Lake Champlain

Experience and Lessons Learned Brief

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1. Overview

The Lake Champlain basin (Figure 1) is home to a diverse and significant array of natural, cultural, and recreational resources. Extending west into New York's Adirondack region, east into Vermont's Green Mountains, and north onto Québec's fertile flatlands, the basin's rich history of human inhabitance is interwoven with its natural features. Not long after glaciers retreated from the area over 10,000 years ago, Native Americans hunted, fished, and later farmed along the lake's shoreline. In 1609, explorer Samuel de Champlain sailed into the lake that would later bear his name, initiating European settlement in the basin. The basin was the site of numerous important military battles during the French and Indian War, the American Revolution, and the War of 1812 (LCBP 1999, 2003).

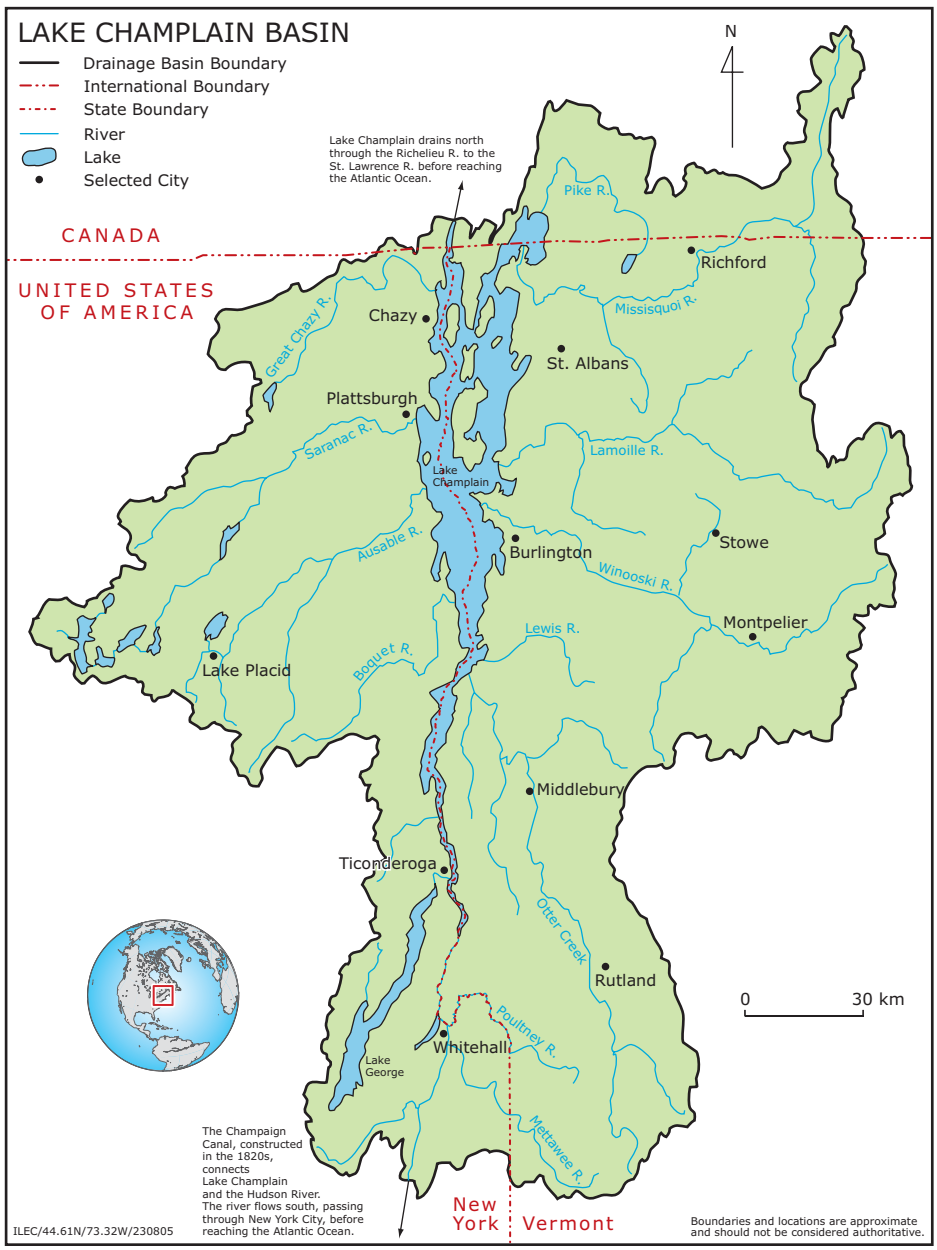

Figure 1. The Lake Champlain Basin.

The economy of the basin has always relied on its natural resources to support the agricultural, forestry, fishing, ice, maple syrup, iron ore and marble industries. The natural beauty of the region made it a popular destination for vacationers beginning soon after the Civil War. Boat building and railroads satisfied the demand to move people and goods through a major transportation corridor for both commerce and recreation (LCBP 1999). Today more than 600,000 people make their home in the basin, and millions of

visitors are drawn to its waters and other natural and historic features each year. Nearly everyone in the basin depends on the lake for a wide variety of uses, from drinking water and recreation to agriculture, industry and waste disposal (LCBP 2003).

The basin's living natural resources are part of a complex ecosystem of interconnected aquatic and terrestrial habitats, including broad open water, rivers and streams, wetlands, forests, agricultural lands, and other areas. Much of the Lake Champlain basin lies in the 650 km (400 mile) long Northern Forest, extending from the Canadian Maritime Provinces to eastern New York. Within the basin are extensive forest lands under various levels of protection and management, including a large section of the six million acre Adirondack Park region, parts of the Green Mountain National Forest, and the Missisquoi National Wildlife Refuge. Diverse natural communities are preserved at these and numerous other State, Provincial, and private-owned lands. Besides humans, the basin supports about 81 species of fish, 318 species of birds, 56 species of mammals, 21 species of amphibians and 20 reptile species, a number of which are at the northern edge of their range (LCBP 1999). In 1989, the basin and adjoining Adirondack Park were designated a Biosphere Reserve by the United Nations Man and the Biosphere Programme.

The health of the economy of the Lake Champlain Basin is tightly linked to its natural, cultural and recreational resources. One-third of the total employment in the Lake Champlain region was in the service industries in 1990, with recreation and tourism as major components (Holmes & Associates 1993). Tourism in the basin creates an estimated US$3.8 billion in economic activity annually (LCBP 2003). In Vermont, tourism makes up 15% of the state's economy, 23% of the jobs and 23% of total statewide personal income, and over two thirds of this sector of the Vermont economy occurs in the Lake Champlain basin (Holmes & Associates 1993). Towns along Lake Champlain's shore benefit from US$1.5 billion in tourism expenditures from visitors, with US$228 million of that spent on Lake Champlain related activities (e.g., boating, camping, fishing, motels, etc.) (LCBP 2003). Agriculture in the basin, which depends on clean water and productive soil, generated about US$526 million in sales of agricultural products—such as milk, cheese, maple syrup, and apples—in 1997 (LCBP 2003). Recreation-related industries also depend on a clean lake. Residents within thirty-five miles of Lake Champlain spent US$118 million in 1997 on water-based recreational activities on Lake Champlain, while visitors from outside the area spent an additional US$228 million (Gilbert 2000).

Clearly, life in the Lake Champlain basin is inextricably connected to the natural resources found there. Every resident and visitor to the towns and villages of the basin in some way enjoys the natural beauty of the region, its economic and recreational opportunities, and a sense of connection with the basin's cultural and natural heritage.

1.1 Quantitative Description

The following quantitative facts about the Lake Champlain basin were adapted from the Lake Champlain Basin Atlas, online version (LCBP 2002).

- The Lake Champlain basin covers 21,325 km² (8,234 mi²). About 56% of the basin lies in the State of Vermont, 37% in the State of New York, and 7% in the Province of Québec.
- Lake Champlain is 193 km (120 mi) long, flowing north from Whitehall, NY to the Richelieu River in Québec, with 945 km (587 mi) of shoreline.
- The Lake consists of five distinct segments (depicted in Figure 2), each with its own physical and chemical characteristics:
  - The South Lake: The South Lake is narrow and shallow, much like a river.
  - The Main Lake: The Main (or Broad) Lake holds most of the lake's water and its deepest and widest points.
  - Mallets Bay: Mallets Bay is largely restricted hydrologically due to railroad causeways.
  - The Inland Sea: The Inland Sea (or Northeast Arm) is a lake segment lying east of the Champlain Islands.
  - Missisquoi Bay: Missisquoi Bay is a shallow bay at the northernmost part of the lake whose waters flow south to the Inland Sea.
- The lake is 19 km (12 miles) at widest point, covering a surface area of 1,127 km² (435 mi²). There are over 70 islands in the lake.
- At its deepest point, the lake is over 120 m (400 ft) deep, but its average depth is 19.5 m (64 ft). The maximum depth of some of the lake's bays is less than 4.5 m (15 ft).
- The volume of the lake averages 25.8 million m³ (6.8 trillion gallons).
- Precipitation averages 76 cm (30 in) annually in the Lake Champlain valley, and 127 cm (50 in) in the mountains. Rivers and streams contribute more than 90% of the water which enters Lake Champlain.
- The surface of the lake has an average elevation of 29 m (95.5 ft) above mean sea level.
- The basin includes the highest elevations in both New York (Mt. Marcy at 1629 m (5344 ft)) and Vermont (Mt. Mansfield at 1339 m (4393 ft)). The growing season averages from 150 days on the shoreline to 105 days in the higher altitudes.

- Due to Lake Champlain's low water temperatures, the best collection of underwater shipwrecks in North America has been well preserved through more than two centuries. Several shipwrecks in Vermont and New York are included in an Underwater Preserve network, supported by the LCBP, where SCUBA divers can visit them and learn about the rich history of Lake Champlain.

1.2 Landscape

The landscape of the basin was shaped by geologic events over millions of years. The basin consists of five physiographic regions: the Champlain Valley, the Green Mountains, the Adirondack Mountains, the Taconic Mountains and the Valley of Vermont (Figure 3). The Adirondack Mountains, formed over one billion years ago, were bordered to the east by the Iapetus Ocean, an ocean over 500 million years older than the present day Atlantic Ocean. Marine fossils can be found throughout the basin, including the Chazy Reef in Isle La Motte, Vermont, well known as the world's oldest reef. When the Iapetus Ocean closed over 400 million years ago, the sedimentary rocks of the shoreline and eastern continental shelf were folded and faulted to form the Green Mountains. During this time, portions of the earth's crust began to break and move as large fault blocks, where younger rocks have been pushed up and over metamorphosed continental shelf rocks beneath. Geologists and students come to Lake Champlain from around the world to view the exposed thrust faults at cliffs and road cuts (LCBP 1996, 2002).

The Great Ice Age brought several glacial advances to the Lake Champlain basin beginning about 1 million years ago, covering the entire basin with a sheet of ice more than one mile thick. About 12,500 years ago, the glaciers retreated and Lake Vermont formed from the melted ice. When the glaciers retreated further about 10,000 years ago, marine waters from the St. Lawrence estuary flooded the basin, forming the Champlain Sea, an arm of the Atlantic Ocean (Figure 4). Evidence from this period includes a Beluga whale skeleton found in Charlotte, Vermont. As the glacial ice disappeared from the region, the earth's surface rebounded and the sea was again cut off from the Atlantic Ocean, isolating the present day freshwater Lake Champlain (LCBP 1996, 2002).

