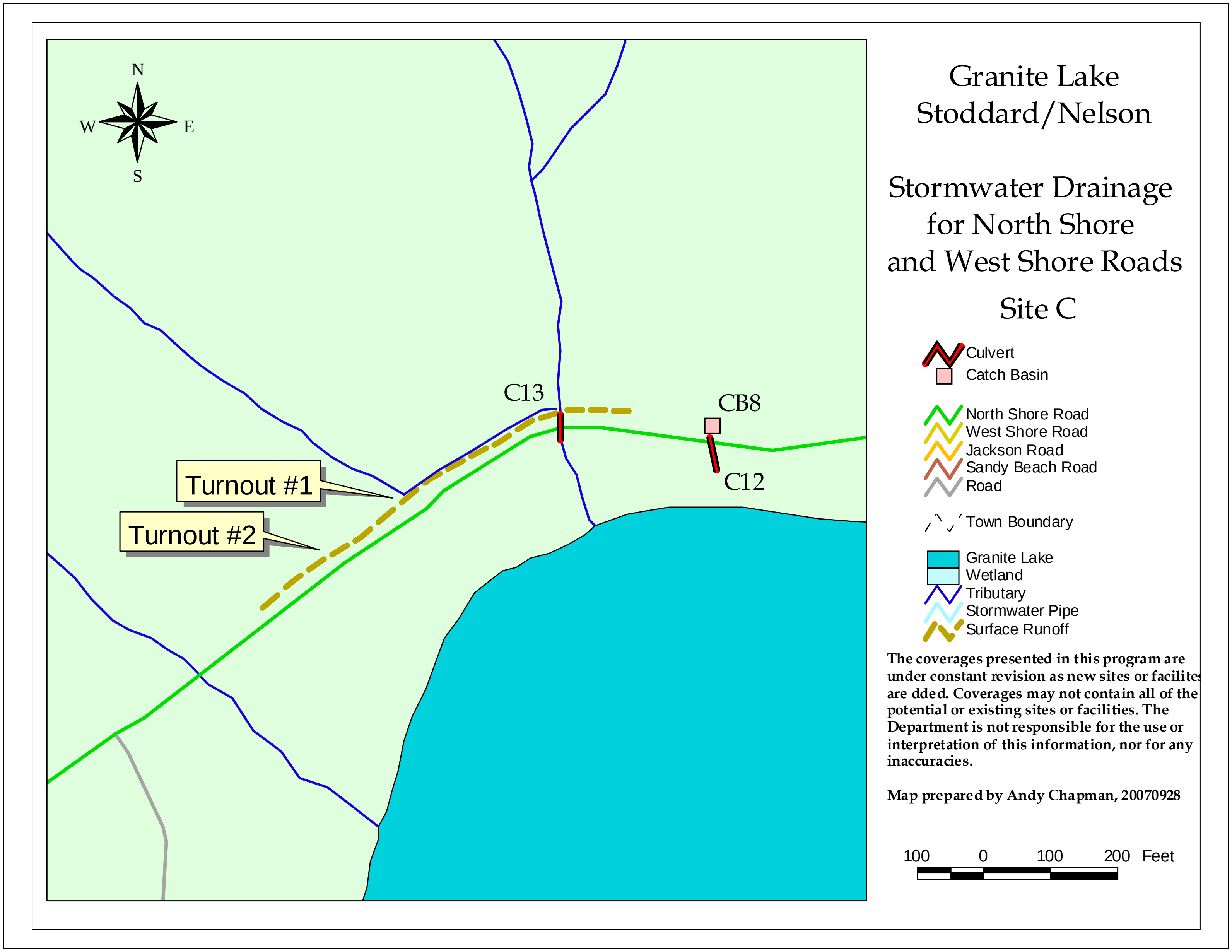

Figure 4: Site C, North Shore Road, house #395 to #431

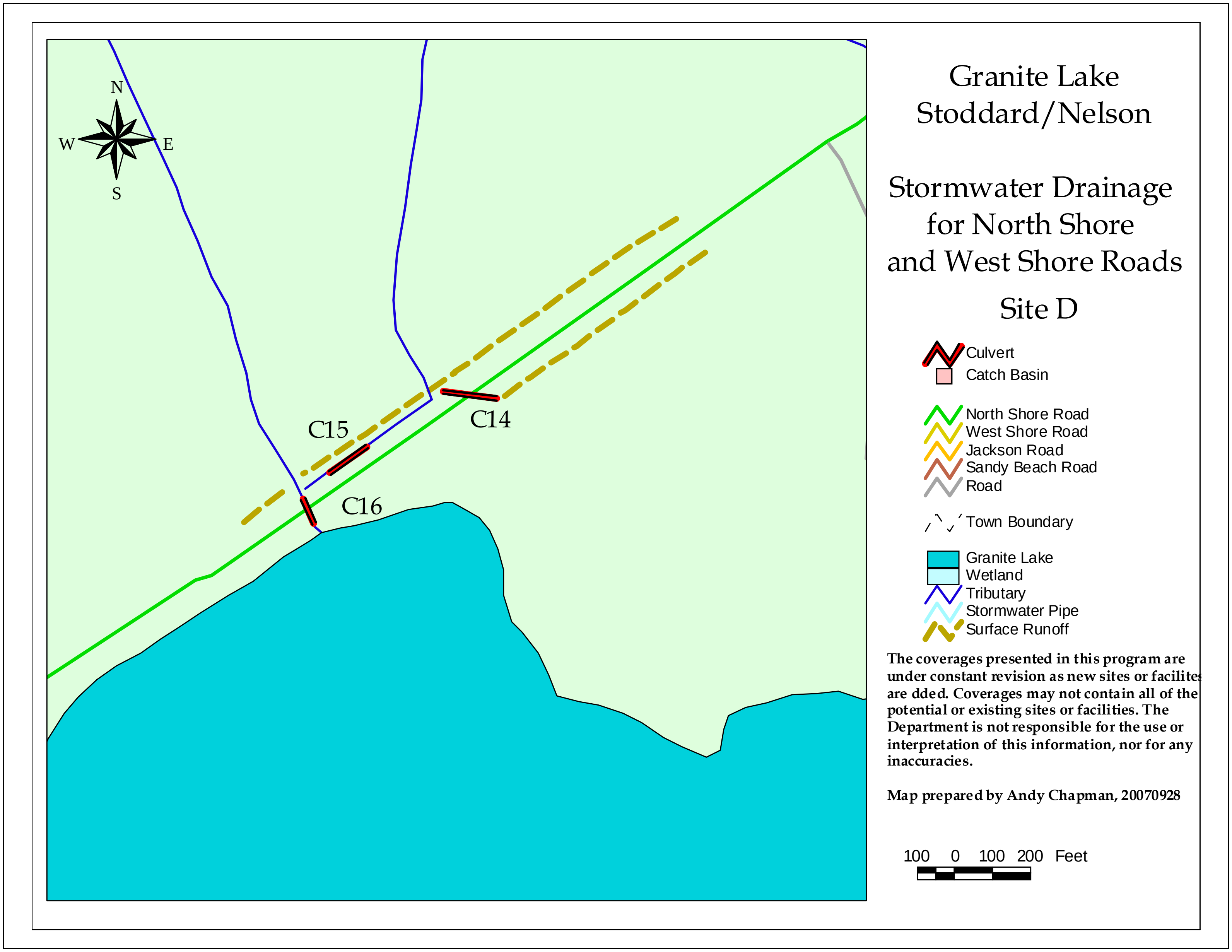

Figure 5: Site D, North Shore Road, house #489 to West Shore Road and Aten Road intersection

