

**REGIONAL ASSESSMENT
LAKE SAINT-FRANÇOIS**

Regional Assessment Lake Saint-François

Revised by
Marie-José Auclair
ZIP Working Group

NOTE TO READERS

Reports on Priority Intervention Zones (known as ZIPs) are produced as part of the St. Lawrence Vision 2000 action plan by Environment Canada's St. Lawrence Centre, in conjunction with Fisheries and Oceans, Health Canada and the Ministère de l'Environnement et de la Faune du Québec (MEF).

Production Team

**Concept and Writing
(preliminary version)**

**Jean Robitaille,
Bureau d'Ecologie Appliquée**

Co-ordination

Marie-José Auclair

ZIP Working Group

**Alain Armellin, Jean-François Bibeault,
Jean Burton, Guy Fortin, Anne Jourdain,
Pierre Mousseau, Yolaine St-Jacques**

**Cartographic Analysis
and Illustrations**

Marcel Houle

Text Revision (French version)

Monique Simond

**Copyediting and Layout
(English version)**

Patricia Potvin

Translation

James Cookson

Figures Layout

Denise Séguin

Contributors

Ministère de l'Environnement et de la Faune du Québec

Secteur Environnement

Direction des Écosystèmes Aquatiques

Carolle Lachapelle

Denis Laliberté

Francine Richard

**Direction de la Conservation
et du Patrimoine Ecologique**

Rosaire Jean

Secteur Faune

Direction Régionale de la Faune

Pierre Dumont

Pierre Fournier

Michel Letendre

Martin Léveillé

Fisheries and Oceans

Fish Habitat Branch

Claude Grondin

Luce Chammard

Maurice Lamontagne Institute

Gordon Walsh

Health Canada

Georges Arvanitakis

Environment Canada

Environmental Protection Branch

Caroll Bélanger

Élie Fédida

Gervais Leclair

André Pelletier

Canadian Wildlife Service

Léo-Guy de Repentigny

Communications

Paul Millot

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Preface

In April, 1994, the governments of Canada and Québec approved a four-year action plan to carry on the work of the St. Lawrence Action Plan.

The goal of St. Lawrence Vision 2000 is to conserve and protect the St. Lawrence so that the people who live along its shores can reclaim use of their river in the spirit of sustainable development.

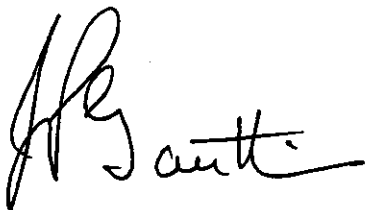
The Priority Intervention Zones Program – better known by its French acronym ZIP – is a major element of the Community Involvement component of the St. Lawrence Vision 2000 action plan.

Through the ZIP Program, riverside communities are invited to play an active part in achieving the objectives aimed at restoring the St. Lawrence.

The program urges various community partners, non-governmental organizations and citizens' committees to work together to identify common priorities for the conservation and restoration of the St. Lawrence.

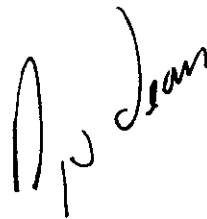
We are pleased to present this assessment, which reports on the uses, resources and main environmental problems specific to this area. It has been prepared using all the data available from the various federal departments and provincial ministries involved in St. Lawrence Vision 2000.

We hope it will prompt a more enlightened public debate based on information that is as objective as possible, and that the debate will help the various partners involved to develop and implement a plan of action for restoration of the area in question.



Jean-Pierre Gauthier
Regional Director General
Québec Region
Environment Canada

Co-Chair, St. Lawrence Vision 2000



Denys Jean
Assistant Deputy Minister, Policies
Ministère de l'Environnement et
de la Faune du Québec

Co-Chair, St. Lawrence Vision 2000

Management Perspective

The Priority Intervention Zones (ZIP) Program is a federal–provincial initiative that aims to involve stakeholders and riverside communities in implementing rehabilitation measures for the St. Lawrence River. The program has three phases: producing a regional assessment report on the state of the St. Lawrence, consulting riverside partners at all levels and setting priorities for action, and developing an ecological rehabilitation action plan.

The regional assessment is based on a synthesis of three technical reports focusing on the biological, physico-chemical and socio-economic aspects of the study area. These reports are prepared by the ZIP team of the St. Lawrence Centre in co-operation with the federal and provincial partners of the St. Lawrence Vision 2000 action plan, of which the ZIP Program is a component.

The process of gathering and analysing data on a local scale has never before been undertaken for the St. Lawrence. The technical reports go even further, providing an assessment of the current state of a given area based on known quality criteria.

The challenge, then, is to formulate a scientific opinion based on the available information. The pitfalls are numerous: the data were collected for other purposes, the geographic and temporal coverage is less than ideal and the chemical analysis methods are not standardized, to name but a few.

The ZIP team remains nonetheless convinced that an enlightened and thoughtful overview of each study area can be presented without further delay. This first assessment, written for the riverside partners in each study area, is therefore a starting point and discussion paper.

Perspective de gestion

Le programme des Zones d'intervention prioritaire (ZIP) relève le défi de la concertation entre les gouvernements fédéral et provincial et de l'implication des intervenants et des communautés riveraines, en vue de mettre en oeuvre des mesures de réhabilitation du Saint-Laurent. Ce programme comporte trois grandes étapes, soit l'élaboration d'un bilan régional sur l'état du Saint-Laurent, la consultation auprès de tous les partenaires riverains, avec l'identification de priorités d'intervention, et l'élaboration d'un plan d'action de réhabilitation du milieu naturel.

Le bilan régional est établi à partir d'une synthèse des trois rapports techniques portant sur les aspects biologiques, physico-chimiques et socio-économiques du secteur étudié. Ces rapports sont préparés par l'équipe ZIP du Centre Saint-Laurent en collaboration avec les partenaires fédéraux et provinciaux du plan d'action Saint-Laurent Vision 2000, dont le programme ZIP est un des volets.

La cueillette et l'analyse des données existantes à l'échelle locale est une première pour le Saint-Laurent. Les rapports techniques vont plus loin encore, en proposant un bilan des connaissances sur l'état actuel d'un secteur à partir de critères de qualité connus.

Le défi consiste donc à poser un jugement scientifique fondé sur l'information disponible. Les embûches sont nombreuses : les données ont été recueillies à d'autres fins, la couverture spatiale ou temporelle n'est pas idéale, les méthodes d'analyses chimiques ne sont pas uniformes, etc.

L'équipe ZIP demeure convaincue qu'il est possible de poser, sans plus attendre, un regard éclairé et prudent sur chaque secteur. Cette première évaluation constitue un point de départ et un document de base rédigé à l'intention des partenaires riverains de chaque secteur d'étude.

Abstract

Lake Saint-François is the first widening of the St. Lawrence River in Quebec; its main source is the Great Lakes. In the early 1930s, control structures were built to regulate water flow, considerably reducing the flood plain and modifying the flow pattern. The lake is bordered by vast wetland areas, especially in its upstream portion. These areas are noteworthy for their wide variety of wildlife habitats, particularly the many prime nesting sites and migratory bird staging areas that make them some of the richest of the freshwater St. Lawrence. Many nature-lovers visit the Lake Saint-François National Wildlife Area because of the diversity of its plants and animals.

Although no major industry is located on its banks, toxic substances have been found throughout the lake ecosystem. These toxic substances are mainly discharged by industrial plants in the Cornwall–Massena region, directly upstream from Lake Saint-François. There are few sources of contamination along the lakeshore itself and their effects are local. Discharges of municipal sewage into the lake are minimal. Household wastewater is largely eliminated by septic tanks. The water's chemical quality is generally good and the lake is suitable for recreational activities. Organic pollutants found at the inlet to the lake are cause for concern, however. Areas of contaminated sediment have been reported, although the chemical quality is getting better in the surface layers, indicating that water and sediment quality has improved over the past few years. Sediment in the Cornwall region has been found to contain toxic substances in concentrations harmful to benthic organisms. Toxic substances have also been reported in other links in the food chain (fish, reptiles and birds). Lower levels of fish flesh contamination reflect an overall improvement in this environment over the last decade. Nonetheless, there are still restrictions on eating fish or game caught at the lake.

In spite of certain limitations on its use, Lake Saint-François has very good potential, especially for recreational activities.

The shores of the lake are occupied chiefly by permanent and secondary residences, and cottaging is one of the region's chief tourist attractions. Unfortunately, this type of development has led to the disappearance of large wetland areas.

A great deal of hunting and sport fishing takes place in and around the lake, along with boating and swimming. Commercial fishing in Québec has changed considerably over the last few decades and today it is a modest economic activity for about a dozen fishermen on the lake.

Résumé

Le lac Saint-François est le premier élargissement du fleuve Saint-Laurent au Québec; ses eaux proviennent principalement des Grands Lacs. Au début des années 1930, les eaux ont été régularisées par des ouvrages de contrôle, ce qui a considérablement réduit l'étendue des plaines inondables et modifié le régime d'écoulement. Les abords du plan d'eau, particulièrement dans sa partie amont, sont couverts de vastes milieux humides. Ces milieux sont parmi les plus riches des eaux douces du Saint-Laurent, offrant une large variété d'habitats fauniques, notamment de nombreux sites propices à la nidification et aux haltes migratoires des oiseaux. L'observation de la nature attire d'ailleurs beaucoup de visiteurs à la Réserve nationale de faune du lac Saint-François, en raison de la diversité de sa flore et de sa faune.

Bien qu'aucune industrie majeure ne soit implantée sur les berges du lac Saint-François, on rapporte des substances toxiques dans l'ensemble de l'écosystème. Ces substances toxiques proviennent principalement des rejets des industries polluantes de la région de Cornwall et de Massena situées directement en amont du lac Saint-François. Les sources de contamination sur les rives sont peu nombreuses et leur effet est local. Les rejets municipaux aux abords du lac sont minimes. L'élimination des eaux usées domestiques se fait principalement au moyen de fosses septiques. La qualité chimique de l'eau est généralement bonne et le lac est propice aux activités récréatives. La présence de certains polluants organiques à l'entrée du lac est toutefois préoccupante. On observe des zones de sédiments contaminés, mais la qualité chimique s'améliore dans les couches superficielles, ce qui dénote une amélioration de la qualité de l'eau et des sédiments au cours des dernières années. Dans les sédiments de la région de Cornwall, certaines substances toxiques sont présentes en teneurs nuisibles pour les organismes benthiques. Dans les autres maillons de la chaîne alimentaire, comme chez les poissons, les reptiles et les oiseaux, on observe aussi des substances toxiques. La baisse de contamination constatée dans la chair des poissons reflète une amélioration générale du milieu au cours de la dernière décennie. Malgré cela, la consommation de poissons provenant des activités de pêche sportive et de

subsistance demeure sujette à des restrictions. Il en va de même du gibier recherché à des fins de subsistance.

En dépit de certaines limitations d'usages, le lac Saint-François présente un potentiel de mise en valeur des plus intéressants.

Les rives sont surtout occupées par des résidences permanentes et secondaires. La villégiature est l'un des principaux attraits touristiques de la région. Ce type de développement a toutefois entraîné la disparition de grandes superficies de milieux humides.

Le lac est très fréquenté pour la chasse et la pêche sportives, le nautisme et la baignade. La pêche commerciale a connu de profondes transformations au Québec durant les dernières décennies et représente aujourd'hui une activité économique modeste qui occupe une dizaine de pêcheurs au lac Saint-François.

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The mere mention of the St. Lawrence evokes in most Quebecers a deep-rooted feeling of belonging to this land traversed by the river on its way from the Great Lakes to the sea. Images of a mighty river spring to mind, hugged on either side by fertile plains, shaded banks and rich wildlife.

This country was born on the banks of the river – as is still evident today in the division of land, a vestige of the seigneurial system. Back then, people had to learn to live with the spring flooding of the St. Lawrence. In return, the river provided the European settlers, still struggling with unreliable harvests, with a sure supply of fish and a first-rate means of communication linking the first towns and villages that grew up along its banks.

With time, forests gave way to farmland, and then towns and cities sprang up. Until that point, the low population density and the very size of the St. Lawrence meant that human use of the river had had virtually no impact on its resources. But things would soon change. The first major impact appears to have been caused by logging and the beginnings of industrialization, in the nineteenth century; this included the floating of timber down the Ottawa River and the St. Lawrence to Quebec City, the building of dams and sawmills along tributaries, and the construction and commissioning of the first hydro-electric power plants.

The pace of change accelerated in the twentieth century, with the construction of major dams on the St. Lawrence itself to control the flow of water, ship channels and then the St. Lawrence Seaway. More and more industries were established near towns and cities, often right on the river. The proximity of the river offered several advantages: it reduced the cost of transporting raw materials, solved water supply problems and provided an easy way of getting rid of waste.

The St. Lawrence gradually succumbed to the accumulated abuse. A few informed observers noted that some animal species were becoming less abundant and suggested that this was the result of habitat disturbance. Their warnings elicited little public interest, however.