The land use and land cover in the Lake Champlain basin varies from alpine meadow to lakeside floodplain forest. Much of the vegetative land cover in the basin has been altered by human activities ranging from logging to agriculture. Today, forested areas dominate the landscape, covering over 70% of the basin overall and continuing to increase from 100 years ago, when approximately 30% was forested. Agricultural land is the second largest cover category in the basin covering about 15%. The amount of land in agricultural use is decreasing as abandoned crop and grazing lands revert back to forest or they are converted to urban and suburban uses, which, as of 1999, represent about 5% of the total area of the basin (Hegman et al. 1999).

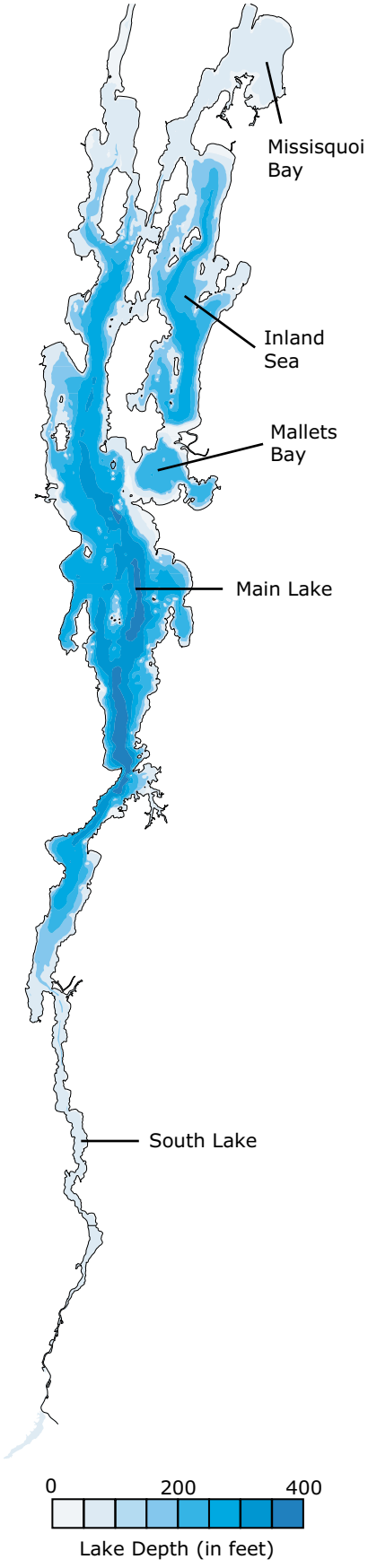

Figure 2. Lake Champlain Bathymetry and Lake Segments (Source: Adapted from figure available at http://www.lcbp.org).

Agricultural lands in the basin are primarily concentrated in the Lake Champlain valley and along the fertile floodplains of the major river tributaries to the lake. The basin's human population is largely dispersed in many towns, villages, and hamlets. Major population centers with urban and suburban land use include Clinton County, New York (including the City of Plattsburgh, total population of nearly 80,000 in 2000), Chittenden County, Vermont (including the Cities of Burlington, South Burlington, and Essex and other towns, total population of over 146,000 in 2000) and the City of Rutland, Vermont (population 17,292 in 2000) (LCBP 2002).

2. Lake Management Issues and Activities

2.1 Cooperative Management Efforts

Because the Lake Champlain basin spans state and international borders, the need for interjurisdictional cooperation has been recognized for decades. The following organizations have at various times played an important role in the cooperative management of the basin's resources (LCBP 1996, 2003).

2.1.1 International Joint Commission (IJC)

Formed by the Boundary Waters Treaty in 1909 between Canada and the United States, the IJC coordinates activities related to United States-Canada boundary waters. The IJC membership is comprised of six commissioners appointed by the President of the United States and the Prime Minister of Canada. The IJC convened a Champlain-Richelieu Board to examine a controversial proposal to regulate water levels in Lake Champlain during the 1970s, with a new control structure in the upper Richelieu River. After careful research and deliberation, the IJC recommended that no control structure be permitted to regulate lake level, and both the US and Canada have accepted this resolution of the issue.

2.1.2 Interstate Commission on Lake Champlain (INCOCHAMP)

Formed in 1949, INCOCHAMP was intended to coordinate and foster cooperation for environmentally sound development in the basin. The INCOCHAMP became a *pro forma* organization in 1968. Vermont ended its participation in the commission in 1990, while New York has never formally done so.

2.1.3 New England River Basins Commission (NERBC)

The NERBC existed from 1969-1981 as a federal-state partnership composed of the six New England States and New York, 10 federal and six interstate agencies. Its mission was to encourage the conservation, development, and utilization of water and related land resources on a coordinated basis by federal, state, and local governments and private enterprise. Its activities included developing a Level B Study and Management Plan for Lake Champlain in 1979. The program terminated shortly after completion of the Management Plan, due to cuts in US federal funding.

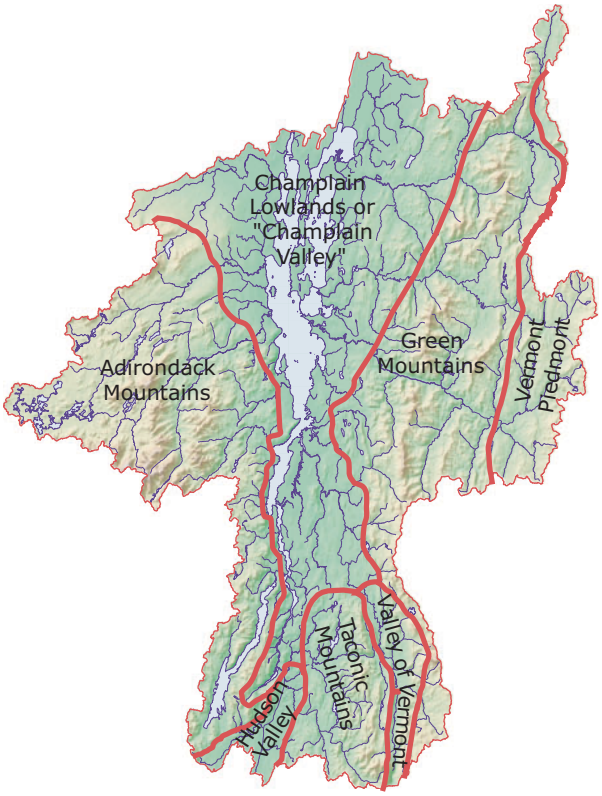

Figure 3. Physiographic Regions of Lake Champlain Basin (Source: Adapted from figure available at http://www.lcbp.org).

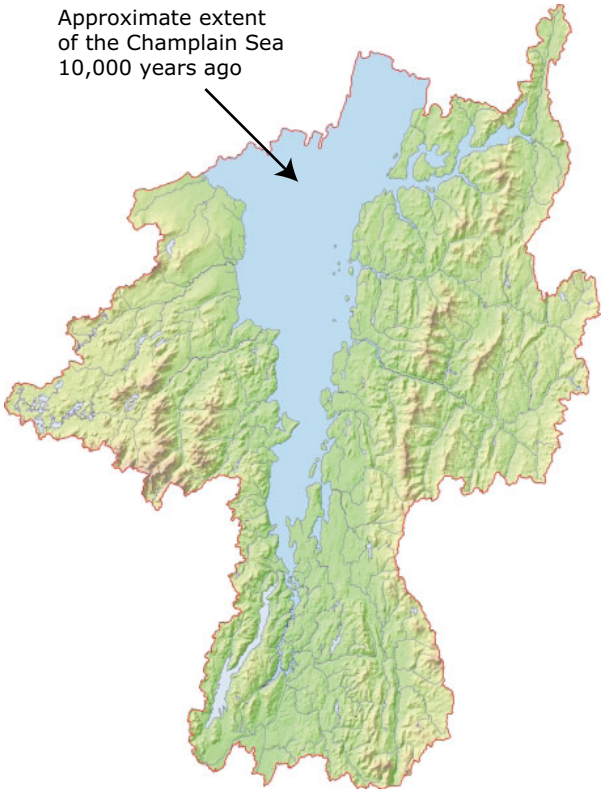

Figure 4. The Champlain Sea (Source: Adapted from figure available at http://www.lcbp.org).

2.1.4 *Lake Champlain Fish and Wildlife Management Cooperative (LCFWMC)*

The LCFWMC was created in 1973 and continues as a federal-state cooperative between the United States Fish and Wildlife Service, the New York State Department of Environmental Conservation, and the Vermont Fish and Wildlife Department, that manages the fish and wildlife resources of Lake Champlain. The Cooperative Agreement, which was updated in 1995, created a Policy Committee consisting of program directors from the three agencies, and Management and Technical Committees of agency staff. Organizations in Québec are not formal partners within the LCFWMC, but coordinate and communicate with it regularly. The LCFWMC leads the program to control the sea lamprey, an invasive, parasitic fish species.

2.1.5 *Memorandum of Understanding on Environmental Cooperation on Lake Champlain (MOU)*

This MOU between New York, Vermont, and Québec was first signed in 1988 and has been renewed at regular intervals since, most recently in 2003. The MOU established the Lake Champlain Steering Committee with representatives from the three jurisdictions, as well as Citizen Advisory Committees from Vermont and New York. The Steering Committee currently guides the activities of the Lake Champlain Basin Program. Through this MOU, several cross-boundary protocols have been established, including a Joint Toxic Spill Response Agreement that mandates prompt communication between governments in the event of a spill, and a Québec-Vermont phosphorus reduction agreement for Missisquoi Bay. The MOU and subsequent agreements provide an opportunity to test regulatory cooperation. In practice, the three jurisdictions treat these agreements as binding covenants, though they are not strictly enforceable.

2.1.6 *Lake Champlain Basin Program (LCBP)*

The LCBP is a partnership between the States of New York and Vermont, the Province of Québec, the USEPA, other federal and local government agencies, and local groups. Created by Congress through the Lake Champlain Special Designation Act of 1990 (Public Law 101-596) and updated with a continuing authorization in 2002 (Public Law 107-303), the LCBP works cooperatively with many partners to protect and enhance the environmental integrity and the social and economic benefits of the Lake Champlain basin. The LCBP serves as the coordinating body for the development and implementation of the comprehensive management plan for Lake Champlain known as *Opportunities for Action*.

2.1.7 *Lake Champlain Ecosystem Team*

Established by the United States Fish and Wildlife Service, the Ecosystem Team is an association of organizations throughout the Lake Champlain basin involved in the conservation of plants, animals, and their habitats. The Team's mission is to maintain and enhance ecological integrity throughout the basin. Its work includes enhancing interdisciplinary cooperative partnerships among federal and state agencies, conservation organizations, and academic institutions; facilitating and coordinating resource conservation activities; and exchanging information.

2.1.8 *Lake Champlain Research Consortium (LCRC)*

The Consortium is a multidisciplinary research and education program for Lake Champlain established in 1991. Membership in the Consortium currently consists of selected academic institutions conducting research within the basin boundaries. The LCRC periodically prepares a list of research needs and priorities related to the management issues identified by the Lake Champlain Basin Program.

2.2 Major Issues and Management Activities

Although Lake Champlain remains a vital and attractive lake with many assets, there are several serious environmental problems that demand action.

2.2.1 *Phosphorus*

Phosphorus is necessary for life, but concentrations of this nutrient in parts of Lake Champlain are high enough to cause excessive growth of algae and other aquatic plants. This growth results in reduced water transparency and oxygen levels, odors, and poor aesthetics, thereby posing the single greatest threat to water quality, living organisms, and human use and enjoyment of Lake Champlain.