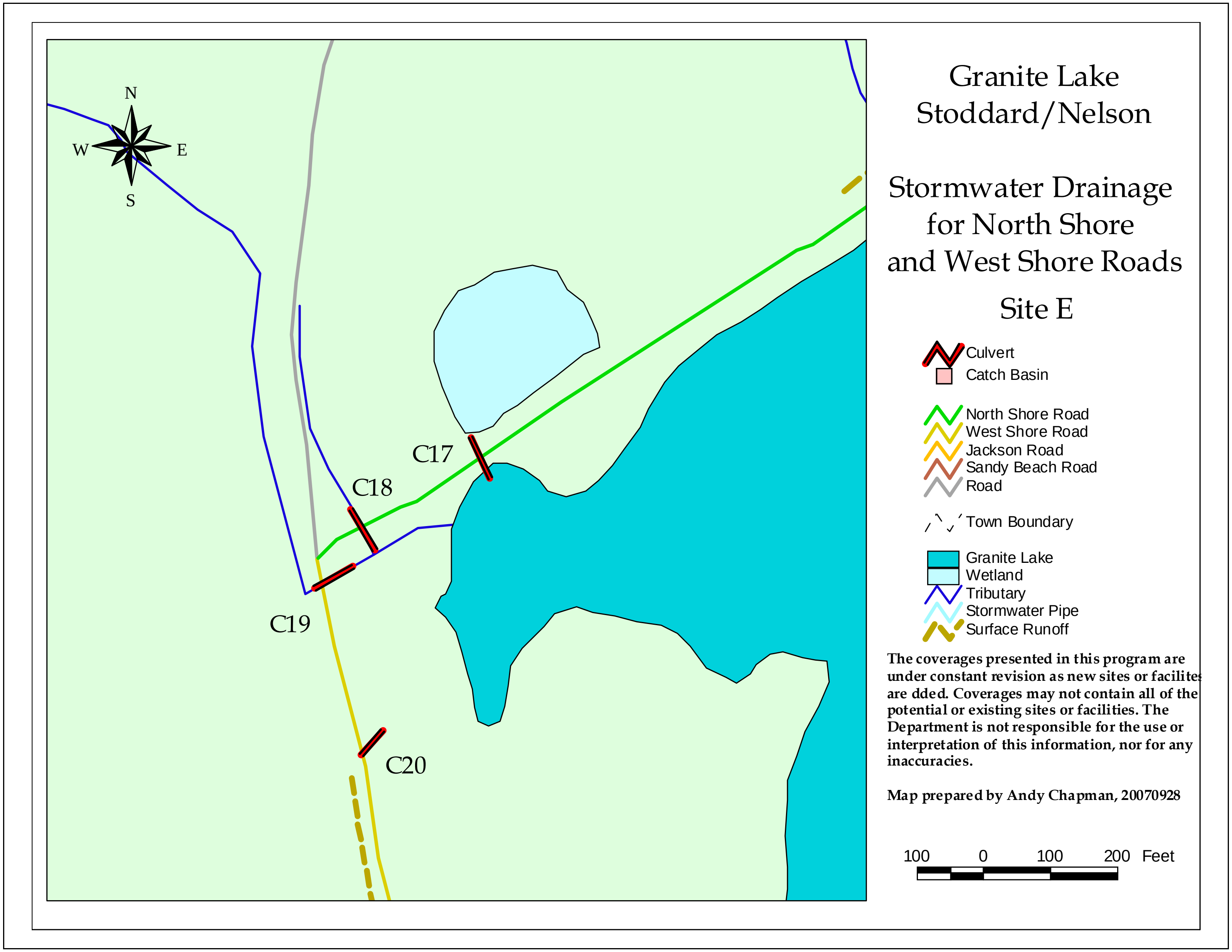

Figure 6: Site E, Intersection of North Shore Road and West Shore Road

