Perkins Pond
Sunapee, New Hampshire

Pond and Watershed Diagnostic Study

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

2009

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Perkins Pond and Watershed Diagnostic Study

Final Report
2009

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1.0 INTRODUCTION AND PURPOSE

1.1 Introduction

The Department of Environmental Services has conducted this Diagnostic Feasibility Study (DFS) for Perkins Pond at the request of the Town of Sunapee and the Perkins Pond Protective Association ("the Association").

Much of the Perkins Pond shoreline is densely developed with small lots, and there has been growing concern that old and poorly functioning septic systems may be causing an accelerated rate of eutrophication in the pond. A proposal for a bond issue to extend town sewer to Perkins Pond residents has been presented to Sunapee voters four times, in 1999, 2000 (twice), and 2001, and failed each time.

DES met with the newly formed Perkins Pond Citizens Advisory Committee on February 26, 2003 to discuss the perceived problems with the pond, and to prioritize the purpose and the desired outcomes from the DFS. Based on the recorded meeting notes, the primary desired study outcome is to conduct an analysis of the watershed to determine the water quality benefits of extending the Sunapee sewer line to the Perkins Pond shoreline, and to evaluate existing and future land use under various build-out scenarios and septic system conditions for contributions to the phosphorus loading to the pond (Appendix 1).

The Association has been actively monitoring Perkins Pond and its watershed since 1987 through the New Hampshire Volunteer Lake Assessment Program (VLAP). The data collected throughout this time period generally indicate that the lake, from the perspective of Total Phosphorus, Chlorophyll-a, and Clarity trends, is in a stable state with regards to water quality and trophic condition. The most recent VLAP report, containing the historical data, can be found at http://des.nh.gov/WMB/VLAP/2006/ .

1.2 Purpose

The study purpose is to provide Sunapee decision-makers with data and information about effects of land use and sewer system extension on Perkins Pond through model predictions for each of the scenarios listed below. This information will assist the town in evaluating development and sewer extension scenarios in the Perkins Pond watershed to prevent increased phosphorus loading and maintain a stable trophic state and stable water quality in Perkins Pond.

Specifically, phosphorus loading was estimated for the following future scenarios:

1) Existing conditions in the watershed, with detailed analysis of phosphorus loading from land use and septic systems within a 250 foot near shore buffer.

2) Conversion to full-time occupancy of developed shorefront lots in the 250 foot near shore buffer, with no municipal sewers for shorefront lots, septic systems remaining in existing locations, no nonpoint source BMPs within the 250 foot near shore buffer, and 2 acre lot build-out in the rest of the watershed to the extent allowed by soil conditions.

3) Conversion to full-time occupancy of developed shorefront lots in the 250 foot near shore buffer with municipal sewers, no nonpoint source BMPs within the 250 foot near shore

buffer, and 2 acre lot build-out in the rest of the watershed to the extent allowed by soil conditions.

4) Conversion to full-time occupancy of developed shorefront lots in the 250 foot near shore buffer with municipal sewers plus nonpoint source BMPs within the 250 foot near shore buffer, and 2 acre lot build-out in the rest of the watershed with BMPs for minimum lot disturbance for residential construction at 2 acre lot build-out in the rest of the watershed to the extent allowed by soil conditions.

2.0 LAKE AND WATERSHED

2.1 Lake and Watershed Characteristics

Perkins Pond is a natural lake located in west central New Hampshire. The Perkins Pond watershed (Figure 2-1) encompasses an area of 265.15 hectares (655.21 acres) which includes the pond area of 63.54 hectares (157.01 acres). Appendix 2 contains a summary of development history in the watershed.

The New Hampshire Lake Assessment Program provided morphometric data for the Perkins Pond watershed (Table 2-1). The Perkins Pond watershed is unique in that the North Outlet behaves as an inlet, outlet, or part of the pond depending on several factors. These factors include pond level, Ledge Pond Brook flow and dam height, which is occasionally impacted by debris and beaver activity where Ledge Pond Brook discharges to the North Outlet. Under normal conditions as was seen during the study period, the North Outlet acts solely as an outlet as elevated pond levels and lack of beaver activity allow for the majority of the Ledge Pond Brook flow to discharge via the North Outlet and downstream of the pond. As a result, the Ledge Pond Brook watershed (1037.40 acres) was not included as having an impact on the pond during the study period.

There are several intermittent streams, four perennial or year-round streams, areas of direct overland flow and groundwater seepage entering Perkins Pond. See Figure 2-1 for subwatershed, tributary and outlet locations. Additional Perkins Pond watershed and tributary maps can be found in appendices 3 and 4 respectively.

The North Outlet flows into Long Pond Brook before discharging to Loon Lake and eventually the Sugar River near the Route 11 and Reeds Mill Road intersection. In addition to the North Outlet, some water discharges from Perkins Pond through the South Outlet, flowing into the Sugar River just east of the Rte. 11 and Sleeper Road intersection.

Table 2-1
Morphometric Data

Parameter	Lake Information/ Morphometric Data
Lake Name	Perkins Pond
Town	Sunapee
County	Sullivan
River Basin	Connecticut
Latitude	42°43’24” N
Longitude	72°72’07” W
Elevation (ft)	1,082
Shoreline Length (meters)	3,900
Watershed Area (hectares/ acres)	201.6/ 498.2
Pond Area (hectares/ acres)	63.54/ 157.01
Maximum Depth (m)	3.0
Mean Depth (m)	1.4
Volume (m^3)	877,000
Areal Water Load (m/yr)	1.81
Flushing Rate (yr^{-1})	1.3
Phosphorus Retention Coefficient	0.83
Lake Type	Natural w/ dam

* Watershed Area: Using GIS analysis (Base Map: USGS digital raster graphics files, 1:24,000 – scale 7.5’ topographic quadrangles) maps and calculations for this study were based upon a watershed area equal to 201.6 hectares (498.22 acres or 2,016,224.81 m^2). Watershed area does not include pond area.

** Pond Area: Using GIS analysis (Base Map: USGS digital raster graphics files, 1:24,000 – scale 7.5’ topographic quadrangles) maps and calculations for this study were based upon a lake area equal to 64.0 hectares (158.14 acres or 639,980 m^2).

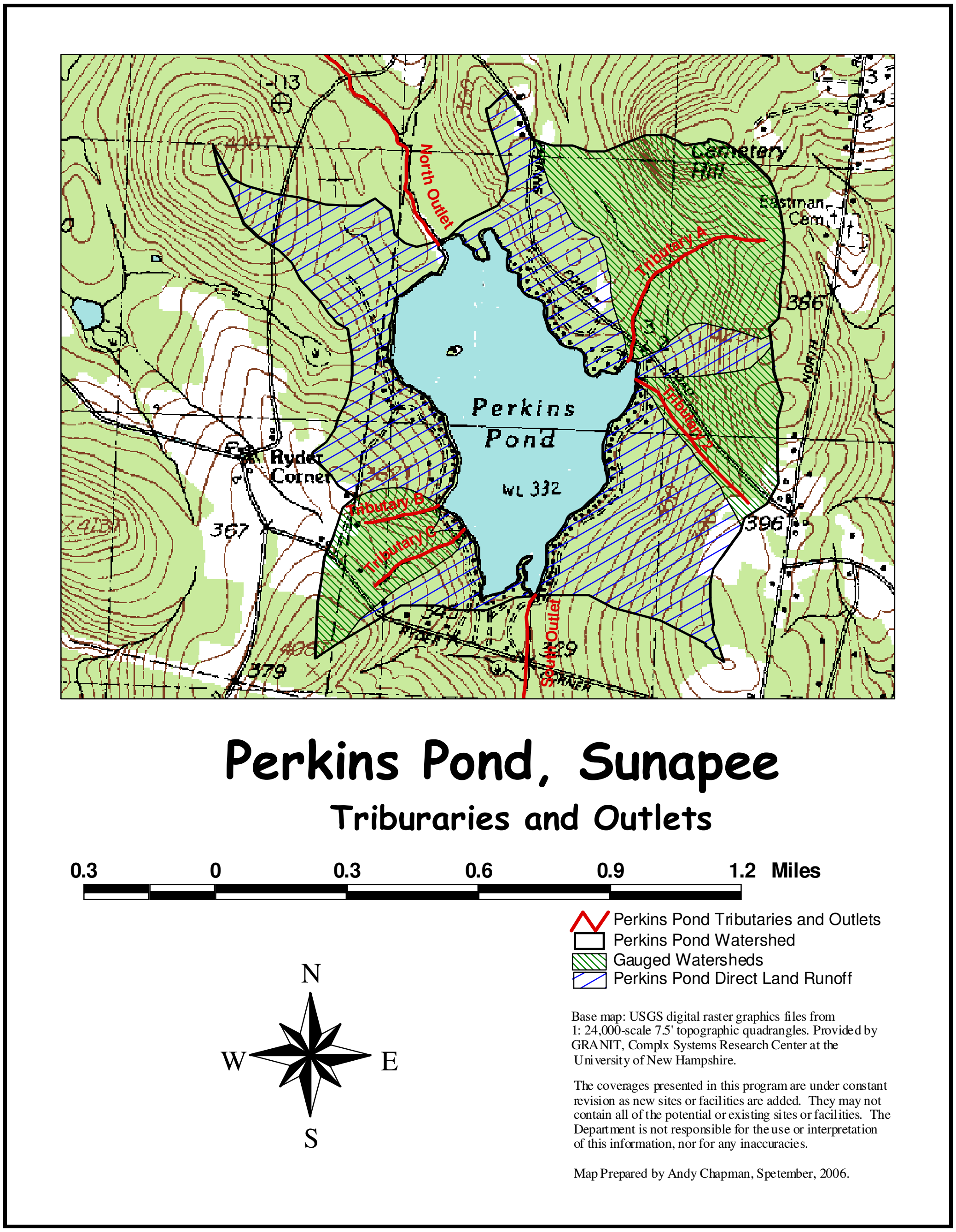

Figure 2-1: Perkins Pond watershed, tributaries, subwatersheds and outlets.

