The Phosphorus Problem in St. Albans Bay

A summary of research findings

July 3, 2003

Prepared for the St. Albans Area Watershed Association

By Eric Smeltzer
Vermont Department of Environmental Conservation
Water Quality Division
103 South Main St.
Waterbury, VT 05671-0408
(802) 241-3792
ericsm@dec.anr.state.vt.us

The Vermont Department of Environmental Conservation is an equal opportunity agency and offers all persons the benefits of participating in each of their programs and competing in all areas of employment regardless of race, color, religion, sex, national origin, age, disability, or other non-merit factors.

This document is available upon request in large print, braille, or audio cassette.

Persons with a TDD may call 1-800-253-0191 (Vermont Relay Information Service) to communicate requests to offices that do not have a TDD.

St. Albans Bay has a long history of water quality problems including excessive algae growth caused by phosphorus enrichment, nuisance aquatic plant infestations, and fecal bacteria contamination. The problem of phosphorus enrichment and summer algae blooms, in particular, has been the subject of a considerable amount of research over that past two decades in order to better understand the causes of the problem and the reasons why it has been so difficult to solve.

This paper was prepared at the request of the St. Albans Area Watershed Association. The purpose of this paper is to provide a concise summary of the major research findings about the phosphorus problem in St. Albans Bay in order to identify what we know, and what we do not know, about the problem. The lake management implications of these research findings will also be discussed in order to suggest where we should go from here. The hope is that this summary will inform renewed efforts by the St. Albans Area Watershed Association and water quality management agencies to find effective solutions to the phosphorus problem in St. Albans Bay.

Summary of Research Findings

1. St. Albans Bay residents and users have suffered from the effects of algae blooms in the bay for decades.

St. Albans Bay has a long history of serious water quality problems related to excessive phosphorus enrichment. Severe summer blooms of predominantly blue-green algae prompted the St. Albans Bay Association to begin an annual program of treatment with the algicide copper sulfate in 1966. The copper sulfate treatments were conducted through the 1970's until they were abandoned for lack of effectiveness, while the nuisance algal conditions continued. Attendance at the St. Albans Bay State Park at the northern end of the bay declined precipitously during the 1970s as a result of algae blooms and severely impaired swimming conditions at the park beach, and the park eventually closed (Figure 1). The Town of St. Albans has since acquired the park and now operates the facility, although the water quality problems persist. A 1984 study[1] found that the value of shoreline properties along St. Albans Bay were depressed by about 20% relative to the value of similar properties located outside of the bay.

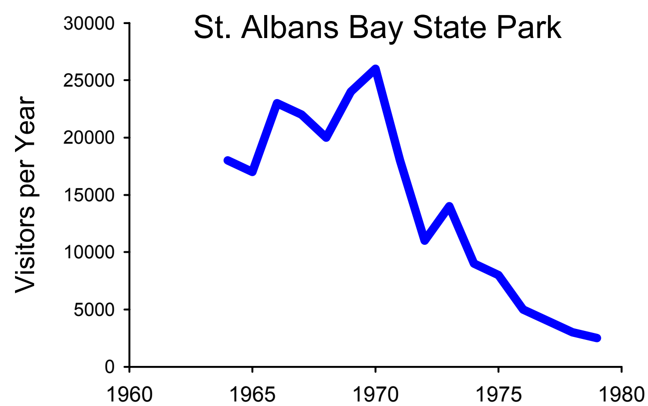

Figure 1. Annual visitor use at St. Albans Bay State Park, 1964-1979. (Source: St. Albans Bay Rural Clean Water Program)

2. Phosphorus inputs to St. Albans Bay climbed to excessive levels over a period of more than a century before significant efforts were made to reduce phosphorus loading.

A 1994 study[2] produced estimates of historical phosphorus loadings based on research into the growth of population, industry, and commerce in the City of St. Albans and its surrounding region since 1850. Point source phosphorus loadings from domestic, creamery, and other industrial wastewater sources were estimated using information on the development of sewers and wastewater treatment facilities in St. Albans, including data on the population and industries served by these sewers. Historical nonpoint source phosphorus loading estimates were inferred from agricultural statistics maintained for Franklin County, Vermont since 1850 and from nonpoint source phosphorus loading measurements obtained during the St. Albans Bay Rural Clean Water Program.

The combined estimates of historical point and nonpoint source phosphorus loading to St. Albans Bay (Figure 2) show that there was a steady increase in loading between 1880 and 1930, followed by sustained loading of about 50 metric tons per year (mt/yr) for the next several decades. The 1987 treatment plant upgrade for phosphorus removal resulted in a 30% drop in total annual loading to the bay.

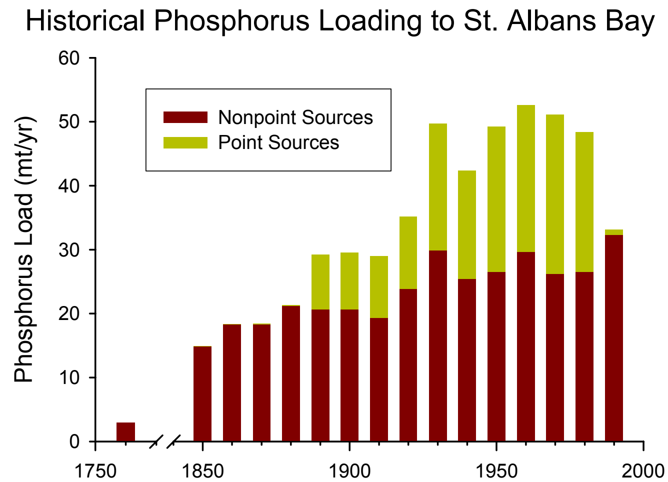

Figure 2. Historical phosphorus loading to St. Albans Bay from point and nonpoint sources, 1760-1990[2].

3. State and federal water quality management agencies supported serious efforts to reduce phosphorus loading to the bay during the 1980s.

