Deering Lake Hydrologic and Nutrient Loading Analysis

DEERING, NEW HAMPSHIRE

PREPARED FOR:

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Project No.: C506-000

November 18, 2003

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1.0 INTRODUCTION

ESS Group, Inc. evaluated the potential impact to Deering Lake from two proposed residential subdivisions to be constructed within the Deering Lake watershed. The CASA Land & Timber, LLC (CASA) development is located to the west of Deering Lake, nearly ½ mile from the lakeshore. The CASA development is proposed as a nine-lot single-family residential subdivision on a 69.4-acre parcel. The parcel has extensive wetlands throughout; the wetlands span each of the nine lots. A significant portion of each lot (reportedly <3.5 acres/lot) will be maintained as conservation land. CTR Development, LLC (CTR) has proposed the second residential subdivision for a site located northeast of Deering Lake. The CTR development plan is described as an eight-lot single-family residential subdivision on a parcel of approximately 20 acres. The CTR property abuts Deering Lake and is drained directly to the lake by a wetland and stream system (Morrotta Inlet). CTR is currently proposing a “cluster” development to minimize the development’s footprint (the area of land that is disturbed) thereby minimizing impervious surfaces (typically driveways).

Town officials and local residents have expressed concern over the potential for these developments, as well as future developments, to result in excessive nutrient loading to the lake and contribute to a subsequent decrease in water quality. With respect to the perceived water quality of the lake, it was made clear that most watershed stakeholders are very pleased with the quality and clarity of the water in Deering Lake at the present time. Deering Lake is classified by New Hampshire Department of Environmental Services (NHDES) as an oligotrophic (low productivity) waterbody. It is expected that this hydrologic and nutrient loading analysis will aid the Town in protecting the quality of the lake and will serve to determine whether the proposed developments (or other developments and activities within the watershed) are compatible with maintaining current in-lake conditions.

As such, the goal of our analysis was to first model the Deering Lake system to establish its current condition with regard to hydrologic and nutrient loading. ESS then determined how the addition of the two proposed development projects to the watershed would affect the nutrient loading budget and ultimately the quality of water within the lake. ESS considered project-specific information as supplied by each project proponent, although some conservative assumptions were made when specific project development details were not available. This report also contains specific Best Management Practices

(BMPs) that should be considered in order to minimize the potential impacts associated with each development.

2.0 STUDY APPROACH

The Deering Lake watershed assessment consisted of a review of background information, topographic maps, soils data, field data collected by volunteers over the past 15 years, hydrologic modeling, and nutrient load modeling. Water quality information collected by the volunteers was crucial to providing insight into potential sources and the degree of pollutant loading to the system as currently developed. While additional data collected from within the watershed would be desirable (particularly flow data), the data that was readily available was sufficient to make reasonable assumptions regarding pollutant inputs and in-lake water quality.

Background data and general lake and watershed information were compiled from existing sources, including the United States Geological Survey (USGS, 2000) topographic map (Figure 1), 2001 GRANIT land-use data (Figure 2), NHDES Volunteer Lake Assessment Program reports, long-term climatological data, and property maps provided by CASA and CTR.

The hydrologic (water flow) and nutrient (phosphorus and nitrogen) budgets for Deering Lake were calculated using the long-term climatological data, knowledge of lake morpohology, and from field data collected by volunteers. Nutrient budgets were determined using a variety of limnological modeling techniques based on watershed features and field data specific to the lake. The modeling effort relied heavily upon system hydrology and nutrient concentrations exhibited from the in-lake and tributary stations between 1998 and 2002 (the most recent data). Nutrient loading to the lake was also assessed using land use data and land use export coefficients specific to each watershed sub-basin.

3.0 STUDY RESULTS

3.1 Watershed Features

A USGS topographic map was used to identify the watershed of Deering Lake (Figure 1). The watershed, including Deering Lake, was calculated to be approximately 2,820 acres or slightly more than eight times the area of the lake itself. Generally speaking, when a lake's watershed area is 10 times the area of the lake or less, the lake usually does not experience significant water quality problems unless development within the watershed is excessive or poorly designed.

The majority of land within the Deering Lake watershed is forested (78%) with slightly more than 1% devoted to residential (based on GRANIT land use cover maps). Other land uses include cropland and pasture, wetlands, open land, transportation (roads), and surface water (Figure 2, Table 1).

Although the majority of the Deering Lake watershed is vegetated, many of the roads and residences are located in close proximity to the lake.

Further delineation of the watershed allowed ESS to designate four (4) discrete watershed sub-basins (Figure 2, Table 1). Land use data of these sub-basin delineations indicate that sub-basin 1, the largest sub-basin, is located west of the lake and is predominately forest (90%). Sub-basin 2, located northwest of the lake and drained by two unnamed tributaries that enter the lake at the Zowski Inlet, is also predominately comprised of forest (87%), but with a relatively large fraction of land devoted to cropland/pasture (5%). Sub-basin 3, located directly north of the lake is less forested than any of the other basins (70%). Sub-basin 3 contains the greatest percentage of cropland/pasture (nearly 16%). Finally, sub-basin 4, located around the entire perimeter of the lake is predominately comprised of forest (88%), transportation (4%), and residential (2.5%). Sub-basin 4 drains to the lake by small, possibly intermittent, tributaries and via overland flow.

Table 2 is provided to present the expected land use coverage within the Deering Lake watershed once the CASA and CTR developments are completed. The CASA property, located in sub-basin 1, would convert 13.5 acres of forested land to residential land, while the CTR property, located in Sub-basin 4, would convert approximately 10.5 acres of forested land to residential land (one of the proposed lots is already developed). These changes would result in a 1% decrease in the percentage of watershed that is forested (from 78% to 77%) and a nearly 2% increase in the percentage of residential land within the watershed (from slightly more than 1% to 3%).

3.2 Lake Features

3.2.1 Physical Characteristics

Deering Lake (a.k.a. Deering Reservoir) is approximately 329 acres in size (Table 1). Deering Lake is primarily fed by its main inlet (Tuckernuck Inlet), which drains sub-basin 1. Several other minor inlets feed into the lake in its northern cove. The outlet from Deering Lake is located at its southeastern end (Figure 1) and is controlled by a man-made outlet structure.