Then, in the early 1970s, public opinion was suddenly roused when it was realized that mercury contamination of fish was not just an abstract research topic but a real risk to which some Native peoples and many sport fishermen were exposed. As the list of toxic substances reported in the aquatic environment continued to grow, the general public changed its perception of the problem and put the quality of the environment at the top of its list of concerns. There is virtually unanimous agreement now that the comforts afforded by an industrial society have a drawback: unbridled exploitation of resources and the increasing quantity of contaminants will eventually threaten all forms of life, including human beings.

Most industrialized countries have now agreed to base their economies on sustainable development. Profit can no longer be the sole guiding force of human activity. Given the fragile nature of our environment and the limitations of our planet, sustainable economic development must ensure that scarce resources are used for a variety of purposes; it must also take into account the quality of life of human beings and promote the maintenance of biological diversity.

Priority Intervention Zones (ZIP) Program

Beginning in the 1960s, the awakening of public opinion about the state of the environmental degradation of the Great Lakes and St. Lawrence and the urgency of the situation prompted governments to undertake concrete, concerted action. This action paved the way for a 1972 Canada–U.S. agreement to clean up the Great Lakes. An amendment was made in 1987 to include a program to restore use at the local level (remedial action plans or RAPs). In addition, an agreement to control the discharge of toxic waste into the Great Lakes system and the Great Lakes Charter were signed by the eight U.S. states concerned, Ontario and Quebec in 1988. Out of concern for the poor quality of the water in the river and its tributaries, the Government of Quebec launched its wastewater treatment program in 1978.

In 1989, the Government of Canada and the Government of Quebec agreed to co-ordinate their efforts under the St. Lawrence Action Plan; in 1994, the plan was extended and given the new name St. Lawrence Vision 2000 (SLV 2000). One of the objectives of the plan is to draw up a comprehensive assessment of the state of the environment of the Quebec stretch of the river. Under the ZIP program, the St. Lawrence has been divided into 23 Priority Intervention Zones (better known as ZIPs) within which people and organizations will be encouraged on a local level to work together to restore and protect the river and co-ordinate its use (Figure 1). As part of the groundwork for the consultations, the partners of SLV 2000 are reviewing and synthesizing current knowledge about the state of the environment in each area.

This report summarizes the highlights of the technical reports¹ and assesses current knowledge of the state of resources and present and future uses of Lake Saint-François (which takes in ZIPs 1 and 2), and the associated constraints.

1. One report deals with the physical chemistry of the water and sediments (Fortin et al. 1994), another examines biological communities (Armellin et al. 1994), and a third discusses relevant social and economic questions (Jourdain et al. 1994).

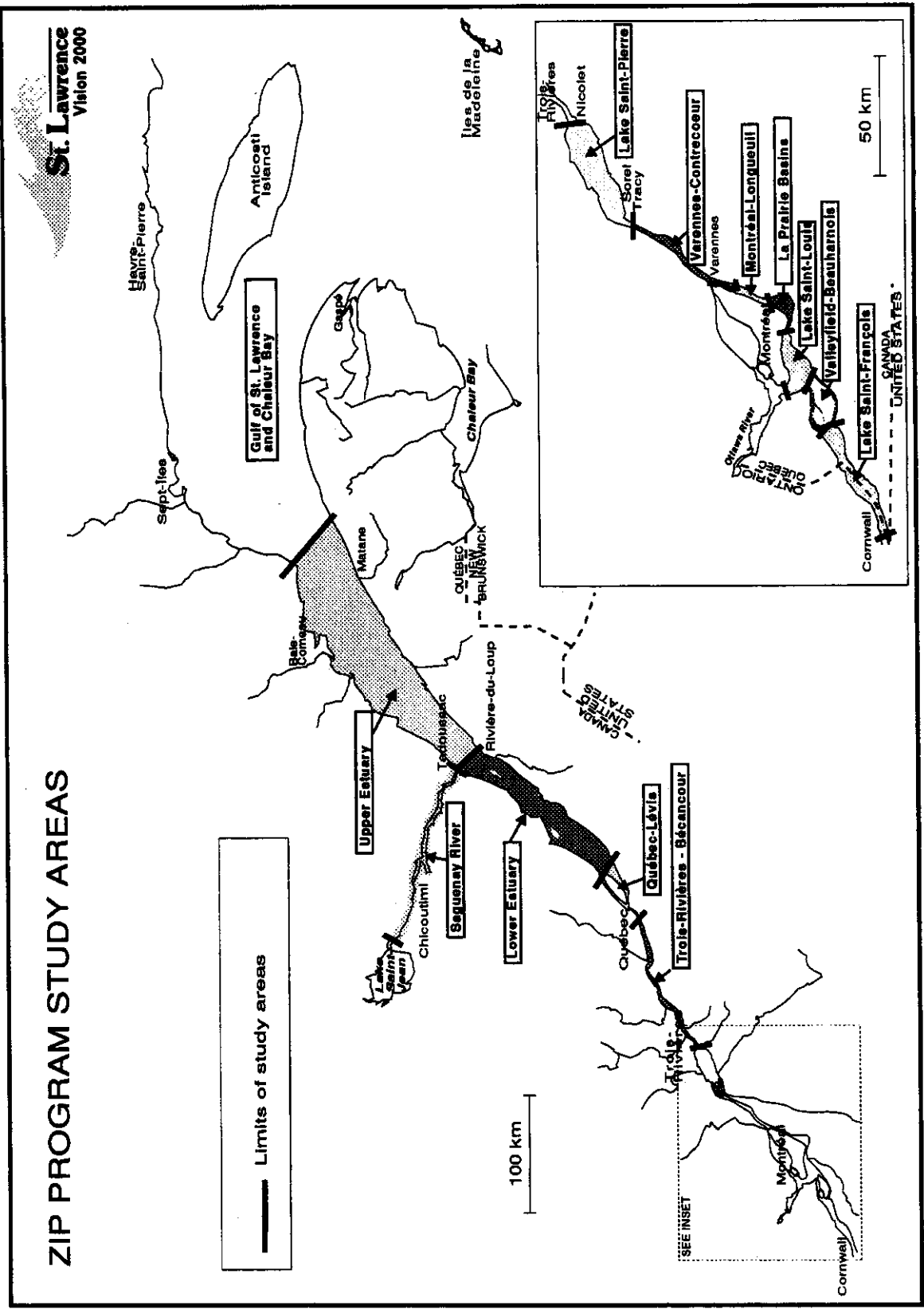


Figure 1 ZIP Program study areas

The purpose of this effort to review and synthesize our existing knowledge is to provide the various riverside stakeholders with accessible, objective scientific data so that they can define their priorities for action. They will then be able to draw up and implement action plans on a local and regional level, with each partner acting within its sphere of responsibility, but in co-ordination with the other partners.

The sector examined here stretches from Cornwall to the western tip of De Salaberry Island (Figure 2). Lake Saint-François is the first natural widening of the St. Lawrence in Quebec. One of its prime characteristics is that virtually all the water that flows through it comes from the Great Lakes.

To assess the extent of the changes wrought by human activity on Lake Saint-François, ideally we would have to compare its original state with its present state. Unfortunately, this is impossible because most of the environmental data have been collected in the last few decades, i.e. after the lake underwent major changes in the 1930s. To take just one example, the first fish surveys of Lake Saint-François were conducted in the 1970s, well after water control structures that modified flow patterns and fish habitat had been built. Some species may well have disappeared from the lake before their existence could be recorded.

In spite of these limitations, a description of the general features of the lake is useful for putting environmental disturbances into context and arriving at a rough estimate of the extent of their impact.

3.1 Physical Environment

At the time of the last ice age, several thousand years ago, a major arm of the sea was located in southern Quebec and Ontario. When the ice receded, uplift of the Earth's surface gradually left some places dry, while isolating salt water in the huge basins that now form the Great Lakes. The lakes are supplied with precipitation from a drainage basin of 1.2 million square kilometres. What they cannot hold flows to the sea by way of the St. Lawrence River, at an average rate of $6850 \text{ m}^3/\text{s}$ as it leaves Lake Ontario. This is what is called the Great Lakes–St. Lawrence ecosystem.

Over thousands and thousands of years, the river carved out its bed in the unconsolidated deposits and clay that settled at the bottom of the former arm of the sea. This fertile plain, the St. Lawrence Lowlands, is bounded by the Canadian Shield to the north and by the Appalachians to the south.

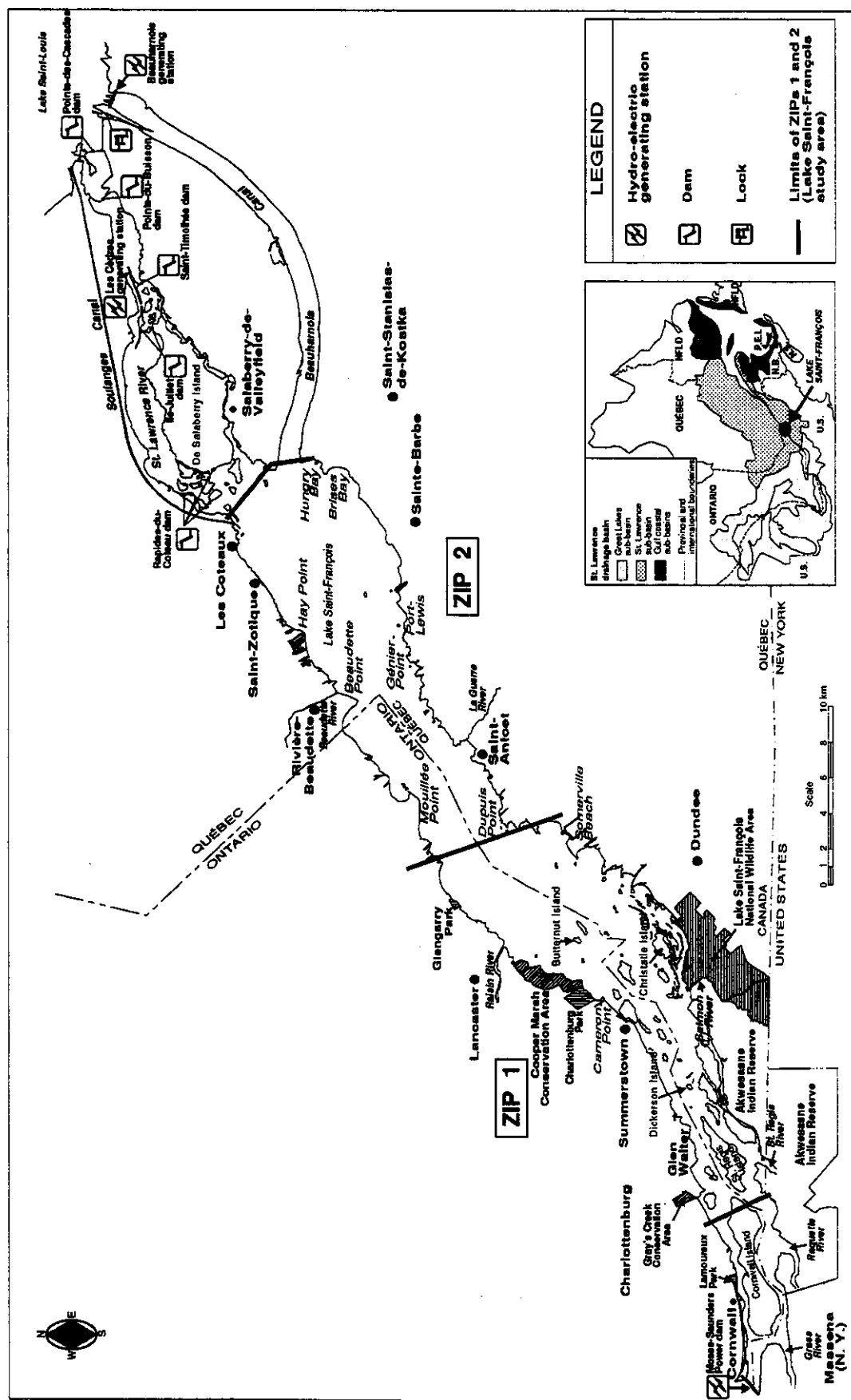


Figure 2 Map of study area — Lake Saint-François (ZIPs 1 and 2)

From Lake Ontario to Lake Saint-François, the St. Lawrence now marks the Canada-U.S. border, running approximately 170 km between Ontario and the state of New York. The input of tributaries along this stretch of the river is relatively small, as the flow increases here by only about 13%.

Lake Saint-François itself is more a widening of the river than a real lake. The current running through it is strong enough to prevent thermal stratification of the water.² It does, however, have some characteristics typically associated with lakes. Its upstream portion is dotted with a large number of islands surrounded by beds of aquatic plants and separated by shallow channels. Its shoreline includes bays where a lack of current allows the water to warm up significantly.

