PHOSPHORUS CONTROL ACTION PLAN

and Total Maximum Daily (Annual Phosphorus) Load Report

HIGHLAND LAKE

Cumberland and Oxford Counties, Maine

Highland Lake PCAP-TMDL Report

Maine DEPLW 2004 - 0658

Maine Department of Environmental Protection

LAKES ENVIRONMENTAL ASSOCIATION and

Maine Association of Conservation Districts

Final EPA Document - August 12, 2004

HIGHLAND LAKE Phosphorus Control Action Plan (PCAP)

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HIGHLAND LAKE

Total Maximum Daily (Annual Phosphorus) Load

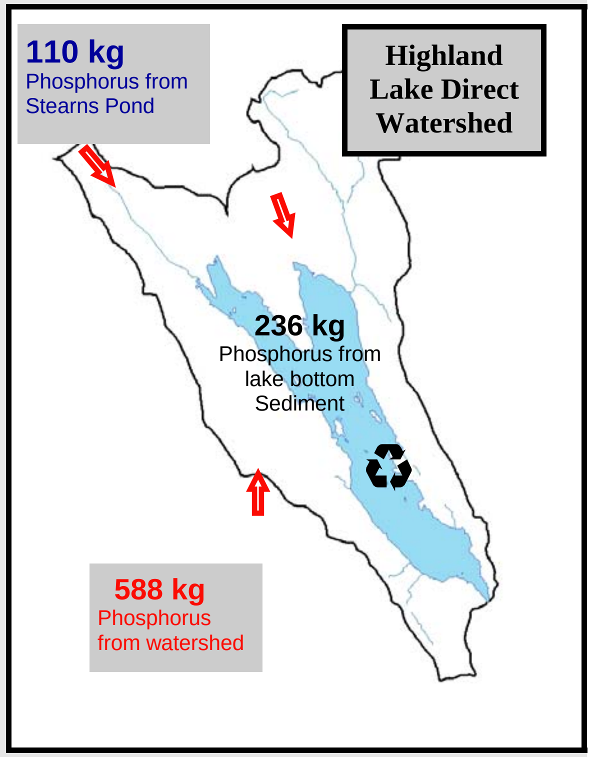
ACKNOWLEDGMENTS

In addition to Maine DEP and US-EPA New England Region I staff, the following individuals, groups and agencies were instrumental in the preparation of this combined Highland Lake Phosphorus Control Action Plan-Total Maximum Daily (Annual Phosphorus) Load report: Lakes Environmental Association (Peter Lowell, Colin Holme); MACD staff (Jodi Michaud Federle, Forrest Bell and Tim Bennett); Cumberland County Soil & Water Conservation District (Tamara Lee Pinard); Town of Bridgton (Bill Foye, Georgiann Fleck, Jim Kidder); Jean Preis (LEA volunteer); Jesse Logan-Cottingham (LEA Volunteer); Orbis Mapping (Rosemary Mosher); USDA (Lindsay Hodgman); VLMP (Scott Williams), and Maine Department of Inland Fisheries and Wildlife (Francis Brautigam, Region A, Gray Office).

HIGHLAND LAKE PHOSPHORUS CONTROL ACTION PLAN SUMMARY FACT SHEET

Background

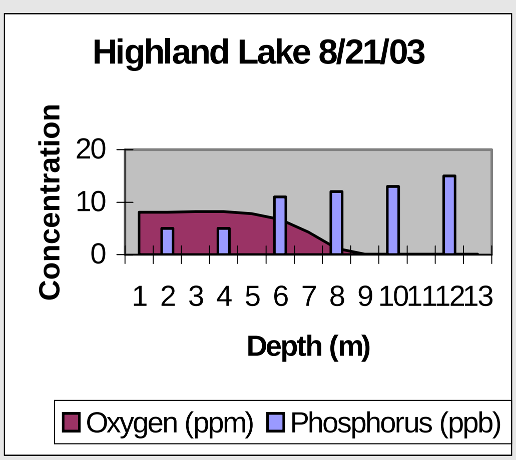
HIGHLAND LAKE is a 1,334-acre waterbody located in the town of Bridgton in Cumberland County, south western Maine. Highland Lake has a direct **watershed** (see map) area of 10.2 square miles (including Sweden and Waterford in Oxford County); a maximum depth of 49 feet, a mean depth of 20 feet; and a **flushing rate** of 0.91 flushes per year. The total Highland Lake watershed drainage area, with subwatersheds, is 20.4 square miles.



Highland Lake has experienced a gradual decline in water quality over the past decade. Average annual Secchi disk readings (measures of water clarity) over the past decade are about one meter less than during the previous decade, which reflect increases in algae and sediment deposits in the lake. In addition, the average dissolved oxygen in the lake's lower layer during September has declined to levels that threaten the lake's cold water fishery. This decline is due in large part to the contribution of **phosphorus** that is prevalent in area soils and effectively transported via storm flows. Excessive soil erosion in lake watersheds can have far-reaching water quality consequences. Soil particles transport phosphorus, which essentially "fertilizes" the lake and decreases water clarity. Studies on lakes in general have also shown that as lake water clarity decreases, lakeshore property values decline. Excess phosphorus can also stimulate the growth of aquatic invasive plants such as variable leaf milfoil, which fortunately has not yet been found to occur in Highland Lake.

Stakeholder Involvement

Federal, state, county, and local groups have been working together to effectively address this nonpoint source water pollution problem. In 2001, the Maine Department of Environmental Protection funded a project in cooperation with the Maine Association of Conservation Districts, Lakes Environmental Association and Cumberland County Soil and Water Conservation District to identify and quantify the potential sources of phosphorus and identify the **Best Management Practices** needed to be installed in the watershed. A final report, completed in the late spring of 2004, is entitled "Highland Lake Phosphorus Control Action Plan" and doubles as a **TMDL** report, to be submitted to the U.S. Environmental Protection Agency, New England Region, for their final review and approval.

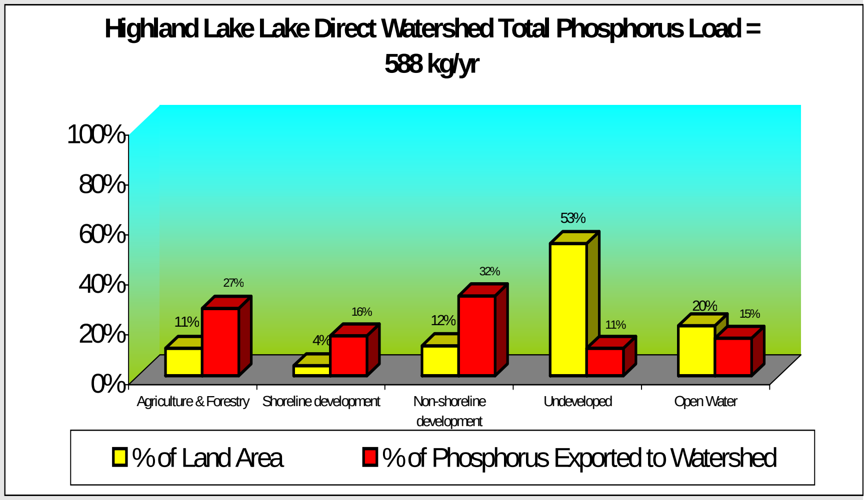


What We Learned

A land use assessment was conducted for the Highland Lake watershed to determine potential sources of phosphorus that may run off from land areas during storm events and springtime snow melting. This assessment utilized many resources, including generating and interpreting maps, inspecting aerial photos, and conducting field surveys. A similar land use assessment is being conducted for Long

Lake, located in Bridgton and the neighboring towns of Naples and Harrison.

An estimated 588 kilograms (kg) of phosphorus per year is exported to Highland Lake from the direct watershed. The bar chart (right) illustrates the land area for each land use vs. its total phosphorus export load.



The total phosphorus contribution from upstream Stearns Pond was estimated at 110 kg/yr. Over the past 14 years, the amount of phosphorus being recycled internally (236 kg/yr) from the bottom sediments of Highland Lake during the summertime have been fairly stable, however, showing an increase in recent years.

Phosphorus Reduction Needed

Highland Lake has a natural capacity to effectively process up to 467 kg of phosphorus annually without harming water quality. This amount equates to an in-lake phosphorus concentration of 8 ppb. Highland Lake's actual in-lake average annual TP concentration is 10 ppb, equal to 585 kg TP. Taking into account a 44 kg allocation for potential future watershed development, the total phosphorus reduction needed to maintain water quality (algal bloom-free conditions) standards in Highland Lake approximates 162 kg.

What You Can Do To Help!

As a watershed resident, there are many things you can do to protect the water quality of Highland Lake. Lakeshore owners can use phosphorus-free fertilizers and maintain natural vegetation adjacent to the lake. Agricultural and commercial land users can consult Lakes Environmental Association, Cumberland County Soil and Water Conservation District or Maine Department of Environmental Protection for information regarding Best Management Practices (BMPs) for reducing phosphorus loads. Watershed residents can always become involved by volunteering to help Lakes Environmental Association and participating in events sponsored by LEA. All stakeholders and watershed residents can learn more about their lake and the many resources available, including review of the Highland Lake Phosphorus Control Action Plan. Following final EPA approval, copies of this detailed report, with recommendations for future NPS/BMP work, will be available online at www.state.me.us/dep/blwq/docmonitoring/tmdl2.htm, or can be viewed and/or copied (at cost) at Maine DEP offices in Augusta (Bureau of Land and Water Quality, Ray Building, AMHI Campus).

Key Terms

- ***Watershed*** *is a drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*
- ***Flushing rate*** *refers to how often the water in the entire lake is replaced on an annual basis.*
- ***Phosphorus****: is one of the major nutrients needed for plant growth. It is naturally present in small amounts and limits the plant growth in lakes. Generally, as phosphorus increases, the amount of algae also increases.*
- ***Best Management Practices*** *are techniques to reduce sources of polluted runoff and their impacts. BMPs are low cost, common sense approaches to reduce storm runoff and velocity to keep soil out of lakes and tributaries.*
- ***TMDL*** *is an acronym for Total Maximum Daily Load, representing the total amount of a pollutant (e.g., phosphorus) that a waterbody can annually receive and still meet water quality standards.*

Project Premise

This project, funded through a Clean Water Act section 319 grant from the United States Environmental Protection Agency (EPA), was directed and administered by the Maine Department of Environmental Protection (Maine DEP) in partnership with the Maine Association of Conservation Districts (MACD) and Lakes Environmental Association (LEA), from the summer of 2001 through the late spring of 2004.

The objectives of this project were twofold: first, a comprehensive land use inventory was undertaken to assist Maine DEP in developing a Phosphorus Control Action Plan (PCAP) and a Total Maximum Daily Load (TMDL) report for the Highland Lake watershed. Simply stated, a TMDL is the total amount of phosphorus that a lake can receive without harming water quality. Maine DEP, with the assistance of the MACD Project Team, will address and incorporate public comments before final submission to the US EPA. *(For more specific information on the TMDL process and results, refer to the Appendices or contact Dave Halliwell at the Maine DEP Augusta Office at 287-7649 or at David.Halliwell@maine.gov*).