Wastewater treatment and industrial discharges are the main point sources of phosphorus, contributing about 20% of the total phosphorus entering Lake Champlain. Nonpoint sources, which account for about 80% of the phosphorus load, include lawn and garden fertilizers, dairy manure and other agricultural wastes, pet wastes, and areas of exposed or disturbed soil, such as construction areas and eroding streambanks (LCBP 2003). Agricultural activities contribute approximately 55% of the annual nonpoint phosphorus load to the lake. Forests cover a majority of the basin's surface area but contribute only an estimated 8% of the average annual nonpoint source phosphorus load. Urban land covers only a small portion of the basin, yet it produces approximately 37% of the average annual nonpoint source phosphorus load to the lake—much more phosphorus per unit area than either agricultural or forested land (Hegman et al. 1999). The average phosphorus concentrations for each segment of the lake are presented in Figure 5. It is essential to note that many decades of high phosphorus inputs to the lake have also resulted in the accumulation of a large amount of phosphorus in lake-bottom sediments which contribute to water quality problems through internal loading.

Since the 1970s, phosphorus loads have been dramatically reduced through actions such as banning phosphate detergents, regulating wastewater treatment plants and industrial discharges, and voluntary pollution control efforts on farms. In 1993, after completion of an extensive diagnostic feasibility study of the lake and its tributaries, New York, Vermont, and Québec signed a Water Quality Agreement establishing in-lake phosphorus concentration criteria (goals)

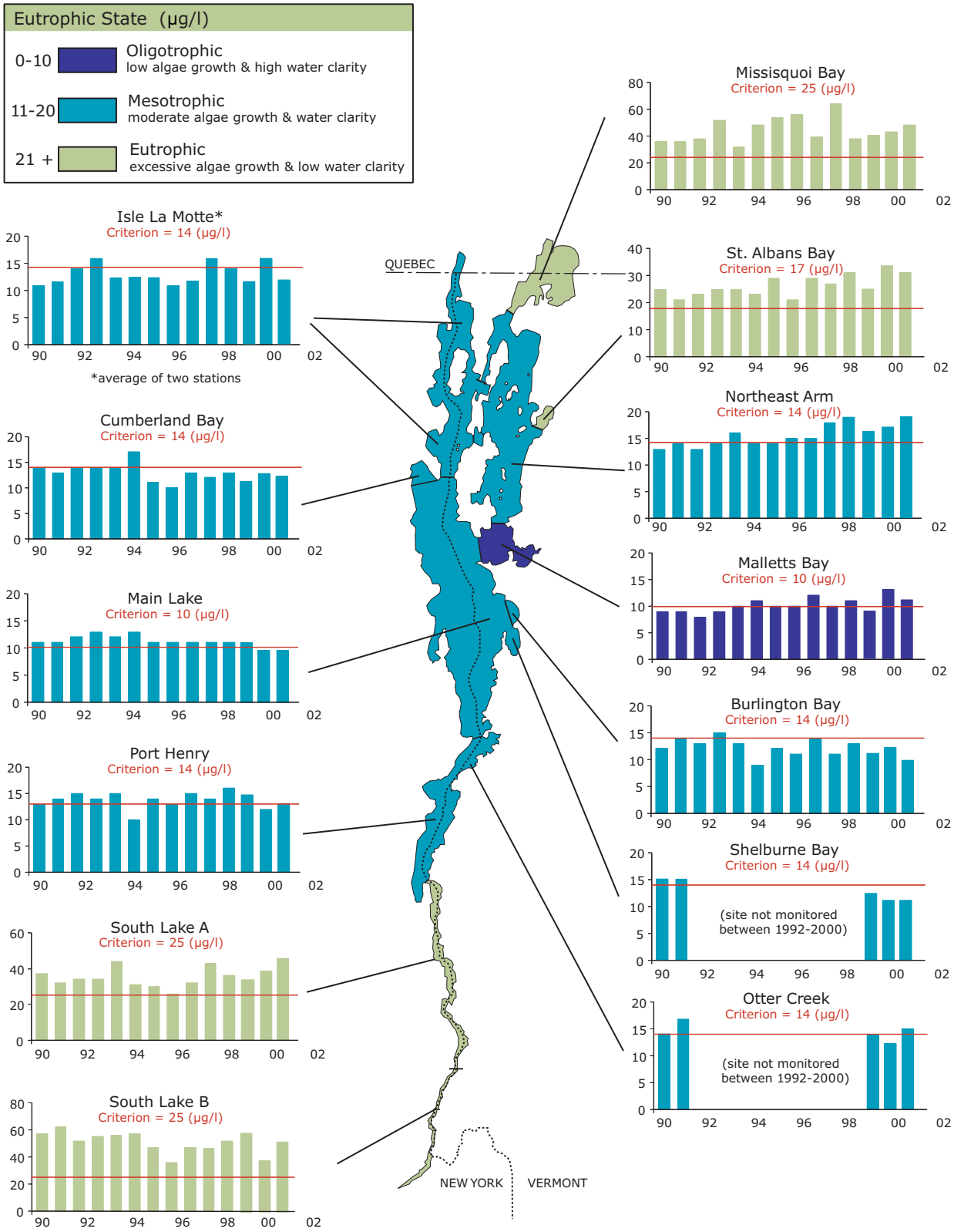

Figure 5. Phosphorus Levels in Segments of Lake Champlain, 1990-2003 (Source: Adapted from figure available at http://www.lcbp.org).

for thirteen lake segments (Figure 5), and committing to measure point and nonpoint source phosphorus loads to the lake and develop a load reduction strategy to attain the in-lake criteria (VTDEC and NYSDEC 1997).

Using an optimization procedure to determine the cost-effectiveness of various strategies for attaining the in-lake phosphorus criteria (Holmes and Artuso 1995), load reduction targets considered both fair and cost-effective were then developed (Figure 5). Vermont and New York have committed to reducing the difference between the 1995 loads and the target loads in each lake segment watershed by at least 25% for each five-year period over 20 years, pending available federal and/or state funds to support implementation. Vermont and Québec have also developed an agreement dividing responsibility for phosphorus reductions in the Missisquoi Bay lake segment (QMENV and VTANR 2002; MBTF 2000). The loading and in-lake concentration targets agreed to by the two states have become the basis of a federally mandated phosphorus Total Maximum Daily Load (TMDL) plan for Lake Champlain, prepared jointly by Vermont and New York (VTANR and NYSDEC 2002). The development and implementation of the TMDL are consistent with the priority actions detailed in *Opportunities for Action*.

In 2000, the LCBP released a Preliminary Evaluation of Progress Toward Lake Champlain Phosphorus Reduction Goals (LCBP 2000). The report estimated that Vermont, New York, and Québec reduced the phosphorus inputs to Lake Champlain by about 38.8 metric ton/yr by 2001, far exceeding the first five-year interim reduction goal of 15.8 metric ton/yr. The report also concluded, however, that not all lake segments can be brought to the loading targets needed to meet the in-lake phosphorus criteria by relying solely on existing reduction programs. The report indicated that, because developed land generates significantly more phosphorus per unit area than other land uses, conversion of land use from agricultural to urban uses is offsetting some of the gains achieved to date by point and nonpoint source reduction efforts. Potential options for achieving the additional phosphorus reductions necessary to account for these increases include both additional point and nonpoint source treatment.

2.2.2 Toxic Substances

Toxic substances are elements, chemicals, or chemical compounds that can poison plants and animals, including humans. Recent efforts to improve the understanding of toxic pollution in Lake Champlain suggest that, while levels are low compared to more industrialized areas such as the North American Great Lakes, there is already cause for concern. The presence of toxic substances, such as polychlorinated biphenyls (PCBs) and mercury, has caused New York and Vermont to issue health advisories suggesting limiting consumption of certain fish species. A survey of lake-bottom sediments funded by the Lake Champlain Basin Program has identified three areas in Lake Champlain (Cumberland Bay, Inner Burlington Harbor, and Outer Mallets Bay) where lake-bottom sediments are contaminated with toxic substances at levels that may be harmful to aquatic biota or human health (Figure 6). A list of Toxic Substances of Concern has also been prepared to help direct management actions (Table 1) (LCBP 2003).

In recent years, hazardous waste cleanup and containment projects have been undertaken at the Pine Street Barge Canal in Burlington, Vermont and in Cumberland Bay near Plattsburgh, New York. Cleanup of other less-contaminated sites called brownfields is also underway to protect water quality and encourage economic development. Additional research and monitoring efforts are needed to better understand the sources and effects of toxic pollutants in the basin. Efforts to promote pollution prevention, from household hazardous waste collections to reducing pesticide use, must be continued and increased.

Table 1. Toxic Substances of Concern Found in the Lake's Biota, Sediment, and Water.

Priority	Toxic Substances	Criteria for Selection
Group 1	PCBs, mercury[a]	Persistent contaminants found lake-wide (in either sediment, water, or fish) at levels above standards, indicating potential risk to human health, wildlife, or aquatic biota. These are highest priority for management action.
Group 2	Arsenic, cadmium, chromium, dioxins/furans, lead, nickel, PAHs, silver, zinc, copper, persistent chlorinated pesticides[b]	Persistent contaminants found in localized areas (in either sediment, water, or fish) at levels above standards or guidelines, indicating potential risk to human health, wildlife, or aquatic biota. These are next highest priority for management action.
Group 3	Ammonia, phthalates, chlorinated phenols, chlorine, atrazine, alachlor, and pharmaceuticals	Contaminants found above background levels in localized areas of the lake, but below appropriate standards or guidelines.
Group 4	VOCs, such as benzene, acetone, pesticides, strong acids and bases, and other potential pollutants, such as fluoride	Contaminants known to be used or known to occur in the Lake Champlain Basin environment.

Source: LCBP (2003).
Notes: a) Based on US FDA standards.
b) Based on a variety of guidelines (NOAA, Ontario, USEPA) regarding toxics in sediments.

2.2.3 *Nonnative Aquatic Nuisance Species*

The fish, wildlife, and other living resources of the Lake Champlain basin have been negatively impacted by the introduction of nonnative aquatic nuisance species, such as sea lamprey, water chestnut, Eurasian watermilfoil, zebra mussels, and recently alewives. At least 23 nonnative aquatic nuisance species are known to live in the waters of the Lake Champlain basin (Eliopoulos and Stangel 2002). These species can interfere with the recreational use and ecological processes of the Lake. Zebra mussels, for example, can clog residential, municipal, and industrial water intake pipes, foul boat hulls and engines, and obscure priceless underwater archeological artifacts. Because nonnative species are often transported across borders to reach the basin, coordination among the different management agencies is required to prevent their introduction and spread. The Lake Champlain Aquatic Nuisance Species Management Plan was approved by New York and Vermont in 1999 and accepted by the National Aquatic Nuisance Species Task Force in 2000. The plan is a comprehensive action strategy to protect ecologically valuable habitats, to control the spread of nuisance species, and prevent additional introductions of nonnative species.

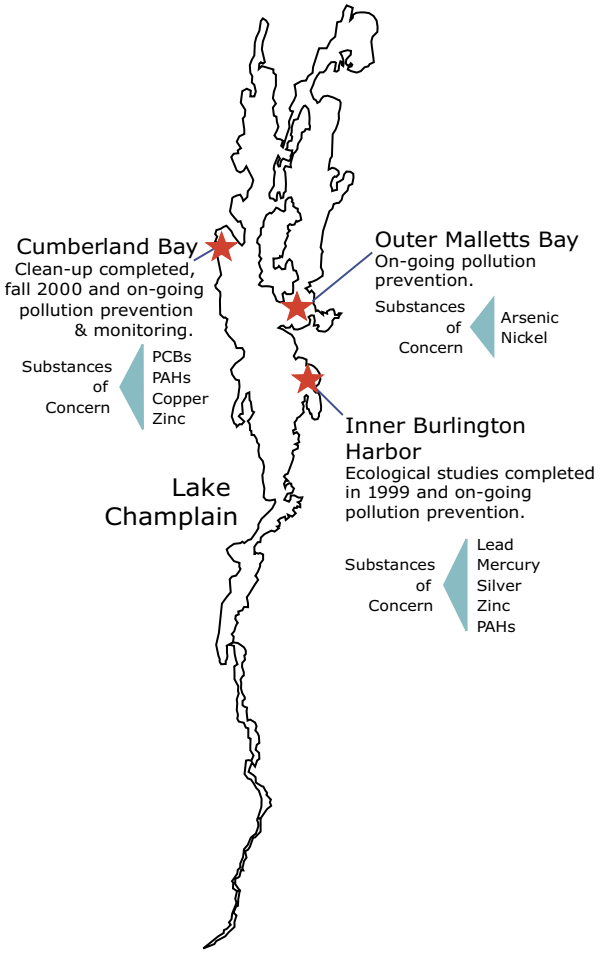

Figure 6. Sites of Concern for Toxic Substances in Sediments (Source: Adapted from figure available at http://www.lcbp.org).

