WATER BUDGET

Introduction

A water budget is a series of calculations that account for all the inputs and outputs of water in a lake. The budget generates a flushing rate, which represents the number of times the volume of water in a lake is replaced throughout a year (Chapman 1992). This knowledge can be helpful in determining lake vulnerability to pollution and nutrient loading. Lakes with a low flushing rate tend to retain the same water through the course of the year, allowing pollutants and nutrients to accumulate. Buildup of this material could lead to algal blooms, unswimmable waters, and other problems. On the other hand, the water within a lake with a high flushing rate will have a higher turnover rate, clearing detrimental pollutants, particles and excess nutrients that may build up in a lake with a low flushing rate. This high turnover rate prevents the build up of pollutants and excess nutrients and allows an accelerated recovery from depositional events (George et al. 2007).

Another important insight gained from a lake water budget is the percent input of water that other water bodies contribute to the lake. With this information, the relative impact of major water bodies contributing to the lake can be identified and assessed. For example, Long Pond South receives water directly from Long Pond North, Ingham Pond and two smaller ponds within the Long Pond South watershed (Doloff Pond and Unnamed Pond) meaning any change in water quality of these four water bodies could influence Long Pond South.

Methods

The water budget calculation for Long Pond South includes all inputs of water entering the lake and deducts lake water loss due to evaporation to create a net input (I_{net}) of water into the lake, measured in cubic meters per year and a flushing rate measured in flushes per year. The following formulae were used to calculate I_{net} and flushing rate for Long Pond South (see Appendix C):

I_{net}= (runoff x watershed land area) + (precipitation x lake and ponds area) – (evaporation x lake and ponds area)

Flushing Rate= [(I_{net} Long Pond South) + (I_{net} Long Pond North) + (I_{net} Ingham Pond)]/ (mean depth x Long Pond South surface area)

Although lake water levels constantly change due to droughts and storm events, this study assumed that the amount of water entering the lake was equal to the amount leaving the lake at any given time over the course of the year because lake size was not increasing. I_{net} values of Long Pond North and Ingham Pond were included in the flushing rate calculation because they both flow directly into Long Pond South, making them an indirect part of the Long Pond South watershed. It is important to note that Moose Pond, Doloff Pond, and Unnamed Pond are also located within the Long Pond South but were not directly included in the flushing rate calculation for Long Pond South (see Appendix C). Moose Pond was not directly included because it flows directly into Ingham Pond and not direcly into Long Pond South. Consequently, its contribution to the I_{net} of Long Pond South was included in the I_{net} of Ingham Pond. Because Doloff Pond and Unnamed Pond are part of Long Pond South watershed their areas were added to the precipitation and evaporation portions of the I_{net} equation. By doing this, runoff and storm events adding water and evaporation subtracting water to these ponds were included in the study.

Parameters for the inputs of the Long Pond South water budget were derived from many sources. The runoff coefficient (0.508 m/yr) and mean lake depth (8.4 m) for the I_{net} calculation of Long Pond South were obtained from the Maine DEP vulnerability compilation of Long Pond South (MDEP 2007b). A study of the Lower Kennebec Basin produced an evaporation constant of 0.56 m per yr that was used in this study (Prescott 1969). Mean precipitation was measured over a 10-year period by the National Oceanic and Atmospheric Administration (NOAA 2006) from a recording station located at the Waterville Treatment Plant. Watershed land area was calculated using ArcGIS®9.2 with layers received from Steve Harmon from the Maine DEP (Harmon, pers. comm.). The flushing rates of Ingham Pond and Long Pond North were obtained from the Maine DEP (PEARL 2007b) and CEAT (2007) respectively.

Results and Discussion

Long Pond North contributes the most water to Long Pond South (79%) with land runoff (12%), Ingham Pond (6%), and storm events (3%) also contributing. In contrast, water exits Long Pond South via Belgrade Stream and evaporation. Because most of the water entering

Long Pond South begins in Long Pond North, the quality of water within Long Pond South is heavily influenced by this input. A study of Long Pond North by CEAT (2007) categorized Great Pond as one of the most important inputs to Long Pond North. The position of Long Pond South in the Belgrade Lakes chain suggests that the water quality of Long Pond South is indirectly affected by the water quality of most other Belgrade Lakes.

Although most other Belgrade Lakes have relatively low flushing rates, the flushing rate of Long Pond South was found to be approximately 3.5 flushes per year (Table 8). In an independent study the Maine DEP also found the flushing rate of Long Pond South to be 3.5 confirming the accuracy of the flushing rate (MDEP 2007a). The flushing rate of Long Pond South is much higher than the mean rate of the Belgrade Lakes and of Maine lakes in general (Table 8). Because the water in Long Pond South is replaced at this high rate, high concentrations of nutrient and pollution loading are less likely to occur in the water column and a high cleansing potential is possible. A high flushing rate may be one important reason Long Pond South is generally considered a healthy lake. Despite its recent trend in declining dissolved oxygen, Long Pond South has yet to experience algal blooms.

Table 8. Watershed areas, volumes, and flushing rates for Belgrade Lakes including Long Pond North and South.

Lake	Watershed Area (m^2)	Volume (m^3)	Flushes/year
Great Pond[c]	214,710,014	209,160,000	0.52
Messalonskee Lake[c]	125,084,285	150,249,096	1.59
Long Pond, South Basin	39,190,184	46,191,231	3.61
North Pond[d]	30,920,000	37,148,856	1.36
Long Pond, North Basin[a]	23,161,123	34,922,160	3.79
Salmon Lake[e]	23,126,300	28,410,750	0.58
East Pond[b]	10,598,777	33,848,120	0.29

[a]CEAT 2007, [b]CEAT 2000, [c]PEARL 2007, [d]CEAT 1997, [e]CEAT 1995.