Secondly, watershed survey work, including a shoreline survey, was conducted by the Maine DEP-MACD-LEA project team to help assess **total phosphorus** reduction techniques that would be beneficial for the Highland Lake watershed. Watershed survey work included assessing many direct drainage **nonpoint source (NPS) pollution** sites that were not identified during the Highland Lake Watershed Project (1998-2000). This project involved identifying NPS pollution sites though computer modeling and field surveys during storm events. BMPs were then designed and implemented to help mitigate phosphorus and sediment loading to Highland Lake on the identified priority sites. The watershed project report also includes model phosphorus ordinances, recommendations for continued monitoring, and phosphorus load reduction calculations.

***Total Phosphorus (TP) -** is one of the major nutrients needed for plant growth. It is generally present in small amounts and limits the plant growth in lakes. Generally, as the amount of lake phosphorus increases, the amount of algae also increases.*

***Nonpoint Source (NPS) Pollution** - is polluted runoff that cannot be traced to a specific origin or starting point, but appears to flow from many different sources.*

Note: *To protect the confidentiality of landowners in the Highland Lake watershed, site-specific information is not provided as part of this report.*

This Phosphorus Control Action Plan (PCAP) report compiles and refines land use data derived from various sources, including the municipality of Bridgton, the Maine Office of GIS, the Casco Bay Estuary Project, the Cumberland County Soil & Water Conservation District (SWCD), and LEA. Local citizens, watershed organizations, and conservation agencies should benefit from this compilation of data as well as the watershed assessment and the NPS Best Management Practice (BMP) recommendations. Above all, this document is intended to help Highland Lake stakeholder groups to effectively prioritize future BMP work in order to obtain the funding resources necessary for NPS pollution mitigation work in their watershed.

Study Methodology

Highland Lake background information was obtained using several methods, including a review of previous studies of the lake and watershed area, numerous phone conversations and personal interviews with municipal officials, regional organizations and state agencies, and several field tours of the watershed, including boat reconnaissance of the lake and shoreline.

__GIS__—or __geographic information system__ combines layers of information about a place to give you a better understanding of that place. The information is often represented as computer generated maps.

Land use data were determined using several methods, including (1) **Geographic Information System (GIS)** map analysis, (2) analysis of topographic maps, (3) analysis of town property tax maps and tax data, (4) analysis of aerial photographs (US-FSA 1995, 1997 & CITIPIX 2001) and (5) field visits. Much of the undeveloped land use area (i.e., forest, wetland, scrub shrub) was determined using GIS maps utilizing data from the Casco Bay Estuary Project (landuse coverage interpreted and digitized by James W. Sewell Company, May 1990), and Lakes Environmental Association (landuse data interpreted and digitized from Maine Office of GIS 2001, ortho-hfs and 1995 MEDOQs). The developed land use areas were obtained using the best possible information available through analysis of methods 2 through 5 listed above. Necessary adjustments to the GIS data were made using best professional judgment.

Roadway data were gathered by taking actual road width measurements of the various types of roads (state, town, private/camp) in the watershed. Roads were measured between the two outer edges of the roadside ditches or berms. An average width was used for each of the three road types. Final measurements for all roadways within the watershed were extrapolated using GIS (Casco Bay Estuary Project, LEA and road and aerial photo data from the Maine Office of GIS), and USGS topographical maps. Finally, the roadway area was determined using linear distances and average widths for each of the three main road types.

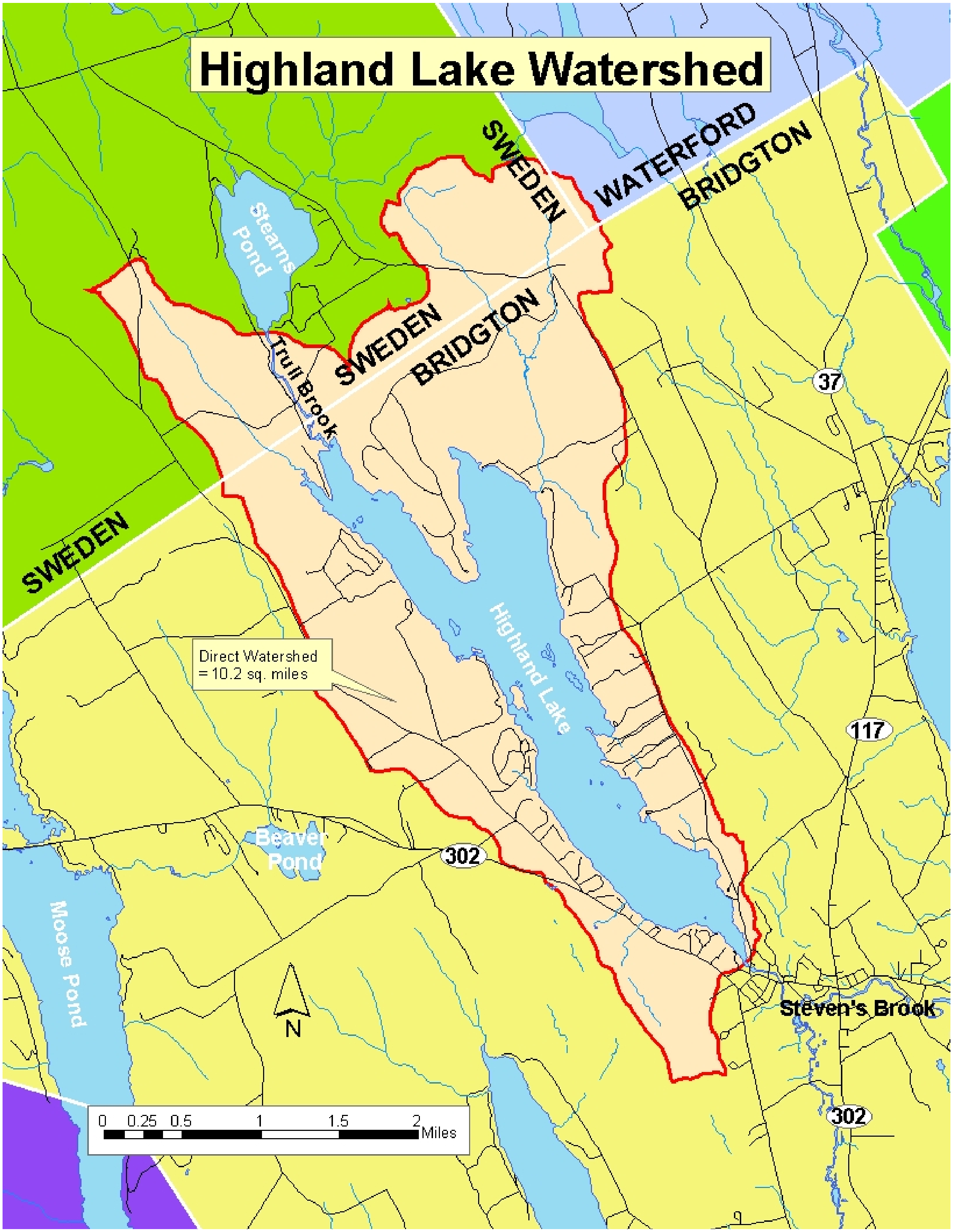
Additional land use data (i.e. non-shoreline residential, institutional, operated forestland) were determined using GIS cover mapping, aerial photos, topographic and property tax maps as well as personal consultation and, when necessary, field visits.

Agricultural information within the Highland Lake watershed was provided by the Cumberland County Soil and Water Conservation District (CC-SWCD).

Study Limitations

Land use data gathered for the Highland Lake watershed is as accurate as possible given available information and resources utilized. However, the final numbers for the land use analysis and phosphorus loading numbers are approximate, and should be viewed as carefully researched estimations only.

Figure 1. Map of Highland Lake Direct Watershed



HIGHLAND LAKE Phosphorus Control Action Plan

DESCRIPTION of WATERBODY (MIDAS Number 3454 and WATERSHED)

HIGHLAND LAKE is a 1,334 acre single-basin waterbody, located within the town of Bridgton (DeLorme Atlas, Maps 4 and 10), in Cumberland County, located in southwestern Maine. Highland Lake has a **direct watershed** area (see Figure 1) of 6,512 acres (10.2 square miles), including Sweden and Waterford (Oxford County) within the Sebago Lake - Presumpscot River drainage system. Highland Lake has a maximum depth of 15 meters (49 feet), an overall mean depth of 6 meters (20 feet) and has a flushing rate of .91 times per year. The total Highland Lake watershed drainage area, including the upstream sub-watersheds of Stearns, Black and Duck ponds, is 13,024 acres (20.4 square miles).

*The **direct watershed** refers to the land area that drains to the lake without first passing through another lake or pond.*

Drainage System – Duck and Black ponds drain into Stearns Pond which outlets into Highland Lake through Trull Brook. Highland Lake is drained at its outlet by Steven's Brook, which flows southeasterly into Long Lake in Bridgton. The town of Bridgton controls the water level of Highland Lake with a dam at the outlet.

Water Quality Information

Highland Lake is listed on the Maine DEP's Clean Water Act section 303(d) list of lakes that do not meet State water quality standards as well as the State's Nonpoint Source Priority Watersheds list; hence, the preparation of a Phosphorus Control Action Plan (and TMDL) was prepared, publicly reviewed, and completed in the late spring of 2004.

Water quality monitoring data for Highland Lake, including temperature, oxygen, **Secchi disk transparency**, color, pH, conductivity, alkalinity and **Chlorophyll-a** has been collected regularly since 1976. Together, these data document an overall trend of increasing **trophic state,** in direct violation of the Maine DEP Class GPA water quality criteria requiring a stable or decreasing trophic state.

Trout and other coldwater fish require oxygen levels greater than 5 ppm to survive and even higher levels (7-8 ppm) to grow and reproduce. Since dissolved oxygen levels in Highland Lake's **hypolimnion** fall far below this level during most summers, it is possible that the lake has experienced a moderate to severe reduction in coldwater fish habitat (CC-SWCD 1999). Nonpoint source pollution is the main reason for declining water quality in Highland Lake. During storm events, nutrients such as phosphorus - naturally found in Maine soils - drain into the lake from the surrounding watershed by way of streams and overland flow.

***Secchi Disk Transparency**—a measure of the transparency ability of light to penetrate water obtained by lowering a black and white disk into water until it is no longer visible.*

***Chlorophyll-a** is a measurement of the green pigment found in all plants including microscopic plants such as algae. It is used as an estimate of algal biomass; the higher the Chl-a number, the higher the amount of algae in the lake.*

***Trophic state**—the degree of eutrophication of a lake. Transparency, chlorophyll-a levels, phosphorus concentrations, amount of macrophytes, and quantity of dissolved oxygen in the hypolimnion can be used to assess trophic state.*

***Hypolimnion**—lower, cooler layer of a lake during summertime thermal stratification.*

Phosphorus is naturally limited in lakes and can be thought of as a fertilizer, a primary food for plants, including algae. When lakes receive excess phosphorus from NPS pollution, it "fertilizes" the lake by feeding the algae. Too much phosphorus can result in algae blooms, which can damage the ecology/aesthetics of a lake, as well as the economic well-being of the entire affected watershed community.

Principal Uses: The dominant human uses of the Highland Lake shoreline are residential (both seasonal and year-round occupancy) and recreational—boating, fishing and swimming/beach use. A town-operated public boat launch is located at the southern tip of the lake off Highland Road in Bridgton. There are three commercial motels located on the lakeshore, but no commercial camps, campgrounds or marinas on the lake.