Sea lamprey are primitive parasitic fish that feed on the body fluids of other fish, resulting in reduced growth and sometimes causing the death of the host fish. Evidence collected on Lake Champlain indicates that sea lamprey have a profound negative impact upon native and sport fish populations. Their presence has thwarted efforts to establish and restore new and historical sport fisheries. The Lake Champlain Fish and Wildlife Management Cooperative (LCFWMC) completed an eight-year experimental sea lamprey control program in 1998. The LCFWMC is now implementing a long-term sea lamprey management program, including chemical and non-chemical approaches.

Zebra mussel densities have increased dramatically since their discovery in Lake Champlain in 1993. A monitoring program is in place to document the spread of zebra mussels and to characterize the conditions that may limit their growth (see Figure 9 below). Additional effort is needed in educating people about zebra mussel issues and to determine the long-term effect of zebra mussels on the aquatic food web.

Eurasian watermilfoil, first discovered in the basin in 1962, now occupies an extensive range throughout the lake and at least 40 other waterbodies in the basin. Because Eurasian watermilfoil is spread by plant fragments transported by waves, wind, currents, people, and to some extent, animals, its spread is not easily controlled. Control techniques using chemical and biological agents such as aquatic moths and weevils are being investigated in the basin.

Like Eurasian watermilfoil, water chestnut displaces other aquatic plant species, is of little food value to wildlife, and forms dense vegetative mats that change habitat and interfere with recreational activities. The most extensive infestations are limited to southern Lake Champlain. Water chestnut has also been found in Québec near Missisquoi Bay. In recent years, a consistent, well-funded lakewide spread prevention and control program of surveying, mechanical harvesting, and handpulling of water chestnut has successfully pushed the northern extent of the South Lake infestation back nearly 40 miles (Figure 7).

2.2.4 *Human Health*

There are potential health threats associated with poor water quality in the Lake Champlain basin, including drinking water, eating fish and wildlife, and swimming in the lake. Pathogens are disease-causing agents such as bacteria, viruses, and parasites. Water-related pathogens cause gastrointestinal illnesses when ingested. Exposure to pathogens is primarily through ingestion, either accidentally while swimming, or when drinking water from the lake. Drinking water suppliers depend on high quality source water to produce the highest quality drinking water as economically as possible. The presence of pathogens causes occasional beach closings in some areas of the lake. Sources of pathogens include agricultural wastes, failed septic tanks, combined sewer overflows and sanitary sewer overflows, and urban stormwater runoff.

Blue-green algae, also known as cyanobacteria, are normally harmless and widely scattered through the surface waters of Lake Champlain. Under favorable conditions for growth, however, thick blue-green algae blooms develop, especially in calm and shallow waters. Some strains of common blue-green algae species can produce toxins that can damage the nervous system or liver. These toxins have been detected sporadically in Lake Champlain, although the conditions that result in the production of toxins have yet to be fully characterized. In recent years, the deaths of several pets that ingested large amounts of blue-green algae laden water indicate that the health risk associated with blue-green algae blooms has increased. Late in the summers of 2002 and 2003, significant areas in Missisquoi Bay were contaminated by toxins associated with large blooms of blue-green algae, resulting in public health advisories. Current research is focused on developing a coordinated health advisory program among Vermont, New York, and Québec, and an examination of the factors that trigger these extreme conditions.

Mercury and PCBs (polychlorinated biphenyls) are a human health concern because they accumulate to high levels in some fish species. State Health Departments have issued health advisories for several species of fish and waterfowl caught in Lake Champlain. The fish sampling programs for Vermont, New York, and Québec are currently not well coordinated, and do not yet provide a comprehensive database, making it difficult to discover trends or provide statistically valid conclusions.

Communicating risks is an important part of any effort to protect human health. New York and Vermont have worked together to inform each other of any press releases or health advisories before they are released, and both states use similar methods of educating the public and communicating risks. However, some of the general advisories, for example limitations on fish consumption due to mercury contamination, are not consistent among the three jurisdictions, and therefore may be confusing to the public. It is important to develop effective means to alert the public about these health risks (LCBP 2003).

2.2.5 Fish and Wildlife

Fish and wildlife provide tremendous social, economic, and environmental benefits to the Lake Champlain basin. The structure and function of the food web affect water quality, bioaccumulation of toxins, and habitat suitability for fish and wildlife. Abundant fish and wildlife attract recreational hunters, bird watchers, and anglers, resulting in significant economic benefit to local communities. The complex array of plants and animals also provides other important benefits to humans, such as pollution filtration through wetlands and other vegetated areas, scenic beauty, and recreational opportunities. Natural species diversity is a highly valued part of the region's natural heritage and a critical component of the ecosystem that supports all life on earth.

Populations of some rare, threatened, and endangered plant and animal species and rare natural communities in the Lake Champlain basin are declining as a result of habitat degradation, invasions of non-native species, collection, and other factors. Of the approximately 487 vertebrate species of fish and wildlife thought to be in the basin, 30 species are officially listed by federal and state agencies as endangered and threatened. More information on the status of and threats to these species and natural communities, in addition to more public education, is necessary for their protection and restoration. A comprehensive inventory of these species and their habitats for the entire Lake Champlain basin is essential, as is close coordination by various agencies on all aspects of protection and restoration (LCBP 2003).

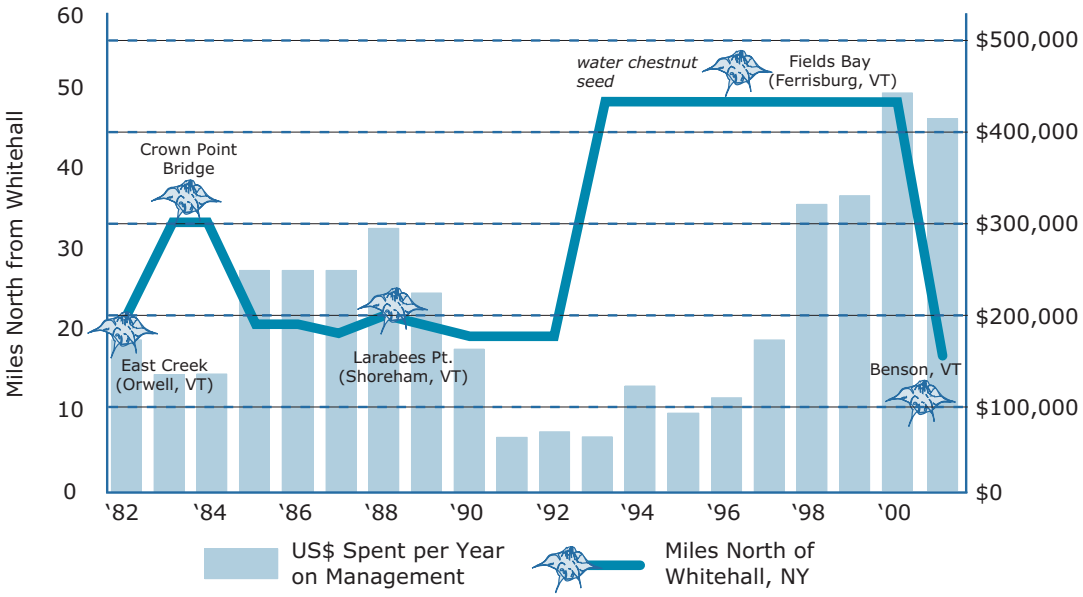

Figure 7. Lake Champlain Water Chestnut Management: Annual Funding and Northernmost Mechanical Harvesting Site (Source: Adapted from figure in LCBP (2003)).

2.2.6 Wetlands, Streams and Riparian Habitats

The Lake Champlain basin includes some of the highest quality wetlands in the northeastern United States, including extensive lakeside wetland complexes and many rare or declining natural wetland communities. In addition to providing critical habitat and nourishment for fish and wildlife, the more than 300,000 acres of wetlands improve water quality by filtering sediments, pollutants, and nutrients. Wetlands also help control flooding, protect groundwater and drinking water supplies, stabilize shorelines, prevent erosion, and provide recreational opportunities. Despite federal, state, and local wetlands protection regulations, threats to wetlands in the Lake Champlain basin persist. Wetlands are often drained or filled for agricultural, residential, or commercial purposes.

Human impacts on stream and riparian habitats have also been severe and wide ranging. For the last three centuries, people have altered the landscape and the flow of streams and rivers for flood control, bridges and roads, power generation, agriculture, development, and even erosion control or bank stabilization. Adverse impacts include loss of historic floodplains, increased river channel instability, degradation of water quality, decreased water storage and conveyance capacity, loss of habitat for fish and wildlife, and decreased recreational and aesthetic value. Unfortunately, in the past, most stream manipulation did not take into consideration the natural dynamic processes at work in the stream channel, riparian habitat, and floodplain, or the need for streams and rivers to transport both flow and sediment. Adequate riparian buffers are one of the most effective tools for limiting nonpoint sources of pollution and promoting the long-term stability of stream banks and channels, as well as providing wildlife habitat corridors and thermal protection to the stream.

The Lake Champlain Basin Program sponsored a wetland acquisition strategy that laid the groundwork for a four-phase, multiyear program to permanently protect almost 9,000 acres of wetlands in the Champlain Valley. By 2001, US$1.4 million in federal funds had been provided to the project, which had conserved 4,000 acres of wetlands and surrounding areas in the basin. Other projects in the basin being conducted by citizens groups and public agencies include numerous streambank restorations using natural channel design techniques, designating an ecological preserve in Québec, and creating miles of buffer areas along streams and rivers (LCBP 2003).

2.2.7 Recreation and Cultural Heritage Resources

The history of humans in the Lake Champlain basin spans more than 10,000 years. It includes Native American and early Euro-American settlements, French and British explorations and occupations, pivotal military conflicts, and a dynamic period of 19th century commerce. Many archaeological and historic sites provide a context and sense of place to people today. Lake Champlain is also a popular recreation resource for basin residents and visitors alike. Swimming, fishing, scuba diving, and boating are just a few of the activities enjoyed on the lake. Recreation also contributes to the local economy. Total tourism-related expenditures in the basin were estimated at US$3.8 billion in 1998-99.

Efforts are being made to support initiatives that promote ecologically sustainable economic activity utilizing natural, cultural, and historical resources in the basin, while minimizing congestion and conflicts between users. Protection and enhancement of the environment and cultural and recreation resources is clearly important to visitors to the basin, as these resources are often the main focus of their experience. Fostering more opportunities for diverse groups to access and enjoy the lake will encourage more people to value it and support water quality protection, ultimately increasing the number of people engaged in lake stewardship. Issues of congestion and conflicts of use can be addressed through user cooperation and/or education on a site-by-site basis. For example, the Lake Champlain Basin Program funded a demonstration project that identified solutions to the boating congestion and other problems in Malletts Bay, the Malletts Bay Recreation Resources Management Plan.