2.2 Trophic Classification Summary

A summary of three classification schemes (Table 2-2) shows that the Dillon-Rigler and Vollenweider models classify Perkins Pond as oligotrophic under current conditions. The New Hampshire Lake Classification from 1986 also classifies Perkins Pond as oligotrophic while the 2003 classification specifies a mesotrophic status. However, only one instead of two secchi disk trophic points was mistakenly assigned in the 1986 survey. This and perhaps an even more significant change in the objective evaluation result for plant abundance which increased from "scattered" in 1986 to "common" in 2003 survey resulted in the mesotrophic classification in 2003. See appendix 5 for information on data descriptions and NH data ranges. Information on trophic classifications can be found in appendix 6.

Table 2-2
Perkins Pond Trophic Classification Summary

Classification Model	Trophic Status
1. New Hampshire Lake Classification, 1986	Oligotrophic
2. New Hampshire Lake Classification, 2003	Mesotrophic
3. Dillon-Rigler	Oligotrophic
4. Vollenweider	Oligotrophic

2.3 Climate and Precipitation

The climate of the region is characterized by moderately warm summers, cold, snowy winters, and ample precipitation. Mean annual precipitation is about 40 inches. Generally, snow is present from mid-December until the end of March or early April. Ice-out typically occurs by mid-April.

Precipitation data sets from two National Oceanic and Atmospheric Administration (NOAA) weather stations (Lebanon, NH, Springfield, VT), one NH DES Dam Bureau weather station (Sunapee Harbor) and one Town of Sunapee Department of Public Works (DPW) weather station (Georges Mills, Sunapee) were evaluated. Total precipitation over the course of the study period varied greatly between stations with the NHDES Dam Bureau weather station recording 29.18 inches of precipitation and the Sunapee DPW recording 54.04 inches of precipitation (Table 2-3). The two NOAA weather stations recorded total precipitation of approximately 39-40 inches. The Sunapee DPW precipitation data set was selected for the diagnostic study as the most reflective of actual storm events within the Perkins Pond watershed as documented by personal observations of lake shore residents. This weather station is the nearest to the Perkins Pond area of the stations evaluated.

Table 2-3
Watershed Monthly Precipitation (July 2004-June 2005)
Perkins Pond (based on Sunapee DPW Georges Mills rain gauge)

Month	Total Precip (in)	Total Precip (m)	Total Precip (m^3)	Total Precip (10^3 m^3)	Percent Study Period Contribution
Jul-04	5.51	0.14	282178.73	282.18	0.10
Aug-04	2.70	0.07	138272.70	138.27	0.05
Sep-04	4.41	0.11	225845.41	225.85	0.08
Oct-04	1.45	0.04	74257.56	74.26	0.03
Nov-04	4.19	0.11	214578.74	214.58	0.08
Dec-04	5.47	0.14	280130.24	280.13	0.10
Jan-05	5.67	0.14	290372.66	290.37	0.10
Feb-05	3.64	0.09	186412.08	186.41	0.07
Mar-05	5.95	0.15	304712.06	304.71	0.11
Apr-05	4.96	0.13	254012.07	254.01	0.09
May-05	3.39	0.09	173609.05	173.61	0.06
Jun-05	6.70	0.17	343121.14	343.12	0.12
Total	**54.04**	**1.37**	**2767502.43**	**2767.50**	**1.00**

Perkins Pond watershed surface area= 2,016,224 m^2, not including Perkins Pond

2.4 Land Use

Data pertaining to existing land use in the Perkins Pond watershed were derived from the 2001 New Hampshire Land Cover Assessment using satellite images acquired from Landsat Thematic Imager between 1990 and 1999. Town of Sunapee Tax Map information for properties within 250 feet of the Pond, generally within the first and second tiers from the shoreline, were merged with the NH Land Cover Assessment data to more accurately reflect the residential development that has occurred in this area. Table 2-4 provides total land area (acres) for the current land use in the Perkins Pond watershed. Figure 2-2 illustrates the land use cover in the Perkins Pond watershed that was used in the analyses.

Table 2-4
Perkins Pond Watershed Land Use Area

Land Use	Area (ac)	Area (ha)
Forested	407.70	164.99
Cleared/Disturbed/Other Open	4.83	1.95
Active Agriculture	14.53	5.88
Residential	50.16	20.30
Water/Non-forested Wetlands	8.36	3.38
Transportation	12.66	5.12
Total	498.24	201.63

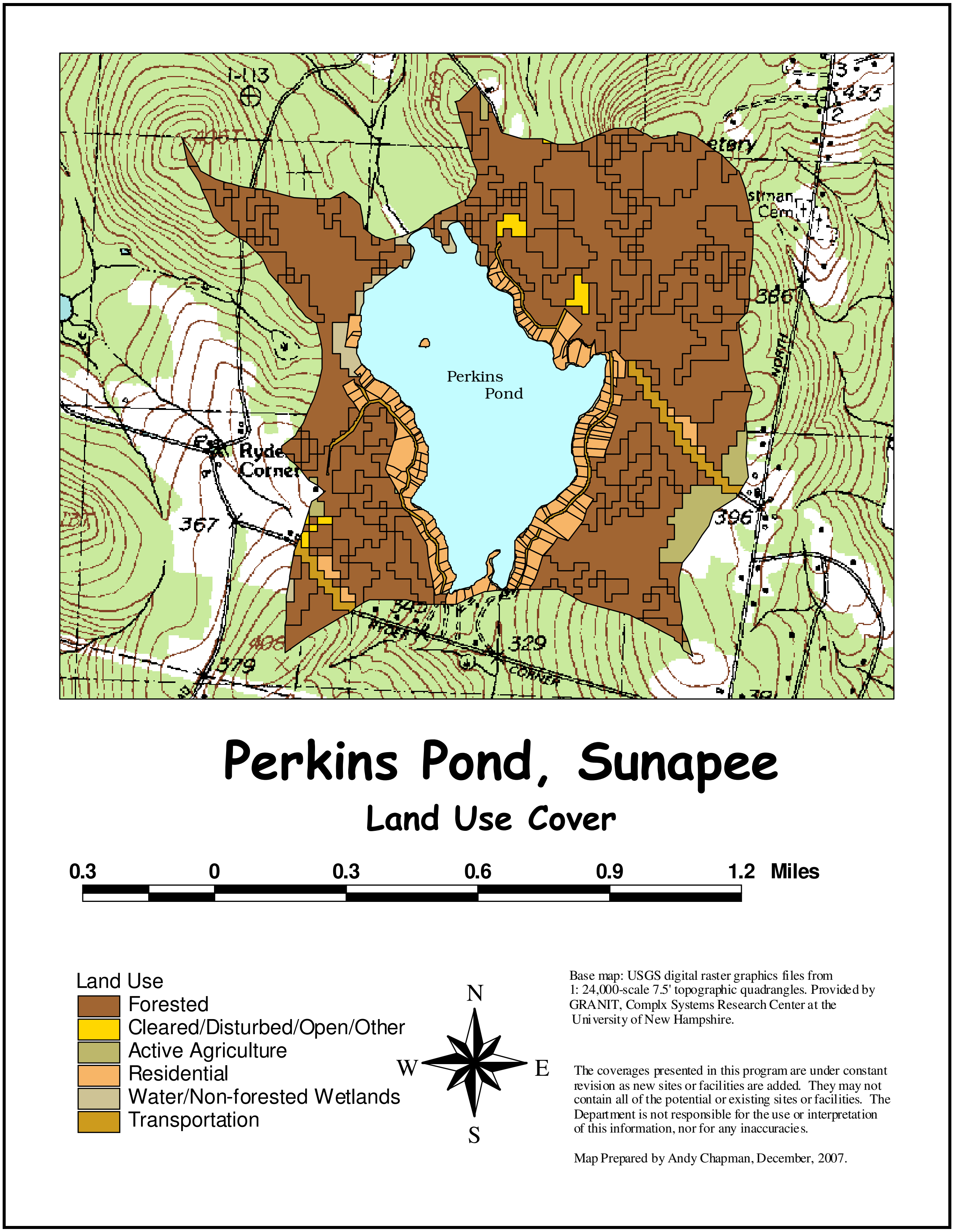

Figure 2-2: Perkins Pond Watershed land use map.

