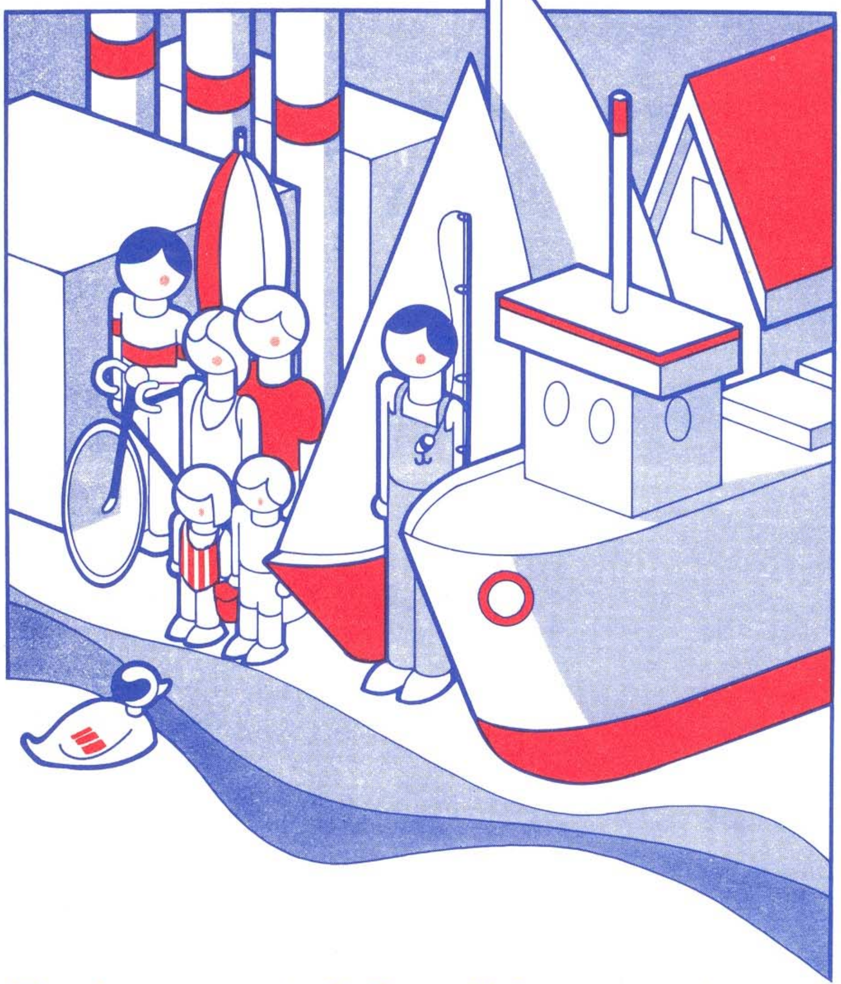
Remedial Action Plan for
Hamilton Harbour



Environmental Conditions and Problem Definition

Second Edition of the Stage 1 Report

October 1992

REMEDIAL ACTION PLAN

Hamilton Harbour

Stage I Report:

ENVIRONMENTAL CONDITIONS

and

PROBLEM DEFINITION

Prepared by the Staff of:

Ontario Ministry of the Environment
Environment Canada
Fisheries and Oceans Canada
Ontario Ministry of Agriculture and Food
Royal Botanical Gardens
Ontario Ministry of Natural Resources

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This report does not constitute publication. Many of the results are preliminary findings. The Stage 1 report has been provided as information to the Remedial Action Plan process only. The information findings should not be quoted without the consent of the individual authors.

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Canada Ontario
Canada-Ontario Agreement Respecting Great Lakes Water Quality
L'Accord Canada-Ontario relatif à la qualité de l'eau dans les Grand Lacs

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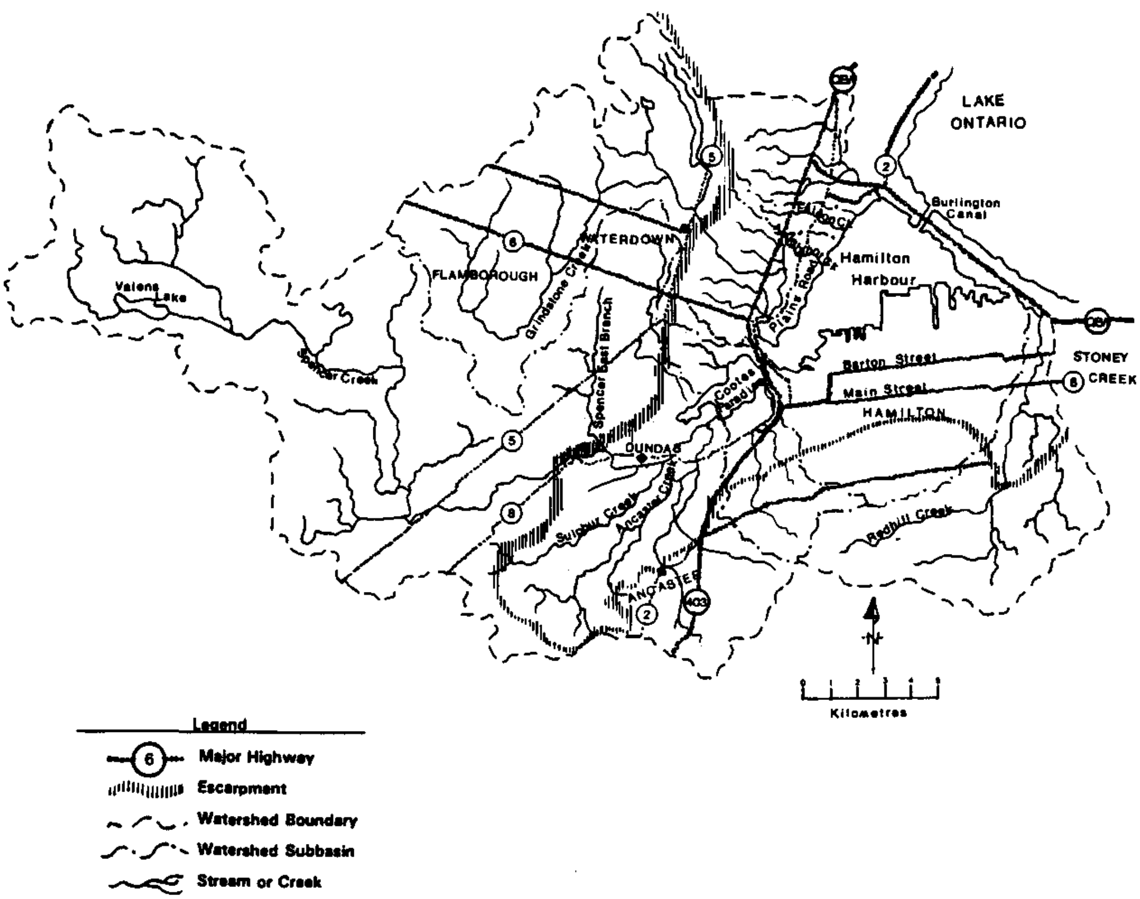
This report is a revised portion of the discussion document Goals, Problems and Options, presented to the Stakeholder Group and the public in the spring of 1988 and of the Stage I submission with the same title as this report in 1989. Many of the revisions embodied in this report are the result of the contributions and advice of many Stakeholders (see list of Stakeholder membership, Appendix G), which are gratefully acknowledged.

THE WATERSHED

Hamilton Harbour

Three major creeks - Grindstone, Spencer and Redhill feed into Hamilton Harbour from the Watershed



PREFACE

This report provides a summary of conditions as they are presently known in Hamilton Harbour, and in Cootes Paradise, a shallow tributary embayment to the Harbour. The Harbour, or as it is often called "the Bay", is a large and excellent industrial harbour which is used extensively in conjunction with the iron and steel industry. Other major current uses of the Harbour are recreational boating and as a receiving waterbody for industrial and municipal waste discharge.

Consultation with the Stakeholders (a public advisory group formed for this Area of Concern) has led to investigation of a wide range of existing and potential water uses within the context of an ecosystem approach. The Stakeholder Group represents environmental groups, industry, municipal, provincial and federal agencies, user groups, and citizens. In addition to its endorsement of the primacy of the Ecosystem Approach, it has also provided guidelines concerning human health, zero discharge or virtual elimination of persistent toxic chemicals, infilling, public access to the shore, land use planning, discharge from the Harbour to Lake Ontario, and the conditions under which waste can be discharged into the Harbour.

While serving as the technical data base for understanding the potential for making water quality and other changes to the Harbour, this report also serves as an updated Stage I submission to the International Joint Commission, in accordance with the Canada-Ontario commitment to the Great Lakes Water Quality Agreement. The original Stage I Report (dated March 1989) met the requirements as determined by the Canada/Ontario Agreement Review Board and the International Joint Commission. A number of the comments made in these reviews have been addressed in this revision.

Investigative work is still in progress as the Plan is being completed (the Stage 2 report). This work is directed at assessment of remedial technology for contaminated sediment, at determining the most economical methods for handling stormwater and treating sewage, as well as towards refinement of loading targets for several key contaminants.

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A summary of the scientific and technical information available on Hamilton Harbour and areas draining into the Harbour has been prepared with the assistance of several agencies. The report has built upon the earlier Ministry of Environment summary report on sediment and water quality (MOE, 1985), and the first Stage I Report (COA, 1989) for the Harbour. New information has been added on fish and wildlife populations, marsh and other habitat, contaminated sediments, water levels, socio-economic conditions and human health. Water quality data and mass balance loadings have been updated.

The substantial improvements in water quality, the abundance of fish, the increased and more diverse waterbird populations and improvements in the contaminant content of both fish and birds are documented. These are the results of remedial actions taken to date. The funds expended in this effort locally have been in the order of $600 million (in 1990 dollars).

Some problems remain. The Harbour receives all industrial and municipal waste, as well as urban and rural runoff from the complete watershed. No wastewater discharges from the watershed are made directly to Lake Ontario. All municipal and industrial 'point sources' presently meet the current provincial standards and go beyond them in several respects. Despite this, the aquatic ecosystem upon which these discharges impact and the uses of the water are still adversely affected. The difficulty lies in the small size of the Harbour receiving these wastewaters.

There remains a substantial stress on the quality of this body of water, and serious habitat stresses for fish and wildlife. The key issues are as follows:

(a) Water Quality/Eutrophication/Water Clarity

General water quality as reflected in the advanced eutrophic condition of the Harbour, poor water clarity, excessive algae production and low dissolved oxygen conditions in the summer hypolimnion still places constraints on the nature of the fishery, and on swimming, boating and viewing conditions.

The solution to these conditions lies in more advanced treatment of sewage treatment plant effluents for nutrients and suspended solids and reduction of suspended solids loadings from creeks due to erosion - primarily erosion from construction activities, and stream bank erosion.

(b) Contamination from Trace Metals and Trace Organics

Due to remedial work done by the two major steel industries discharging wastewater into the Harbour, current water quality standards are met throughout almost all of the

Harbour. However, PCB standards are not met, seemingly due to residues or recycling of PCBs from the sediments or PCBs in rainfall.

Contaminated sediments have been assessed both in terms of toxicity testing and contaminant content. Three or four locations in the Harbour are particularly toxic to test organisms and require attention immediately. But it is, as yet, unclear what should be done with the large remainder of the Harbour.

The problem of acute toxicity is probably due to ammonia or hydrogen sulphide in the sediments. This toxicity goes through a seasonal cycle in the thin topmost layer of sediment, similar to many lakes. The impact of the trace metals and trace organics is indistinct even though their concentrations are at levels that raise warnings of potential impact for chronic toxicity and for bioaccumulation in the food chain.

Since the objective for ***persistent*** toxic chemicals is virtual-elimination/zero discharge, further reductions of loading to the Harbour from industries discharging to the Harbour or sewer systems will take place. It is not yet certain that current discharges of trace metals and organics are adequate to ensure that newly deposited sediments will meet the requirements of a healthy aquatic ecosystem.

(c) Bacterial Contamination (Human Health Concerns)

For the past 50 years faecal bacterial contamination in the Harbour has made swimming unsafe. Major improvements to these conditions in recent years gives hope that swimming may be restored in some areas of the Harbour. The principal sources of these bacteria are the combined sewer overflows or sewage treatment plant by-passes, and local contaminated urban drainage that reaches the Harbour in creeks or from road drainage.

(d) Stresses on Fish and Wildlife

The progression from a thriving fishery in 1900 to the current pollution-tolerant, coarse, warm-water fishery is radical, but not uncommon in the Great Lakes. While productive, the Harbour fishery is a stable one dominated by carp, bullhead and other foraging fish. Nonetheless, there are 60 species present and 42 of these are reproducing in the Harbour.

The fish are not fully healthy, experiencing high incidences of tumours and skin papillomas. The origin of these problems is unclear. Chemical associations are indicated for some and non-chemical for others. Hamilton Harbour has problems comparable to other areas of western Lake Ontario but distinctly worse than other areas in the Great Lakes less impacted by urbanization or industrialization.

Fish habitat for spawning, for juvenile and for adult fish has been eliminated along the formerly productive south shore through infilling, and through 'hardening' of the shoreline with docks.

Consumption advisories for fish, while increasingly less restrictive, are still in effect for 5 out of 12 sport fish.

Colonial bird populations are expanding but their nesting habitat is threatened by development. Colonial bird populations are not now nearly as seriously affected by toxic chemicals as they were in the 1970s.

Snapping turtle populations, algae and zooplankton production, and bottom fauna are all affected by toxic substances in the water, in the sediments or in the organisms that they feed upon.

Improvements in the amount and quality of habitat is crucial for the restoration of healthy self-sustaining balanced populations of biota including amphibians, muskrat, mink and other animals intrinsic to the aquatic marsh and stream ecosystems. Further improvements in general water quality, and removal of stress from trace metals and trace organics will be required to restore these populations to a more satisfactory condition.

(e) Aesthetics and Access

Aesthetic aspects of water clarity, water colour, and unsightly algae accumulations have been dealt with in Item (a). Combined sewer overflows and urban runoff are also major sources of 'unsightly materials'. Air pollution and noise from various sources are also factors affecting the enjoyment of the water-side or on-water human experience.

More seriously, though, there is major lack of access to the waterfront for the general public. In our public consultations there are repeated calls for more access and higher quality access where it already exists. Amenities in these locations are required as well as easy public transit access.

If the benefits of improved water quality are not realized by the general public as a whole we will have lost a major benefit of the water quality clean-up.

(f) Planning and Coordination

Jurisdictional gridlock will have to be circumvented in the management of the multiplicity of actions required of many agencies. We will gain collective strength by sharing the load and the success that will come through this cooperation.

To protect the Harbour in future years, it will be necessary to incorporate loading targets into our planning for a variety of contaminants like phosphorus, suspended solids or ammonia. This will need to be reflected in official plans and regulations affecting community activities and development in the watershed of Hamilton Harbour.

SUMMARY OF CURRENT ENVIRONMENTAL CONDITIONS

The current environmental conditions in terms of the fourteen beneficial uses stipulated in the Great Lakes Water Quality Agreement (1978; 1987 Protocol) are summarized in the table which follows:

TABLE A: **Summary of the state of beneficial uses in Hamilton Harbour.**

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(i)	Restriction on fish and wildlife consumption	(a) Fish: Although there are current consumption advisories (mercury (Hg), Polychlorinated biphenyls (PCBs) and Mirex) on five of twelve fish species listed for the Harbour, four of the species accumulate contaminants Lake-wide because they migrate into the Harbour from Lake Ontario. It is unlikely that reduced loadings to the Harbour alone will result in elimination of fish consumption advisories since Lake Ontario conditions, atmospheric sources (not primarily local sources) as well as local contaminated sediment are all possible sources. In addition, smelt, alewife and gizzard shad - valuable food fish for harbour predators - also move contaminants from Lake Ontario into the Harbour and its food chain.	- Mercury (Hg), PCB, Mirex - Pesticides - very low levels of the insecticide DDT and DDE (breakdown of product of DDT).	- Sediments - Sewage Treatment Plants (STPs), (PCBs - origin may be by atmospheric and/or urban non-point sources). - Lake Ontario - in prey species and in top predators that move contaminants into the Harbour and its tributaries. - Atmospheric deposition	The connection between the many possible sources of the contaminants and the contaminants found in fish is unclear since current judgement is based on relatively weak circumstantial evidence.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		(b) Wildlife: Generally hunting is not permitted in the area. PCB concentrations in mallard ducks and snapping turtles are well above U.S. and N.Y. standards. There may be risk to hunters in other areas from migrating birds that spend time in this Harbour.	PCBs in food for birds.	Potentially PCBs in sediments in feeding areas or feeding on higher levels of the food chain that are contaminated from more general PCB distributions.	Wildlife should be examined more thoroughly. PCB and mercury distributions and links to local regional sources should be identified more precisely. Canadian standards for wildlife consumption are required. Standard methods for establishing more clearly that local sources are not significantly contributing to the problem need to be established and incorporated into the surveillance program.
(ii)	Tainting of fish and wildlife flavour	(a) Fish: No impairment is known to exist for fish. Fishing occurs in the Harbour but there have been no complaints regarding the tainting of fish flavour. (b) Wildlife: Tainting of wildlife flavour is not observed for Hamilton Harbour as hunting is not permitted in the area.			No formal study of tainting of fish and wildlife has yet been undertaken.
(iii)	Degraded fish and wildlife	a) Fish: Prior to initiation of the Remedial Action Plan (RAP) there were no objectives for desired fish population densities. A reduction in the carp	- Loss of spawning, nursery and adult habitats - Low dissolved oxygen (DO),	- Dense algal blooms - Contaminated sediments - Shoreline filling - Introduction of	Storm loadings of suspended solids from watersheds. Information on fish and wildlife regarding habitat requirements for various life stages of fish and wildlife (see (iv)).

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		population has been proposed in order to minimize the negative impact on the macrophyte communities and other species that depend on this type of habitat. Pike have been stocked in order to increase the population of top predators in the warmwater fishery. Fifty-nine species of fish have been found in the Harbour, forty-two of which are reproducing here. However, these populations indicate a highly degraded eutrophic system. (b) Wildlife: Two of the four recommended objectives for numbers of colonial waterbirds have been exceeded. Numbers of double-crested cormorants and black-crowned night herons are slightly below target levels. A reduction in the population of ring-billed gulls has been proposed.	ammonia toxicity - Degraded benthos (see (vi)) - Low aquatic plant diversity and abundance	exotic species - Poor light penetration	
(iv)	Fish tumours or other deformities	Liver and skin neoplasms and epidermal papillomas have been reported on several species of fish. Carcinogens	- Polyaromatic hydrocarbons (PAH) in contaminated sediment.	- Contaminated sediment from historical sources in	- Cause of tumours not clearly established. - Role of virus' not yet confirmed.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		are present in Harbour sediments. These sediments have induced liver tumours in fish in laboratory studies. Overall tumour frequency for Harbour fish is similar to the frequency of tumours found in fish from other sites in western Lake Ontario. The occurrence of hepatocellular carcinomas at low levels in white suckers strongly suggests chemical carcinogens in western Lake Ontario.	- Viruses may be responsible for epidermal papillomas.	the steel industry and general combustion products. - Urban runoff - Sewer system - Lake Ontario (perhaps)	
(v)	Bird or animal deformities or reproductive problems	To date, control sites have not been selected for bird or animal populations, and selection of sentinel wildlife species has not been made. There are no active bald eagle nests in the area although eagles have recently been sighted (1991). Reproduction rates for colonial bird populations are considered normal. Bird populations are being monitored. Higher levels of PCBs, organochlorines, and reproductive anomalies have been observed in snapping turtles in Cootes Paradise relative to a control site in Algonquin Park. The significance of this information is under study.	- Organochlorines, metals - DDT and its metabolites	- Historical deposits of contaminants in sediment - Contaminants in Lake Ontario	High concentrations of contaminants in turtles are poorly understood; other animals not yet studied. Acceptable control populations need to be better established.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(vi)	Degradation of benthos	The composition of the benthic community is characteristic of a highly eutrophic and urban/industrial contaminated environment. Both contaminants in sediment and low oxygen conditions (0.5-1.0 mg/1) in the hypolimnion in summer contribute to the problem.	- High nutrient levels - Decomposition of organic material in sediments releasing ammonia and hydrogen sulphide - Low dissolved oxygen - Trace contaminants in sediments	- STPs - Historical deposits of organic material in the bottom sediments.	Storm loadings of sediment. Time for end of sediment phosphorus reflux. Natural burial time for effective capping of contaminated sediments. Redistribution of sediment by ship traffic. Bioassays need to be standardized to define the end point.
(vii)	Restrictions on dredging activities	Hamilton Harbour sediments exceed acceptable limits for open water disposal of dredgeate under Provincial Guidelines. One cannot employ open water disposal for sediment dredged in the Harbour. Present CDF capacity is only adequate to the year 2010.	- PCBs in sediment - Metals, PAHs exceed guidelines in sediment	- STPs - Industry - Urban and rural runoff - Steel Industry - Combined Sewer Overflows (CSOs)	Quality of current deposits. Source control limits need to be set related to desired sediment quality.
(viii)	Eutrophication or undesirable algae	Ammonia and phosphorus concentrations exceed the requirements for the growth of algae at acceptable levels in the Harbour. The algae present an aesthetic problem as they reduce water clarity and foul beaches and rocks.	- High Phosphorus - High ammonia	- CSOs - STPs - Steel Industry - Runoff	Non Point Source contribution not known accurately enough. Update estimates of impact from phosphorus and ammonia loadings.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		The ammonia and decomposing algae create an oxygen demand that lowers summer hypolimnetic dissolved oxygen to levels averaging 0.5-1.0 mg/1. This, in turn, reduces fish habit, interferes with the normal food chain operation and increases the release of some contaminants from the bottom sediments. Major improvements in water clarity, and in total phosphorus and chlorophyll concentrations have been observed in the past three years, apparently as the result of new phosphorus control measures. But little change in dissolved oxygen conditions has been recorded in this period.			
(ix)	Restrictions on drinking water consumption or taste and odour problems	The drinking water supply for the residents of the Hamilton area and Burlington is Lake Ontario, not the Harbour. No drinking water supply is taken from the Harbour. However, existing water quality conditions in the main body of the Harbour now meet all objectives for a potable water supply. The Harbour water discharges to Lake Ontario through the Burlington Ship Canal which is 4 to 5 km from both the Burlington and	Not used for drinking water.	Not used for drinking water.	

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		Hamilton water supply intakes to the northeast and southeast of the Canal, respectively. Intake water quality data to date indicate no problems related to the Harbour discharge.			
(x)	Beach closings	In the 1940's, on the advice of the Medical Officer of Health, the Hamilton Harbour Commissioners enacted a by-law prohibiting swimming in the whole Harbour. The basis of the ban was unacceptably high levels of faecal bacteria. There may also be some risk to recreational boaters where capsizing of small sailing craft often occurs. Results of sampling carried out in 1988, 1990 and 1991 indicate that remedial programs might be effective in bringing some specific areas of the Harbour within bacterial standards. Further investigation is required if swimming is to be considered for the Harbour, in terms of bacterial contamination, water clarity, beach sediment contamination and water quality conditions.	- High faecal bacteria levels during and after storms	- Raw sewage overflows (CSOs, STPs) - Streams and related urban and rural runoff.	Detailed bacterial data. Other sediment and water quality standards for swimming requested of the health authorities if they deem this necessary.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(xi)	Degradation of aesthetics	Oil sheens are observed occasionally and, there are periodic occurrences of objectionable turbidity, floating scum, debris, and putrid material. Reduced water clarity persists in shallow areas particularly. This is due primarily to discharge of suspended solids from tributaries, resuspension of bottom sediments by waves and by carp, and to some extent, by algal production.	- Occasional oil sheens - algal blooms - suspended solids - debris and putrid matter.	- Spills - industrial, highway, shipping - Runoff - Resuspension of sediment - Inadequately treated sewage (STPs, CSOs)	
(xii)	Added cost to agriculture or industry	(a) Agriculture: Hamilton Harbour water is not used for agricultural purposes. Lawn watering using Harbour water probably benefits from the nutrient content. (b) Industry: Treatment of the Harbour water for industrial use is routine, and includes the addition of chlorine to rid pipes of algal build-up, travelling screens to remove debris and fish, water strainers to remove suspended material for some uses, and bacterial control for special uses. Industry considers this source of water to be adequate or good compared with other areas in the Great Lakes.	- Algae - Debris - Fish - Suspended material - Bacteria	- CSOs - STPs - Storm runoff	

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(xiii)	Degradation of phytoplankton and zooplankton	With the exception of one species (Moina brachiata), zooplankton populations are similar in composition to populations in the Bay of Quinte. Abundance is high, reflecting eutrophication and increased productivity. Moina brachiata populations are high in Cootes Paradise and lower in the Harbour. This species is absent from Lake Ontario and from the Bay of Quinte. Zooplankton sizes are small, indicating heavy predation by zooplankton and feeding fish such as alewife. A new investigation of the zooplankton and phytoplankton assemblage is planned. Earlier studies of the toxicity of Harbour water to phytoplankton and zooplankton indicated no unusual toxicity. This situation is under review through application of new bioassays.	- High organic carbon - Nutrients - Light limitation - Low dissolved oxygen in bottom layers - Contaminated sediment - Predation by alewife	- Self-shading - Municipal and Industrial sources, generally - STPs, CSOs - No submerged plants for habitat	Assess toxicity of Harbour water to phytoplankton and zooplankton. Target numbers and test protocols have to be established.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(xiv)	Loss of fish and wildlife habitat	Fish and wildlife management goals are being developed which will define the amount and quality of physical, chemical, and biological habitat. There are very obvious water-quality-related habitat problems for fish that must be addressed. These include the general loss of submerged vegetation due to the water clarity problems as detailed in (xi), and the low oxygen conditions observed in the summer hypolimnion. Other habitat problems relate to loss of marsh areas due to high water levels, poor water quality, the uprooting activities of carp and siltation in Cootes Paradise and in shallow stream estuaries in the Harbour. Infilling of key habitat through past industrial, transportation and urban development activities has destroyed major portions of the habitat (i.e. 26% of the surface area of the Harbour and 80% of the Harbour shoreline have been altered since the early 1800's). Wildlife marsh habitat has been both destroyed (marsh and creeks on south shore for animals and waterbirds) and created (CDFs serving as nesting habitat for colonial waterbirds).	- Low dissolved oxygen (DO) - Loss of submerged and marsh vegetation - Shoreline development and redevelopment - Turbidity in the water	- High lake levels - Filling from urban development - Heavy algal blooms caused by nutrients STPs and CSOs - Resuspension of bottom sediments from high energy shores or from carp activity.	The impact of shoreline development and redevelopment needs to be assessed and controlled.