A bathymetry map exists for the lake, depicting 10-foot contour intervals. Water depths are reported to reach a maximum of 37 feet (NHDES) with an average depth calculated to be nearly 11 feet. The northern cove of the lake is relatively shallow (<8 feet) and gently sloped. This condition is conducive to the establishment of rooted plant growth when nutrients and soft sediment are abundant. Calculations based on our bathymetric data indicate that the lake has an approximate volume of approximately 157 million cubic feet of water (Table 3).

3.2.2 Chemical Characteristics

3.2.2.1 Surface Water Analysis

ESS was provided with water quality data covering a period of 1987 through 2002 (15 years). For this analysis, only the most recent data (from 1998 though 2002) was used since this is believed to be most reflective of current water quality conditions. Water quality monitoring stations were established within the lake at its surface, mid-depth, and bottom as well as at the three primary inlets (Tuckernuck, Zowski, and Morrotta) and the outlet.

Water quality monitoring was reported to have occurred on dry weather and wet weather sampling dates; however, no record of conditions was provided with the data set made available to ESS. It should also be noted that flow data was not provided with the water quality data provided to ESS. Below is a summary of the water quality data pertinent to the current analysis.

Dissolved Oxygen and Temperature

Dissolved oxygen is the amount of molecular oxygen (O_2) dissolved in water. Dissolved oxygen below 5 mg/L is generally considered unsuitable for many forms of aquatic life. Additionally, release of phosphorus (which promotes algal and plant growth) from bottom sediments can often be enhanced under anoxic (no oxygen) or very low oxygen (<1.0 mg/L) conditions. Temperature and dissolved oxygen are typically measured within the water column to determine the extent of lake stratification.

Temperature profiles for Deering Lake indicate that the lake is stratified during each summer with the thermocline occurring at an approximate depth of 6.7 meters. In all instances, the dissolved oxygen levels in the epilimnion (i.e., waters above the thermocline) are greater than 5 mg/L and therefore, reflect a well oxygenated environment; however, the lake bottom was found to be poorly oxygenated (≤ 5 mg/L) at depth of more than 7 or 8 meters.

Water Transparency

Water transparency (or clarity) in Deering Lake was measured by volunteers in the field with a Secchi disk at the in-lake station. Factors such as plankton concentration, water color, and suspended particles within the water column directly impact Secchi depth measurements.

Secchi depth values were higher than most New Hampshire lakes with an average of approximately 6 meters. Typically, Secchi depths from New Hampshire lakes and ponds average 3.7 meters (NHDES).

Phosphorus and Nitrogen

Phosphorus and nitrogen are essential plant nutrients. Excessive concentrations of one or both of these nutrients can result in undesirable growth of algae in the water column (phytoplankton) and accumulations of attached algae (periphyton) on the shallower bottom sediments (within the euphotic zone). In addition, excessive quantities of these nutrients can also promote rooted plant growth.

Phosphorus

Typically, phosphorus values no greater than 0.02 mg/L (20 ppb) are desirable for maintaining low algal biomass and high water clarity, while concentrations above 0.05 mg/L (50 ppb) are considered excessive and indicative of a eutrophic system (Canavan and Siver, 1995).

Average total phosphorus values measured at the in-lake station during the period of 1998 through 2002 were 0.007 mg/L in the epiliminion (upper waters) and 0.016 mg/L in the hypolimnion (bottom waters). These data suggest that higher levels of phosphorus are available within the lake but may be confined to the hypolimnion of the basin. These data, in combination with the dissolved oxygen profile data, suggest that anoxic conditions on the lake bottom may also be promoting the release of sediment bound phosphorus into the water column. This phosphorus rich bottom water would be circulated throughout the lake during periods when the thermocline is not established, typically during the spring and fall when the lake “turns over”.

Average total phosphorus values from the main inlet (Tuckernuck Inlet), Zowski Inlet, and Morrotta Inlet averaged 0.017, 0.023, and 0.029 mg/L, respectively, during the period of 1998 through 2002. The values observed from Zowski and Morrotta suggest that these tributaries are exhibiting slightly elevated phosphorus values and may be contributing to the degradation of water quality within the lake.

Nitrogen

Nitrate-nitrogen, one of the several major forms of nitrogen, within Deering Lake was generally low, averaging <0.05 m/L (NHDES). Nitrate-nitrogen levels from the inflowing tributaries were not available in the data provided to ESS.

Similarly, total Kjeldahl nitrogen or TKN, another form of nitrogen that represents a measure of the amount of ammonia and organic nitrogen in a sample, was also relatively low. Average TKN values for the in-lake station were 0.22 mg/L (NHDES). TKN levels at the inflowing tributaries were not available in the data provided to ESS.

Together, TKN and nitrate-nitrogen form the significant portion of total nitrogen that is typically observed in aquatic systems (nitrite, not analyzed in the present study, is typically present as an insignificant fraction comprising total nitrogen). Typically, total nitrogen values no greater than 1.0 mg/L are desirable for maintaining high water quality, while concentrations above 5.0 mg/L are considered excessive and indicative of a hyper-eutrophic system. The average total nitrogen level for the in-lake stations was 0.25 mg/L, although this represents only a few measurements collected over a very limited period of time. These data suggest that very low levels of nitrogen are available within the lake.

3.2.3 Hydrologic and Nutrient Loading

Hydrologic Load Analysis

It is possible to estimate the amount (load) of phosphorus and nitrogen being contributed to Deering Lake by its watershed when an estimate of water flowing into the lake and the concentration of each nutrient in this water is known. Water flowing into Deering Lake comes from three primary sources: surface water, groundwater, and direct precipitation.