Table 1 summarizes some of the characteristics of Lake Saint-François in its current state. It now covers a larger surface area than it did originally, as the water level was raised by some 40 cm in the 1930s to provide a reservoir for the Beauharnois generating station.

The data also show that the input of tributaries to the flow of the lake, in relation to the flow of the river itself, is very minor (less than 2%). This explains why the water of Lake Saint-François, in contrast to the other stretches of the St. Lawrence, flows in a single uniform mass. Hard and alkaline, the water's chemical composition is very similar to that of Lake Ontario.

3.2 Vegetation and Habitats

The land vegetation around Lake Saint-François would tend to form sugar maple-hickory stands were it not for changes brought about by human activities. The poor drainage of the lowlands in the immediate vicinity of the lake causes the vegetation to tend to be dominated by plants typical of wetlands. In the Lake Saint-François National Wildlife Area, where relatively undisturbed habitats have been preserved, grassland and swamp sit atop a layer of well-

2. Fishermen are familiar with thermal stratification, a characteristic of true lakes. They know that some fish gradually move away from the surface water when it warms up during the summer and take refuge at deeper levels, where it remains cold.

decomposed peat. The swamp vegetation is dominated in some places by shrubs (Alder and Willow) and in others by trees (Larch, Red maple or Red ash). These areas are a botanist's paradise because of the enormous diversity of plant life. Several species of plants that are thought to be threatened or vulnerable in Quebec are found here, especially in the Wildlife Area (see Appendix 1).

Table 1
Some characteristics of Lake Saint-François

Area	233 km ²
Length	50 km
Width	Average: 4.7 km Maximum: 7.5 km
Depth	Average: 6 m Maximum: 22 m
Volume of water	2.8 km ³
Mean annual flow	<div> <div>- of St. Lawrence, at inlet to lake</div> <div>7720 m³/s</div> </div> <div> <div>- of tributaries</div> <div>144 m³/s</div> </div> <div> <div>- total, at outlet from lake</div> <div>7864 m³/s</div> </div>
Retention time of water in lake	1 to 6 days (depending on sector)
Length of shoreline, excluding islands	
- in Ontario	59 km
- in United States	23 km
- at Akwesasne	27 km
- in Quebec	81 km
- total	190 km

The land surrounding the lake is low, and so the transition from the terrestrial to the aquatic environment is gradual (Figure 3). Reaching the actual shore of the lake requires crossing

wetlands (swamp and wet meadows) that are very broad in some places. It has been estimated that in the late 1970s, the wetlands around the lake occupied a surface area of close to 11 000 ha; marsh covered approximately 1150 hectares (ha). The marshes, which are prime wildlife habitats, existed at the turn of the century, but they expanded when the water level of the lake was raised in the 1930s.

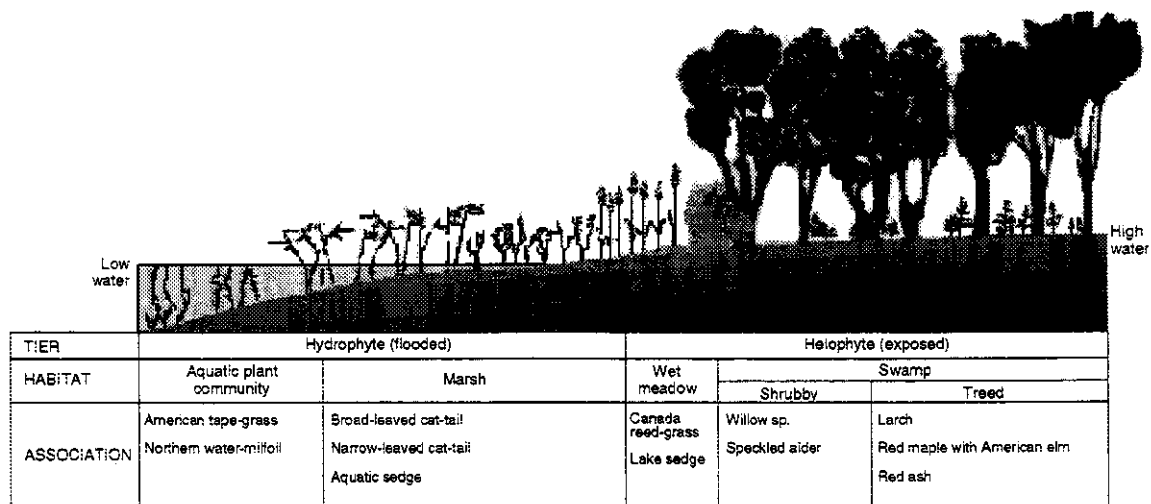
The rich, dense plant life even extends out from the shore, under the surface of the water. Wherever the nature of the lake bed and the lack of a strong current make it possible, aquatic plants form vast communities dominated primarily by *Myriophyllum* and *Vallisneria*. Since the water is clear, enough light penetrates that plants can colonize the lake bed to a depth of 6 m.

Today's wetland area is as extensive as it was in the 1970s (Figure 4). Aquatic plants cover one-third of the surface area of the lake. The largest plant communities are in the upstream part of the lake, and reach as far as the Beaudette River; the sector is dotted with some 60 low islands surrounded by shallow water. These very dense aquatic plant communities provide habitat for a wide range of abundant small invertebrates that find shelter and food there. This concentration of prey in turn attracts waterfowl and fish. The plant beds are also major breeding sites for several species of fish, including Yellow perch, Northern pike and Brown bullhead. The plants help keep roe above the mud. After hatching, fry can find food and shelter in the same location. These habitats are also favourable to birds, amphibians, some reptiles and Muskrats.

3.3 Benthos

The term *benthos* refers to all organisms that live on the water bottom, affix themselves to it or burrow into it. In Lake Saint-François, the most prevalent benthic organisms are gastropods, commonly called snails, of which there are 14 species in all. The distribution of these animals in the environment depends to a great extent on local conditions (presence of plant communities, nature of bed, depth) and the requirements of each species in this regard; one may be found almost exclusively among plants, while another will seek out areas where there is virtually no vegetation. The same is true of most of the other groups of benthic organisms.

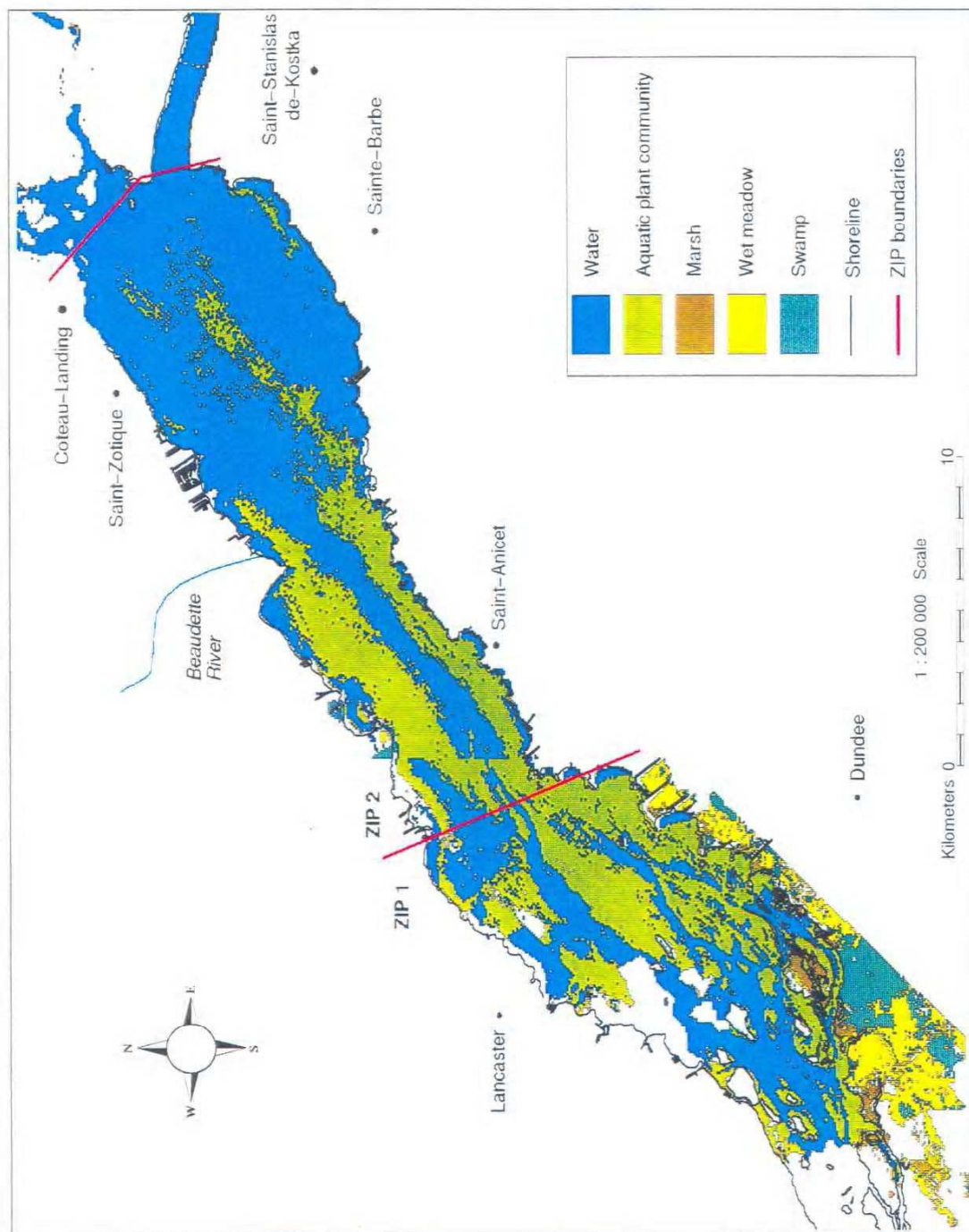
SEMI-AQUATIC MAMMALS	Zone used by Muskrat, Beaver and Mink			
AMPHIBIANS AND REPTILES	Zone used by turtles, frogs and salamanders			
FISH	Spring feeding zone for fish (Walleye, Yellow perch, Northern pike, Smallmouth bass, Brown bullhead, Lake sturgeon) Spawning of Northern pike and Yellow perch in spring Spawning of Largemouth bass and Brown bullhead			
BIRDS	Migrating diving ducks Dabbling ducks Great blue heron American wigeon Pied-billed grebe (feeding)	Dabbling ducks (feeding and brood rearing) Great blue heron Marsh wren (feeding) Black tern Swamp sparrow Virginia rail (nesting)	Dabbling ducks Swamp sparrow (nesting)	Great blue heron (nesting) Wood duck (nesting) Willow flycatcher Yellow warbler



Adapted from: St. Lawrence Centre and Université Laval. 1992. *A Mosaic of Habitats: Freshwater and Brackish Ecosystems. Environmental Atlas of the St. Lawrence*. St. Lawrence Centre, Conservation and Protection, Environment Canada, Quebec Region.

Source: Armellin et al. 1994. *Synthèse des connaissances sur les communautés biologiques du lac Saint-François*. Technical report on ZIPs 1 and 2. St. Lawrence Centre, Conservation Branch, Environment Canada, Quebec Region.

Figure 3 Transition from terrestrial to aquatic environment



From: Létoumeau, G. 1994. *Répertoire des activités de télédétection au Centre Saint-Laurent*. Environnement Canada, Conservation and Protection, Quebec Region.

Figure 4 Lake Saint-François wetlands

3.4 Plankton

Determining the level of productivity of a lake requires a close examination of its plankton, a group of tiny organisms, plant or animal, that live suspended in water. The composition of the plankton samples collected in the central part of the lake, where the flow of water is concentrated, is very similar to what is found in Lake Ontario. In shallow areas along the shore, however, the plankton is more abundant and varied, reflecting the conditions that are much more favourable to its growth in these environments. Lake Saint-François as a whole can be classified as fairly productive based on the assessment of its plankton; however, shallow areas are very productive, especially in plant communities.

3.5 Fish

The number of species of fish reported in Lake Saint-François (57) is significantly fewer than that reported in Lake Saint-Louis (77) and Lake Saint-Pierre (78). This discrepancy could in part be explained by natural causes, since Lake Saint-François consists of a single homogeneous water mass, in contrast to the other two lakes, and thus offers less diversity in its fish habitat. However, the difference has probably been reinforced by the construction of dams upstream and downstream from the lake, as we will see later. Given that the first fish surveys of Lake Saint-François were done well after its flow was regulated, any attempt to determine the relative importance of these two factors can only be speculation.

Yellow perch is the dominant species, in terms of numbers and biomass, while the most common predators are Northern pike and Walleye. The species composition of the fish in Lake Saint-François would appear to be typical of a lake of average productivity.