A major upgrade of the City of St. Albans Treatment Plant was completed in 1987. The upgrade included the construction of phosphorus removal facilities for advanced wastewater treatment by chemical addition, flocculation, and sand filtration. The total cost of constructing phosphorus removal facilities at the St. Albans Treatment Plant was $2.3 million.

In the nonpoint source area, a U.S. Department of Agriculture Rural Clean Water Program project was initiated for the St. Albans Bay Watershed in 1980[3]. The purpose of the project was to reduce water pollution from agricultural sources in the watershed through the implementation of "best management practices" such as animal waste management, fertilizer management, and erosion control. The program was successful in implementing best management practices for 60% of the farms in the watershed, including 74% of the critical acres and 80% of the total manure loads. The total cost for best management practice implementation in the St. Albans Bay Watershed was $2.2 million, of which 25% was cost-shared by local landowners.

4. The upgrade of the St. Albans City treatment plant in 1987 resulted in dramatic reductions in phosphorus loading from this source.

The 1987 treatment plant upgrade reduced phosphorus loading from this facility by about 90% from previous levels (Figure 3). Since the phosphorus removal facilities became operational in 1987, the plant has consistently met its permitted effluent total phosphorus concentration limit of 0.5 milligrams per liter (mg/l), which is the lowest phosphorus permit limit applied to any municipal wastewater treatment plant discharge in Vermont. The facility is also operating well below its wasteload allocation phosphorus load limit of 2.762 mt/yr established in the Lake Champlain Phosphorus Total Maximum Daily Load (TMDL) document[5].

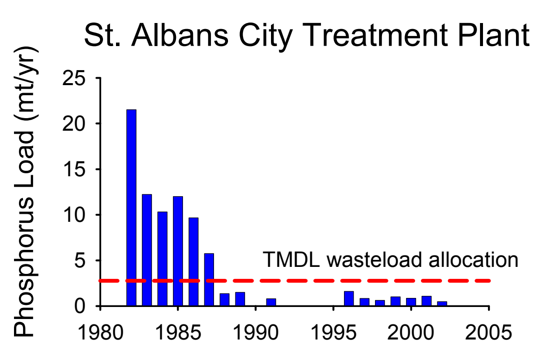

Figure 3. Phosphorus loads from the St. Albans Wastewater Treatment Facility, 1982-2002[3,4]. (No data were compiled from 1992-1995.)

5. Agricultural best management practices implemented in the St. Albans Bay watershed during the 1980s did not produce measurable reductions in phosphorus loading to the bay.

The St. Albans Bay Rural Clean Water Program[3] provided continuous monitoring of the phosphorus loads near the outlets of the Jewett Brook, Stevens Brook, and Mill River watersheds while agricultural best management practices (BMPs) were being implemented during the 1980s. The monitoring results (Figure 4) indicated that there were no statistically significant reductions in annual phosphorus loads from these tributary watersheds during the monitoring period, except for a reduction in Stevens Brook that was related to improvements at the St. Albans Treatment Plant. There was considerable variability in the annual loads resulting from hydrologic differences between years (i.e., wet and dry years) and other factors. Possible reasons for the lack of documented watershed-level phosphorus load reductions in response to agricultural BMP implementation include the following[6]:

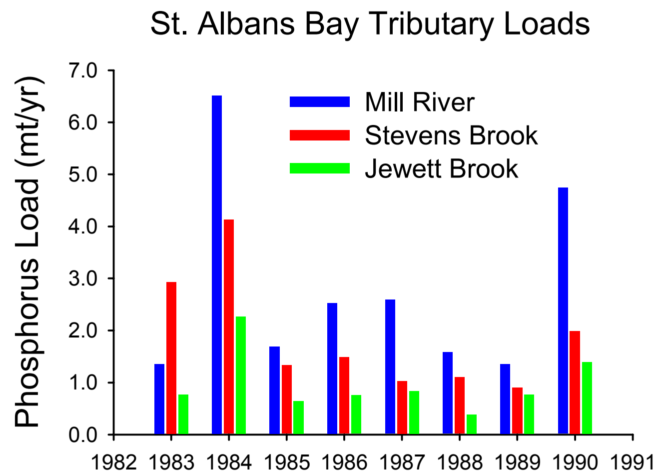

Figure 4. Annual phosphorus loads in St. Albans Bay tributaries during BMP implementation, 1983-1990[3].

- The nature, timing, or level of BMP treatments may have been inadequate to change water quality above background variability.
- Despite the relatively high level of farmer participation, loads from a few non-participants (e.g., from winter manure spreading that continued on some farms) may have overwhelmed BMP treatment effects.
- Additional or different BMPs may be required, such as riparian zone reclamation, field nutrient management, and livestock exclusion from streams.
- Storage of sediment and phosphorus in the streambed may contribute to a lag time between land treatment and water quality response.

There has been no monitoring of phosphorus loads from St. Albans Bay tributaries since 1992. It is therefore not known whether nonpoint source loads to the bay have declined since the completion of the St. Albans Bay Rural Clean Water Program.

6. Nonpoint source phosphorus loading rates from St. Albans Bay tributary streams rank among the highest (per unit of drainage area) of all streams in the Lake Champlain Basin.

Phosphorus loading measurements were made during 1991 on 31 tributary streams throughout the Lake Champlain Basin[7] Figure 5 compares the nonpoint source phosphorus export rates among the tributary rivers on a unit of drainage area basis (e.g., kilograms of phosphorus runoff per hectare of land per year). The two St. Albans Bay tributaries, Mill River and Stevens Brook, yielded some of the highest amounts of phosphorus of all Lake Champlain sub-watersheds. These findings indicate that there is an unusually high intensity of nonpoint source phosphorus problems within the St. Albans Bay watershed.