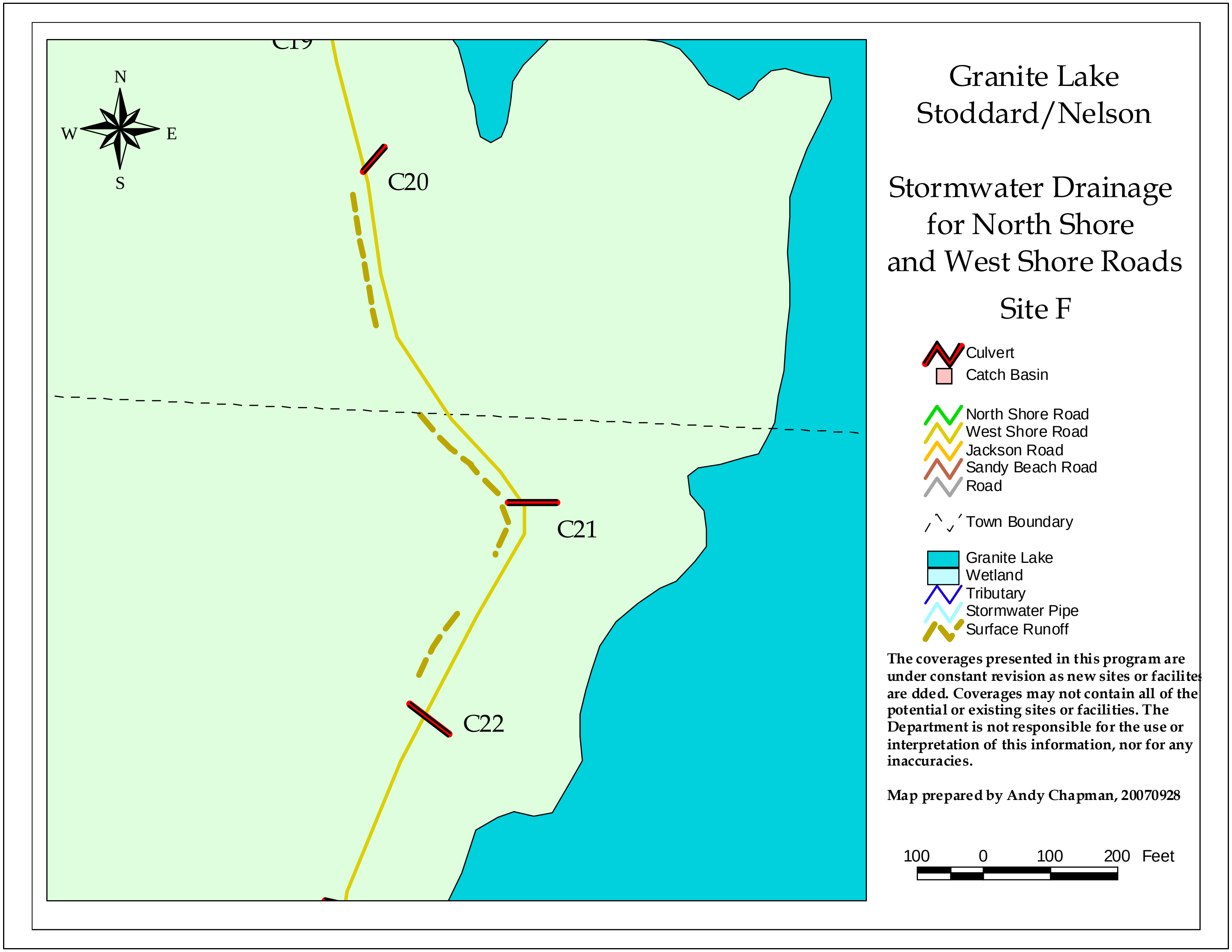

Figure 7: Site F, North Shore and West Shore Road intersection to #84 West Shore Road