PHOSPHORUS BUDGET

Introduction

This study used a phosphorus loading model to estimate the amount of phosphorus entering the south basin of Long Pond in 2007. The model helped to determine the movement of phosphorus within the Long Pond South watershed and estimate the phosphorus entering from point sources outside the watershed. Categorizing the watershed into different land-use types enabled CEAT to assign export coefficients to each land use type. Export coefficients assess the estimated impact of each land-use type (see Appendix D). Point sources such as Long Pond North and Ingham Pond were also factored into the model as sources of phosphorus. Other sources of phosphorus such as septic systems and sediment release from lake bottom sediments were also taken into account.

The model estimated the phosphorus concentration in Long Pond South and this estimate was compared to test results obtained from water chemistry (see Water Chemistry) to validate the accuracy of the model. Once the model was adjusted by changing coefficients, it was used to project the impact of trends within the watershed on phosphorus levels (see Phosphorus Projections). The phosphorus fluctuation in the lake as development and population size increase is important because anthropogenic activity can lead to cultural eutrophication (see Background: Trophic Status of Lakes).

Methods

The phosphorus model used for Long Pond South was adapted from a study by Reckhow and Chapra (1983), as well as previous studies on regional lakes (CEAT 2005, CEAT 2006, CEAT 2007). The following equation was used to estimate the yearly phosphorus influx into the Long Pond South watershed. W represents the total mass of phosphorus entering Long Pond South in kg per year. To calculate W, export coefficients, soil retention coefficients, septic system abundance and location, sediment release, and point source input were factored into the model.

$W = (Ec_a \times Area_{ls}) + (Ec_{ag} \times Area_{ag}) + (Ec_{mf} \times Area_{mf}) + (Ec_{cf} \times Area_{cf}) + (Ec_{df} \times Area_{df}) + (Ec_w \times Area_w) + (Ec_{cc} \times Area_{cc}) + (Ec_{cm} \times Area_{cm}) + (Ec_{sl} \times Area_{sl}) + (Ec_{cr} \times Area_{cr}) + (Ec_{sr} \times Area_{sr}) + (Ec_s \times Area_s) + (Ec_{ns} \times Area_{ns}) + [(Ec_{ss} \times \text{\# capita years}_{ss} \times (1-SR_1)) + (Ec_{nss} \times \text{\# capita years}_{nss} \times (1-SR_2))] + (Sd_{lb} \times Area_{lb}) + PSI_{lpn} + PSI_{ip}$

Export coefficients, denoted by the Ec term, were derived for various land-use types within the watershed. Each export coefficient corresponds to a different land-use type and its relative phosphorus contribution in kg per hectares per year (see Appendix D Phosphorus Model Equation). The phosphorus input sources included in the model are: atmosphere (a), agricultural land (ag), mixed forest (mf), coniferous forest (cf), deciduous forest (df), wetlands (w), cleared land (cc), commercial land (cm), successional land (sl), camp roads (cr), paved roads including state and municipal roads (sr), shoreline development (s), and non-shoreline development (ns). The export coefficient for each land-use type was multiplied by the area of the corresponding land-use type to obtain the phosphorus contribution (kg per hectare per year) into Long Pond South of each land-use type. The area of the corresponding land-use type for the atmospheric coefficient was denoted by lake surface (ls).

Point sources, soil retention values, and sediment release values were also included in the model. PSI_{lpn} and PSI_{ip} represent the point source inputs from Long Pond North and Ingham Pond, respectively. The soil retention coefficients SR_1 and SR_2 signify the ability of shoreline (SR_1) and non-shoreline (SR_2) soils to sequester phosphorus. Soil retention coefficients are based on a scale from 0 – 1.0 (Reckhow and Chapra 1983). A higher soil retention coefficient indicates that the soil retains more phosphorus and prevents more phosphorus from entering the lake than a lower coefficient, which represents a decreased phosphorus retention capacity. Soil retention coefficients are based on soil phosphorus adsorption capacity, natural drainage, permeability, and slope (Reckhow and Chapra 1983). $Area_{ls}$ represents the surface area of Long Pond South. Sd_{lb} represents the amount of phosphorus released from sediments at the bottom of Long Pond South, and $Area_{lb}$ represents the surface area of the lake bottom. The surface area of Long Pond South, the surface area of the lake bottom, and the areas for the land-use types were obtained using ArcGIS®9.2 (see Land Use Patterns).

To calculate the input of phosphorus from septic systems, the impact from shoreline and non-shoreline septic systems were each calculated separately and the resulting values were added together. The export coefficient for shoreline septic systems was multiplied by the number of capita years for shoreline residences and by one minus the coefficient value for shoreline soil retention. The same equation was used to find the phosphorus contribution value for non-shoreline septic systems.

The term "capita year" defines the number of people inhabiting a house multiplied by the number of days per year that the house is occupied. Based on a 2000 census, the estimated mean ($\pm$ SE) was 2.6 $\pm$ 1.4 people per household (pph) in Mount Vernon, Rome, and Belgrade (Najpauer, pers. comm.). Year-round homes are occupied for more days per year than seasonal homes. This longer occupation period implies that the septic systems of year-round homes generally are used more than seasonal homes. Year-round homes can have a higher per capita year value than seasonal homes. As a result, year-round homes contribute a greater amount of phosphorus to the lake than seasonal homes in general. This greater phosphorus contribution is contingent upon the proximity to the water of a certain residence, the quality of the septic system, and the actual number of residents of a particular residence. Year-round and seasonal residences were estimated to be occupied for 355 and 95 days of the year, respectively. In the Long Pond North watershed, which encompasses the towns of Belgrade and Rome, the mean number of pph was 2.54 in 2007 (Najpauer, pers. comm.). Year-round and seasonal residences were occupied for approximately 355 and 95 days of the year in Long Pond North. The year-round occupation period of Long Pond South is similar to the year-round periods of surrounding watersheds (355 days). The occupation period for seasonal residences in Long Pond South is higher than some ponds in the area (East Pond, 90 days) and similar to others (Great Pond, 95 days) (CEAT 2000, CEAT 2007).