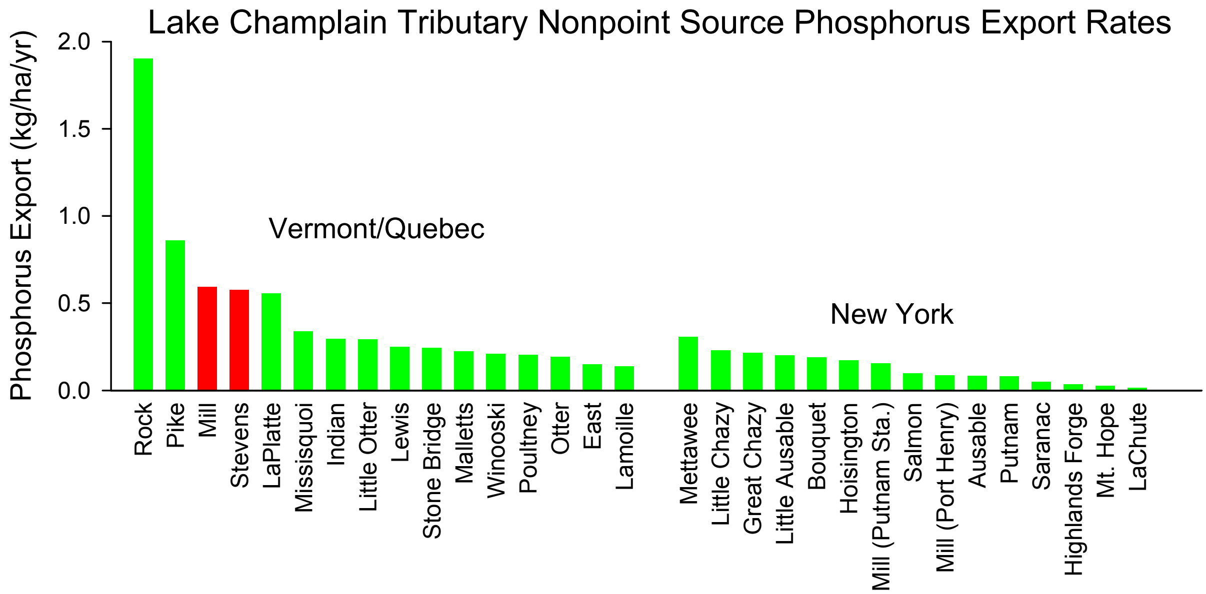

Figure 5. Comparison of Lake Champlain tributary nonpoint source phosphorus export rates (kilograms P per hectare per year) during 1991[7]. St. Albans Bay tributaries are shown in red.

7. Present-day phosphorus loading to St. Albans Bay is dominated by agricultural nonpoint sources, but with a growing contribution from urban runoff.

The amount of nonpoint source phosphorus loading in the Lake Champlain Basin derived from three major land use categories was estimated using land use and land cover data (ca. 1993) with a phosphorus export modeling analysis[8]. The results for the St. Albans Bay watershed (Figure 6) show that agricultural sources contribute 73% of the current phosphorus load to the bay. Wastewater sources (St. Albans City and Northwest Correctional Facility, 1996-2002 average loads) are a relatively small portion (7%) of the total load. Runoff from urban land is a significant (18%) contributor of phosphorus to St. Albans Bay.

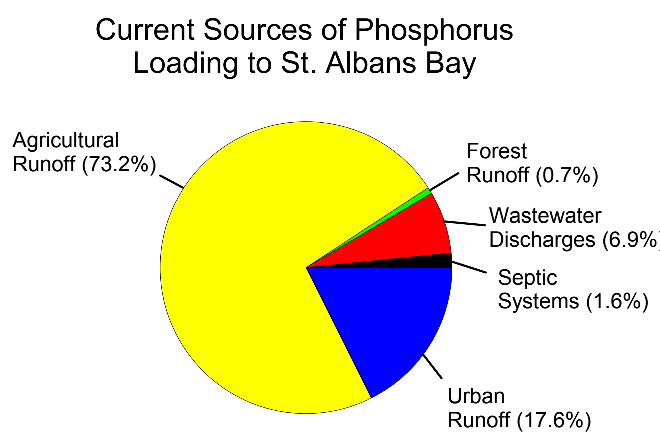

Figure 6. Current sources of phosphorus loading to St. Albans Bay[4,8,10].

Urban nonpoint sources are likely to be a growing source of phosphorus to the bay because as land is converted from forest or agricultural uses to developed uses, the rate of phosphorus export per unit of land area tends to increase. A study by the Lake Champlain Basin Program[9] found that land conversion to urban uses may be offsetting some of the gains made by point source and agricultural nonpoint source phosphorus reduction efforts.

Shoreline septic systems are not likely to be a significant source of phosphorus to St. Albans Bay. A 1991 study done for the Towns of Georgia and St. Albans[10] evaluated the potential for phosphorus loading to the bay from septic systems, based on phosphorus removal rates in soil column tests and on sanitary survey information. Septic systems were estimated to contribute less than 2% of the total phosphorus load to St. Albans Bay. This estimate was based on the assumption (not directly verified) that 20% of the shoreline septic systems provided no phosphorus removal treatment before discharge to the bay. The finding that septic systems are a relatively small phosphorus contributor is consistent with results from studies of other Vermont lakes and with a nonpoint source assessment for the Lake Champlain Basin as a whole[11].

8. Phosphorus concentrations in St. Albans Bay have not declined over the past two decades, and phosphorus levels remain above the criterion for the bay established in the Vermont Water Quality Standards.

Long-term phosphorus monitoring data for St. Albans Bay are available from two programs. The Vermont Lay Monitoring Program[12] has included a sampling station in St. Albans Bay nearly every summer (June-August measurements) since 1979. The Lake Champlain Basin Program has supported monitoring during May-October in St. Albans Bay since 1992[13].