3.6 Birds

The extensive wetland areas provide habitat for abundant, varied birdlife. Altogether, 260 species can be found in the region at some time or other of the year, and of this number, 134 breed there. The lake is an important staging ground on the Atlantic flyway, a major migration route for waterfowl. The most abundant species are diving ducks, birds that disappear completely under the surface of the water when feeding: the Greater scaup, Lesser scaup,

Ring-necked duck and Redhead. The largest flocks of pochards along the St. Lawrence are to be found on Lake Saint-François. When staging, these birds congregate at aquatic plant communities for feeding.

The main species of ducks that breed around the lake are dabbling ducks, such as Mallards, American wigeons and Gadwalls. Waterfowl breeding grounds are located chiefly at Charlottenburg, at Bainsville Bay and between Beaudette Point and Saint-Zotique, on the north shore, or throughout the marshy area on the south shore. Lake Saint-François is one of the rare sites in Quebec where Redhead nesting has been observed. It is also a major overwintering ground for the Common goldeneye and the Common merganser.

Among the other points of interest regarding the birdlife on Lake Saint-François, there is a small colony of Common terns on Butternut Island and a heronry on Dickerson Island, in the Quebec part of Akwesasne. Four species of wading birds cohabit this spot: the Great blue heron, Black-crowned night-heron, Green-backed heron and Great egret. In the case of the Great egret, it is the only colony in Quebec.

Birds considered to be at risk in Quebec that have been reported in the Lake Saint-François area are listed in Appendix 1.

3.7 Human Occupation

In 1991, some 77 000 people lived in the Lake Saint-François area, including Cornwall.³ This mostly rural population was split among 11 riverside municipalities and the Akwesasne Indian Reserve.

Two urban industrial centres are located just at the upstream and downstream limits of the Priority Intervention Zones examined here (ZIPs 1 and 2). The one upstream is composed of Cornwall on the north bank of the St. Lawrence and Massena on the south bank. A number of industrial plants are located in these two municipalities, which are linked by a bridge and serve as a point of entry on the Canada-U.S. border. The second centre, consisting primarily of the

3. According to 1991 data, the numbers break down as follows: approximately 11 000 people in the Quebec section of the area under study; 55 000 in the Ontario part (including 47 000 in Cornwall alone); and 10 600 on the Mohawk Reserve of Akwesasne. The township of Massena, N.Y., had a population of slightly over 13 000 in 1988.

municipality of Salaberry-de-Valleyfield, which is a satellite town of Montreal, extends to the suburbs of Les Coteaux (formerly called Coteau-Landing) and Saint-Zotique, within the boundaries of ZIPs 1 and 2.

Designated urban land represents only 8% of the total study area and consists primarily of a low-density strip stretching along a major part of the shoreline. This urban strip is composed chiefly of residences, cottages and vacant lots.

The Mohawk Reserve of Akwesasne straddles the borders of Quebec, Ontario and New York. A population of 10 600 people live in this 81-km² area, which extends along the south shore and includes many islands. With the exception of the four main localities on the reserve, Mohawk land is essentially rural.

Human Activities and Their Main Effects on the Lake

This chapter briefly describes the main human activities in the area of Lake Saint-François, their effects on the aquatic and riparian environment, and their impact on certain aspects of the lake's potential.

4.1 Water Level Regulation and Channelization

The construction of hydro-electric generating stations and dams upstream and downstream from Lake Saint-François was a factor in concentrating industrial activity and waste discharge in the Cornwall-Massena and Valleyfield areas. These structures seem to have had considerable effects on sediment dynamics, wildlife habitats and biological communities.

While other structures built earlier also altered flow conditions on this stretch of the St. Lawrence, the most significant changes came with the construction of the Beauharnois generating station from 1921 to 1931. From then on, Lake Saint-François was used as a reservoir, causing the level of the lake to rise by almost 40 cm and then to stabilize. The Beauharnois Canal was gradually dug and widened, from 1929 to 1961, while dams (Coteau 1 to 4) across the rest of the riverbed diverted a larger and larger proportion of water to the generating station. Today, approximately 84 percent of the river's flow goes through the Beauharnois Canal and power station.

As time went by, other flow-control structures were built for various purposes upstream from Lake Saint-François. In 1958 a Canada-U.S. agreement came into force to stabilize the level of Lake Ontario while ensuring a minimum water level in the Port of Montreal. The Iroquois, Long-Sault and Moses-Saunders dams all regulate the flow of the river.

Maintaining the water level of Lake Saint-François has had the effect of eliminating the flood plains that were once used as breeding and feeding grounds by many animal species. The only spots where spring flooding still occurs are the mouths of some tributaries such as the Salmon and La Guerre rivers.

The slight changes in level that occur in Lake Saint-François in the course of an annual cycle contrast with the conditions typical of a natural environment. The water is low in spring, rises gradually throughout the summer, declines during the fall and reaches its highest point in the winter. This phenomenon affects the reproduction and development of plant and animal species, particularly those adapted to the annual cycle of spring flooding.

The control of the flow pattern, followed by the dredging of the St. Lawrence Seaway in the late 1950s, altered the currents in the lake. The new flow conditions reduced the amplitude of the seasonal process of releasing sediment back into circulation while favouring a permanent buildup in some areas. The clarity of the water is a good indication that the quantity of suspended solids being transported is generally small. During a short period corresponding to the spring thaw, the international section of the St. Lawrence carries more suspended solids, chiefly originating from Ontario and U.S. tributaries. Most of these particles wash through the middle of Lake Saint-François, where the current is the strongest. Approximately 4% to 8% of the suspended solids are permanently deposited on the bottom of the lake in deep basins (over 4 m in depth), particularly in the downstream portion of the lake.

Lake Saint-François itself contributes very little to the sediment load of the river because flooding is minor and not much sediment is supplied by its tributaries. In addition, as the strongest current is concentrated in the central channel, there is less possibility of shore erosion.

Vegetation in the lake and on its shores has also been affected by the change in flow pattern. In the 1930s, when the water level was raised by about 40 cm, marsh and swampy areas expanded at the expense of farmland. This change, coupled a few years later with the elimination of natural fluctuations, caused certain plant communities adapted to spring flooding to disappear in some spots, while other associations thrived under the new conditions. Aquatic plant communities expanded and their composition changed.

As mentioned earlier, the fish communities of Lake Saint-François are less diverse than those of Lake Saint-Louis or Lake Saint-Pierre. It is risky, however, to blame this difference entirely on control of the flow pattern. There are no experimental fishing surveys dating from before the existing flow-regulation system was built that might prove that the number of species present in the lake has really and truly declined. Also, the physico-chemical properties of the water of the other lakes on the St. Lawrence are more diverse because of major tributaries on the north bank of the river, coming from the Canadian Shield.

It is fairly certain, nevertheless, that fish species that reproduce primarily in spring flood areas have suffered as a result of the artificial regulation of the water level in Lake Saint-François.

The existence of dams upstream and downstream from the lake also makes it very hard for migratory species of fish such as American eel and Lake sturgeon to move up or down the St. Lawrence. The very vulnerable situation of the latter species may be related to the loss of access to spawning grounds. Though this problem has been recognized since the 1940s, it has continued to worsen.

The impact of the new flow pattern on wildlife has not been entirely negative. The dumping of material dredged from the Seaway, especially in the upstream sector, appears to have favoured the expansion of some aquatic plant communities, which in turn has enlarged the available wildlife habitat. Some wetland species, such as diving ducks, seem to have benefited from this expansion. The use of Lake Saint-François by these species increased substantially between the late 1950s and the mid-1970s.

4.2 Pollution

Discharging effluent into the river was long regarded as a convenient, inexpensive way of getting rid of it. Industrial plants, municipalities and farms released their waste and drainage water into the river without treating it, until the impact of the pollution could no longer be ignored. The scale of the problem forced the governments to monitor effluent and establish concentration levels for various substances. A number of chemicals and metals persist in the environment anyway and continue to contaminate it many years after their discharge. The volume

and nature of the types of effluent determine their effects on the environment. For instance, industrial plants are usually the main sources of toxic substances, while municipal sewage contributes to bacterial contamination and a strong increase in biological productivity which, among other things, can cause a proliferation of algae and give water a foul smell that is not very inviting to swimmers.

In the case of Lake Saint-François, the sources of pollution that have had the most impact on the environment are, in decreasing order, the international section of the St. Lawrence,⁴ tributaries⁵ and municipal sewage.

4.2.1 Sources of pollution

Industrial effluent. The industrial operations that have a harmful effect on the quality of the water of Lake Saint-François are not located along its shores, but upstream. Lake Ontario, which feeds the international section of the St. Lawrence, is heavily polluted by industry; most contaminants would therefore be expected to come from that source. Yet studies have progressively shown that the biggest sources of certain toxic substances found in Lake Saint-François are actually situated very close by, in the Cornwall–Massena area. The waste discharged in this sector reaches the lake via the international section of the St. Lawrence.

There are also plants on the U.S. side that discharge their waste directly into the river or its tributaries (Figure 5). The volume and toxicity of the effluent from three of these plants,⁶ which are metallurgical facilities, was particularly high in 1990 (Table 2).

4. While the water quality of the international section of the St. Lawrence must be considered as a whole, a significant body of data emphasizes the overwhelming impact of the industrial plants in the Cornwall–Massena area. This report therefore pays particular attention to that area even though it lies outside the geographical boundaries of the study.

5. The tributaries, which actually collect non-point source pollution from their entire drainage basin, are here treated as though they were specific sources of effluent on the bank of the river.

6. Reynolds Metals, Aluminum Company of America (ALCOA) and General Motors Central Foundry (GM).

Table 2
Main toxic substances discharged by industrial plants
in the townships of Massena and Ogdensburg, N.Y.

<i>Substances</i>	<i>ALCOA</i>	<i>Corning Glass</i>	<i>General Motors</i>	<i>Gouverneur Talc</i>	<i>James River Paper</i>	<i>Newton Falls Paper</i>	<i>Ogdensburg</i>	<i>Potsdam Paper</i>	<i>Reynolds Metals</i>	<i>Zinc Corp. of America</i>
Total PCBs	●		●						●	
Total PAHs	●								●	
Aluminum	●		●						●	●
Arsenic									●	
Cadmium							●			●
Chromium			●		●					
Copper	●	●	●		●	●	●			●
Cyanides	●					●	●		●	●
Iron		●	●	●						●
Mercury										●
Nickel						●				
Lead							●			●
Zinc	●			●	●		●	●	●	●

Source: New York State Department of Environmental Conservation, 1990. *St. Lawrence River at Massena Remedial Action Plan — Stage 1.*

On the Cornwall side of the river, a large number of industrial plants have been operating in recent years. In the Cornwall Remedial Action Plan (RAP), nine of these plants were regarded as major sources of pollution of the St. Lawrence.⁷ Most of the plants were in an industrial park near the Moses-Saunders Power Dam, and their effluents were combined before being discharged into the river (Table 3). A number of these plants have recently been shut down, and only the Domtar paper mill is still operating. This plant discharges the highest volume of effluent: over 100 000 m³/day. Significant mercury contamination of Lake Saint-François can

7. The five biggest polluters are Domtar, ICI (formerly CIL), Cornwall Chemicals, Stanchem Chemicals and Courtaulds Fibres. It should be noted that the Courtaulds Fibres plant and the ICI industrial complex, which included Cornwall Chemicals and Stanchem Chemicals, ceased operations in 1993 and 1994, respectively.

be traced to use of this metal as a bactericidal agent by Domtar until 1970 and by ICI for electrolysis.

Table 3
Estimated volume of main industrial effluent from Cornwall and amounts of contaminants discharged daily into the aquatic environment, in 1985 (kg/d)

<i>Effluent</i>	<i>Domtar, ICI and Cornwall Chemicals (combined effluent)</i>	<i>Courtaulds Fibres</i>
Volume (m ³ /d)	116 990	8 467
Estimated toxic substance load (kg/d)		
Arsenic	0.17	0.012
Chromium	—	0.45
Copper	4.7	0.31
Mercury	0.22	0.06
Lead	—	1.4
Zinc	7.6	125.26
Iron	50.3	16.4
Chloroform	41.2	1.336
Carbon tetrachloride	53.0	—
Bromodichloromethane	—	0.036
Benzene	1.64	—
Toluene	—	0.012
O-xylene	1.64	—
Guaiacol	27.5	—
Phenols	16.5	—
Total phenols	168.6	—

Source: Anderson, J. 1990. "St. Lawrence River Environmental Investigations. Volume 4: Assessment of Water and Sediment Quality in the Cornwall Area of the St. Lawrence River." In *St. Lawrence Remedial Action Plan*. Ontario Ministry of the Environment.