Human Development: The Highland Lake shoreline is moderately developed. Of the 363 shorefront lots, 93 are undeveloped. Of the 270 shorefront residences within the 250' shoreland zone, approximately 85% are seasonal and only 15% are year-round (Peter Lowell, LEA).

The direct watershed of Highland Lake is located within the towns of Bridgton (approximately 80% of the watershed), Sweden, (approximately 20% of the watershed) and Waterford (less than 1% of the watershed). Bridgton is a rural, residential suburb, located in the northwest corner of Cumberland County, 40 miles from Portland, 45 miles from Lewiston-Auburn and 25 miles from North Conway, New Hampshire. Commercial and employment centers are located in and around the Bridgton area, concentrated primarily along Routes 302 and 117. Sweden is a rural town with little commercial development, located in Oxford County and directly abutting Bridgton to the north. A small sliver in the northern portion of Highland Lake's watershed lies within the town of Waterford. Waterford is also a small rural town with little commercial development, located within Oxford County.

Highland Lake is on the State's **Nonpoint Source Priority Watersheds** list due primarily to a declining trend for dissolved oxygen levels. In addition to NPS pollution, high population growth rates are a concern for the watershed. Based on estimates from the 2000 census, a total of 4,883 people currently reside in Bridgton. The population of Bridgton generally increases by approximately 50% in the summer months. Between 1990 and 2000, Bridgton's population has increased by 13.4%. Some of the population increase in Bridgton that has occurred during this time period involves the conversions from seasonal to year-round residences.

*Waterbodies within designated **NPS priority watersheds** have significant value from a regional or statewide perspective and have water quality that is either impaired or threatened to some degree due to NPS water pollution. This list helps to identify watersheds where state and federal agency resources for NPS water pollution prevention or restoration should be targeted.*

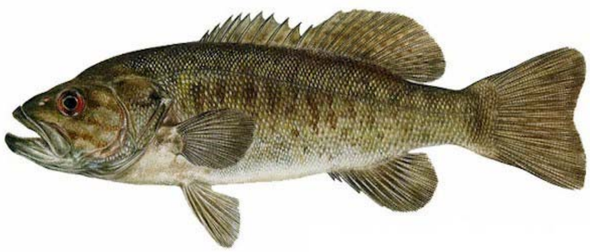
Outlet Dam Management - The outlet dam is owned, operated and maintained by the town of Bridgton. The dam was originally constructed during the 1800s. Prior to the installation of the dam, the waterbody was substantially smaller and referred to as Crotched Pond. The dam was rebuilt in 1900, 1978 and again in 1999. The summer lake water level is maintained at one foot higher than the winter water level. The lake is lowered starting in October from 6.5 feet to 5.5 feet (as measured at the dam outlet). Water level in the spring fluctuates slightly depending on precipitation and melting (Jim Kidder, Bridgton Public Works).

Highland Lake Fish Assemblage & Fisheries Status

Based on records provided by the Maine Department of Inland Fisheries and Wildlife (Maine DIFW) and a recent conversation with Francis Brautigam (Region A, Gray DIFW office), **Highland Lake** (Town of Bridgton - Presumpscot River drainage) is currently managed as primarily a warmwater fishery (smallmouth bass and white perch) with limited holdover of stocked brown trout (3 to 4 pound range). Highland Lake was originally surveyed by Maine DIFW in 1957, while their lake summary fisheries report was last revised in 1999. A total of **13** fish species are listed, including: **8** native indigenous fishes (American eel, golden shiner, fallfish, white sucker, brown bullhead, chain pickerel, pumpkinseed, and yellow perch) and **4** previously introduced fishes (white perch, smallmouth and largemouth bass, rainbow smelt, and brown trout).

***Dissolved Oxygen**—refers to the amount of oxygen measured in the water. It is used by aquatic organisms for respiration. The higher the temperature, the less oxygen the water can hold. Oxygen will naturally decline during the summer months as water temperatures rise.*

Reportedly, smallmouth bass are commonly found to be heavily infested with bass tapeworm, while white perch are typically very abundant and are characterized by a good mix of different size classes, including some of exceptional size quality (Maine DIFW 1999).



In terms of fisheries, **Highland Lake** has a history of seasonal water quality problems, which are apparent during the summer months when severe **dissolved oxygen** deficiencies develop in the deeper stratified waters. According to Maine DIFW, this places severe limits on the success of coldwater fishery management efforts in Highland Lake. Given that the trophic state of Highland Lake has been disturbed by human impacts over the past several decades, then a significant reduction in the total phosphorus load in the Highland Lake watershed may lead to maintaining in-lake nutrient levels within the natural assimilative capacity of this lake to effectively process phosphorus - to the benefit of existing warmwater and potentially coldwater (brown trout) fisheries.

Watershed Topography and Characteristic Soils (Source: USDA SCS 1974): The majority of the soils within Highland Lake drainage area are deep, somewhat poorly to moderately well drained soils formed and associated with glacial till. Approximately 52% of the soils within the watershed are potentially highly erodible and 17% are highly erodible. The soils within the watershed are described by the following associations:

Hermon-Peru-Paxton—These deep, somewhat excessively drained to moderately well drained soils dominate the Highland Lake watershed.

Hermon series soils are type A hydrologic soils which indicates a high groundwater transport rate. The Hermon series consists of deep, well drained, to somewhat excessively drained soils. These soils are formed in granitic glacial till and contain many small and large stone fragments. The water table generally is at a depth of 3 to 5 feet. Permeability is rapid and available water capacity is low. Malfunctioning septic systems located in these soils have the potential to contribute phosphorus through groundwater transport.

Peru series soils are type C hydrologic soils which have the potential for moderate-to-high surface runoff. The Peru series consists of deep, moderately well drained soils that are formed in very firm, stony, glacial till. Permeability is moderate to moderately slow and available water capacity is high.

Paxton series soils are also type C soils which have the potential for moderate-to-high surface runoff. The Paxton series consists of deep, well drained moderately coarse textured soils. These soils are formed in very firm stony glacial till. Permeability is moderate to moderately slow and available water capacity is high.

Land Use Inventory

The results of the Highland Lake watershed land use inventory are depicted in Table 1. The various land uses are categorized by developed land vs. non-developed land. The developed land area comprises approximately 27% of the watershed and the non-developed land including the water surface area of Highland Lake, comprises the remaining 73% of the watershed. These numbers may be used to help make future planning and conservation decisions relating to the Highland Lake watershed. The information in Table 1 was also used as a basis for preparing the Total Maximum Daily (Annual Phosphorus) Load report (see Appendices).

Descriptive Land Use and Phosphorus Export Estimates

Agriculture: Non-manured hayland is the primary agricultural land use within the watershed and totals 171 acres. Additionally, a small 3 acre orchard lies along the southern boundary of the watershed. The agricultural land area of the Highland Lake watershed currently comprises 3% of the total watershed area and 8.8% of the external phosphorus load.

Operated Forest Lands: Generally, poorly managed forestry operations have the potential to negatively impact a waterbody by erosion and sedimentation from logging sites. Within the Highland Lake watershed, Operated Forest Lands were assessed and put into one of three categories: heavily harvested, moderately harvested and low impact/sustainable harvesting. Within the watershed, there was a total of 282 acres of moderately harvested land and 292 acres of low impact/sustainable harvesting. No heavily harvested areas were documented.

Table 1. Highland Lake Direct Watershed - Land Use Inventory and P-Loads.

LAND USE CATEGORY	Total Land Area Acres	Total Land Area %	TP Export Total%
Agricultural & Forested Land			
Low-Intensity Hayland	171	3	8.8
Orchard	3	0	0.0
Operated Forest Land	574	9	17.9
Sub-Totals	**748**	**12%**	**27%**
Shoreline Development			
Low Density Residential	67	3	1.4
Medium Density Residential	149	2	6.0
Septic Systems	—	—	5.6
Parks (Public Boat Launch Area)	1	0	0.0
Commercial	3	0	0.3
Private/Camp Roads	10	0	3.1
Sub-Totals	**230**	**5%**	**16%**
Non-Shoreline Development			
Low Density Residential	182	3	3.6
Medium Density Residential	402	6	14.3
State/Town Roads	92	1	10.5
Cemeteries	1	0	0.0
Industrial	3	0	0.3
Utilities	51	1	0.7
Paved Parking Areas	6	0	0.7
Commercial	5	0	0.5
Institutional (Public)	5	0	0.7
Gravel Pits	3	0	0.0
Golf Course	4	0	0.5
Sub-Totals	**754**	**12%**	**32%**
Total: DEVELOPED Land	**1,732**	**28%**	**75%**
Non-Developed Land			
Inactive/Passively Managed Forest	3,241	50	9.9
Wetlands	109	2	0.0
Scrub Shrub	71	1	0.5
Islands	11	0	0.0
Other open water	14	0	0.2
Total: NON-DEVELOPED Land	**3,446**	**53%**	**11%**
Total: Surface Water (Atmospheric)	**1,334**	**20%**	**15%**
TOTAL: DIRECT WATERSHED	**6,512**	**100%**	**100%**

The total acreage for all harvested land within the Highland Lake watershed accounts for 9% of the drainage area and 18% of the external phosphorus load.

Shoreline Residential (House and Camp Lots):

In general, Highland Lake is surrounded by medium to low-density residential development with the exception of the several "historic cottage communities" which are composed of multiple small camps or rental cottages in compact areas in close proximity to the lake. There are still large tracts of natural undeveloped shorefront, particularly towards the northern end of the lake. There is one public boat launching facility near the outlet of the lake and approximately six private launching facilities around the shore. Three commercial motels and several residential lots along the western and south-eastern shore of the lake have significant lawns.

A shoreline survey was completed in April of 2002 by Maine DEP-MACD-LEA project staff. The survey was conducted from a boat, approximately 50 feet from the shoreline. The survey results provide a shoreline structure tally as well as evaluate the nonpoint source pollution impact of each lot in regard to phosphorus loading. There are 270 homes and cottages on Highland Lake, which are comprised of approximately 85% seasonal and 15% year-round dwellings (Peter Lowell, LEA).

To help characterize shoreline development, each lot was assigned an NPS pollution impact rating using best professional judgment. The ratings range from 1 to 5, with 1 being very low impact (natural - best case scenario) and 5 being high impact (unnatural – worst case scenario). Table 2 outlines the impact ratings assigned to each shoreline lot during the survey. Lots receiving a rating of 1 have a full naturally vegetated buffer. Conversely, a lot given a score of 5 would have little or no vegetative buffer and support bare (eroding) soil – a visible source of phosphorus input to the lake. A grass covered mowed lawn leading down to a rip-rapped shoreline or beach would receive a rating of 4 – but, only if there was no evidence of bare soil, in which case a rating of 5 would be assigned.

Table 2. Highland Lake Shoreline Survey Results (2002)			
NPS Pollution Potential Severity Score	**Impact rating characterized by one or more of the following:**	**Number of shoreline sites identified within each category**	**% of sites within each category**
1 = very low impact	All natural vegetation—great buffer; good setback from lake	77	22%
2 = low impact	Good natural vegetation; good setback from lake	48	14%
3 = moderate impact	Lack of adequate buffer; close to lake	163	47%
4 = moderately high impact	Lack of buffer; steep slopes; close to lake	56	16%
5 = high impact	Lack of buffer; steep slopes; close to lake; bare soils	4	1%

- *To convert kg of total phosphorus to pounds—multiply by 2.2046*
- *To convert kg/hectare to lbs/acre—multiply by .892*

Overall, 64% of all shoreline lots that were surveyed (including undeveloped lots) on Highland Lake have a moderate to high impact due to inadequate or nonexistent vegetative buffers and/or close proximity to the lake. Many of the shoreline areas have been adequately rip-rapped at the toe of the slopes, but lack vegetative plantings (other than mowed lawns) above the rip-rapped areas. Vegetative buffers help to decrease the amount and flow of run-off from the site. Many of the homes and cottages have mowed grass lawns that stretch down to the lake and do not serve as adequate vegetated buffers.