As Table 2-4 and Figure 2-2 indicate, the predominant land cover type within the Perkins Pond watershed is forest. The forested portion of the watershed can be characterized as a mixed forest, with white pine and eastern hemlock comprising the evergreen component, and beeches, maples, and oaks comprising the majority of the deciduous trees.

While more than 80 percent of the pond's watershed is forested, the most critical areas adjacent to the pond, within a 250 foot buffer, have undergone a dramatic land use change in the past 50-100 years from a forested landscape to residential land use. Residential land use now accounts for approximately 50 acres or 10 percent of the watershed's land area, and most of this is near the shoreline of the pond. Areas of residential development occur along nearly the entire shoreline of Perkins Pond. This development is characterized by seasonal cottages and cottages converted or expanded into year round homes. In addition, construction of larger year round homes set farther back from the lake shore has recently occurred.

2.5 Lake Ecology and the Role of Phosphorus

Most New Hampshire lakes are phosphorus limited which means only a small amount of this nutrient is needed to cause phytoplankton (algae) growth. Plants and algae use this nutrient in the process of photosynthesis to grow and produce chlorophyll. A slight increase of in-lake phosphorus concentration can lead to excessive plant and algae growth, and a shift in trophic status.

Phosphorus is an essential element for plant and animal cell metabolism and is contained in organic matter (living things) such as animals, plants, insects, and humans. Phosphorus readily attaches to soil and sediment particles and can move in water or through the atmosphere. Phosphorus that does reach the atmosphere returns to the earth attached to precipitation.

Phosphorus can be derived from natural or anthropogenic sources in a watershed. Human waste products and automatic dishwasher detergents discharged to septic systems and fertilizers contribute phosphorus. Fecal material from wildlife or domestic animals can also contribute phosphorus. While some erosion and phosphorus transport occurs in natural watersheds, human activity can greatly increase the rate of phosphorus transport within the watershed. With landscape change from forest to residential, stormwater runoff rates and volumes increase. As a result, sediment and other organic materials with their associated phosphorus loads have a greater tendency to be carried downstream to surface waters, including Perkins Pond.

3.0 STUDY SCOPE AND SITE SURVEY DATA

3.1 Scope

The study estimated the current and future phosphorus loadings to Perkins Pond through the use of several models to estimate loadings from various sources. Model inputs were refined by collecting site specific land use and septic system data within a 250 foot buffer zone.

3.2 Land Use Data

A detailed analysis of the land use cover for shoreline properties (Table 3-1), was conducted using the results of lot-by-lot surveys. See the report insert for a complete land use cover map for properties within 250 feet of the shoreline. The surveys were conducted by DES with the assistance of the association. Surfaces having no or poor infiltration capacities, including buildings roof tops, paved and unpaved roads, and concrete pads, accounted for approximately 17 percent of the watershed area within the 250 foot buffer. Almost 65 percent of the 250 foot buffer consisted of land use types such as forested or undisturbed areas, considered to have good or excellent infiltration capacities. The remaining 17 percent had land use types such as grassed, landscaped, and mulched areas with fair to moderate infiltration capacities.

Table 3-1
Perkins Pond Watershed Land Use within 250 Feet of the Shoreline

Land Use	Acres	Hectares	% of Total	Infiltration Capacity
Building	2.7753	1.125	3.74%	poor
Concrete Pad	0.0786	0.031	0.10%	poor
Decking	0.5707	0.226	0.75%	fair
Dock	0.2219	0.083	0.28%	fair
Forested	40.946	16.569	55.06%	excellent
Grass	6.379	2.578	8.57%	fair
Herbaceous Cover	5.2239	2.115	7.03%	good
Herbaceous Wetland	2.2795	0.923	3.07%	excellent
Landscape Stone	0.1992	0.079	0.26%	poor
Landscaped	0.3963	0.157	0.52%	moderate
Mulch/Duff	2.8984	1.167	3.88%	moderate
Pavement	0.8652	0.349	1.16%	poor
Rock	0.1349	0.054	0.18%	poor
Sand Beach	0.1362	0.054	0.18%	fair
Sand/Gravel	9.112	3.693	12.27%	poor
Transitional	2.0352	0.819	2.72%	moderate
Woody Wetland	0.1852	0.072	0.24%	excellent
Total	**74.4375**	**30.094**	**100.00%**	

3.3 Septic System Survey Data

An extensive septic system survey was conducted in 2005-2006 for shoreline (first tier) and second tier properties within approximately 250 feet of Perkins Pond. The purpose of the survey was to evaluate adequacy of existing septic systems and the population using the septic systems on an annual basis. DES staff conducted on-site surveys with property owners and the Association conducted follow-up mail surveys when an on-site meeting was not possible. The following list summarizes the type of information collected during the septic system survey. A complete survey can be found in appendix seven.

a. Building occupancy by annual quarter
b. Number of bedrooms
c. Plumbing fixtures, including toilets, washing machines, sinks, dishwashers, water softeners
d. Septic tank size: from DES records and interview
e. Leach bed size and location: from DES records and from interview
f. Septic system problems/ maintenance history

g. Leach bed age/ installation date

A total of 171 lots are within 600 feet of Perkins Pond. Of the 171 lots, 105 properties have a residential structure on the lot that requires a septic system. Residential structures include any living quarters ranging from year-round homes to seasonal cabins or tents, used for extended periods of time. With hard work, persistence and multiple septic survey mailings by the Association, 80 surveys were returned to DES. This is an outstanding return rate of more than 76 percent and double the typical return rate for similar Diagnostic Feasibility Study surveys. However, it should be noted that not all returned surveys were complete, leaving some questions with partial or no response. For properties without returned surveys, field observations were used to estimate annual occupancy. In general, it was assumed that 2 people were occupying a residence when in use. Appendix 8 contains a detailed analysis of septic survey results.

According to the returned surveys, 28 percent of structures represented year-round, primary residences, 34 percent as seasonal use residences, 11 percent as year-round vacation homes being occupied for only a few days a year, 2 percent were never used, and the remaining 24 percent did not respond to the survey question (Figure 3-1).

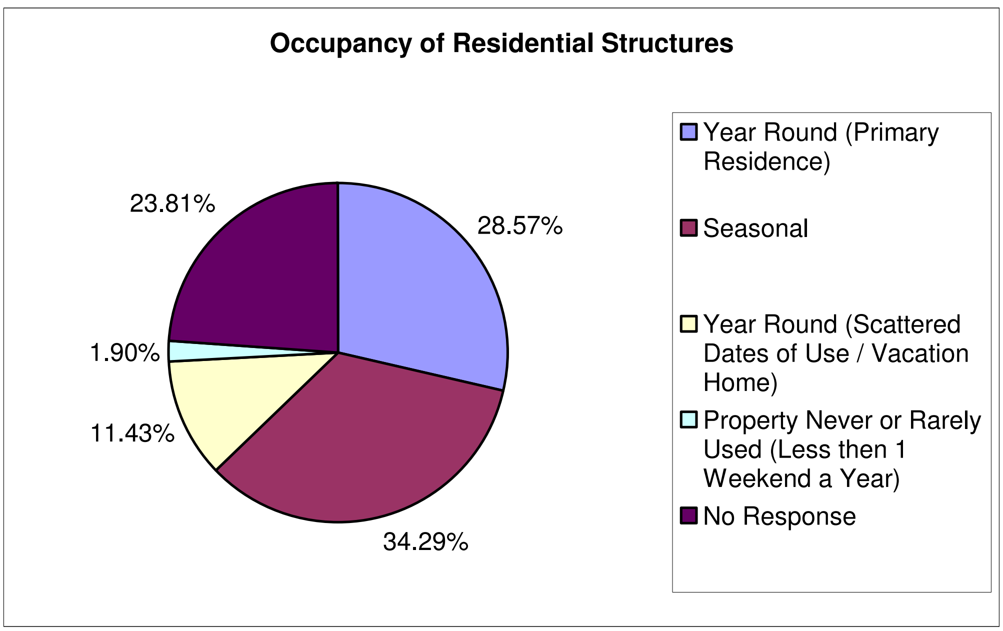

Figure 3-1: Occupancy of residential structures within the Perkins Pond Watershed.