Plans are underway to commemorate the 400th anniversary of Samuel de Champlain's arrival in the basin (2009). Both New York and Vermont have established State Commissions to coordinate and promote the preparations for this quadricentennial event. The focus in quadricentennial preparations will be on developing the regional infrastructure so that this celebration of regional heritage will be successful and will shape the economy in a sustainable way. Associated with this anniversary is a comprehensive initiative to significantly improve lake water quality by 2009 through a rapid and effective implementation of the TMDL program. The National Park Service (1999) recently completed a study of the Champlain Valley that assesses the potential for establishing a national heritage corridor in the region. A follow-up project to develop a framework for heritage tourism in the region that is compatible with local interests has been completed by the LCBP. Other initiatives—the Lake Champlain Birding Trail, the Lake Champlain Paddlers' Trail, Lake Champlain Walkways, the Lake Champlain Underwater Preserve System, the Waterfront Revitalization Program in New York, Lake Champlain Byways and Lake Champlain Bikeways—have also made notable progress in promoting low impact, non-motorized tourism in the basin. Continuing and expanding these and similar initiatives in a more coordinated manner fosters stewardship for the lake and its surrounding natural, cultural, recreational, and historic resources within the basin, while also contributing to the economic vitality of the region (LCBP 2003).

3. Socioeconomic Threats to Sustainable Use

3.1 Pressures from Within the Basin

Socioeconomic factors in the Lake Champlain basin are tightly linked to the natural, cultural, and recreational resources there. Protecting these resources and enhancing access to them generates substantial economic revenues (LCBP 2003). In turn, increased awareness and use of resources can result

in a greater concern and need for their protection. However, economic activity can also threaten the very resources on which it depends if it is not carried out in a sustainable way. Sustainable development is an economic development concept that gives full consideration to the social, economic, quality of life, and environmental aspects of development decisions and seeks to avoid depleting or degrading the economic resource base. To promote sustainable development, it is essential to work closely with economic development agencies, chambers of commerce, business and industry groups, real estate development interests, local government, and environmental organizations to identify actions and programs that can lead to sustained economic activity, good wages, long-term employment, affordable housing, and a cleaner environment (LCBP 2003).

3.1.1 Local Economies

Local economies in the basin must remain vital to support sustainable development and implementation of effective pollution controls, such as phosphorus removal in wastewater treatment and upgrading failing septic systems. In addition to tourism, major sectors of the basin economy include manufacturing, agriculture, retail and wholesale trade, healthcare, universities, prisons, and state government. In the 1990s, employment in the service sector comprised 35% of basin employment, followed by trade (22%), and manufacturing (15%). The trend in the last 20 years has been towards an increase in the service and trade sectors and a decrease in the manufacturing sector. Income from wages, especially in the rural portions of the basin, lags behind the national average. In the Adirondack Park region, average annual wages in 1992 were US$20,621, in contrast to US$32,411 for all of the State of New York and US$25,903 nationwide. In Vermont, non-metropolitan earnings per job were US$24,774 in 1999, while metropolitan earnings were US$28,039. Nationally, the averages for non-metropolitan earnings were US$24,408 and metropolitan earnings were US$36,526. In several locations around the basin, businesses related to agriculture, mining, and forestry are the major employers (Holmes & Associates and Artuso 1996; LCBP 2003; US Department of Commerce's 1990 Census).

3.1.2 Agriculture

In the ten counties of New York and Vermont that lie predominately within the basin, there were approximately 4,840 farms in 1987, roughly one-third in New York and two-thirds in Vermont. According to the 1997 Census of Agriculture, the number of acres of farmland in Vermont decreased by one percent from 1992 to 1997, to 1.3 million acres, while the number of full-time farms decreased six percent to 3,300. By 1997, sales from Vermont farms totaled US$476 million, indicating that the total value of Lake Champlain basin agricultural products of US$526 million. Dairy products account for the majority of farm sales in both New York and Vermont basin areas (LCBP 2003).

Farming in the basin, the dairy industry in particular, is subject to potentially conflicting resource management goals. Farms in the basin provide milk, cheese, meat, and other products, while preserving open space and maintaining the character of the rural landscape that is so attractive to basin residents and visitors alike. At the same time, farm activities are a major source of pollutants to the basin's surface and ground waters. Small farms need considerable assistance to manage manure in an environmentally responsible manner. With milk prices low, small farms are being forced to increase milk production (i.e., the number of cows they keep) or go out of business. Although economies of scale can be realized, larger farms also face proportionately larger challenges in effectively managing the manure from their facilities. In addition to manure management issues, low milk prices also tend to discourage farmers from taking land out of production to install streamside buffers that provide habitat and filter pollutants from the stormwater runoff that flows from fields. It is then difficult for government assistance programs to offer payments to create such buffers that are high enough to make them attractive to farmers.

3.1.3 Forest Products

Forest products include a wide diversity of commodities and manufactured items such as building materials, paper, maple syrup, and furniture. The importance of specific forest products-related industries to local economies varies from one part of the basin to another. In Vermont, Caledonia, Orleans, and Windsor counties each account for 14% of the volume of sawlogs produced in the state. Of those, Orleans is considered a basin county, and about half of the county lies within the basin. In the New York portion of the basin, a significant amount of the land area is classified as commercial forestland: Clinton County (69%), Franklin County (61%), Essex County (48%), Warren County (59%), and Washington County (48%).

Maple syrup contributes significantly to local rural economies in the basin. In 1999, Vermont was the largest maple syrup producing state in the nation, accounting for 31% of the total US maple production. Vermont's maple syrup production was valued at US$10.5 million in 1999, while production in the New York portion of the Lake Champlain basin was valued at US$1 million.

Manufacturing of paper and paper products makes a significant economic impact on rural economies as well. For example, in 2000, International Paper's Ticonderoga Mill employed 690 people and had a payroll of US$36 million. In 2000, the mill purchased more than US$30 million in goods and services in the Ticonderoga area of New York State. The mill also purchased US$20 million of fiber, wood chips, and bark from the Adirondack region, and 285 private truckers were involved in bringing wood to the mill. In 1997, the mill received the New York State Governor's Award for Pollution Prevention for eliminating chlorine and hypochlorite in its pulp bleaching process, resulting in reduced dioxin and chloroform emissions.

According to recent research on the forest-based economy of the northern forest region of New York, Vermont, New

Hampshire, and Maine, jobs in lumber, wood, and paper products have declined from 1987 to 1997. There is local evidence of that decline in the closing of several sawmills and plywood mills during 2000-2001 in the New York portion of the basin, and related reductions in the workforce in paper mills in the region. However, wood manufacturing of value-added products, such as furniture, is a growing and strong economic sector (LCBP 2003).

The forest products industry is clearly a large economic driver in the basin. It is important to encourage sustainable forestry practices that also balance consumptive use, recreational access, and wildlife habitat values in the basin's forests. Expanding the production of value-added products from forests that are managed in a sustainable manner will add revenue to the local economy while reducing pressure to use practices that produce short-term profits at the expense of long-term economic stability and balanced use of forest resources.

3.1.4 Population, Development and Land Use Change

A major landscape issue facing the basin is known as sprawl, a cumulative development process that results from the incremental growth of low density, single-use development, typically scattered along a highway. Sprawl generally begins at the edge of traditional community centers and moves outward into previously rural areas, requiring new or larger roads, water and sewer capacity, and utility lines. Although sprawl is not a new phenomenon in the basin, the amount and rate of this form of development has made it a topic of concern and study.

The effects of sprawl often include water quality degradation from increased urban runoff and wetland losses. As the landscape becomes increasingly fragmented, wildlife habitat, farmlands, and forests also become less productive. The discussion of both the positive and negative impacts of sprawl on the landscape, culture, and economy of the basin has taken on a new sense of importance in view of recent development trends. Information about land use change is an important resource for communities to guide their own economic destiny and to ensure the future quality of life in the basin. To this end, the Lake Champlain Basin Program has characterized the land cover and land use of the basin, using data from 1993. Updated land use information and new "smart growth" initiatives will be increasingly important for local municipalities (LCBP 2003).

Population change can be an indicator of economic activity—or lack of economic opportunity—and can indicate high growth areas where land use planning is needed to protect water quality. Preliminary 2000 Census data indicates that approximately 45% of Lake Champlain basin residents live in lake shoreline towns. As shown in Table 2, the Vermont portion of the Main Lake area, which includes the Winooski River basin and contains the cities of Burlington and Montpelier, comprises almost one-half of the population in the basin (47%). The other main population center is the Plattsburgh area of New York which includes the Saranac and Chazy River basins where 15% of the population resides. Between 1990 and 2000, high growth areas included Mallets Bay, Lake George, Missisquoi Bay, and the Inland Sea watershed areas (LCBP 2003).

Seasonal residents and visitors are also very important to the basin economy. According to the 1990 Census data, there were 38,530 seasonal homes in the basin, or approximately 14.6% of all basin housing units. Approximately 9,118 of the seasonal homes are located in the Lake Champlain shoreland areas, representing 24% of all seasonal homes in the basin. These seasonal homes bring a large population increases to parts of the basin each summer.

3.2 Pressures from Outside of the Basin

3.2.1 Air Deposition of Pollutants

In addition to pollutants generated by activities within the Lake Champlain basin, mercury, PCBs (polychlorinated biphenyls) and other pollutants from sources hundreds of miles away travel through the air and are deposited to the land and water of the basin. According to the United States Environmental Protection Agency (USEPA 2000), atmospheric deposition is a significant source of certain pollutants to Lake Champlain and other surface waters in the United States. These pollutants

Table 2. Population Change in Lake Champlain Watershed Areas, 1950 to 2000.

Lake Champlain Lake Segment/Watershed	Percent Change					
	1950-60	1960-70	1970-80	1980-90	1990-2000	1950-2000
Missisquoi Bay	-6.4	3.2	13.6	10.7	11.4	35.4
Inland Sea	5.0	7.3	5.2	14.7	10.6	50.3
Mallets Bay	1.3	43.2	37.2	20.1	16.1	177.4
Broad Lake, VT	8.3	18.4	11.4	9.5	7.4	67.9
South Lake, VT	13.0	-0.2	11.7	10.6	6.5	48.6
South Lake, NY	-2.5	8.5	2.0	10.2	3.8	23.5
Lake George	29.5	14.9	12.2	-3.2	13.6	83.7
Broad Lake South, NY	7.7	-2.1	9.8	5.5	5.2	28.5
Broad Lake North, NY	30.3	-2.3	10.8	6.2	-6.1	40.6
Total Change	10.2	11.4	12.7	9.8	6.1	61.1

Source: LCBP (2003).

may occur at levels that can be harmful to both human and ecological health. For humans, the risk is greatest for those who consume large amounts of fish. Although it appears that the amount of deposition of mercury and other pollutants is decreasing or holding steady, it is likely that atmospheric deposition will continue to be a source of several pollutants for some time to come and that they will continue to be found in water, sediments, and biota.

The USEPA (1997) has concluded that coal-fired power plants and municipal trash incinerators are the two largest sources of mercury emissions in the United States, and that the Federal Drug Administration "action level" for mercury consumption must be lowered to adequately protect human health. The states in the northeastern United States and the eastern Canadian Provinces have joined forces to develop a Mercury Action Plan which sets a goal of virtual elimination of man-made mercury releases in the region (USEPA 2000).

The release of sulfur (SO_2) and nitrogen (NO_X) compounds from fossil fuel combustion can create acid deposition (also known as acid rain). The source of nearly two-thirds of the SO_2 and one-fourth of all NO_X is from electric power generation using fossils fuels such as coal. While in the air, these pollutants can reduce visibility and be harmful to human health. When they fall to earth, either in rain, fog or snow, or as particles and gases, they cause acidification of surface waters, and can damage trees, soils, and building materials. The United States Federal Clean Air Act Amendments of 1990 set a goal to reduce annual SO_2 emissions by 50%, and annual NO_X emissions by two million tons, compared to 1980 levels, primarily through restrictions on fossil fuel-fired power plant emissions in eastern and midwestern states (USEPA 2002).