Surface water flows can be estimated from actual flow data or from known relationships for water yield from similar watersheds. Three major inflowing tributaries to the lake exist; however, surface water also enters the lake directly during rain events as overland runoff. The average annual flow rate to the lake was calculated to include both sources of flow and was based on the area of the watershed and local precipitation data. Directly measured stream flow data was not provided to ESS. An estimate of the rate of groundwater movement into the lake was based on averages obtained for New England lakes and lakes of similar geo-morphometry. Typically, groundwater movement is measured directly through the use of seepage meters. Inputs from direct precipitation were determined from long-term climatological data for the region (37.36 inches of precipitation per year) and the known surface area of the lake.

Estimated average water input to Deering Lake from surface water, groundwater, and direct precipitation is 6.3, 1.1, and 0.95 cfs, respectively, for a total average annual flow of approximately 8.36 cfs (Table 3 and the Hydrologic Loading Analysis - Appendix 1). This flow will vary appreciably among seasons and weather conditions. Surface water runoff contributes significantly (75.5%) to the total lake inflow, while groundwater inflow (13.2%) and precipitation

(11.3%) makes up the remainder. Typically, surface water flow can be further divided into dry weather (background) flows and wet weather (storm) flows. For Deering Lake, dry weather flows were estimated to be approximately 0.57 cfs, while wet weather flows were determined to be 5.73 cfs (Table 3).

Based on total lake volume and the calculated flow through the lake, average detention time was calculated to be 217.3 days (0.6 years) (Table 3). Detention time represents the duration of time necessary to exchange the volume of water in the lake one time. Flushing rate is the inverse of detention time, and represents the number of times per year the lake volume is replaced; for Deering Lake the flushing rate is about 1.68 times per year. This is a moderate flushing rate, but would be anticipated for Deering Lake, which is a moderately deep lake with a moderately sized watershed.

When detention time is known, a calculation can be made to determine response time (time needed for a lake to fully realize nutrient inputs), which for Deering Lake ranges between 224 and 374 days. Since Deering Lake's detention time (217.3 days) is less than its response time, the effect of nutrients entering the lake is not likely to be expressed fully before passing through the system (i.e., the conditions within the lake are likely to be better than would be anticipated based on the water quality it receives).

Nutrient Loading Analysis – Land Use Export Coefficient Model

The nutrient water quality data can be placed into further perspective once the values are interpreted as a measurement of the nutrient load to Deering Lake. An approach for estimating the nutrient load to Deering Lake that may be the most insightful method when trying to determine the effects of development on a watershed, is to calculate the nutrient load generated by each acre of land in the watershed based on its use (Table 4). This nutrient export modeling approach was developed the U.S. Environmental Protection Agency (USEPA) (Reckhow et. al, 1980) and is used by many lake modelers. Attenuation coefficients are used to calculate the total load that actually would be expected to reach the lake based on the structure of the watershed and the relative distance of the drainage area from the lake. Based on the size of the Deering Lake watershed, its predominantly forested composition, and the limited drainage afforded by tributaries, an average of only 21% of the phosphorus and nitrogen load generated within the watershed would be expected to reach Deering Lake; however, this varies for each watershed sub-basin (Table 4). Table 4 summarizes the above calculation for the Deering Lake watershed. The expected average phosphorus load to Deering Lake using these calculations would be roughly 190.1 kg/yr.

Table 5 presents the same calculations, but includes the developments proposed by CASA and CTR within the watershed. Based on the proposed development conditions, the average annual phosphorus loading rate would be expected to increase by 6.1 kg/yr (Table 7) resulting in a total average annual loading rate to the lake of 196.3 kg/yr. This represents an increase in loading of approximately 3.3%.

Nutrient Loading Analysis – In-Lake Modeling Theory, Existing Conditions

Based on the expected loading increase, it is possible to determine how the lake quality would change to reflect the increased phosphorus load. First, a calculation of the minimum existing nutrient load was made by multiplying the volume of the lake by its flushing rate and the average concentration of the nutrient observed during the study period (1998 – 2002). The minimum existing phosphorus and nitrogen loads delivered to Deering Lake were determined to be 0.06 g/m^2/yr (86 kg/yr) and 1.40 g/m^2/yr (1,865 kg/yr), respectively, based on the in-lake concentration data collected provided to ESS (Table 6 and Deering Lake Existing Conditions - Appendix 1)*.* The actual load of phosphorus or nitrogen will exceed the estimated minimum load as a consequence of loss processes that reduce the in-lake concentration over time. Since phosphorus is viewed as the nutrient that controls productivity in this freshwater lake, emphasis is placed on a more detailed modeling analysis of phosphorus loading to Deering Lake.

A more detailed and realistic estimate of nutrient loading can be obtained by using a combination of actual field data and in-lake modeling theory. Nutrient loads are calculated based on nutrient values measured within the lake and hydraulic features of the lake. The predicted phosphorus load necessary to achieve the values found in Deering Lake ranges between 0.11 g/m^2/yr (142 kg/yr) and 0.21 g/m^2/yr (281 kg/yr) based on this approach (Table 6, Existing Conditions - Appendix 1). The average predicted phosphorus load for all models was 0.13 g/m2/yr (174 kg/yr). The nitrogen load necessary to achieve the observed in-lake concentrations was estimated to be 2.17 g/m2/yr (2,891 kg/yr) (Bachmann 1980) in this manner (Table 6).

Vollenweider (1968) established criteria for calculating the phosphorus load below which no productivity problems were expected (permissible load) and above which productivity problems were almost certain to persist (critical load). These loading limits are also based on the hydraulic properties of the lake and depend upon average depth and detention time. The average of phosphorus loads estimated for the lake through in-lake modeling (174 kg/yr) is well below the calculated permissible level of 315 kg/yr, and considerably lower than the critical level of 629 kg/yr (Table 6). This indicates that phosphorus levels in Deering are well below levels that would be likely to result in degraded water quality conditions. This knowledge is useful for determining the value of the various management alternatives and watershed development strategies.

Similar loading limits for nitrogen have not been established, owing to the less predictable relationship between nitrogen, lake hydrology, and primary productivity. Although nitrogen data are very useful in understanding lake conditions and processes, phosphorus is the logical target for controlling algal biomass and plant growth in Deering Lake.