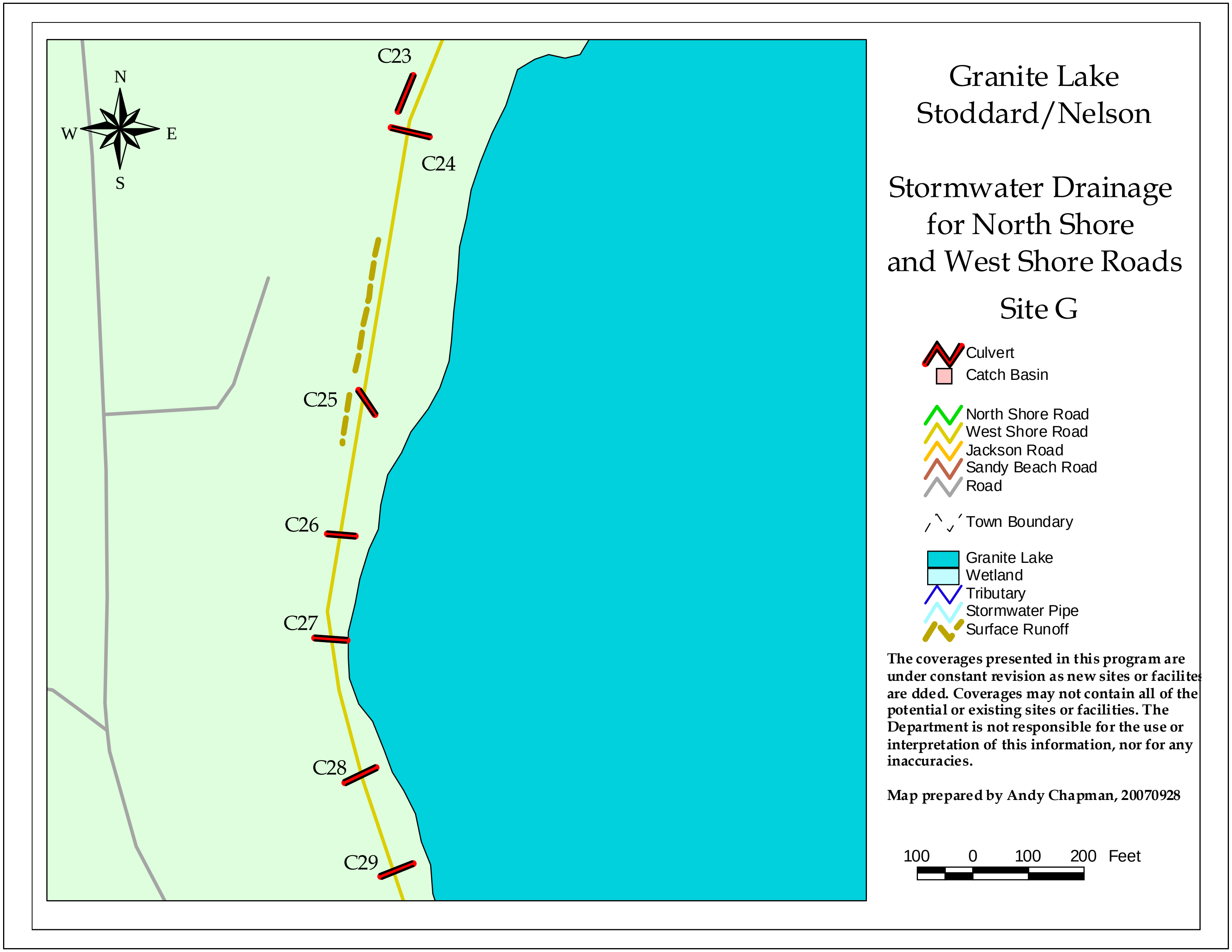

Figure 8: Site G, 84 West Shore Road to Mill Pond Road

Photo 1: Bridge E-2 approach looking north.

Photo 2: Bridge E-2 decking with sediment along shoulder.

Location: Site A, North Shore Inlet Bridge (E-2)
Findings/Problem: a. sand carried to bridge from approaching traffic/plows. b. some sediment transport at southwest abutment.
Recommendation: a. Improve wingwall to prevent sediment transport around SW abutment to stream. b. Pave or stone both approaches to bridge (40-50 ft each side) lower grade of south side approach and possible north side to allow stormwater flow away from bridge decking. c. Do not increase the travel way of North Shore Road.

