2
History of Key Uses of the Great Lakes

The Great Lakes inspire evocative language and hyperbolic metaphors. Samuel de Champlain called these massive fresh waters the "sweet seas." Two hundred years later, the American explorer Henry R. Schoolcraft wrote of the "riches of the soil and the natural beauty of the country" on the "bold shores" of the Saginaw Valley in the Territory of Michigan. In 1996, the historian Pierre Berton (1996, 18) would write lyrically:

> Each inland sea is like a small nation in its infinite variety. Each has its own character ... I see Superior ... as remorseless and masculine. Huron, with its thirty thousand islands, reminds me of a fussy maiden aunt. Michigan, half wild to the north, heavily industrialized to the south, is an errant uncle. Erie is a wilful ingenue of changeable mood and false promise. Ontario is a complacent child.

The attitudes, values, and behaviours of settlers, both Aboriginal and European, often reflect the utilitarian rather than the lyrical values of these lakes and their resources. Six thousand years ago, the early inhabitants were hunters and gatherers who used the indigenous copper in their tools and weapons. Four hundred years ago, the European explorers sought a Northwest Passage to the riches of the Orient but returned with evidence of furs, fish, and trees for exploitation. And only a decade ago, a "Grand Canal Plan" to divert 30 percent of the discharge of the Great Lakes to the American southwest and drier regions of western Canada merited serious consideration by the then (Canadian) Inquiry on Federal Water Policy (Pearse, Bertrand, and MacLaren 1985, 126-29). The history of the Great Lakes can be seen as a history of the uses of the resources in the basin as well as a history of human stresses on its ecosystems.

The common law and customs of the early settlers reflected this utilitarian premise. English common law was structured along use lines. Different uses of natural resources required different legal solutions to conflicts that would arise over these uses. So the common law on fisheries, for example, differed from the common law on navigation and water transport. And when they came into conflict, the common law offered guidelines as to which use merited priority. For example, in both Canada and the United States, the common law rule of "navigable servitude" permits the uses of shipping and navigation to trump all other uses. This rule originated in the Magna Carta (Sproule-Jones 1993).

The restoration of the Great Lakes must take into account the many uses of the basin by its 33 million inhabitants and the demands on its waters by people living beyond its borders. These other values, and the rules developed for their "equitable" expression, provide the context within which policies for environmental restoration must interact. Some history of these alternative uses is thus in order.