To estimate phosphorus loading from residential shoreline use, the shoreline area was classified as low and medium density development. Phosphorus loading coefficients were developed using information on residential lot stormwater export of algal available phosphorus (Dennis et al. 1992). Seasonal and year-round camp and home lots on Highland Lake comprise 5% of the land area and an average of 43 kg of total phosphorus annually, which approximates 7% of the estimated total phosphorus load.

Shoreline Septic Systems: Currently, there are no public sewer services for the land areas within the Highland Lake watershed. Bridgton's Shoreland Zoning Ordinance has a provision to increase the minimum setback distance beyond 100 feet from great ponds, rivers and wetlands to the most suitable location within the Shoreland Zone as determined by the Code Enforcement Officer. The CEO shall consider soil suitability, runoff conditions and existing land uses in making the determination.

In order to estimate total phosphorus loading from shoreline septic systems, a simple model was used based on the following attributes: seasonal or year-round occupancy; estimated age of the system; estimated distance of the system to the lake; and an estimated 1.5 people per bedroom per dwelling. The attribute values were determined by shoreline survey, town records, personal interviews with Town of Bridgton officials and LEA's working knowledge of the lake shoreline.

Estimates of the loading from residential septic systems and the three commercial motel septic systems ranged from a low of 19 kg to a high of 59 kg total phosphorus per year. Combined residential and commercial shoreline septic system loading approximates an average total watershed phosphorus export of 33 kg TP annually, or approximately 6% of the total phosphorus export.

Private/Camp Roadways: There are 10 acres of camp roadway area within the immediate shoreland zone (250' from shore) of Highland Lake. These roadways adjacent to the lake account for 3% of the total phosphorus load.

Other shoreline land uses include three commercial motels encompassing three acres and adding less than 1% of the total phosphorus load, as well as the public boat launch, park and swim area located near the outlet (1 acre) which adds a negligible amount of phosphorus to Highland Lake.

Other Development and Land Uses

Non-Shoreline Development consists of all lands outside the immediate shoreline area of Highland Lake, including state and town roadways, residential areas and other land uses such as commercial, institutional (public) areas and gravel pits.

Residential Homes: Town tax records, property tax maps, high resolution aerial photos and GIS maps were used to determine the number of low and medium density residential dwellings outside of the shoreland zone but within the Highland Lake watershed. Low-density residential areas, characterized by dispersed, low-density single-family homes, account for 3.6% of the total phosphorus load to Highland Lake and 3% of the total watershed land area. Medium-density residential area is characterized by one or more single family residence per acre, accounting for 6% of the total watershed and 14.3% of the total phosphorus load.

State/Town Roadways: There are 92 acres of public roadways within the Highland Lake watershed. This land use category accounts for a much greater percentage of the phosphorus load (10.5%) versus its land area (1.4%) in the Highland Lake watershed.

Other Non-Shoreline Land Uses

Cemetery: Included in this category is a small (half-acre) cemetery on Route 93. The total phosphorus export of from this area is negligible.

Industrial: The only industrial land use within the Highland Lake watershed is a portion of a lot used for storage and access for a sheet-metal factory. This land use contributes a negligible amount to the total phosphorus load.

Utilities refer to two separate utility transmission lines used by Central Maine Power (51 acres). The lines are kept vegetated with grasses or low growing shrubs and parts are periodically sprayed with defoliant to suppress tree and sapling growth. Utility transmission lines account for 1% of the watershed and less than 1% of the total phosphorus export.

Paved Parking Areas refer to paved parking areas not directly associated with a commercial, industrial or residential use within the watershed, totaling 6 acres and accounting for 0.7% of the total phosphorus export.

Commercial development within the watershed consists of three motels, a restaurant and a trading post. This land use accounts for 1% of the total phosphorus load to Highland Lake.

Institutional land areas include a small portion of the Bridgton Hospital, a dental office and a piece of the old Town Hall lot (5 acres). Institutional land areas account for less than 1% of the total phosphorus load to Highland Lake.

Gravel Pits: There are two small gravel pits located north of the lake accounting for less than 1% of the total watershed. Prior to the 1999-2000 Highland Lake 319 project, one of the pits partially drained to the road and into a nearby tributary. To correct this problem, the pit was re-graded to drain internally and a detention pond was installed to control road run-off. Because both pits are presently internally draining, there is no phosphorus export associated with this land use category.

Golf Course: A small portion of land owned by a popular golf course is located in the upper Highland Lake watershed. The land within the watershed consists of one fairway, one green and a sliver of "rough". The total golf course land area within the watershed is less than 4 acres and accounts for 0.5% of the phosphorus load.

Phosphorus Loading from Non-Developed Lands and Water

Inactive/Passively Managed Forests: Of the total land area within the Highland Lake watershed, 50% (3,241 acres) is forested, characterized by privately-owned non-managed deciduous and mixed forest plots (LEA GIS 2004). About 10% of the phosphorus load is estimated to be derived from non-commercial forested areas within Highland Lake's direct drainage area.

Other Non-Developed Land Areas: Combined wetlands, scrub and shrub fields and islands account for the remaining 3% of the land area and 0.6% of the non-cultural total phosphorus export load.

Atmospheric Deposition (Open Water): Highland Lake surface waters (1,334 acres) and other open waters within the watershed (15 acres) comprise 20% of the total watershed area, representing 15% of the total phosphorus load entering Highland Lake.

Figure 2. Highland Lake Direct Watershed Total Land Area

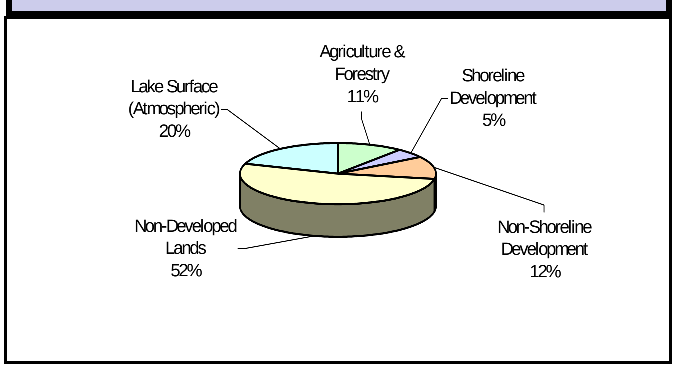
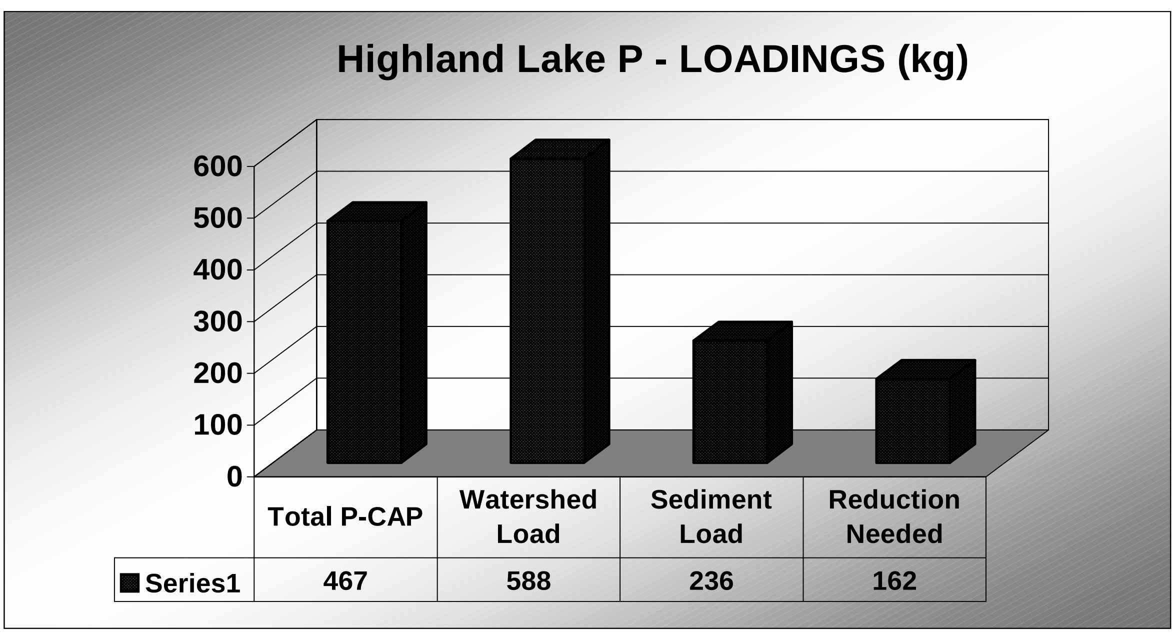


Figure 2 depicts the percentage of total land area covered by each land use.

PHOSPHORUS LOADS – Watershed, Sediment and In-Lake Capacity

Supporting documentation for the phosphorus loading analysis includes the following: water quality monitoring data from Maine DEP, LEA and the Volunteer Lake Monitoring Program, and the development of a phosphorus retention model (see Appendices for detailed information).

- Total phosphorus loadings to **Highland Lake** originate from a combination of watershed and lake sediment sources. Watershed total phosphorus sources, totalling 588 kg annually have been identified and accounted for by land use (See Table 3 - page 27).
- Total phosphorus loading from associated upstream **Stearns Pond** accounts for an indirect watershed average load of 110 kg TP annually, determined on the basis of *flushing rate x volume x TP concentration,* representing typical area gauged streamflow calculations.
- The contribution of annually accumulated internal sources of total phosphorus recycled within Highland Lake sediments range from 211 to 296 kg with an average annual value approximating 236 kg (see page 30 for more information).
- The annual total phosphorus contribution to account for future development for Highland Lake is 44 kg.
- The lake's assimilative capacity for all existing and future non-point pollution sources for Highland Lake is 467 kg of total phosphorus per year, based on a target goal of 8 ppb.
- A change in 1 ppb in phosphorus concentration in Highland Lake is equivalent to 59 kg. The difference between the target goal of 8 ppb and the measured average summertime total phosphorus concentration (10 ppb) is 2 ppb (2 x 59) or 118 kg.
- Given a 44 kg allocation for future development (0.75 x 59), the total amount of phosphorus needed to be reduced, on an annual basis, to maintain water quality standards in Highland Lake is estimated to be 162 kg (118 + 44).



HIGHLAND LAKE

PHOSPHORUS CONTROL ACTION PLAN

Recent and Current NPS/BMP Efforts

In May of 2000, LEA completed the Highland Lake Watershed Project. This study documented significant water quality impairments to Highland Lake, recommended steps for restoration and implemented BMPs on some of the most problematic sites in the watershed. The project was primarily funded by the US EPA, under section 319 of the Clean Water Act.