In recent years, U.S. and Ontario government agencies have increased their monitoring of industrial effluent and tightened up their standards. A number of companies that are now involved in a pollution clean-up program have improved their facilities in order to treat

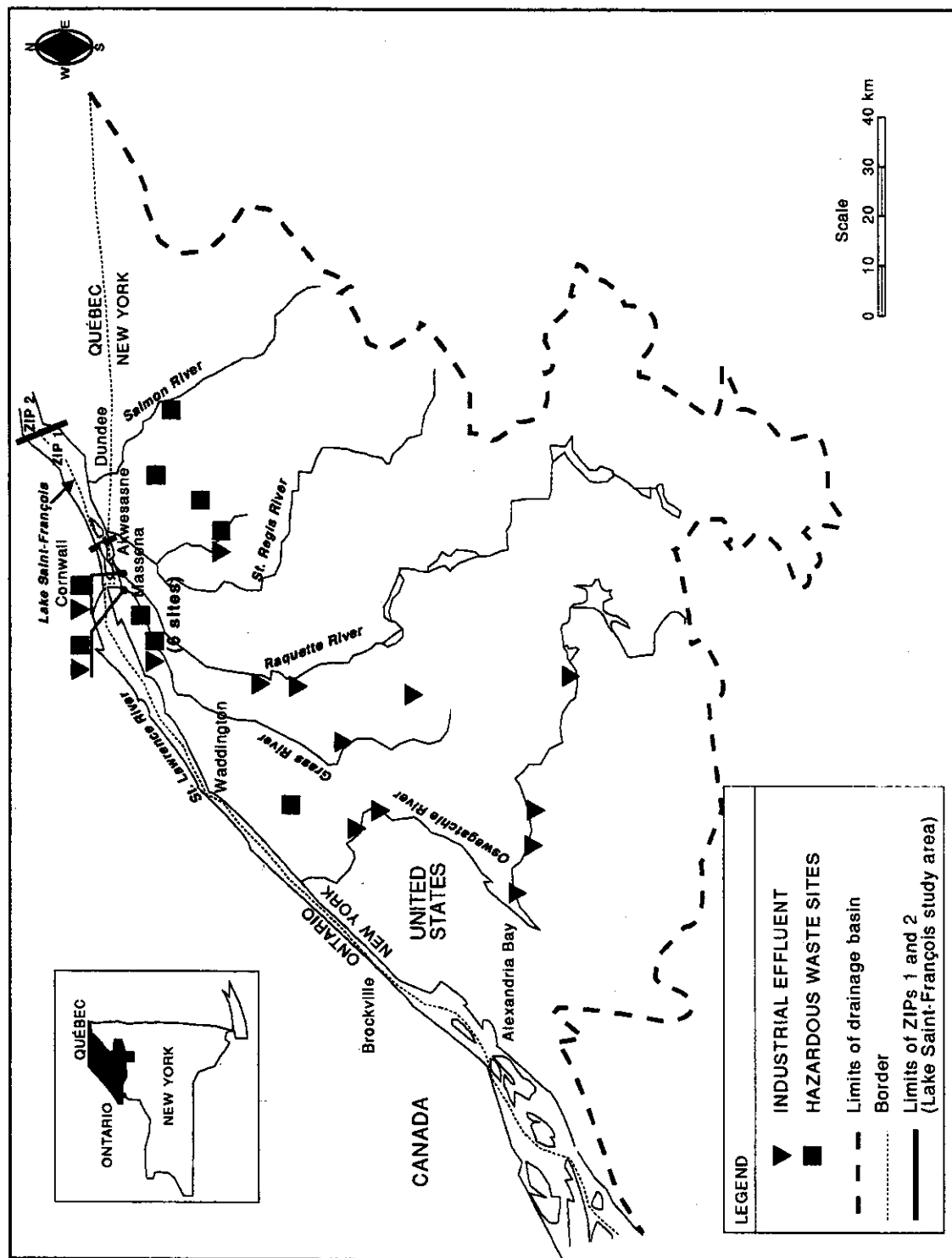
their process water before discharging it into the river. A short time ago, Domtar began using a new cleaner, more economical paper-making process. In addition, the new treatment plant should help the plant meet the new regulations governing pulp and paper mills.

Hazardous waste sites. In addition to effluent, industrial plants produce hazardous waste, which they dispose of in landfills. These sites also add to the contamination of the aquatic environment. Some products can flow on the surface or migrate to the groundwater, eventually ending up in rivers and streams. Fourteen hazardous waste sites were counted in 1990 in the U.S. part of the Lake Saint-François drainage basin (Figure 5). Some sites have been the source of contamination of the aquatic environment by PCBs, mercury and other pollutants. An environmental remediation program under the Massena RAP addresses these sites.

Municipal effluent. In the Quebec part of the area in question, most homes and cottages have septic tanks; those that have none discharge their sewage into Lake Saint-François. The municipalities of Les Coteaux, Saint-Zotique and Rivière-Beaudette do have sewer systems, but the sewage they collect drains into the river without being treated.⁸ This municipal effluent is primarily a source of organic and microbial contamination. However, the total volume discharged is small (estimated to be less than 0.1 m³/s) owing to the low population density. To place it in context, it is less than one-tenth of the volume that the municipality of Salaberry-de-Valleyfield releases into the Beauharnois Canal.

Upstream from Lake Saint-François, the south bank is the source of most of the sewage discharged into the river. Altogether, 22 American municipalities, Massena included, treat their household and industrial wastewater before releasing it into the St. Lawrence or one of its tributaries. Cornwall, too, has its own sewage treatment plant, which also processes some industrial effluent.

8. The municipalities of Les Coteaux and Saint-Zotique should have sewage treatment facilities soon (by 1995).



Source:

New York State Department of Environmental Conservation, 1990. *St. Lawrence River at Massena Remedial Action Plan — Stage 1.*

Figure 5

Main industrial effluent and hazardous waste sites in the U.S. part of the Lake Saint-François drainage basin

Tributaries. Industrial and municipal effluents from point sources in their drainage basins are also collected by some tributaries, which carry them to the St. Lawrence (Table 4). As well, tributaries are the main gateway by which fertilizers, pesticides and liquid manure used on farms get into the aquatic environment. In contrast to industrial and municipal waste, which are released into the environment at specific points, agricultural pollution has no single source. The rain-, melt- and irrigation-water that seeps through plowed fields carries nutrients and pesticides to rivers via a multitude of channels, ditches and streams. This runoff degrades water quality, makes the environment inhospitable to aquatic species and spoils the appearance of the lake.

Table 4
Origin of pollutant load of tributaries

<i>Tributary</i>	<i>Sources of pollution</i>			
	<i>Industrial effluent</i>	<i>Municipal effluent</i>	<i>Hazardous waste</i>	<i>Agricultural production</i>
Oswegatchie River	•	•	•	•
Grass River	•	•	•	•
Raquette River	•	•	•	•
St. Regis River	•	•	•	•
Salmon River		•	•	•
La Guerre River				•
Raisin River			•	•
Beaudette River				•

In the Quebec section of the study area, 80 percent of the land is designated for rural use, mainly farming. The lowlands of the St. Lawrence River Valley are a productive agricultural area owing to the clay soil and the length of the growing season. The main products of the 294

farms active in 1991 were milk, grain and beef cattle. The major grain crops have the greatest impact on the aquatic environment because they require large amounts of fertilizer and pesticide, part of which ends up in rivers and creeks.

Few data are available, however, on the non-point source pollution of Lake Saint-François attributable to agriculture.

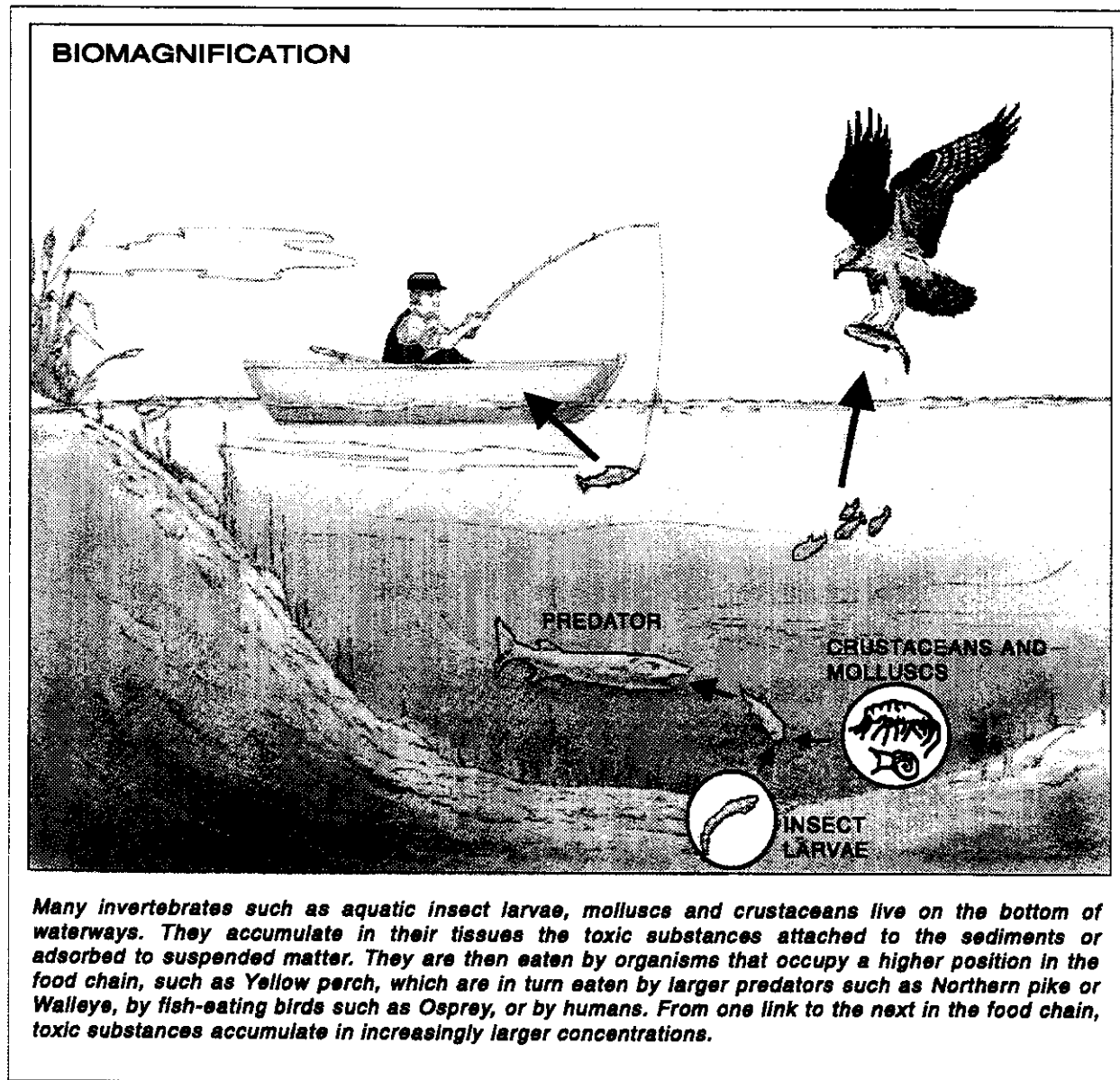
4.2.2 Effects of pollution on aquatic environment

Whatever their origin, the pollutants found in the aquatic environment present varying degrees of risk to the normal functioning of living organisms. Some types of pollution have no lasting effects, and the quality of the environment improves quickly as soon as the discharge of waste stops. This is the case, for instance, with bacterial pollution, the enrichment of water by nutrients, or highly soluble chemicals that are almost all carried out to sea by the current. Other pollutants, however, can become concentrated in sediment or organisms because they are chemically stable in their original form or as by-products of a substance that breaks down in the environment. These substances that persist in the environment can be found in high concentrations in living organisms.

The level of a toxic substance in an organism can increase throughout its life, a phenomenon known as *bioaccumulation*. It can also increase as materials are passed up the food chain, through a process known as *biomagnification*. Substances are thus gradually transferred to predators (fish, birds or mammals) at the upper levels of the food pyramid, attaining high concentrations in these animals (Figure 6).

For researchers seeking to confirm the presence of a substance in the environment, biomagnification can provide useful clues. Analyses of the flesh of predator fish can sometimes reveal the presence of contaminants that are in too small quantities to be directly detectable in water or sediment, even when the best techniques are used.

Analysing cases where standards are exceeded is a way of identifying substances in the environment that are cause for concern and should be given special attention because they present a potential danger to human health, aquatic organisms or associated fauna. A list of environmental quality criteria is provided in Appendix 2.



Adapted from: *Toxics in the St. Lawrence: An Invisible But Real Threat*. St. Lawrence Update series, St. Lawrence Centre, Environment Canada, Conservation and Protection, Quebec Region, June 1990.

Figure 6 Risks of biomagnification

Water. In recent years, the quality of the water in Lake Saint-François has generally been fairly good.

In the 1980s, concentrations of coliform bacteria above the criteria set for swimming were reported at a few sites, particularly downstream of Cornwall. More detailed analyses showed that the abundant coliform bacteria in the area were not fecal in origin, but consisted primarily of *Klebsiella*, a bacterium that is abundant in pulp and paper mill effluent. In other places, especially Saint-Zotique, conditions unfit for swimming have been reported on occasion. For the lake as a whole, however, the most recent (1990–1994) surveys indicate that the bacteriological quality of the water is very good.