4.0 WATERSHED MODELS

Several methods were used to estimate phosphorus loads to Perkins Pond. They include:

a. Phosphorus Budget Method
b. Land Use Total Phosphorus Export Coefficient Method
c. Simple Method for Stormwater Phosphorus Loading
d. ArcView Generalized Watershed Loading Function (AVGWLF) Model

4.1 Phosphorus Budget Method

The phosphorus budget consists of estimates of monthly phosphorus transport into and out of the pond. The budget is created by measuring water flow into and out of Perkins Pond in several compartments, and multiplying this by the estimated phosphorus concentration in each of the compartments. Inflows include tributary flow, overland flow, precipitation, and groundwater. The outflows are lake outlet flows and evaporation. It is assumed that there is no outflow seepage from the pond through the lake bed. The hydrologic budget can be represented by the following equation:

Streamflow from gauged watersheds + Direct runoff from ungauged watersheds + Groundwater seepage from ungauged watersheds + Direct precipitation –Evaporation–Outlet flow = 0

Similarly, the Phosphorus budget can be represented by the following equation:

Tributary Inputs + Groundwater inputs + Direct precipitation inputs – Outlet Outflow = 0

1. Tributaries - Stream gauges and level loggers were installed at each perennial stream and within the lake of Perkins Pond to determine outflow. Weekly flow measurements and staff gauge readings were documented to determine a stage-discharge curve relationship for each tributary measuring location. Phosphorus concentration data and regression analyses for flow and were used to estimate monthly phosphorus loading from each tributary.
2. Overland Flow- Phosphorus loads from un-gauged watersheds were estimated using literature values for Total Phosphorus (TP) export coefficients based upon land use type. A runoff coefficient is the annual mass export of phosphorus from the landscape to surface water per unit land area.
3. Precipitation - Phosphorus concentrations from precipitation were estimated from phosphorus concentrations in precipitation collected at NH DES, Concord, NH.
4. Groundwater - Seepage meters were installed at seven locations within the littoral (shallow water) zone of Perkins Pond to monitor groundwater seepage and recharge zones in areas around the pond. Seepage meter locations were evenly distributed around the pond, targeting areas of both low and high shoreline development. Groundwater flow rates and phosphorus concentrations from seepage meters were used to estimate phosphorus loading from near shore areas.

As mentioned in Section 2, The Sunapee DPW precipitation data set was selected for the diagnostic study as the most reflective of actual storm events within the Perkins Pond watershed as documented by personal observation and using mass balance for the hydrologic budget. This precipitation data set in combination with the NH DES precipitation phosphorus concentrations was used for phosphorus loading estimates where phosphorus precipitation input direct to the pond was necessary.

Evaporation estimates were obtained from the Lakeport weather station in Laconia, NH where daily weather trends are recorded.

The total amount of annual precipitation and evaporation are multiplied by the lake surface area to determine the water volume that fell directly on the lake and volume that evaporated directly from the lake surface area.

Table 4-1 provides the phosphorus budget for Perkins Pond. Raw data and summaries for the hydrologic budget can be found in appendices 9 through 21. Raw data and summaries for the nutrient budget can be found in appendices 22-29.

Table 4-1
Perkins Pond Total Phosphorus Budget Load (kg)

Perkins Pond TP Table- Monthly (Mass reported as kg/month)														
TP Hydrologic Load Component	July	August	September	October	November	December	January	February	March	April	May	June	***Annual Total***	***Monthly Average***
2	0.0145	0.0135	0.0160	0.0197	0.0087	0.0724	0.0112	0.0196	0.0187	0.0515	0.0975	0.1067	***0.4501***	***0.0375***
A	0.0500	0.0155	0.2065	0.0369	0.0869	0.3648	0.1354	0.0656	0.0825	0.6677	0.1733	0.1941	***2.0792***	***0.1733***
B	0.0026	0.0006	0.0160	0.0027	0.0015	0.0182	0.0110	0.0037	0.0017	0.1843	0.0173	0.0295	***0.2891***	***0.0241***
C	0.0023	0.0009	0.0409	0.0030	0.0027	0.0082	0.0037	0.0045	0.0050	0.1289	0.0259	0.0361	***0.2622***	***0.0218***
GWI (S1)	0.0172	0.0052	0.0353	0.0473	0.0764	0.1269	0.1269	0.1146	0.1269	0.2032	0.1557	0.4008	***1.4366***	***0.1197***
GWI (S2)	0.0059	0.0860	0.0650	0.0343	0.0067	0.0424	0.0424	0.0383	0.0424	0.0753	0.1351	0.3530	***0.9267***	***0.0772***
GWI (S3)	0.0306	0.1214	0.0495	0.0460	0.0169	0.0561	0.0561	0.0507	0.0561	0.0893	0.5683	0.2625	***1.4035***	***0.1170***
GWI (S4)	0.0478	0.6143	0.1642	0.0736	0.1063	0.4001	0.4001	0.3614	0.4001	0.5740	1.5198	0.4504	***5.1119***	***0.4260***
GWI (S5)	0.0186	0.2348	0.2698	0.0749	0.2232	0.2648	0.2648	0.2391	0.2648	0.2387	0.2631	0.4941	***2.8506***	***0.2376***
GWI (S6)	0.0789	0.0659	0.3222	0.0529	0.0414	0.5544	0.5544	0.5007	0.5544	1.3970	0.2494	0.5137	***4.8853***	***0.4071***
GWI (S7)	0.0465	0.1722	0.3247	0.1787	0.0427	0.1889	0.1889	0.1706	0.1889	0.6849	0.2271	0.2117	***2.6258***	***0.2188***
GWI Sum*	0.2455	1.2999	1.2308	0.5077	0.5137	1.6335	1.6335	1.4754	1.6335	3.2624	3.1185	2.6862	***19.2404***	***1.6034***
Watershed Overland Runoff	3.1476	1.5424	2.5192	0.8283	2.3935	3.1247	0.0000	0.0000	6.0581	5.4926	1.9365	3.8274	***30.8704***	***2.5725***
Direct Lake Wetfall	1.7466	0.2341	0.6691	0.1807	0.4087	0.5039	0.0000	0.0000	1.3791	1.6672	0.5878	4.1386	***11.5157***	***0.9596***
Total Load In	**5.2091**	**3.1069**	**4.6984**	**1.5790**	**3.4157**	**5.7257**	**1.7949**	**1.5689**	**9.1786**	**11.4545**	**5.9568**	**11.0186**	***64.7071***	***5.3923***
SO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0140	0.1201	0.0000	1.1052	***1.2393***	***0.1033***
(NO and Gw o)	1.7428	1.7797	3.1501	1.0473	1.1714	2.6976	1.8458	0.0493	2.8957	2.7650	3.2621	1.8779	***24.2844***	***2.0237***
Total Load Out	***1.7428***	***1.7797***	***3.1501***	***1.0473***	***1.1714***	***2.6976***	***1.8458***	***0.0493***	***2.9097***	***2.8850***	***3.2621***	***2.9831***	***25.5237***	***2.0491***
TP Retention in Pond	***3.4663***	***1.3272***	***1.5483***	***0.5317***	***2.2443***	***3.0281***	***-0.0509***	***1.5196***	***6.2690***	***8.5695***	***2.6947***	***8.0356***	***39.1834***	***2.8316***
*GWI Sum = the sume of GWI (S1) through GWI (S7)														

4.2 Land Use TP Export Coefficient Method

Phosphorus loads from the Perkins Pond watershed were calculated using TP export coefficients. Table 4-2 provides the phosphorus budget using the TP Export Coefficient Method for the entire watershed.

Table 4-2
Phosphorus Export,
Perkins Pond Watershed

Entire Watershed-current condition			Mid	
Land Use	**Area (ac)**	**Area (ha)**	**TP coeff. (kg/ha/yr)**	**Annual TP load (kg)**
Forested	403.61	163.34	0.2	32.67
Hay/Pasture	14.53	5.88	0.6	3.53
Residential	53.43	21.62	0.5	10.81
Open Water	7.85	3.18	0	0.00
Transportation	21.03	8.51	0.5	4.26
	500.44	**202.52**		**51.26**

Approximately 75 acres is within 250 feet of the Perkins Pond shoreline. As shown in Table 4-3, when TP export coefficients are applied to land use cover areas for this area, this accounts for an estimated 10.09 kg P discharged to Perkins Pond. It is not clear from the literature if TP export coefficients include septic system contributions. For this analysis, it is assumed that septic system phosphorus contributions are not included in the export coefficient value.

Table 4-3
Phosphorus Export,
Perkins Pond Watershed, 250 Foot Buffer

Watershed, 250 ft buffer			Mid	
Land Use	**Area (ac)**	**Area (ha)**	**TP coeff. (kg/ha/yr)**	**Annual TP load (kg)**
Forested	40.95	16.57	0.2	3.31
Hay/Pasture	0.00	0.00	0.6	0.00
Residential	19.88	8.05	0.5	4.02
Open Water	0.00	0.00	0	0.00
Transportation	13.61	5.51	0.5	2.75
Total	**74.44**	**30.12**		**10.09**

Approximately 426 acres encompasses the remaining portion of the watershed. As shown in Table 4-4, TP export coefficients applied to existing land use cover areas for this area, results in an estimated 41.17 kg P discharged to Perkins Pond.

Table 4-4
Phosphorus Export,
Perkins Pond Watershed, Less 250 Foot Buffer

Entire Watershed-current condition less 250 ft. buffer			Mid	
Land Use	**Area (ac)**	**Area (ha)**	**TP coeff. (kg/ha/yr)**	**Annual TP load (kg)**
Forested	362.67	146.77	0.2	29.35
Hay/Pasture	14.53	5.88	0.6	3.53
Residential	33.55	13.58	0.5	6.79
Open Water	7.85	3.18	0	0.00
Transportation	7.42	3.00	0.5	1.50
	426.00	**172.40**		**41.17**

4.3 Simple Method

A separate analysis was conducted for the land within 250 feet of the shoreline, using a Simple Method model developed by the Center for Watershed Protection, and adapted for use in New Hampshire. The Simple Method uses rainfall data, NRCS runoff curve numbers, land cover data, and regional estimates of mean phosphorus concentrations in stormwater runoff (called Event Mean Concentrations) to estimate annual phosphorus stormwater loads from the landscape. Input data included Georges Mills rainfall data, literature values for regional Event Mean Concentrations, and the results of the detailed near shore land use and septic system surveys conducted by DES and the Association. This method was applied to the land within a 250 foot buffer from the shore. Results are shown in table 5-1. Appendix 30 contains the Simple Method analysis.