The project began by identifying erosion sites within the watershed by a variety of methods. The first method used was an automated GIS watershed survey called the "Phosphorus Hotspots Model". The basic building block of this model was a land use coverage for which each land use was assigned a phosphorus export coefficient. Additional coverage's were then developed which showed soil type, slope class, and proximity to the lakeshore or tributaries. "Influence factors" were developed for soil type, slope class and proximity range. The GIS system then used a progressive formula to adjust the original land use export coefficient to account for the variable influences of soil, slope and proximity. The final product was a map that color codes the watershed regions according to their potential for phosphorus export. In conjunction with a property parcel overlay coverage, the "Hotspots" model was used to inventory possible demonstration sites that were subsequently field checked.

The second method used to identify erosion sites within the watershed was called a "Deluge Study". To do this survey, LEA waited for a significant rainstorm to conduct a rapid survey and assessment of the secondary road system of the entire watershed. The deluge tour was completed in one day. Field notes, photos, sketches and site maps were used to document the worst sites in the watershed. This approach allowed for better identification of sites, the ability to prioritize sites by covering the whole watershed in a narrow time frame and a look at some worst-case scenarios to help give an accurate sense of which solutions might be the most cost effective.

The final method was LEA's "Clean Lake Check-Up Program" which offered property owners free site visits and consultations throughout the project. This service encouraged individuals and road associations to review their own property and ask for assistance. This method helped raise awareness and identify and fix smaller problem areas.

As a result of the project, six high priority lake sites were reconstructed using various BMPs, including cross culverts, sumps, level lip spreaders, open-top culverts, broad based drainage dips, revegetation and ditching. Forty-two Clean Lake Check-Ups were conducted during the project period, of which nine were acted upon. Several demonstration sites were implemented and two non-functioning septic tanks on an island were connected to a waste disposal system because the old tanks were leaching into the lake.

Recommendations for Future Work

Highland Lake is a waterbody that has impaired water quality due to the historical accumulation of phosphorus in its bottom sediments - originating from nonpoint source (NPS) pollution. Specific recommendations regarding recent and current efforts in the watershed, best management practices (BMPs), and actions to reduce external watershed total phosphorus loadings in order to improve water quality conditions in Highland Lake are as follows:

Existing erosion sites: Obtain funding to repair existing erosion sites within the watershed.

Shoreline Residential: Enhance local shoreland zoning standards to limit non-conforming expansions to the rear of the building only, improve vegetative clearing standards to regulate the cutting of brush and vegetation taller than three feet in height and maintain strong enforcement of existing shoreland zoning standards. Mandate detailed site plans for earthmoving, soil disturbance or new construction activities that affect more than 200 square feet of area within the shoreland zone. Expand number of tributaries under shoreland zoning act.

Action Item # 1: Fix Existing Erosion Sites		
Activity	**Participants**	**Schedule & Cost**
Repair or mitigate existing erosion sites within the watershed	Watershed residents, LEA, CC-SWCD, OC-SWCD, Municipalities, local contractors	2004-2006 **$80,000**

Roadways: Institute a series of inspections and technical assistance workshops for camp roads and road associations. Enhance shoreland zoning to require new public and private roads to meet the phosphorus control standards outlined in the DEP's Phosphorus Control in Lake Watersheds: A Technical Guide to Evaluating New Development (1992).

Action Item # 2: Enhance Local Shoreland Zoning Standards		
Activity	**Participants**	**Schedule & Cost**
Enhance building expansion and brush cutting standards in Shoreland Zoning. Require site plans for earth moving.	Watershed municipalities, LEA, local contractors, town citizens, and Maine DEP.	2005 Town Meeting **$2,000/yr**

Agriculture: Identify and monitor cultivated fields, manured or fertilized fields and livestock areas.

Action Item # 3: Camp Road Monitoring, Phosphorus Standards for New Roads		
Activity	**Participants**	**Schedule & Cost**
Institute inspections and offer technical assistance for camp roads. Require new public and private roads to meet phosphorus standards	Watershed municipalities, LEA, CC-SWCD, OC-SWCD, camp road associations, private landowners, developers, Maine DEP	Annually beginning in 2005 **$4,000/yr**

Action Item # 4: Identify and Monitor Agriculture Activities		
Activity	**Participants**	**Schedule & Cost**
Identify and monitor cultivated, manured, or fertilized fields and livestock areas. Increase agricultural BMP awareness.	Watershed municipalities, CC-SWCD, OC-SWCD, USDA NRCS, agricultural landowners	Annually beginning in 2005 **$1,000/yr**

Increase landowner awareness of agricultural and livestock BMPs.

Operated Forest Lands: Investigate financial incentives for sustainable yield forestry including the purchase of development rights by land trusts or the town. Promote the "Certified Logging Professional" program.

Individual Actions: Seek technical assistance through LEA's Clean Lake Check-Up Program and

Action Item # 5: Financial Incentives for Sustainable Forestry		
Activity	**Participants**	**Schedule & Cost**
Investigate financial incentives for sustainable forestry practices, including the purchase of development rights.	Watershed municipalities, local land trust, logging professionals.	Beginning 2005 **Cost dependent on incentives**

SWCD/NRCS programs. Monitor and maintain individual septic systems. Continue to support non-phosphorus fertilizer ordinance in Bridgton. Maintain and enhance downslope buffers of all development within the watershed. Implement more stringent standards than set forth in the State's mandatory shoreland zoning and land use standards.

Municipal Action: Implement town comprehensive plans and phosphorus control ordinances.

Action Item # 6: Technical Assistance and Self Monitoring for Individuals		
Activity	**Participants**	**Schedule & Cost**
Utilize existing LEA and SWCD consultation services. Monitor septics, enhance buffers and restrict fertilizers.	Landowners, LEA, CC-SWCD, OC-SWCD	2004 **No cost**

Improve shoreland zoning standards and implement land use standards for non shoreline development. Maintain strong enforcement of existing standards.

Action Item # 7: Municipal Implementation and Enforcement		
Activity	**Participants**	**Schedule & Cost**
Implement town comprehensive plans and phosphorus control/buffer ordinances. Improve and enhance zoning while maintaining enforcement	Bridgton, Sweden and Waterford Municipalities	2004 **$2,000**

Watershed Management: Adopt and implement a simple phosphorus control/ buffer ordinance in the town of Bridgton similar to the phosphorus control standards found within Sweden's Zoning and Land Use Ordinance. If water quality continues to deteriorate, implement an updated version of the "Highland Lake Ordinance" found in the appendix of the Highland Lake Watershed Project report.

Action Item # 8: Implement Water Quality Ordinances		
Activity	**Participants**	**Schedule & Cost**
Develop and Implement a simple phosphorus and buffer ordinance for the town of Bridgton	Watershed municipalities, LEA, CC-SWDC, OC-SWCD, watershed and town citizens	2005 Town Meeting, updates depend on water quality conditions—**minimal cost**

WATER QUALITY MONITORING PLAN

Historically, the water quality of Highland Lake has been monitored via Secchi disk transparencies, temperature and oxygen profiles, and pH readings during the open water months since 1975 . Chlorophyll-a and alkalinity have been monitored on the lake from 1976 to the present. Color and conductivity have been monitored from 1977 to the present. Total phosphorus has been measured regularly from 1989 to the present (LEA and Maine DEP). Continued long-term water quality monitoring within Highland Lake will be conducted bi-weekly, from May to October, through the continued efforts of the Lakes Environmental Association in cooperation with Maine DEP. Under this planned, post-TMDL water quality-monitoring scenario, sufficient data will be acquired to adequately track seasonal and inter-annual variation and long-term trends in water quality in Highland Lake. A post-TMDL adaptive management status report will be prepared five to ten years following EPA approval.

PCAP CLOSING STATEMENT

The Lakes Environmental Association (LEA), in cooperation with area landowners, has worked since the late 1970's to correct both point and nonpoint source pollution within the Highland Lake watershed. Today, point source pollution to Highland Lake is no longer a problem and efforts have been focused on correcting nonpoint source pollution problems. LEA is continuing to work with landowners, the towns of Bridgton, Sweden, and Waterford and state and federal agencies to help correct this problem. Through LEA's Clean Lake Check-Up program, property owners are able to receive free technical assistance regarding erosion, land use standards and camp road maintenance. LEA also assists the planning boards and comprehensive planning committees in all three towns to help ensure better development standards. In addition, LEA's water testing program, which is partially financed by the towns, continues to increase public awareness and interest in nonpoint source pollution as well as provide valuable water quality data. The Town of Bridgton has also shown a high level of commitment to protecting Highland Lake by maintaining strong enforcement of existing Shoreland Zoning standards and by creating additional levels of protection such as the erosion and sedimentation control district. With continued diligent work in the watershed by residents, the towns and local and regional organizations, Highland Lake's water quality is likely to improve in future years.

APPENDICES

HIGHLAND LAKE

Total Maximum Daily (Annual Phosphorus) Load

Introduction to Maine <u>Lake TMDLs</u> and Phosphorus Control Action Plans (PCAPs)

You may be wondering what the acronym 'TMDL' represents and what it is all about. TMDL is actually short for '<u>T</u>otal <u>M</u>aximum <u>D</u>aily <u>L</u>oad.' This information, no doubt, does little to clarify TMDLs in most people's minds. However, when we think of this as an <u>annual phosphorus</u> load (*Annual Total Phosphorus Load),* it begins to make more sense.

Simply stated, excess nutrients or phosphorus in lakes promote nuisance algae growth/blooms - resulting in the violation of water quality standards as measured by water clarity depths of less than 2 meters. A lake TMDL is prepared to estimate the total amount of total phosphorus that a lake can accept on an annual basis without harming water quality. Historically, development of TMDLs was first mandated by the Clean Water Act in 1972, and was applied primarily to *point sources* of water pollution. As a result of public pressure to further clean up water bodies, lake and stream TMDLs are now being prepared for watershed-generated *Non-Point Sources* (NPS) of pollution.

Nutrient enrichment of lakes through excess total phosphorus originating from watershed soil erosion has been generally recognized as the primary source of NPS pollution. Major land use activities contributing to the external phosphorus load in lakes include residential-commercial developments, roadways, agriculture, and commercial forestry. Statewide, there are 38 lakes in Maine which do not meet water quality standards due to excessive amounts of in-lake total phosphorus.

The first Maine lake TMDL was developed (1995) for Cobbossee Lake by the Cobbossee Watershed District (CWD) - under contract with Maine DEP and US-EPA. TMDLs have been approved by US-EPA for Madawaska Lake (Aroostook County), Sebasticook Lake, East Pond (Belgrade Lakes), China Lake, Webber, Threemile and Threecornered ponds (Kennebec County), and Mousam and Highland (Duck) lakes in Cumberland County and Annabessacook Lake and Pleasant Pond (Cobbossee Watershed District). PCAP-TMDLs are presently being prepared by Maine DEP, with assistance from the Maine Association of Conservation Districts (MACD) and County Soil and Water Conservation Districts (SWCDs) - for Sabattus Pond (final EPA review), Unity Pond (stakeholder review) and Toothaker Pond (in preparation). Ongoing PCAP-TMDL lake studies include: Long Lake (Naples & Harrison), Togus, Duckpuddle and Lovejoy ponds; Little Cobbossee Lake and Upper Narrows Pond - the latter two under separate contract with CWD.