Over the last decade, contaminants have been found in the water, but in general their concentrations have not reached worrisome levels. Arsenic levels exceed the quality criterion for raw water (i.e. untreated water taken directly from a river or lake), although they do meet the standard for drinking water. The fairly uniform values measured throughout the St. Lawrence–Great Lakes system suggest that the arsenic levels are natural rather than the result of sources of contamination. Aluminum, iron and phosphorus concentrations that exceed the quality criteria for the protection of aquatic organisms (chronic toxicity to aquatic life) have been measured on several occasions in the vicinity of the St. Regis River. These concentrations are not harmful to humans, however. The iron and aluminum seem to be natural in origin, as they are major elements of the rocks in the drainage basin. It is possible that some proportion of these metals is not available to aquatic organisms, which would reduce their toxic potential. The high phosphorus concentrations appear to be the result of the fertilization of farmland in the drainage basin. The enrichment of rivers and streams with nutrients such as phosphorus causes a proliferation of aquatic plants which, upon decomposition, reduce the dissolved oxygen content in the water. These conditions are unfavourable to aquatic species, and the decaying plants are unsightly and smelly.

The PCB levels measured in the past are now regarded as doubtful, for a number of reasons. Experts agree, however, that the significantly lower concentrations found today with more reliable analytical techniques are still cause for concern, especially in spring and summer

at the inlet to the lake. They exceed the criteria for raw water and aquatic organism contamination. Furthermore, these new techniques have revealed the existence of DDT in the water at concentrations that also exceed these established quality criteria.

Sediment. A number of contaminants attach themselves to suspended particles in the water that tend to collect on the bottom in areas where the current slows down. This is how form the beds of polluted sediment that contribute to the contamination of bottom-dwelling organisms. Areas where sediment is deposited are often those where aquatic plants grow, which themselves are home to a rich benthos at the bottom of the food chain. The presence of contaminated sediment is thus a risk to the fish, birds and mammals that feed at these sites, and ultimately to the hunters and fishermen who eat them.

To assess the extent of the contamination of Lake Saint-François sediment and the associated risks to the environment, three sampling campaigns have been conducted since 1976. The data collected were used to establish the location of the contaminated areas (Figure 7). The two most worrisome contaminants were mercury, along the north shore of the lake, and PCBs, along the south shore. In the late 1980s, mercury was found in higher concentrations in the sedimentation areas closest to Cornwall. The levels measured fall off from west to east. A similar phenomenon can be observed with PCBs on the south shore: PCB levels in sediment decline with distance from their point of discharge, which is in the Massena area; however, the levels rise again near the outlet of the lake.

Even if the distribution of contaminants is more or less the same as in the past, the most recent data (1989) point to an improving trend in the surface layers of sediment. It appears that mercury has declined by 37%, on average, on the north shore since the late 1970s while PCB concentrations have fallen by 95% on the south shore. This drop in contamination levels has been associated with efforts by industrial plants and municipalities to clean up pollution in the upstream part of the lake. Other substances are present in the sediment in concentrations that vary with the location.⁹ In general, the degree of pollution of Lake Saint-François sediment does little

9. Copper, zinc, cadmium, lead, arsenic, naphthalene, endrin and aldrin.

harm to benthic organisms (minimal effect threshold), except in the area of the Courtaulds Fibres outfall, where the mercury, copper, lead and zinc levels can be harmful to benthic organisms (toxic effect threshold).

Plants. Analyses of aquatic plants have confirmed that they accumulate certain contaminants. Industrial waste discharged upstream of the lake has in the past been responsible for high concentrations of beryllium, strontium and cobalt, but there is no information available on the possible effects of each of these substances on aquatic plant communities.

Benthos. No benthic organisms from Lake Saint-François are consumed directly by human beings. The concentrations of some heavy metals, such as lead and mercury, reported in some animals in 1976 would have made them unfit for commercial sale in any case. The concentrations of copper measured in the benthos of Lake Saint-François were, at that time, the highest in the entire Quebec section of the St. Lawrence.

Although many contaminants are present in the sediment, the concentrations observed more recently do not seem to be causing any major damage to benthic communities. Except at a few points highly polluted by mercury or PCBs, the benthic communities studied in 1992 were, in the lake as a whole, more influenced by the presence of aquatic plants and the depth or type of sediment than by contaminant concentrations. One study indicates that in the vicinity of the Courtaulds Fibres outfall, however, the growth of benthic organisms is being affected by toxic substances.

Since benthos moves relatively little, its degree of contamination gives a good idea of the distribution of toxic substances in the lake. Two species of mussels¹⁰ were selected for more detailed studies on account of their capacity to accumulate organic contaminants. The concentrations of PCBs and certain pesticides found in these mussels are higher in the western part of the lake, which suggests that the substances originate in Lake Ontario or the Grass River. Moreover, the composition of the PCBs in mussels in the St. Lawrence changes beginning at

10. *Lampsilis radiata radiata* and *Ellipsio complanata*.

Massena. This finding suggests that the Massena area is the main source of PCB contamination between Lake Saint-François and Lake Saint-Pierre.

Fish. Fishermen have known since the early 1970s that there is mercury in the fish in Lake Saint-François. According to surveys done at that time, the highest mercury concentrations were found in Walleye, Northern pike and White sucker; the problem appeared to be less serious in Largemouth bass and Smallmouth bass. Subsequent sampling showed a significant reduction in mercury concentrations in the flesh of these fish between 1970 and 1975, following a reduction in the amount of mercury discharged by the ICI and Domtar plants in Cornwall. New assays conducted in 1988 confirmed that the level of mercury contamination in fish had fallen 30% since 1976, while PCBs had dropped 80%. Nevertheless, the mercury levels found in the flesh of Northern pike and Walleye still exceed the limit set for commercial sale. In contrast, the PCB concentrations in these same species are all below this limit. However, they do frequently exceed the level set for the protection of fish-eating (piscivorous) birds and animals.

Other contaminants for which fish flesh was tested in 1988 and 1989 were found to be present in very small quantities. Among those that were found (total DDT, mirex and heptachlor epoxide), the levels were all below the limits set for commercial sale. However, even if such a level of contamination is not a threat to human health, it is still a cause for concern, particularly for fish-eating animals (Figure 6). Considering the affinity of some organic compounds for tissues other than flesh and the fact that piscivorous animals ingest the fish whole, some vital functions (reproduction, development) may be impaired.

The distribution of the concentrations of toxic substances measured between Cornwall and Portneuf in the fry of certain species of fish clearly shows that the PCBs that contaminate Lake Saint-François come from the area directly upstream.

Birds. In waterfowl, the degree of contamination also varies by species and substance. In addition, the type of food consumed and the area inhabited have an influence on the quantity of contaminants that accumulate in the flesh.

Ducks that had been shot were sampled in 1988. Most appear to have nested on Lake Saint-François. Analyses showed that the levels of PCBs, chlordane and mirex often exceeded Canadian standards for the commercial sale of fowl. Ducks living in the vicinity of Cornwall Island were the most contaminated, with levels exceeding the guidelines issued by the U.S. Food and Drug Administration for PCBs and mirex. One Pekin duck that had spent 56 days on Lake Saint-François had accumulated large quantities of PCBs, mirex and Aroclor in its liver. Studies of bird colonies also indicated very high levels of PCBs and dieldrin in Common tern eggs and of mirex and octachlorostyrene in Great blue heron eggs.

Hunting itself is a significant factor in lead contamination. So much hunting is done on the shores of Lake Saint-François that ducks frequently ingest lead shot and develop lead poisoning. Beginning in 1996, only cartridges with non-toxic shot will be used for hunting waterfowl in Quebec.

Other wildlife. Other types of wildlife may also have been affected by the contamination problem. Included in this category are two species hunted by the Mohawks of Akwesasne: the American mink and the Snapping turtle. In the latter species, which is hunted for food, the flesh is contaminated by dioxins and furans above the limit set for the commercial sale of fish.

4.2.3 Human health risks

The level of contamination found recently in sediment and fish suggests that the general quality of the environment has improved over the last decade. Despite this improvement, certain use restrictions still apply today to Lake Saint-François. Generally speaking, the chemical quality of the water is acceptable for drinking. However, in the upstream section of the lake, PCB and DDT levels give cause for concern. For these substances, drinking the water is deemed to be safe, but there may be long-term health risks when aquatic organisms are eaten in addition. The Akwesasne Indian Reserve gets its water from this area of Lake Saint-François.

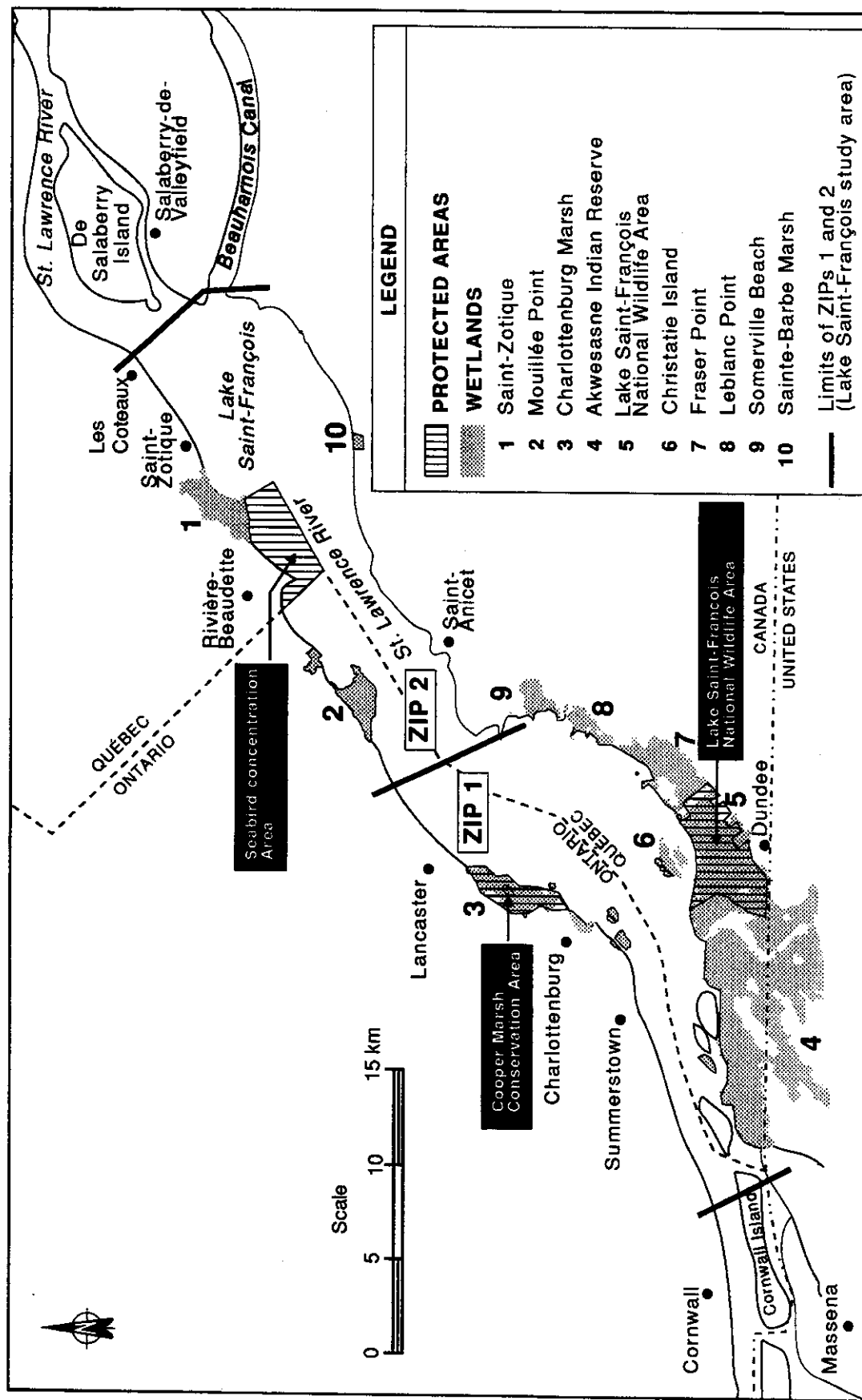
As bacterial contamination is non-existent or very low, most of the beaches on the lake are classified as good to excellent for swimming.

Consumption of fish or game from the lake continues to constitute a risk, however, with sport fishermen or those who practise subsistence hunting or fishing, such as the Akwesasne Mohawks, being the most exposed.