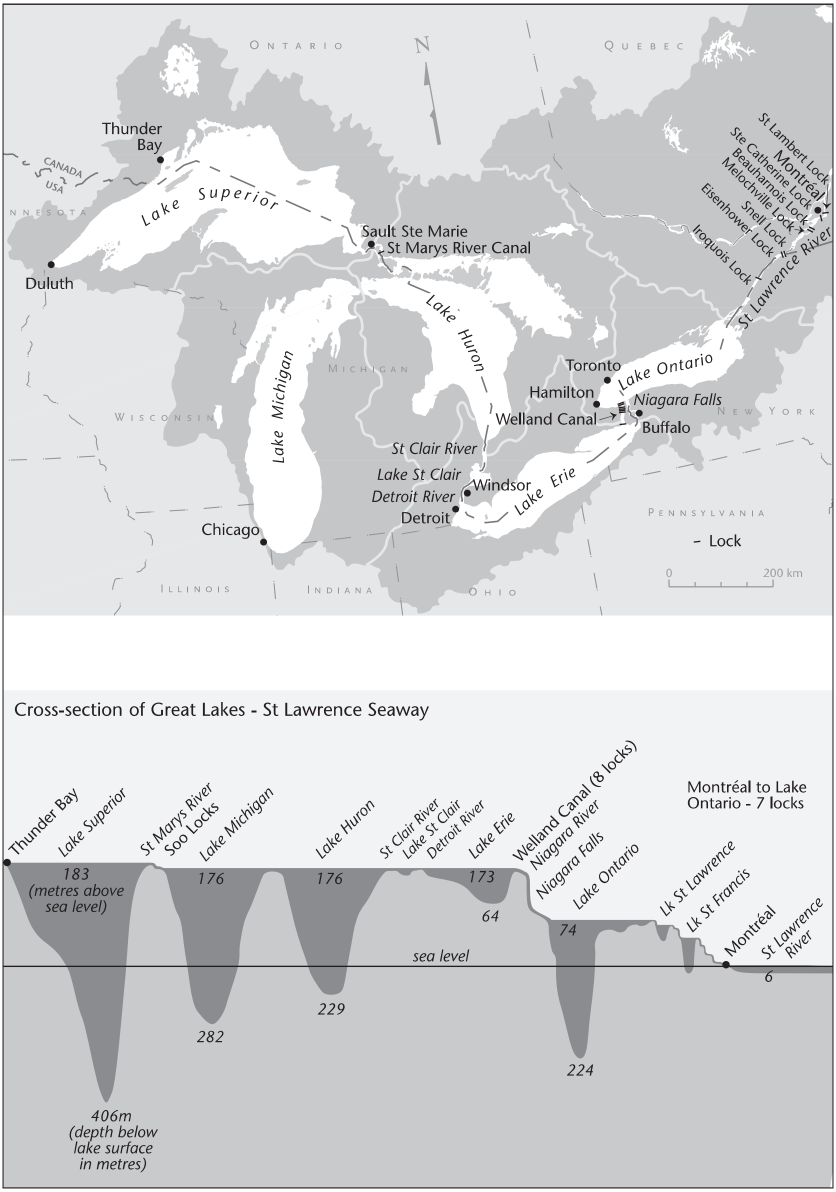
Transportation

Human settlements and the exploration of the interior of the New World were intimately related to the transportation links provided by rivers and lakes. The St. Lawrence River and the interconnecting five Great Lakes provided an early and major example of this, at least for incipient European populations. The goal, in part, was the extraction of furs (particularly beaver). The means were largely canoes, which would use waterways and portages. The partners of the trappers and voyageurs were French missionaries, literate men with the skill to make maps and chart the miles of navigable waters (Kaufman 1989). Eventually, albeit fitfully, small enclaves of farmers and military families dotted the harsh and dangerous shores from the south shore of the St. Lawrence through to the Grand Portage on the far western shore of Superior in what is now the State of Minnesota (Ashworth 1986; Berton 1996).

The late eighteenth century saw the introduction of newer ships and ship technologies on the lakes. Some were naval vessels belonging to both sides in the American Revolution and the War of 1812. Some were merchant schooners built to ply their trade in goods and people from the Atlantic shores. Both were restricted by physical obstacles that connected the lakes. Canals were the solution in the St. Lawrence River, in the portages between Lakes Ontario and Erie, and between Lakes Superior and Huron. The building of the Erie Canal (1825), connecting Albany and Buffalo in New York (and, through them, Chicago and New York City), was a key precipitating factor in the construction of additional

Figure 2.1

The Great Lakes basin showing transportation links



Source: Environment Canada, *Our Great Lakes, 1999*, <www.ec.on.gc.ca/glimr.maps-e.html>.

and deeper canals on the St. Lawrence and the first Welland Canal in 1829. It was not until 1855 that the "Soo" was circumnavigated by the state lock linking Lake Superior with Lake Huron.

The changes presaged a massive expansion of settlement and resources exploitation throughout the lower basin. Millions of European settlers moved across the lakes on steamships, which then returned with freight, particularly lumber and fish. Sailing ships continued to ply their trade; over 1,100 were registered with the Dominion government in the 1850s. Small human settlements burst with populations. Chicago, for example, went from 500 persons in 1838 to 2 million in 1900 (Ashworth 1986, 95-96).

Bulk cargo ships made from iron gradually replaced the wooden schooners. These were needed, inter alia, to transport iron ore to the new steel cities like Cleveland, Buffalo, and Hamilton. Vessel sizes went from 100 to 500 feet, and cargo weights from 400 to 4,000 tons. Shipping channels, especially the upgraded Welland Canals bypassing Niagara Falls, were as important as were railroads in transforming the Great Lakes.