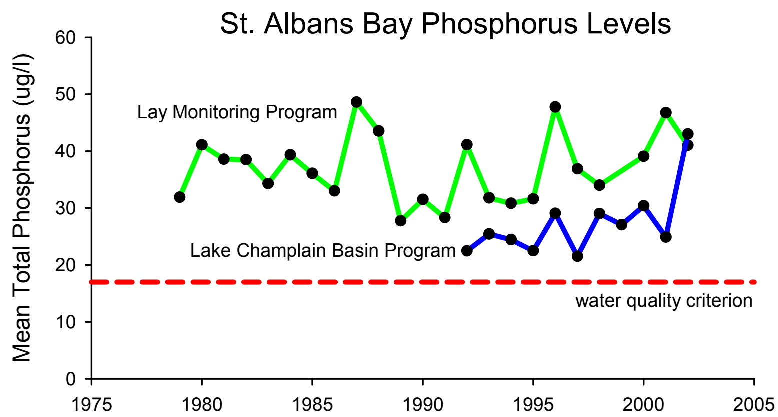

Figure 7. Long-term trends in total phosphorus concentration in St. Albans Bay, based on data from two monitoring programs[12,13].

The monitoring records from the two programs (Figure 7) tell similar stories. There have been no significant reductions in phosphorus concentrations in the bay over the past two decades. In fact, there has been a statistically significant increasing trend in St. Albans Bay during the 1990s[14].

The Vermont Water Quality Standards specify an annual average phosphorus concentration criterion of 17 micrograms per liter (µg/l) for St. Albans Bay. This criterion applies to the central, open water areas of the bay. Although the two monitoring programs use slightly different station locations and sampling methods, both sample the central areas of the bay. The results from both programs clearly indicate that the water quality standard for the bay is not being achieved.

9. Phosphorus concentrations in St. Albans Bay are persisting at high levels years after the treatment plant upgrade because phosphorus stored in the bay's sediments is being released back into the water by the process called "internal loading."

Inputs and outputs of phosphorus in St. Albans Bay have been tracked by measuring the phosphorus "mass balance" for the bay (analogous to tracking income and expenditures in a bank account balance). Figure 8 illustrates the major routes of phosphorus input to, and loss from, the water in St. Albans Bay. Phosphorus enters the bay through external loading from the tributary streams (Stevens Brook, Jewett Brook, Mill River) and the wastewater treatment plant discharges. Phosphorus concentrations are highest in the inner bay and decrease along a gradient outward to the open lake. Mixing of water by wind-driven currents exchanges high-phosphorus water in the inner bay with lower-phosphorus water in the outer lake. Phosphorus is taken up by algae and other planktonic organisms which eventually settle to the lake bottom and accumulate in the sediments. Some of the phosphorus in the sediments can later be recycled back into the overlying water in the process called internal loading.

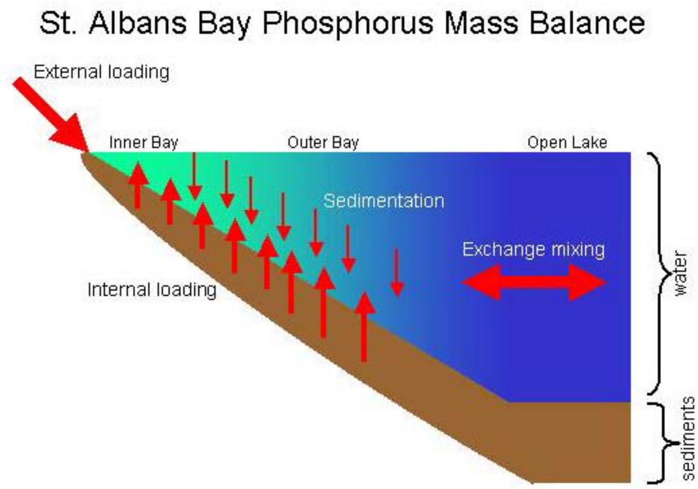

Figure 8. Diagram of phosphorus mass balance processes in St. Albans Bay.

The phosphorus concentrations that exist in the bay water are determined by the balance of all these input and output processes. If sufficient field measurements are made to quantify these processes, the response of phosphorus levels in the bay to changes in loadings can be modeled and predicted.

A phosphorus modeling study completed in 1991 by the Vermont Department of Environmental Conservation (DEC)[15] compared the phosphorus mass balance for St. Albans Bay before and after the 1987 wastewater treatment plant upgrade. The model focused on summer conditions, using data obtained during June-August only. When the model's predictions of pre-upgrade phosphorus concentrations in the bay were compared with the actual measurements made in the bay (Figure 9), it was found that the model did a good job of predicting the actual pre-upgrade phosphorus concentrations in the bay, within the limits of prediction uncertainty shown by the error bar ranges. However, when post-upgrade external phosphorus loading rates were used in the model, the model did a poor job of predicting post-upgrade phosphorus concentrations. The model

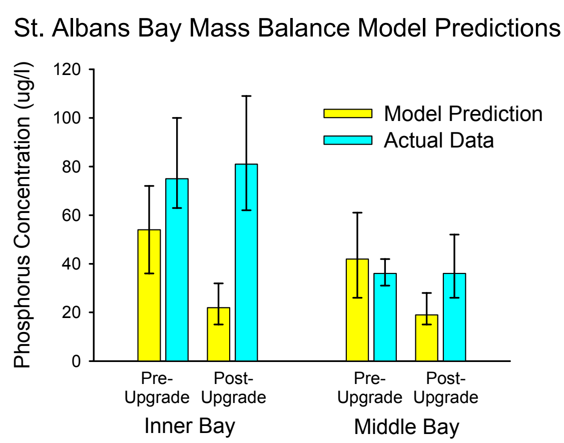

Figure 9. Comparison of the actual data with the model-predicted summer phosphorus concentrations in St. Albans Bay for treatment plant pre-upgrade (1982-1986) and post-upgrade (1987-1990) periods[15]. Error bars are 95% confidence intervals.

predicted substantial reductions in bay phosphorus concentrations that did not occur after the treatment plant was upgraded.

The modeling results shown in Figure 9 indicate that the external phosphorus loads received by St. Albans Bay after the treatment plant upgrade cannot account for the continued high phosphorus concentrations measured in the bay water during the summer. The treatment plant discharge was reduced to a small fraction of its previous levels (Figure 3) and the nonpoint source loads delivered by the streams were minimal during the summer low flow conditions. The discrepancy between the model predictions and the actual phosphorus concentrations measured in the bay during the summer can only be explained by the presence of a major internal source of phosphorus loading to the bay.