4.4 ArcView Generalized Watershed Loading Function (AVGWLF) Model

Phosphorus loading from the entire Perkins Pond Watershed was estimated using the ArcView Generalized Watershed Loading Function (AVGWLF) Version 6.3 model. AVGWLF is based upon the Generalized Watershed Loading Function (GWLF) model developed by Haith and Shoemaker (1987). A customized interface developed by Pennsylvania State University for the ArcView GIS package was used to parameterize input data for the GWLF model (Evans et al., 2002). In utilizing this interface, the user is prompted to identify required GIS files and to provide other information related to "non-spatial" model parameters such as beginning and end of the growing season. See http://www.avgwlf.psu.edu/ for information about AVGWLF including the AVGWLF Manual.

The AVGWLF model simulates runoff, sediment and nutrient (nitrogen and phosphorus) loads from a watershed given the size of watershed source areas with various land cover types such as agricultural, forested, and developed land. It also has algorithms for calculating septic system loads, and allows the inclusion of point source discharge data. This continuous simulation model uses daily time steps for weather data and water balance calculations. Monthly calculations are made for nutrient loads based on the daily water balance accumulated to monthly values (AVGWLF Manual, August 2006).

The model does not spatially distribute the source areas, but simply aggregates the loads from each area type into a watershed total; there is no spatial routing. For subsurface loading, the model uses a water balance approach for the entire watershed. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated subsurface zone, where infiltration is simply computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration (AVGWLF Manual, August, 2006). See appendices 31-33 for additional information on the AVGWLF model.

AVGWLF model default inputs were modified by refining the weather, basin, unpaved roads and land use cover data to more accurately reflect conditions for the Perkins Pond watershed. The septic system routine in AVGWLF was not used for the model, but septic system data was analyzed separately using the equations provided in AVGWLF. See Table 4-5 for AVGWLF input data used for the Perkins Pond model analysis. Model inputs shaded in green indicate model inputs that were modified from the default values.

Table 4-5
AVGWLF GIS Data Coverage, Perkins Pond

File Names	Short Description	Required	Added	Modified
Shape Files				
Weather Stations	Weather station location (points)	Y	Required	Y
Point Sources	Point source discharge locations (points)	N	N	N
Water Extraction	Water withdrawal locations (points)	N	N	N
Tile Drain	Locations of tile drained areas (polygons)	N	N	N
Basins	Basin boundary (watersheds) used for modeling (polygons)	Y	Created basin boundary	Created basin boundary
Streams	Map of stream network (lines)	Y	Required	N
Unpaved Roads	Map of unpaved roads (lines)	N	Y	Y
Roads	Road map (lines)	N	Y	N
Counties	County boundaries- for Universal Soil Loss Equation (USLE) data (polygons)	N	N	N
Septic Systems	Septic system numbers and types (polygons)	N	Based upon census data	Y, analyzed separately
Animal Density	Animal density (in Animal Equivalent Units (AEUs) per acre (polygons)	N	N	N
Soils	Contains various soil related data	Y	N	N
Physiographic Provinces	Contains hydrologic parameter data polygons (polygons)	N	N	N
Grid Files				

Land Use/Cover	Map of land use/cover (16 classes)	Y	Based on GRANIT Landsat data	Y
File Names	**Short Description**	**Required**	**Added**	**Modified**
Elevation	Elevation grid	Y	N	N
Groundwater-N	Background estimate of N in mg/l	N	N	N
Soil-P	Estimate of soil P in mg/kg (total or soil test P)	N	N	N

AVGWLF Weather Stations

The closest AVGWLF default weather stations were in Hanover, New Hampshire and Cavendish, Vermont. Both weather stations were greater than 20 miles from Perkins Pond and only included weather data through 2004. Therefore data from the weather station maintained by Sunapee DPW at Georges Mills, less than three miles from Perkins Pond, was added to the weather station data file. In addition to precipitation data, the weather file requires minimum and maximum air temperature data, information not recorded at the Georges Mills station. Therefore temperature data from the Hanover, New Hampshire station were used to supplement the Georges Mills weather station data file.

AVGWLF Basins

The AVGWLF Basin file was modified to include the Perkins Pond basin, the watershed used for all models in the diagnostic study (Figure 2.2)

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AVGWLF Unpaved Roads

The AVGWLF unpaved roads file is an optional data layer. During the field work for the diagnostic study the unpaved road network around Perkins Pond was documented as discharging sediment to the pond. Therefore the unpaved roads data layer based upon the New Hampshire Department of Transportation road data set was added to the data input source file.

AVGWLF Land Use

The AVGWLF land use file is based upon the New Hampshire Land cover data set developed by the Complex Systems Research Center at the University of New Hampshire, Durham. This is a fairly broad analysis, specifying land use types in 30 meter pixels and not recommended for land use analyses at scales greater than 1:60,000. It is recommended that this data set may be adequate for large watersheds greater than 5 square miles. The Perkins Pond watershed is much smaller, being roughly 1 square mile and best viewed at a 1:300 scale. Due to the coarseness of this data set, some land use changes within the watershed, especially along the Perkins Pond shoreline, were refined to improve the data output. It should also be noted that the total watershed area in Table 4-6 is 181 hectares, roughly 20 hectares less than the actual watershed size. This is due to the elimination of some 30 meter pixels directly in line with the watershed boundary that occurred when the land use grid file was clipped using the basin boundary.

Table 4-6
AVGWLF Land Use Model Input, Current Condition

Land Use Type	Initial Area (Hectares)	Modified Area (Hectares)
Rural, Hay/Pasture	5	5.88
Rural, Forest	173	163.34
Unpaved Roads	0	3.00
Paved Roads	0	3.56
Urban, Hi Intensity	3	0
Urban, Low Intensity	0	22.68
Open Water*	0	3.23 (not included)
Total	**181**	**198.46**

*Open Water was not added to the modified land use area since sediment and phosphorus loading from open water is insignificant.

4.5 AVGWLF Land Use Scenarios

Water quality models such as AVGWLF that predict nutrient loading can be used to predict phosphorus loading for various scenarios, ranging from completely forested to full build-out conditions.

In order to achieve this task; full build-out conditions first must be defined. The impact of build-out conditions or the maximum number of lots that could be developed based on current zoning is variable in itself. For example, a developed lot may be selectively cleared and a house site prepared with limited grading and earth work. On the other hand, some developed lots are almost entirely cleared, stripped of topsoil and regraded, with greatly reduced vegetative cover, and compacted soils all reducing the ability of the pre-development landscape to naturally infiltrate stormwater. Land use scenarios for this study included a completely undeveloped (forested) condition, the current condition (year 2004-05), and two build-out conditions. The two build-out conditions are based upon either 30 percent or 70 percent land use conversion (forested to cleared lot with houses) and current zoning requirements for both Croydon and Sunapee which are approximately 3.5 acre and 2.0 acre house lots, respectively. It should be noted that septic system loading associated with all conditions was not included in this analysis, as it is estimated separately.

Rainfall data from the Sunapee Department of Public Works, Georges Mills rain gauge (July, 2004 through June, 2005) was applied to all conditions.

<u>Forested Condition</u>

The natural phosphorus loading most closely correlated with a Perkins Pond watershed that is completely forested with no land use changes. This can be seen in Figure 4-1. For this condition, AVGWLF predicts a total watershed phosphorus load of 25 kg/yr.