Throughout the lakes, water transportation improvements in terms of canals, locks, and diversions were accompanied by port development. Hundreds of small harbours were developed, often by private companies, for trade in bulk commodities like iron ore and wheat. The prospect of direct competition with railroads over shipping bulk goods to Europe led shippers, shipping lines, and port managers to lobby for both capital improvements and institutional changes on the lakes. A fourth Welland Canal, with a draft of 15 feet, was opened in 1887; a new canal was constructed at Cornwall, and improvements were made to widen and deepen existing channels (Sussman 1979).

In 1871, the Treaty of Washington finally settled the exact international boundary between the two nations on the open waters, and, more important, the rules of navigation on the St. Lawrence River. Binational water issues, including the funding of commonly shared benefits of capital improvements, led to the creation of an International Waterways Commission in 1895 and, eventually, to the Boundary Waters Treaty of 1909. This treaty established the International Joint Commission (described in the next chapter), which had the power to examine and recommend solutions to binational problems along the international borders. Article 1 of the Boundary Waters Treaty is significant for our purposes. It states that the navigation of all navigable boundary waters shall forever continue free and open for the purposes of commerce to the inhabitants and to the ships, vessels, and boats of both countries equally, subject to non-discriminatory laws and regulations not inconsistent with the privilege of free navigation. This article reconfirms the domestic policy of both countries and their incorporation of the common law principle of "navigable servitude" into rules pertaining to shared international waters (Sproule-Jones 1993).

Later articles spell out some of the further implications for multiple water uses. In general, the IJC must approve new (post-1909) uses, diversions, and obstructions of the flow and levels of waters on the Great Lakes. Article 8 attempts to prioritize uses in the approval process. Water supply and waste disposal within waters are accorded a higher priority than is navigation, which itself has a higher priority than do power generation and irrigation. The act is silent, however, on ecosystem, recreational, and other uses. Nevertheless, the IJC has been involved in granting certificates of approval for specific building projects that could negatively affect navigation (e.g., the St. Lawrence Power Project, which regulates outflows from Lake Ontario) or positively affect it (e.g., the Toussant Causeway in the St. Lawrence, which reduces currents for shipping) (Chandler and Vechsler 1992).

The shipping and railroad interests became major competitors in the movement of bulk goods, both dry and liquid, during and after the two world wars. The shipping industry was particularly well positioned to transport iron ore pellets from Quebec and Labrador to both US and Canadian steel manufacturers on the Great Lakes. Grain could be moved downstream when the ships returned and thus feed European populations. Plans for a uniform draft of 25 feet to be built jointly by both countries under 1932 and 1941 treaties was defeated in the US Senate (under the two-thirds majority rule for treaty ratification). Some authors attribute this defeat to the power of US railroad interests (Toro and Dowd 1961; Sussman 1979), although the treaty included diversions for hydroelectric power at Niagara, construction to generate power at the St. Lawrence, as well as navigation concerns.

In 1951, the St. Lawrence Seaway Act was passed by the Canadian Parliament. The act authorized the construction of navigation works on the Canadian side of the St. Lawrence River from Montreal to Lake Ontario. Tolls were designed to pay for the project. The Americans took coordinated action on their side in 1954, building facilities to circumvent the international rapids section. In 1959 the St. Lawrence Seaway was opened, providing a 27-foot draft from Montreal to Lake Erie. Navigation improvements were coordinated with hydroelectric construction projects determined by the Hydro Electric Power Commission of

Ontario and the Power Authority of the State of New York. A St. Lawrence Seaway Authority (Canadian) manages five locks in the Montreal-Lake Ontario section plus the Welland Canal. The Seaway Development Corporation (American) manages two locks at Massena plus other American sections of the St. Lawrence. Despite these continual improvements, the seaway is still too small for the massive ocean container ships that typically have at least a 35-foot draft and exceed the maximum length (700 feet) of the locks (McCalla 1994, 172).