I INTRODUCTION

I.1 Hamilton Harbour: "An Area of Concern"

As a component of the overall strategy to address pollution in the Great Lakes, Canadian and U.S. jurisdictions identified 43 Areas of Concern (Appendix H, Map 1), and reported them to the Water Quality Board of the International Joint Commission (IJC). Areas of Concern are locations where water quality, or sediment and biota contaminant content, do not meet standards. Hamilton Harbour is one of these.

In their 1985 report, the Water Quality Board outlined their reasons for so designating Hamilton Harbour:

IJC Water Quality Board Assessment - NATURE OF PROBLEM (as of June 1985)	
Types of Problems	**Sources**
Conventional Pollutants Heavy Metals Toxic Organics in Fish Contaminated Sediments Eutrophication Fish Consumption Advisories Aesthetics	Municipal Point Sources Industrial Point Sources Urban Non-Point Combined Sewer Overflows In-Place Pollutants
Municipal and industrial discharges, urban drainage, sediments, and algal decay increase oxygen demand. This oxygen demand depresses hypolimnetic dissolved oxygen levels, especially in the summer. This, in turn, limits the suitability of the deeper part of the Harbour as a fish habitat. Aesthetic quality is diminished by poor water clarity and colour, as a result of high levels of suspended solids, chlorophyll, and dissolved organics, thereby deterring broader recreational use of the Harbour. Significant levels of nutrients, several heavy metals, and PCBs have been detected in the surface sediments from several portions of Hamilton Harbour. Water quality objectives are exceeded for total dissolved solids, zinc, ammonia, and phosphorus. Iron, cyanide, and phenolics also exceed water quality objectives on occasion, especially adjacent to the steel mills on the south shore. Levels of trace organics (PCB, PAH), and phenols in fish are under investigation.	
Source: IJC, 1985	

I.2 The RAP Process

Prompted by the Ontario Ministry of the Environment report on management options for Hamilton Harbour (MOE, 1985), a separate initiative was undertaken to obtain community consensus on what should be done to complete the rehabilitation of the Harbour.

This effort then came under the auspices of the Remedial Action Plan Program, led in Canada by the Canada-Ontario Agreement Review Board. The Review Board supports the development of Remedial Action Plans through financial support in public consultation, facilitation of inter-agency participation, and direction of the research and engineering expertise of federal and provincial agencies towards analysis and development of solutions for problems associated with the RAP areas.

The fact that a new process for developing an Action Plan has been initiated does not imply that nothing has been done in the past to control pollution in the Harbour. Industry and municipal governments have spent approximately $300 million on pollution abatement programs ($600 Million in 1990 dollars). In 1990 the major industries discharging to the Harbour met all the requirements of the current Ontario Ministry of the Environment control orders. The Provincial government has also put into effect new programs, like the Municipal Industrial Strategy for Abatement (MISA), that further reduce the discharge of persistent toxic substances.

There is still a need to consider what additional measures should be taken to restore beneficial uses - uses which are still impaired in spite of existing effluent controls. These existing effluent standards may not be adequate to protect the Harbour from the sum of all loadings of nutrients and chemicals and their interactions, nor do current effluent standards address historical deposits of contaminants in the Harbour. No program to restore or replace lost fish and wildlife habitat existed before the Remedial Action Plan Program.

There are a number of recent reports on water quality in the Harbour that serve as the basis for analysis in this report. Prime among these is the technical summary on Hamilton Harbour conditions published by the Ontario Ministry for the Environment (MOE, 1985). The present analysis has been expanded to include Cootes Paradise, as there are links to both water quality and habitat development for fish and wildlife. And it has expanded on earlier work in its attempt to address more fully the biological aspects of the Harbour. Furthermore, it is clear that to address both present and future conditions the complex watershed must be the minimum sized ecosystem to be considered.

There are, however, some difficulties in using only the existing information to quantify the impact of some of the major remedial projects that have to be considered. For this reason the Writing Team has also drawn upon recent unpublished work and have identified the need for additional information, which will be reflected in our recommendations for work in the future.

I.2.1 The Role Of The Writing Team

The Writing Team for the Hamilton Harbour Remedial Action Plan (RAP) has been asked by the Canada/Ontario Review Board to address the problems identified by the Water Quality Board of the International Joint Commission and the goals specified by the public. The Plan is to be prepared by the Writing Team in consultation with the public and Stakeholders. The Plan, in its final form, should include an analysis of the existing conditions, and an Action Plan to meet specific objectives, including dates and estimated costs. Finally, the Plan must include the design of a monitoring system to ensure that the Action Plan and the expected results are proceeding on schedule.

Our knowledge of the Harbour and of Cootes Paradise continues to grow. Much of the new information coming forward is targeted specifically on questions raised in the development of this Action Plan. The Team will need to regularly consult and incorporate these new data into the Plan as it progresses. And, indeed, the provision of annual or biennial reports seems essential throughout the progress of the remedial action.

The Writing Team has also been helped extensively by other staff of the organizations represented on the team. Their assistance is gratefully acknowledged.

I.2.2 Public Consultation

Public consultation is an important element of the process in developing the Remedial Action Plan. It is needed for refinement of the goals and timetables for water quality and ecosystem improvements. As well, it provides a forum for discussion of cross-jurisdictional issues and develops heightened awareness of the overall program.

Two public consultation processes are being employed. Public meetings and information sessions for the general population of the watershed are open sessions designed to provide the most recent information on the Remedial Action Plan, and to permit formal presentation of briefs from interested groups. Citizens are also asked to submit their views at the meetings or in writing. These briefs and comments have been considered by the Writing Team and the Stakeholder Group.

The second process has been to establish a 'Stakeholder Group' made up of agencies, organizations, institutions, government departments, industries and private citizen groups who make use of, who wish to make use of, or in some manner have jurisdiction over the use of Harbour water. Some 60 potential Stakeholders were interviewed individually, and eventually 49 formed the group. Currently there are 42 members (Appendix G).

During a 2-day workshop in July, 1986, and through subsequent meetings, the Stakeholder Group developed an Interim Report which summarizes their proposals (Hamilton Harbour

Stakeholders, 1986). This report was submitted to the Ministers of the Environment for Canada and Ontario in September 1986, and forms a basic point of reference for the Writing Team.

The development and updating of the Remedial Action Plan will require continuing consultation. The Stakeholder Group has collectively expressed the wish to be a forum for review of matters having a bearing on the remedial actions proposed for the Harbour, both during and after the Plan is established. The Bay Area Restoration Council and Bay Area Implementation Team will carry out these roles during the implementation of the Plan.

The Interim Report of the Stakeholders is a detailed analysis of the present or possible beneficial uses for the Harbour. It describes principles for development of the Remedial Action Plan including the ecosystem approach, human health, public acceptance, and aesthetics. The principle of zero discharge of persistent toxic substances was added after subsequent discussions in 1987.

The Stakeholders' Interim Report also contains recommendations and general remedial actions for two groups of goals. One set of goals and actions is to permit the current defined uses, including recreational boating, water sports, shipping and navigation, industrial uses, and waste water receiving. Goals and recommendations were also identified for uses that are presently impaired to a substantial degree, including fisheries, wildlife appreciation, swimming, and the use of the Harbour as an educational resource. The Writing Team is considering this comprehensive list of beneficial uses in the context of the IJC goals for water quality improvement. The reader is encouraged to consult the full report of the Stakeholders.

In April 1988, the second Interim RAP Report entitled, "Goals, Problems and Options - A Discussion Document" was released by the Writing Team. The report lists the future use goals for Hamilton Harbour, describes limitations to achieving those goals, and outlines some of the remedial options that are available in order to achieve the goals.

During a two day workshop in June and July of 1989, Stakeholders met to review decisions made to date and to develop a consensus on recommendations for remedial actions.

The Writing Team prepared a draft Preferred Options Report which was released to Stakeholders for review in January 1990. Recommendations for remedial actions were reviewed by the Stakeholders and their comments incorporated into the draft Stage 2 RAP (December, 1991).

In September 1990, the Stakeholder Group participated in a two day visioning workshop. The purpose of this exercise was to develop a vision of the Harbour, identifying their priorities for making this vision a reality, and identifying obstacles to attaining this vision.

Following the development of the Stage 2 report, the Agencies will develop program schedules and funding commitments to result in the final Remedial Action Plan.

II DESCRIPTION OF THE HAMILTON HARBOUR AREA

II.1 Geography and Geology

II.1.1 Geographic Description of the Harbour

Hamilton Harbour is located at the west tip of Lake Ontario (Figure 1). A sandbar separates the Harbour from Lake Ontario and exchange with the Lake is accommodated through the Burlington Ship Canal (820 m x 88 m x 9.5 m). The Harbour is triangular in shape with an east-west axis of 8 km and a north-south axis of 5 km. The surface area of Hamilton Harbour is 2,150 hectares. With a mean depth of 13 m and a maximum depth of 26 m, the Harbour has a theoretical hydraulic residence time (i.e. volume/inflow) of about 500 days but exchange with Lake Ontario shortens the residence time to an average of only 90 days.

The mouth of Grindstone Creek, in the northwest sector of the Harbour, is an important shallow littoral habitat area. About 17% (380 hectares) of Hamilton Harbour is shallower than six metres (the littoral zone) but only about 90 hectares are currently colonized by aquatic vegetation due to various physical stresses and poor water clarity.

The pelagic zone occupies 83% of the Harbour area. Due to the morphometry of the Harbour basin, the summer hypolimnion contains 50% of the total volume of water in the Harbour (the total volume is 2.8×10^8 m^3). The hypolimnion is significant in the Harbour because during the summer when stratification becomes established, oxygen exchange with the atmosphere is cut off and the oxygen remaining in the hypolimnion is quickly reduced to 0.5 to 1 mg L^{-1}, much below guidelines of 4 to 6 mg L^{-1}.

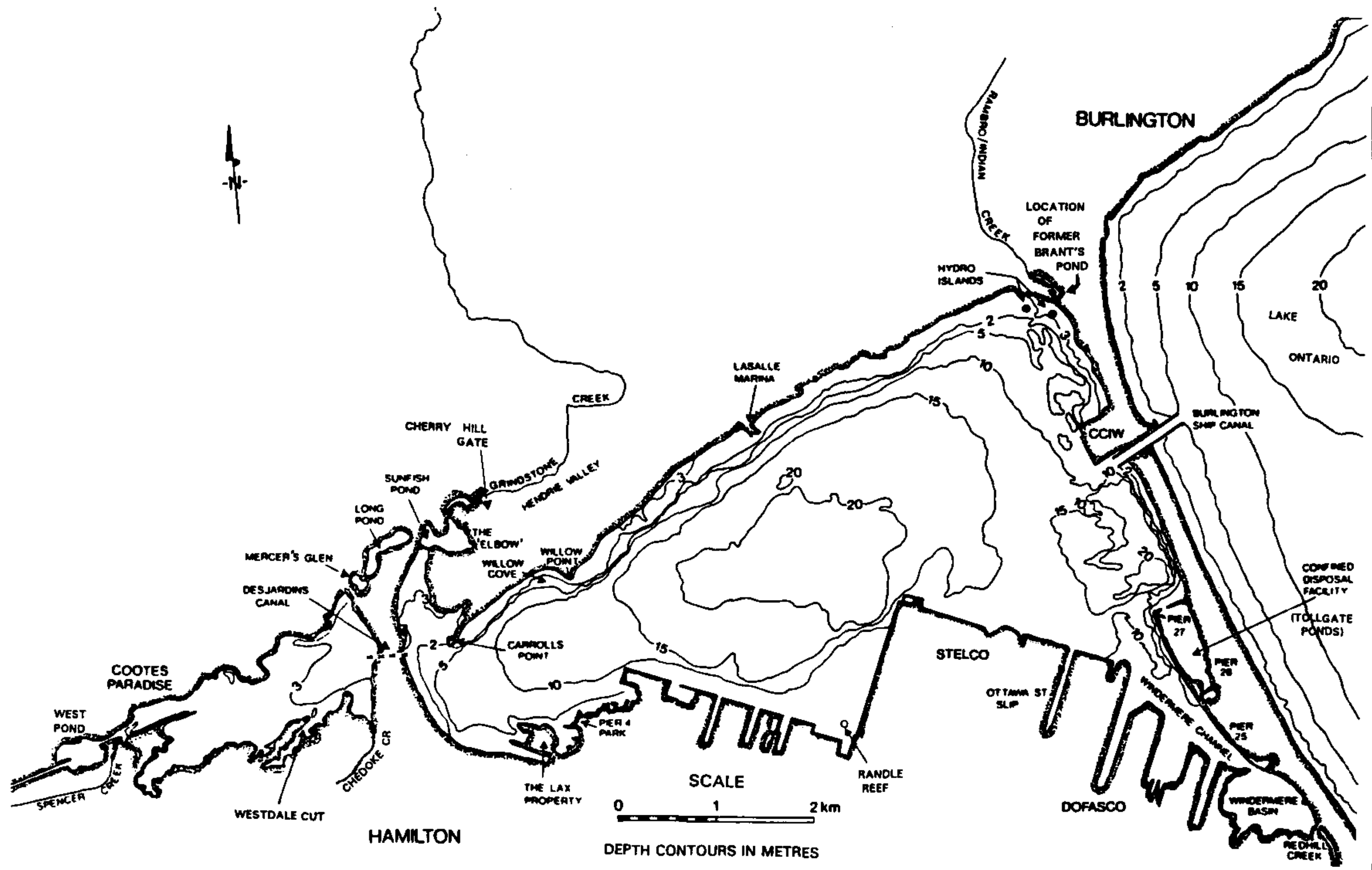
At the far west end of Hamilton Harbour is the Desjardins Canal, which leads to Cootes Paradise (Figure 1). Cootes Paradise has an open-water surface area of 250 hectares, a mean depth of 0.7 m, and a hydraulic residence time of 2 to 40 days for spring and summer, respectively (Harris, 1975). The long axes of both Cootes Paradise and Hamilton Harbour are oriented northeast-southwest which is also the predominant axis for the prevailing winds.

Windermere Basin, in the southeast corner of Hamilton Harbour, had a surface area of approximately 40 hectares and a mean depth of 0.7 m (Figure 1).

II.1.2 Historical Changes to the Harbour

The present outlet from the Harbour to Lake Ontario was constructed in 1823. Little change in the shoreline of the Harbour occurred until 1853 when a new outlet, the Desjardins Canal, was constructed from Cootes Paradise to the Harbour. The old channel was filled in to permit railway construction, leaving Mercer's Glen, Long Pond and Sunfish Pond as remnants of the original channel. Little filling has been done on the north shore with the

Figure 1: Hamilton Harbour/The Bay - Location Map.



exception of the LaSalle Park Pier and the filling of Brant's Pond in the northeast corner. The southwest end of the Harbour was modified by railway construction in the late 1800s.

Between 1862 and 1926, industrial and port expansion began filling in the extensive marsh habitat on the south shore. By 1959, the south shore marshes had been filled in and Windermere Basin had been created (Figure 2). By 1976, 22% of the open water area in the Harbour was lost, relative to 1926. The most serious loss to the Harbour was the extensive marsh littoral area. The current wetland area is estimated to be less than 50 hectares from an historic maximum of approximately 500 hectares (Figure 2). The loss of marsh littoral area has had a profound impact on the fishery and wildlife.

II.1.3 Drainage Basin

The total drainage basin of Hamilton Harbour (including Cootes Paradise) is 49,400 hectares (Figure 3). Cootes Paradise receives runoff from five sub-watersheds for a total sub-basin area of 26,000 hectares. Spencer Creek, with a total area of 17,000 hectares, is the largest sub-watershed in the Cootes Paradise drainage basin. Redhill Creek (7,190 ha.), Grindstone Creek, Indian Creek/Rambro Diversion, as well as numerous combined sewer water overflows and smaller creeks flow into the Harbour.

II.1.4 Hydrology

Annual precipitation ranges between 65 to 108 cm. The major runoff period is February to April, and the total annual runoff is approximately 1.1 to 2.1 x 10^8 m^3. Creek inflows (Cootes: 60%, : Redhill 15%, Grindstone: 14%) account for 89% of the natural runoff, with storm water runoff from the cities of Hamilton (4%) and Burlington (7%) accounting for the remainder. Of the 2.6-3.8 x 10^6 m^3/day of water entering the Harbour from all sources, natural runoff accounts for only 2-19%, sewage treatment plants (STPs) account for 7-16%, and Lake Ontario accounts for 72-87%. The water entering the Harbour from the Burlington and Hamilton STPs comes from Lake Ontario by way of the Regional water supply plants. Exchange of Lake Ontario water through the Burlington Ship Canal dominates the water budget of the Harbour. The result of all these flows in and out of the Harbour is that residence times vary from 73 to 107 days for summer and winter respectively.

II.1.5 Topography of the Watershed

The watershed's topography is characterized by a number of major, natural features which influence drainage and land use patterns. The Niagara Escarpment or 'The Mountain' as it is known in Hamilton, is the most outstanding physiographic feature of this region (Figure 3). Above the Niagara Escarpment, three major physiographic areas can be identified (the Galt Moraine to the west, the Flamborough Plain to the north and the Haldimand Plain to the south). Two major areas are present below the Niagara Escarpment (the Iroquois Plain from the shore of Lake Ontario and Hamilton Harbour to an elevation 30 to 40 m above current water levels and the Dundas Valley which is the major 'notch' in the escarpment).

Figure 2: Hamilton Harbour Shoreline Changes

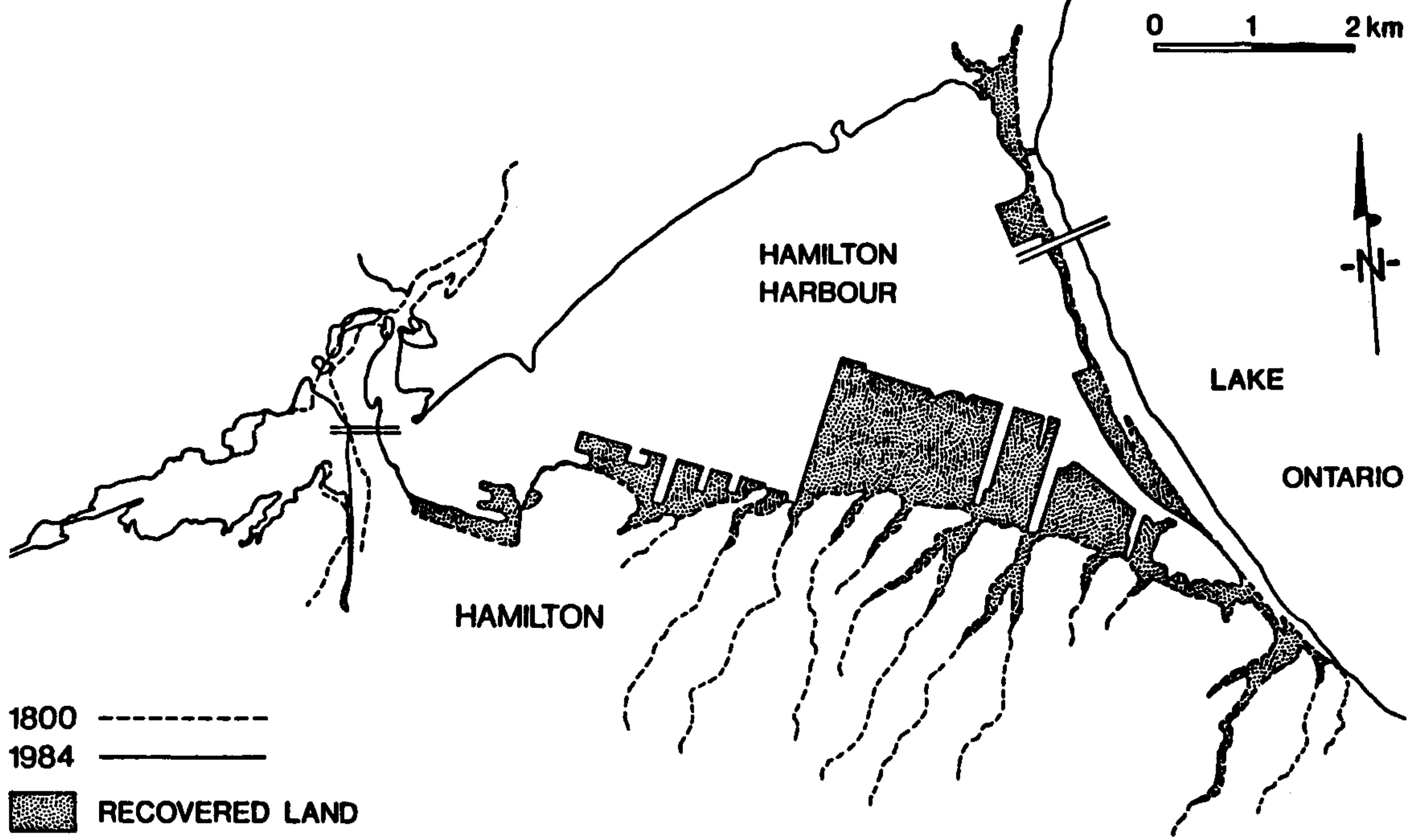
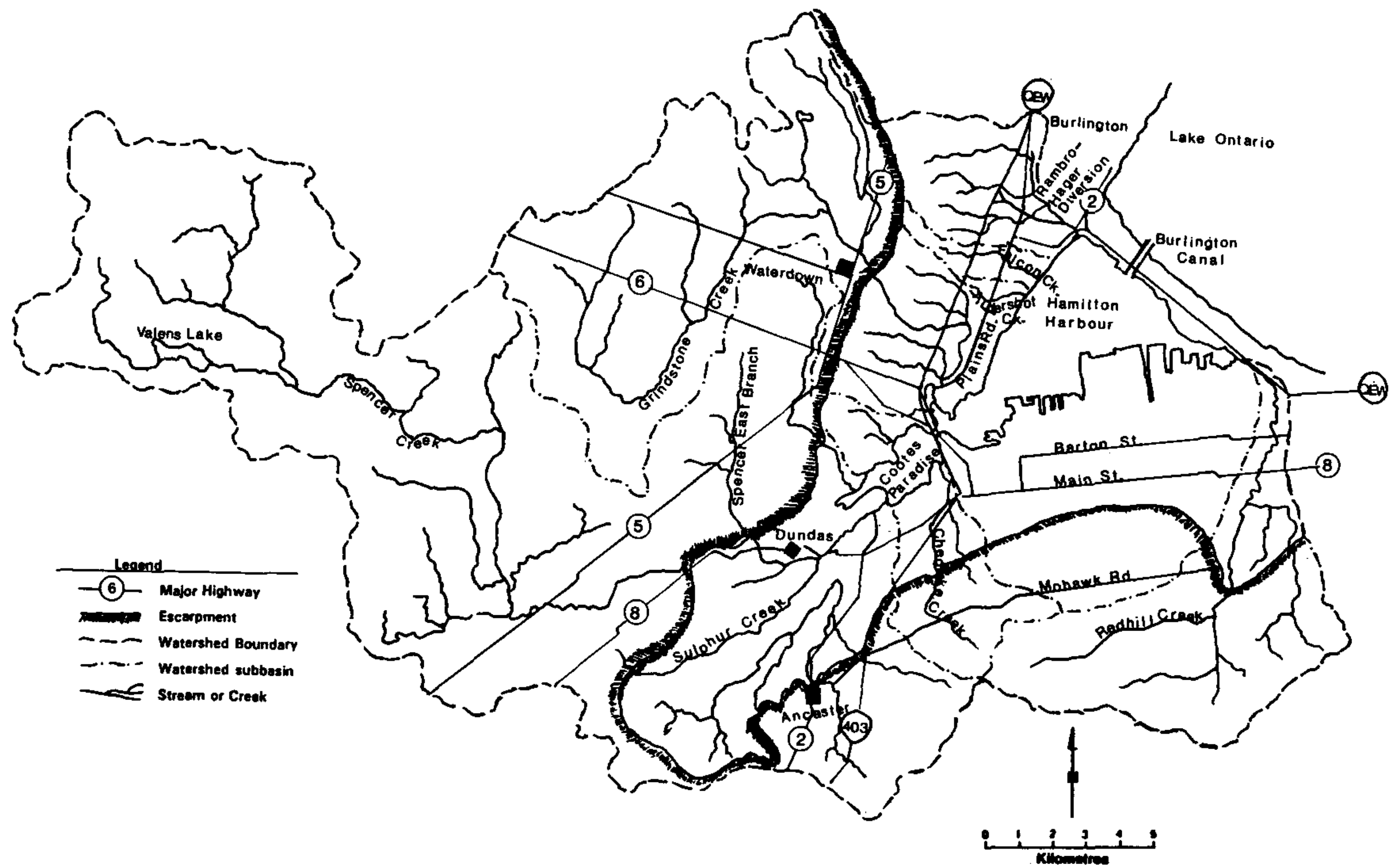


Figure 3: Hamilton Harbour Watershed



Source: Drawing provided by H. Ng, NWRI

II.1.6 Geology and Groundwater

The area is one of both glacial and lacustrine deposition, and therefore contains most types of glacial deposits and landforms. The Galt Moraine, drumlin, esker, kame, and outwash-deposit complex occurs in the Town of Flamborough. This moraine is quite stony, with a rough hummock topography. The Flamborough Plain occupies part of the Town of Flamborough, and has shallow deposits above bedrock. The south is characterized by thin lacustrine deposits, while sand and silt occur in the north. These deposits merge with the outwash sand and gravel of the drumlins in the north. The Waterdown and Vineland Moraines can be found at the top of the escarpment. In the township of Glanbrook and parts of the towns of Ancaster and Stoney Creek is the extensive Haldimand clay plain.