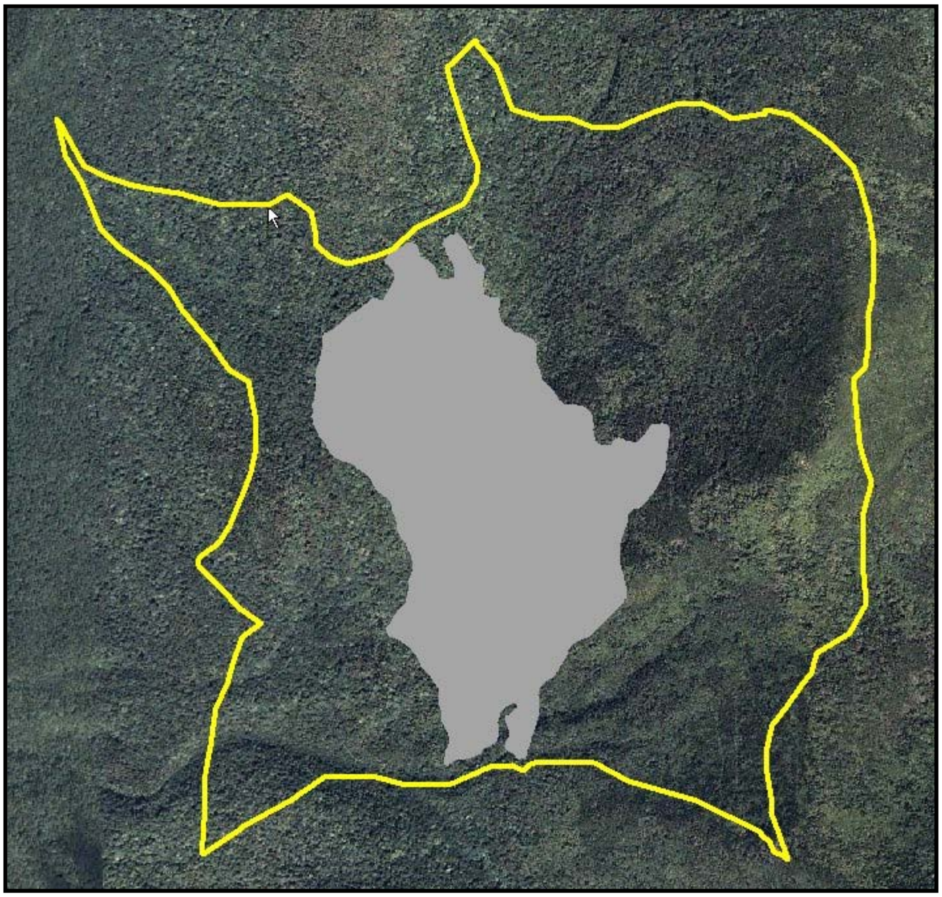

Figure 4-1: Perkins Pond Watershed completely forested.

AVGWLF Current, 2004-2005 (condition 1)

The current condition was evaluated based upon 2004 aerial photography and field observation in 2005. In 2004-2005 there were roughly 94 residential house lots in the Perkins Pond watershed. Most of the development was concentrated along the pond's shoreline. Figure 4-2 displays existing residences with red markers. The blue dashed line represents the divide between Croydon and Sunapee. No residential development existed in Croydon within the Perkins Pond watershed in 2004. AVGWLF predicts a phosphorus load of 46.5 kg/yr for this existing condition.

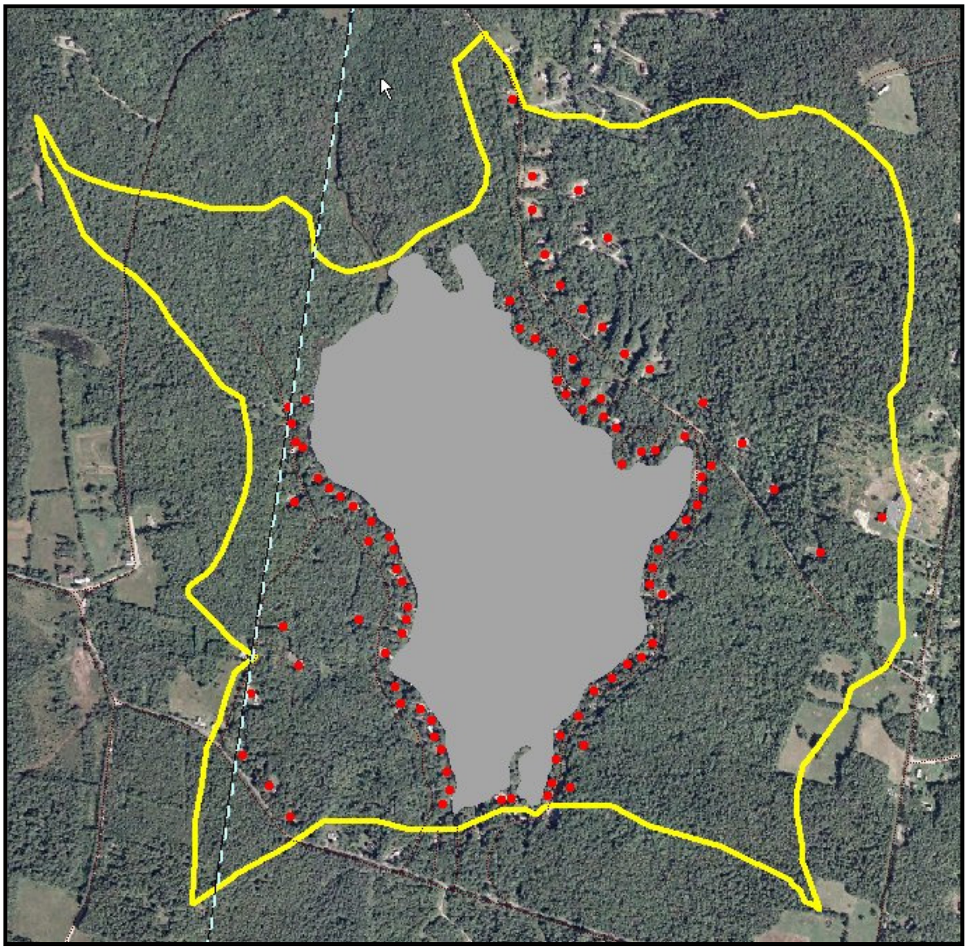

Figure 4-2: Perkins Pond Watershed, current condition (2004), with houses indicated by red markers.

AVGWLF Build-out (conditions 2 and 3)

To determine the build-out conditions for the Perkins Pond watershed, details on current zoning is necessary. The town of Croydon zoning designates this area as rural residential with a minimum 3.5 acre lot size. The town of Sunapee zoning designates this area as rural-residential, subject to overlay districts. Lot sizes vary from 1.5 – 2.0 acres, depending on overlay districts. For the purpose of this evaluation, it was assumed that all house lots would be 3.5 acres in Croydon and 2.0 acres in Sunapee. As a result, an additional 18 house lots could be developed in Croydon and 203 house lots in Sunapee for a total of 221 new house lots in the watershed. Potential road locations were created for visualization, without considering of soils and topography or other possible limiting conditions. All new roads were assumed to be gravel and 24 feet wide, resulting in 18 hectares of new gravel road surface area.

Conditions 2 and 3 assumed land use conversion from forest to non-forest residential of either 30 percent or 70 percent for each lot. Non-forest residential includes houses, driveways, roads, lawns, and other cleared land. All developed house lots (red) and roads (tan) along with potential new house lots in Croydon (purple) and Sunapee (green) and roads (brown) are conceptually shown in Figure 4-3. Site development restrictions due to wetlands, steep slopes, etc. were not factored into the conceptual build-out scenario.

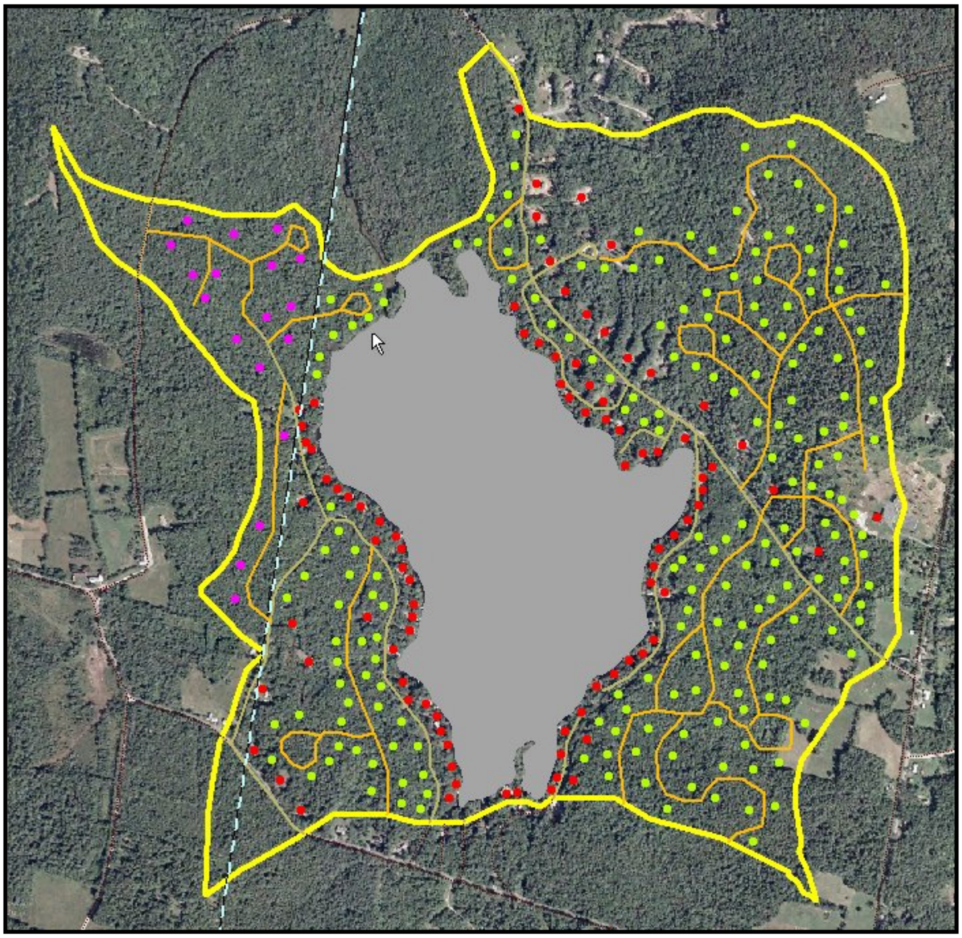

Figure 4-3: Perkins Pond Watershed developed to full build-out.