High, low, and best estimates of export coefficients were assigned to each land-use type by assessing the ability of the land to retain phosphorus as water drained into the lake and the relative phosphorus contribution of each land-use type. High and low estimates were used to derive confidence intervals, which help compensate for possible error resulting from natural fluctuations and estimation. The best estimate coefficients were what CEAT believed to be the best representation of phosphorus contribution for each land-use type. The coefficients were based on a phosphorus loading model by Reckhow and Chapra (1983), past studies on local watersheds (CEAT 1995, CEAT 2003, CEAT 2005, CEAT 2006, CEAT 2007), and the Total

Maximum Daily Load Reports for Long Lake (MDEP 2005a), Togus Pond (MDEP 2005b), and Wilson Pond (MDEP 2007a).

The following formulae, from Reckhow and Chapra (1983), facilitated the calculation of atmospheric and land-use phosphorus input into Long Pond South (P):

$$q_s = Q_{total} / A_s$$

$$L = W/A_s$$

$$P = L/(11.6+1.2q_s)$$

Annual atmospheric loading (q_s) in m per yr was calculated by dividing the total volume of inflow (Q_{total}) in m^3 per year by the lake surface area (A_s) in m^2 (see Water Budget; Appendix D). L is the annual areal phosphorus loading in kg per hectare per year and is calculated by dividing the high, low, and best phosphorus loading values (W) by (A_s) lake surface area. Dividing L by the settling velocity of phosphorus ($11.6+1.2q_s$) gives total phosphorus concentration (P) in parts per billion (ppb).

Results and Discussion

The phosphorus loading model predicted a phosphorus range of 1,637 kg per year to 3,222 kg per year entering Long Pond South from external sources and non-point sources within the watershed, with a best estimate of 2,039 kg per year. When sediment release (internal phosphorus loading) was considered, the model predicted a range of 1,691 to 3,762 kg per year of phosphorus entering the lake from internal sources, external sources, and non-point sources within the watershed, with a best estimate of 2,363 kg per year. According to the model, the best estimate for total phosphorus concentration was 8.9 ppb, with a range of 6.4 to 14.1 parts per billion (ppb). The best estimate of the total phosphorus concentration from the model corresponds with the mean phosphorus concentration determined for epicore samples collected by CEAT from 31-May-07 to 13-September-07 at Site 1 (mean $\pm$ SE; 9.1 $\pm$ 3.0 ppb, n= 11).

The phosphorus released into Long Pond South came from runoff, point-source inputs, and sediment release. Runoff from land within the watershed is defined as non-point source loading within the watershed. Point-source inputs are considered external phosphorus loading and sediment release is a form of internal phosphorus loading. External loading contributed 54 percent (1,280 kg), non-point source loading within the watershed contributed 32 percent (759 kg), and internal loading (sediment release) contributed 14 percent (324 kg) of the phosphorus entering Long Pond South.

Two point-source inputs, Long Pond North and Ingham Pond, contribute 54 percent (1,280 kg per year) of the total phosphorus entering Long Pond South. Long Pond North contributes 90 percent (1157 kg) of the phosphorus entering Long Pond South from point sources and 49 percent of the total phosphorus entering Long Pond South from all sources. Ingham Pond, influences Long Pond South in a similar manner to Long Pond North, but to a lesser extent since Ingham Pond is much smaller than Long Pond North. Ingham Pond is located in the south end of Long Pond South near where the water flows into Belgrade Stream. Water coming from Ingham Pond does not remain in Long Pond South for a long period of time before it is flushed out of the lake.

Runoff contributed 32 percent of the total phosphorus entering Long Pond South. Of all of the sources of runoff, agricultural land, atmospheric input, successional land, and mixed forest contributed the greatest amounts of phosphorus (Table 9).

Agricultural land, including cropland, pasture, and tree farms, contributed the largest quantity of phosphorus to Long Pond South via runoff (126 kg). Agricultural land represents 7.6 percent of the total watershed area. Agricultural land contributes phosphorus because crop fertilizers contain phosphorus to foster growth, not all of which can be used by the crops. Agricultural land is traditionally planted in rows with spaces between that lack plants. This lack plants and their root systems in most agricultural lands prevents runoff water from slowing. Since the runoff is not slowed by vegetation and nutrients are not adsorbed by roots, relatively high amounts of phosphorus can flow into the lake from this agricultural land, as the high export coefficient (0.45 kg per hectare per year) indicates (Table 9).

Atmospheric input accounted for 12 percent (88 kg) of phosphorus loading from runoff because although the coefficient value is relatively low (0.17 kg per hectare per year), the water body comprises 9.6 percent of the watershed. The combined area of Dolhov Pond and Unnamed Pond was added to the watershed area. Dolhov and Unnamed Pond are located in the northwest corner of the lake (see Watershed Description). Phosphorus can be deposited into the lake by precipitation once it is released into the atmosphere (Reckhow and Chapra 1983). Woodstoves and industrial production are two of the many processes that release phosphorus into the air

(Reckhow and Chapra 1983). Due to these processes of phosphorus accumulation from the atmosphere, the total amount of phosphorus deposited into Long Pond South is high (Table 9).

Successional land contributes 12 percent (94 kg) of phosphorus entering the lake via runoff. Successional land has a relatively high export coefficient (best 0.3 kg per hectare per year) and it represents 6 percent of the Long Pond South watershed area. Successional land encompasses reverting land and regenerating land. Both of these land-use types do not have much undergrowth to slow runoff and prevent sediment from moving into lake water, so in a similar manner to agricultural land, successional land can contribute phosphorus into the lake (Table 9).

Table 9. Low, best, and high estimates of percent contribution of phosphorus for all land-use types within the Long Pond South watershed based on the Phosphorus Model (see Phosphorus Budget: Results and Discussion). Land-use types are rated from highest to lowest contribution. Calculations omit phosphorus loading from point sources. Values reflect the amount of phosphorus input for each land use type relative to the total phosphorus load.