Consequently, Montreal has become (with the New York–New Jersey complex) a hub port with spokes for further re-transport of containers by smaller ship or by rail and road. The seaway relies on bulk cargoes, 70 percent of which are exportable grains. With the development of subsidized grain production by the European Union (EU), the seaway has seen its cargo flows decrease and its financial situation move from serious to perilous. Cargoes fell by 30 percent from the early 1970s to the early 1990s, and the number of commercial vessels fell by over 50 percent. The operating deficit rose from \$2.1 million to \$7.8 million between 1971 and 1991 (St. Lawrence Seaway Authority 1971, 1992).

For 400 years, the navigational and shipping use of the Great Lakes–St. Lawrence has enjoyed primacy, but now other uses are attaining relatively greater significance. Nevertheless, the ecosystem still remains substantially altered.

Hydroelectricity

Public works in the Great Lakes, and specifically in the Niagara–St. Lawrence Rivers, provided joint benefits (as well as costs) from the generation of electricity. Indeed, many of the construction projects for the seaway were to be constructed for the joint purposes of navigation and power (McCalla 1994, 159). Niagara power became instrumental in the industrial development of southern Ontario and western New York. The first US generating station at Niagara was opened in 1881, the first Canadian one in 1893.

Subsequently, Niagara hydroelectric power became a major issue in Ontario politics (Nelles 1974). Originally, a private monopoly was granted exclusive rights to generate power at Niagara (1892), but it was succeeded by a private cartel (1903), which was succeeded by a public utility that undercut private competition and became a major Crown corporation (1920s).

Today, Ontario Power Generation (formerly most of Ontario Hydro) is the second largest supplier of energy in North America (Vining 1981), with approximately 20 percent of its power originating in Niagara

Peninsula hydro (Colborn 1990, 58). Less than 10 percent of the power of the eight Great Lakes states is generated from water. Ontario Power Generation remains a key component of industrial development in Ontario and a primary user of the water of the Niagara River.

The non-Niagara hydroelectric systems are generally small in scale, if not in numbers. In Michigan, there are 113 plants, but they produce only 1.5 percent of the power needed to meet existing demands. There are 120 comparable plants in Wisconsin and similar facilities in New York State. The St. Marys River Dam and the Moses-Sanders Dam on the St. Lawrence are major plants. There are no estimates of the impact of hydro power on fish transportation and habitat, although the remedial action plan for the Nipigon River attempts to manage water levels to the advantage of both hydro and fisheries interests (SOLEC 1996a, 23).

Fisheries

The Great Lakes provided an abundant source of food for Aboriginal communities as well as a sustainable trade item (Doherty 1990). European settlers discovered more than 150 species of fish, and the abundance of fish was commonly noted in the accounts of early settlers (Wallace 1945). One 1813 account describes the whitefish population at Pasque Isle as so plentiful that "one might fill a net by simply casting it into the water from the beach" (Prothero 1973, 11).

As early as 1795 a commercial fishery was established on Lake Erie, and by the 1830s another major fishery was established on Lake Superior (Ashworth 1986, 116). By the turn of the century, Lake Superior was producing 8 million pounds of whitefish alone; Lake Michigan's trout fishery exceeded 3 million pounds; Lake Huron produced 7 million pounds of trout; Lake Erie produced over 33 million pounds in its commercial fishery; and Lake Ontario provided over 2 million pounds of whitefish (Ashworth 1986, 110-17; Wallace 1945).

It was, however, an open access common pool, with few limits on fishing. At particular sites, like Hamilton Harbour, voluntary restrictions were adopted by fishers to avoid overfishing and the potential exhaustion of stocks (Holmes and Whillans 1984). However, the fast transportation of fish to large markets was facilitated by railroad expansion, and overfishing and the destruction of habitat by urbanization patterns were beginning to severely restrict fish yields. By 1910, for example, the whitefish population in Lake Superior had been reduced to below commercial viability.

In 1868 the first Fisheries Act was passed by the Dominion government. This act was administered by the Department of Marine and Fisheries

(Pearse, Bertrand, and MacLaren 1985), and its main purpose was to control overfishing and to maintain stocks. It enabled the Dominion government to place restrictions on the taking of any fish species that showed signs of becoming exhausted. The Dominion could control fishing seasons and methods, and restrict the dumping of such materials as sawdust into rivers and creeks (Wallace 1945). Provinces could also enforce their own regulations in addition to those contained in the Fisheries Act (Pearse, Bertrand, and MacLaren 1985).