The Iroquois Plain extends from Lake Ontario to an elevation of about 100 metres, and consists of weathered red shale overlain by lenses of clay till and lacustrine sand. Between this area and the escarpment is a rolling area dissected by ravines which sometimes extend back into the escarpment. The Dundas Valley is the largest and deepest of such ravines.

The Niagara Escarpment was produced by differential erosion of several rock types. The Queenston formation of red shale, with occasional greenish siltstone bands forms the base of the escarpment. The Cataract and Clinton groups of white and grey sandstones, grey shale and buff dolomite rest upon this Queenston formation and are exposed along the escarpment. Capping the escarpment is resistant dolomite of the Lockport formation.

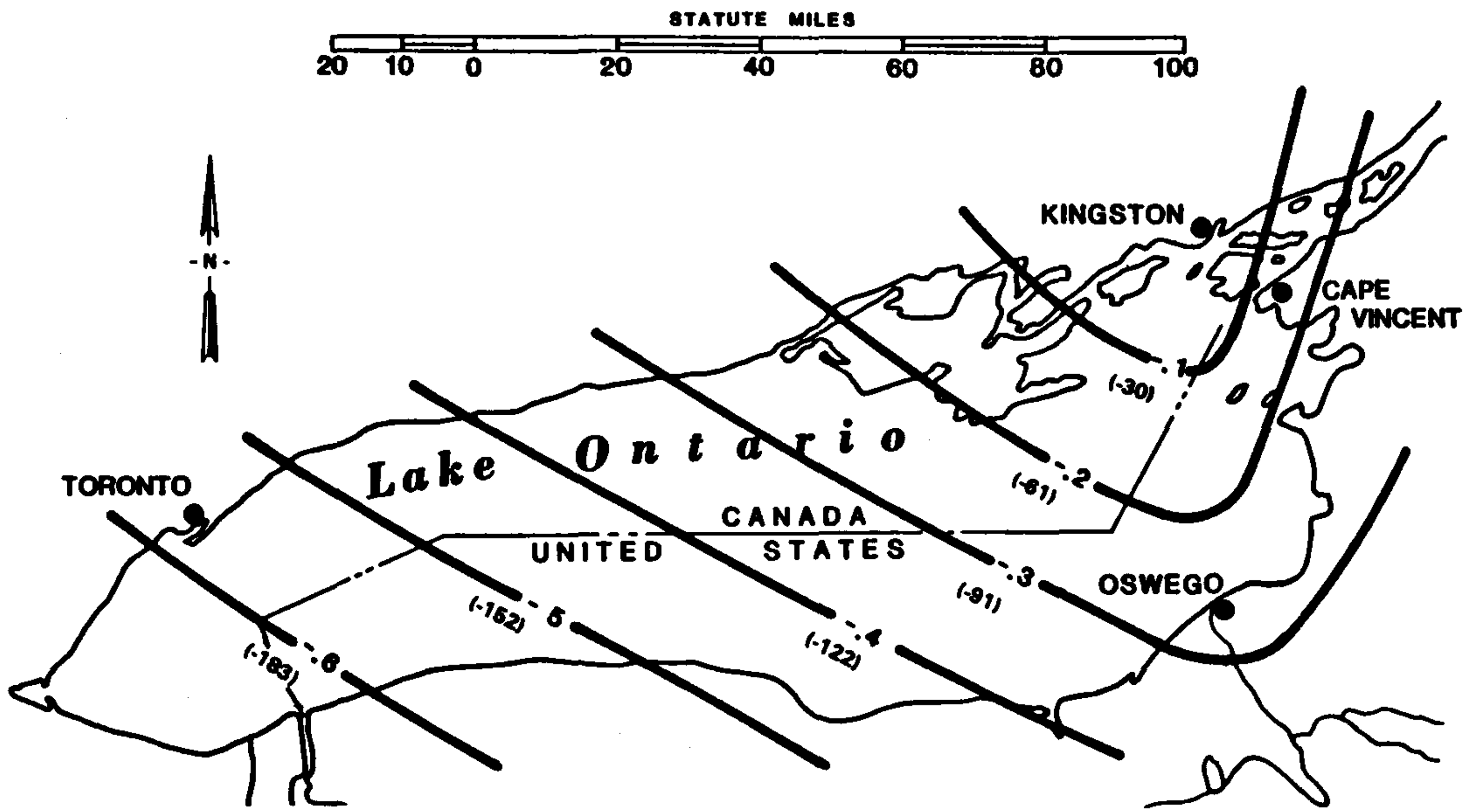
II.1.6.1 Crustal Rebound

While it is not as dramatic as an earthquake, the earth's crust in the Lake Ontario basin is tilting gradually. This tilting is the very slow isostatic rebound of the earth's crust following the depression of the crust by weight of a mile or more of ice during the Ice Age. This gradual tilting will raise water levels in the Harbour thereby affecting erosion, shore development and marsh vegetation.

The measured historic vertical movement is illustrated in Figure 4. If this movement continues through the next 100 years, the eastern outlet of Lake Ontario will rise 0.6 feet (18 cm) more than Hamilton Harbour. If there is no erosion at the outlet (or control section) in the upper reaches of the St. Lawrence River, control measures were to remain the same as present, and water supplies were the same, water would rise 18 cm along the shores of the Harbour. Evidence of the past history of such a tilting is found in the 'drowned' valleys in places at the western end of Lake Ontario such as Jordan Harbour, Grindstone Creek and the numerous inlets that formed along the south shore of the main Harbour before they were filled in.

The immediate significance of crustal rebound on Hamilton Harbour may not be apparent to the reader. Last century, Cootes Paradise and Grindstone Creek delta were 18 cm shallower than present. These areas are shallow enough that an 18 cm difference in water level

Figure 4: Measured vertical movement, contoured as uplift in feet (and mm) per century, on the basis of lake-level gauge records relative to Kingston, Ontario.



Source: Coordinating Committee on Great Lakes Basic Hydraulic and Hydrological Data, 1977.

significantly influences the vegetation communities growing there. In other words, in the last century an emergent marsh community was much more likely. Now, with crustal rebound and regulation of water levels in Lake Ontario not permitting lows to occur, a marsh is less likely. Areas like Cootes Paradise and Grindstone Creek will be restricted to submerged plants provided water clarity is adequate. Infilling through siltation could mitigate this effect.

Some erosion may take place at the outlet of Lake Ontario over the next 100 years, so that the full effect of isostatic rebound won't take place. Predictions regarding climate warming will have a more marked effect, however. While rebound will mitigate the effects of the loss of water supply due to climate warming, the scale of water supply loss is so great that water levels will depend more heavily on the policy governing changes to the water level regulation plan that is in effect at the time.

II.1.7 Soil Types

Many soil types are present in the watershed. The surface textures of the soils include loams such as Burford, Guelph, Jeddo, Lily and Parkhill; silt loams and silty clay loams such as Colwood, Toledo, Lincoln and Morley; sandy loams such as Flamboro, Granby, Grimsby, Jeddo and Springvale; and gravelly loams such as Donnybrook. Well drained soils include Burford, Donnybrook, Guelph, and Grimsby soils; and poorly drained soils include Colwood, Flamboro, Granby, Jeddo, Lily, Lincoln, Morley and Parkhill soils.

The topography of the soils vary from gently undulating to undulating for the Burford and Grimsby soils to level to depressional for the Colwood, Flamboro, Granby, Jeddo, Lily, Lincoln, Morley and Parkhill soils. Donnybrook soils are rolling to hilly, and Guelph soils undulating to gently rolling.

II.1.8 Erosion

The combination of soil texture, drainage and topography determines to a great extent the agricultural use of the soils, which in turn determines the potential for soil erosion from agricultural areas. Table 1 illustrates the interaction between soil erosion and soil type, slope and land use for three soil types found in the watershed, using the Universal Soil Loss equation.

Silt loam and silty clay loam soils can be very susceptible to erosion compared to other soil types. In addition, areas of steep slopes, whatever the soil type, will be more susceptible to erosion. The conventional cultivation of row crops with little soil cover over winter and spring has the potential for increased movement of the soil.

The loss of 3 tonnes/acre of soil is the maximum acceptable level of soil loss, since mineral soils develop at about that rate. However, if the loss of soil is greater than 1 tonne/acre from fields adjacent to water courses, water quality may be affected. A survey was recently completed for the rural areas of the Hamilton Harbour Watershed (Ecologistics, 1988).

The use of conservation tillage techniques including cross slope cultivation and planting, residue management using conservation tillage equipment, crop rotation with forage grasses and legumes, cover crops, and buffers may reduce the erosion potential to an acceptable level for agronomic and water quality reasons.

TABLE 1: **Potential soil erosion (tonnes/acre/year).**

		Slopes %				
Soil Type	Crop	0 - 0.5	0.5 - 2	2 - 5	5 - 9	9 - 15
Loam	Corn	3	3	9	24	47
	Grain	3	3	8	23	44
	Forage	<1	<1	2	5	10
	Woodlot	<1	<1	1.5	4	8
Silt, loam	Corn	4	4	12	31	59
Silty clay loam	Grain	4	4	11	29	55
	Forage	<1	<1	2.5	6	12
	Woodlot	1	<1	2	5	10
Sandy loam	Corn	1.8	18	5	13	25
	Grain	1.6	1.6	4.5	12	23
	Forage	<1	<1	1	2.7	5
	Woodlot	<1	<1	<1	2	4

Source: R. Van den Broek and H. Lang, OMAF.

Erosion of soils, transportation, sedimentation and resuspension has resulted in an average sedimentation rate in the east end of Cootes Paradise of 1 cm/year. Suspended solids concentrations as high as 2,300 mg/L were observed in a 1987 runoff event in Spencer Creek. Urban construction practices in Dundas and Ancaster are felt to be the major contributor, since the watershed above the escarpment has a flood control reservoir which would dampen the impact of rainfall events (Ecologistics, 1988). Grindstone Creek also has significant erosion events that have resulted in the deposition of clay/silt sediments at its mouth in Hamilton Harbour. As far back as 1966, erosion was identified as a serious problem in Grindstone Creek. In 1966-67, Grindstone Creek discharged 2,260 tons of suspended solids. When compared to other area creeks and rivers, Grindstone was by far the worst. Grindstone, Spencer and Redhill Creeks had 87, 42 and 10 tons respectively per year per cfs of suspended solids in 1969. The following types of erosion were observed in the Grindstone Creek watershed: sheet, rill, gully, channel, in-stream, unstabilized stream banks, urban construction practices, road embankments, and excavations. A 1978 survey concluded that the majority of the suspended solids originated in the lower portion of Grindstone Creek, below the escarpment. Steep slopes combined with relatively impervious clay and shale deposits resulted in the rapid erosion of any exposed soil.

The average annual sedimentation rate in the Harbour has been estimated from limited sediment trap data to be approximately 6.5 $g/m^2/day$ (Charlton, NWRI, unpub. data). The total annual amount settling out over the entire Harbour would be approximately 5.2×10^7 kg. Assuming an average surficial sediment weight of 0.34 g/cc (Nriagu et al., 1983), the sedimentation rate measured in the water column translates to an annual deposition of 0.7 cm/yr. Nriagu et al., (1983) determined a deposition rate of between 0.12 cm/yr and 0.35 cm/yr.

Pb-210 dating of 8 sediment cores from the Harbour showed accumulation rates ranging from 0.06 to 0.96 cm/yr with a simple average of 0.53 cm/yr. The dating results suggest a mean consolidated thickness of polluted, "industrial" sediment (sediment younger than 100 years) of about 35 cm and annual deposition of about 20 million kg of sediment, about half of the loading indicated by data from suspended-sediment traps. Grain-size and water-content data from cores showed considerable variation vertically and horizontally presumably because of the effects of dredging and dumping of dredge spoil. This variability makes it important to ensure that apparent changes in sediment properties with time are real and not merely the result of sampling disturbed sediments, (Rukavina, pers. comm.).

A net accumulation rate of 0.3 cm/yr was also determined for the area in Lake Ontario, outside the Burlington Ship Canal (Poulton et al., 1988).

The general sedimentation rate across the complete Harbour will figure significantly in the discussion of contaminants in the bottom sediments.

II.1.9 Groundwater

The volume of groundwater is meeting the needs of the present rural population in the watershed with little indication of depletion. The quality of groundwater is somewhat variable, however. The quality of water from deep drilled wells is good. A number of studies of shallow wells have, however, indicated that bacterial contamination is found frequently, that there are some elevated sodium levels and a few wells with elevated nitrate levels (Regional Municipality of Hamilton-Wentworth, 1991). The source of bacterial contamination in many cases appears to be inadequate septic systems or poor well maintenance. The impact of agriculture and rural housing developments is indicated as well.

There have also been isolated instances of seepage of petrochemicals from underground storage tanks (Regional Municipality of Hamilton-Wentworth, 1990). The main problems occur within the shallow aquifer and with dug wells.

Groundwater concerns are also often raised in the discussion of landfill sites - past and present (see Section II.2.2, for examples).

Overall there is a need for a more comprehensive review of groundwater in the watershed. Except as a component of baseflow of streams entering the Harbour, there is no comprehensive analysis available of separate groundwater flows to the Harbour, though it is not considered to be a significant fraction of the current contaminant loadings from streams or from discharges by industry and the sewer system.

II.2 Current Land Uses

II.2.1 Introduction

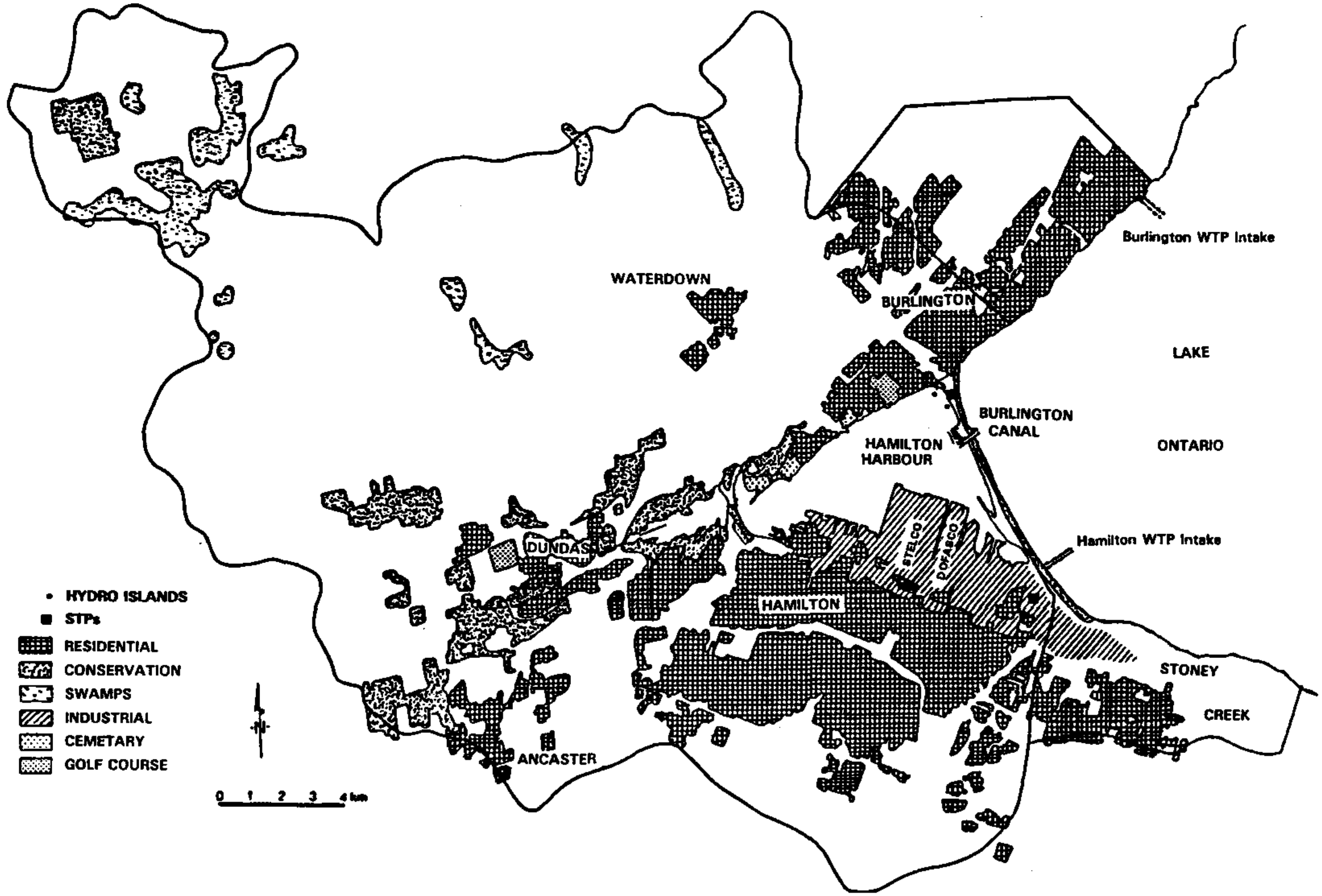
A land use survey has not been conducted on the complete Hamilton Harbour watershed. Some general features can, however, be presented (Figure 5).

Urban centres located in the watershed are Hamilton (pop. 306,000), Burlington (120,000), Stoney Creek (43,000), Dundas (20,000), and Ancaster (17,000). Projected population increases for the basin are approximately a total of 10% from these 1986 estimates to the turn of the century. Urban growth within the watershed has historically centred on the City of Hamilton. Development has resulted in a nearly continuous urban area surrounding the Harbour. The urban centres are largely below the Niagara Escarpment. The greatest pressure for development is in the eastern and north-eastern parts of the watershed. A few small towns exist above the escarpment. Waterdown (pop. 4,000) has a 2,400 m^3/day sewage treatment plant discharging into Grindstone Creek.

The Harbour's deep water port supports the largest concentration of heavy industry in Canada. The port and the associated industries are located along the south shore of the Harbour. The major industries are iron and steel. Direct and indirect employment related to the port facilities is estimated at 30% of the total area employment.

In addition to being a major shipping centre, the Harbour is ringed by major highways which impinge on water quality and habitat in the Harbour.

Figure 5: Hamilton Harbour Watershed Land Use



II.2.2 Landfill Sites

There are eight municipal landfill sites, all closed in the last twenty years, in the Hamilton Harbour watershed. Four of these have leachate collection for treatment at municipal sewage treatment plants (STPs). Four privately operated non-hazardous solid industrial waste sites are located in the watershed. Only one of these sites is receiving putrescible material. Leachate from this site is being collected for treatment at a municipal STP.

Studies have been carried out at all landfill sites and reports are available from the regional MOE office. No detrimental effect on receiving waters is being observed at any of these sites.

The Burlington Landfill site is approximately 29.3 hectares and was closed in 1989. The site is adjacent to Falcon Creek, approximately 3.5 kilometres from Hamilton Harbour. The leachate is collected for treatment at the municipal STP. The Halton Region also has a detailed monitoring program for Falcon Creek.

The Bayview Park Landfill site in Burlington closed in 1972 and occupied an area of approximately 18 hectares. The site is adjacent to Indian Creek. A leachate collection system was installed in 1986 for pumping and treatment of the leachate at the Burlington STP. The Halton Region has a detailed monitoring program for ground and surface water quality.

The 403 Landfill site was closed in 1977 and is now Kay Drage Park. The 15 hectare site is adjacent to Chedoke Creek in Hamilton. No leachate collection system is in place. Sampling of Chedoke Creek is done above and below the park.

The Edgewood Road Landfill site in Flamborough was closed in 1978. The 4 hectare site is adjacent to Beverly Swamp.

The Dundas Landfill site in the town of Dundas was closed in 1976. The 9.4 hectare site has been sampled by the Region of Hamilton-Wentworth.

The Brampton Street Site is approximately 5 hectares and was closed in 1977. The site is adjacent to Redhill Creek in Hamilton. Redhill Creek is monitored by the regional office of the Ministry of Environment.

The Upper Ottawa Street Landfill site in Hamilton was closed in 1980. The site is one kilometre north of the escarpment adjacent to Redhill Creek. Leachate collection systems have been installed and the leachate is pumped to the Woodward Avenue STP. An Upper Ottawa Street Landfill Site Study was produced in 1986. Monitoring is performed by the Ministry of Environment and the Region of Hamilton-Wentworth.

The Jersey Road Landfill site in Ancaster was closed in 1980. The 19.8 hectare site has a leachate collection system and the leachate is pumped to the Woodward STP.

The Steetley Industries Landfill site is approximately 16.3 hectares and is located in the Town of Flamborough. The site is limited to non-hazardous solid industrial waste. Leachate is collected and pumped to the Dundas STP. A groundwater monitoring program is also performed.

Taro Aggregates Landfill site in Stoney Creek is approximately 24.3 hectares and is also limited to non-hazardous solid industrial waste. A groundwater monitoring program is conducted.

Stelco Inc. Landfill Sites (No. 2 Rod Mill and No. 3 Dock) are approximately 18.5 hectares and 35.4 hectares respectively. They are constructed on landfill in the Harbour and are restricted to non-putrescible non-hazardous industrial waste. Groundwater monitoring programs are performed by Stelco and annual reports sent to the Ministry of Environment.

II.2.3 Agricultural

Approximately 60,000 hectares in the Hamilton Harbour watershed and in areas adjacent to it is classified as agricultural. About 15% of this land is woodland, and the remainder is intensively cropped. Of the farms in the area, the Agricultural Census (Statistics Canada, 1986) reports that about 80% are mixed farms, raising livestock and growing hay, cereal grains and corn; 10% are tree fruit farms; and 10% are vegetable farms. A few nurseries and sod farms also operate in the watershed.