Land Use Type	Low Estimate (%)	Best Estimate (%)	High Estimate (%)
Agriculture	25.9	21.9	21.9
Atmospheric	17.4	11.6	11.6
Regenerating land	13.2	12.4	14.6
Mixed Forest	12.3	13.0	13.0
Deciduous Forest	5.9	6.9	4.9
Non-shoreline Development	5.4	5.1	8.0
Cleared Land	5.3	5.0	5.2
Shoreline Septic Systems	3.6	5.1	6.9
Shoreline Development	2.9	3.7	3.5
Non-shoreline Septic Systems	2.2	1.9	2.5
Camp roads	2.0	5.9	5.1
Coniferous Forest	1.7	3.1	2.1
Paved Roads	1.5	2.1	3.9
Commercial Land	0.8	0.4	0.4
Wetlands	0.0	1.7	1.6

Mixed forest contribution accounted for 13 percent (99 kg) of the phosphorus contained in runoff. Mixed forest has a low export coefficient (0.045 kg per hectare per year) but represents 40.9 percent (5, 389 acres) of the watershed area (see Watershed Land-Use Patterns). Mixed forest has significant root structures to slow runoff and adsorb nutrients and sediment from the water. Each hectare of mixed forest contributes a small amount of phosphorus relative to other land-use types per hectare contribution. Since mixed forest comprises such a large area of the watershed, its total phosphorus contribution is high because the small amounts of phosphorus per hectare accumulate (Table 9).

Sediment release was calculated using similar export coefficients as used in Long Pond North (CEAT 2007). Since the north and south basins of Long Pond are the same lake, the sediment composition and the sediment release should be similar. The sediment coefficient ranged from 0.1 to 1.0 kg per hectare per year, with a best estimate of 0.6 kg per hectare per year. These values are low relative to previous studies performed on various anoxic lake sediments, but the calculated total phosphorus concentration estimates of Long Pond South are significantly lower than the lakes in previous studies (Nurnberg 1988, Mattson and Isaac 1999).

Depending on the time of year, wetlands can be a "phosphorus sink" and contribute to the maintenance of water quality. Wetland ecosystems have intrinsic abilities to modify or trap a wide spectrum of water-borne substances commonly considered pollutants or contaminants (Hammer 1993). Wetlands comprise much of the land directly adjacent to Long Pond South (11.9 percent of the watershed) and may prevent phosphorus from different land use types from entering the lake. The export coefficient is the lowest of all coefficients assigned to land-use types within the watershed. With a best estimate of zero kg per hectare per year contribution, wetlands retain phosphorus. Wetlands sequester phosphorus in the myriad of root systems provided by dense grass, shrubs, and other vegetation (see Watershed Land-Use Patterns: Wetlands). Long Pond South has more wetlands than Long Pond North (3,867 acres and 251 acres, respectively), which may help prevent lake water quality from declining due to phosphorus increase. These wetlands should be protected and preserved to maintain lake water quality.

Long Pond is the second to last lake in the Belgrade Lakes chain, and previous studies have shown that the phosphorus concentration in Long Pond North is influenced by phosphorus loading from Great Pond because the two lakes are connected (CEAT 2007). Additionally, East Pond, North Pond, and Salmon Pond flow into Great Pond and these are all lakes on the impaired waters list (MDEP 1996). These lakes have experienced algal blooms and have higher phosphorus levels than Long Pond South (9.1 ppb) or Long Pond North (7.8 ppb) (CEAT 2007). As a result of phosphorus loading from point sources, Great Pond has experienced a decline in lake health as characterized by *Gloeotrichia echinulata* blooms and an increased phosphorus concentration (see Long Pond Characteristics: *Gloeotrichia*). Long Pond South may experience a similar increasing trend in phosphorus concentration if the water quality of Long Pond North continues to decline. Monitoring the water quality of Long Pond North, Great Pond, and the other lakes in the Belgrade Chain is critical in maintaining the health of Long Pond South, since the six lakes in the chain are connected.

FUTURE PROJECTIONS

POPULATION TRENDS

Historic Population Trends

Census data from the University of Maine (2001) indicate that the Towns of Belgrade, Mount Vernon, and Rome have all experienced population growth from the beginning of the 20th century to today, particularly since 1930 (Figure 46). The population fluctuated between 1930 and 1970 in both Mount Vernon and Rome. Over this period the population varied between highs of 755 in Mount Vernon and 420 in Rome to lows of 596 and 362 respectively (University of Maine 2001). On the other hand, Belgrade experienced continuous population growth throughout this time, though not at a constant rate. All three towns experienced rapid population growth in the period between 1970 and 1980 (Figure 46). In Belgrade alone, the population of young adults (22 to 34 years old) increased by 141 percent during the 1970s (Town of Belgrade 1998). This surge in population size can be partly explained by a national trend of Americans moving out of cities to live in suburban and rural areas. People moved to Belgrade in particular to enjoy low taxes, beautiful scenery, and abundant land in close proximity to Augusta and Waterville (Town of Belgrade 1998). Currently, a growing number of individuals and couples approaching retirement are converting seasonal homes into year-round homes in Mount Vernon (Marble, pers. comm.). Conversion does not increase the number of houses in the watershed, but it does add to the number of year-round residents. Population growth in turn leads to an increase in activities that are potentially harmful to the lake, such as septic system use, and continued growth will pose threats to Long Pond South in the future.