The American federal government was much slower to respond to the overfishing problem than was the Canadian federal government. Complaints from Canadian fishers about their American counterparts were recorded as early as 1872 (Wallace 1945). Unrestricted fishing on the American shore prompted the Department of Marine and Fisheries to lobby American federal and state authorities to act on the overfishing problem. Although many American representatives favoured such restrictions, the federal government had difficulty securing the approval of the state legislatures concerned (Wallace 1945).

Canada's fishery officials were involved in restocking programs and hatcheries. After 1875, restocking lakes with desirable sport fish was an accepted Canadian government practice (Wallace 1945). From this period on, Ontario maintained its own hatchery system. Records from 1853 indicate that the first successful hatching of fish eggs was conducted by Theodotus Garlick of Cleveland, who used eggs he had gathered at Port Stanley (Prothero 1973). By 1917, Canada had developed 61 hatcheries (Prothero 1973, 199), which stocked whitefish, salmon trout, salmon, speckled trout, and pickerel. For many years, those in the fishing industry believed that hatcheries were the solution to overfishing and pollution problems. By the 1930s, however, it became evident that no restocking program could alleviate the declining fish populations.

In 1908, with the Inland Fisheries Agreement, the two national governments made a modest attempt at establishing coordinated fisheries policies. This agreement consisted largely of enforcing poaching regulations in each other's waters rather than developing sustainable fisheries. In the 1920s, the sea lamprey invasions of the lakes above Ontario exacerbated the overfishing problem. Commercial fisheries catches were roughly stable at approximately 1 billion pounds from 1921 through 1981, until concerns about contamination of fish by toxic chemicals and heavy metals led to major reductions in allowable catches (Great Lakes Fisheries Commission 1979, 2000).

Since the 1950s, with the establishment of the Great Lakes Fisheries Commission in 1956 (subsequent to the Convention on Great Lakes

Fisheries that was ratified by Canada and the United States in 1955), there has been a joint attempt to develop sustainable commercial fisheries. The commission recommends measures that would permit the maximum sustained productivity of fish of common concern, and itself formulates and implements a sea lamprey control program (Great Lakes Fisheries Commission 1993). Its effectiveness depends upon the policies adopted and implemented by the respective federal, provincial, state, and Aboriginal natural resources agencies, each of which has one representative on five lake committees. The policies in question, however, seem to be dominated by the interests of sports fisheries.

Today, some 17 million "angler days" occur in four Great Lakes (excluding Ontario), with 12 million of these in Lakes Erie and Michigan. (An angler day is an individual who fishes for at least 20 minutes during any one day.) There are over 6 million angler days on Lake Ontario (Canada [DFO] 1999), and the economic value of the sport fishery is estimated at over US$2 billion (Talheim 1988, 11). In contrast, the major commercial fishery, based in Lake Erie, consists of only 750 fishers who land 50 million pounds per annum (United States EPA and the Government of Canada 1995, 20) and the estimated landed value for all five Great Lakes is only US$40 million (Talheim 1988, 25). The United States prohibits the sale of fish affected by toxic contaminants, and fish consumption advisories (recommended maximum individual annual consumptions of different species) exist for all lakes. It is the sport and thrill of the catch that remains the most valuable of the attributes of a once massive natural resource.

Water Supply

Water is withdrawn in large volumes from the Great Lakes – 56,920 million gallons per day, or 2,493 cubic metres per second (IJC 2000, 7) – and then put to a variety of uses on the land. About 5 percent of these volumes is actually withdrawn and consumed; the remainder returns as flows from "on-the-land" uses.

The IJC estimates that 29 percent of the withdrawals are used for irrigation, 28 percent for public water supply, and 24 percent for industrial uses. Of the remainder, 6 percent goes for hydroelectric and thermoelectric power generation, 4 percent for self-supplied domestic uses, and 3 percent for livestock watering. The volume of groundwater withdrawals, as opposed to surface water withdrawals, is unknown (IJC 2000, 8).