These estimates are based on the relatively limited number of samples and could be influenced by the conditions prior to the commencement of the sampling or by the size of the particular storm events sampled. Although it is believed that this analysis is generally accurate since a sufficient number of samples were collected over a range of dates and years, it is acknowledged that the analysis could be further refined if weather data and flow data become available.

Nutrient Loading Analysis – In-Lake Modeling Theory, Proposed Conditions

Based on the phosphorus loading increase established by the land use export coefficient model (6.2 kg/yr), it is possible to model the expected effect on the water quality of Deering Lake. The results of this modeling effort are presented in Table 6 as calculated in Appendix 1 (Deering Lake Proposed Conditions). Based on the addition of the two developments, as proposed, the average annual phosphorus load to the lake would increase by approximately 6 kg/yr, resulting in an average annual phosphorus load of approximately 180 kg/yr. This is still far below the Vollenweider permissible and critical loading levels and would indicate that there would not be a significant change in water quality as a result of the two proposed developments.

This phosphorus loading increase is likely to result in a slight increase in maximum Chlorophyll levels from 5.7 μg/L to 6.9 μg/L and a corresponding decrease in predicted water clarity from the current modeled maximum of 5.9 meters to a modeled maximum of 5.7 meters. These values are still considered oligotrophic and significantly superior to state averages for New Hampshire lakes.

4.0 MANAGEMENT RECOMMENDATIONS

Existing water quality within Deering Lake is generally acceptable or superior for most intended uses of the lake (boating, wildlife viewing, fishing, etc.). Concentrations of phosphorus, however, considered to be the most important plant nutrient, are believed to be elevated in the tributaries draining to the lake, particularly during storm events. Although not currently a problem, the condition may worsen as additional development of the watershed occurs unless the development is conducted in a manner that is sensitive to controlling and managing surface water runoff. The loading of other contaminants such as sediment, nitrogen, bacteria and salt to Deering Lake is most likely erratic and largely a function of episodic storm events and seasonal conditions.

Loading analysis suggests that the phosphorus load to Deering Lake is well below the permissible level, suggesting that eutrophic (nutrient enriched) conditions are not likely to be experienced in the lake unless nutrient loading increases substantially. Preventative management actions within the drainage basin are justified, and primary consideration should be given to managing nutrient (especially phosphorus), sediment and even fecal coliform inputs. Storm water runoff is believed to be responsible for a large fraction of the phosphorus load. Possible actions include behavioral modifications and additional land use planning.

4.1 Behavioral Modifications

Behavioral modifications include alteration of individual or group practices that lead to increased runoff or pollutant loading. Actions relating to lawn care, yard waste disposal, automotive cleaning and maintenance, and deicing would be likely targets for this approach. Modifications are usually attained by a combination of education and regulation, but there are practical limits in an urban environment. Most behavioral controls are best implemented on a voluntary basis as a preventative measure since they are unlikely to provide more than a five to ten percent reduction in loads. Mandatory controls are better suited to situations of clear non-compliance, as with illegal hook-ups to the storm drainage system or poorly designed or maintained sewage disposal systems. Since the homes surrounding the lake and within the watershed area are not sewered, it is likely that poor or faulty sewage disposal systems are occurring in a limited number of homes. Further study is warranted to identify specific violations or to identify areas in which storm water runoff quality is exceedingly poor. Such a study may involve expanded monitoring of discharges at key locations within the watershed to define any “hot spots.” Funding on the order of $8,000 is estimated be necessary, although some cost savings may be achieved if volunteers conduct their own research. At a minimum, professional design of the monitoring program and analysis of the results is recommended.

There are typically no permits or tangible costs associated with any of the above-described behavioral modifications, but compliance is difficult to measure and major changes in water quality are rarely observed as a result. It would be beneficial, however, to encourage appropriate residential property management through the development of an educational brochure aimed at informing watershed residents of their link to water quality and role in protecting it within the Deering Lake watershed. Such a brochure could be professionally produced and distributed for an estimated cost of $3,500 and for significantly less if produced by a small group of motivated volunteers with assistance from NHDES.

4.2 Land Use Planning

The lake is a reflection of its watershed, which is currently well developed around only a portion of the lake's perimeter and even less so for the majority of its watershed. It is recommended that efforts be made to preserve natural areas not subject to protection (as with wetlands) and encourage BMPs for agriculture (including gardens) and construction. The approach offered by CASA Land & Timber to set aside a significant fraction of each lot in conservation easement is ideal and should be encouraged at future sites proposed for development within the watershed. Similarly, CTR Development's proposal to develop their site as a cluster development is also desirable since this will hopefully minimize the area of roads, and therefore runoff, associated with the site.

Since neither developer has proposed specific property development plans it is difficult to comment on the specific actions that could be taken at either site to reduce runoff (which is the primary mode of transport for phosphorus to the lake) and encourage infiltration. In general, it is hoped that pavement area will be kept to a minimum and roof runoff will be infiltrated into the ground or directed into grass swales rather than discharged to paved surfaces or driveways. Ideally, landscaping design would be considerate of surface runoff movement and therefore direct flows into vegetated depressions, swales, or other infiltrating features.

Costs for implementing such actions throughout the watershed for future developments are highly variable and unpredictable, but could be minimal with thoughtful use of existing regulations and programs. Performing a build-out analysis (about $4,000) for the Deering Lake watershed would be beneficial toward determining how water quality would change if all available sites were developed. A build-out analysis would also discuss how such impacts might be mitigated for any future development.

4.3 Summary and Conclusions

Based on the analysis performed by ESS, it is apparent that the CASA and CTR properties will not substantially impact the quality of water within Deering Lake. The minimal nature of their impacts is primarily attributable to the fact that significant amounts of each property will remain in their natural state due to limitations imposed on the project design through conservation easements, cluster development, or due to the wetlands contained on the properties which cannot be developed. The modeling conducted by ESS represents a conservative estimate of the potential loading increases associated with these two developments. A substantial amount of additional improvements can be incorporated into each project's civil and landscaping design to further reduce the impact of these parcels on the lake. Since ESS does not currently posess detailed project designs for either property, it is not possible to make specific recommendations for improving runoff quality at this time.