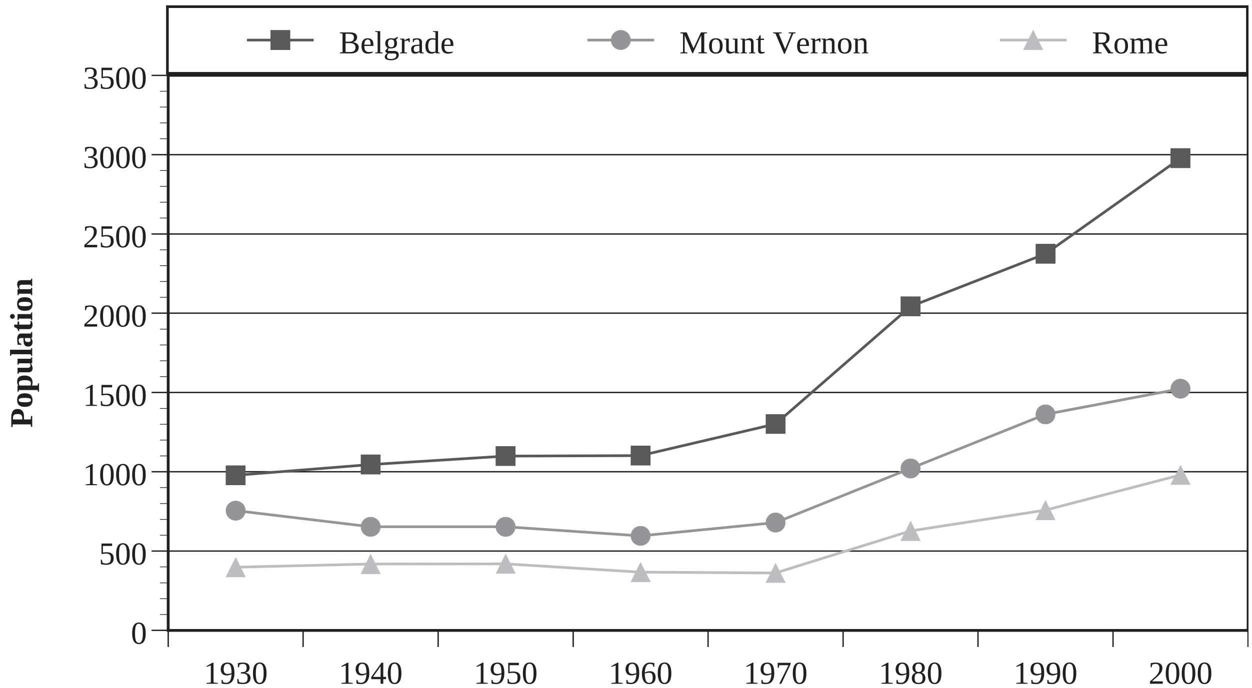

Figure 46. Population counts from the Census Bureau of the United States Department of Commerce for the Towns of Belgrade, Mount Vernon, and Rome, Maine for the years 1930-2000 (University of Maine 2001).

Future Population Projections

The same qualities that attracted residents to the Belgrade Lakes area in the past 40 years continue to draw new people to the area. As people search for shoreline land in Maine for second homes or a place for retirement living, they often begin looking in the Sebago Lakes Region in southern Maine and continue their search moving northward if property is unavailable or too expensive (Najpauer, pers. comm.). The number of available lots in the Long Pond South watershed will almost certainly decrease in the next few decades as more people move to the area. Generally, shoreline lots are the first to be developed, and development then continues away from the lakefront (Cole, pers. comm.). Some residents fear that these quiet lakeside towns will resemble a bustling suburb of Augusta by 2050 (Marble, pers. comm.). Data from the State of Maine Planning Office (Najpauer, pers. comm.) predict a 65 percent increase in the population from 5482 to 8460 for the Towns of Belgrade, Mount Vernon, and Rome between 2000 and 2030 (Figure 47). The three watershed towns will undoubtedly grow in population numbers, necessitating construction of new homes on undeveloped land.

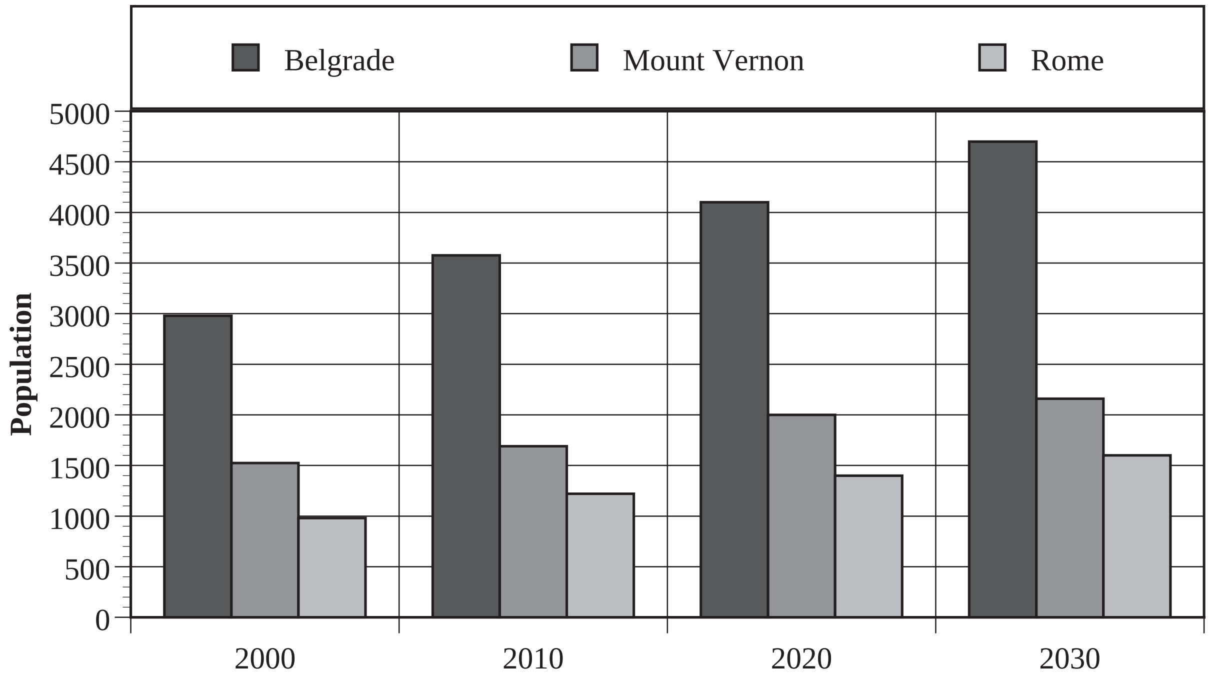

Figure 47. Population predictions for Belgrade, Mount Vernon, and Rome (Najpauer, pers. comm.).