Farmers apply nitrogen, phosphate and potash fertilizers, and lime to field and horticulture crops according to recommendations based on the soil test requirements. The summary of the 1986 Ontario Ministry of Agriculture and Food soil testing information indicates that farmers in the regions of Hamilton-Wentworth and Halton tested 1,487 soil samples. The average soil test values for all crops indicate the soils are neutral in pH with an average phosphorus reading of 32 mg/L and an average potassium reading of 124 mg/L. These average values are slightly higher than the provincial average due to the horticultural crops grown.

Pesticide use in the two regions is summarized in Table 2.

The agricultural use of land in the Hamilton Harbour watershed, especially adjacent to watercourses, may have some effect on water quality in the rural areas if recommended management techniques are not followed. Where recommended crop and livestock management practices are followed, the impact of agricultural use of land on water quality is expected to be minimal.

TABLE 2: Pesticide use in 1983 (kg).

	Herbicides				Insecticides	Fungicides
	Crop	Triazine	Phenoxy	Other		
Hamilton-Wentworth Region	Field	25350	8070	26460	6670	0
	Fruit	130	10	270	7930	23520
	Veg.	730	310	2420	4850	4980
	Roads		880	110		
Halton Region	Field	7370	2350	0	0	0
	Fruit	10	0	70	2420	6420
	Veg.	100	10	280	600	760
	Roads		670	20		

Source: Ontario Ministry of Agriculture and Food, 1983.

II.2.4 Recreational

The Hamilton-Wentworth Conservation Authority has 13 conservation areas in the watershed for a total of approximately 2,000 hectares. Most of these areas support recreational activities such as hiking, bird watching, family picnics, fishing, swimming, canoeing, and sailboarding. Cootes Paradise is a 835 hectare nature preserve owned and managed by the Royal Botanical Gardens (RBG). Numerous passive recreational activities are supported by Cootes Paradise. Public use of Cootes Paradise and the RBG natural areas for outdoor education and enjoyment is approximately 63,000 user days per year. The Niagara Escarpment with its associated natural areas and trails is also a major recreational resource.

II.2.5 Wildlife Habitat

The Cootes Paradise/Hamilton Harbour area lies within two broad and overlapping life zones: the Great Lakes-St. Lawrence, and the Carolinian (Deciduous Forest Region). The Carolinian life zone is widespread in the eastern United States but only extends into Canada in southwest Ontario in the area bordered by Lakes Huron, Erie and Ontario. Consequently the flora and fauna reflect elements of both of these major biomes. Nationally, provincially, and regionally significant plant and animal species are present. Sixteen rare mammals, 25 rare fish, 53 rare breeding birds, and 22 rare reptiles and amphibians have been identified in the Hamilton-Wentworth Region. A major review and survey of the biota in the Hamilton-Wentworth Region is currently underway, led by the Hamilton Naturalists Club and supported by municipal and senior levels of government as well as others.

The Niagara Escarpment, Dundas Valley, Redhill Creek Valley and upland areas of Cootes Paradise and Grindstone Creek Valley comprise a continuous green belt providing corridors for wildlife utilization within the region.

II.2.6 Environmentally Sensitive Areas

Environmentally sensitive areas (ESAs) are areas with some inherent biological sensitivity, and were identified using the criteria established by conservation authorities and the Halton Region Ecological and Environmental Advisory Committee. ESAs are areas containing or representing:

1) unusual and/or distinctive landforms
2) vital ecological functions (water storage, headwaters, habitat)
3) unusual/distinctive plant and/or animal communities
4) unusual/distinctive habitat
5) high diversity of biological communities
6) habitat for rare or endangered species
7) large and undisturbed area
8) other combination of habitat/landforms valuable for research or education
9) other combination of habitat/landforms with a high aesthetic value

The Hamilton-Wentworth Region has a total of 44 ESAs of which 27 are in the Hamilton Harbour watershed (11,400 ha). Halton Region has a total of 38 ESAs with 5 contained in the watershed (600 ha). Twenty-five percent of the Hamilton Harbour watershed has been identified as environmentally sensitive.

The ESA policy is designed to protect significant natural areas within the limits provided by existing legislation. The intent of the policy is not to unnecessarily restrict development within the ESA, but rather to ensure that such development does not adversely affect the ESA as determined through preparation of environmental impact assessments. In many cases, ESAs may need all or large portions of their area to be protected.

Many of the areas are also identified by other agencies as special areas such as the Parkway Belt West Plan, the Niagara Escarpment Commission Mandate, Class 1 Wetlands, Carolinian Canada, or ANSI (Areas of Natural Scientific Interest).

II.3 Current Water Uses

II.3.1 Water Supply

The drinking water supply for Hamilton area and Burlington residents is Lake Ontario. Water is drawn from intakes 5 kilometres south and north from the Ship Canal. Ultimately, 368,000 m^3/day of what originally was Lake Ontario water is processed at the Hamilton and Burlington water treatment plants. See Section II.3.5 for its ultimate fate.

II.3.2 Navigation

Hamilton Harbour is the second largest Canadian Port on the Great Lakes and ranks sixth for total tonnage in Canada. Imports include general cargo, steel, ingot moulds, machinery and fertilizers. Exports include steel, general cargo, beans, grain, newsprint, rubber, synthetic resin, road graders, ductile iron water pipe, and cement. Bulk shipments of coal, iron ore, sand, scrap metal, petroleum products, and molasses are handled.

Since 1922, the tonnage handled in the port has steadily increased. In the past ten years, however, the level of shipping activity in the Harbour has fluctuated. Tonnage has levelled off (11 million metric tonnes) and is expected to remain relatively stable with modest yearly increases.

On behalf of the Hamilton Harbour Commissioners (HHC), Public Works Canada oversees regular maintenance dredging projects which maintain the required navigational depth (approx. 9 m) in the main ship channels and slips. From 1976 to 1984, 350,000 m^3 of sediments have been dredged from the Harbour and placed in the confined disposal facility (CDF) managed by the Hamilton Harbour Commissioners at the east end of the Harbour.

II.3.3 Wildlife

Hamilton Harbour has six areas within the basin identified as having significant wildlife associations. The areas are: Cootes Paradise, Hendrie Valley/Carrolls Point, the Hamilton Harbour Commissioners' Confined Disposal Facility, Hydro Islands, Windermere Basin, and Hamilton Harbour proper.

The west end of Lake Ontario, including Hamilton Harbour, is an important local and regional waterfowl habitat area (Dennis et al., 1984). The North American Waterfowl Management Plan has specific objectives regarding the acquisition and protection of 27,300 hectares of breeding and migration habitat for black ducks and mallards within the Canadian St. Lawrence-Great Lakes Lowlands area.

The Ontario Ministry of Natural Resources has classified Cootes Paradise as a Class One Wetland (OMNR, 1987), the highest ranking classification. Given the importance of the area for waterfowl both locally and within the context of the North American Waterfowl

Management Plan, and given the serious reduction in the critical marsh littoral habitat, Cootes Paradise could achieve regional and national prominence if its wetlands and waterfowl usage could be improved.

II.3.4 Recreation

The calm waters of the Harbour are enjoyed by many sailing, canoeing, and rowing enthusiasts. Many individuals fish for salmon, trout, bass, pike, and panfish. Swimming is prohibited by a bylaw of the Hamilton Harbour Commissioners.

At present, 737 boat slips, 250 moorings and 70 dry sail spaces are available in the Harbour. Approximately 70% are occupied by sailboats and 30% by power boats. Four ramps are provided, two in Hamilton and two in Burlington. Seven boat clubs or marinas are located in the Harbour, with all except one located in the southwest corner. These recreational boating facilities provide approximately 78,000 user days per year. Increased canoeing and kayaking activities have been noted in Cootes Paradise and the Harbour, but the extent has not been measured adequately.

The Ontario Angler Survey and annual creel surveys indicate that fishing activity is predominately in Lake Ontario and oriented toward cold water species. Almost all of the fishing in the Harbour has been observed to be shore fishing. Several warm water and cold water species are caught in the Harbour. The total user days are an estimated 4,400 per year.

II.3.5 Waste Disposal

The Hamilton and Burlington sewage treatment plants (STPs) discharge into Hamilton Harbour (391,000 m^3/day). All industries in Hamilton discharge their wastes to the sewage treatment plant; however, both Stelco and Dofasco discharge a portion of their waste directly to the Harbour after on-site treatment. Combined sewers do overflow during heavy rains and result in raw sewage entering the Harbour directly. Two smaller STPs discharge to Cootes Paradise (Dundas) and to Grindstone Creek (Waterdown). Some stormwater is also treated in the Woodward Ave. (Hamilton) STP.

II.3.6 Industrial Uses

Both of the iron and steel industries withdraw water for direct contact cooling (2×10^6 m^3/day) but virtually all is returned to the Harbour. This "once-through" cooling process presents the industries with serious difficulties in controlling contaminant discharges. Discussion concerning effluent discharges (concentrations and loadings) appears in Chapter IV.

II.4 Political Jurisdictions

Hamilton Harbour and its watershed encompasses a number of municipal jurisdictions (Figure 6). In addition, there are many agencies with legislated mandates that have an impact on the Harbour. One of the major challenges in trying to realize fully the beneficial uses affected by water quality will be to coordinate the work of these agencies to achieve common goals. It is therefore necessary to identify where these mandates reside.

Historically, the Constitution Act of 1867 (British North America Act) gave the issue of free navigation primacy over all other uses within public harbour areas. Public harbours were the property of the federal government. Harbour jurisdiction extended to the bed and the foreshores of the harbour, where these foreshores were actually used for harbour purposes. Autonomous Harbour Commissions were created to manage and administer public harbours on behalf of the federal government.

II.4.1 Hamilton Harbour Commissioners

Hamilton Harbour was not a public harbour at the time of Confederation in 1867. The City of Hamilton was given jurisdiction over the Harbour area when the city was incorporated in 1846. The Hamilton Harbour Commission Act of 1912, gave the authority to the Hamilton Harbour Commissioners (HHC) to administer the Harbour on behalf of the City of Hamilton. This authority applied to all waters and inlets of the Harbour, and all waterfront properties, water lots, docks, shores, and beaches. The act gave the HHC jurisdiction over lands developed for shipping and Harbour uses and the power to regulate the use of Harbour foreshore lands. The HHC passed its own by-laws to control activities relating to shipping and navigation within the Harbour or on Harbour land.

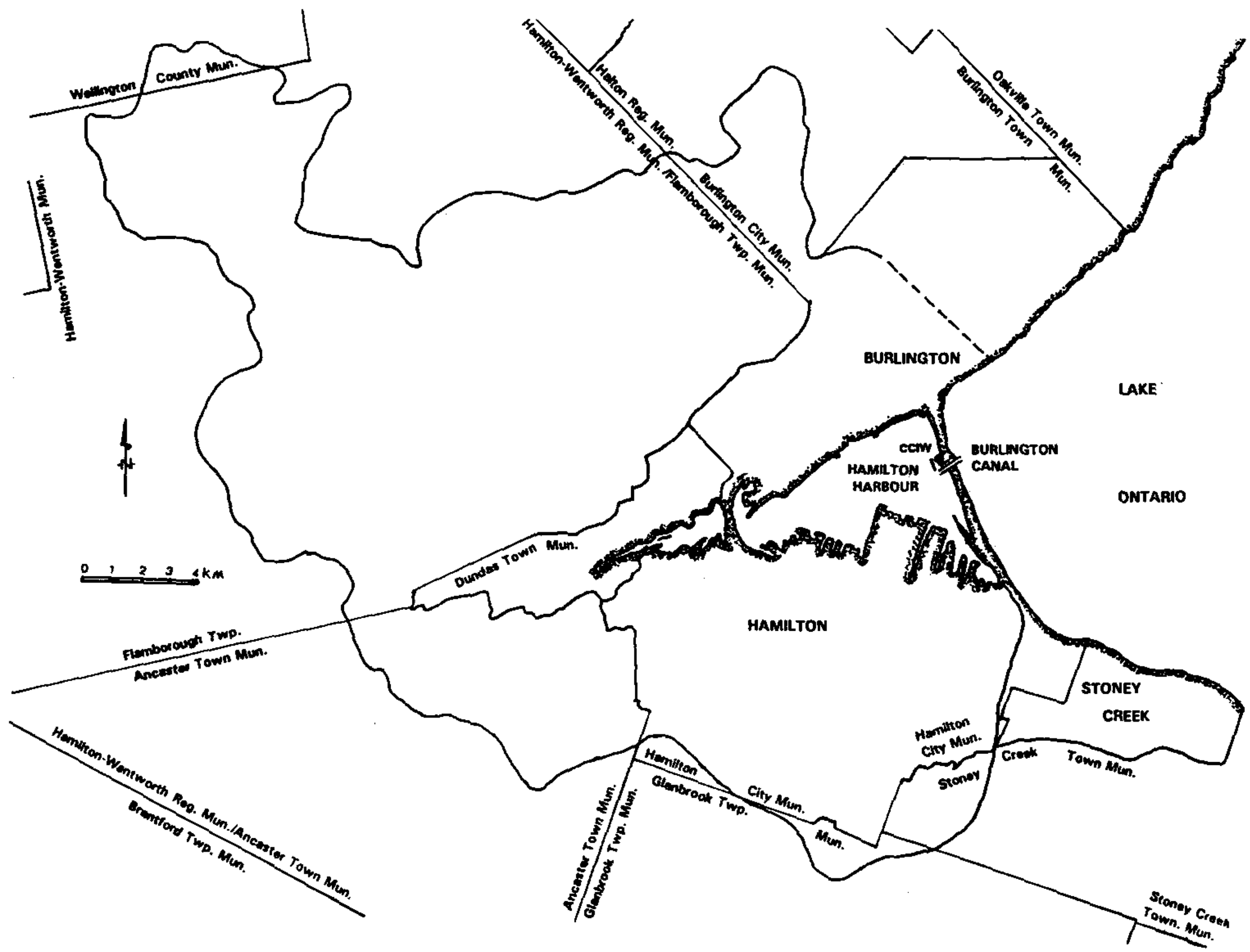
As indicated in Section II.4.5, a court decision in 1978 ruled that the City can regulate land use within the Harbour area, as long as that land use does not interfere with shipping or navigation uses. Where conflicts arise, federal jurisdiction over shipping and navigation prevails.

The federal government appoints two commissioners to the Hamilton Harbour Commissioners. The third commissioner is appointed by the City of Hamilton. The HHC submits an annual report on activities and a financial statement to the Minister of Transport. However, it conducts its activities independent of the Minister of Transport.

II.4.2 Federal

The authorities for federal jurisdiction in Hamilton Harbour derive primarily from the Canada Shipping Act, the Navigable Waters Protection Act, the Public Works Act as it pertains to navigational dredging, and the Fisheries Act. The federal government owns some water lots adjacent to the Canada Centre for Inland Waters (CCIW).

Figure 6: Hamilton Harbour Watershed Political Boundaries



Apart from the Burlington Ship Canal, which is the responsibility of Transport Canada, the federal government has in the past exerted very little direct jurisdiction over Hamilton Harbour.

Through its treaty power, the federal government can enter into international agreements such as the Boundary Waters Treaty of 1909 with the United States. This has enabled the Canada-United States Great Lakes Water Quality Agreement and consequently the Canada-Ontario Agreement on Great Lakes Water Quality which impose certain obligations on the various levels of government to reduce pollution inputs to the Great Lakes. Since Hamilton Harbour water discharges into the Great Lakes system, the quality of this water is of direct concern.

Projects initiated, funded or carried out by the federal government are subject to the Environmental Assessment and Review Process (EARP) by an Order-in-Council. This is a self-assessment process which requires the proponent to determine if the proposed project has the potential for environmental implications. All federal departments are required to follow the EARP, however, Crown Corporations and agencies such as the HHC are requested to participate voluntarily. The HHC has voluntarily followed the EARP in the past.

The federal Fisheries Act provides the means to protect fisheries habitat from degradation through pollutant discharge and spills into the aquatic system or by direct physical destruction. A Canada-Ontario Fishery Agreement has recently been signed regarding fisheries management in Ontario. Fisheries and Oceans Canada has also recently adopted a policy to improve habitat management and protection. A Canada-Ontario Subsidiary Agreement on the management of fish habitat is currently under discussion.

Under the Canada Water Act, the federal government has authority to enter into agreements with the provinces regarding special interest watersheds or basins. Such agreements allow joint research and study efforts, or the implementation of various or specific measures to manage the watershed for the enhancement of water quantity or quality. No specific management watershed designation has ever been formally applied in Ontario to date.

However, a major Canada-Ontario Agreement (COA) was signed to facilitate the responses of Canada and Ontario to their commitments under the Great Lakes Water Quality Agreement of 1972 (revised in 1978 and 1987). Several programs are active under that Agreement, but the program most pertinent to this report is the Remedial Action Plan Program, under which this reporting activity falls.

II.4.3 Provincial

By virtue of the Constitution Acts of 1867 and 1982, the prime jurisdictional authority over water management is generally held by the provinces. Therefore, the province is the main "water manager" and can determine its apportionment or regulate its quality to meet provincial economic and social objectives. The Constitution Acts give the provinces ownership of public lands, minerals, rivers, and water courses, and jurisdiction over generally all matters of a local/private nature in the province. In the case of Hamilton Harbour, the Hamilton Harbour Commissioners in fact regulate activities and facilities within the Harbour.

Through its jurisdiction over pollution control and local works and undertakings, Ontario is the major actor in the regulation of waste disposal into the Harbour. Under the Ontario Water Resources Act (OWRA), the Ministry of Environment is provided with authority to regulate the discharge of sewage and the taking of water, by licensing municipal and industrial sewage works and potable water treatment systems, and by granting permits to take water. The OWRA also prohibits the impairment of any lake, river, or stream through discharges of polluting substances under recourse of injunction, fine and imprisonment. The Ontario Environmental Protection Act (also administered by MOE) provides for the regulation of the deposit, discharge, or emission of wastes and substances (solid, liquid, gaseous) from industrial and other generating sources, processes and the licensing of waste disposal sites and systems. The Ontario Environmental Assessment Act is also applicable to municipal and provincial undertakings, and through regulation could be applied to new undertakings by industry.

There are other provincial legislative instruments which potentially can pertain to the Hamilton Harbour environment. The Public Health Act authorizes the Ministry of Health to advise and set requirements for drainage, water supply, disposal of garbage and sewage. The Ontario Planning and Development Act (Ministry of Housing) allows for the designation of development planning areas, the preparation and approval of development plans, and the requirement for local official plans and zoning by-laws to conform with development plans. The Ontario Municipal Board, created under the Act of the same name, is responsible for approvals under the Planning Act including zoning by-laws and redevelopment plans, and municipal boundary revisions, amalgamation or annexations under the Municipal Act.

The Ministry of Natural Resources administers the Public Lands Act, The Beds of Navigable Waters Act, the Lakes and Rivers Improvement Act, and the Beach Protection Act. These reflect provincial authority on public lands and waters (to dispose by grant, lease, or sale, and to licence water lots); to reserve 25% of shorelands for public use; to enter into beach management agreements with municipalities; and to regulate alterations on lakes and rivers and the removal of sand from shorelands (beaches and beds) for commercial purposes. MNR also carries out fisheries management under the auspices of the Canada Fisheries Act and an associated Canada-Ontario agreement.

The Ministry of Agriculture and Food (OMAF) administers the Ministry of Agriculture and Food Act. This Act provides the Provincial authority to grant assistance to agriculture or any branch of it. Programs such as the Land Stewardship Program and the Ontario Soil Conservation and Environmental Protection Assistance Program are funded to provide grants to farmers for soil conservation projects on agricultural land.

II.4.4 Regional

Each Regional Municipality has its own enabling provincial act. Thus, the Regional Municipality of Hamilton-Wentworth Act and the Regional Municipality of Halton Act generally provide for the development of regional official plans which set out broad land use planning guidelines and the development of zoning by-laws. Also pertinent in this context are the Planning Act and the Municipal Act. Additionally, water, sewage systems and landfill sites are the responsibility of these Regional Municipalities.

II.4.5 Municipal

Both the City of Hamilton and City of Burlington which front onto Hamilton Harbour (Figure 6) operate within the context of the Municipal and Planning Acts, and within the framework of their respective Regional Municipalities. The municipal governments develop district plans which are implemented by specific re-zoning or by-law amendments, subdivision approvals, agreements, and site plan controls, such as through the issuing of building permits. Under the Planning Act, the City can prohibit or otherwise regulate the use of all lands and improvements within the municipality, subject to Ontario Municipal Board approval. The City of Hamilton has, for example, enacted a by-law (#6593) which restricts certain uses and characteristics of land and building structures within its boundaries, which include the adjoining shores of Hamilton Harbour, Cootes Paradise, and Lake Ontario. Based on a court decision in 1978, however, city by-laws affecting land use within the Harbour are only applicable where they do not explicitly attempt to control the use of land for shipping or navigation-related purposes.

II.4.6 Conservation Authorities

The Conservation Authorities Act, administered by the Ministry of Natural Resources, establishes provincial regional Conservation Authorities (with representation of local municipalities) to conserve, develop and manage all natural resources, with the exception of oil, gas and minerals, within their designated watersheds. The Act provides authority to construct dams and create reservoirs, control the flow of surface waters, alter watercourses, and make regulations regarding the use of water in rivers and lakes (subject to approval of the Lt. Governor-in-Council). It also allows the Conservation Authority to regulate changes in watercourses, construction in flood-prone areas, and the dumping of fill into water.

Since the Hamilton Harbour Commissioners Act of 1912, jurisdiction over Cootes Paradise has been transferred to the Royal Botanical Gardens. The jurisdiction of the Hamilton-Wentworth Region Conservation Authority has been found by courts not to <u>extend</u> into Hamilton Harbour for purposes of regulating or prohibiting the dumping of fill. Infilling is a major issue relating partly to water quality, but more significantly to alterations in habitat within the Harbour and Cootes Paradise.

II.5 Socio-Economic Conditions

The text of this section is based on the RAP-related reports that appear in the references for Schaefer et al., (1991) and Robinson et al., (1991).

II.5.1 Population and Demographics

II.5.1.1 Hamilton-Wentworth

The population of Hamilton-Wentworth (H-W Economics Report #49, 89-2) is expected to increase by 12.5% from 1989, to about 483,000 by 2006, based on recent forecasts prepared by the Region's planning department. The rate of growth within the Region is expected to remain below the provincial average, which will likely continue to slow down over the 1988 to 2006 period. This is consistent with historical growth patterns from 1956 to 1988, and reflects the particular age structure and migration patterns which characterize the Region. The data below (Table 3) shows population growth to 2011 for the two Regions, under the "most likely" scenario, which assumes that moderate fertility and migration patterns prevail.

TABLE 3: Population Trends

	Population Profile - Hamilton Harbour							
	1921	1931	1956	1976	1981	1986	2001	2011
H-W	124,715	190,019	312,924	409,490	411,445	423,398	476,560	507,830
Halton	25,540	26,588	71,611	228,495	253,885	271,389	350,070	398,100

Overall, migration into Hamilton-Wentworth is expected to remain positive, stimulated by the higher real estate prices in Toronto and sustained by the future availability of development infrastructure locally. International migration is expected to account for almost 60% of future population growth in the Region.

The number of households is projected to increase from 161,100 in 1986, to about 193,500 by 2006. About 87% of this household growth is expected to occur in the periphery of the city of Hamilton.

II.5.1.2 Halton (Burlington)

The regional Municipality of Halton (IBI Group #41, #49, 1989) has experienced steady growth both in absolute terms, and in terms of its size as a percent of total Greater Toronto Area population. It increased from 5.6% of the GTA total in 1961, to 7.5% in 1986. Population growth in Halton is expected to exceed that for Hamilton and for the province as a whole, according to projections by the Ontario Ministry of Treasury and Economics

(MTE). This aggressive outlook reflects the Region's strategic location near Toronto, strong transport links, relatively low cost land, and other environmental amenities.

For Burlington, the only Halton area municipality located in the Hamilton Harbour watershed, population growth has historically exceeded that for the Region, averaging 2.9% annually over the period from 1967-86. Future growth in the Halton Region is expected to focus on urban Milton however, and Burlington's growth is expected to average only 1.5% per year from 1987 to 2011. From 1986, population is expected to increase by 51,300 to reach 168,000 by 2011. As a percent of Halton's total population, Burlington will therefore account for roughly 39% in 2011, compared to 43% in 1986. For residents living around the Harbour, population growth will add even more pressure to develop suitable public access to the waterfront.

II.5.2 Age Structure

Another widely recognized demographic feature, the aging population phenomenon, applies particularly to Hamilton and Burlington. The Hamilton Census Metropolitan area, which includes both areas, was identified in the 1986 census as having the third oldest average population of the 33 Canadian cities listed (33.4 years). This "aging" phenomenon obviously comes as the result of fewer new babies and more seniors living longer.