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6.0 GLOSSARY

Anoxic: Greatly deficient in oxygen.

Aquifer: A water-bearing layer of rock (including gravel and sand) that will yield water in usable quantity to a well or spring.

Bathymetric Map: A map illustrating the bottom contours (topography) and depth of a lake or pond.

Best Management Practices (BMPs): Any of a number of practices or treatment devices that reduce pollution in runoff via runoff treatment or source control.

Cultural Eutrophication: The acceleration of the natural eutrophication process caused by human activities, occurring over decades as opposed to thousands of years.

Ecosystem: An interactive community of living organisms, together with the physical and chemical environment they inhabit.

Erosion: A process of breakdown and movement of land surface that is often intensified by human disturbances.

Eutrophication: The process, or set of processes, driven by nutrient, organic matter, and sediment addition to a pond that leads to increased biological production and decreased volume. The process occurs naturally in all lakes and ponds over thousands of years.

Groundwater: Water found beneath the soil surface and saturating the layer at which it is located.

Habitat: The natural dwelling place of an animal or plant; the type of environment where a particular species is likely to be found.

Infiltration Structures: Any of a number of structures used to treat runoff quality or control runoff quantity by infiltrating runoff into the ground. Includes infiltration trenches, dry wells, infiltration basins, and leaching catch basins.

Littoral Zone: The shallow, highly productive area along the shoreline of a lake or pond where rooted aquatic plants grow.

Mesotrophic: A trophic state (degree of eutrophication) in which a lake or pond is slightly nutrient rich and sustains moderate levels of biological productivity. Moderately dense macrophyte growth, moderate sediment accumulation, occasional algae blooms, moderate water transparency and infrequent oxygen depletion in the hypolimnion are common characteristics.

Morphometry: A term that refers to the depth contours and dimensions (topographic features) of a lake or pond.

Nonpoint Source: A source of pollutants to the environment that does not come from a confined, definable source such as a pipe. Common examples of non-point source pollution include urban runoff, septic system leachate, and runoff from agricultural fields.

Nutrient Limitation: The limitation of growth imposed by the depletion of an essential nutrient.

Nutrients: Elements or chemicals required to sustain life, including carbon, oxygen, nitrogen and phosphorus.

Oligotrophic: A trophic state (degree of eutrophication) in which a lake or pond is nutrient poor and sustains limited levels of biological productivity. Sparse macrophyte growth, low rates of sediment accumulation, rare algae blooms, high water transparency, and rare occurrences of oxygen depletion in the hypolimnion are common characteristics.

Pollutants: Elements and compounds occurring naturally or man-made introduced into the environment at levels in excess of the concentration of chemicals naturally occurring.

Secchi disk: A black and white or all white 20 cm disk attached to a cord used to measure water transparency. The disk is lowered into the water until it is no longer visible (secchi depth). Secchi depth is generally proportional to the depth of light penetration sufficient to sustain algae growth.

Seepage meter: A device used to measure the groundwater volume entering a lake, pond or stream over time.

Sediment: Topsoil, sand, and minerals washed from the land into water, usually after rain or snowmelt.

Septic system: An individual wastewater treatment system that includes a septic tank for removing solids, and a leachfield for discharging the clarified wastewater to the ground.

Septic System Leachate: The clarified wastewater discharged into ground from a septic system.

Siltation: The process in which inorganic silt settles and accumulates at the bottom of a lake or pond.

Storm water Runoff: Runoff generated as a result of precipitation or snowmelt.

Temperature Profile: A series of temperature measurements collected at incremental water depths from surface to bottom at a given location.

Thermal Stratification: The process by which a lake or pond forms several distinct thermal layers. The layers include a warmer well-mixed upper layer (epilimnion), a cooler, poorly mixed layer at the bottom (hypolimnion), and a middle layer (metalimnion) that separates the two.

Thermocline: A term that refers to the plane of greatest temperature change within the metalimnion.

TKN: Total Kjeldahl nitrogen, essentially the sum of ammonia nitrogen and organic forms of nitrogen.

Turbidity: A measure of the light scattering properties of water, often used more generally to describe water clarity or the relative presence or absence of suspended materials in the water.

Vegetated Buffer: An undisturbed vegetated land area that separates an area of human activity from the adjacent water body, can be effective in reducing runoff velocities and volumes and the removal of sediment and pollutant from runoff.

Water Column: Water in a lake or pond between the interface with the atmosphere at the surface and the interface with the sediment at the bottom.

Water Quality: A term used to reference the general chemical and physical properties of water relative to the requirements of living organisms that depend upon that water.

Watershed: The surrounding land area that drains into a water body via surface runoff or groundwater recharge and discharge.

Tables

Table 1. Existing land use within the Deering Lake watershed.
The Deering Lake watershed and sub-basin delineations are depicted on Figure 2.

Land Use Classification *	Basin 1 (acres)	Basin 2 (acres)	Basin 3 (acres)	Basin 4 (acres)	Deering Lake (acres)	Total Watershed (acres)	Percentage of Watershed
Cropland and Pasture	23.5	26.3	20.1	24.5	0.0	94.4	3%
Forest	937.4	431.5	90.3	727.6	0.0	2186.8	78%
Wetland	36.3	0.0	0.0	11.4	0.0	47.7	2%
Open/Cleared Land	10.8	19.7	7.0	14.9	0.0	52.4	2%
Residential/Commercial/Industrial	3.6	5.6	3.8	20.9	0.0	33.9	1%
Transportation	24.5	12.4	5.4	29.3	0.0	71.6	3%
Water	4.4	0.0	0.0	0.0	329.0	333.4	12%
Total	**1041**	**496**	**127**	**829**	**329**	**2,820**	**100%**

* Based on GRANIT, NH Land Cover 2001 and Roads and Trails 1987

Table 2. Proposed land use within the Deering Lake watershed (Includes CTR and CASA Developments).
The Deering Lake watershed and sub-basin delineations are depicted on Figure 2