GENERAL DEVELOPMENT TRENDS

New home and road construction will be necessary to facilitate growing populations in Belgrade, Rome, and Mount Vernon. The development that has occurred on Long Pond in the North Basin is likely to be continued in the South Basin. Additionally, the number of camps converted to year-round homes is likely to increase, as more homeowners reach retirement age.

There are roughly 50 shoreline lots available for development in the watershed. An estimate of the number of available shoreline lots was obtained by subtracting the total number of lakefront houses in the watershed from the total number of lakefront lots as indicated by tax maps of Belgrade, Mount Vernon, and Rome. Of the property available for development, there are approximately 16 shoreline lots are available in Belgrade on the eastern shore opposite Site 6 and approximately 31 shoreline lots are available in Mount Vernon on the western shore south of

Site 5 (Figure 30). It is possible that some of the available lots could be subdivided and developed into areas with multiple houses, because several of the shoreline lots are large. In Belgrade, there are at least four lots along the northeast corner of Long Pond South and at least two lots further south along the shore that could potentially be subdivided. There are also larger lots on the non-shoreline side of Timber Point Road with a lakefront common access point in this area. The lots could be subdivided and new residents may be inclined to build in this area because of the proximity to the lakeshore. Development along the lakeshore in Mount Vernon may be more limited because much of this land is wetland as indicated by the current tax maps.

Additional development is also likely within the Belgrade watershed. In the period between 1988 and 1998, the growth rate of Belgrade was twice that of the entire State of Maine (Town of Belgrade 1998). The 1998 Comprehensive Plan explains that development in the town during that time was scattered, and no open space was conserved to compensate for the loss of undeveloped land. The Plan expressed concern that this type of development would eventually change the town from a rural to a suburban community, and that population growth would create environmental problems such as reduced water quality (Town of Belgrade 1998). Ten years later, the town continues to experience population growth and past concerns related to this pattern still apply today. Within Belgrade, there are a number of non-shoreline areas where development is likely or has already begun. CEAT road surveyors found cleared lots and/or construction vehicles along Murdock Place and Rockwood Drive. Holly Hill Drive appears to be an established subdivision on the Belgrade tax maps; however, CEAT surveyors found construction vehicles and cleared land in this area, indicating that this area will soon be developed.

In Mount Vernon, the number of new homes constructed per year has been declining (Marble, pers. comm.), but the value of new homes is increasing (Figure 48). There are a number of large lots throughout Mount Vernon that could potentially be subdivided and further developed. In some areas, development may be limited by steep elevation changes, the presence of wetlands, and the absence of adequate roads. Also, there are no current plans for new subdivisions or road construction, but rising home values have led to an increase in the conversion of seasonal residencies to year-round residences (Marble, pers. comm.).

In Rome, there is an abundance of available, non-shoreline property; however, it is likely that many of these lots cannot be developed without mitigation because they contain wetlands and/or steep slopes, and have drainage issues. Any available lots without these issues will likely be developed over time, including properties in the Wild Flower Estates subdivision, which falls in the Long Pond South watershed (Najpauer, pers. comm.). There are 255 lots in Wild Flower Estates. CEAT counted only 14 homes in this area, suggesting that more construction is possible. However, development in Rome may be limited as a result of public opinion. Many Rome residents have protested new home construction by refusing to sell land for necessary road widening projects (Najpauer, pers. comm.). State legislation and town ordinances may regulate construction and housing conversion, but they will not eliminate environmental degradation caused by these activities altogether. As long as development continues in the watershed, phosphorus loading in Long Pond South will persist as well.

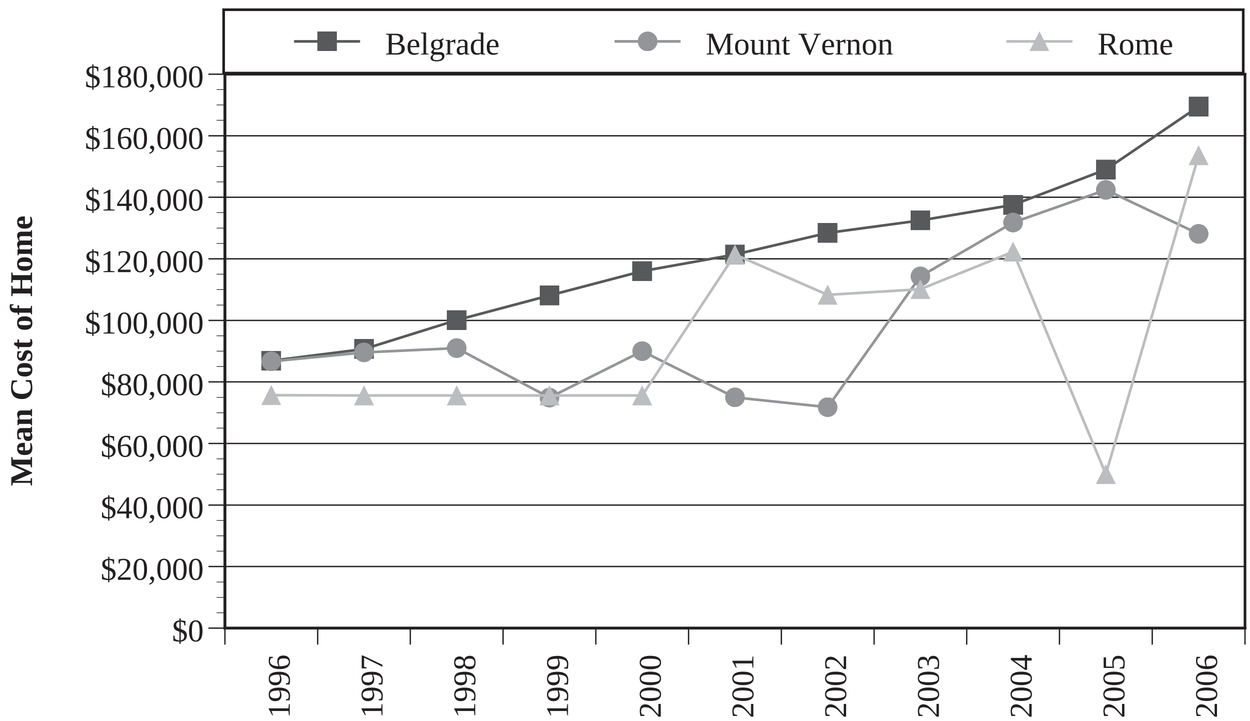

Figure 48. The mean cost of a newly constructed single-family home in the Towns of Belgrade, Mount Vernon, and Rome (City-Data.com 2007).