It is likely that the many decades of excessive point and nonpoint source phosphorus loading to St. Albans Bay (Figure 2) have resulted in an historical accumulation of phosphorus in the bay's sediments that is now being released back into the bay water. The 1991 Vermont DEC report concluded that the sediments of St. Albans Bay should be in a state of "self-purification[16]" after the point source loading reduction, where a net loss of phosphorus from the sediments is occurring over time. However, the actual magnitude of the internal loading was not directly measured during the 1991 study.

The internal loading situation in St. Albans Bay is not at all unique. Internal phosphorus loading has prevented or delayed the recovery of many other lakes worldwide after significant reductions in external loads were achieved.[17,18,19,20,21] Shallow lakes are especially sensitive to internal loading, and many shallow lakes have experienced long time delays before responding to wastewater treatment plant upgrades and other phosphorus load reduction efforts.

A number of research questions about the internal loading problem in St. Albans Bay remained after the 1991 Vermont DEC modeling study. Additional studies (discussed below) were initiated to answer these questions and to help identify the most appropriate lake management actions that should be taken.

- Is phosphorus stored in the bay's sediments being depleted over time?
- How long will it take for the internal phosphorus loading to subside and for phosphorus concentrations in the water to decline?
- What are the mechanisms and the seasonal timing of the internal loading?
- What areas of bay sediments are contributing to the internal loading?

10. The concentrations of phosphorus and organic matter in the sediments of St. Albans Bay declined between 1982 and 1992.

Levels of phosphorus and organic matter in the sediments throughout St. Albans Bay were measured during 1992 and compared with data from a 1982 study using the same sampling sites and analytical methods[22]. Total phosphorus concentrations in the sediments (averaged across all sites) were found to have declined by 23% between 1982 and 1992 (Figure 10). Significant reductions in the percent organic content of the sediments were also noted. These findings indicate that phosphorus is being released from the sediments at a faster rate than it is being deposited (consistent with the "self-purification" concept[16]). The reduction in sediment organic content suggests that algal productivity has declined in the bay on an average annual basis. These types of sediment phosphorus surveys have not been repeated in St. Albans Bay since 1992, so it is not known whether the gradual purging of phosphorus from the sediments is continuing.

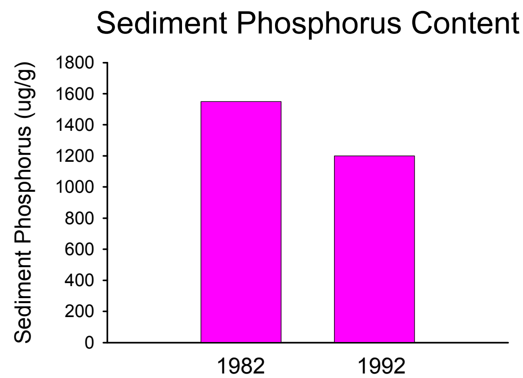

Figure 10. Comparison of the average total phosphorus concentration (micrograms P per gram of sediment) in the top 8 cm of the sediments of St. Albans Bay between 1982 and 1992[22].

11. St. Albans Bay sediments have some of the highest rates of phosphorus release to the water measured among sites throughout Lake Champlain.

A study of sediment phosphorus chemistry in Lake Champlain obtained sediment cores at sites throughout the lake during 1994-1996 and measured the release of phosphorus from these cores to the overlying water in laboratory experiments[23]. The release of soluble reactive phosphorus under summer conditions occurred at the highest rates in St. Albans Bay, Missisquoi Bay, and the South Lake (Figure 11). These areas of the lake are the ones where internal phosphorus loading has the greatest potential to delay water quality recovery after external phosphorus load reductions are achieved.

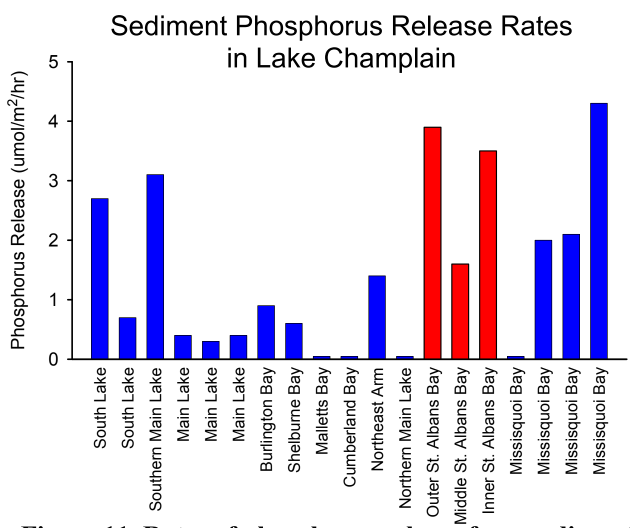

Figure 11. Rates of phosphorus release from sediments to the water (micromoles P per square meter per hour) measured at sites throughout Lake Champlain[23]. St. Albans Bay sites are shown in red.

12. Predictions made by more advanced phosphorus mass balance models of long-term reductions in phosphorus levels in St. Albans Bay have not proven accurate.

More advanced mass balance modeling analyses were completed for St. Albans Bay during the 1990s. Models developed by Youngstown State University[22] and by HydroQual, Inc.[24] included sediment phosphorus concentrations and their influence on internal loading over time. Both models used external (point and nonpoint source) phosphorus loading rates to the bay measured during the 1980s and early 1990s to represent long-term future loading conditions. The models were used to predict how long the excessive internal phosphorus loading might continue to delay the recovery of water quality in the bay after the treatment plant upgrade.

Both models produced similar predictions of a relatively rapid initial decline in internal phosphorus loading from the sediments, followed by a more gradual improvement over a period of several decades. The full response could take up to 50 years.