3.2.2 Non-native Aquatic Nuisance Species

As discussed above, controlling the introduction of non-native aquatic nuisance species from outside the basin is a key part of protecting the Lake Champlain basin ecosystem. Additional safeguards, educational efforts, and intergovernmental coordination are needed to restrict further introduction of these species as many of them are inadvertently transported here by people from regions outside of the basin.

4. Policy, Legislative and Institutional Reforms

Managing the natural and cultural resources of the Lake Champlain basin is a complex undertaking. Various management agencies and programs have made significant progress in areas such as controlling point source discharges of pollution from industry and wastewater treatment plants and strengthening the lake's sports fishery (LCBP 2003). The Clean Water Act (i.e., Federal Water Pollution Control Act of 1972 and subsequent amendments) has been the driving force behind many of the water quality improvements for the past three decades. However, effective management of these resources requires action from all levels of private and public organization, from homeowners and businesses, from local governments, and state and federal agencies.

4.1 The Lake Champlain Basin Program

To address the need for cooperative, basin-wide management, the Lake Champlain Basin Program (LCBP) was created by the United States Congress through the Lake Champlain Special Designation Act of 1990 (Public Law 101-596). The LCBP is a partnership among the States of New York and Vermont, the Province of Québec, the USEPA, other federal and local government agencies, and many local groups, both public and private, working cooperatively to protect and enhance the environmental integrity and the social and economic benefits of the Lake Champlain basin (LCBP 2003).

Steppacher and Perkins (1999) have summarized the formation and workings of the LCBP through the management plan development phase. Following previous management efforts, the Special Designation Act called for a comprehensive planning process that would involve stakeholders with diverse interests throughout the basin. It also encouraged the process to consider the interconnected nature of the Lake Champlain basin ecosystem, from plants to animals and humans. The 31-member Lake Champlain Management Conference (LCMC) was initiated in 1991 to lead the planning effort, including development of a comprehensive plan, conducting research and monitoring studies, and implementing an education and outreach program.

In 1996, the LCMC completed the management plan, *Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin*. The LCMC dissolved and the leadership of the LCBP was passed on to an expanded Lake Champlain Steering Committee established in the 1988 MOU. Howland (2001) has described the structure and operation of the LCBP in the current plan's implementation phase. Like the LCMC, the Steering Committee is comprised of a broad spectrum of representatives of government agencies, the chairs of advisory groups representing citizen lake users, scientists, and educators. These advisory groups include: a Technical Advisory Committee, composed of resource managers, physical and social scientists, and economic experts; Citizens Advisory Committees from New York, Vermont, and Québec; an Education and Outreach Advisory Committee; and a Cultural Heritage and Recreation Advisory Committee. The LCBP continues to be jointly administered by the USEPA, the States of Vermont and New York, and the New England Interstate Water Pollution Control Commission. Other cooperating agencies include the US Fish and Wildlife Service, the US Department of Agriculture, the US Geological Survey, the National Oceanographic and Atmospheric Administration, and the National Park Service. The Province of Québec is also represented on the Steering Committee and each of the advisory committees.

4.2 Strengths and Successes

4.2.1 Partnerships

The success of the LCBP is rooted in the maintenance of partnerships and collaborations, a multiple stakeholder

approach, sharing of information with the public, and basing management decisions on good science (LCBP 2003; Stickney et al. 2001). Successful implementation of the management plan is achieved by developing many partnerships among natural resource agencies, citizens, and other lake and watershed stakeholders throughout the basin (LCBP 2003). The first revision of the management plan was a two-year process that began in 2001 and relied extensively on partnerships with stakeholder groups, public meetings and citizen involvement. Stakeholder involvement in the revision of the management plan is described by Howland and Hoerr (2002).

Since its inception, the LCBP has evolved into an internationally recognized natural resource management initiative characterized by inter-jurisdictional management, and the enhancement of the stewardship role of local leaders (Stickney et al. 2001). Transboundary relations are guided by a sequence of nonbinding, nonregulatory consensus-based agreements. Since the 1988 Memorandum of Understanding, 14 additional agreements have been signed, ranging from joint declarations and watershed plans to in-lake phosphorus criteria and toxic spill responses. These agreements are typically renewable and this incremental approach has enhanced cooperation and trust among the jurisdictions (Stickney 2003; Harris et al. 2001).

4.2.2 Consensus

Principles of consensus and trust-building helped overcome initial policy differences among the three jurisdictions during the plan development phase, and they are still being utilized today. This approach to decision-making creates a "win-win" atmosphere where minority opinions are normally incorporated into Steering Committee decisions, and motions pass by unanimous vote, reflecting the full consensus of the group. However, on rare occasions when consensus is not possible, votes are held and the majority prevails. The latter prospect provides an incentive for all parties to work assiduously to achieve consensus, while ensuring that timely decisions may be made. The LCBP process encourages open and public discussion, with subsequent meeting summaries (but without recorded transcript), so that committee members can freely explore decisions before making commitments.

Many management policy debates arise from different perspectives on issues about which there is inadequate information. Flexibility in the decision-making process has enabled the LCBP to take an adaptive management approach to difficult issues. When scientific information is not adequate to guide a management decision, the LCBP allocates funds to support focused and timely research or monitoring to address the knowledge gap. When the needed information thus is made available, an appropriate management decision may be more easily reached by the group. In this way, research and monitoring has an essential role in informing policy development.

The consensus building process gives all participants a meaningful role in developing viable solutions and results in a sense of group ownership of decisions that is unattainable through other means. While the consensus process employed by the LCBP tends to minimize the polarization of hard ideological positions, it does require that common goals (such as drinkable, swimmable waters) be shared by all participants. The motivating influence of the policy accord expressed by the Governors and the Premier in the 1988 MOU (reaffirmed in 2003) and in the management plan *Opportunities for Action* (2003), together with the universal appeal of a clean lake and a thriving economy, can hardly be overstated.

5. Constraints to Environmentally Sound Management

5.1 Investments

Since the establishment of the LCBP, efforts to protect and preserve the resources in the Lake Champlain basin have been well-supported by the States of New York and Vermont, the Province of Québec, and the US federal government, as well as local governments, businesses, and citizens. Because funding support for activities related to Lake Champlain basin resource protection comes from such varied sources, it is difficult to quantify exactly the level of funding committed each year. Highlights of typical funding are presented below. Note that the funds below are in addition to those spent through the base operations of local, state, provincial, and federal agency programs.

- From 1991-2001, Vermont has spent over US$20 million dollars on reducing phosphorus discharges from municipal wastewater treatment plants in the Lake Champlain basin. During the same period, New York spent over US$10 million dollars building and enhancing wastewater treatment plants. From 1991-1998, Québec invested over US$13 million in wastewater treatment plant construction for areas discharging to the Lake Champlain basin and Richelieu River (LCBP 2000).

- Approximately US$9.6 million was applied to controlling nonpoint sources of phosphorus in the Vermont portion of the basin between 1996 and 2001. The funds supported cost-share projects with farmers. About 58% of the funds came from the US federal government (United States Department of Agriculture—Natural Resource Conservation Service), 22% from Vermont, and 20% from farmers. New York has committed over US$15 million to environmental projects in the basin through the Clean Water/Clean Air Bond Act of 1996 and the Environmental Protection Fund. Québec spent nearly US$1.8 million to help farmers manage manure in the Lake Champlain basin, representing 70% of the total project costs that were shared by farmers (LCBP 2000).

- The USEPA generally provides US$1-2 million annually toward operation of the Lake Champlain Basin Program office and its technical and local grant projects. Additional EPA funding has been directed toward wastewater treatment plant upgrades in the basin,

stormwater management demonstration projects, and development of a lakefront laboratory and science museum.

- The US Army Corps of Engineers (USACE) generally provides about US$400,000 annually toward invasive species management, primarily for the harvesting of nuisance aquatic plants. In recent years, the Corps also has provided additional funds for restoring the Burlington Harbor breakwater. The USACE is presently working with the LCBP to develop a Corps General Management Plan for Lake Champlain that will bring significant new funds (US$500,000 in 2004) to the support of *Opportunities for Action* and an enhanced partnership with the Corps.

- The US Geological Survey spends US$400,000-500,000 annually on Lake Champlain tributary flow gauging and research projects.

- The USDA NRCS has spent about US$300,000 annually since 2001 on research and demonstration of alternative manure management techniques. Many of these programs have been managed by the LCBP on behalf of the NRCS.

- The National Oceanic and Atmospheric Administration (NOAA) has provided US$150,000 annually toward research in hydrodynamics and atmospheric processes, awarded on a competitive basis through the Lake Champlain Research Consortium. The NOAA also contributes approximately US$150,000 annually for the Lake Champlain Sea Grant program in New York and Vermont.

Despite these commitments, significantly expanded funding is needed to meet the goals that have been set for protecting and restoring the Lake Champlain basin's resources.

- Preliminary cost estimates from *Opportunities for Action* (LCBP 2003) suggest that implementing actions in the plan will require at least US$12 to US$15 million annually, and at least US$170 million for the period through 2016. Estimates were not developed for all actions.

- In 1999, it was estimated that over US$62 million would be needed to implement phosphorus management on all remaining farms in the Vermont portion of the basin. However, additional nonpoint or point source phosphorus controls will be needed to achieve the phosphorus goals in sub-basins where farm treatments are not expected to result in the needed load reductions (LCBP 2000).

- Québec has estimated that implementing needed erosion control projects for nonpoint phosphorus control would cost nearly US$14 million (LCBP 2000).

- An estimated US$139 million will be needed to fully implement the TMDL phosphorus reduction plan for the Vermont sector of the Lake Champlain basin (VTANR and NYSDEC 2002). The timeline for achieving phosphorus load reduction goals has been accelerated (from 2016 to 2009) by Vermont and Québec largely in response to the increasing blue-green algae problems in the Missisqoui Bay, a part of the lake shared by these two jurisdictions. Annual recommendations by the Technical Advisory Committee and its workgroups for vital technical projects needed to implement *Opportunities for Action* are typically many times the amount available for such projects.

- The total annual amount of technical and local grant project proposals to the Lake Champlain Basin Program is typically four times the amount available for such projects.

5.2 Human Resources and Institutional Capacity

The Lake Champlain basin is fortunate to have a broad assemblage of committed and knowledgeable people who are interested in protecting the basin's resources, from local citizens joining in wildlife monitoring programs and cleanup days, to watershed and lake groups planting vegetation along streambanks and shorelines, to professional scientists and managers studying water quality and restoring cultural treasures. Over the past decade, these individuals have become increasingly skilled and effective in their work.

Many of the actions included in Opportunities for Action call for greater coordination among the groups working on particular issues. Dedicated human resources are generally needed to provide the level of coordination needed to address issues through a cooperative process that brings together the strengths and resources of participating partners.

- The Lake Champlain Basin Program supports several staff positions involved in coordination work. The LCBP also helps to support a number of state agency staff positions involved with particular aspects of implementing *Opportunities for Action*. Lastly, the LCBP supports the staff of local watershed, cultural and recreation groups, primarily through project grants, but also through small professional development and organizational support grants (Figure 8).

- Vermont has hired several basin planners to oversee watershed planning in river basins throughout the state, including those in the Lake Champlain basin. These efforts are being coordinated with the LCBP and are consistent with *Opportunities for Action*.

- Federal funds have been made available for controlling pollution from agricultural sources, but these funds are often restricted to costs related to design and construction of waste storage structures. Additional

funding or expanded access to existing funding is needed to provide the technical staff who plan and implement projects and provide services such as developing Comprehensive Nutrient Plans that will also significantly reduce agricultural pollution in addition to structural approaches.