PHOSPHORUS MODEL PREDICTIONS

Introduction

The CEAT phosphorus model was validated by comparing its total phosphorus concentration value with the actual total phosphorus concentration found through field-testing. With this validation, it is possible to use this model to approximate future phosphorus level through the manipulation of variables within the model.

Methods

Projected land use and population changes based on information gathered by CEAT in Rome, Belgrade, and Mount Vernon were used in conjunction with the 2007 phosphorus model of Long Pond South to forecast future phosphorus levels within the lake. Trends in land development were created first by digitizing 1966 satellite photos of the Long Pond South watershed and then comparing them to a 2003 land use map of the watershed using ArcGIS®9.2. Patterns of development for specific areas and land-use types of the watershed were then extrapolated to create projected land-use changes. Population projections of Rome, Belgrade, and Mount Vernon were obtained from the State Planning Office of Maine (Najpauer, pers. comm.). The population growth model predicted changes in population size after each decade. The change in population from each decade was divided by mean number of people per household (# capita years) to obtain number of houses that would be constructed. A mean (± SE) per capita number of 2.6 ± 1.4 people per household was estimated from 2010 to 2020 and 2020 to 2030, respectively (see Development: Subsurface Disposal Systems). The total number of houses was divided into shoreline and non-shoreline houses based on the current proportion of the watershed. The land area of new lots replaced area that was formerly mixed forest. Land that had been regenerating was labeled as mixed forest due to succession over 10 and 20 years.

Results and Discussion

Land-Use and Development

Using 2010 projections as current population (6,487 people), overall growth between 2010 and 2030 was estimated to be 30 percent (1,973 people) (Maine State Planning Office 2007). Growth from 2010 (6,487 people) to 2020 (7500 people) was 15.6 percent, while growth from 2020 to 2030 showed a 12.8 percent increase (960 people). Based on per capita numbers, this growth will produce 390 new houses by 2020 and 320 additional houses by 2030 for a total of 710 houses. Using the current proportions of 34.5 percent shoreline and 65.5 percent non-shoreline, 135 shoreline units and 255 non-shoreline units would be constructed by 2020. However, 50 shoreline lots are currently available for construction (see Future Predictions: Future Population Trends), limiting the projected 135 shoreline units to 50 units and increasing the 255 non-shoreline units to 340 units. Using these same limitations and proportions for 2030, 320 non-shoreline additional units could be constructed. These numbers may change if lots are subdivided or if lots are bought and designated as conservation sites.

Regardless of the number of subdivisions land would have to be cleared for the construction of new homes. For the purposes of this study it was assumed that the land cleared would be from the dominant land-use type of mixed forest. Based on the number of houses being built and the acreage required to build each house, it was estimated that 132 ha of mixed forest would be converted to residential area by 2020 and an additional 114 ha by 2030. In contrast to mixed forest loss to residential development, some regenerating land will become mixed forest by 2020 and 2030. To account for this the satellite photos of 1966 were compared to the current land-use map of the watershed to determine approximate succession rates (Figure 11). With this comparison it was determined that five percent (16 ha) and ten percent (31 ha) of current regenerating land would become mixed forest by 2020 and 2030, respectively. Shifting land-use trends indicate a net conversion of 116 ha from mixed forest to residential lots by 2020 and an additional 83 ha by 2030.

Phosphorus Budget Projections

The current trend of increasing residential population in the Long Pond South watershed indicates a rise in phosphorus within Long Pond South by both 2020 and 2030. When entered into the Phosphorus Model, the land-use projections produced a low estimate of 6.59 ppb, a high estimate of 15.88 ppb and a best estimate of 9.36 ppb of total phosphorus concentration within Long Pond South by 2020. The model projected a low estimate of 6.79 ppb, a high estimate of 17.34 ppb and a best estimate of 9.74 ppb phosphorus concentration by 2030. These numbers suggest a best estimate increase in phosphorus concentration of five percent by 2020 and ten percent by 2030.

The projected population enlargement implicates increased construction of residential buildings within the watershed, more impervious surfaces, additional septic systems, increasing road area, a net loss of mixed forest, and a constant wetlands area. Each house needs a driveway and access road, which is often gravel, and other impervious surfaces (see Watershed Land-Use Patterns: Residential Areas). Impervious surfaces do not absorb water and increase runoff into the lake that may contribute phosphorus to the lake. Septic systems contribute phosphorus to the lake by leaching of effluent into ground or surface water resources (see Watershed Development Patterns: Subsurface Disposal Systems). Converting mixed forest, which has a low export coefficient (Ec_{mf} = 0.045 kg/ha/yr), to residential lots, which have a higher relative export coefficient (Ec_{sd} = 1.1 kg/ha/yr and Ec_{n} = 0.4 kg/ha/yr), increases overall external land-use phosphorus contribution (see Appendix D). Wetlands are protected by the Wetlands Protection Act (EPA 2007b)**,** which limits development to greater than 250 ft away from wetlands (see Watershed Land-Use Patterns: Wetlands). The export coefficient for wetlands is very low (Ec_{w} = 0 kg/ha/yr) and wetlands retain phosphorus and other nutrients (Hammer 1993). Existing wetlands will continue to trap phosphorus, but will not prevent total phosphorus concentration increase if more land-use types contribute greater amounts of nutrients to the lake.