Condition 2 and 3 assumed a 30 percent and 70 percent, respectively, land use conversion on each lot of the undeveloped, forested and agricultural lands to low intensity urban development. Table 4-7 provides the land area, or AVGWLF input data, for each development condition 1 through 3.

Table 4-7
AVGWLF Land Use for Current and Build-out Conditions

	Condition 1	Condition 2	Condition 3
Land Use	Current Condition (2004) (Ha)	Full-buildout (30% conv.) (Ha)	Full-buildout (70% conv.) (Ha)
Rural, Hay/Pasture	5.88	4.12	1.76
Rural, Forest	163.34	96.34	31
Unpaved Roads	3	21	21
Paved Roads	3.56	3.56	3.56
Urban, Low Int.	22.68	73.45	141.13
Total	**198.46**	**198.46**	**198.46**

1 Hectare (Ha) = 2.47 acres

3.23 Hectares of open water within the watershed was not included in the analysis

AVGWLF Phosphorus Loading

Each of the three conditions was evaluated using AVGWLF. As the Perkins Pond watershed is developed, stormwater runoff will increase and represent the broadest long-term water quality impact to Perkins Pond, driving increased sediment and nutrient loads to the pond, influencing in-lake water quality conditions. As the watershed continues to undergo land use changes (development) from a forested condition, pond water clarity will decrease, plant and algae growth will increase, and dissolved oxygen concentrations will have larger diurnal swings with greater primary productivity causing lower oxygen concentrations during nightfall.

Figure 4-4 provides the phosphorus loading for conditions 1 through 3. AVGWLF predicts an almost three-fold increase in land use phosphorus load to the pond from the current condition to full build-out (70 percent land use conversion from undeveloped to residential and roads), if no action is taken in the watershed to establish conservation areas and to apply best management practices for phosphorus load reduction to lots and roads as they are developed.

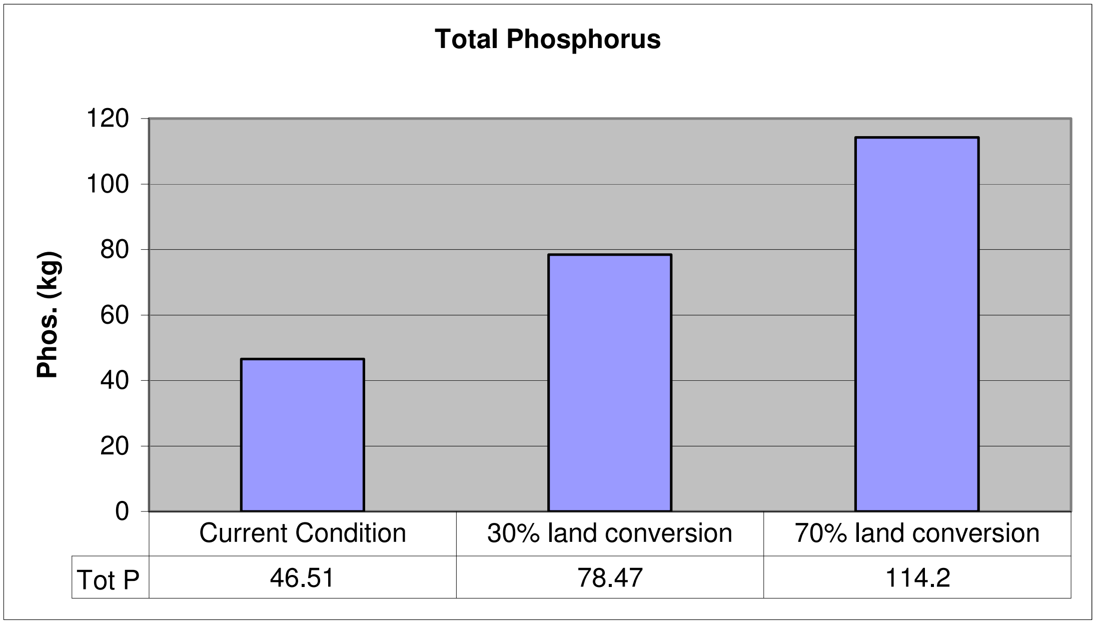

Figure 4-4: Perkins Pond phosphorus load, conditions 1 through 3

4.5 Septic System Analysis

Septic system phosphorus load was estimated using the method contained in AVGWLF. According to this method, normal systems are defined as not generating a phosphorus load to the receiving waters of Perkins Pond. A normal system would be a properly maintained and operating system with a sufficient distance to the pond or surface water so all phosphorus in the septic tank effluent is absorbed into the soil by natural processes. To account for the septic system phosphorus load to the pond, septic survey data was used to document populations served by each septic system and system setbacks from surface water. Adjustments to the septic system data file were made based upon population and septic system location data derived from the septic system and detailed lot surveys described in sections 3.2 and 3.3. Where no location and population data existed, the septic system setback was set at the primary building location and a default occupancy value was set to 2 people per residence. Adjustments for seasonal occupancy were made based upon winter site inspections.

The most significant assumption for data input to determine septic systems phosphorus loads relied on determining the population served by a "short-circuited" septic system. Based on groundwater seepage hydraulic load and phosphorus concentrations, short-circuited septic systems were defined as those systems within 50 feet of the pond shoreline (Figure 4-5). Normal septic systems as defined by AVGWLF do not result in phosphorus load to the pond. Table 4-8 provides the existing and full occupancy populations served by different normal and short circuited septic systems.

The following equation specifies the load rate applied for short circuited septic systems.

$$SL_{1m} = 0.001\ a_{1m}\ d_m\ (e - u_m)$$

a= the number of people

d= the number of days in the month

e= the "per capita tank effluent" which defaults to 2.5 grams/day of P.

u= the "per capita growing season P uptake" which defaults to 0.4 grams/day of P.

0.001 is the conversion factor necessary to convert grams to kilograms

Table 4-8
Septic Systems within 50 feet of the Shoreline

	Current Condition		Year-round conversion	
	Normal Septic Systems	Short Circuit Septic Systems	Normal Septic Systems	Short Circuit Septic Systems
	Leach field >50 ft. from shore	Leach field <50 ft. from shore	Leach field >50 ft. from shore	Leach field <50 ft. from shore
Month	# people	# people	# people	# people
April	120	5	209	8
May	120	5	209	8
June	209	8	209	8
July	209	8	209	8
August	209	8	209	8
September	138	5	209	8
October	138	5	209	8
November	138	5	209	8
December	113	4	209	8
January	113	4	209	8
February	113	4	209	8
March	120	5	209	8

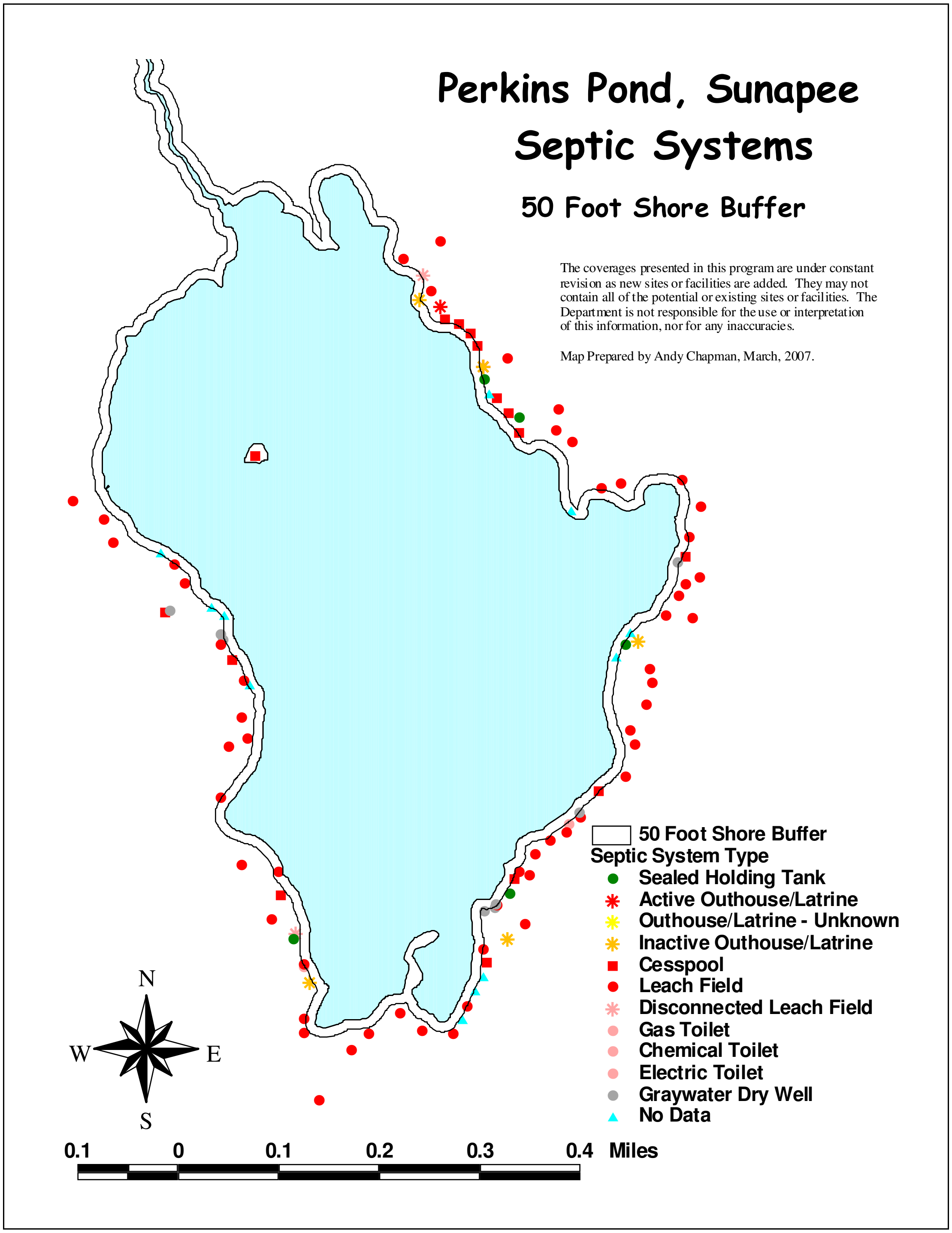

Figure 4-5: Distance of Sewage disposal from the pond.