Long-term changes in the average phosphorus concentrations in St. Albans Bay predicted by the Youngstown State University model[22] are shown in Figure 12. When the model predictions are compared with subsequently obtained phosphorus monitoring data for the bay, it is obvious that the phosphorus declines are not occurring as predicted. The HydroQual, Inc. model[24] also performed poorly in St. Albans Bay, predicting phosphorus concentrations well below the levels actually measured in the bay water. The reasons for the inaccurate model predictions are not clear. Either the internal loading processes in St. Albans Bay are not well enough understood to model adequately, or the external phosphorus loading rates to the bay are higher than what was measured by previous studies.

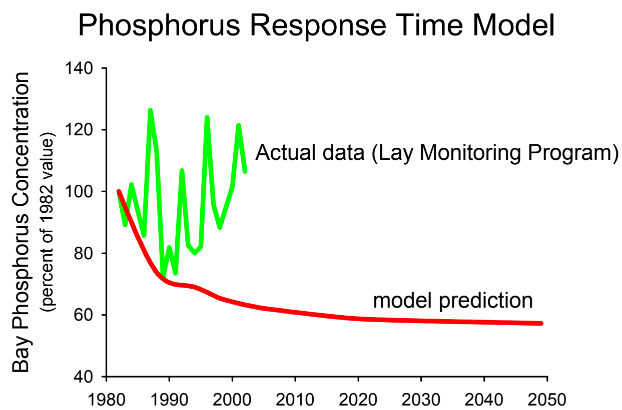

Figure 12. Model predictions of long-term phosphorus reductions in St. Albans Bay[22], compared with actual monitoring data from the Vermont Lay Monitoring Program[12].

13. Control of the late summer surge in phosphorus concentrations in St. Albans Bay would require elimination of the excessive internal loading throughout the entire inner bay and wetland area.

Phosphorus concentrations and algae levels in St. Albans Bay typically peak in late summer (August and early September). This seasonal phosphorus peak is driven by internal loading processes. A "dynamic" (time-varying) phosphorus mass balance model of St. Albans Bay was completed by the Vermont DEC in 1994, based on field data obtained during 1992[25]. The purpose of the study was to model seasonal and spatial aspects of the internal loading phenomenon in order to identify the locations within the bay's sediment area where most of the internal phosphorus load is derived. If most of the internal load was found to originate from relatively confined areas of phosphorus-rich sediments (such as the Stevens Brook wetland), then control of the internal loading problem might be more feasible.

Figure 13 shows model predictions of seasonal phosphorus concentrations in the inner bay area under different internal loading management scenarios. With no control of internal loading, the phosphorus concentrations in the water climb to over 60 µg/l during late summer. If the wetland area was treated in some way to eliminate the excessive internal loading, then there would be some improvement in the bay, but phosphorus levels would peak during the summer at levels approaching 50 µg/l, which is still high enough to stimulate severe algae blooms. The model results indicated that it would be necessary to eliminate the excessive internal loading over the entire wetland and inner bay area (about 700 acres of sediments) in order prevent the summer surge in phosphorus levels in the bay.

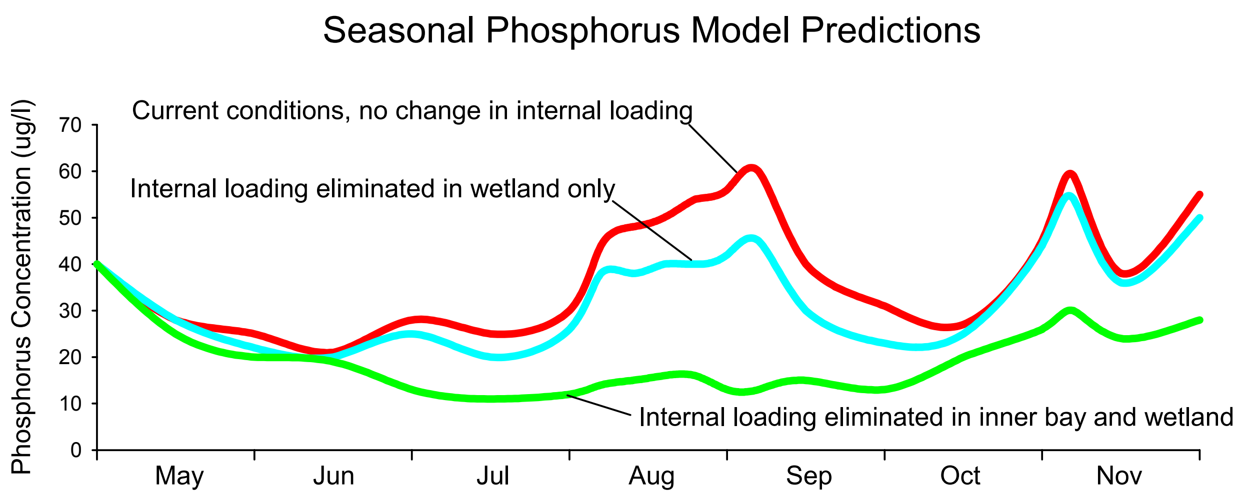

Figure 13. Dynamic phosphorus mass balance model simulations of phosphorus concentrations in inner St. Albans Bay under different internal phosphorus loading management scenarios[25]. Predictions are based on 1992 conditions.

14. There are several physical, chemical, and biological mechanisms that could contribute to internal phosphorus loading in St. Albans Bay.

The phosphorus mass balance modeling studies suggested a number of possible mechanisms that might be driving the internal loading process in St. Albans Bay. The late summer period of peak phosphorus concentrations in the bay corresponds to the time of highest water temperatures and pH values (Figure 14). Both of these factors are known to promote phosphorus release from shallow lake sediments[26]. August is also the month with the lowest average wind velocities (Figure 14). Since wind-driven lake currents produce exchange mixing of water between the bay and the outer lake (Figure 8), the relative lack of exchange mixing during late summer may allow the internal load of phosphorus to accumulate in the bay water[25]. Physical resuspension of sediments by wind-driven water currents or waves could also play a role[27], although this process would be expected to be more important during windier times of the year.