Photo 3: NE wingwall with stormwater pipe.

Photo 4: CB1

Photo 5: CB2

Location: Site A, bridge E-2 to #110 North Shore Road.

Findings/Problem:

a. Catch basin #1 (CB1) at PSNH UP 28/3 across from Sandy Beach Rd. entrance # 1.
b. Catch basin #2 (CB2), 30 ft. before Sandy Beach Rd. entrance #2. CB2 has a 15 inch pipe inlet and outlet. 2, 4 inch white PVC pipe discharging to CB2.
c. Metal pipe close to surface between CB1 and CB2.
d. 12 inch CMP length to inlet under driveway of house #110 is appr. 100 ft. in length.
e. Road width through this section is appr. 18 ft., with 1-2% grade.

Recommendation:

a. Potentially replace metal pipe from stormwater outlet to CB1 and CB1 to CB2 if rotted. If high groundwater and minimal cover, replace with metal pipe.
b. No room to daylight stormwater pipe prior to stream. Consider Sunapee Swirler or Vortechnics.
c. Consider shallow vegetated swale so stormwater flow doesn’t continue down edge or road.

Photo 6: Jackson Road, looking East from North Shore Rd.

Photo 7: C1 discharge to Granite Lake Inlet.

Location: Site A, Jackson Road
Findings/Problem: a. Approximately 160 ft. off North Shore Road, slight rise in road. b. Jackson Road has minimal traffic volume. c. Sheet flow off Jackson Road to Tributary. No ground vegetation or swale buffers between road and stream.
Recommendation: a. Grade road to the north, away from house and drive into woods. Possibly use 1 or two turnouts if necessary. Flow will drain to 6 inch plastic pipe (C1) located 100 ft. off North Shore Road. This may need to be upgraded with a larger culvert. If so, may want to construct small sediment pool at 6 inch pipe inlet and outlet. 2-3 ft. in diameter. b. If the road continues to be graded with a crown, increase the vegetated buffer between the road and the stream. Potentially construct a small swale to settle sediment before sheet flow runoff to the stream. c. Do not increase the travel way of Jackson Road.

Photo 8: North Shore Road, looking north in front of house #168. CB3 located in bottom right of photo.

Photo 9: CB3 clogged with pine needles and sediment.

Location: Site B, North Shore Road, #150 to #210

Findings/Problem:

a. Stream crossing (200+ft 24 inch) plastic pipe between house #150 and #168.
b. Stormwater and stream flow at C2.
c. Flow from road and driveways (#168) discharges large substantial amount of stormwater runoff to CB3 and eventually C2.
d. Some driveway runoff from house #184 flows along roadway to CB3.
e. CB3 clogged with debris and sediment.
f. Some driveway runoff from house #184 flows north to C3.
g. C3 is a half buried concrete pipe, discharging approximately 30 ft. from the lake.
h. C4 is a 12 in. concrete pipe.
i. C5 is a 24 in. plastic pipe.
j. C3, C4 and C5 headwalls in various conditions of disrepair.

Recommendation:

a. Driveway #184, reduce stormwater runoff rates and volumes by constructing turnouts, adding stone to driveway and infiltrating stormwater before discharging to the road.
b. C3 inlet and outlet headwalls need improvement.
c. C3 headwalls need repair, at both inlet and outlet.
d. C4 headwalls need repair, at both the inlet and outlet.
e. C5 headwalls need repair, preferably with concrete or mortar/rubble.

Photo 10: CB4

Photo 11: CB5

Photo 12: CB6, marked by a wooden stake

Location: Site B, North Shore Road, #210 to #254/256

<u>Findings/Problem:</u>

a. CB4 has minimal sump and is completely clogged.
b. Flow bypasses CB4 to CB5.
c. CB5 located in front of #220 North Shore Road.
d. CB5 collects flow from CB4, CB4 bypass and road runoff between #216 and #254.
e. CB5 discharges to lake.
f. CB5 possibly discharges to CB6 in addition to the lake.
g. Driveway and roof areas from #254-256 discharges substantial amount of runoff given the land area and grade. All water flows to CB6.
h. CB6 discharges to lake.

<u>Recommendation:</u>

a. All CBs to be replaced with deep sumps for periodic sediment removal maintenance.
b. All CBs could be constructed as dry wells with outlets to promote infiltration during smaller rain events.
c. Potentially consider rain garden(s) to infiltrate stormwater from house #254/256.


Photo 13: Drive for house #254/256.


Photo 14: CB7 with sediment.


Photo15: Driveway for house #284/286.