II.5.3 Regional Growth Patterns

One widespread transition experienced in the Hamilton Harbour area, as in many communities throughout North America, is a substantial increase in peripheral development and suburban sprawl. Since 1931, in Halton Region alone, 45% of the total farmland has been replaced by urban development (Troyak, 1990). While there are substantive advantages in terms of individual land and property ownership, there are, from a more holistic or sustainable perspective, a number of limitations. As with many North American communities, the spilling of development outside of the urban framework has resulted in: lost open space; reductions in agricultural land; an increased reliance on the automobile, yielding increased traffic congestion, air pollution and ultimately, water pollution; increased flooding activity during heavy rainfall; and costly infrastructure expansion.

II.5.3.1 Implications for Harbour Remediation

An increase in population in the Hamilton Harbour AOC has at least two implications for remediation. First, there will be increased stress on existing sewage treatment plants, most of which are near capacity. From a socio-economic perspective, this highlights the enormous potential for water demand management (water conservation, pricing mechanisms, leak detection, pressure reductions, etc.) in the Hamilton-Wentworth area to reduce the quantity of water being used and thereby extending the life of treatment plants and potentially reducing the loadings of certain contaminants in sewage plant effluent.

Secondly, as the population around the Harbour continues to grow, there will undoubtedly be an increase in the demand for water-based recreational activity. This warrants a closer look at the anticipated growth of the various existing and potential uses in the Harbour to facilitate in the allocation of waterfront land. This point will become increasingly important as waterfront land becomes available in an already intensely used waterfront on the main Harbour (Figure 5).

The aging phenomenon may be more significant in the context of RAP plans for waterfront recreational use. For planning future remedial options, it suggests relatively more demand for passive uses like trail-walking and bird-watching, and less demand for strenuous watersports and other active uses. This implies that passive multi-use greenspace might be given higher priority among competing foreshore uses.

Given the comprehensive nature of remedial action planning, as outlined in the Great Lakes Water Quality Agreement, there is some merit in investigating the implications of changing development patterns for improving water quality in the Hamilton Harbour AOC. A decentralized development pattern, from an environmental perspective, can be quite unsustainable (Greenbelt Alliance). To alleviate many of the problems of decentralization and to make more efficient use of existing land, more attention can be directed at strengthening metropolitan districts, largely through more diverse housing (for all ages and income groups), improved public transportation (increased number of links with employment hubs, etc.), and strengthened commerce. In short, there is a greater need to integrate the various 'people activities' (i.e. working, shopping, entertainment, etc.). These suggestions provide little help for immediate water-related problems in the AOC, but can go a long way to facilitating the maintenance of restored beneficial uses, in the long term.

II.5.4 Employment and Industry Outlook

On a combined basis, employment growth within the Greater Hamilton Census Metropolitan Area (CMA) has been strong between 1980 and 1988, with the total labour force increasing by 20.5% from 268,000 to 323,000. Meanwhile, unemployment rates have fallen annually in the post-recession period after a peak of over 11.0% in 1982 to 6.1% in 1988. The expanding labour force and a declining unemployment rate suggests that job creation in the CMA has been sufficient to absorb the annual increase in those employed or looking for work. For 1989, unemployment in the area averaged 5.9%, but is expected to rise during 1990 and 1991 (Coke CEIC pers. comm., 1990).

Underlying this recent employment growth is a fundamental shift in the nature of local employment, away from manufacturing and towards the service sector. Changes in industry employment from 1981 to 1986 are indicated in Table 4. In 1986, business services overtook manufacturing as the single largest industry sector; it now accounts for 37% of total employment, up from 33% in 1981. Also, the aging population is expected to create substantial new job opportunities in the service sector, ranging from tourism services to nursing-home care. Meanwhile, manufacturing employment in the area declined by approximately 12.0% from 1981 levels. From 1981 to 1986, average employment income for males increased from $18,337 to $32,737 ($24,430 in constant 1981 dollars), and for females, it increased from $8,316 to $19,697 ($14,699 in constant 1981 dollars).

One scenario, based on international changes in the quantity and types of steel sought, a strengthening of the European community, and the resultant changing of production techniques, suggests that the quantity of waterfront land required by the two main steel producers may be reduced. (Currently, the two steel producers and allied infrastructure occupy approximately 32% of the main Harbour.) Current trends within the steel industry towards continuous casting and mini-mills indicate more concentrated production lines and reduced use of land in the steel-making process. Already there is restructuring taking place, with continuous casting having made the intermediate operations like the ingot floor virtually obsolete. With the onset of direct reduction technologies by the end of the first Quarter of the next century, there may no longer be a need for coke ovens or the coke byproducts areas.

TABLE 4: Labour Force Employment by Industrial Sector

Industry Sector	1981	1986	% Change 1981-1986
Primary	3,905	4,595	17.7
Manufacturing	69,945	61,575	-12.0
Construction	12,715	13,288	3.8
Transportation*	10,955	11,325	3.4
Trade	32,900	37,610	14.3
FIRE*	8,875	10,375	16.9
Government	7,725	7,635	-1.2
Other Services	59,000	68,580	16.2
Total	206,020	214,895	4.3

* Transportation includes communications and utilities; FIRE refers to Finance, Insurance and Real Estate.

II.5.4.1 Implications for Harbour Remediation

The steady growth in business services since 1971 is a trend that will likely continue into the future. To some extent it depends on whether the local mix of labour skills continues to meet the demands of new high-paid business service occupations. But more importantly perhaps, it depends on regional policy-makers' ability to ensure a healthy working environment for attracting more skilled labour into the area. This means providing affordable office space with suitable access, but also implies a willingness to control pollution and to create additional recreation amenities. In this way, the region can promote a well diversified labour force which will minimize the risk of depending too much on one economic sector.

With respect to the large 'footprint' of the industrial uses of the waterfront land, it seems difficult to foresee how public access could be realized in the face of proven safety and security concerns. However, access is such an important public issue that consideration should be given to establishing a community committee to explore the practical potential for providing access through existing industrial or Harbour Commissioners properties.

II.5.5 Summary

This section is not exhaustive in its description of socio-economic conditions in the Hamilton Harbour AOC. It has, however, discussed the importance of including social and economic information in the remedial action planning process, and has provided some illustrations of its relevance in facilitating the selection of remedial options to ensure the maintenance of restored beneficial uses. Some of these observations are summarized below.

Increases in population levels will continue to put stress on existing water supply and wastewater infrastructure, and exacerbate the pressure for improved access to the Harbour. Specifically, demographic trends point towards an aging population base for the future, with more leisure time on their hands. This suggests a relatively strong future demand for passive recreational uses like trail walking and bird watching and improved employment opportunities in the tourism, recreational and other service sector industries.

The Area of Concern's economic structure is becoming increasingly diverse. With the adoption of new technologies, more automation and increased international competitiveness, the area's main manufacturers may become less labour and land intensive. Steel making may no longer be the engine of growth for Hamilton. Employment in business services has recently overtaken manufacturing as the single largest employment sector and will continue to grow. Skilled service sector occupations have grown substantially in the recent past and this trend is expected to continue into the foreseeable future, with the growth of small business.

Successfully adapting the local economy to this structural change will depend on regional policy-makers ability to create a healthy working and living environment and the creation of new and improved recreation amenities to attract more skilled labour into the area.

Perhaps the most pressing issue is increased public access to the Harbour. A potentially smaller industrial footprint on the Bayfront lands, will offer greater opportunity for greenspace and other uses along the waterfront.

Finally, there is a real need to examine water demand management and effluent charges as a cost effective approach for improving water quality and for extending the sewage carrying capacity of the Harbour.

II.6 Water, Sediment, and Biota Guidelines and Objectives
II.6.1 Introduction

The principal tools used by regulatory agencies in enforcement for environmental or human health concerns are water quality objectives, water and sediment quality standards, or water quality guidelines. These are numerical "targets" set on a substance-by-substance basis, and set with regard to the best information available at the time of their establishment. These standards change from time to time, as new information comes forward. They usually have built into them safety factors of 100 to 1,000, especially for contaminants that could potentially affect human health.

Whether for human health concerns or for concerns about living organisms in the natural environment, it is possible that these standards are necessary, but not sufficient, conditions. In each individual site situation it is therefore necessary to assess the biological system that we are attempting to protect - to assure that the system is receiving the benefit of our remedial action. This should be reflected in the monitoring program design and in assessing structural and functional changes in the biological systems of the Harbour (Stokes and Piekarz, 1987).

II.6.2 Provincial Water Quality Objectives

The Provincial Water Quality Objectives pertinent to the present and future uses of Hamilton Harbour are a set of narrative and numerical criteria designed for the protection of aquatic life and recreation in and on the water (MOE, 1978). They define a desirable level of water quality that the Ministry strives to maintain in surface waters of the Province. The Objectives for raw water supplies for drinking water are generally not as restrictive as the Objectives for the protection of aquatic life.

The Objectives for recreational water uses are based on public health and aesthetic considerations. The Objectives for aquatic life are set at such values as to protect all forms of aquatic life and all aspects of the aquatic life cycles. The clear intention is to protect all life stages during indefinite exposure to the water. When insufficient information exists to develop an Objective, a Guideline is provided with the understanding that site-specific information would be necessary to manage the water body with respect to the chemical in question. Phosphorus is an example were the Province has supplied only a Guideline.

Table 5 lists the Provincial Water Quality Objectives for those chemicals which currently or in the past have caused concern in Hamilton Harbour. If a chemical is not listed in Table 5, its Objective has routinely been met in the Harbour.

II.6.3 Canadian Water Quality Guidelines

The Task Force of Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers published Canadian Water Quality Guidelines (CCREM, 1987). The federal Guidelines listed in Table 5 are specific for the protection of freshwater aquatic life. Guidelines for some of the chemicals vary with water hardness, temperature or pH. The values reported in Table 5 are adjusted for the hardness and pH conditions within Hamilton Harbour.

II.6.4 Great Lakes Water Quality Agreement Objectives

The Canada-United States Great Lakes Water Quality Agreement (GLWQA) also has water quality objectives (Canada-United States, 1978) (Table 5). The Objective for phosphorus is to minimize eutrophication problems and to prevent degradation with regard to phosphorus in the boundary waters of the Great Lakes System. The goals of phosphorus control are specified in Annex 3 of the Great Lakes Water Quality Agreement of 1978. The goal most appropriate to Hamilton Harbour is the elimination of algal nuisance growths wherever they occur. Hamilton Harbour is defined as a part of the Boundary waters designated in the Agreement.

TABLE 5: Water Quality Objectives pertinent to Hamilton Harbour. All units in μg/L unless specified otherwise.

Parameter	Objectives		
	Provincial	Federal	GLWQA
Aluminum	-	0.1 mg/L	-
Ammonia (Nitrogen)	20[1]	0.4-2 mg/L[2]	20[1]
Arsenic	100	50	50
Cadmium	0.2	1.3	0.2
Chlorine	2	2	2.0*
Chromium	100	20 (fish) 2 (plankton)	50
Copper	5	3	5
Cyanide	5	5	5*
Diss. Oxygen	4-5 mg/L	5-6 mg/L	6 mg/L
Iron	300	300	300
Lead	25	4	25
Mercury	0.2	0.1	0.2
Nickel	25	110	25

Continued next page.....

Parameter	Objectives		
	Provincial	Federal	GLWQA
Phosphorus	20(3)	20(3)	20(3)
Zinc	30	30	30
Phenol	1	2	-
DDT	3 ng/L	1 ng/L	3 ng/L
PCBs	.001	1 ng/L	0.1 μg/g fish
Mirex	.001	-	<DL(4)
Total Diss. Solids	-	500 mg/L(5)	200 mg/L
Turbidity	10% Secchi increase	10 mg/L susp. solids increase	10% Secchi increase
Clarity	1.2 m Secchi	1.2 m Secchi	-
Faecal Coliforms	100/100 ml	200/100 ml	-
Total Coliforms	1000/100 ml	-	-

Petrochemicals: Oil and grease should not be present in concentrations that a) can be detected as a visible film, sheen, or discolouration on the surface; b) can be detected by odour; c) can cause tainting of edible aquatic organisms; or d) can form deposits on shorelines and bottom sediments that are detectable by sight or odour, or are deleterious to resident aquatic organisms.

Temperature: Water discharge should not alter the natural thermal regime of the receiving water body.

PAHs: There is insufficient information to establish specific numerical guidelines.

(1) Un-ionized ammonia
(2) Total ammonia (temperature and pH dependent)
(3) General guideline; specific objectives are set for each site.
(4) Below detection limit
(5) Drinking water Objective

*Addition of substance proposed but not in Agreement and not approved by Commission.

II.6.5 Water Quality, Habitat and Use Objectives for Cootes Paradise

In response to requests from the Ontario Ministry of the Environment, the Royal Botanical Gardens established water quality (Table 6), habitat and use Objectives for Cootes Paradise in 1975. The intent of the Objectives was to ensure that plant and animal life were not depressed or killed by chemical substances or suspended solids from upstream areas. The objectives were intended to be realistic levels of chemical and physical parameters that will ensure the survival of fish, bottom fauna, insects and plant life in all parts of Cootes Paradise.

Habitat Goals: The open water area of Cootes Paradise is currently 250 hectares (1975). It is anticipated that approximately 50% or 190 hectares will be suitable for macrophyte restoration and manipulation with the goal of producing a high quality habitat complex for waterfowl and other marsh-dependent wildlife. The Royal Botanical Gardens (RBG, 1975) has stipulated the following objectives:

Objectives:

1. Foremost, to maintain this water and marsh habitat with contiguous lands as a wildlife sanctuary by protecting the integrity of habitats for a rich variety of flora and fauna through a firm stand on all activities which interfere with diverse ecological interactions and militate against such a preservation policy.

2. To provide limited public access and interpretative facilities for public education and quiet appreciation only to an extent consistent with #1.

3. To continue to provide reasonably natural aquatic and terrestrial habitats for studies in environmental science by students at all levels.

TABLE 6: Water Quality Objectives for Cootes Paradise

Parameter	Maximum
Chlorophyll (May-October)	50 μg/L
Ammonia (un-ionized)	20 μg/L
Turbidity (Jackson Units)	25 JU
BOD (effluent quality)	<5 mg/L
Dissolved Oxygen	>4 mg/L
Chlorine	<0.11 mg/L

Source: L. Simser, RBG.

Use Goals: The objective is to ensure that Cootes Paradise becomes a suitable aquatic habitat for the following natural biological components, for aquatic biological studies and for specific limited aspects of public recreation.

The aquatic habitat of Cootes Paradise must be made suitable for the needs of a full range of resident organisms common to similar habitats in southern Ontario. These include birds, animals, amphibians, invertebrates and plants. Advanced pollution reduces diversity: the goal here is to achieve diversity in these components through water quality improvement.

Cootes Paradise, with other major natural aquatic areas, plays an important role in successful bird migration, (particularly waterfowl) in both spring and autumn. Water quality influences the production of food and cover for migrating waterfowl.

Both native and introduced lake fish enter Cootes Paradise and its tributaries to spawn. Water quality must be conducive to their survival and the survival of the fry which are hatched here and journey back to Lake Ontario. Water quality must be such that Cootes Paradise can play its part in the regeneration of fish to serve the resurgence of fishing in Lake Ontario.

Present high coliform counts in the inflows of Chedoke Creek and upper Desjardins Canal prevent any use of these areas for aquatic studies beyond those of researchers trained to work in polluted waters. Water quality must be such that school classes and the public on interpretive excursions will not contract skin diseases or infections from handling specimens or dipping into the water. Many unique research opportunities exist with McMaster University which is within walking distance of Cootes Paradise.

While it is not suggested that the waters of Cootes Paradise meet the standards of total immersion sports, coliform counts must be drastically lowered before encouraging quiet boating without health hazard.

II.6.6 Provincial Open-Water Disposal Guidelines

The Ministry of Environment has Guidelines for the open-water disposal of sediment dredged for navigation purposes (MOE, 1987c) (Table 7). If contaminants in the sediments exceed the Guidelines then the sediment must be either disposed of on land or in a confined disposal facility (CDF). These are cells to hold sediment, and are surrounded by berms and capped with clean material. The Hamilton Harbour Commissioners manage such a facility on the east shore of the Harbour, south of the shipping canal. It is used for sediments dredged for navigational purposes. The Ministry of Environment is drafting new Open Water Disposal Guidelines which will include numerical criteria for contaminants, based on biological effects. These new guidelines are not official yet but are being applied in practice. The United States Environmental Protection Agency also has guidelines for the classification of contaminated sediments. The EPA "heavily polluted" criteria are included in Table 7 for comparison.

II.6.7 Fish Consumption Guidelines

The Ontario Ministries of the Environment, Natural Resources and Labour cooperate in a monitoring program called the Sport Fish Testing Program. Annually the "Guide to Eating Ontario Sport Fish" is published providing advice on recommended levels of consumption of

TABLE 7: Existing Guidelines for disposal of dredged sediment. All units in μg/g unless otherwise specified.

	MOE Open-Water	EPA Heavily Polluted	Lowest Effect Level*
Organic Content	6%	>8%	1%
Sediment Oxygen Demand	50 mg/g	>80 mg/g	
Ammonia (NH_3)	100	>200	
Total Kjeldahl Nitrogen	2 mg/g	>2 mg/g	550
Total Phosphorus	1 mg/g	>0.65 mg/g	600
Iron	10 mg/g	>25 mg/g	2%
Copper	25	>50	16
Chromium	25	>75	26
Nickel	25	>50	16
Zinc	100	>200	120
Lead	50	>60	31
Cadmium	1	>6	0.6
Mercury	0.3	>1	0.2
Cobalt	50	-	
Arsenic	8	>8	6
Ether Ext.	1.5 mg/g	>2 mg/g	
PCBs	0.05	>10	0.07

* Draft Provincial Sediment Quality Guidelines

Source: MOE, 1987c.

game or sport fish from over 1,400 of Ontario's lakes, rivers, and locations on the Great Lakes (MOE, 1988a). The substances included in the monitoring program are mercury, copper, nickel, zinc, cadmium, manganese, chromium, arsenic, selenium, lead, PCBs, DDT, Mirex, Dioxin, HCB (hexachlorobenzene), Lindane, Heptachlor, Aldrin, Chlordane, and Toxaphene.

The consumption guidelines are based on the Canadian Government Health Protection Guidelines. The guidelines reflect the maximum recommended consumption of fish according to the contaminant content and the duration of the consumption (one, two, three weeks and long-term).

II.6.8 Wildlife Consumption Guidelines

Although there is good evidence that wildlife have elevated contaminant levels in their flesh, there are no national standards or consumption advisories to protect wildlife and consumers of wildlife (refer to Section III.4.8.4 for data on wildlife).

II.7 Human Health Aspects

Those aspects of human health most directly linked with water quality include bacterial contamination by human pathogens of waters used for swimming, the quality of drinking water, and the contaminant content of fish flesh and waterbird flesh as it pertains to human consumption.

Indirect aspects relate to the impact of remedial measures themselves. Concerns here include air pollution (or additional energy requirements) from the remedial action itself. It can also stem from efficacy of contaminant containment (like a confined disposal facility or landfill) or for any residue from the treatment processes. Some treatment chemicals such as chlorine are also hazardous to transport, store and use. Chlorine is now used to disinfect sewage effluents discharged into the Harbour. It could also be used to disinfect storm water that affects potential beach sites. Consideration of human health aspects should properly include the full range of interactions in so far as these can be assessed.

II.7.1 Beach Contamination

The details of existing knowledge on contamination of bathing waters by human pathogens are described in Section III.4.1.1. In essence, the Harbour has been declared 'off limits' for swimming by the Medical Officer of Health since the 1940s although recent data suggest that this ban might be reconsidered for certain areas if some minor, local clean-up were carried out.

Beaches on the Lake Ontario side of the sand bar separating the Harbour from the Lake are monitored regularly by the respective Medical Officers of Health during the swimming season. Occasionally, the beaches have to be closed due to high faecal coliform (indicator) counts. This usually happens after a rainfall or during intensive use by the public. There is no indication that Harbour water causes these lake beach closings. The beach closings appear to be due to very local drainage conditions or heavy use.

Public Health officials have deferred any decision on opening beaches in the Harbour until more definite data on bacteriological and general water quality have been collected and assessed.

II.7.2 Water Quality at Water Supply Intakes

Both Hamilton-Wentworth and Burlington areas draw their drinking water supplies from Lake Ontario. These intakes are 1 to 1.5 km from the shore of Lake Ontario at a distance of 4 to 5 km from the location of the discharge from the Harbour through the Burlington Ship Canal. Water circulation along the shores in this area is some what weaker than areas in the central part of Lake Ontario and is variable in direction along the shore. Both intakes are occasionally subject to the influence of dilute Harbour discharge in the Lake, nearby industrial outfalls, river inflows or sewage treatment plant effluents along the shores of the Lake in either direction.

We depend on processes which dilute these discharges to reduce their impact on the quality of water at intakes.

Hence, the intake water is regularly tested and treated before distribution to homes and industries. There is monitoring by the regional municipalities to ensure that treatment is adequate. In addition, the Province carries out analyses for about 160 chemical constituents, 12 times per year on raw water (before treatment), treated water and at two distribution sites in the water supply system (the Drinking Water Surveillance Program). This program began in April 1986.

Based on these programs, the Hamilton-Wentworth and Burlington water supplies have been determined to be of "good (bacteriological) quality", "the inorganic and physical parameters were below any applicable Drinking Water Objectives", and "of approximately 110 organic parameters tested for on a monthly basis, none exceeded health related guidelines". (see, for example, the 1987 report: Hamilton Water Treatment Plant - Drinking Water Surveillance Program).

II.7.3 Contaminants in Game Bird Flesh

Since hunting is not permitted in the Harbour area, the exposure of local residents to contaminants in bird flesh is potentially eliminated. However, since some migrating birds spend time in the Harbour, we have to consider whether contaminants absorbed by birds, while in this area represent a risk to hunters elsewhere. The worst case for consideration of what migrant birds could take from the area would be equivalent to what is found in resident waterfowl, such as the Mallard duck. These have been tested at one seriously contaminated site in Windermere Basin (now under remediation). The data are reported in Section III.4.8.4 of this report and indicate high levels of PCBs.

Currently, there is no Canadian or Ontario guidelines for human consumption of wild birds. However, the high level of PCBs in resident duck flesh in relation to guidelines in other jurisdictions gives cause for concern.

II.7.4 Contaminants in Fish Flesh

There are advisories in effect for consumption of fish found in Hamilton Harbour. The Guide to Eating Ontario Sport Fish (1990) outlines the precautions that should be taken in selecting and preparing sport fish meals and is available to all fishermen free of charge. The details are given in Section III.4.7.3 of this report. In general, the larger the fish, the higher the concentration of contaminants in the fish flesh. For example, a 110 cm long chinook salmon has a PCB concentration three times greater than one that is only 55 cm long.

In general there has been improvement in the contaminant levels in fish over the past 10 years, but it is still necessary to advise taking precautions.

It is not adequate, however, as a long-term goal to depend on fish advisories to protect public health, and more detailed information is required on the degree of fish consumption by anglers. Such surveys could assess the number of people catching and consuming fish taken from the Harbour, the quantity, fish age and species being consumed, and the methods of preparation of the fish for consumption - all combined with complementary laboratory analysis of fish tissue as prepared for eating.

II.7.5 General Health Concerns and their Relation to Water Quality in the Harbour

Health concerns of citizens centre primarily around persistent toxic chemicals and secondarily around the exposure to undesirable conditions for swimming. To the exposures noted above through fish, wildlife, drinking water and swimming, one would also have to consider atmospheric pollution, and home and workplace exposures, including ingestion of foods or drugs (or of soil, in the case of small children), and through inhalation or through direct skin contact with toxic chemicals.

The potential adverse human health effects of the contaminants found in places around the Great Lakes, in general, are fully summarized in a recent report on toxic chemicals (Environment Canada et al., 1991). The two significant findings in relation to human health are:

(i) "The limited number of published studies available indicates the rates of cancer incidences and mortality and adverse reproductive outcomes in the Great Lakes basin are no higher than would be expected in any highly industrialized area of the country. Some epidemiological studies do show an association between maternal consumption of contaminated fish and adverse effects in developing children. Clearly some sub-populations (nursing infants and heavy consumers of contaminated fish and wildlife) in the Great Lakes basin and elsewhere in Canada have higher exposure to contaminants and are at greater risk. Others such as the elderly, the fetus or those who are already ill are also at greater risk because they may be more sensitive to the effects of pollutants. These sub-populations have not yet been adequately studied."