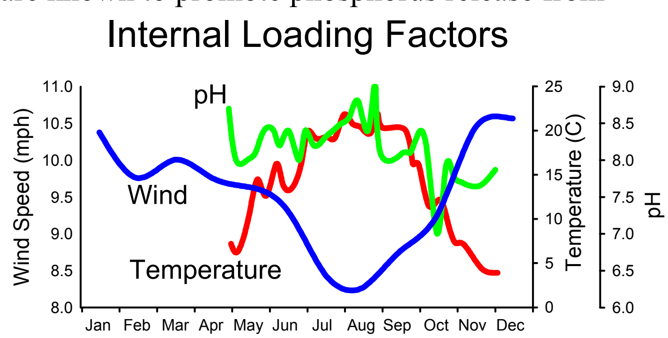

Figure 14. Temperature and pH measured in inner St. Albans Bay during 1992, and 1983-1992 monthly average wind speeds recorded at the Burlington Vermont International Airport[25].

Biological mechanisms could also be involved in the internal loading process. Many "bivalves" (small clams) were present in some of the sediment cores obtained from St. Albans Bay, and high rates of phosphorus release from the sediments to the water were measured in these cores[23]. It is possible that the feeding and excretion activities of these bivalves could play a significant role in recycling phosphorus in the sediments back into the water. Blue-green algae, which dominate in St. Albans Bay during the summer, can regulate their buoyancy and could be absorbing nutrients from the sediments near the bottom before floating to the surface to multiply. Senescence and seasonal die-off of aquatic vegetation in the bay and wetland could also release phosphorus stored in the plants into the water. However, the period of plant senescence and die-off in late September occurs after the summer peak in phosphorus concentrations in the bay.

The research to date has not identified a single dominant process causing the internal phosphorus loading in St. Albans Bay. One or more of the internal loading mechanisms discussed above could be important.

Where do we go from here?

Excessive amounts of phosphorus have been delivered to St. Albans Bay for many decades. Corrective actions such as the St. Albans Wastewater Treatment Facility upgrade and implementation of agricultural best management practices have occurred relatively recently. It would not be realistic to expect an instant water quality recovery in the bay following phosphorus clean-up actions. Long-term phosphorus accumulation has occurred in the bay's sediments, and this phosphorus is being released back into the water by the process of internal loading.

The various studies and modeling analyses summarized in this report have been helpful in documenting the nature and extent of the internal phosphorus loading problem in St. Albans Bay. The models predicted that improved water quality conditions in the bay will occur gradually over several years or decades. However, these predictions have so far proven to be overly optimistic when compared with the actual monitoring data. Phosphorus levels in St. Albans Bay remain in excess of the amount allowed by the Vermont Water Quality Standards, and the situation does not seem to be improving as predicted.

The wastewater phosphorus loads to the bay are well under control. The St. Albans Treatment Facility is consistently meeting its strict effluent phosphorus limits. However, nonpoint source loads to the bay from agricultural and urban runoff occur at very high rates for such a small watershed. While nonpoint source runoff is minor during the dry summer months when phosphorus levels in the bay are at their peak, it is possible that nonpoint source phosphorus delivered to the bay during the springtime and other wet seasons is being temporarily stored in the sediments and then released back into the water during the summer as internal loading. The continuing excessive nonpoint source phosphorus loads could be adding to the historical phosphorus stored in the sediments, thereby slowing the bay's recovery.

Control nonpoint sources

It seems clear that renewed efforts are needed to reduce nonpoint source phosphorus loads in the St. Albans Bay watershed. The Lake Champlain Phosphorus TMDL[4] established a nonpoint source load target of 5.2 metric tons per year for St. Albans Bay, representing a 2.0 mt/yr (28%) reduction from the nonpoint source phosphorus loading rate of 7.2 mt/yr measured in 1991. Achieving this load reduction will require actions in the following areas, as discussed in the Lake Champlain Phosphorus TMDL implementation plan[4]:

- Agricultural sources
- Stream stability and riparian corridor management
- Stormwater discharge permitting
- Erosion and sediment control at construction sites
- Better backroads
- Local municipal actions for water quality protection
- Wetland protection and restoration

Evaluate the feasibility of an alum treatment

Even if the necessary nonpoint source phosphorus reductions are successfully achieved in the St. Albans Bay watershed, it is uncertain whether acceptable water quality in the bay will return within a reasonable time period. The Lake Champlain Phosphorus TMDL implementation plan[5] suggests that a sediment phosphorus inactivation treatment using aluminum sulfate (alum) might be considered in order to accelerate the bay's recovery following external phosphorus load reductions.

A sediment alum treatment to control internal phosphorus loading in St. Albans Bay would need to be a large-scale project involving about 700 acres of bay and wetland area[25]. Feasibility studies, possibly including pilot treatments of small areas, would be necessary to determine the potential for resuspension and loss of alum floc from the shallow areas of the bay, and to evaluate possible adverse effects of an alum treatment on the bay, wetland, and human users.

If external phosphorus sources are not adequately controlled first, the effectiveness of an alum treatment will be limited. For this reason, progress in reducing nonpoint source phosphorus loading to St. Albans Bay should be a prerequisite before any alum treatment is attempted.

Monitor phosphorus loads

Phosphorus concentrations in the bay and in the wastewater discharges are adequately monitored each year, thanks to the efforts of volunteer lay monitors and others. However, nonpoint source phosphorus loads from the streams draining to St. Albans Bay have not been measured since 1992. Long-term tributary monitoring in the Lake Champlain Basin is limited under current programs[13] to larger rivers. Restoring previous tributary monitoring stations in the St. Albans Bay watershed would be useful in order to assess progress in reducing nonpoint source loads and to determine compliance with the load allocations in the Lake Champlain Phosphorus TMDL. The major cost would be to construct and operate continuous flow gages on Stevens Brook and the Mill River. The U.S. Geological Survey operates a network of flow gage stations in Vermont and would be the best organization from which to seek flow gaging assistance in the St. Albans Bay watershed. Phosphorus sampling of St. Albans Bay tributaries could be added to the existing Lake Champlain Basin Program long-term water quality monitoring effort at relatively little extra cost.