Lake PCAP-TMDL reports are based in part on available water quality data, including seasonal measures of total phosphorus, chlorophyll-a, Secchi disk transparencies, and dissolved oxygen-water temperature profiles. Actual reports include: a lake description; watershed GIS assessment and estimation of NPS pollutant sources; selection of a total phosphorus target goal (acceptable amount); allocation of watershed/land-use phosphorus loadings, and a public participation component to allow for stakeholder review.

PCAP-TMDLs are important tools for maintaining and protecting acceptable lake water quality and are designed to 'get a handle' on the magnitude of the NPS pollution problem and to develop plans for implementing Best Management Practices (BMPs) to effectively address the lake's water pollution problem. Landowners and watershed groups are eligible to receive technical and financial assistance from state and federal natural resource agencies to reduce watershed total phosphorus loadings to the lake. **Note:** for <u>non-stormwater regulated lake watersheds</u>, the *development of phosphorus-based <u>lake</u> PCAP-TMDLs are <u>not</u> intended by Maine DEP to be used for regulatory purposes*.

For further information, you may contact Dave Halliwell, Maine Department of Environmental Protection, Lakes PCAP-TMDL Program Manager, SHS #17, Augusta, ME 04333 (287-7649).

Water Quality Monitoring: (Source: Maine DEP and VLMP 2002) Water quality monitoring data for Highland Lake has been collected annually since 1976. This water quality assessment is based on 28 years of Secchi disk transparency (SDT) measures, combined with 16 years of epilimnion core total phosphorus (TP) data, 18 years of total phosphorus (TP) grab data and 17 years of water chemistry and chlorophyll-a monitoring data.

Water Quality Measures: (Source: Maine DEP 2000 and LEA 2002) Highland Lake is a non-colored lake (average color 14 SPU) with an average Secchi Disk Transparency (SDT) of 6.6 m (21.6 ft). The range of epilimnetic water column Total Phosphorus (TP) (from core samples only) for Highland Lake is 4-16 parts per billion (ppb) with an average of 8 ppb, while Chl-a ranges from 1.2 - 10.3 ppb with an average of 2.9 ppb. Dissolved oxygen (DO) profiles show moderate to severe DO depletion in deep areas of the lake. The potential for TP to enter the water column from the bottom sediments and become available to algae (internal loading) is moderate. Oxygen levels below 5 parts per million (ppm) stress certain cold-water fish and a persistent loss of oxygen may eliminate habitat for sensitive cold-water species. Together, these data indicate a historical cyclic trend of increasing trophic state and hence a violation of the Class GPA water quality criteria requiring a stable or decreasing trophic state.

Priority Ranking, Pollutant of Concern and Algal Bloom History: Highland Lake is listed on the State's 2002 303(d) list of waters in non-attainment of Maine state water quality standards and was moved up in the priority development order due to stakeholder interest and need to complete an accelerated approach to lakes TMDL development. The Highland Lake TMDL has been developed for total phosphorus, the major limiting nutrient to algae growth in freshwater lakes in Maine.

The water quality of Highland Lake during the summers of 2001-02 appeared to be unimproved in contrast to 2000 and the preceding 25 years of record. During July of 2002, Highland Lake experienced a brown algal bloom of the species *Chrysophaerella longispina* — this brown algal bloom reduced Secchi disk transparencies to under two meters in the northeastern bay of the lake for approximately two days (source: Lakes Environmental Association). Also, during the summer of 1982, a golden-brown algal bloom of the species *Uroglena americana* impacted the southern quarter of the lake for approximately two days (source: Lakes Environmental Association).

Natural Environmental Background Levels for Highland Lake were not separated from the total nonpoint source load because of the limited and general nature of available information. Without more and detailed site-specific information on nonpoint source loading, it is very difficult to separate natural background from the total nonpoint source load (US-EPA 1999). There are no known point sources of pollutants to Highland Lake.

WATER QUALITY STANDARDS & TARGET GOALS

Maine State Water Quality Standard for nutrients which are narrative, are as follows *(July 1994 Maine Revised Statutes Title 38, Article 4-A*): "Great Ponds Class A (GPA) waters shall have a stable or decreasing trophic state (based on appropriate measures, e.g., total phosphorus, chlorophyll a, Secchi disk transparency) subject only to natural fluctuations, and be free of culturally induced algae blooms which impair their potential use and enjoyment."

Maine DEP's functional definition of nuisance algae blooms include episodic occurrence of Secchi disk transparencies (SDTs) < 2 meters for lakes with low levels of apparent color (<26 SPU) and for higher color lakes where low SDT readings are accompanied by elevated chlorophyll a levels. Highland Lake is a non-colored lake (average color 14 SPUs), with an average Secchi disk transparency (SDT) of 6.6 m (21.6 ft). The range of epilimnetic water column total phosphorus (TP) (from core samples only) for Highland Lake is 4 -16 parts per billion (ppb) with an average of 8 ppb, while Chl-a ranges from 1.2 -10.3 ppb with an average of 2.9 ppb. Currently, Highland Lake does not meet water quality standards due to a significant decline in water transparency trends over time and hence a trend of increasing trophic state. This water quality assessment uses historic documented conditions as the primary basis for comparison. Given the context of "impaired use and enjoyment," along with a realistic interpretation of Maine's goal-oriented Water Quality Standards (WQS), Maine DEP has determined that episodic, non-cyanobacteria based algae blooms (e.g. diatoms), limited to the fall or spring periods only, are in WQS attainment for GPA waters.

Designated Uses and Antidegradation Policy: Highland Lake is designated as a GPA (Great Pond Class A) water in the Maine DEP state water quality regulations. Designated uses for GPA waters in general include: water supply; primary/secondary contact recreation (swimming and fishing); hydro-electric power generation; navigation; and fish and wildlife habitat. No change of land use in the watershed of a Class GPA water body may, by itself or in combination with other activities, cause water quality degradation that would impair designated uses of downstream GPA waters or cause an increase in their trophic state. Maine's anti-degradation policy requires that "existing in-stream water uses, and the level of water quality necessary to sustain those uses, must be maintained and protected."

Numeric Water Quality Target: The water quality goal for Highland Lake is to halt its trend of increasing trophic state so that it can attain Maine DEP standards of stable or decreasing trophic state. The numeric (in-lake) water quality target for Highland Lake, to meet this goal, is conservatively set at 8 ppb total phosphorus (467 kg TP/yr). Since numeric criteria for phosphorus do not exist in Maine's water quality regulations - and would be less accurate targets than those derived from this study - we employed best professional judgment to select a target in-lake phosphorus concentration that would attain the narrative water quality standard. Spring-time (late April – late May) total phosphorus levels in Highland Lake approximated 7-8 ppb during the time period 1976-2003. In direct contrast, in-lake (epilimnion core) total phosphorus summer-time (July through August) measures averaged 9-10 ppb. In summary, the numeric water quality target goal of 8 ppb for total phosphorus in Highland Lake was based on observed late spring – early summer mixed water column data, corresponding to continued maintenance of non-bloom conditions, as reflected in suitable (water quality attainment) measures of both Secchi disk transparency (> 2.0 meters) and chlorophyll-a (< 8.0 ppb).

ESTIMATED PHOSPHORUS EXPORT BY LAND USE CLASS

Table 3 details the numerical data used to determine external phosphorus loading for the Highland Lake watershed. The key below explains the columns and the narrative that follows the table (pages 28-29) relative to each of the representative land use classes.

Key for Columns in Table 3

Land Use Class: The land use category that was analyzed for this report

Land Area in Acres: The area of each land use as determined by GIS mapping, aerial photography, Delorme Topo USA software, and field reconnaissance.

Land Area %: The percentage of the watershed covered by the land use.

TP Coeff. Range kg TP/ha: The range of the total phosphorus coefficient values listed in the literature associated with the corresponding land use.

TP Coeff. Value kg TP/ha: The selected coefficient for each land use category. The total phosphorus coefficient is determined from previous research – usually the median value, if listed by the author. The coefficient is often adjusted using best professional judgment based on conditions including soil type, slope, and best management practices (BMPs) installed.

Land Area in Hectares: Conversion, 1.0 acre = 0.404 hectares

TP Export Load kg P: Total hectares x applicable total phosphorus coefficient

TP Export Total %: The percentage of estimated phosphorus exported by the land use.

Table 3. Highland Lake Direct Watershed - Phosphorus Export by Land Use Class

LAND USE CLASS	Land Area Acres	Land Area %	TP Coeff. Range kg TP/ha	TP Coeff. Value kg TP/ha	Land Area Hectares	TP Export Load kg TP	GIS Adjusted* kg TP	TP Export Total %
Agricultural and Forested Land								
Low Intensity Hayland	171	2.6%	0.35 - 1.35	0.64	69	44	52	8.8%
Orchard	3	0.0%	0.06 - 0.75	0.40	1	0	0	0.0%
Operated Forest Land	574	8.8%	0.20 - 0.60	0.40	232	93	105	17.9%
Sub-Totals	**748**	**11%**	**Highland**	**Lake**	**302**	**137**	**157**	**27%**
Shoreline Development								
Low Density Residential	67	2.6%	0.25 - 1.75	0.25	27	7	8	1.4%
Medium Density Residential	149	2.3%	0.40 - 2.20	1.25	60	75	35	6.0%
Parks (Public Boat Launch Area)	1	0.0%	0.25 - 1.75	0.50	0	0	0	0.0%
Commercial	3	0.0%	0.77 - 4.18	1.50	1	2	2	0.3%
Private/Camp Roads	10	0.2%	0.60 - 10.0	4.00	4	16	18	3.1%
Septic Systems		Highland	Lake	Septic	Model	33	33	5.6%
Sub-Totals	**230**	**5%**	**Highland**	**Lake**	**92**	**132**	**96**	**16%**
Non-Shoreline Development								
Low Density Residential	182	2.8%	0.25 -1.75	0.25	74	19	21	3.6%
Medium Density Residential	402	6.2%	0.40 - 2.20	0.50	163	82	84	14.3%
State/Town Roads	92	1.4%	0.60 - 10.0	1.50	37	56	62	10.5%
Cemetery	1	0.0%	0.14 - 4.90	0.80	0	0	0	0.0%
Industrial	3	0.0%	0.77-4.18	1.92	1	2	2	0.3%
Utilities	51	0.8%	0.10- 0.20	0.20	21	4	4	0.7%
Paved Parking Areas	6	0.1%	0.77- 4.18	1.50	2	3	4	0.7%
Commercial	5	0.1%	0.77 - 4.18	1.50	2	3	3	0.5%
Institutional (Public)	5	0.1%	0.77- 4.18	1.50	2	3	4	0.7%
Gravel Pits	3	0.0%	0.00-0.00	0.00	1	0	0	0.0%
Golf Course	4	0.1%	0.70 - 4.50	1.50	2	3	3	0.5%
Sub-Totals	**754**	**12%**	**Highland**	**Lake**	**305**	**175**	**187**	**32%**
Total: DEVELOPED LAND	**1,732**	**28%**	**Highland**	**Lake**	**699**	**445**	**440**	**75%**
Non-Developed Land								
Inactive/Passively Managed Forest	3,241	49.8%	0.01 - 0.04	0.04	1,312	52	58	9.9%
Wetlands	109	1.7%	0.00 - 0.05	0	44	0	0	0.0%
Scrub Shrub	71	1.1%	0.10 - 0.20	0.1	29	3	3	0.5%
Islands	11	0.2%	0.01 - 0.04	0.04	4	0	0	0.0%
Other Open Water	14	0.2%	0.11 - 0.21	0.16	6	1	1	0.2%
Total: NON-DEVELOPED Land	**3,446**	**53%**	**Highland**	**Lake**	**1,395**	**56**	**62**	**11%**
Total: Surface Water (Atmospheric)	**1,334**	**20%**	0.11 - 0.21	0.16	**540**	**86**	**86**	**15%**
TOTAL: DIRECT WATERSHED	**6,512**	**100%**	**Highland**	**Lake**	**2,634**	**579**	**588**	**100%**

**See Appendix A, page 33*

Total Phosphorus Land Use Loads

Estimates of total phosphorus export from different land uses found in the Highland Lake are presented in Table 3, representing the extent of the current direct watershed phosphorus loading to the lake (588 kg TP/yr). Total phosphorus loading from the associated upstream Stearns Pond (110 kg TP/yr) accounts for loading from the indirect watershed, determined on the basis of *flushing rate (1.6) x volume (8,128,679) x TP concentration (8.5 ppb),* representing typical area gauged streamflow calculations (Jeff Dennis, Maine DEP).