Land Use Classification *	Basin 1 (acres)	Basin 2 (acres)	Basin 3 (acres)	Basin 4 (acres)	Deering Lake (acres)	Total Watershed (acres)	Percentage of Watershed
Cropland and Pasture	23.5	26.3	20.1	24.5	0.0	94.4	3%
Forest	***923.9***	431.5	90.3	***717.1***	0.0	2162.8	***77%***
Wetland	36.3	0.0	0.0	11.4	0.0	47.7	2%
Open/Cleared Land	10.8	19.7	7.0	14.9	0.0	52.4	2%
Residential/Commercial/Industrial	***17.1***	5.6	3.8	***31.4***	0.0	57.9	2%
Transportation	24.5	12.4	5.4	29.3	0.0	71.6	***3%***
Water	4.4	0.0	0.0	0.0	329.0	333.4	12%
Total	**1041**	**496**	**127**	**829**	**329**	**2,820**	**100%**

* Based on GRANIT, NH Land Cover 2001 and Roads and Trails 1987

Notes: CASA property is 69.4 acres located in Basin 1, less than 1.5 acres per lot (total of 9 lots) are proposed to be converted to residential land us
CTR property is ~20 acres located in Basin 4, details on development are not available, therefore assumed 1.5 acres per lot (total of 7 lots) will be converted to residential land use with 1 lot existing as residentia

Table 3. Annual hydrologic loading for Deering Lake.

Source	Hydrologic Load (cfs)	(m^3/yr)	(%)
Direct Precipitation w/ Evapotranspiration	**0.95**	846,060	11.3
Ground Water Inseepage	**1.10**	981,716	13.2
Surface Water	**6.31**	5,627,016	75.5
Dry Weather*	**0.57**	508,707	6.8
Wet Weather*	**5.74**	5,118,309	68.6
Total Annual	**8.36**	7,456,577	100.0

*Subset of surface water total

Deering Lake Statistics:

Volume	**156,885,400**	cu. ft
Mean Depth	**10.9**	ft
Detention Time	**217.3**	days
Flushing Rate	**1.68**	times/year
Response Time	**224-374**	days

Table 4. Average annual phosphorus load by land use cover type within the Deering Lake watershed - Existing condition

The Deering Lake watershed and sub-basin delineations are depicted on Figure 2.

Land Use Classification	Basin 1 (kg/yr)	Basin 2 (kg/yr)	Basin 3 (kg/yr)	Basin 4 (kg/yr)	Deering Lake (kg/yr)	Total Watershed (kg/yr)	Percentage of Phosphorus Load
Cropland and Pasture	37.7	42.2	32.3	39.4	0.0	151.6	16%
Forest	231.6	106.6	22.3	179.8	0.0	540.4	56%
Wetland	9.0	0.0	0.0	2.8	0.0	11.8	1%
Open/Cleared Land	16.0	29.2	10.4	22.1	0.0	77.7	8%
Residential/Commercial/Industrial	6.2	9.7	6.6	36.2	0.0	58.6	6%
Transportation	42.4	21.4	9.3	50.7	0.0	123.8	13%
Water	0.0	0.0	0.0	0.0	0.0	0.0	0%
Total Annual Phosphorus Load	343.0	209.2	80.9	330.9	0	963.9	100%
Attenuation Coefficient	0.15	0.25	0.25	0.20	0.0		
Actual Total Annual Phosphorus Load	**51.4**	**52.3**	**20.2**	**66.2**	**0**	**190.1**	

Note: Phosphorus export coefficients based on median value predicted by Reckhow (1980)

Table 5. Average annual phosphorus load by land use cover type within the Deering Lake watershed - Proposed condition (Includes CTR and CASA Developments)

The Deering Lake watershed and sub-basin delineations are depicted on Figure 2

Land Use Classification	Basin 1 (kg/yr)	Basin 2 (kg/yr)	Basin 3 (kg/yr)	Basin 4 (kg/yr)	Deering Lake (kg/yr)	Total Watershed (kg/yr)	Percentage of Phosphorus Load
Cropland and Pasture	37.7	42.2	32.3	39.4	0.0	151.6	15%
Forest	228.3	106.6	22.3	177.2	0.0	534.4	53%
Wetland	9.0	0.0	0.0	2.8	0.0	11.8	1%
Open/Cleared Land	16.0	29.2	10.4	22.1	0.0	77.7	8%
Residential/Commercial/Industrial	29.6	9.7	6.6	54.3	0.0	100.1	10%
Transportation	42.4	21.4	9.3	50.7	0.0	123.8	12%
Water	0.0	0.0	0.0	0.0	0.0	0.0	0%
Total Annual Phosphorus Load	363.0	209.2	80.9	346.4	0.0	999.5	100%
Attenuation Coefficient	0.15	0.25	0.25	0.20	0.0		
Actual Total Annual Phosphorus Load	**54.4**	**52.3**	**20.2**	**69.3**	**0.0**	**196.3**	

Notes: Phosphorus export coefficients based on median value predicted by Reckhow (1980)

CASA property is 69.4 acres located in Basin 1, less than 1.5 acres per lot (total of 9 lots) are proposed to be converted to residential land us

CTR property is ~20 acres located in Basin 4, details on development are not available, therefore assumed 1.5 acres per lot (total of 7 lots) will be converted to residential land use with 1 lot existing as residentia

Table 6. Existing and Proposed Nutrient loads for Deering Lake.

Variable	Total Phosphorus Existing	Total Phosphorus Proposed	Total Nitrogen Existing
In-lake concentration (mg/l)	0.011	0.012	0.25
Min. load g/m2/yr	0.06	0.07	1.40
In-lake Predictive Models			
Bachmann (N) g/m2/yr			2.17
Bachmann (N) kg/yr			2,891
Kirchner-Dillon (P) g/m2/yr	0.15	0.15	
Vollenweider (P) g/m2/yr	0.08	0.08	
Reckhow (general P) g/m2/yr	0.21	0.22	
Larsen and Mercier (P) g/m2/yr	0.11	0.12	
Jones and Bachman (P) g/m2/yr	0.11	0.11	
Average all phosphorus models g/m2/yr	0.13	0.14	
Average all phosphorus models kg/yr	**174**	**180**	
Vollenweider's permissible load			
load g/m2/yr	0.24		
load kg/yr	**315**		
Vollenweider's critical load			
load g/m2/yr	0.47		
load kg/yr	**629**		

Note: Calculations are provided in Appendix 1

Table 7. Nutrient loading attributable to CASA Land & Timber and CTR Development property changes.