(ii) "The limited human tissue residue data available indicate that the general population residing in the Great Lakes basin is probably not exposed to higher levels of the most persistent pollutants than people residing elsewhere in North America. However, individuals consuming large amounts of contaminated fish and wildlife, especially native peoples and sportsmen, have greater exposure to several persistent pollutants. Elevated levels of contaminants in the Great Lakes basin (and elsewhere) do pose a threat to health but the precise nature and extent of the threat is unclear. Residents of the basin consuming large quantities of contaminated fish and wildlife should be aware of these concerns and reduce their intake of sport fish and wildlife in accordance with current advisories."

In the current situation where toxic chemicals are used or produced widely in society, and where persistent chemicals now are found throughout the environment including the fatty tissue of humans, we have a dual task of:

(a) avoiding the worst possible current exposures, and

(b) eliminating as far as possible the discharge of chemicals to the environment to improve the situation for the future, as well as recovering or inactivating the chemicals that have already been emitted, wherever that is possible.

To understand what one can do about environmental exposures it is useful to consider the fact that generally, in the population as a whole, the exposure to chlorinated organic chemicals through drinking water is considered to be less than 1% of the total, 80-90% through food, and 5-10% from air (Environment Canada et al., 1991). The significance of the food chain as represented by fish and aquatic birds is clear. And particular populations within the general population may be more at risk than others if they use fish and wild bird meat in their diets.

The fact that drinking water is far less risky than other exposure routes does not mean that measures to reduce water pollution are less necessary. These chemicals move throughout the environment, and are being found in water, air, rain and soil. They also bioaccumulate through the food chain because they are fat-soluble materials. This means that all possible sources have to be considered including air emissions (i.e. not just discharges to the water) if the aquatic environment is to be restored.

II.7.6 Public Concerns about Pollution and Health

Public concerns about their personal health in relation to pollution find expression in recent polls. Air pollution and water pollution are considered by over 85% of Canadians polled around Lake Ontario as being serious enough to regulate with strong laws even if the environment risks are not clearly identified and demonstrated (Decima Research, 1989 for Pollution Probe). Eighty-nine percent of Canadians also believe that 'zero discharge' of persistent toxic chemicals should be achieved within 10 years, if possible.

Researchers and regulators, speaking through the International Joint Commission (1989), and through the report of the Institute for Research on Public Policy and the Conservation Foundation (1990) have stated that there are threats to health, that the extent of that threat is unknown, and that, in spite of our lack of specific knowledge about these effects, further efforts must be made immediately to virtually eliminate the discharge of harmful substances to the air, water and land.

The ultimate goal is 'zero discharge' as expressed in the Great Lakes Water Quality Agreement, and in the deliberations of the Hamilton Harbour RAP Stakeholders who have ranked zero discharge as one of their first principles.

II.7.7 Current Programs

Health officials at both the local, provincial and national level are engaged in efforts to address human health concerns. The health agencies of Hamilton-Wentworth Region (representing the largest number of people in the watershed) have collaborated in compiling a useful summary of health and related socio-economic/demographic data (Poland et al., 1988). Local problems are being addressed by the Medical Officers of Health.

Health and Welfare Canada have recently (1990) inaugurated an enhanced health program for the Great Lakes Region that includes, among other things,

(a) an epidemiological study of fish eaters (a group of people that may have ingested a higher amount of trace contaminants than the average population).

(b) assessment of cancer and congenital anomalies found in the region.

(c) assessment of co-associations between pollution and environmental health indicators.

(d) assessment of strategies to use research on reproductive impairment.

(e) toxicology of polychlorinated biphenyl (PCB) congeners.

(f) assessment of the impact of hexachlorobenzene, mercury and lead in follicular fluid, on the development of young children.

(g) expansion, initiation or development of data collection programs to aid in developing an adequate level of information on how extensively the population or specific sub-populations are exposed to toxic chemicals.

For this program, some residents of the Hamilton Harbour region will be part of the groups that are studied. Some Hamilton residents have already been included in initial surveys for study (f), for example.

II.7.8 Summary

The potential exposure for humans to harmful chemicals and pathogens that are associated with the aquatic ecosystem of the Harbour are detailed in the appropriate sections of this report dealing with human pathogen indicators (faecal coliforms), and contaminants in water, fish flesh and bird flesh. Monitoring and advisory programs are designed to assist the public in avoiding the associated risks in the current situation.

The impact of the aquatic-related exposures in relation to other health risks is less well understood. While efforts have been undertaken to put this concern into context of all societal efforts to alleviate risk of illness, injury, reduction of vitality or early death, the general direction of policy has been to reduce the level of contamination in the environment to the greatest degree practicable.

III DESCRIPTION OF ENVIRONMENTAL CONDITIONS IN HAMILTON HARBOUR

III.1 Physical Processes

III.1.1 Harbour Circulation

The Harbour is very dynamic, and a weak thermocline develops in the Harbour during the summer. Currents within the Harbour are influenced by wind, friction, the intrusions of Lake water described below, density differences (due to temperature differences or the dissolved salt and suspended sediment content of the water), the morphology of the Harbour, oscillations due to Lake Ontario water level oscillations, and the earth's rotation. The currents have been found to vary in speed and direction, with surface currents predominantly affected by wind. Under the ice, currents are generally weaker due to the drag of the ice and reduced wind drag.

The net result of the dynamic nature of the Harbour and the summer stratification is that there are substantial horizontal and vertical gradients in water quality. Hence, subtle changes in water quality are inherently difficult to detect (MOE, 1985). A high degree of small-scale variability or patchiness in the thermal, chemical and biological properties of the Harbour has been observed.

The exchange of water through the Burlington Ship Canal comprises the largest component in the water balance of the Harbour and has a major effect on water quality in the Harbour. The flow through the Canal is driven by differences in water levels between the Lake and Harbour, and by differences in density (due to temperature differences) between the Lake and Harbour. Wind-driven surface drift currents may also be important at times. All of these forcing mechanisms exhibit fluctuations on a wide range of time scales, from minutes to weeks or longer. As a result, the flow in the Canal is itself highly unsteady with frequent flow reversals. As well as being unsteady, the velocity varies both with depth and lateral distance in any given cross-section particularly under conditions of thermal stratification during summer. The temporal and spatial variability make accurate gauging of discharge in the Canal difficult. As a result, some uncertainty surrounds the basic water budget for the Harbour.

Several investigators have estimated the residence time for water in the Harbour (Kohli, 1984; MOE, 1985; Klapwijk and Snodgrass, 1985). While the results are quite variable, the general pattern is indicative. That is: if only watershed runoff is considered to be flushing the Harbour, the residence time would be about 500 days; if runoff plus the STP inputs are considered, the residence time is between 300 and 350 days; but when the Ship Canal exchange is also taken into account, the residence time drops to about 90 days. Hence the Lake-Harbour exchange is crucial to water quality in the Harbour. The monthly pattern of flows given by Klapwijk and Snodgrass (1985) have a distinct peak from July to October, while Kholi's (1984) flow pattern data show a peak in early summer. Clearly it is difficult to estimate the Harbour-Lake exchange, but the process is significant.

The flushing time is the most significant physical parameter when it is long compared to the time taken for materials to mix to uniformity within the Harbour itself, as is the case for this Harbour (see below).

"Short circuiting" of a contaminant would occur if the sources of the contaminant were close to the Ship Canal; contaminants would pass to the Lake with a minimum dilution by Harbour water under specific, favourable, flow conditions. Horizontal mixing time scales for the Harbour have not been measured directly, but they can, in principle, be inferred from current measurements (study in progress). A very crude estimate of horizontal diffusion for Hamilton Harbour based on an analysis of large scale diffusion in Lake Erie (Boyce and Hamblin, 1975) is 1.5×10^5 cm^2/s with an associated mixing time scale of wind-driven surface waters of five days. Over long time scales, the short circuiting effect may not have a big influence on the Harbour overall, but will affect the quality of water leaving the Harbour. Numerical modelling would be helpful in ranking these scenarios. If the flows are short-circuited from their point of inflow to the Harbour outlet without completely mixing with the main body of the Harbour, the flows will have less impact on concentrations within the Harbour. A second factor in net exchange between the Harbour and Lake Ontario involves the oscillation of flows within the Burlington Ship Canal. Under some circumstances, flow from the Hamilton and Burlington STPs could follow a path along the eastern shoreline directly to the Harbour outlet without first extensively mixing with the main body of the Harbour (Figure 7) (Barica, 1989). Obviously, this would be beneficial for the Harbour, but would result in the higher concentrations of the STP effluent in the outflow plume from the Harbour to Lake Ontario. The second short-circuiting mechanism involves the oscillation of the Lake-Harbour exchange, as exhibited by the frequent flow reversals in the Burlington Ship Canal. The measurement and explanation of the periodicities associated with these oscillations has been a subject of several studies (MOE, 1974, 1977a; Freeman et al., 1974; Palmer and Poulton, 1976). An example of the highly dynamic nature of the flow in winter in the Burlington Ship Canal and its effects on the Harbour is shown in Figure 8 which depicts a sequence of water level fluctuations at the western end of Lake Ontario known as seiches (the top panel). These seiches are particularly pronounced on February 9 and are seen to drive vigorous inflows and outflows plotted in the second panel. These inflow events (plotted as negative flow) are sufficiently strong to transport low conductivity water from the Lake to the Harbour. This is evident in the two conductivity curves of the lower panels of the figure which were taken at the entrance to the Harbour. Figure 8 demonstrates that flows only occur during extreme events. Further measurements employing an advanced acoustical current meter revealed for the first time that the summer exchange flow in the Ship Canal is as dynamic as the winter case presented in this figure (Hamblin et al., 1989; Hamblin and Lawrence, 1990).

It is clear that Lake water enters the Harbour. Evidence for the presence of intrusions of oxygen-rich lenses of water between the Harbour entrance and the middle of the Harbour, has been noted by several investigators (Figure 10) (Harris et al., 1980a; MOE, 1975, 1977a, 1985; Spigel, 1989). The frequency with which Lake water forms an underflow in

Figure 7: Approximate exchange zone of Hamilton Harbour (shaded) affected by dilution of Lake Ontario water, estimated from ammonia-N. Arrows indicate major nutrient loads.

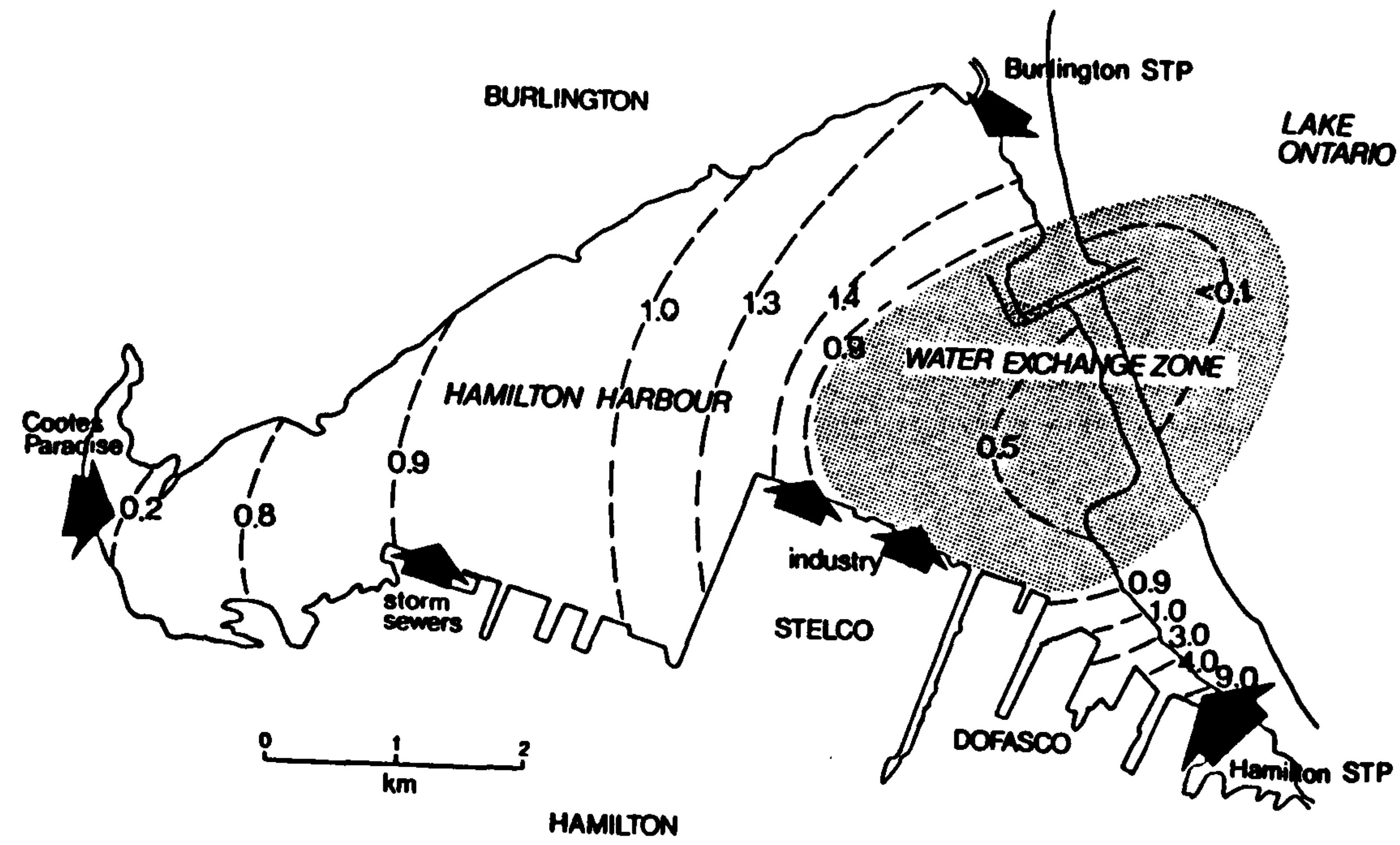
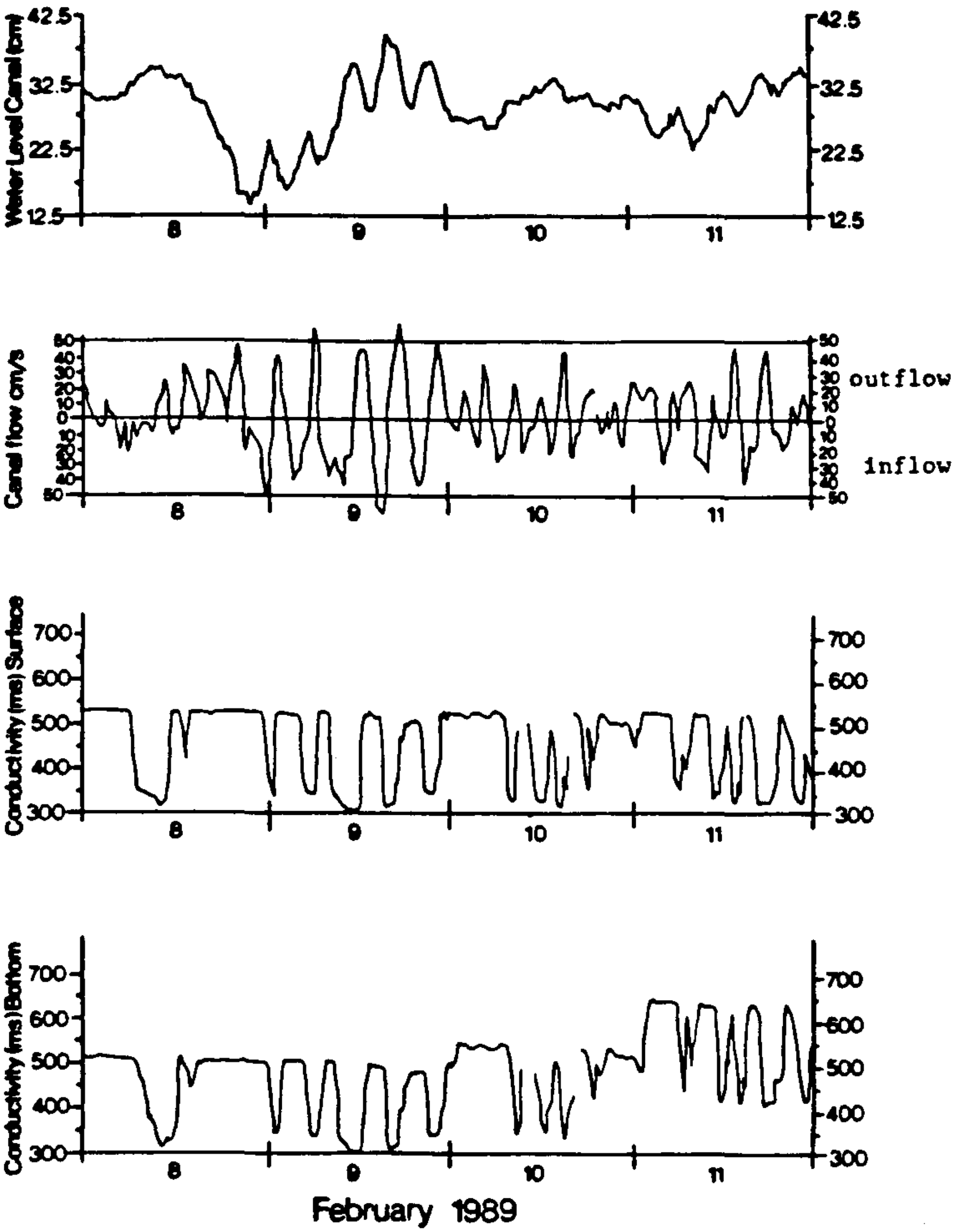


Figure 8: A sequence of water level fluctuations at the western end of Lake Ontario known as seiches and associated conditions in the Burlington Ship Canal.



Source: Hamblin, 1990

the Harbour is of considerable importance for Harbour water quality. No concurrent study of water temperature profiles at either end of the Canal has been made, but data from MOE (1985) for temperatures in the Harbour, and from Dobson (1984) for Lake Ontario, indicates that underflow may be frequent and may occur primarily in the summer. The dominant pattern of Lake-Harbour exchange in summer may thus be one in which water from Lake Ontario enters the hypolimnion of the Harbour, displacing Harbour water upward, with water from the epilimnion of the Harbour comprising the outflow from the Harbour. A particular case is revealed for stations shown in Figure 9 and with data plotted in Figure 10 (from Spigel, 1989) where a cold, low conductivity (lake), high oxygen 'slug' of water from the Lake is found near the bottom just inside the inner end of the Ship Canal.

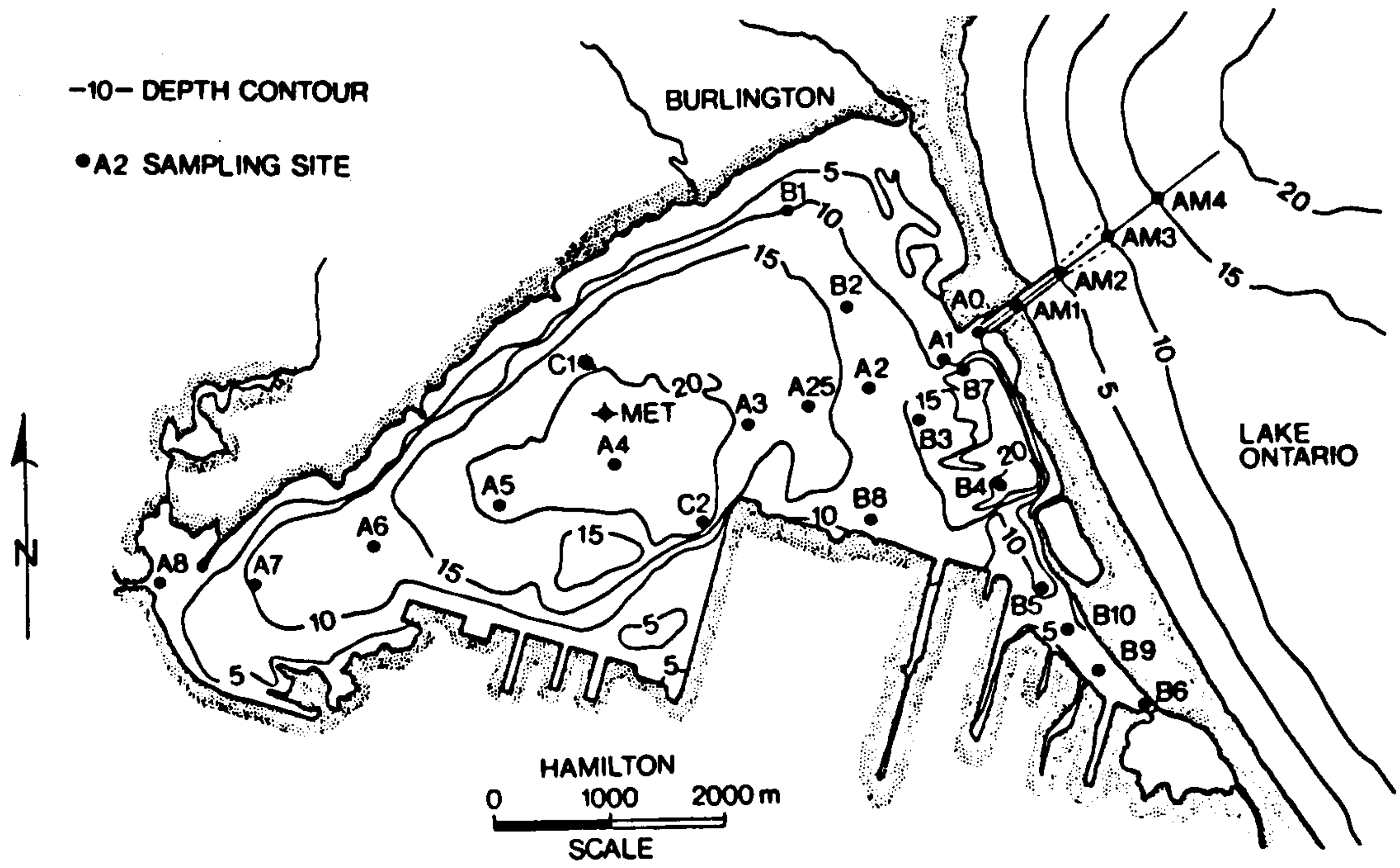
Landfilling around the perimeter of the Harbour can also affect the pattern of Lake-Harbour exchange. The results of Freeman et al., (1974) and Dick and Marsalek (1973) have shown that the duration and magnitude of flows from Lake Ontario to the Harbour depend on the surface area of the Harbour. Decreasing Harbour surface area decreases the total annual volume of inflow from the Lake. Dick and Marsalek state that landfilling from 1926 to 1972 resulted in a decrease in Harbour surface area of approximately 25%. They estimate that, consequently, the total volume of the Lake water entering the Harbour annually decreased by approximately 3.2×10^8 m^3 over that period. Moreover, percentage decreases in surface area and annual inflows were roughly equal, and therefore the 25% decrease in surface area given above resulted in an estimated 24% decrease in inflow volume from 1.35×10^9 m^3/yr to 1.03×10^9 m^3/yr. (This latter figure is roughly equal to the 1.04×10^9 m^3/yr for Lake inflow deduced from Klapwijk and Snodgrass' figures cited earlier). Dick and Marsalek concluded that further percentage decreases in Harbour surface area would result in roughly equal percentage decreases in Lake inflows.

The question arises, then, as to the effect of decreasing Lake inflow on Harbour water quality. The change in residence time is dominated by the change in flow rate. The relative change in volume is very small compared to a decrease in surface area because most of the landfilling was carried out in shallow littoral areas where large losses of surface area resulted in only small losses in volume (Dick and Marsalek, 1973). (A corollary is that there has been no change in volume to the deeper regions of the Harbour due to shoreline infilling.)

Of some interest historically (and perhaps for future developments) is the size and location of the Harbour exit channel. Before the Ship Canal was built, the exit was in the north-east corner of the Harbour, and was quite shallow. It seems unlikely that the intrusion of colder, fully-oxygenated water which occurs now (with the deep, wide Ship Canal) could have been extensive before the 1820s. The change in location of the exit channel probably did not affect matters greatly.