Total phosphorus loading measures are provided as a range of values to reflect the degree of uncertainty generally associated with such relative estimates (Walker 2000). The watershed total phosphorus loadings were primarily determined using literature and locally-derived export coefficients as found in Schroeder (1979), Reckhow et al. (1980), Dennis (1986), Dennis et al. (1992), and Bouchard et al. (1995) for residential properties, roadways, agriculture and other types of land uses (e.g., recreational, commercial).

In some cases (primarily roads and shoreline residential) selected phosphorus loading coefficients were reduced to account for the estimated bioavailability of the soil runoff sources according to available literature (Lee et al. 1980 and Sonzogni et al. 1982) and to better account for algal available-P export values as reflected in Dennis et al. (1992). These adjustments accounted not only for the readily available SRP (soluble-reactive-phosphorus) in the runoff, but also a substantial portion of the particulate inorganic component, particularly the P which is weakly adsorbed on the surface of soil particles (relative to discussion in Chapra 1997, pg. 524). **Note:** *These adjustments in P-load coefficients did not effectively alter the overall conclusions and final recommendations of the Highland PCAP-TMDL report regarding identified needs and NPS/BMP implementation plans for the Highland Lake watershed.*

Agricultural and Forest Operational Lands: Phosphorus loading coefficients as applied to agricultural land uses were adopted, in part, from Reckhow et. al. 1980: (orchard—0.40) Dennis and Sage 1981: low-intensity hayland 0.64 kg TP/ha; and from past Maine DEP 1982 studies. The phosphorus loading coefficient applied to operated forestlands (0.40 kg TP/ha) was derived (best estimate) from the original Cobbossee Lake TMDL report (Monagle 1995).

Shoreline Residential Lots (House and Camp): The range of phosphorus loading coefficients used (0.25 – 2.20 kg ha/yr) were developed using information on residential lot stormwater export of algal available phosphorus as derived from Dennis et al (1992).

Private Camp Roads: The total phosphorus loading coefficient for private camp roads (4.00 kg/ha) was chosen, in part, from previous studies of rural Maine highways (Dudley et al. 1997), as well as proximity to the waterbody - this category includes only those portions of camp roads that are within the 250' shoreland zone.

Shoreline Erosion: Undeveloped areas of the lake shoreline that may be eroding due to natural causes (i.e., wind, wave and ice action) are not included as a source of phosphorus due to the difficulty in quantifying impact area and assigning suitable coefficients.

Non-Shoreline Development

Residential: Non-shoreline residential areas in the watershed are best characterized as low and medium density residential - reflected in the 0.25 and 0.50 TP loading coefficients.

Golf Courses: The total phosphorus loading coefficient (1.50 kg TP/ha) applied to the golf course area takes into account the varying amounts of fertilizer used on greens, fairways and rough areas.

Public Roadways: Town and state roadways (37 ha) were assigned a total phosphorus loading rate of 1.50 kg per hectare per year. This coefficient was chosen, in part, from previous studies of rural Maine highways (Dudley et al. 1997).

Total Developed Lands Phosphorus Loading: A total of 74% (426 kg) of the total phosphorus loading to Highland Lake is estimated to have been derived from the cumulative effect of the preceding cultural land use classes: agriculture and forestry (27% - 157 kg); non-shoreline development (32% - 187 kg) and shoreline development (16% - 96 kg), including septic systems (5.6% - 33 kg) and camp/private roads (3.1% - 18 kg) – as depicted in Table 3.

Non-Developed Lands Phosphorus Loading: The phosphorus export coefficient for forested land (0.04) is based on a New England regional study (Likens et al 1977). The lower total phosphorus loading coefficient chosen for atmospheric deposition (0.16 kg TP/ha) is similar to that used for the China Lake TMDL (Kennebec County), while the upper range (0.21 kg TP/ha) generally reflects a watershed that is 50 percent forested, combined with agricultural areas interspersed with urban/suburban land uses (Reckhow et al. 1980). Non-Developed Land Uses: Forested land, wetlands, old field scrub shrub and islands account for 11% (62 kg) of the total non-cultural or non-developed land total phosphorus export load as depicted in Table 3.

Atmospheric Deposition (Open Water): Highland Lake surface waters (540 ha) comprise 20% of the total watershed area (2,634 ha) and account for an estimated 86 kg of total phosphorus, representing 15% of the total phosphorus load entering Highland Lake.

Phosphorus Load Summary

It is our professional opinion that the selected export coefficients are appropriate for the Highland Lake watershed. Results of the land use analysis indicate that a best estimate of the present total phosphorus loading from external (both direct and indirect watershed generated) nonpoint source nutrient pollution approximates 698 kg TP/yr. This annual external watershed generated loading to Highland Lake equates to a total phosphorus loading modeled at 12 ppb (703 kg TP/year) - 236 kg above the total phosphorus based TMDL target goal of 8 ppb (467 kg TP/year).

LINKING WATER QUALITY and POLLUTANT SOURCES

Assimilative Loading Capacity: The Highland Lake TMDL is expressed as an annual load as opposed to a daily load. As specified in 40 C.F.R. 130.2(i), TMDLs may be expressed in terms of either mass per unit time, toxicity, or other appropriate measures. It is thought appropriate and justifiable to express the Highland Lake TMDL as an annual load because the lake basin has a annual flushing rate of 0.91 flushes/year, somewhat less than the average flushing rate for Maine lakes of 1.50.

The Highland Lake basin lake assimilative capacity is capped at 467 kg TP/yr, as derived from the empirical phosphorus retention model based on a target goal of 8 ppb. This value reflects the modeled annual phosphorus loading responsible for current trophic state conditions, based on a long term goal of maintaining average phosphorus concentrations at or below 8 ppb.

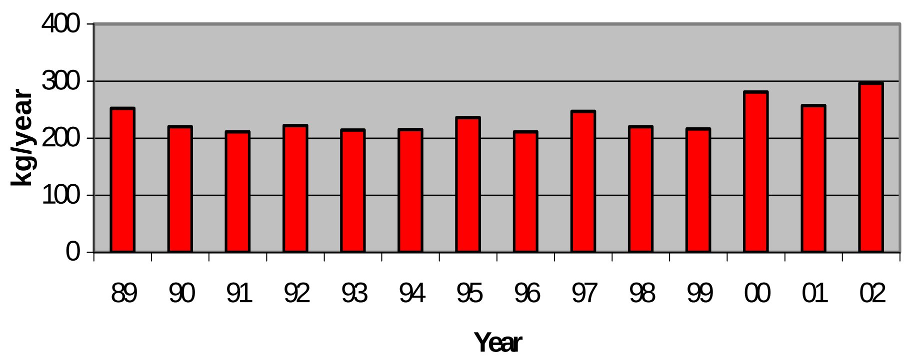
Future Development: In order to effectively meet the stated goal of maintaining current trophic state conditions, further reductions in existing watershed phosphorus loading is necessary for two important reasons. First, Highland Lake has a flushing rate of only 0.91 times per year and is a well-mixed waterbody. Hence, much of the phosphorus laden water in the lake entered from 2 to 5 years ago. Some development has occurred in the watershed over the past 5 years, no doubt resulting in an increase in annual phosphorus loading from the watershed. Given the lag time in lake response to this additional P-load, existing annual watershed phosphorus loads should be reduced by at least the amount of increase in P-load over the past 5 years. The unmitigated rate of increase in Highland's lake annual phosphorus load due to new development approximates 2.5 kg TP/yr, or 12.5 kg TP over a 5-year period (Dennis et al., 1992 application).

The Maine DEP water quality goal of maintaining a stable trophic state includes a reduction of current P-loading which accounts for both recent P-loading as well as potential future development in the watershed. The methods used by Maine DEP to estimate future growth (Dennis et al. 1992) are inherently conservative, as they provide for relatively high-end regional growth estimates and largely non-mitigated P-export from new development. This provides an additional non-quantified margin of safety to ensure the attainment of state water quality goals.

This projected amount is a conservative estimate, since most of the development during this period (1999-2003) did in fact incorporate measures to mitigate phosphorus export from the Highland Lake watershed. The second reason for the need to further reduce existing watershed P-loads is that growth will, no doubt, continue to occur in the Highland Lake watershed, contributing new sources of phosphorus to the lake. Previously unaccounted P-loading from anticipated future development on the Highland Lake watershed is 44 kg (1 ppb change in trophic state = 59 kg x 0.75). Hence, existing phosphorus source loads must be reduced by at least 44+ kg/yr to allow for anticipated new sources of phosphorus to Highland Lake. Reductions already underway in non-point source total phosphorus loadings are expected from the continued implementation of best management practices - primarily from improvements to roadways and residential shoreline vegetative buffer plantings (see NPS/BMP Implementation Plan and PCAP Summary, pp. 19-22).

Internal Lake Sediment Phosphorus Mass: The relative contribution of internal sources of total phosphorus within Highland Lake - in terms of sediment TP recycling - were analyzed (using lake volume-weighted mass differences between early and late summer) and estimated on the basis of water column TP data from 1989 to 2002 (Figure 3). Estimated internal sediment TP loads for this 14-year period ranged from 211 to 296 kg with an average annual value of 236 kg. The amount of phosphorus being released from the sediments of Highland Lake, during the summer period, has been fairly regular, approximating one-half of Highland Lake's capacity for in-lake phosphorus assimilation (467 kg TP/year).

Figure 3. Highland Lake Average Internal Sediment Load (236 kg P)



Linking Pollutant Loading to a Numeric Target: The basin loading assimilative capacity for Highland Lake was set at 467 kg/yr of total phosphorus to meet the numeric water quality target of 8 ppb of total phosphorus. A phosphorus retention model, calibrated to in-lake phosphorus data (20-year springtime average, 1976-2003), was used to link phosphorus loading to a numeric target.

Supporting Documentation for the Highland Lake TMDL Analysis includes the following: Maine DEP and VLMP water quality monitoring data, and specification of a phosphorus retention model – including both empirical models and retention coefficients.