- The state environmental conservation agencies in the basin have minimal staff resources to administer and enforce the environmental regulations under their purview. Additional staff are needed to facilitate sub-watershed level planning and assessment work. Additional staff are also needed to address stormwater pollution. Stormwater management and permitting issues have recently become litigious in the basin.

- Small watershed and lake associations engage numerous restoration and education activities, often with funding from small grants and member contributions. It is often difficult for these groups to consistently maintain even part-time staff to oversee their operations, implement projects, and provide a point of contact for ongoing business. Organizational Support Grants from the LCBP in recent years have done much to build capacity that will make these small organizations become fully functional and sustainable. Additional funding is needed to sustain these local groups.

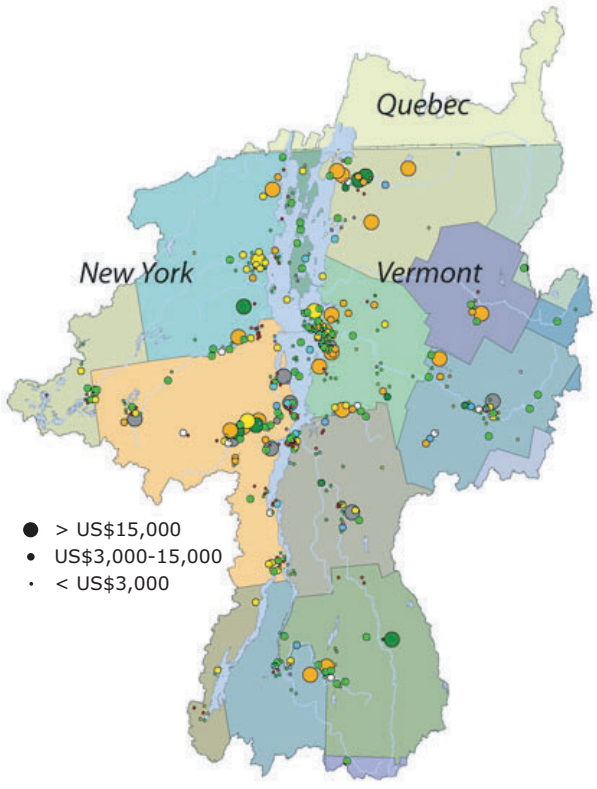

Figure 8. Lake Champlain Basin Program Local Grants Projects, 1992-2002 (Source: Adapted from figure available at http://www.lcbp.org).

6. Lessons Learned

6.1 Involve Stakeholders in the Design and Implementation of Programs

A diverse array of stakeholders participate in the management of Lake Champlain basin's resources, from citizen watershed groups concerned about the health of their local streams to government agencies mandated to implement the laws designed to protect these resources. These stakeholders understand the close connection between the condition of the basin's resources and their quality of life, including economic opportunity, health, heritage, and aesthetics. Because stakeholders have been involved from the beginning of the planning process, they have shown a greater acceptance of the policies and actions developed, and a greater willingness to form partnerships to work toward implementation.

The Lake Champlain Basin Program sponsored 28 formal public meetings around the basin while developing the first version of *Opportunities for Action*, and countless informal meetings. A similar process was used when *Opportunities for Action* was revised in 2003. Hundreds of local citizens and representatives of various organizations attended these meetings and provided comments on draft plan materials throughout the planning process. The Lake Champlain Management Conference also established a series of advisory committees, subcommittees, and workgroups whose members represented the various interests associated with specific areas of the plan. LCBP staff and committee members made presentations and conducted outreach activities for hundreds of groups during the five-year planning phase.

The LCBP continues to invite stakeholders to participate in its annual budget planning process, soliciting advice on management priorities and ideas for projects related to implementing the management plan. The LCBP's Technical Advisory Committee (TAC) plays a key role in informing the development of policy by the Lake Champlain Steering Committee, especially through recommendations of scientifically sound approaches to management issues in the basin. Steering Committee policies characteristically reflect the technical advice provided by the TAC.

Local river and lake associations play a key role in organizing watershed protection efforts (LCBP 2003). These associations accomplish a great deal through education and outreach programs, participation in local planning, development reviews, and citizen monitoring and restoration activities. Watershed associations also act as catalysts for developing nonregulatory protection programs. River and lake associations can encompass several local jurisdictions, sometimes even spanning state boundaries. Watershed associations work closely with local government, where most land use planning occurs, respecting a wide variety of interests, including property rights, environmental protection, and economic development.

Local capabilities for watershed planning vary greatly throughout the basin in both New York and Vermont. In some areas (often near urban centers), municipalities have already developed watershed plans and instituted aggressive water quality protection measures—Lake George, New York provides a good example of aggressive lake protection. Municipalities in these areas typically benefit from ongoing technical support from local staff, watershed associations, regional planning commissions, county planning offices, or conservation districts. In other parts of the basin, municipalities have very limited local capacity for any type of planning or land use regulation. Working in partnership with willing landowners is especially productive as most land in the basin is privately owned.

The LCBP has been supporting increased communication between local groups in the basin. It has sponsored several meetings each year where representatives from these groups can gather to share ideas and receive training on a topic of common concern, from water quality monitoring to increasing membership. The LCBP also publishes an annual newsletter which includes information about watershed group activities.

The sustainability of lake management institutions in the Lake Champlain basin, from small groups working on sub-watersheds to the Lake Champlain Basin Program, relies on continual participation of stakeholders in both planning and implementing management projects. Although the activities of local watershed associations and other groups are primarily conducted by volunteers, to maintain these efforts over the long-term it is often critical for these organizations to retain paid staff to coordinate planning, recruit volunteers, and seek funding for projects. Without such staff, it can be difficult for these groups to build and sustain the momentum that comes from implementing successful projects and gaining technical and logistical expertise. LCBP supports these organizations through several grants programs, including a general operating support grant program, available only to watershed associations, designed to assist with the daily operating expenses so critically important to their success.

The LCBP has continued to ensure strong participation of its stakeholders through strengthening representation on its steering and advisory committees. Effective governance of the LCBP and the optimal management of the natural resources of the basin are achieved through consensus-based decision-making that accords a vital role to non-governmental stakeholders, primarily citizen leaders in the basin (Stickney et al. 2001; Drost and Brooks 1998). The key to sustaining stakeholder interest in cooperative management is to ensure that stakeholder concerns are heard, taken seriously, and included in the process leading toward management decisions. For implementation to occur, the key stakeholders representing the logistical, technical, and political aspects of any decision must be involved in the decision process, increasing the likelihood of them being informed supporters during implementation. Stakeholders will continue to engage in these efforts only if they see some value-added result from what can be a significant investment of their time and resources.

6.2 Strengthen the Knowledge of Basin Residents and Visitors

Since watershed-level management is a voluntary process, education and outreach efforts are essential to building stakeholder awareness and interest in participating in the Lake Champlain Basin Program. The LCBP has had a strong education program from the beginning, complementing the planning and technical work in the basin. Three examples include the Lake Champlain Basin Program's Resource Room within ECHO at the Leahy Center for Lake Champlain; Champlain 2000, a media partnership between a local television station, a business sponsor; and the LCBP newsletter, *Casin' the Basin*. These three resources provide citizens and educators access to Lake Champlain information in person, on weekly television news segments and quarterly programs, on the internet, or mailed to their homes and businesses. Over 125 local projects have been featured (LCBP 2003). The LCBP employs an Education and Outreach Coordinator and a Communications and Publications Coordinator, who make nearly 200 presentations a year to school groups. LCBP staff at the Resource Room assist nearly 2,000 visitors per month, a significant (14%) fraction of the total visitor volume at ECHO at the Leahy Center. Additionally, the LCBP distributes several important fact sheets on specific issues challenging the health of the basin.

6.3 Policy Must be Based on Sound Science and a Strong Monitoring Program

The Lake Champlain Basin Program has always sought to base planning and policy decisions for the basin on sound scientific information. Without this strong foundation in sound science, a watershed management program will not succeed. Nearly two dozen representatives from the technical community throughout the basin have been brought together in a Technical Advisory Committee (TAC) to examine the scientific issues of every major policy question, and to provide guidance to the Steering Committee in policy and budget development each year. The TAC also reviews research and implementation projects to ensure both scientific merit and successful conclusion. Moreover, the Technical Advisory Committee is chaired by a non-governmental scientist who maintains a seat on the Lake Champlain Steering Committee.

On scientific questions, the Technical Advisory Committee, speaking through its chair, is the sole advisor to the Steering Committee concerning the technical and scientific merits of policy alternatives and also concerning detailed task specifications in the budgeting process each year for funded programs. This strength, that scientific expertise is systematically brought to the policy-generating body, gives relevance and credibility to the entire program and ensures that management policy is continually informed by sound science. Budgeting and funding decisions are, however, made exclusively by the Lake Champlain Steering Committee.

In 1992 the LCBP and Lake Champlain Research Consortium co-sponsored a workshop to review existing technical information and to set a research and monitoring agenda (LCRC 1992). From that time to the present, consistent funding has been directed to technical projects that provide key information to inform management decisions. During the development of *Opportunities for Action*, several critical information gaps were recognized, and research and monitoring projects were designed, funded and completed, to extend the knowledge base of environmental conditions in these areas. After the plan was completed in 1996, research and monitoring were continued, both in the form of targeted projects investigating particular issues, and ongoing monitoring designed to document the long-term trends in the quality of the basin's resources.

Continued funding and support for research and monitoring is an essential part of watershed management. A strong research and monitoring program serves to build on what is known about the ecological processes of the basin, track progress toward management goals, facilitate adaptive management, and address emerging issues.

6.3.1 Monitoring

Monitoring environmental conditions in the lake and basin is an essential component of measuring the success of lake and watershed management efforts and typically requires up to US$300,000/year, or 15% of the annual EPA funds available to the LCBP. Additional funds from the USEPA, the Department of Agriculture and the Department of Interior also are directed to monitoring the effectiveness of agricultural and urban best management practices. The US Geological Survey regularly funds stream gauging stations in the basin that provide critically important tributary discharge data. Monitoring data provide information on natural processes occurring in the lake, basic characteristics of the ecosystem, long-term water quality trends, and the effectiveness of selected management actions. This information is essential for understanding how human activities, including management actions, affect the lake (LCBP 2003).