Location: Site B, North Shore Road, #254/256 to #305
Findings/Problem: a. CB7 receives continuous water flow from stream/spring under house #284/286. b. Some driveway runoff discharges to CB7. c. Substantial driveway erosion for house #284/286. d. Dirt driveways north of house #284/286 have erosion around culverts (C9, C10) and within ditchline. e. C11 is a 48 inch metal pipe. Minimal erosion around headwalls.
Recommendation: a. CB7 to be replaced with deep sumps for periodic sediment removal maintenance. b. CB7 could be constructed as dry wells with outlets to promote infiltration during smaller rain events. c. Ditchline improvement between driveway for house #284 and CB7. d. Driveway for house #284/286 could be crowned, stabilized with ditchlines. e. Potentially consider rain garden(s) to infiltrate stormwater from house #284/286. f. Stabilize ditchlines north of house #284/286. g. Construct headwalls for C9 and C10, north of house #284/286. h. Potentially stone or pave approaches to C11 culvert crossing to minimize plow and sand sediment pushed over the bank and into the stream.

Photo 16: North Shore Road, looking north uphill from C13.

Photo 17: North Shore Road, looking downhill at potential turnout location #1

Location: Site C, North Shore Road, #305 to #431

Findings/Problem:

a. CB8 is a concrete cap catch basin with a metal pipe (C12).
b. C13 has (2) 36 inch culverts.
c. Ditchline sediment and erosion on stream banks from North Shore Road stormwater.
d. Driveway #431, culvert, no headwall, slight erosion.

Recommendation:

a. Construct two turnouts on land side of North Shore Road. The first turnout would be located approximately 200 ft. uphill of C13. The second turnout would be constructed on the same side of the road approximately 300 ft. uphill of C13. Both turnouts would be stabilized with 6 inch stone.
b. Improve the lower 150 ft. of ditchline prior to discharging to C13. Improvements would include increased capacity and 6 inch stone to stabilize the ditch. Filter fabric may need to be placed in the ditchline before placement of stone.
c. Construct headwall for house #431 driveway culvert.

Photo 18: North Shore Road, #489 to #514.

Photo 19: #534 North Shore Road (C15)

Photo 20: 24 inch concrete pipe (C16) inlet at house #564.

Location: Site D, North Shore Road, #489 to #564

Findings/Problem:

a. Road slope estimate 9-10% from house #489 to #514
b. 10 inch culvert (C14) carries lake side ditchline flow to land side ditchline flow, creating additional stormwater in the land side ditchline.
c. Stormwater flows through ditchline plastic drive pipe (C15) for house #534.
d. Stormwater flow and stream flow carried to C16, a 24 inch concrete pipe.

Recommendation:

a. Improve ditchline capacity on land side of North Shore Road, adding filter fabric and 6 inch stone.
b. If road washouts are a problem, consider paving the steep portion of North Shore Road.
c. Potentially construct check dams in ditchline to capture eroded road bed material.
d. Construct plunge pool/check dam prior to 24 inch concrete pipe (C16) inlet to trap sediment.


Photo 21: C17

Photo 22: C18 outlet discharge to stream.

Photo 23: Severe bank erosion at outlet of C19.

Location: Site E, North Shore Road, Cove Woods Road to Aten Road/West Shore Road
<u>Findings/Problem:</u> a. Beach across from Cove Woods Road, unstable, signs of erosion into lake. b. C17, 18 inch plastic pipe, no headwall, erosion around pipe outlet. c. Significant erosion at C18 (24 inch plastic pipe) outlet. Outlet pipe directed into stream banking. d. Significant erosion at C19 (24 inch plastic pipe) outlet. Outlet pipe directed into stream banking.
<u>Recommendation:</u> a. Land area for all beaches around lake should be eliminated/ reduced and replaced with native vegetation. Beaches that remain should be perched to prevent erosion into the lake. b. Construct concrete headwall on C17 outlet. c. Town(s) should hire an engineer to perform a hydrologic analysis of this subwatershed discharging at the North Shore/ West Shore/ Aten Road intersection.

Photo 24: C21 inlet.

Photo 25: C22 inlet

Photo 26: C22 outlet piped under garage to lake

Location: Site F, West Shore Road to house #84
Findings/Problem: a. Paved section of West Shore Road, culvert (C20) several hundred feet from lake. b. No headwall at culvert (C21) at house #106. c. C21 is a 15 inch plastic pipe. The outlet discharges a few hundred feet from the lake. d. Ditchline from house #106 to #92 has minimal stormwater capacity. e. C22 oultet pipe to concrete basin on private property.
Recommendation: a. Construct inlet headwall at culvert C21 b. Construct small plunge pool at inlet or outlet of C21. c. Improve ditchline capacity from house #106 to #84, add stone/ check dams to reduce velocity rates. d. Construct headwall at C22 e. Maintain catch basin structure on private property at the outlet of C22 before being piped under recently constructed garage.