Conversion of seasonal or vacation homes to year round, primary residences could negatively impact the water quality of Perkins Pond. Many of today's modern amenities, including dishwashers, garbage disposals, water softeners, and washing machines, additional water and waste loads to the septic system which are greater than initially intended and designed for will ultimately occur. Most phosphorus from septic systems within 50 feet of the shoreline is likely to discharge to the pond through groundwater. The following table shows estimates of phosphorus loading using the AVGWLF formula, under current conditions and if properties with septic systems within 50 feet of the shoreline were converted to full-time occupancy.

Table 4-9
Phosphorus Export,
Septic Systems, Current Condition,
AVGWLF

Mar-May	June-Aug	Sept-Nov	Dec-Feb	
P Load (kg)	P Load (kg)	P Load (kg)	P Load (kg)	Total TP (kg/yr)
1.10	1.47	1.10	0.79	4.45

Table 4-10
Phosphorus Export,
Septic Systems, Year-round Occupancy Conversion,
AVGWLF

Mar-May	June-Aug	Sept-Nov	Dec-Feb	
P Load (kg)	P Load (kg)	P Load (kg)	P Load (kg)	Total TP (kg/yr)
1.66	1.47	1.66	1.72	6.52

To verify the reasonableness of septic system model results, near shore groundwater seepage was measured using seepage barrels (for hydraulic loading) and interstitial pore water samplers (for interstitial pore water P concentration). These data were used to estimate septic system P loads under the existing condition for near shore lots. The resulting estimate of phosphorus load from septic systems in the 250 foot buffer is 17.9 kg/yr. This indicates that the septic system loads estimated by the AVGWLF method may be underestimated.

5.0 WATERSHED MODEL PHOSPHORUS LOAD SUMMARY

As described in Section 4, Watershed Models, phosphorus loading to Perkins Pond was estimated by several methodologies. For each method, loading was divided into compartments for estimation purposes. The methods are different in how P loads are compartmentalized and in their spatial resolution and estimation ability, but the overall results are comparable.

Table 5-1 provides the phosphorus load estimate for each methodology, providing a low and high range for annual phosphorus load to Perkins Pond for the following four conditions:

1) Existing conditions in the watershed, with detailed analysis of P loading from land use and septic systems within a 250 foot near shore buffer.

2) Full-time occupancy conversion of developed shorefront lots in the near shore buffer, with septic systems remaining in existing locations, no municipal sewers for shorefront lots, no nonpoint source BMPs within the 250 foot near shore buffer, and 2 acre lot build-out in the rest of the watershed to the extent allowed by soil conditions.

3) Municipal sewers and no nonpoint source BMPs within the 250 foot near shore buffer, and 2 acre lot build-out in the rest of the watershed to the extent allowed by soil conditions.

4) Municipal sewers and nonpoint source BMPs within the 250 foot near shore buffer, and 2 acre lot build-out in the rest of the watershed with minimum lot disturbance for residential construction.

Table 5-1
Perkins Pond Phosphorus Load Summary, All Methods

PHOSPHORUS LOAD SUMMARY					
		Condition 1	**Condition 2**	**Condition 3**	**Condition 4**
		a) Existing conditions	a) Full build-out, no BMPs in 250 foot buffer, (rest of undeveloped watershed goes to 70% residential)	a) Full build-out, no BMPs in 250 foot buffer, (rest of undeveloped watershed goes to 70% residential)	a) Full build-out, BMPs in 250 foot buffer, (rest of undeveloped watershed goes to 30% residential)
Compartment	**Estimation Method**		b) no municipal sewer	b) with munipal sewer	b) with municipal sewer
Septic Systems in 250 foot buffer	AVGWLF, 50 ft. short circuit distance	4.5	6.5	0.0	0.0
Septic Groundwater	Phosphorus Budget	17.9	17.9	0.0	0.0
land Use in 250 foot buffer	Export Coefficient	10.1	12.7	12.7	10.7
	Simple Method	9.6	16.3	16.3	8.6
Land use in rest of watershed	Export Coefficient	41.2	85.1	85.1	69.5
Land Use in entire watershed	Phosphorus Budget	53.2	NOT APPLICABLE	NOT APPLICABLE	NOT APPLICABLE
	AVGWLF (no septics)	46.5	114.2	114.2	78.5
TOTALS	**Low**	**51.0**	**104.3**	**97.8**	**78.1**
	High	**69.1**	**148.4**	**130.5**	**89.1**

blue shade indicates value used to calculate both **low** and **high** phosphorus load range for specified condition
green shade indicates value used to calculate **low** phosphorus load range for specified condition
orange shade indicates value used to calculate **high** phosphorus load range for specified condition
yellow shade indicates value **not applied** to the low or high range calculation for the specified condition

Note: The Phosphorus load ranges do not include direct precipitation to the pond which was estimated to be 11.5 kg during the study period.

6.0 CONCLUSIONS AND RECOMMENDATIONS

According to AVGWLF and other model results, land use and wastewater disposal in septic systems contribute substantially to the phosphorus loading into Perkins Pond. Even a completely undeveloped, forested watershed would result in phosphorus loading of 25 kg/year.

The discussion below is an interpretation and analysis of the model results presented in Table 5-1. See appendices 34-36 for pond in-lake data and trophic status predictions.

For the existing condition (2004), the phosphorus loading is likely between 50 and 70 kg/year or more than twice that of a completely forested watershed condition. About 2/3 of this comes from the watershed outside the 250 foot buffer. Within the buffer, 5-18 kg/year comes from septic systems located within 75 feet of the shoreline. However, with long usage, soils may become saturated with phosphorus from septic systems. As a result, an additional 10-25 kg/yr of phosphorus could discharge to the pond from all septic systems within 75 feet of the shoreline. In addition, about 10 kg/yr P comes from the landscape within the 250 foot buffer. This value does not include septic system loads.

For a fully developed condition, with no action taken to reduce phosphorus loads, the low estimate for the full watershed is about twice the existing condition, and the high estimate is three times. This much phosphorus load would undoubtedly result in degradation of the lake.

The best scenario to maintain lake quality while allowing reasonable development in the watershed is controlled development that retains as much forest cover as possible, municipal sewers or community septic systems for near shore lots in the 250 foot buffer, and active management of land use in the 250 foot buffer to reduce phosphorus load from stormwater runoff. Even with these actions, phosphorus loading could more than double from current levels. Most of this increase would come from a reduction in the forested landscape of the outer watershed, so conservation of forested land in the watershed is very important. There are several mechanisms for this such as acquiring conservation land by purchase or easement and incorporating limits for residential density or on land clearing into land use regulations.

The model techniques used in this study give equal weight to near shore phosphorus loads and loads in the outer watershed. However, control of phosphorus loads in the near shore 250 foot buffer would be expected in general to be more important for maintenance of water quality in Perkins Pond. Within this near shore buffer, phosphorus loads can actually be reduced, even with full occupancy of existing structures and 70% development of the remaining forest land in the buffer. The Existing phosphorus load in the buffer is 14 to 28 kg/year. Removing sewage disposal loading from this area, as would occur with municipal sewer service, would likely remove 5-18 kg/yr, and conscientious implementation of best management practices in this buffer could result in reductions of another kilogram or two, for a total near shore phosphorus load on the order of 6-20 kg/yr.

Applicable best management practices for near shore lots include minimizing areas of driveways and paths, maintaining as much natural buffer as possible with minimization of maintained lawns, creating “rain gardens” or other infiltration techniques for roof runoff, and directing driveway drainage either away from the pond or to areas where infiltration is possible. See appendices 37-39 for information on zoning, stormwater BMPs and watershed management.

In conclusion, removing septic system phosphorus loads from the 250 foot buffer and implementing stormwater best management practices for all developed land in the buffer will have a significant benefit in maintaining lake water quality over the long term. Equally important is the maintenance of forest cover in the rest of the watershed.

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