RECOMMENDATIONS

The water quality of Long Pond South is currently in good condition, but future development within the watershed and especially along the shoreline could result in degradation. Future changes in shoreline development, road construction, recreational activity, and land-use could damage to the water quality of Long Pond South. The Colby Environmental Assessment Team (CEAT) suggests that the following actions be done to help maintain the healthy condition of Long Pond South and prevent future damage to the lake water quality.

WATERSHED MANAGEMENT

Buffer strips/Erosion

The maintenance of buffer strips along the shoreline is crucial to the preservation of water quality in Long Pond South. Approximately 62 percent of shoreline houses have good or acceptable buffers, but additional steps can be taken to improve the remaining buffer strips that are in fair or poor condition. Some of the shoreline houses were built before the Mandatory Shoreland Zoning Act was implemented in 1971, 1974 and as a result, they may not have suitable buffers to protect the lake from nutrient-laden runoff.

- CEAT recommends that homeowners replant native shrubs along the shoreline to restore the natural buffer.
- Homeowners should replant areas of exposed soil and visible erosion.
- Homeowners should be advised to avoid the use of fertilizers especially along the shoreline or use phosphorus-free fertilizer.

Roads

Many camp roads within the watershed have erosion problems that contribute to additional phosphorus entering Long Pond South. These problems should be corrected in a timely matter. To help prevent future erosion and potential phosphorus loading, camp road maintenance is essential.

- Proper maintenance includes periodic re-grading of the road surface, removing berms, filling rutted areas, and clearing debris from ditches and culverts.
- Regular maintenance of camp roads will benefit camp-owners as well as help prevent phosphorus loading due to erosion.
- Development should be planned in ways that minimizes the number of new roads that are required in Belgrade, Mount Vernon, and Rome.
- New roads should be constructed with proper drainage structures to minimize phosphorus inputs from erosion.

Septic Systems

CEAT recommends that current homeowners continue to monitor and maintain their septic systems. Many of the grandfathered septic systems in the watershed have been replaced because of the concern of responsible homeowners, which has reduced the potentially damaging effects of malfunctioning systems.

- Belgrade, Mount Vernon, and Rome should set a goal for upgrading all remaining grandfathered septic systems in the watershed, giving priority to the replacement of those along the shoreline.
- Old septic systems should be phased out as soon as possible before new development increases the potential nutrient loading in the lake.

Land-Use

Increased development in the Long Pond South watershed is highly likely given the historic population trends and future projections for the Belgrade Lakes region. As development in the watershed increases, phosphorus levels within the lake will increase if growth is not properly managed. Mount Vernon, Belgrade, and Rome should consider water quality and phosphorus loading when developing new regulations.

- Builders and planners should continue to consider phosphorus mitigation strategies for new construction.
- Builders should continue to use effective silt barriers during construction to reduce phosphorus inputs due to erosion.
- Builders should be especially prudent near wetlands and close to the shoreline because construction in these areas can increase phosphorus loading.
- The natural beauty and quiet, rural character of the towns are highly valuable. Residents should strive to protect these unique traits from the negative consequences of development.

IN-LAKE MANAGEMENT

Recreation

Recreation is an important factor in the protection of Long Pond South because it draws seasonal visitors to the area and reminds people about the value of good water quality. Fishing is a popular recreational activity, but the local fisheries may be threatened by declining water quality, especially dissolved oxygen levels. The Long Pond public boat ramp near Castle Island is a prime site of accidental introduction of invasive plant species and erosion. The Belgrade Regional Conservation Alliance (BRCA) has been crucial to the invasive species prevention effort in Long Pond South by conducting frequent surveys, lake inspections, and public education.

- The watershed towns should preserve Long Pond South as a recreational resource with managed fish stocking, invasive species control, and habitat preservation.
- The Belgrade Regional Conservation Alliance should continue their good work of educating boaters about invasive species. BRCA should continue to check outboard motors and boats for invasive plant species that can potentially damage the Long Pond South ecosystem.
- Continue to raise public awareness of the issue, both at the boat ramp and in the surrounding communities.

Water Quality

The declining water quality of other lakes in the Belgrade Lakes Region indicates the potential for similar degradation of Long Pond South. As Long Pond South approaches mesotrophic status, there is concern about maintaining the current condition of the lake and preventing additional nutrient influx. Approximately 79% of the water in Long Pond South comes from Long Pond North, which creates a strong link between these two lakes.

- To maintain the water quality of Long Pond South, Long Pond North must continue to be monitored periodically and maintained at the same standards.
- This recommendation also applies to Great Pond and lakes in the upper chain because the low levels of dissolved oxygen and increased presence of *Gloeotrichia echinulata* in recent years may threaten water quality in Long Pond North and South.
- Environmental professionals and volunteer lake monitors should continue to watch the dissolved oxygen levels in the Long Pond South metalimnion to gain an understanding of the cause of this problem.
- Phosphorus loading should continue to be monitored, especially in the hypolimnion, to be sure that changes in the Long Pond South watershed are not negatively impacting the water quality of the lake.

COMMUNITY AWARENESS AND EDUCATION

The Belgrade Lakes Association has already made significant strides in protecting Long Pond South. Because all of the lakes are connected, coordination among lake associations is essential to improve the water quality of every lake in the Belgrade Lakes region. CEAT encourages the Belgrade Lakes Association to continue making strong alliances with the other lake associations to help improve lake water quality.

- The Belgrade Lakes Association should continue to work with the Conservation Corps in hiring high school students and summer employees in their work mitigating phosphorus loading into the lake, as well as continue to hold community awareness demonstrations.

- Watershed community members should be encouraged to join in the Belgrade Lakes Association and expand discussion regarding the prevention of future impairments to the water quality of Long Pond South.
- The Belgrade Regional Conservation Alliance should continue their work to unify efforts by area towns and lake alliances to protect local watersheds.