Water is also removed from the basin by diversions. The largest diversion, 91 cubic metres per second, occurs in Chicago (IJC 2000, 10). A canal was built in the mid-1800s to divert water from Lake Michigan into the Des Plaines River, which empties into the Illinois River (which is part of the Mississippi River basin). The original reason for the canal was to allow transportation between the Great Lakes and the Mississippi; however, later it was used for public water supply and sewage disposal. The Chicago diversion is actually an out-of-basin diversion and is more than compensated for by an into-the-basin diversion at Long Lac and Ogoki on Lake Superior. There, 158 cubic metres per second are diverted for hydroelectric power purposes by the province of Ontario.

Other smaller diversions occur on the lower Great Lakes, and removals from the basin occur in the forms of bottled water, slurry, and ballast water. It appears as if the basin imports fourteen times more water than it exports (IJC 2000, 11), but the prospect of tanker withdrawals in 1997 and 1998 led to major political controversies throughout the region. Major new diversions or removals from the basin would violate the Great Lakes Charter of eight US states and the provinces of Ontario and Quebec. The charter requires the consent and concurrence of other jurisdictions should withdrawals exceed 5 million gallons/day in any 30-day period. Further, domestic US and Canadian legislation would require approvals for water removals from the basin. These legal arrangements appear to have done little to assuage the emotional concerns about water exports, especially in Canada.

Waste Disposal

The Great Lakes basin experienced massive population increases during the nineteenth century. Over 10 million people had settled on the shores by 1900, with the large majority of these being in the Lake Michigan and Lake Erie subsystems (Environmental Atlas and Resource Book 1995, 18). Urbanization and industrialization occurred, with major population nodes around southern Lake Michigan, western and southern Lake Erie, and the northwest shores of Lake Ontario. Heavy manufacturing (e.g., steel, paper, and chemicals) provided the primary sources of urban employment, while water and electrical power provided cheap sources of energy. Chicago proved to be a "model": it went from 500 people to over 2 million in the 70 years preceding 1900. Chicago was the confluence of agricultural and metals processing that expanded in tandem with the cheaper rail and water transportation routes to the east.

The expanded human settlements were largely cavalier in their disposal of wastes. Many cities like Chicago and Hamilton experienced cholera epidemics due to contaminated well and nearshore water intakes (Sproule-Jones 1993, Chap. 7). Solid wastes were frequently dumped into marshlands, which were considered non-valuable sites that could not support buildings and roads. Hamilton Harbour, for example, was eventually reduced by 25 percent, and this experience was replicated throughout the urbanized portion of the Great Lakes. Industrial wastes were either buried or diluted and dumped into nearshore waters and wetlands. Some communities were even proud of their air pollution, believing it to be a sign of progress.

Today, 33 million people live in the basin, and 80 percent of these live in 17 metropolitan areas (11 in the United States and 6 in Canada) (SOLEC 1996b, 5). The Conservation Foundation estimates that each resident generates about 2 kilograms (4.4 pounds) of solid wastes per year (Colborn 1990, 67). Most of these kinds of wastes are placed into landfills rather than dumped into rivers or lakes. However, rainfalls and snowmelts exceed evaporation throughout the basin, and, consequently, the leachates are likely to enter some parts of the water courses. In addition to these dumps, some 116 sites on the US side of the basin are considered hazardous (and part of the US's former Superfund program), and roughly 5 percent of 342 Ontario dumps are comparable (Colborn 1990, 63). Liquid wastes are dumped directly into the lakes and streams. These are estimated, albeit widely, at some 57 million tonnes per year (Colborn 1990, 64).

Wastes also enter the ecosystem through soil erosion, pesticide use, and manure "management" practices on agricultural land. Estimates of the scale of these activities are available, but there are no estimates of the extent to which they end up in non-point source pollution (SOLEC 1996b, 10). Similarly, wastes washed into storm drains, creeks, rivers, and bays from non-agricultural lands may be highly polluted, but again, no quantity estimates are available.