Photo 26: C23 outlet and C24 inlet at house #58


Photo 27: C25 inlet


Photo 28: C26 inlet

Location: Site G, West Shore Road, house #84 to Mill Pond Road
Findings/Problem: a. House #58 to #49 has limited road width/shoulder. b. 15 inch culvert pipe (C23) for driveway #58. c. 15 inch metal pipe (C24) discharges 100-200 feet from the lake. d. C25 has sufficient room to construct BMP at this site on land side of road near house #49. e. Culvert C25 headwalls in disrepair. f. C25 outlet only a few feet from the lake. g. C26 at house #44, discharges a few feet from lake. h. C26, 15 inch metal pipe, inlet headwall in disrepair. i. C27, 15 inch metal pipe, no headwall. j. C28, 15 inch metal pipe, no headwall. k. C29, possibly a concrete pipe, no headwalls.
Recommendation: a. At outlet of C23/ inlet of C24, construct a stormwater settling area. b. Possibly place check dam at outlet of C24 to trap sediment. c. Improve ditchline capacity to trap road sediment before discharging to C25 if space allows. d. Rebuild C25, 26, 27, 28 and 29 headwalls.

Appendix G

ENSR LRM Coefficients and Data

Table G-1: Granite Lake Tributary Summer Water Quality 2003-2009

Statistic	TP-Inlet	TP- Outlet in Stream	TP-Townline Inlet	TP-Foxweldon	TP-North Shore End	TP-North Shore West Shore	TP-210 North Shore Rd	TP-305 North Shore Rd
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Count	18	20	20	3	3	3	3	3
Min	2.5	2.5	2.5	6.5	2.5	2.5	7.0	2.5
Mean	16.7	6.7	5.5	7.5	5.3	2.5	11.0	2.5
Max	41.0	26.0	10.0	8.6	7.1	2.5	14.0	2.5
Median	15.5	5.0	5.4	7.5	6.4	2.5	12.0	2.5

Statistic	TP-395 North Shore Rd	TP-431 North Shore Rd	TP-558 Granite Lake Rd	TP-586 Granite Lake Rd	TP-603 Granite Lake Rd	TP-614 Granite Lake Rd	TP-657 Granite Lake Rd	TP-668 Granite Lake Rd	TP-Warren Dr	TP-Little Granite Lake Inlet	TP-Logging Road	TP-Nye Meadow Outlet
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Count	3	2	2	3	3	3	2	2	1	1	1	1
Min	2.5	10.0	6.6	5.7	2.5	6.6	2.5	2.5	7.6	20.0	15.0	15.0
Mean	5.0	13.0	9.8	6.0	2.5	8.9	2.5	10.3	7.6	20.0	15.0	15.0
Max	6.7	16.0	13.0	6.4	2.5	11.0	2.5	18.0	7.6	20.0	15.0	15.0
Median	5.8	13.0	9.8	5.9	2.5	9.1	2.5	10.3	7.6	20.0	15.0	15.0

Table G-2. Land use categories used in Granite Lake ENSR-LRM.

ENSR-LRM LAND USE	Land Use Description	Land Cover Code[1]	Land Cover Description	NWI code[2]	Windshield Survey	P export coefficient range
Urban 1 (Residential)	Residential			not wetland area		0.19 - 6.23
	Residential					
	Residential					
	Residential					
Urban 2 (Mixed Urban/Commercial)	Mixed Urban/ Commercial			not wetland area		0.19 - 6.23
	Municipal Buildings					
	Educational Buildings					
Urban 3 (Roads)	Transportation	140				0.19 - 6.23
Urban 4 (Industrial)						0.19 - 6.23
Urban 5 (Parks, Recreation Fields, Institutional)	Municipal Fields	17			X	0.19 - 6.23
		700				
	Non-Ag Fields	790			X	
Agric 1 (Cvr Crop)	Agriculture				X	0.10 - 2.9
Agric 2 (Row Crop)	Agriculture	211	Row Crops		X	0.26 - 18.26
Agric 3 (Grazing)	Agriculture		Hay/rotation/permanent pasture		X	0.14 - 4.90
Agric 4 (Hayland-no manure)	Agriculture	212	Hay/rotation/permanent pasture			0.64
Agric 5 (Orchard)	Agriculture	221	Fruit Orchard			0.05-0.30
Forest 1 (Deciduous)	Forested	412	Beech/oak			0.29 - 0.973
	Forested	414	Paper birch/aspen			
	Forested	419	Other hardwoods			
Forest 2 (Non-Deciduous)	Forested	421	White/red pine			0.01 - 0.14
	Forested	422	Spruce/fir			
	Forested	423	Hemlock			
	Forested	424	Pitch pine			
Forest 3 (Mixed)	Forested	430	Mixed forest			0.02 - 0.83
Forest 4 (Wetland)	Forested			PF___		0.02 - 0.83
		610	Forested wetlands			
Open 1 (Wetland / Lake)	Water	500	Non-forested wetlands			0.02 - 0.83
	Open wetland	620	Open water			
				PSS_, L1_, PEM__		
Open 2 (Meadow)					X	0.02 - 0.83
Open 3 (Cleared/Disturbed Land)	Gravel pits, quarries	710	Disturbed		X	0.14- 4.90
Other 1:						

[1] Land cover data created by GRANIT using Lansat 5 and 7 imagery and other available raster and vector data.