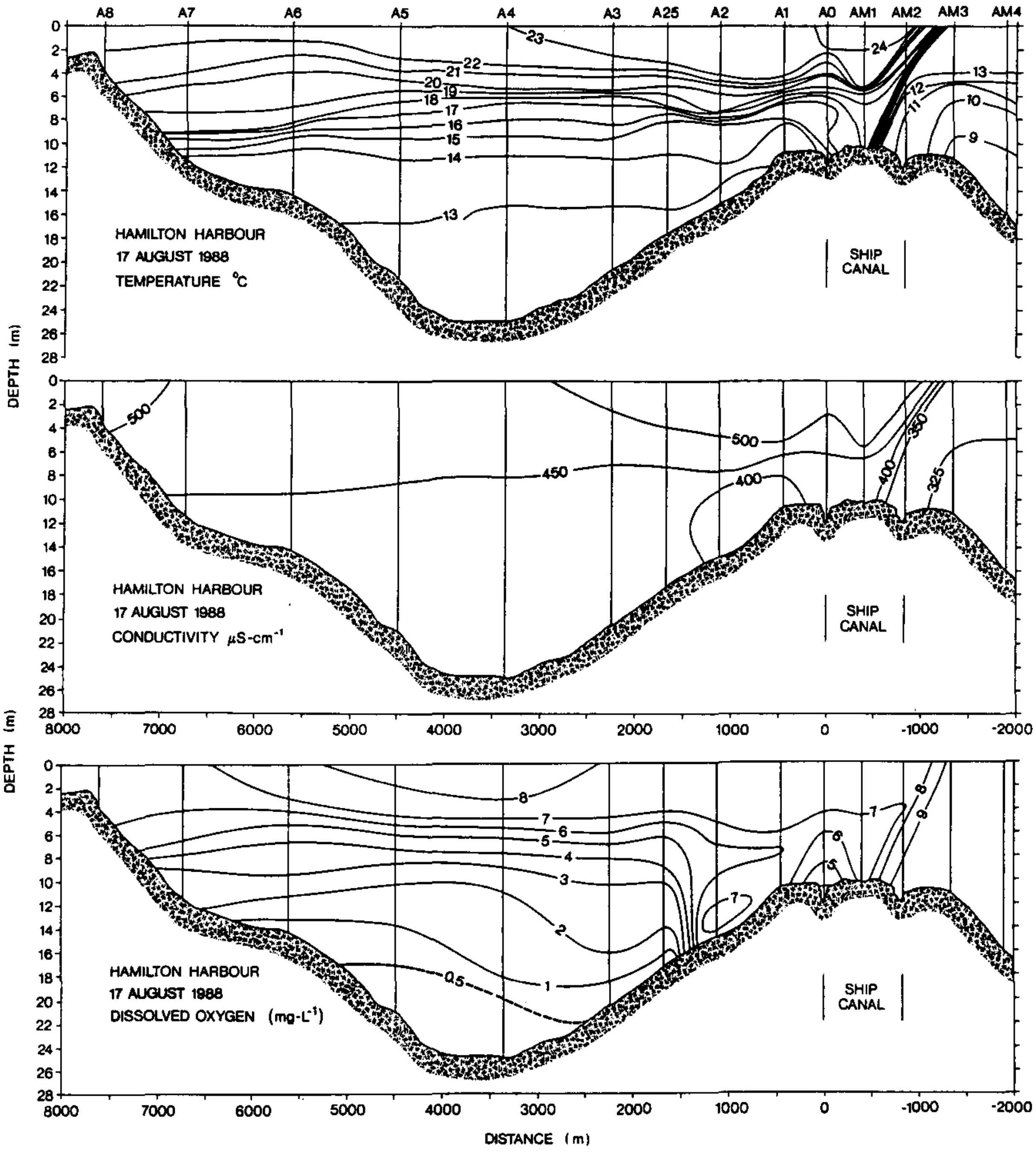
If one considers the residence time of the hypolimnion alone, rather than that of the entire Harbour, it is clear that increases in residence time due to decreases in flushing flows are not

Figure 9: Depth contours and sampling sites for profile measurements.



Source: R.H. Spigel, 1989

Figure 10: Hamilton Harbour temperature, conductivity and dissolved oxygen profiles, August 17, 1988.



Source: Data from R. Spigel, 1989 - NWRI.

offset by decreases in volume. It may be argued that the residence time of the hypolimnion is a more meaningful index for water quality than the residence time of the entire Harbour. Using Dick and Marsalek's estimate for the inflow of 1.03 x 10^9 m^3/yr, assuming that all of this is used to flush the hypolimnion, and taking the volume of the hypolimnion as roughly one half the total Harbour volume, gives a residence time for the hypolimnion of approximately 50 days. The significance of the residence time becomes clear if one compares it with the time for oxygen depletion in the hypolimnion during summer stratification, a time which is about a month or less (MOE, 1985). Decreasing the residence time to less than the oxygen decay time would prevent extremely low oxygen levels assuming complete horizontal mixing in the hypolimnion. Increasing the residence time (or reducing the Lake inflow) would further prolong the period of low oxygen.

A further consequence of infilling shallow littoral areas is to reduce the net heat capture from the atmosphere by the epilimnion in summer. This in turn reduces the temperature (and hence density) differential between Harbour and Lake waters during summer. The net effect is to decrease exchange flows that are driven by density differences alone, as opposed to those driven by water level differences. The temperature stratified flows observed in the Canal by Dick and Marsalek (1973), Kholi (1979), Spigel (1989), and others are probably driven by a combination of density and water level differences.

Circulation and mixing of the Harbour determines the zone of impact of many contaminant sources. Currents are variable, with typical net speeds of 1-2 km/day. Currents in windy periods are strongest along the shores (in the direction of the wind), and tend to stay parallel to shore. Currents are stronger in surface layers than at depth. The flow from Redhill Creek fills the surface layers of Windermere Channel out to the Canal with high conductivity water. Inflow to the hypolimnion from the Ship Canal in summer tends to move north-west and west along the bottom.

III.1.1.1 Other Studies and Work in Progress
III.1.1.1.2 Mathematical Modelling

A numerical model of the winter exchange flow based on winds and water levels has been developed and successfully tested on historical data but awaits final confirmation on more accurate flow data collected by an acoustical travel time flow meter (AFFRA) in the Burlington Ship Canal (Hamblin et al., 1989). A theory has been developed for the steady two-layer summer exchange in the Ship Canal based on the water temperature differences and flow ratios between the two layers and successfully applied to 18 field experiments in summer 1988 (Hamblin, 1989).

A water quality model for the winter ammonia regime of the Harbour has been formulated and employed to demonstrate that the cessation of bacterial activity at low temperature was responsible for the winter build-up of ammonia and during the low temperature period exchange with Lake Ontario was the principal factor controlling ammonia concentrations (Hamblin and Bucens, 1990 unpubl.). A one-dimensional water quality model was used to simulate the annual temperature cycle of the Harbour and to illustrate the relative insensitivity of various industrial waste heat discharge strategies on the thermal regime despite the large quantities of heat involved (Lee et al., 1990). The model showed that this was due to the dominating influence of the exchange with Lake Ontario.

More recently, work has been undertaken to model the hydrodynamics of the Harbour in order to prepare for environmental assessment of habitat reconstruction projects. Flow patterns for various wind directions,'run-up' time scales, and typical plume and spill dispersal characteristics have been developed for an unstratified Harbour on a Harbour-wide scale and on the scale of several Harbour segments likely to be affected by the projects (Tsanis et al., 1992). These models are consistent with much of the data available and are useful tools to make qualitative judgements in all cases and quantitative comparisons in some cases for the options that can affect flow patterns and dispersion within the Harbour.

III.1.1.1.3 Observational Studies

A series of current meter measurements concurrent with suspended sediment concentrations in the deep hole suggested that this area is depositional and seldom undergoes sediment resuspension. A time series of detailed profiles of current and temperature in the western portion of the Harbour revealed the complex nature of the summer flow field (Chiocchio et al., 1990). Additional profiles of current and backscattered acoustical energy have been taken with an advanced acoustical instrument in the Ship Canal both during winter and summer simultaneously with water samples which are being analyzed for contaminant concentrations. As well, current profiles were collected alongside a mooring of conventional current meters in the deep hole during summer.

In summary, it is clear that the interactions of Harbour circulation and mixing with the exchange flows through the Canal are complex. A better understanding of these processes is necessary before operational quantitative predictions of water quality can be made.

III.1.2 Impact of Hamilton Harbour on Western Lake Ontario

At the root of some concerns about Hamilton Harbour is the anticipation of the adverse effects of Hamilton discharges on the long open-lake beaches on the east side of the "beach strip", and its possible effects on the quality of water drawn into the Hamilton and Burlington water supply intakes in Lake Ontario. On a broader scale, concern for the discharge of toxic contaminants to Lake Ontario and its impact on the whole larger system is also being examined as part of the Lake Ontario Toxics Management Program (LOTMP).

Wastes in this region are all discharged to the Harbour. The Harbour acts as an oxidation pond and accumulates some of the sediments (and associated chemicals) discharged into it. Chemicals that stay dissolved in the water column are diluted to varying degrees in the Harbour, but eventually find their way out into Lake Ontario.

The question then arises, what impact does this partially-diluted, partially-treated material have on the nearby uses made of Lake Ontario?

The net drift of water masses along the shore of the Lake measured over periods greater than 1 or 2 weeks is to the south-southeast due to large, slow but irregular counter-clockwise circulation patterns in Lake Ontario. Water currents just offshore in western Lake Ontario are highly variable and relatively weak. Current speeds vary from 0-12.8 cm/sec with currents less than 5 cm/sec (about 4.5 km/day) observed for 58% of the time. Currents are faster in winter. Periods of "stagnation" ranged from 0.5 to 12 days with most being less than 5 days. Periods of stagnation in other coastal areas of the Great Lakes are usually less than a day. This difference is due to the fact that Hamilton Harbour is located in the extreme, and narrow elliptical, western end of Lake Ontario. Since Lake circulation is generally counter-clockwise, the flow approaching the western end of the Lake must slow down before turning south and then east along the southern shore.

The extent of travel of water from Hamilton Harbour through the Burlington Ship Canal, has been estimated to be 0.5-1.5 km due to momentum of water leaving the Canal (MOE, 1985). The concentrations of pollutants are diluted 9 times on the average at a distance of 1,250 m from the Canal. The Burlington and Hamilton water intakes are about 5 km from the Canal, north-east and south respectively so dilution at these distances are even greater (100s).

The annual average suspended sediment loading to Lake Ontario from Hamilton Harbour was estimated to be 9,800 kg/day based on 1983/84 studies, compared with 15,900 kg/day in 1979 (MOE, 1986a). This apparent reduction is qualitative only, and is being verified and updated through the development of a sediment mass balance model. The suspended solids load could vary considerably from year to year.

Concentrations of all metals in surface sediments in the nearshore zone of western Lake Ontario increased with depth and the higher values were generally found at stations where the mean sediment particle size was less than about 50 μm. Metal concentrations measured in the uppermost 1 cm of cores from a depth of 100 m in the Niagara Basin zone were 3-20 times more than in the nearshore zone. These distributions appear to suggest that metallic discharges from Hamilton Harbour may not have a significant impact on the sediment quality in the area immediately adjacent to the Burlington Ship Canal. This is consistent with studies which indicate that most trace metals are exported from the Harbour in association with fine particles which would have a short residence time in the nearshore zone (MOE, 1986a).

Results of sequential extraction analysis on sediments collected in 1982/83 (to identify the geochemical forms of metals) suggest that metals are less bioavailable outside the Harbour than inside (MOE, 1986a). However, a 1983 study comparing sediments from outside the Harbour to those from Windermere Basin showed this difference to be relatively slight (MOE, 1987a).

PAH analysis on sediment samples from outside the Harbour showed that the PAH concentrations depended upon the distribution of fine-grained sediment particles in a fashion similar to total metals. Based on the pattern of PAH concentrations in the sediments, there appears to be a second source of PAHs to the east of the Burlington water intake (MOE, 1987a).

Analysis of material collected in sediment traps within the Harbour during 1987, and future measurements of the quality and quantity of suspended material entering and leaving the Harbour will clarify the effects of the Harbour on Lake Ontario.

The Hamilton and Burlington water intakes were sampled regularly from May 20 to September 1, 1982 and the water chemistry was compared to offshore water and Harbour plume water chemistry. Burlington water intakes had consistently higher copper concentrations than either the offshore or Harbour plume water suggesting a local source of copper. Ammonia concentrations were elevated in 6 of 23 samples from the Hamilton water intake and 4 of 21 samples from the Burlington intake. It appears that only 1 day of this elevated ammonia concentration was caused by Hamilton Harbour (MOE, 1986a). The other days can be explained by local loadings, storm events and resuspension phenomena. The occasional elevations of trace metal concentrations also appear to have been from sources other than Hamilton Harbour. Therefore of the 21 or 23 days studied, only on 1 day was the Hamilton water intake apparently influenced by the plume from Hamilton Harbour. The dilution of the plume by a factor of at least 9 with Lake Ontario water within 1 to 1.5 km and the fact that Hamilton Harbour water itself has not exceeded the Provincial Water Quality Objectives for the last five years would suggest that the possible impact of the Harbour plume on the two water intakes is not a concern at this time. The Provincial Drinking Water Quality Program has monitored both intakes for several years and there is no clear evidence of any impact on water quality by Hamilton Harbour (MOE, 1988b, c).

Bacteria sampling in the Confederation Beach area confirms the drinking water intake observations. Elevated bacteria counts are a result of local sources and not a result of the Hamilton Harbour plume. Runoff from creeks during and after rainfall events seems to be the most probable source of bacterial contamination. Since the faecal coliform counts in Hamilton Harbour are now much reduced, the Harbour outflow plume is probably not responsible for beach closures adjacent to the Canal in Lake Ontario.

III.1.3 Water Levels and Their Regulation

Water level changes in Hamilton Harbour and Cootes Paradise for time scales of the order of a week or more are determined largely by the level of Lake Ontario. (Shorter term variations are addressed in Section III.1.1.) Consequently, conditions affecting the seasonal changes in water level (high in June/July and low in December) and the longer term year-to-year shifts are found in available water supply, such as rain and snow melt, and changing water level regulations.

Water levels require examination in several contexts: the modelling of water quality conditions in the Harbour on a seasonal basis as affected by the hydraulic consequences of water level change; the annual and long-term effects of water level on conditions for marsh development on shallow areas such as Cootes Paradise and the Grindstone Creek estuary; the use of the shoreline for docks, beaches, parks, etc.; shore erosion; and the biological significance of the characteristics of the shore in the aquatic ecosystem.

While Lake Ontario water levels are, and have been regulated to a great degree, even the capability that exists today to control these levels does not ensure full control. This arises because the major factors affecting the supply of water to the Lake are precipitation, evaporation and runoff - none of which are controlled or accurately predictable over the long term (Environment Canada et al., 1990).

On behalf of Canada and the United States, the International Joint Commission issues 'orders of Approval' for the construction and operation of facilities that affect the natural level or flow of the boundary waters that constitute Lake Ontario. The Commission also reviews these Orders and the regulation plans used to control the operation of these facilities.

These usually incorporate hydro power generation components, and navigational aids (canals, locks). A major consideration is the protection of shore property where erosion threatens as a result of high levels, or shore facilities such as marinas that are less effective as a result of low levels.

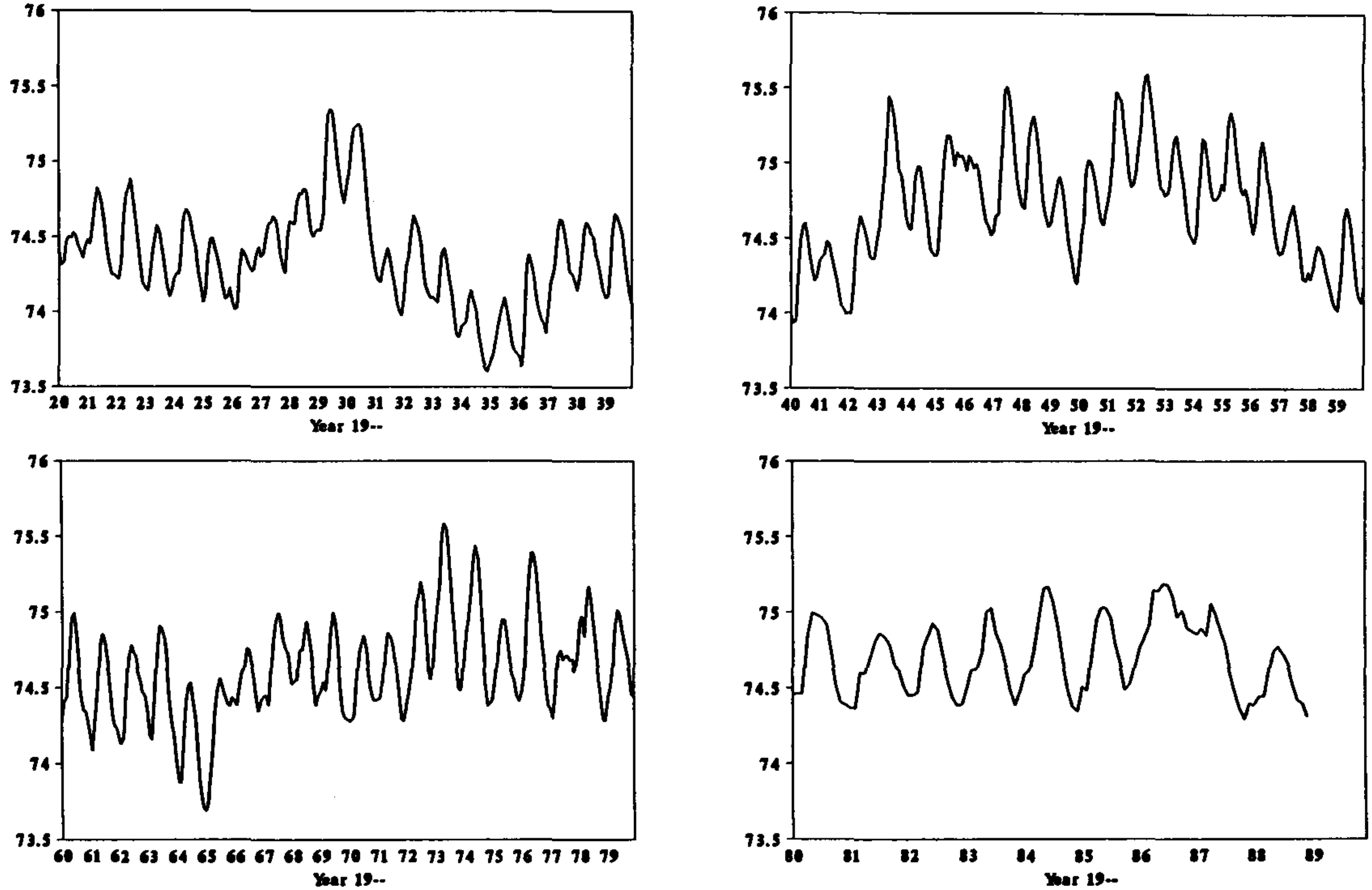
The current Lake Ontario water level regime came about in 1960 with the completion of the St. Lawrence Seaway and Power Project. The primary condition is that the Lake should be regulated within a target range of 74.0 to 75.2 m above sea level. There are emergency regulations to protect riparian owners under high water supply situations and to protect navigation and power interests in low water supply situations. The outflow is adjusted weekly.

The net effect of these regulation plans is to reduce the peak elevations and raise water levels during periods when a low water supply would normally generate lower levels. The actual water levels over the past few decades is shown in Figure 11. These illustrate the variety of annual cycles and the periods of persistently high or low levels under the variety of different control regimes that have existed during this period.

III.2 Water Quality
III.2.1 Eutrophication

The concentrations of ammonia and nitrate in the Harbour affect fish and exceed the requirements for a reasonable level of algae growth. Ammonia concentrations are a function of loadings versus biological processes and flushing losses to Lake Ontario. The important

Figure 11: Lake Ontario Water Levels (elevation above sea level in metres).



Source: Environment Canada, Cornwall.

biological processes are algal uptake and bacterial nitrification (the conversion of ammonia to nitrate), and both depend on temperature. Therefore, ammonia concentrations are high in the spring due to accumulated loadings during the winter, and the lack of nitrification and algal uptake. In the spring of 1985, ammonia concentrations in the centre of the Harbour were approximately 2,000 μg/L (as nitrogen). The concentration decreased with the onset of warmer temperatures to average values of 300-400 μg/L during summer. Average nitrate concentrations during the early 1980s were 1,700 μg/L. Nitrate concentrations begin the season at the average concentration and then increase through spring and early summer due to the nitrification of ammonia to nitrate. Concentrations decrease through summer and fall, presumably due to algal uptake, reduced nitrification and enhanced denitrification.

More recent data appear to reflect the major reduction in ammonia loadings that have been achieved at the Woodward Avenue STP in the south east corner of the Harbour (Section IV.4.1.1). In Figure 12 the spring near-bottom ammonia values following the enhanced ammonia control in the winter of 1990-91, reflect the change in loading. Mid-summer values are typical of previous years but no violation of the ammonia objective is evidenced now. (Charlton et al., 1992).

However, these same authors note also that ammonia concentrations in sediment pore water is 2 to 8 times the provincial objective for surface water quality and may be a cause of toxicity for bottom fauna. These high levels in sediment are thought to be caused by undecomposed organic matter discharged from sewage treatment plants.

Total phosphorus concentrations in 1985 declined from a May high of 87 μg/L to an October low of 37 μg/L. The seasonal average concentration was 64 μg/L. Most values in 1991 were in the range of 40-50 μg/L which is somewhat lower, but 3 or more times the levels recommended to eliminate nuisance growth of algae. Filtered reactive phosphorus, which is generally believed to be a readily available form of phosphorus to algae, had a seasonal average concentration of 24 μg/L.

The summer chlorophyll a concentration (a measure of algal abundance) in the surface waters of the Harbour was 27 μg/L in 1985. The seasonal average for all stations at all depths was 13.5 μg/L. In 1989 typical surface values were 12 μg/L. In 1990 and 1991 usual surface values were between 4 and 10 μg/L but there were exceptions in heavy late-season blue-green algae blooms (26 μg/L). The case for further phosphorus loading reductions is clear.

The Janus-Vollenweider model relating phosphorus loading and basin retention times to the annual average chlorophyll concentration suggests that the chlorophyll concentration in the Harbour is similar to other lakes around the world, provided the total phosphorus concentration remains below 70 μg/L (Janus and Vollenweider, 1981). There has been little relation between seasonal average chlorophyll and the seasonal average phosphorus concentration during the past decade. Chlorophyll concentrations have averaged between 13-18 μg/L while total phosphorus concentrations have averaged between 40-100 μg/L (Figure 13). The soluble reactive phosphorus half-saturation constant for modelling algal growth in

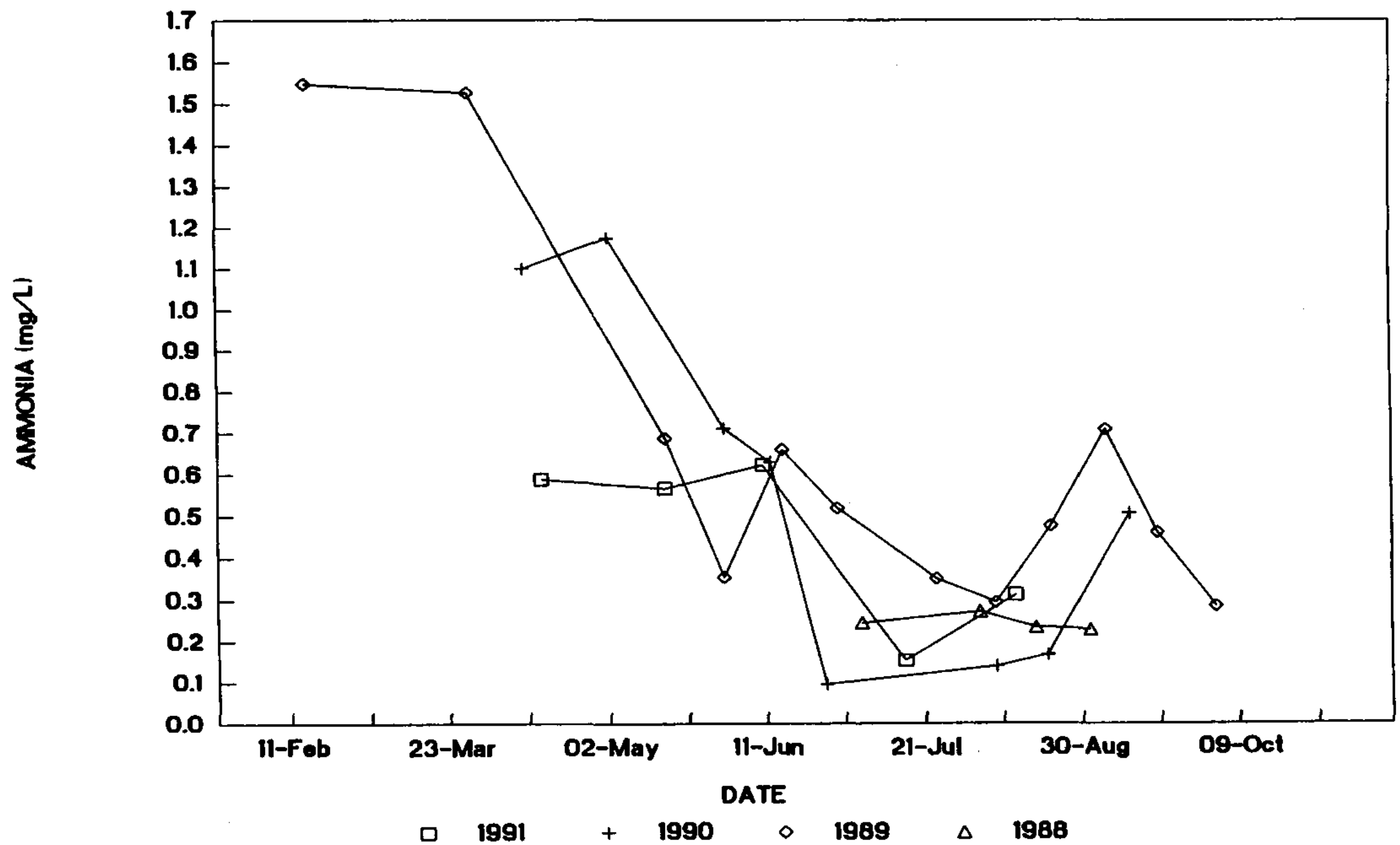
Hamilton Harbour is 10 μg/L (Ng, 1981). From 1984 to 1986, soluble reactive phosphorus (SRP) averaged 13 μg/L but during 1987, SRP averaged only 2.5 μg/L in the surface waters at the centre of the Harbour. According to the model, the recent low phosphorus concentrations would be one of the factors limiting algal growth.