References

[1]Young, C. E. and F.A. Teti. 1984. The influence of water quality on the value of recreational properties adjacent to St. Albans Bay, Vermont. U.S. Dept. Agriculture. Economic Research Service. ERS Staff Rep. No. AGES 831116. Washington, D.C.

[2]Hyde, K., N. Kamman, and E. Smeltzer. 1994. History of phosphorus loadings to St. Albans Bay 1850-1990. Lake Champlain Basin Program Tech. Rep. No. 7b. Grand Isle, VT.

[3]St. Albans Bay Watershed Rural Clean Water Program. 1991. Final Report. 1980-1990. Submitted by Vermont RCWP Coordinating Committee. Burlington.

[4]Vermont Department of Environmental Conservation. Wastewater Management Division. Discharge Monitoring Reports on file. Waterbury, VT.

[5]Vermont Department of Environmental Conservation and New York State Department of Environmental Conservation. 2002. Lake Champlain Phosphorus TMDL. Waterbury, VT and Albany, NY. Available at *www.vtwaterquality.org/lakes.htm*.

[6]Meals, D.W. 1996. Watershed-scale response to agricultural diffuse pollution control programs in Vermont, USA. Wat. Sci. Tech. 33:197-204.

[7]Vermont Department of Environmental Conservation and New York State Department of Environmental Conservation. 1997. A phosphorus budget, model, and load reduction strategy for Lake Champlain. Lake Champlain Diagnostic-Feasibility Study final report. Waterbury, VT and Albany, NY.

[8]Hegman, W., D. Wang, and C. Borer. 1999. Estimation of Lake Champlain basinwide nonpoint source phosphorus export. Lake Champlain Basin Program Tech. Rep. No. 31. Grand Isle, VT.

[9]Lake Champlain Basin Program. 2000a. Preliminary evaluation of progress toward Lake Champlain Basin Program phosphorus reduction goals. A Lake Champlain Basin Program internal report prepared for the Lake Champlain Steering Committee. Grand Isle, VT.

[10]WM Northeast, Inc. 1991. St. Albans Bay Pollution Abatement Feasibility Study. Prep. for Towns of Georgia and St. Albans, Vermont.

[11]Budd, L. and D. Meals. 1994. Lake Champlain nonpoint source pollution assessment. Lake Champlain Basin Program Tech. Rep. No. 6. Grand Isle, VT.

[12]Picotte, A. 2002. 2001 Lake Champlain Lay Monitoring Report. Vermont Department of Environmental Conservation. Waterbury.

[13]Vermont Department of Environmental Conservation and New York State Department of Environmental Conservation. 2002. Long-term water quality and biological monitoring project for Lake Champlain: Cumulative report for project years 1992-2001. Waterbury, VT and Ray Brook, NY. Report and data available at *www.lcbp.org/ltmp2.htm*.

[14]Medalie, L. and E. Smeltzer. 2003. Status and trends of phosphorus in Lake Champlain and its tributaries, 1990-2000. Presented at the Lake Champlain Research Consortium 2002 Spring Symposium, May 20-23, 2002, Saint-Jean-sur-Richelieu, QC, and in press.

[15]Smeltzer, E. 1991. The response of St. Albans Bay, Lake Champlain to phosphorus loading reductions. Vermont Dept. Environ. Conserv. Waterbury.

[16]Nurnberg, G.K. 1991. Phosphorus from internal sources in the Laurentian Great Lakes, and the concept of threshold external load. J. Great Lakes Res. 17:132-140.

[17]Larsen, D.P. 1980. Whatever became of Shagawa Lake? In Restoration of Lakes and Inland Waters. U.S. Environ. Prot. Agency. EPA 440/5-81-010.

[18]Cullen, P. and C. Forsberg. 1988. Experiences with reducing point sources of phosphorus to lakes. Hydrobiologia. 170:321-336.

[19]Ryding, S.-O. and C. Forsberg. 1976. Sediments as a nutrient source in shallow polluted lakes. In H.L. Golterman (ed.). Interactions between Sediments and Fresh Water. W. Junk. Amsterdam.

[20]Havens, K.E. and R.T. James. 1997. A critical evaluation of phosphorus management goals for Lake Okeechobee, Florida, USA. Lake and Reserv. Manage. 13:292-301.

[21]van der Molen, D.T., and P.C.M. Boers. 1994. Influence of internal loading on phosphorus concentration in shallow lakes before and after reduction of the external loading. Hydrobiologia. 275/276:379-389.

[22]Martin, S.C., R. J. Ciotola, P. Malla, N.G. Subramanyaraje Urs, and P.B. Kotwal. 1994. Assessment of sediment phosphorus distribution and long-term recycling in St. Albans Bay, Lake Champlain. Lake Champlain Basin Program Tech. Rep. No. 7c. Grand Isle, VT.

[23]Cornwell, J.C. and M. Owens. 1999. Benthic phosphorus cycling in Lake Champlain: Results of an integrated field sampling/water quality modeling study. Part B: Field studies. Lake Champlain Basin Program Tech. Rep. No. 34b. Grand Isle, VT.

[24]HydroQual, Inc. 1999. Benthic phosphorus cycling in Lake Champlain: Results of an integrated field sampling/water quality modeling study. Part A: Water quality modeling. Lake Champlain Basin Program Tech. Rep. No. 34a. Grand Isle, VT.

[25]Smeltzer, E., N. Kamman, K. Hyde, and J.C. Drake. 1994. Dynamic mass balance model of internal phosphorus loading in St. Albans Bay, Lake Champlain. Lake Champlain Basin Program Tech. Rep. No. 7a. Grand Isle, VT.

[26]Jensen, H.S. and F.O. Anderson. 1992. Importance of temperature, nitrate and pH for phosphate release from aerobic sediments of four shallow, eutrophic lakes. Limnol. Oceangr. 37:577-589.

[27]Laible, J.P. 1985. Progress report on phosphorus transport in Stevens Brook Wetland and St. Albans Bay, Vermont. Dept. Civil Mech. Eng. Univ. Vermont. Burlington.