In Quebec, it is recommended that people eat sport species of fish with low contamination levels — such as Bullhead and Yellow perch — no more than eight times per month, and species with higher concentrations of contaminants — Northern pike, Smallmouth bass, Walleye and Muskellunge — no more than four times per month. It is further recommended that pregnant women and young children eat only those species with low contamination levels. In the Ontario part of the lake, the authorities advise against eating large (> 75 cm) Northern pike or Walleye. The St. Regis Mohawk health service recommends that women of child-bearing age and children under the age of 15 not eat fish caught on the reserve and that other residents limit their consumption to one meal per week. Native hunters are the most likely to bag the most highly contaminated ducks, those which spend the summer near Cornwall Island. The Health Department of the State of New York (HDSNY) advises against eating Merganser and limiting consumption of other species of duck to two meals per month. It should also be noted that the dioxin and furan levels in the flesh and eggs of Snapping turtles, which are traditional foods, are high enough that eating them entails a health risk. The HDSNY and the St. Regis Mohawk health service advise women of child-bearing age and children under 15 not to eat this species of turtle.

4.3 Encroachment on Shores and Wetlands

Land use patterns in the Lake Saint-François region can result in the disappearance of natural shoreline or wetlands. So far, losses of this type of habitat have primarily been noted on Leblanc and Mouillée points, at Saint-Zotique, and at the Somerville Beach (Figure 8). They have been caused by drainage and dredging work performed to improve access to the shore. To allow boats to reach the shore more easily, about 50 ha, consisting essentially of aquatic plants, were dredged. The dredged material was deposited along the shore on wet meadows so as to raise the level of the ground and allow cottages to be built.



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Figure 8 Protected environments and wetlands on Lake Saint-François

This creation of an artificial shoreline destroys wildlife habitats and natural landscapes. If nothing is done to hold this kind of development in check, it may result in extensive loss of Lake Saint-François's natural assets.

Cottaging is the biggest single factor in the urbanization of the shores of Lake Saint-François. Cottages, homes and private lots outside of communities form a narrow strip along 47% of the lakeshore. Cottages are primarily concentrated in the municipalities of Saint-Anicet, Sainte-Barbe and Saint-Stanislas-de-Kostka, on the south shore, and Rivière-Beaudette on the north shore. The population of these municipalities doubles when vacationers arrive in the summer.

Pressure for urban development seems to have been rather weak so far, but there are some indications that it could increase in the near future. The dezoning of farmland at Les Coteaux and Saint-Zotique may foster urban development on the north shore, in the vicinity of Salaberry-de-Valleyfield.

At present, urban land-use plans allow cottaging along the shore, and the lack of spring flooding, as a result of flow control, reduces the risk of damage to homes built near the water. A high proportion (80%) of lakeshore property is privately owned. All the factors required for the rapid creation of an artificial shoreline are thus already present.

The only wetlands now protected are, in Quebec, the Lake Saint-François National Wildlife Area and the area where waterfowl congregate near the Beaudette River and, in Ontario, Cooper Marsh.

4.4 Recreation and Tourism

In addition to the facilities available in the region's two main recreational and tourist centres — Saint-Zotique on the north shore and Saint-Anicet on the south shore — other existing facilities cater chiefly to people who go boating, hunting or fishing. There are 15 or so points providing access to the lake for vacationers. There has been little development of tourist potential. In this regard, the Ontario tourist market might be worth exploring.

On the Ontario side there are two recreational and tourist centres: Cornwall, the larger one, focuses on boating, while the main attraction of the second one, Charlottenburg, is a historical village. Seven of the nine marinas in Ontario are private.

4.4.1 Sport hunting and fishing

Sport hunting and fishing are major recreational activities on Lake Saint-François. Annual fishing effort on the lake has been estimated to be at least 100 000 days. The fishermen are primarily vacationers, either residents of municipalities located near the lake or Montrealers.

Yellow perch is by far the species most often caught. In summer, it accounts for 70% of all catches in the Quebec part of the lake and 80% in the Ontario part. In winter, it represents 90% of all fish taken from the lake. Some go sport fishing in order to sell their catch. Other species of fish caught are Northern pike, which can be quite big, Smallmouth bass and Walleye. Sport fishing for Lake sturgeon has been illegal in Lake Saint-François since 1992.

There are many good fishing spots around the lake. Two in particular, however, enjoy an outstanding reputation: the first is south of Les Coteaux and the Hébert Islands, while the second lies off Brises Bay, at Saint-Stanislas-de-Kostka. In Ontario, sport fishing is concentrated between South Lancaster and Mouillée Point. A number of very popular fishing derbies are held every year, including one for Walleye that is an international event.

Some 30 000 waterfowl — mostly dabbling ducks, but also diving ducks and geese — are shot by hunters each year. In the late 1980s, it was estimated that in the western part of the lake 5000 to 10 000 hunting days were required to shoot 7500 to 15 000 ducks.

4.4.2 Other recreational activities

Lake Saint-François has a number of features that make it attractive for boating. Besides being clear, the water is also deep enough. As the level of the lake does not change and sand bars are rare, there is little risk of damage to boats. This recreational activity does not seem to have any negative impact on the environment, except perhaps very locally.

On the Quebec portion of the lake there are at present three beaches where swimming is allowed: one at Saint-Zotique and two at Saint-Anicet. Other sites could be used, since the water quality ranges from good to excellent, but existing facilities do not always meet safety standards. Four other beaches are open in Ontario.

Bird-watching seems to be attracting a growing number of enthusiasts. The site most frequently visited by bird-watchers is the Lake Saint-François National Wildlife Area, including

Dundee Marsh, where there are specific bird-watching facilities (information stand, trails, observation tower). The main species of interest to birders are the Sedge wren, Willow flycatcher, Redhead and Great egret. The Sainte-Barbe area also has good potential for nature interpretation. There are a large number of good bird-watching sites all around the lake.

4.5 Commercial and Traditional Hunting, Fishing and Trapping

Some types of wildlife harvesting are commercial or subsistence activities rather than recreational. The abundance and quality of the fish and game taken are essential to the continuation of these kinds of hunting and fishing.

In the 1920s and 1930s, commercial fishing was a livelihood for a few dozen fishermen living on the lake. Today it is a modest economic activity that occupies 11 fishermen: eight in Quebec and three in Ontario. Commercial fishing has undergone profound changes in the last 20 to 30 years.

In the 1960s, the expansion of sport fishing led to conflicts about how resources should be shared, and the upshot was a reduction in the share allocated to commercial fishermen. The contamination of some species of fish such as Northern pike, Walleye and Lake sturgeon has resulted in restrictions on their commercial sale. Some commercial species have also suffered from changes to their habitat. This is particularly true of Lake sturgeon, whose numbers were decimated after the flow control structures were built on the St. Lawrence, apparently depriving the species of access to its main spawning grounds. Commercial fishing seems to have contributed to its decline as well, and since 1987 commercial harvesting of Lake sturgeon has been prohibited on Lake Saint-François, although some poaching is suspected.

Commercial fishermen now fish for replacement species such as American eel, which represents 60% of commercial catches, Brown bullhead and Sunfish. Fishermen also sell bait fish as a secondary source of income.

Traditional hunting and fishing by the Akwesasne Mohawks have been compromised by wildlife contamination. The Mohawks consider fish and game on the reserve to be unfit for consumption.

Trapping on Lake Saint-François has had many ups and downs. As elsewhere in Quebec, it has been affected by the decline in the popularity of fur. The number of animals trapped, especially Muskrats, has risen recently, however.

4.6 Conservation

In the Quebec part of the study area, the main land set aside for conservation is the Lake Saint-François National Wildlife Area, which was created in 1971 and is now recognized by the United Nations as an important ecosystem.¹¹ It covers 1347 ha, 83% of which consists of wetlands (Figure 8).

Since the establishment of the wildlife area, burning is no longer used as a means of controlling shrub growth. As a result, shrub swampland has gained ground at the expense of wet meadows, which provide better wildlife habitat for waterfowl.

Wildlife land development has been carried out by Ducks Unlimited on 335 ha of marsh in the wildlife area. Canals and basins have been dug to create expanses of open water, which are used by a variety of wildlife, including frogs, turtles, Muskrats, herons and other birds.

An area of waterfowl concentration near the Beaudette River has a protected status under Quebec regulations respecting wildlife habitats.

On the Ontario side there are three provincial parks along Lake Saint-François: Charlottenburg, Raisin River and Glengarry. The natural area with the largest wetlands is at Cooper Marsh in Charlottenburg, which is managed by the Raisin River Conservation Authority and has 202 ha of marsh. Land development work has been completed to manage water levels, control vegetation and protect wildlife habitats. There is a total of 342 ha of wetland in the Ontario part of the lake, along the north shore.

Outside of wildlife areas, Ducks Unlimited has negotiated agreements with a few waterfront property-owners to develop waterfowl sites on their land.

11. Canada has entered the Lake Saint-François National Wildlife Area on the list of important ecosystems under the terms of the Ramsar Convention, an international treaty intended to protect wetlands.

Although the remainder of the area does not have any special status at present, a number of agencies concerned about the conservation of natural environments have already identified certain sites that should be protected in Quebec and Ontario. For instance, a group has been established to promote the conservation of the Sainte-Barbe marsh.

4.7 "Problem" Species

Exotic species can be introduced through the emptying of ballast water in ship channels. Zebra mussels, which have now spread throughout the Great Lakes and have recently been observed in Lake Saint-François, were brought by ships from Europe. Because of their rapid proliferation, Zebra mussels are notorious for blocking municipal and industrial water intake pipes. Once established in ecosystems, they can be harmful to native species.

Closely related to Zebra mussels, Quagga mussels first appeared in the Great Lakes in 1991 and were found in Lake Saint-François in 1992. They are now thought to be present all the way along the St. Lawrence as far as Quebec City.

Some plant species can also cause ecosystem imbalances because of the way they proliferate.

The expansion of Purple loosestrife at Lake Saint-François was facilitated by changes made to the shoreline. Since it has a tendency to dominate the plant species that characterize wet meadows, Purple loosestrife could affect the quality of waterfowl habitat and the diversity of plant communities.

In late summer, some canals built by Ducks Unlimited are heavily invaded by the species of floating plant called European frogbit, thus limiting use of the canals by waterfowl.

Changes in and stabilization of water levels, input of nutrients and slow currents along the shore have increased the production of macrophytes while modifying species composition. At the end of the growing season, large quantities of undesirable algae are found in some sectors of the lake, particularly on the north shore in the Ontario part and on both shores in the Quebec part. Uprooted plants accumulate and decompose, affecting water quality and giving off a strong smell. The most widespread species are Northern water-milfoil and American tape-grass.

5.1 State of Resources and Uses

Of all the changes that Lake Saint-François has undergone, its transformation into a reservoir seems to have had the most far-reaching and irreversible effects, changing the rate and pattern of flow and reducing both the area of the flood plain and species diversity, especially in the aquatic environment. In conjunction with the dumping of dredged spoil from the St. Lawrence Seaway, the flow control significantly increased the area occupied by aquatic plant communities much favoured by birds and fish. It also reduced seasonal resuspension of sediment. These new conditions have probably heightened the effects of contamination by promoting permanent sedimentation in some deep parts of the lake.

There are few sources of contamination along the shores of Lake Saint-François and their effects are local. The volume of household sewage is low. The bacteriological water quality is good enough for swimming and other recreational activities.

The main source of contaminants is the Cornwall–Massena region upstream. During the 1970s, severe contamination of the aquatic environment — by mercury along the north shore and by PCBs along the south shore — was reported. However, industrial-effluent controls upstream from Lake Saint-François have improved the situation considerably in recent years, and some hazardous waste sites are being cleaned up. Chemically, the water quality is generally good. Except for a few sites that are still polluted, chiefly near Cornwall and Massena, the contaminant levels found in sediment and organisms do not seem to be causing any significant imbalance in biological communities.

There are some restrictions on eating sport fish, ducks near Cornwall and Akwesasne, and Snapping turtles, but they have not prevented the lake from being very popular with sport hunters and fishermen. Sport hunting and fishing, along with boating, swimming and cottaging, are the main activities that draw tourists to the area.

Bird-watching is also drawing an increasing number of visitors to the Lake Saint-François National Wildlife Area, which is particularly attractive to nature-lovers because of its diverse flora and fauna.

5.2 Toward Sustainable Lake Development

In planning future use of the lake in keeping with the objectives of sustainable development, a number of aspects of the problems mentioned so far must be kept in mind. While there must be limitations on some types of use, we must also accept that the permanence of certain changes makes them practically impossible to undo. For example, use of the lake as a reservoir is a constraint that can be considered irreversible for a number of reasons.¹² It therefore seems preferable not to attempt to restore the natural flow pattern, but to seek better ways of diminishing the negative effects of flow control.

We must also be wary of unpleasant surprises that may result when what appears to be a minor problem is put off to a later date. Special attention should be paid to artificial changes to the shoreline, for example. This gradual encroachment on natural environments often goes unnoticed until it is realized, too late, that the most important sites have been irretrievably lost.

At this time, the lake is able to support recreational activities that generate economic spinoffs; with proper management, it should continue to do so over the long term. Hunting, fishing, boating and other water activities do not appear to have any major direct effects on the lake's resources. However, proper precautions must be taken to ensure that these activities do not have undesirable effects, such as increased pressure for shoreline development.