The impacts of these waste disposal activities on the environment intermingle with the impacts of direct human alterations of the ecosystems. Human settlements alter habitats through land development and/or resource extraction, while they alter hydrology through diversions and dredging. Increased sedimentation and sediment transport alter the physical processes on (at least) the nearshores, and biological structures are altered through human disruptions of an ecosystem's food webs (SOLEC 1996c, 39-44). The exact contributions of each of these is impossible to estimate.

The overall consequences show up in degraded water quality conditions and impaired natural ecosystems. Some of these consequences are well known. In 1953, the bottom waters of Lake Erie showed the first signs of anoxia. By the 1960s, the lake was often characterized as "dead," which meant that massive algal blooms were occurring and that several nearshore areas were largely devoid of aquatic life (Colborn 1990, 95). Lake Erie was subject to "cultural eutrophication," whereby phosphorous (as a nutrient) was imposing an algal bloom in a relatively shallow lake, which, in summer months, has relatively low dissolved oxygen levels. Public concern about Lake Erie was, in large part, instrumental in establishing the Great Lakes Water Quality Agreement between the United States and Canada (see Chapter 3). The practical consequence of the agreement was the reduction of phosphorous loadings through improved sewage treatment. Targets and objectives were attained by 1991, and chlorophyll *a* (an indicator of nuisance algal growth) was at acceptable levels by the early 1990s. Conversely, the introduction of the zebra mussel has increased water clarity (77 percent between 1988 and 1991) because of its filtration activities, and aquatic plants are thus spreading into deeper waters (Environment Canada/US EPA 1995).

In 1976, President Carter declared the Love Canal (near the Niagara River in New York State) a federal disaster area. The Hooker Chemical Company had buried 20,000 tonnes of chemical waste that, 30 years later, was seeping into water and air. The effects were showing up as human skin rashes and eye irritations, and detectable levels of persistent toxic chemicals in downstream fish tissue (Levine 1982; Colborn et al. 1990, 56-60). The leachate from Love Canal is now contained and treated, but the Niagara River is still the most significant source of toxic chemicals entering Lake Ontario. Upstream and downstream monitoring indicates that point and non-point sources on the river itself are significant modes of entry for these toxins (Environment Canada et al. 1995).

These two well-known cases of environmental degradation do not amount to an accurate story of the Great Lakes environmental situation. In Chapter 1, we noted the 14 indicators of impaired beneficial uses that need to be restored, at least in part, for the 43 AOCs that were designated by the IJC.

A joint publication of both national governments, *State of the Great Lakes 1995* (Environment Canada/US Environmental Protection Agency 1995) provides some summary overview indicators that extend beyond AOCs. The study suggests that four sets of indicators provide useful reviews of all the lakes. These indicators are:

(1) *Aquatic habitat and wetlands.* There are major losses throughout the basin: Ontario has lost 80 percent and the other lakes some 60 percent since the 1780s. Enhancement and restoration programs

cannot keep up with current habitat losses, with perhaps the exception of the brook trout habitat in the upper lakes.

(2) *Persistent toxic substances*. Loadings of persistent toxic contaminants have been reduced substantially since 1970, and there are declining contaminant concentrations in waters, sediments, fish, and wildlife. In urban areas and for certain species, however, levels are high enough to cause concern. For example, human consumption of top predator and forage fish is discouraged, and there are observed effects of alteration of biochemical function, pathological abnormalities, tumours, and reproductive abnormalities in well-studied species like the herring gull. Table 2.1 lists the critical pollutants that have been referenced by regulatory agencies.

Table 2.1

List of critical pollutants referenced by regulatory agencies

Chemical	Reference							
	GLWQA Annex 1	GLWQI	LaMPs critical pollutants	Pollution prevention	IJC list of I1 critical pollutants	Lake Superior priority substances	COA Tier 1 list	COA Tier II list
Aldrin	√				√		√	
Benzo(a)pyrene	√		√		√		√	
Chlordane	√	√	√			√	√	
Copper	√	√	√					
DDT and metabolites	√	√	√		√	√	√	
Dieldrin	√	√	√			√	√	
Furan	√		√		√		√	
Heptachlor	√	√	√					
Heptachlor epoxide	√		√					
Hexachlorobenzene	√	√	√		√	√	√	
Alkylated lead	√		√	√	√		√	
α Hexachlorocyclohexane	√		√					√
β Hexachlorocyclohexane	√		√					√
Mercury	√	√	√	√	√	√	√	
Mirex	√		√		√		√	
Octachlorostyrene	√		√			√	√	
PCBs	√	√	√		√	√	√	
2,3,7,8-TCDD (a dioxin)	√	√	√		√	√	√	
Toxaphene	√	√	√		√	√	√	