Property	**Loading Rate (kg/acre/yr)**	**Pre-development**		**Post-development**	
		(acres)	**(load in kg/yr)**	**(acres)**	**(load in kg/yr)**
CASA Land & Timber					
Forest/Wetland	0.25	69.4	17.4	55.9	14.0
Residential	1.73	0	0.0	13.5	23.4
Total Property Load			17.4		37.3
Increase in Loading					20.0
Attenuation Coefficient					0.15
Effective Load Increase					**3.0**
CTR Development					
Forest/Wetland	0.25	18.5	4.6	8.0	2.0
Residential	1.73	1.5	2.6	12.0	20.8
Total Property Load			7.2		22.8
Increase in Loading					15.5
Attenuation Coefficient					0.20
Effective Load Increase					**3.1**

Figures

Appendix 1

Hydrologic and Nutrient Load Modeling Calculations

Average Annual Hydrologic Loading for Deering Lake

Watershed for Lake =		2,820	acres		122839200	SF	4.41	sq mi
Lake Area		329	acres		14331240	SF	1331416	meters2
Area of Watershed - Lake Area		2491	acres		108507960	SF		
Lake Circumference		29,035	feet				From NHDES	
Lake Volume		156,885,400	cubic feet				4442500.3	meters3
Area influenced by seepage		1451750	ft2	=	134871.9303	m2		
Groundwater (data)		20	l/m2/day=		0.706	cf/m2/day		
				=	95219.583	cf/day		
				=	1.102	cfs		
Annual PPT/yr		37.36	inches				**Annual average for Concord, NH**	
Annual PPT - ET	25.03	2.09	ft/yr		0.948	cfs		
Runoff (watershed)	20	1.67	ft/yr		5.735	cfs		
Base Flow (Streams) as measured during dry weather					0.570	cfs	Estimated - Data not available	

Estimated Hydrologic Loading by Source

	Ground	PPT	Surfacewater	Total	
Dry	1.102	0.000	0.570	1.672	
Wet	0.000	0.948	5.735	6.683	
Total	**1.102**	**0.948**	**6.305**	**8.355**	cfs
				7,460,677	m3/yr
				263,471,279	CubicFt/Yr
				7,460,676,685	L/yr

Anticipated range of total input into lake:

(1.5 to 2.0 cfs/sq mi of watershed) =

6.61	to	8.81	cfs

DEERING LAKE - Existing Conditions

IN-LAKE MODELS FOR PREDICTING PHOSPHORUS LOADS AND CONCENTRATIONS (Based on Data from 1998 - 2002)

THE TERMS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From data or model	11.5	Enter Value
L	Phosphorus Load to Lake	g P/m2/yr	From data or model	0.06	Enter Value
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	23	Enter Value
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	7.4	Enter Value
I	Inflow	m3/yr	From data	7460677	Enter Value
A	Lake Area	m2	From data	1331416	Enter Value
V	Lake Volume	m3	From data	4442500	Enter Value
Z	Mean Depth	m	Volume/area	3.336673	
F	Flushing Rate	flushings/yr	Inflow/volume	1.679387	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.321739	
Qs	Areal Water Load	m/yr	Z(F)	5.603566	
Vs	Settling Velocity	m	Z(S)	1.073538	
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.678261	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.560171	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.435557	

ADDENDUM FOR NITROGEN (Based on data from '97 and '98 only)

TN	Lake Total Nitrogen Conc.	ppb	From data or model	250	Enter Value
L	Nitrogen Load to Lake	g N/m2/yr	From data or model	1.4	Enter Value
C	Coefficient of Attenuation	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	0.923357	

THE MODELS

NAME	FORMULA	PREDICTION CONC. (ppb)	LOAD (g/m2/yr)
Mass Balance	TP=L/(Z(F))*1000	11	
(minimum load)	L=TP(Z)(F)/1000		0.06
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	5	
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		0.15
Vollenweider 1975	TP=L/(Z(S+F))*1000	9	
(V)	L=TP(Z)(S+F)/1000		0.08
Reckhow 1977 (General)	TP=L/(11.6+1.2(Z(F)))*1000	3	
(Rg)	L=TP(11.6+1.2(Z(F)))/1000		0.21
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	6	
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		0.11
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	6	
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		0.11
Average of Model Values		6	
(without mass balance)			0.13
Reckhow 1977 (Anoxic)	TP=L/(0.17(Z)+1.13(Z(F)))*1000	9	
(Ra)	L=TP(0.17(Z)+1.13(Z(F)))/1000		0.08
From Vollenweider 1968			
Permissible Load	Lp=10^(0.501503(log(Z(F)))-1.0018)		0.24
Critical Load	Lc=2(Lp)		0.47
Mass Balance	TN=L/(Z(F))*1000	250	
(minimum load)	L=TN(Z)(F)/1000		1.40
Bachmann 1980	TN=L/(Z(C+F))*1000	161	
	L=TN(Z)(C+F)/1000		2.17

LOAD ANALYSIS

MODEL	ESTIMATED LOAD (kg/yr)	ESTIMATED LOAD (mg/L)	
Phosphorus			
Mass Balance (no loss)	86		
Kirchner-Dillon 1975	195		
Vollenweider 1975	102		
Reckhow 1977 (General)	281		
Larsen-Mercier 1976	152		
Jones-Bachmann 1976	142		
Model Average (without mass balance)	174	0.0234	
Reckhow 1977 (Anoxic)	106		
Permissible Load	315	0.0422	Permissible Conc.
Critical Load	629	0.0844	Critical Conc.
Nitrogen			
Mass Balance (no loss)	1865		
Bachmann 1980	2891	0.39	(check - av in pond nitrogen concentration - mg/L)