[2] National Wetlands Inventory (NWI) data is used to improve the accuracy of wetland areas that are either not delineated in the land use and land cover data or

Priority ranking is given to the Land Use data set for all non-wetland areas, NWI data for wetland areas, and Land cover for forest type areas.

Table G-3. Land use export coefficients (kg/ha/yr) used in Granite Lake LRM

ENSR-LRM Land Use	Runoff P export coefficient range	Runoff P export coefficient used	Source	Baseflow P export coefficient range	Baseflow P export coefficient used	Source
Urban 1 (Low Density Residential)	0.19-6.23	0.20	Schloss and Connor 2000-Table 5	0.001-0.05	0.01	ENSR Unpublished Data; Mitchell et al. 1989
Urban 2 (Mid-Density Residential/Commercial)	0.19-6.23	1.10	Reckhow et al. 1980	0.001-0.05	0.01	"
Urban 3 (Roads)	0.19-6.23	1.10	Dudley et al. 1997	0.001-0.05	0.01	"
Urban 4 (Industrial)	0.19-6.23	1.10	Reckhow et al. 1980	0.001-0.05	0.01	"
Urban 5 (Mowed Fields)	0.19-6.23	0.80	Reckhow et al. 1980	0.001-0.05	0.01	"
Agric 1 (Cvr Crop)	0.10-2.90	0.80	Reckhow et al. 1980	0.001-0.05	0.01	"
Agric 2 (Row Crop)	0.26-18.26	2.20	Reckhow et al. 1980	0.001-0.05	0.01	"
Agric 3 (Grazing)	0.14-4.90	0.80	Reckhow et al. 1980	0.001-0.05	0.01	"
Agric 4 (Hayfield)	0.35	0.35	Dennis and Sage 1981	0.001-0.05	0.01	"
Forest 1 (Deciduous)	0.29 - 0.973	0.15	Schloss and Connor 2000- Table 4	0.001-0.010	0.004	"
Forest 2 (Non-deciduous)	0.01 - 0.14	0.09	Schloss and Connor 2000- Table 4	0.001-0.010	0.004	"
Forest 3 (Mixed)	0.01-0.138	0.09	Schloss and Connor 2000- Table 4	0.001-0.010	0.004	"
Forest 4 (Wetland)	0.02 - 0.83	0.08	Schloss and Connor 2000-Table 4	0.001-0.010	0.004	"
Open 1 (Wetland/Lake)	0.02 - 0.83	0.07	Schloss and Connor 2000-Table 5	0.001-0.010	0.004	"
Open 2 (Meadow)	0.02 - 0.83	0.20	Reckhow et al. 1980	0.001-0.010	0.004	"
Open 3 (Excavation)	0.14- 4.90	0.80	Reckhow et al. 1980	0.001-0.010	0.004	"

Table G-4. Septic system calculations in Granite Lake LRM.

Category	# of Dwellings	People/ Dwelling	TP Atten Factor	Mean TP Conc (mg/L)	P Load (kg/yr)	Water (cu. m/day)	# of Days	Water Load (m^3/yr)
Year Round Residential New or Upgraded Septics	19	2.5	0.1	8	3.5	0.25	365	4,334
Year Round Residential Old Septics	19	2.5	0.2	8	6.9	0.25	365	4,334
Seasonal Residential New or Upgraded Septics	40	2.5	0.1	8	1.8	0.25	90	2,250
Seasonal Residential Old Septics	47	2.5	0.2	8	4.2	0.25	90	2,644
Total Septic System Loading					16.4			13,563

Table G-5. Current TP loading in Granite Lake

TP INPUTS	Modeled Current TP Loading (kg/yr)	% of Total Load
Atmospheric	23.8	22
Internal	0.0	0
Waterfowl	2.0	2
Septic Systems	16.4	15
BASIN 1- Direct Drainage	6.9	6
BASIN 2- North Shore End	2.5	2
BASIN 3- Foxweldon	1.2	1
BASIN 4-	0.3	0
BASIN 5- Warren Dr	0.3	0
BASIN 6- 431 N Shore	0.8	1
BASIN 7- 395 N Shore	1.7	2
BASIN 8- 305 N Shore	0.7	1
BASIN 9-210 N Shore	1.0	1
BASIN 10- Inlet	46.8	43
BASIN 11- Town Inlet	1.6	1
BASIN 12- 668 GLR	0.7	1
BASIN 13- 603 GLR	1.5	1
BASIN 14- 586 GLR	0.8	1
Watershed	66.9	61
Total	**109.2**	**100**