Total Phosphorus Retention Model (after Dillon and Rigler 1974 and others)

L = P (A z p) / (1-R) where: (1 ppb change = 59 kg)

467 = **L** = external total phosphorus load capacity (kg TP/year)
8.0 = **P** = spring overturn total phosphorus concentration (ppb)
5.24 = **A** = lake basin surface area (km^2)
6.00 = **z** = mean depth of lake basin (m) **A z p = 28.61**
0.91 = **p** = annual flushing rate (flushes/year)
0.49 = **1- R** = phosphorus retention coefficient, where:
0.51 = **R = 1 / (1+ sq.rt. p)** (Larsen and Mercier 1976)

Previous use of the Vollenwieder (Dillon and Rigler 1974) type empirical model for Maine lakes, e.g., Cobbossee, Madawaska, Sebasticook, East, and China Lake TMDLs (2000-2001), and Highland, Webber-Threemile-Threecornered pond complex, Mousam, Annabessacook, and Pleasant Pond PCAP-TMDLs (Maine DEP 2003-2004) have shown this approach to be effective in linking watershed total phosphorus (external) loadings to existing in-lake total P-concentrations.

Strengths and Weaknesses in the Overall TMDL Analytical Process: The Highland Lake TMDL was developed using existing lake water quality monitoring data, derived watershed export coefficients (Reckhow et al. 1980, Maine DEP 1981 and 1989, Dennis 1986, Dennis et al. 1992, Bouchard et al. 1995, Soranno et al. 1996, and Mattson and Isaac 1999) and a phosphorus retention model which incorporates both empirically derived and observed retention coefficients (Vollenwieder 1969, Dillon 1974, Dillon and Rigler 1974 a and b, and 1975, Kirchner and Dillon 1975). Use of the Larsen and Mercier (1976) total phosphorus retention term, based on localized data (northeast and north-central U.S.) from 20 lakes in the US-EPA National Eutrophication Survey (US-EPA-New England) provides a more accurate model for northeastern regional lakes.

Strengths:

❖ Approach is commonly accepted practice in lake management

❖ Makes best use of available water quality monitoring data

❖ Based upon experience with other lakes in the northeastern U.S. region, the empirical phosphorus retention model was determined to be appropriate for the application lake.

Weaknesses:

❖ Inherent uncertainty of TP load estimates (Reckhow 1979, Walker 2000) and associated variability and generality of TP loading coefficients.

Critical Conditions - Occur in Highland Lake during the summertime, when the potential (both occurrence and frequency) of nuisance algae blooms are greatest. The loading capacity of 8 ppb total phosphorus was set to achieve desired water quality standards during this critical time period, and will also provide adequate protection throughout the year (see Seasonal Variation).

LOAD ALLOCATIONS (LA's) The load allocation for Highland Lake equals 467 kg TP on an annual basis and represents, in part, that portion of the lake's assimilative capacity allocated to non-point (overland) sources of phosphorus (from Table 3). Direct external TP sources (totaling 588 kg - GIS adjusted) have been identified and accounted for in the land-use breakdown portrayed in Table 3. Further reductions in non-point source phosphorus loadings are expected from the continued implementation of NPS best management practices (see PCAP pages 19 –22). As previously mentioned, it was not possible to separate natural background from non-point pollution sources in this watershed because of the limited and general nature of the available information. As in other Maine TMDL lakes (see Sebasticook Lake, East Pond, China Lake and

Webber-Threemile-Threecorner Pond TMDLs), in-lake nutrient (phosphorus) loadings in Highland Lake originate from a combination of direct and indirect external (watershed + Stearns Pond) and internal (lake sediment) sources of total phosphorus.

WASTE LOAD ALLOCATIONS (WLA's): There are no known existing point sources of pollution (including regulated storm-water sources) in the Highland Lake watershed, hence, the waste load allocation for all existing and future point sources is set at 0 (zero) kg/year of total phosphorus.

MARGIN OF SAFETY (MOS): An implicit margin of safety was incorporated into the Highland Lake TMDL through the conservative selection of the numeric water quality target, as well as the selection of relatively conservative phosphorus export loading coefficients for cultural pollution sources (Table 3). Based on both the Highland Lake historical records and a summary of statewide Maine lakes water quality data for non-colored (< 26 SPU lakes) - the target of 8 ppb (467 kg TP/yr in Highland Lake) represents a highly conservative goal to assure attainment of Maine DEP water quality goals of non-sustained and non-repeated blue-green summer-time algae blooms due to NPS pollution or cultural eutrophication and stable or decreasing trophic state. The statewide data base for non-colored Maine lakes indicate that summer nuisance algae blooms (growth of algae which causes Secchi disk transparency to be less than 2 meters) are more likely to occur at 18 ppb or above. The 531 kg difference between the in-lake target of 8 ppb and 17 ppb (998 kg) represents a 53% implicit margin of safety for Highland Lake.

SEASONAL VARIATION: This Highland Lake TMDL is protective of all seasons, as the allowable annual load was developed to be protective of the most sensitive time of year – during the summer, when conditions most favor the growth of algae and aquatic macrophytes. With an average flushing rate of 0.91 flushes/year, the average annual phosphorus loading is most critical to the water quality in Highland Lake. Maine DEP lake biologists, as a general rule, use more than six flushes annually (bi-monthly) as the cutoff for considering seasonal variation as a major factor (to distinguish lakes vs. rivers) in the evaluation of total phosphorus loadings in aquatic environments in Maine. Nonpoint source best management practices (BMPs) proposed for the Highland Lake watershed have been designed to address total phosphorus loading during all seasons.

PUBLIC PARTICIPATION: Adequate ('full and meaningful') public participation in the Highland Lake TMDL development process was ensured - during which land use and phosphorus load reductions were discussed - through the following avenues from summer, 2002—spring, 2004:

1. Town of Bridgton Comprehensive Plan Committee meetings
2. Consultation with Bridgton CEO and Public Works Director on information issues
3. Extensive water quality monitoring with shorefront volunteers
4. Clean Lake Checkup Program Property Consultations with shorefront owners
5. Paul Lukowski photo survey of shoreline
6. LEA Highland "Hotspots" public presentations
7. LEA spring road survey consultation with CCSWCD
8. Arial photo interpretation with watershed residents
9. Town of Waterford Comprehensive Plan Implementation Committee meetings
10. Town of Sweden Selectmen's meeting

STAKEHOLDER REVIEW COMMENTS

A Stakeholder Review Document was distributed electronically and by mail on June 5-7, 2004 to the following organizations or individuals that participated in the field work or development of the document: Cumberland County and Oxford County SWCD's, Roy Bouchard and Jeff Dennis (Maine DEP), Tamara Pinard (Southern Maine Lakes Coordinator), Colin Holme and Peter Lowell (LEA), Morten Moesswilde (Maine Forest Service), David Rocque (Maine Department of Agriculture), Bridgton Planning Board (Fred Packard, Peter Dorey, Steve Collins, John Rogers, Chris McDaniel, Gordon Davis, Richard Sens), Bridgton Selectmen (Arthur Triglione, Woody Woodward, Bob McHatton, Ed Hatch, Earl Cash), Bridgton CEO (Bill Foye), Sweden Conservation Commission, Sweden Planning Board, Carroll Murphy (Sweden Selectmen, Chairman), and Eric Gulbrandsen (Sweden Code Enforcement Officer).

Only two individuals responded by the June 21st deadline: Peter Lowell and Colin Holmes of LEA who contributed several minor editorial comments that were fully incorporated into this public review document.

PUBLIC REVIEW PROCESS

The public review process began on Friday, July 2, 2004 and ran for 1-month (4-weeks) through Friday, July 30, 2004. The following 'legal' advertisement was placed in the Bridgton News, Advertiser Democrat (Norway), the Portland Press Herald and Kennebec Journal during the weekends of July 10-11 and 17-18.

HIGHLAND LAKE (Cumberland-Oxford Counties)

Watershed/Lake Nutrient Control/Management Report (PCAP-TMDL)

In accordance with Section 303(d) of the Clean Water Act, and implementation regulations in 40 CFR Part 130 - the Maine Department of Environmental Protection has prepared a combined **Phosphorus Control Action Plan (PCAP)** and **Total Maximum Daily Load (TMDL)** nutrient report for the **Highland Lake** (DEPLW 2004-0658) watershed, located within the towns of Bridgton, Sweden, and Waterford. This **PCAP-TMDL** report identifies and provides best estimates of non-point source phosphorus loads for all representative land use classes in the **Highland Lake** watershed and the total phosphorus reductions required to restore and maintain acceptable water quality conditions. A Public Review draft of this report may be viewed at Maine DEP Central Offices in Augusta (Ray Building, Hospital Street - Route 9, Land & Water Bureau) or on-line: http://www.state.me.us/dep/blwq/comment.htm. Please send all comments, in writing - by July 30, 2004, to Dave Halliwell, Lakes TMDL Program Manager, Maine DEP, State House Station #17, Augusta, ME 04333. e-mail: david.halliwell@maine.gov.

No additional comments were received during the Public Review period.

APPENDIX A - Steps in Creating the GIS Adjusted Total Phosphorus Export

To better quantify phosphorus export within the Highland Lake Watershed, a GIS model was developed. The base for the model was a land use coverage created in 2004 by Lakes Environmental Association using an earlier land use coverage, high-resolution aerial photographs and field verification. Each individual land use was assigned a phosphorus export coefficient. The land use coverage was then "unioned" with slope, soil type and proximity coverages. The phosphorus export from the initial land use coverage was then modified by these additional coverages. The result of the model was an estimation of the kilograms of phosphorus export for each land use incorporating the effects of slope, soil type and proximity. The steps for creating this model are outlined below.

1. An initial land use coverage was created (the coverage included roads and wetlands) for the watershed.

2. A soils coverage was unioned into the land use coverage.

3. A slope coverage was unioned into the land use and soil coverage. Before unioning the slope coverage, all slope classes were categorized. Slopes less than 8% were a slope class 1, slopes between 8 and 30% were a slope class 2 and slopes greater than 30% were a slope class 3.

4. A proximity coverage was created that extended 250 feet from Highland Lake and 75 feet from a small 12 acre open-water wetland in the northern watershed. This coverage was then unioned into the land use/soils/slope coverage. All land uses that were within close proximity to these waterbodies were reclassified as "shoreline" land uses. For example, "medium density residential" development within 250 feet of Highland Lake was now classified as "shoreline medium density residential". As a result of these unions, each original land use polygon was broken down into smaller polygons that reflected a change in soil type, slope and proximity to the lake.

5. The land use/soil/slope/proximity coverage was then joined with a phosphorus export coefficient table. This table matched each land use with its estimated corresponding phosphorus export coefficient.

6. An additional field was added to the land use/soil/slope/proximity coverage called "Soils Adjust". This field assigned the following modifying coefficients for each soil type:

A = 0.7
B = 0.9
C = 1.1
C/D = 1.2
D = 1.3
Unknown or Blank = 1

7. An additional field was added to the land use/soil/slope/proximity coverage called "Slope Adjusted". This field assigned the following modifying coefficients for each of the 3 slope classes:

Class 1 = 1.0
Class 2 = 1.1
Class 3 = 1.3
Unknown or Blank = 1

8. A field was added called "Phosphorus Export Rate" to the land use/soils/slope/proximity coverage. This field takes the original land use coefficient and multiplies it by the "slope adjust" and "soil adjust" factors. (The proximity coverage is already factored in based on "shoreline" code in the land use classes.)

9. The final step was adding a field called "Phosphorus Export" to the coverage. This field multiplies the hectares of each unique polygon by the corresponding Phosphorus Export Rate. This column displays the kilograms of phosphorus exported from a specific soil type, for a particular slope range on a designated land use.

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