PREDICTED WATER CLARITY

PREDICTED CHL AND WATER CLARITY

MODEL	Value
Mean Chlorophyll (ug/L)	
Dillon and Rigler 1974	1.0
Jones and Bachmann 1976	1.1
Oglesby and Schaffner 1978	0.5
Modified Vollenweider 1982	3.1
"Maximum" Chlorophyll (ug/L)	
Modified Vollenweider (TP) 1982	8.3
Vollenweider (CHL) 1982	3.8
Mod. Jones, Rast and Lee 1979	5.0
Secchi Transparency (M)	
Oglesby and Schaffner 1978 **(Avg)**	5.9
Modified Vollenweider 1982 **(Max)**	5.9

DEERING LAKE - Proposed Conditions - Including CTR and CASA Property Developments

IN-LAKE MODELS FOR PREDICTING PHOSPHORUS LOADS AND CONCENTRATIONS (Based on Data from 1998 - 2002 and a 4.6% increase in the phosphorus load based on land use changes)

THE TERMS

SYMBOL	PARAMETER	UNITS	DERIVATION	VALUE	
TP	Lake Total Phosphorus Conc.	ppb	From data or model	**11.9**	Enter Value
L	Phosphorus Load to Lake	g P/m2/yr	From data or model	**0.07**	Enter Value
TPin	Influent (Inflow) Total Phosphorus	ppb	From data	**23.8**	Enter Value
TPout	Effluent (Outlet) Total Phosphorus	ppb	From data	7.4	Enter Value
I	Inflow	m3/yr	From data	7460677	Enter Value
A	Lake Area	m2	From data	1331416	Enter Value
V	Lake Volume	m3	From data	4442500	Enter Value
Z	Mean Depth	m	Volume/area	3.336673	
F	Flushing Rate	flushings/yr	Inflow/volume	1.679387	
S	Suspended Fraction	no units	Effluent TP/Influent TP	0.310924	
Qs	Areal Water Load	m/yr	Z(F)	5.603566	
Vs	Settling Velocity	m	Z(S)	1.037453	
R	Retention Coefficient (from TP)	no units	(TPin-TPout)/TPin	0.689076	
Rp	Retention Coefficient (settling rate)	no units	((Vs+13.2)/2)/(((Vs+13.2)/2)+Qs)	0.559547	
Rlm	Retention Coefficient (flushing rate)	no units	1/(1+F^0.5)	0.435557	

ADDENDUM FOR NITROGEN (Based on data from '97 and '98 only)

TN	Lake Total Nitrogen Conc.	ppb	From data or model	250	Enter Value
L	Nitrogen Load to Lake	g N/m2/yr	From data or model	1.4	Enter Value
C	Coefficient of Attenuation	fraction/yr	2.7183^(0.5541(ln(F))-0.367)	0.923357	

THE MODELS

NAME	FORMULA	PREDICTION CONC. (ppb)	LOAD (g/m2/yr)
Mass Balance	TP=L/(Z(F))*1000	12	
(minimum load)	L=TP(Z)(F)/1000		0.07
Kirchner-Dillon 1975	TP=L(1-Rp)/(Z(F))*1000	6	
(K-D)	L=TP(Z)(F)/(1-Rp)/1000		0.15
Vollenweider 1975	TP=L/(Z(S+F))*1000	11	
(V)	L=TP(Z)(S+F)/1000		0.08
Reckhow 1977 (General)	TP=L/(11.6+1.2(Z(F)))*1000	4	
(Rg)	L=TP(11.6+1.2(Z(F)))/1000		0.22
Larsen-Mercier 1976	TP=L(1-Rlm)/(Z(F))*1000	7	
(L-M)	L=TP(Z)(F)/(1-Rlm)/1000		0.12
Jones-Bachmann 1976	TP=0.84(L)/(Z(0.65+F))*1000	8	
(J-B)	L=TP(Z)(0.65+F)/0.84/1000		0.11
Average of Model Values		7	
(without mass balance)			0.14
Reckhow 1977 (Anoxic)	TP=L/(0.17(Z)+1.13(Z(F)))*1000	10	
(Ra)	L=TP(0.17(Z)+1.13(Z(F)))/1000		0.08
From Vollenweider 1968			
Permissible Load	Lp=10^(0.501503(log(Z(F)))-1.0018)		0.24
Critical Load	Lc=2(Lp)		0.47
Mass Balance	TN=L/(Z(F))*1000	250	
(minimum load)	L=TN(Z)(F)/1000		1.40
Bachmann 1980	TN=L/(Z(C+F))*1000	161	
	L=TN(Z)(C+F)/1000		2.17

LOAD ANALYSIS

MODEL	ESTIMATED LOAD (kg/yr)	ESTIMATED LOAD (mg/L)	
Phosphorus			
Mass Balance (no loss)	89		
Kirchner-Dillon 1975	202		
Vollenweider 1975	105		
Reckhow 1977 (General)	290		
Larsen-Mercier 1976	157		
Jones-Bachmann 1976	147		
Model Average (without mass balance)	**180**	0.0242	
Reckhow 1977 (Anoxic)	109		
Permissible Load	315	0.0422	Permissible Conc.
Critical Load	629	0.0844	Critical Conc.
Nitrogen			
Mass Balance (no loss)	1865		
Bachmann 1980	2891	0.39	(Expected in pond nitrogen concentration - mg/L)

PREDICTED WATER CLARITY

PREDICTED CHL AND WATER CLARITY

MODEL	Value
Mean Chlorophyll (ug/L)	
Dillon and Rigler 1974	1.2
Jones and Bachmann 1976	1.4
Oglesby and Schaffner 1978	1.1
Modified Vollenweider 1982	3.6
"Maximum" Chlorophyll (ug/L)	
Modified Vollenweider (TP) 1982	9.7
Vollenweider (CHL) 1982	4.9
Mod. Jones, Rast and Lee 1979	6.3
Secchi Transparency (M)	
Oglesby and Schaffner 1978 **(Avg)**	5.2
Modified Vollenweider 1982 **(Max)**	5.7