To prevent chaotic development from spoiling the environment and leading to a flurry of speculation and short-term economic activity, it is important to plan land use now. Of course, development is supervised and controlled by various levels of government, but the ecological restoration of the St. Lawrence also requires the involvement of the general public in identifying the major local development issues.

12. Reasons such as the profitability of hydro-electric installations, the need to abide by agreements with the U.S. and Ontario, the possibility of flooding, the recirculation of contaminants, and the impossibility of anticipating future conditions or how long it will take for them to occur.

These issues must be assessed and discussed by groups interested in the development of Lake Saint-François and the quality of life in their communities, so that the policies adopted are acceptable to the public at large. Table 5 provides a general outline for discussion of desirable directions to take in developing the lake; interested parties may, of course, add to it and improve upon it. The points listed are based on principles of sustainable development: maintaining biodiversity, multi-functional use of resources, and quality of life.

Once a consensus on priorities has been reached, they will be more easily translated into a concrete plan of action that the partners can willingly support. At the end of the discussions, it should be possible to co-ordinate the various uses so as to limit damage to the natural environment and conserve the lake's attractions for the long term, making it something of which all shoreline residents are proud.

Table 5
Issues relating to the sustainable development of Lake Saint-François

Characteristics of Study Area	Main Effects on Lake and Its Resources	Current Situation	Future Possibilities
Flow control and channelization (hydro-electricity; Seaway)	Elevation, then stabilization of water level. Less seasonal stirring up of sediment and increased permanent deposits in some areas. Reduction in flood-prone areas. Changes in plant communities and drop in number of species. Aquatic plant communities larger in area.	<p><u>Biodiversity:</u> Reduction in number of animal and plant species, but extent cannot be assessed.</p> <p><u>Uses:</u> Some uses (e.g. commercial sturgeon fishing) have suffered, while others (e.g. boating, hunting) seem to have benefited from the new flow pattern. Other factors besides flow control may have been at work, however.</p> <p><u>Quality of life:</u> Flooding problems have disappeared. The quality of life of most lakeshore residents does not seem to have been affected in any major way, although they do mention some inconveniences (e.g. very dense plant growth in water is an annoyance to boaters and lakeshore residents).</p>	<p><u>Biodiversity:</u> Numerous constraints make it impossible to restore the natural flow pattern (profitability of hydro-electric installations, need to abide by agreements with the U.S. and Ontario, the possibility of flooding, resuspension of contaminants, and impossibility of anticipating future conditions or how long it will take for them to occur). Some measures could help improve diversity: development to diversify wetland habitats, building of fish ways, review of flow control structure operations to facilitate passage of migrating fish.</p> <p><u>Uses and quality of life:</u> Current uses and way of life of lakeshore residents seem to have adapted to the new flow pattern.</p>
Pollution (industrial and municipal effluent; agricultural runoff) <ul style="list-style-type: none"> • Acute mercury and PCB contamination reported in the 1970s now seems to be declining. Worrisome levels of other toxic substances have been reported in water, sediment and organisms. Concentrations are lower, however, and occur at certain specific locations, chiefly the lake's inlet, and not throughout the entire lake. • Agricultural pollutants are affecting water quality in places. 	<p><u>Biodiversity:</u> Pollution reduces the numbers of several species and modifies the structure of living communities. Species that tolerate pollution become dominant. In the case of Lake Saint-François, pollution does not seem to have changed communities irreversibly.</p> <p><u>Uses:</u> Untreated effluent discharged into the St. Lawrence contaminates the environment and causes a whole string of negative effects on some types of use, such as restrictions on eating fish, ducks and turtles in the upstream section, and restrictions on commercial sales of some species of fish. Agricultural runoff causes the proliferation of algae and plants, which interfere with aquatic species and boaters, as well as being unsightly and smelly.</p> <p><u>Quality of life:</u> Contamination of fish means restrictions on eating and selling it, and has an indirect impact on the lake's recreational and tourism potential and on regional economic activity. To the Mohawks of Akwesasne, the contamination of fish and game presents a health risk and means the disappearance of some traditional activities. The proliferation of aquatic plants causes aesthetic problems, which affect the quality of life of lakeshore residents.</p>	<p><u>Biodiversity:</u> The disruptive effects of pollution are reversible over the medium and long term, depending on the substances involved and how long they persist in the environment and in aquatic organisms. Maintaining biodiversity in Lake Saint-François depends on efforts to protect and conserve ecologically important environments.</p> <p><u>Uses:</u> The most effective way to limit losses of use due to pollution is to control effluent discharge at the source, even if this means that industries and municipalities must install costly treatment systems. This option is economically advantageous over the long term, if all the indirect costs of doing nothing are added up. In addition, the improvement of farming practices will encourage conservation of agricultural resources and protection of the environment.</p> <p><u>Quality of life:</u> Through pollution control, communities can regain all the advantages of being close to the water as well as a sense of pride.</p>	

<i>Characteristics of Study Area</i>	<i>Main Effects on Lake and Its Resources</i>	<i>Current Situation</i>	<i>Future Possibilities</i>
Hunting, fishing, recreation and tourism	<p>Lake Saint-François is very popular with sport hunters and fishermen, who take significant numbers of fish and game. It also attracts many pleasure boaters.</p> <p>Most recreational and tourist facilities cater to fishermen.</p>	<p><u>Biodiversity:</u> Generally speaking, wildlife populations withstand hunting and fishing, if they are not excessive. Regulations to prohibit overhunting and overfishing would ensure a rapid rebalancing, when necessary.</p> <p><u>Uses:</u> Currently, recreational and tourist activities on the lake do not seem to conflict with other uses. The recreational and tourism potential of Lake Saint-François remains relatively undeveloped.</p> <p><u>Quality of life:</u> The opportunity to engage in water activities enhances the quality of life of lakeshore residents. If well managed, recreational and tourist activities generate significant spinoffs, which can continue indefinitely.</p>	<p><u>Biodiversity:</u> Hunters and fishermen indirectly finance habitat development that benefits all wildlife. Some projects have already been carried out at Lake Saint-François or are in progress.</p> <p><u>Uses:</u> Hunting, fishing and boating must be well regulated, to prevent conflicts with other types of use (disturbance of bird colonies, respect for private property, safety). Hunters and fishermen must henceforth allow for groups interested in observing wildlife without catching or killing it (bird-watchers, botanists, amateur naturalists).</p> <p><u>Quality of life:</u> Other outdoor and nature activities could promote the development of tourist attractions in the region. The facilities needed for these activities must be chosen and located so as not to harm the environment.</p>
Waterfront development	<p>The building of cottages and homes along the shore encroaches on habitat, makes the lake less accessible and leads to the disappearance of the natural landscape.</p>	<p>Waterfront development adversely affects biodiversity and places limitations on a number of types of use. Although property-owners improve their quality of life by living on the waterfront, they are gradually limiting the opportunities of the community as a whole to enjoy the lake.</p>	<p>This seemingly irreversible deterioration of the lake could be offset by identifying the most important natural sites and giving priority to maintaining them when designing or amending development and urban land-use plans. Certain corridors to the lake could also be designated in order to improve public access. Since development pressure around Lake Saint-François is still weak, these changes could be made without arousing too much controversy.</p>

Appendixes

1 St. Lawrence Action Plan Priority Species Found at Lake Saint-François

Plants*

American hazelnut
Bladdernut
Brainerd's hawthorn
Broadleaf water-milfoil
Bur-reed sedge
Clinton's shield-fern
Cork elm
Creeping selaginella
Discoid beggar-ticks
Dotted water-meal
Engelman's cyperus
Fringed gentian
Ginseng
Hairy wood brome grass
Hairy-fruited sedge
Hitchcock's sedge
Indian wild rice
Le Conte's violet
Long-beaked water-crowfoot
Long-spurred violet
Narrow-leaved athyrium
Nuttall's waterweed
Poke milkweed
Sartwell's sedge
Showy orchis
Smooth arabis
Spotless water-flaxseed
Swamp sumac
Swamp white oak
Virginia hackelia
Wild leek
Wild licorice
Yellow pimpnel
Yellow water-crowfoot

Fish**

American shad
Lake sturgeon

Amphibians and reptiles

Pickerel frog
Northern chorus frog
Northern water snake
Blanding's turtle

Birds**

Least bittern
Yellow rail
Sedge wren

* Most English plant names taken from Fleurbec (1987), Marie-Victorin (1964) or the Centre de données sur le patrimoine naturel du Québec.

** Migratory fish are included, but only species of birds that breed on the lake are listed.

2 Environmental Quality Criteria

(for assessing potential use and loss of use)

Ecosystem Components	Reference Criteria	Objectives
WATER	Raw water (untreated, taken directly from a body of water) (MENVIQ, 1990)	Protect the health of a person who may both drink water taken directly from a body of water and eat aquatic organisms caught there throughout his or her life.
	Contamination of aquatic organisms (MENVIQ, 1990)	Protect human health, which could be endangered by eating aquatic organisms.
	Aquatic life (chronic toxicity) (MENVIQ, 1990)	Protect aquatic organisms and their offspring, as well as wildlife that eat them.
	Recreational activities (primary contact) (MENVIQ, 1990)	Protect the health of humans engaging in a recreational activity in which the entire body is regularly in contact with water, such as swimming or windsurfing.
SEDIMENT	Minimal effect threshold (MET) (SLC and MENVIQ, 1992)	Contaminant levels above which minor but tolerable effects on most benthic organisms are observed.
	Toxic effect threshold (TET) (SLC and MENVIQ, 1992)	Contaminant levels above which effects harmful to most benthic organisms are observed.
AQUATIC ORGANISMS	Protection of aquatic life (IJC, 1987)	Protect health of piscivorous aquatic organisms.
	Fish marketing standards (Health and Welfare Canada, 1985)	Maximal contaminant levels in fish to protect human health.
	Poultry marketing standards (Canada, 1971)	Maximal contaminant levels in fowl to protect human health.
	<i>Guide de consommation du poisson de pêche sportive en eau douce</i> (MSSS and MENVIQ, 1993)	Rules on eating sport fish to prevent harmful effects of contaminants on human health.

Ecosystem Components	Reference Criteria	Objectives
AQUATIC ORGANISMS (cont'd)	Guidelines for poultry consumption (U.S. Food and Drug Administration)	Maximal levels to protect human health.
	Fish consumption advisory (New York State Health Department)	Rules on eating to prevent harmful effects of contaminants on health.

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3 Glossary

Alkaline water: Water with a pH value greater than 7.

Benthos: The plants (phytobenthos) and animals (zoobenthos) that inhabit the bottom of a body of water.

Biomass: The dry weight of living matter, altogether or by systematic group, expressed in terms of a given unit of surface area or volume of the habitat at a given time; examples are plant biomass, insect biomass, herbivorous biomass or carnivorous biomass.

Community: All plants and animals living in the same habitat.

Continental waters: Water table or natural or artificial watercourses, such as lakes, rivers, streams and irrigation, industrial or ship canals, reservoirs and impoundments in which water is in direct contact with the atmosphere. Also called *surface water*.

Drainage basin: The geographic catchment area from which the waters (originating as precipitation) of a particular watercourse or body of water are drawn. Also called *hydrographic basin* or *watershed*.

Ecosystem: Entire physico-chemical environment (biotope, or habitat) and the living beings in it (biocenosis, or community), which can perpetuate itself indefinitely with inputs of matter and energy.

Ecosystem productivity: Biomass produced each year to maintain balance between animal and plant populations.

Effluent: General term for any liquid discharge of pollution, whether sourced in inhabited areas (municipal effluent or sewage) or industrial facilities (effluent or industrial outfall).
Outfalls or sewers: places where liquid pollutants are discharged.

Flood plain: Flat alluvial expanse bordering a waterway that is only underwater during a spate.

Flow: Volume of water running in a water course, pipe, etc., in a given time. Usually expressed in m³/s, but sometimes in L/s for small drainage basins.

Fry: Immature fish that have not yet attained adult form.

Hard water: Water containing a high level of mineral salts, especially calcium or magnesium (> 150 mg/L CaCO₃), liable to form scale.

Non-point source pollution: Pollutants indirectly introduced into a given environment. Agricultural pollution is non-point source pollution, since fertilizers and pesticides are spread over wide areas. Also called *area pollution*.

Sediment: Solid fragmental material formed by the weathering of rocks or other chemical or biological processes, which is transported or deposited by air, water or ice.

Sediment dynamics: All of the features of the flow of a water course influencing sediment transport, sedimentation and sediment erosion.

Suspended solids: Small particles of solid matter ($> 0.45 \mu\text{m}$) floating in a liquid. Also called *suspended particulate* or *suspended load* (see Sediment).

Thermal stratification: Presence of layers of different temperatures in bodies of water, with the warmer water above the cooler water.

Waterfowl: Collective name for geese and ducks.

Water mass: Volume of water having relatively homogeneous physical and chemical properties. Water from the Great Lakes is a distinct body of water, separate from that of the Ottawa River.

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