Abbreviations: GLWQA = Great Lakes Water Quality Agreement GLWQI = Great Lakes Water Quality Initiative LaMP = Lakewide Management Plan IJC = International Joint Commission COA = Canada-Ontario Agreement

Many persistent toxics reside in sediments and represent pollution loadings from previous years and generations. Thirty-eight of the 43 AOCs have restrictions on dredging because of the potential impacts of toxic pollutants in sediments. In-place contaminated sediments can have direct impacts on aquatic life, such as fish, and these may get redistributed through the food chains. Indirect impacts can occur when sediments are resuspended (through ship movements) or dredged and dumped in confined disposal facilities or shallow waters and on beaches. Unless in-place treatment of contaminated sediments is possible, then sediments must normally be dredged and then coupled with treatment technologies – biological, chemical, or thermal. Typical contaminants in the sediments of AOCs are heavy metals, PAHs, and PCBs caused by industrial discharges as well as persistent pesticides and herbicides from non-point sources.

(3) *Eutrophication*. Loadings of total phosphorus are at good or restored levels under the Water Quality Agreement targets. These objectives were also achieved by 1990 for total phosphorus concentrations in open water. Outside some 21 AOCs, levels of chlorophyll *a* are also considered as good or restored. Levels of dissolved oxygen, except for Lake Erie's central basin in summer months, are similarly restored. Nitrate-plus-nitrate levels for the open lakes show some increases, however, especially for Ontario.

(4) *Human health effects*. Thirty-five of the AOCs have fish consumption advisories, as noted above. The impact of toxics in general on humans is both complex and uncertain. Several recent studies associate increased tissue levels of toxic substances with reproductive, developmental, neurological, endocrinological, and immunological problems (SOLEC 1986a, 107). And there are studies linking PCB levels (and some other organochlorides) in blood plasma with fish eating. Ontario and the Great Lakes states have had fish consumption advisories (recommended portions per annum) since the 1970s. Twenty-four AOCs have beach closures or recreational body contact restrictions due to pathogenic pollution. Forty-four percent of the Canadian Great Lakes beaches are closed for at least some of the three-month summer (June to August), and 23 percent of US beaches are also closed during the same time period. (Monitoring of beaches varies by jurisdiction, as do criteria for closures.) There is more recent evidence and concern that the use of chlorine as a major cheap disinfectant in water supply systems from the lakes (as well

> as sewage inputs) is associated with bladder and colon cancers. The dose-response linkages remain unclear, however (SOLEC 1996a, 103-5).

This suite of indicators provides a cursory overview of the pollutant impacts of waste disposal from humans and their activities throughout the Great Lakes basin. Particular sites, like AOCs, can differ. This fact becomes important when analyzing the effectiveness of restoration attempts. The institutional responses to these waste disposal and pollution issues form the basis of the next chapter.

Conclusion

Five major human uses of the Great Lakes have been described. Perhaps the most important one, certainly for the purposes of assessing restoration efforts, is that of waste disposal. Human settlements and the extraction and processing of natural resources in industrial sites on the Great Lakes have generated, and continue to generate, residuals that are either dumped directly or filtered indirectly into the ecosystem. A suite of indicators of their impacts is suggested, including impacts on living systems like fish, wildlife, and mammals.

Humans have also significantly altered the shorelines and connecting channels of the lakes in order to provide shipping channels and hydroelectric power. These, in turn, have made possible a commercial and, especially, a major recreational fishing and boating industry. The interdependencies between uses are also apparent, and we must now examine the framework of rules that has been devised by the major governments around the basin in order to deal with them.