Monitoring projects in the basin have been designed for a variety of purposes and cover a wide range of topics from forest health and biodiversity to atmospheric and surface water quality. Ongoing monitoring projects include the Lake

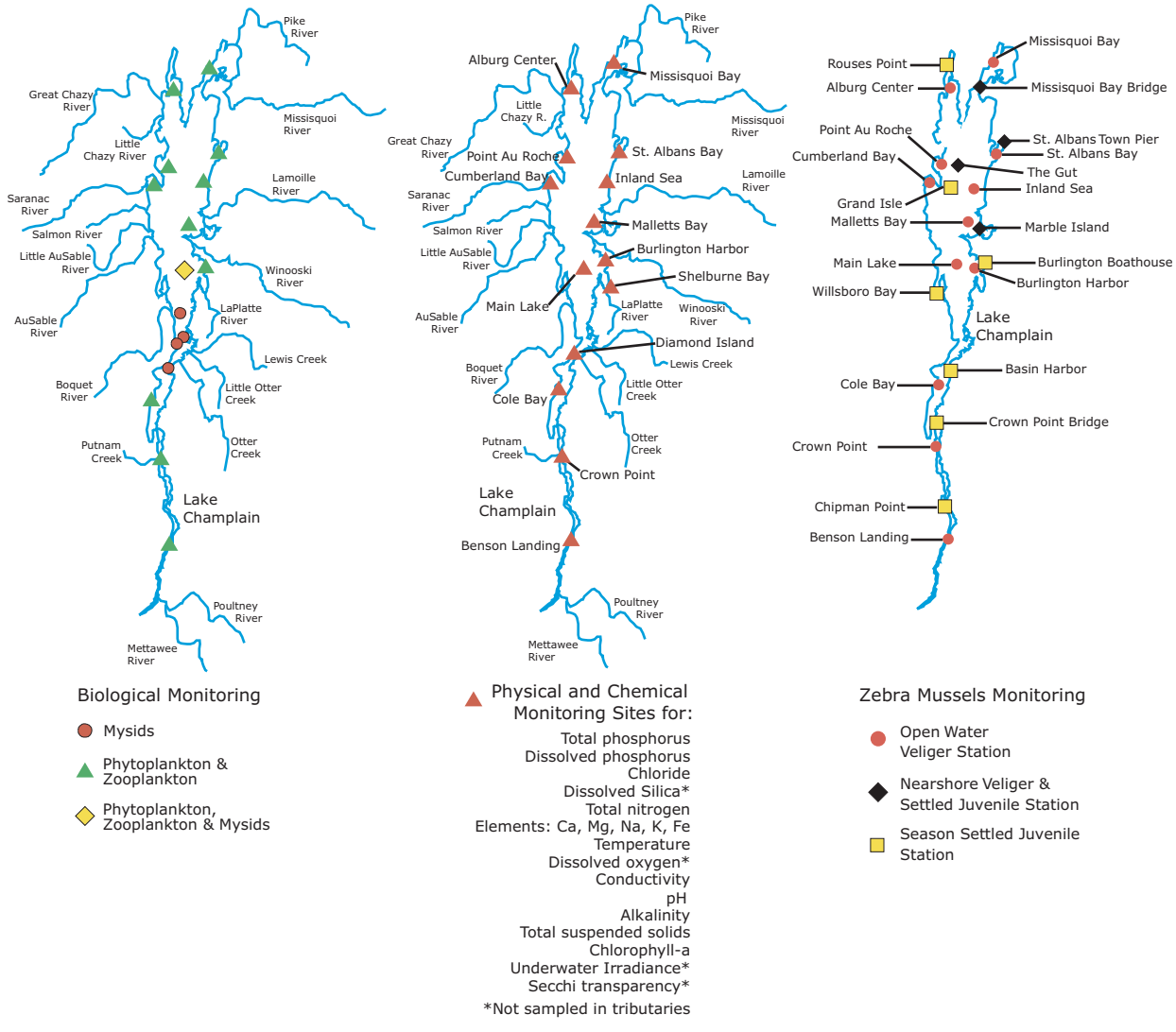

Figure 9. Monitoring Sites (Source: Adapted from figures available at http://www.lcbp.org).

Champlain Long-Term Water Quality and Biological Monitoring Program, the Lake Champlain Zebra Mussel Monitoring Program, and the Vermont Lay Monitoring Program. The distribution of these sampling locations is presented in Figure 9. The Lay Monitoring Program has conducted lakewide monitoring of eutrophication parameters during the summer season using citizen volunteers every year since 1979. It is the second oldest citizen monitoring program in the United States, and information collected by these citizen monitors has been used to develop state water quality standards.

6.3.2 Indicators

Indicators use monitoring data for key aspects of the basin's ecosystem, such as phosphorus concentrations or the type and abundance of zooplankton species, to help detect ecosystem change and enable adaptive resource management that is responsive to such changes. For example, data demonstrating declines or increases in an indicator species could provide information about similar declines of associated species, thus providing early notice of the need for management action. The Lake Champlain Basin Program is sponsoring a project that will more clearly link management goals and objectives to ecological indicators and will better inform and guide management actions. The indicators will be presented in an understandable manner, allowing them to be used to track and report progress toward management goals to both the management community and the public (LCBP 2003).

A list of selected projects recently supported by the Lake Champlain Basin Program is presented below. A complete list of technical reports from completed projects is available at the Lake Champlain Basin Program's website, www.lcbp.org. Note that additional research and monitoring is being conducted by state and provincial agencies in the basin, as well as private organizations.

- Lake Champlain Basin Phosphorus Studies (Hughes et al.; 1999; VTDEC and NYSDEC 1998; Hoffmann et al. 1996; VTDEC and NYSDEC 1994).
- Lake Champlain Basin Economics Studies (Holmes & Associates 1993; Holmes & Associates and Artuso 1995; Holmes & Associates and Artuso 1996).
- Lake Champlain Sediment Toxics Assessment Program (Callihan et al. 1998; McIntosh et al. 1994 and 1997).
- Lake Champlain Nonpoint Source Pollution Assessments. These assessments estimated the relative contributions of phosphorus to the lake and tributaries from major land uses in the basin (Hegman et al. 1999; Pease 1997; Budd and Meals 1994).
- Lake Champlain Wetlands Acquisition Study (Binhammer 1994).
- Lake Champlain Food Web Studies (Levine et al. 1997; LaBar and Parrish 1996).
- Development of Land Cover/Land Use Geographic Information System Data Layer for the Lake Champlain Basin (Millette 1997).
- Lake Champlain Underwater Cultural Resources Survey (McLaughlin et al. 1998).

6.4 Integrate Economic Goals with Environmental Goals

During the early 1990s, the LCBP developed an economic database for the Lake Champlain region based on the results of the 1990 census. The database provides important information on employment by industry and occupation, as well as economic activity generated by agriculture, forestry, mining, and other natural resource-based industries. The study also analyzed the regional tourism economy and the economic benefits generated by various recreational activities, such as fishing, hunting, hiking, and camping. Data on tourism from Québec and use of Lake Champlain by Québec boaters were also gathered (LCBP 2003). Although more recent data was collected in 2001, the early 1990s database must be maintained with current information so that the economic aspects of resource management can be tracked and understood as management actions are implemented.

6.5 Foster the Long-Term Capacity of Lake Organizations

The capacity of the organizations in the Lake Champlain basin to engage in effective resource stewardship has increased along with the skills of their staff and volunteers. The Lake Champlain Basin Program has continued to strengthen its coordinating role by expanding its Steering Committee to include more representation from local municipalities and the Province of Québec. It has reconfirmed and expanded its Technical Advisory Committee, continued its Education and Outreach, and three Citizens Advisory Committees, and added a new Cultural Heritage and Recreation Advisory Committee in recent years.

The LCBP has also increased its support for local organizations through small professional development grants for staff and board members. In 2001, the LCBP initiated a new category of competitive grants designed to help increase organizational capacity. These grants cover costs related to planning and developing new projects or follow-up monitoring and maintenance of completed projects, as well as staffing, supplies and printing for an organization's recurring educational activities. Vermont and New York also offer grants to local groups for a variety of projects. Unfortunately, the number of good projects requesting funds from these grant programs far exceeds the available funding.

6.6 Diversify Funding Sources through Innovative Partnerships

The Lake Champlain Basin Program has continued to diversify its federal funding base in recent years. In addition to base funding from the USEPA, several other federal agencies also are involved in the cooperative partnership to implement *Opportunities for Action*, with several providing contributing funding annually. Annual Congressional earmarks and clear legislative intent that cooperation be effective has been a consistent enabling factor that has fostered interagency partnerships, mutual trust among key staff, and strong cooperative traditions among federal agencies. The development of cost estimates and clear prioritizations for resource management actions, such as those highlighted above, allow the Congressional delegations from New York and Vermont to be effective in funding initiatives through the various federal agencies.

Federal funding supports portions of the coordination, technical, and outreach activities of the LCBP partners. A significant portion of this funding is passed on to nongovernmental groups working on local issues throughout the basin through various LCBP grants. With grant support, local groups are able to conduct projects and outreach activities of their own, often resulting in increased interest, participation, and financial support from local citizens and businesses.

Examples of how public and private investments have been combined to develop a Lake Champlain focused project include the Patrick and Marcelle Leahy Center for Lake Champlain. The Leahy Center partnership consists of the University of Vermont's Rubenstein Ecosystem Science Laboratory, ECHO lake aquarium and science center, Lake Champlain Basin Program Resource Room, LakeNet's global network, Lake Champlain Sea Grant Watershed Alliance, and the Lake Champlain Navy Memorial. Funding for the components of the Leahy Center has come from private donors, the federal government, and other supporting organizations.

The LCBP has also formed an outreach partnership with WPTZ, a network television affiliate in the basin, and a sponsor, KeyBank, called *Champlain 2000*. *Champlain 2000* features weekly news segments and occasional 30-minute specials on lake-related topics. The features, specials and promotional material aired for the project regularly reach millions of viewers in the basin, with the costs shared between the three partners.

6.7 Link to International Watershed Management Activities

Like similar watershed programs for the North American Great Lakes and the Chesapeake Bay, the Lake Champlain Basin Program has been studied as an international model for lake basin and watershed management. Participants in the program represent citizens, scientists, businesses, universities, and governments from the local to regional to federal level.

The Memorandum of Understanding on Lake Champlain of 1988 and the Water Quality Agreement of 1993 signed by Vermont, New York, and Québec are examples of non-binding transboundary covenants. The MOU created a mechanism for the exchange of scientific information and encourages cooperative planning for watershed protection. It established the Lake Champlain Steering Committee with diverse representation among the three jurisdictions and established a role for three citizens advisory committees. The MOU is a five-year renewable agreement and was most recently reaffirmed by all parties in 2003. The MOU facilitated the creation of the 1991 Emergency Spill Response Joint Procedure which mandates rapid notification and a coordinated response to toxic spills among Vermont, New York, and Québec. Similarly, the voluntary 1992 Permit Exchange Agreement between Vermont and New York has facilitated the exchange of regulatory information when permitting issues have caused transboundary concerns (Stickney 2003).

The LCBP is a member of LakeNet, a global network of organizations in over 100 countries created in 1996 that is dedicated to the conservation and sustainable development of lake ecosystems. Bonds between these programs are quite strong, as the LCBP's Manager is a member of the LakeNet's International Steering Committee and the Chair of the Vermont Citizens Advisory Committee serves as a Trustee. Saint Michael's College of Vermont is a partner with LakeNet implementing a grant from USAID to support the Lake Basin Management Initiative.

Lake Champlain also enjoys sister lake exchange programs with Lake Ohrid in FYR Macedonia and Albania, and Indonesia's Lake Toba. The Lake Champlain Basin Program was selected by the Macedonians and Albanians as a model for transboundary relations, since Lake Ohrid is also shared by two countries. The Sister Lake Declarations of Intent signed between Lake Champlain and Lake Ohrid (1996) and Lake Toba (1996) were modeled after the Memorandum of Understanding for Lake Champlain among Vermont, New York, and Québec. Exchanges of policy leaders and technical experts among the countries have focused largely on how business is conducted and how to overcome conflict and cultural differences (Stickney 2001).

7. Summary

The LCBP has evolved as an effective international natural resource management partnership. This partnership is characterized by a regime of mutually agreeable principles, rules and decision-making procedures that govern the interactions of the stakeholders from the three jurisdictions. The key driving force that sustains the LCBP has been the continuous Congressional leadership with requisite legislative authorizations and annual appropriations to federal agencies that provide the essential funding to clean up Lake Champlain. State and Provincial involvement through staffing, matching funds and direct financial support for management activities has reflected the sustained leadership of the Governors of New York and Vermont and the Premier of Québec. Heightened

public concern for the future of the lake and the regional lake-based economy, and informed involvement on the part of citizens, businesses and local leaders, has evolved within a context of civic responsibility that bodes well for the future.

The LCBP, as a management partnership, is designed to address transboundary problems and to promote cross-boundary cooperation at the watershed level. This watershed approach to policy development and plan implementation avoids a top-down management style by enhancing voluntary and collaborative problem solving to achieve the regional, national and international environmental objective of sustained clean water in the Lake Champlain basin.

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