Water clarity, as determined by Secchi disc transparency, was an average of 1.4 m in 1986 (Figure 14). Shoreline Secchi disc transparencies averaged 0.95 m but only the first 100 m from shore had these reduced transparencies. Any location with water depths greater than 2 m had a water clarity similar to offshore water clarity. If water clarity was solely a function of algal biomass, the Secchi disc transparency would be predicted by the OECD empirical model to be between 1.5-2.5 m. Carlson (1977), however, predicted a Secchi disc transparency of only 0.8-1.3 m with the current chlorophyll a concentrations. Harris and coworkers (1979a) examined the relationship between chlorophyll and water clarity as determined by light extinction through the water column and observed a relationship in 4 out of 5 years. However, chlorophyll explained only 11-30% of the variability in light extinction (Harris et al., 1979a; Sephton and Harris, 1984). Other factors such as suspended silt and dissolved substances causing colour are postulated to also be responsible for the reduced Secchi disc transparency. As Figure 14 shows recent water clarity has improved markedly, although still 35% below the target that should be achieved.

An area of particular biological importance is the Grindstone Creek estuary. Aquatic plant abundance in this area is limited by very poor water clarity (Painter et al., 1990). Surveys indicate that poor water clarity in the delta region are due "predominantly (to) the resuspension of silt in the ponds just upstream of the delta, and to a lessor extent (due to) chlorophyll concentrations". The spawning activity of carp is blamed for high turbidity in May-June, since this has occurred during drought conditions. Improvements in silt and chlorophyll conditions could increase plant distribution from 4 to 25 ha.

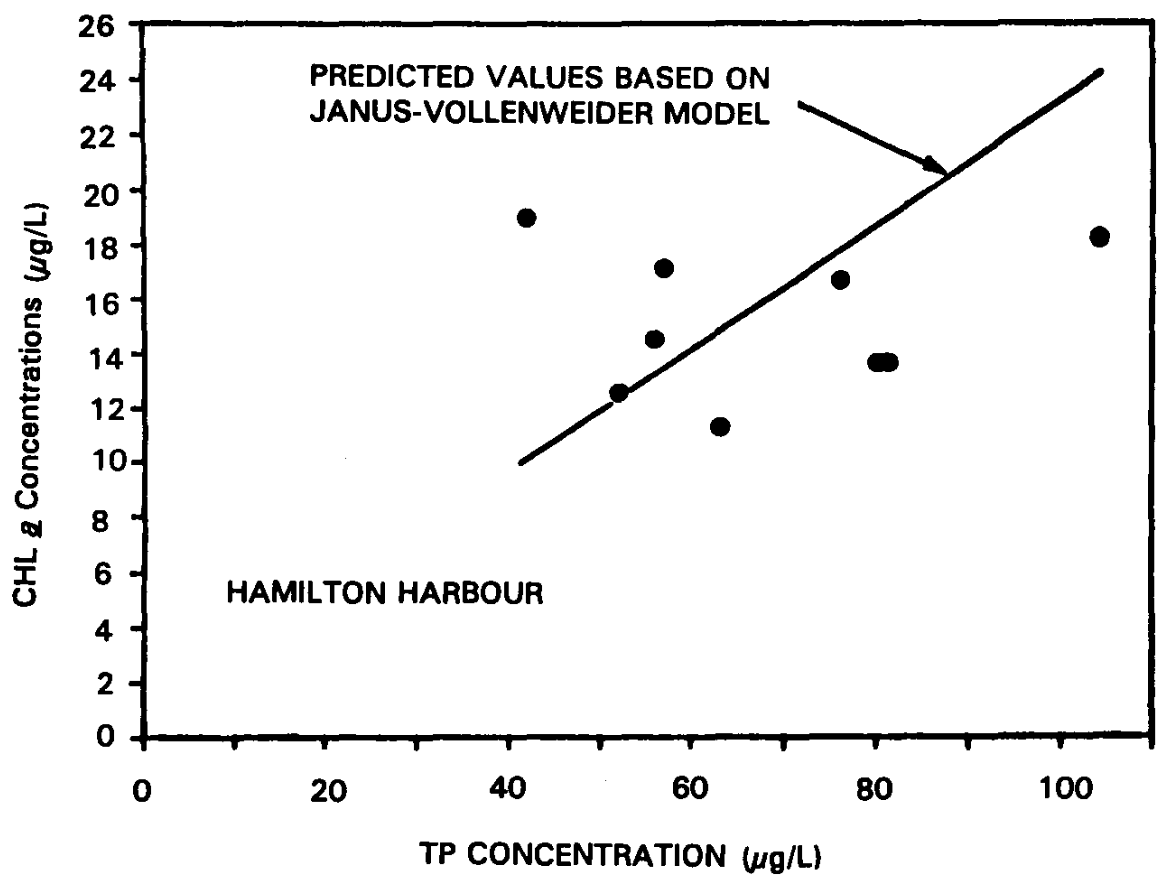
Dissolved oxygen rapidly declines from saturation in early spring to values of 7 mg/L (80% saturation) in the epilimnion and 1-2 mg/L (10-20% saturation) in the hypolimnion during summer. Continuous monitoring of the hypolimnetic oxygen has shown the impact of oxygen-rich Lake Ontario water which flows into the hypolimnion causing the oxygen concentration to oscillate daily between near anoxia to 2 and sometimes 4 mg/L (Figure 15) (MOE, 1975). Oxygen levels remain below saturation in the fall, in both the epilimnion and hypolimnion, due to the breakdown of stratification of the water column and the mixing of poorly-oxygenated hypolimnetic water throughout the water column. The oxygen concentration varies considerably at any date from station to station and year to year. Oxygen isopleths suggest that anoxia may be reached within one-half metre of the Harbour sediments but rarely does the hypolimnion have less than 0.5 mg/L of oxygen. The thermocline, normally located at 6-7 m, has a varying depth due to internal waves and Lake-induced oscillations. Perturbations of several metres have been observed in the depth of the thermocline over short periods of time. Low saturation water can then come within a few metres of the water's surface or move into shallower areas not normally much below saturation.

Figure 12: Ammonia - Concentrations 2 m from bottom - Hamilton Harbour



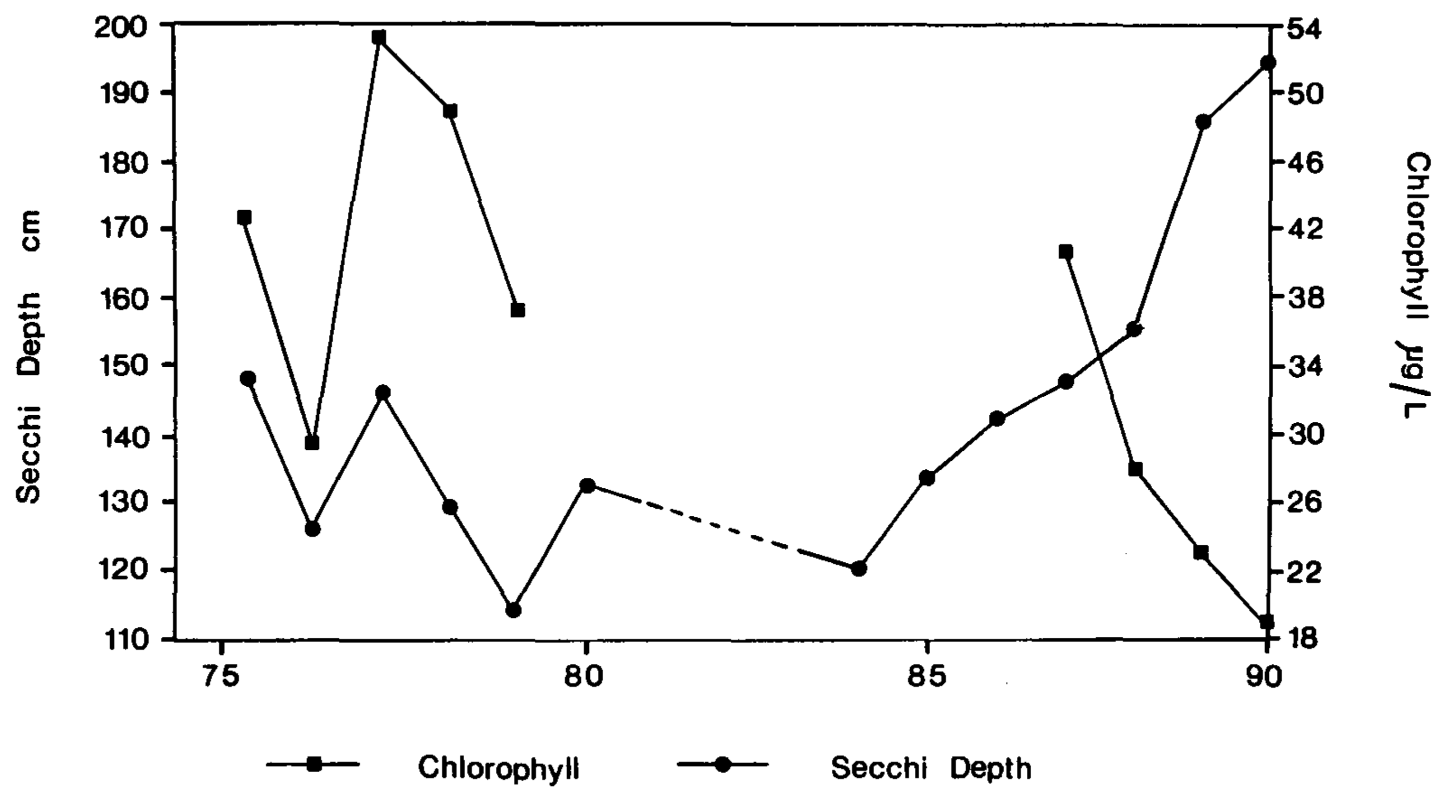
Source: M. Charlton et al., 1992

Figure 13: Total phosphorus concentration vs chlorophyll *a* concentration.



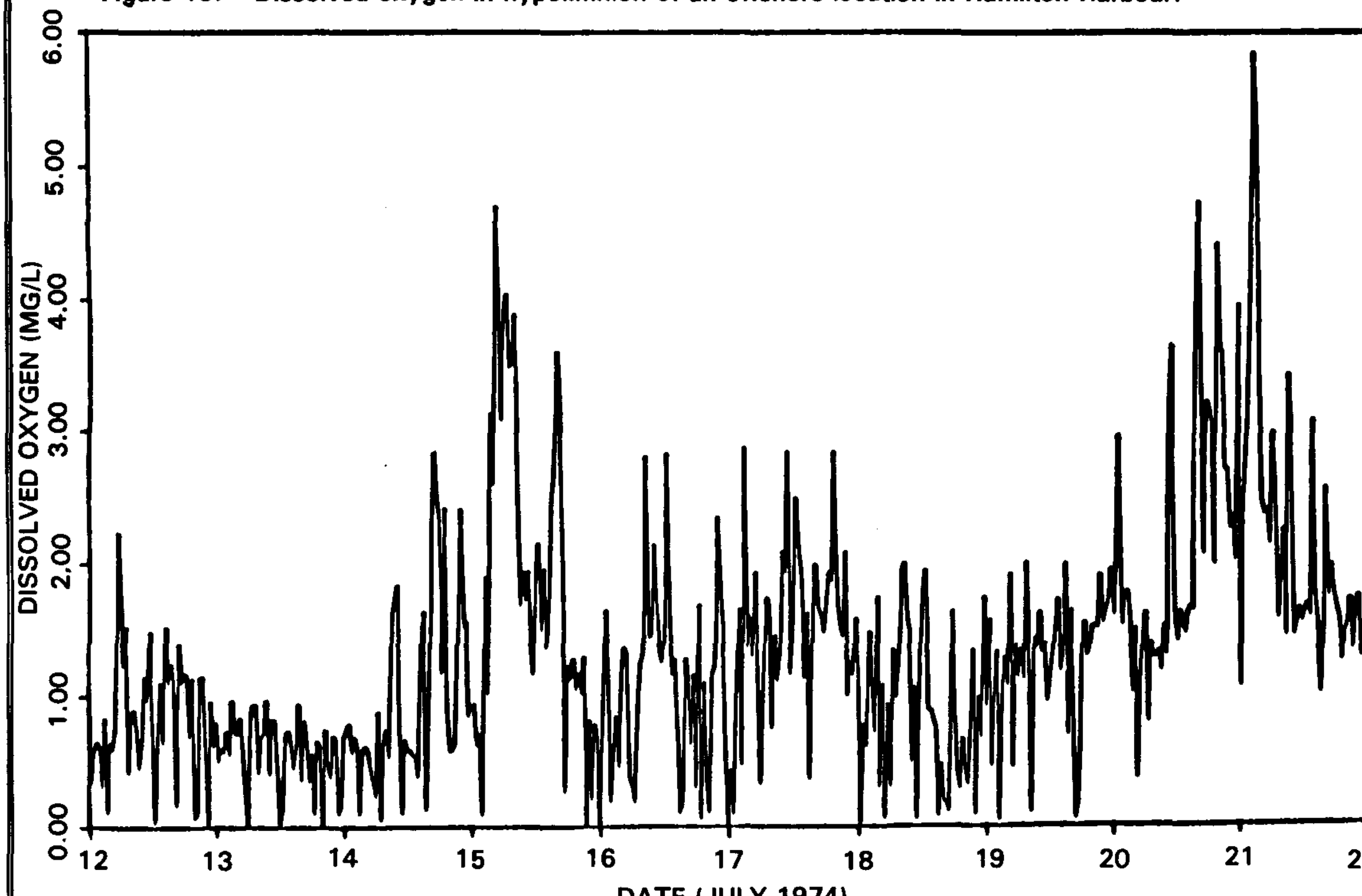
Source: **J. Vogt, MOE**

Figure 14: Hamilton Harbour - Station 258 - Water Clarity



Source: Painter, et al., 1990.

Figure 15: Dissolved oxygen in hypolimnion of an offshore location in Hamilton Harbour.



Source: MOE, 1975

Data for 1990 and 1991 show no significant difference from earlier years (Charlton et al., 1992).

Ng (1981) examined the processes responsible for depleting oxygen in the hypolimnion in summer. He concluded that nitrification of ammonia accounted for 40%, plankton decay for 40%, and sediment oxygen demand for the remainder. Oxygen is added to the water by biological and physical processes such as photosynthesis by algae, reaeration from the atmosphere to the epilimnion, the inflow of oxygenated Lake Ontario water through the Canal, and from tributaries. In the summer, flow from the Lake is usually along the bottom of the Canal, and thence into the hypolimnion, preventing continuous anoxia in July and August.

Cootes Paradise is too shallow to experience tertiary effects of nutrient and silt loadings. The direct impact of silt and algae growth has been substantial. However, although major efforts to reduce suspended solids and phosphorus loadings from the Dundas STP have had other beneficial effects, the water clarity in the main body of Cootes Paradise has not improved since the 1970's (Painter et al., 1991). In these open waters, it appears that water clarity conditions are dominated by silt from Spencer Creek and resuspension of bottom sediments by carp activity.

III.2.2 Trace Contaminants

Levels of waterborne chemicals are much higher in the vicinity of Hamilton and Burlington STPs, and the few remaining effluents from steel industries, than in other areas of the Harbour. These chemicals include metals (iron, cadmium, copper, chromium, lead, nickel and zinc), polychlorinated biphenyls (PCBs) and polynuclear aromatic hydrocarbons (PAHs). There is also contamination by pesticides and PCBs from combined sewer overflows and from tributaries draining urban areas of Hamilton, Dundas, Burlington and Waterdown. From 1962 to 1985, the industrial loadings of conventional pollutants to the Harbour have been reduced 60-95%. From 1977 to 1983, the summer concentration of biological oxygen demand (BOD) in the water column decreased from 3.39 to 3.09 mg/L, although these values relate more to phytoplankton densities than to direct discharge of BOD.

III.2.2.1 Metals

The majority of metal loadings are from the steel industries. Consequently, concentrations of metals are most elevated in the mixing zones around the discharges. The average concentrations in the main body of the Harbour meet Water Quality Objectives (Table 8).

Loading reductions from the iron and steel industries, implemented in 1983/84 and continuing today, have translated into decreased concentrations of trace metals as well as decreased frequency of exceedences of the Objectives. The exceedences are generally not large and the high levels of total organic carbon probably mitigate toxicity to most biota through complexation. The concentration of copper has declined to the point that Lake Ontario water flowing into the Harbour has similar concentrations of copper and similar frequencies of exceedences (MOE, 1986a). Except for iron, few exceedences of the Water Quality Objectives for trace metals have been observed since 1985. Iron is occasionally released from the bottom sediments during summer and exceedences of the iron Objective were observed in the hypolimnetic water only.

TABLE 8: Average concentrations of trace metals in Hamilton Harbour water in 1982 and 1984-87 (μg/L). Also shown are the Provincial Water Quality Objectives (PWQO), and the percent of samples that exceeded these Objectives.

Metal	Concentrations		PWQO	% Exceedences		
	1982	1984-87		1982	1984-87	1986-87
Copper	7.6	3	5	69	11	<1
Nickel	7.2	4	25	4	1	<1
Zinc	23.3	17	30	30	6	2.7
Cadmium	<0.2	ND	0.2	19	9	0
Lead	4.8	ND	25	1	0	0
Iron	248.3	191	300	33	15	9
Manganese	56.2	82	N/A	-	-	-
Mercury	0.07	N/A	0.2	2	-	-
Arsenic	<1.0	N/A	100	0	-	-

ND: Not detected.
N/A: Data not available.

III.2.2.2 Organics

Oil and grease are the largest volume organic materials discharged to the Harbour. MOE (1987d) reported the industrial loadings to be 4,634 kg/day in 1986. Oil and grease are released in relatively low concentrations but in high volume effluents. Sometimes an oil sheen appears on the water surface in areas close to the discharges, affecting the aesthetic aspects of Harbour use. There has been little toxicological study of the oil and grease discharges. Some can be quite benign - others could be highly toxic.

Phenol discharges from industries have decreased by 96% since 1965 and levels in the Harbour are now below the Objective (1 μg/L). Previously, average levels had been as high as 10-50 μg/L. The current levels of phenols represent no threat to aquatic biota.

PCBs, pesticides and related organochlorine compounds were analyzed from six stations on six occasion in 1982 (Poulton, 1987), and from one to six (usually six) stations on ten occasions between 1987 and 1991 (Fox, 1992). In 1982, benzene hexachlorides (BHCs)(α,ß,τ) and hexachlorobenzene (HCB) were the most frequently found organic contaminants (92, 14, 69, and 25% of samples analyzed respectively). α-BHC was evenly distributed seasonally and spatially in the Harbour in 1982 with a median concentration of 4 ng/L which is similar to the median of 4.1 ng/L in Lake Ontario in 1986 reported by Stevens and Nielson (1989). Between 1987 and 1991, α-BHC ranged from <1 to 8 ng/L with the highest values from at Eastport Bridge. τ-BHC (lindane) is the only BHC isomer with a Provincial Water Quality Objective (10 ng/L). In 1982, the median concentration of τ-BHC was 8 ng/L and 14% of the water samples had a concentration exceeding the Objective. Between 1987 and 1992, τ-BHC ranged from <1 to 236 ng/L with the highest values consistently occurring at the Eastport Bridge site. Elevated levels of τ-BHC at the Woodward Avenue STP and concurrent low levels in Redhill Creek upstream of the STP in 1991 suggested intermittent discharges of τ-BHC and related compounds into the Harbour via the STP. For comparison, τ-BHC in Lake Ontario has been measured at 0.4 ng/L (Fox, 1992), and 1.3 ng/L (Stevens and Nielson, 1989). The Water Quality Objective for PCBs in water is 1 ng/L. In 1982, PCBs were measured with a detection limit of 20 ng/L. Five of thirty-six samples (14%) exceeded this detection limit. Up to 100% may have exceeded the Objective (MOE, 1985).

Between 1987 and 1991 PCBs were measured with a detection limit of 1 ng/L. PCB concentrations range from 6 to 48 ng/L with a mean concentration of 16 ng/L. Endosulfan sulphate , heptachlor epoxide, and oxychlordane were measured only in 1982 and were detected in only 3, 3, and 6% of the samples respectively, and no exceedence of the Objectives occurred. Aldrin, α- and τ-chlordane, dieldrin, methoxychlor, endosulfan I and II, endrin, heptachlor, Mirex, and DDT and its metabolites were not detected.

Significant amounts of PAHs were measured in the Harbour sediments some time ago. However, analytical limitations have prevented the measurement of PAHs in water until recently. In 1990 and 1991, Fox (1992) made numerous measurements of PAHs in the Ship Canal and one site in the Harbour. Observed concentrations ranged from 20 to 200 ng/L. The lower concentrations resulted from dilution with cleaner Lake Ontario water at the Ship Canal.

Although persistent trace organics have a high affinity for particulates in the water column, much of the total mass of organics is found in the dissolved phase because of the relatively low concentration of particulates. In the studies of Fox (1992) reported above, both PCBs and PAHs were measured separately in the dissolved and suspended solids (1.0 μm filter).

The PCBs exhibited a mean of 50% in the dissolved phase, with a range of 30 to 70%. The PAHs exhibited a mean of 59% in the dissolved phase, with a range of 34 to 80%.

III.3 Sediment Quality

III.3.1 General Description

Postglacial sediments in the Harbour are derived from tributaries, municipal and industrial discharges, and sewers. Settlement and urbanization have increased sediment loads, compared with presettlement conditions, by increasing sediment production (e.g. construction and farming activity) and by altering basin hydrology (e.g. channelization, creation of impervious land surfaces).

Existing data (MOE, 1985; Poulton, 1987) suggest that a large zone of similar sediments covers the entire deep-water area of the Harbour except the far east end. Pollutants have been gradually mixed and transported towards the deep central basin. Other distinct zones occur near the Burlington Ship Canal, where the effects of Lake-Harbour exchange are important, and along the north shore, where shallow-water silty sediments with lower pollutant concentrations are found. Shallow locations close to the major outfalls represent individual zones related to the nearby discharges. The west end is distinct due to the influence of Cootes Paradise and Grindstone Creek. Most of the surficial sediments in Hamilton Harbour are grey to black, and rich in silt and clay. Sandy sediments are found long the north shore, near the Ship Canal, and at the entrance to Cootes Paradise.

An overall indication of the degree of spatial contamination by trace metals is given in a comparison with proposed provincial guidelines for assessment of contaminated sediment. 100% of the sediments of the Harbour have trace contaminant concentrations that exceed the lowest effect concentration (Table 9). The percentage of sediment in the Harbour that exceeds severe effect levels is also very high. Under the rules, this calls for a more detailed assessment to establish the specific effects that might be seen in biota (for example) and to designate need for action (if any). ***A Lowest Effect Level*** indicating a level of sediment contamination that can be tolerated by the majority of benthic organisms. ***A Severe Effect Level*** indicating the level at which pronounced disturbances of the sediment-dwelling community can be expected. This is the sediment concentration of a compound that would be detrimental to the majority of benthic species.

Temporal trends in contaminant concentrations in surficial sediments (Table 10) are difficult to assess due to variations in sampling and analytical methodologies. Available data are inconclusive as a means of tracking loading reductions (suspended solids, nutrients, metals) at municipal and industrial discharges.

Chemical analysis of sediment cores taken in 1987 show temporal trends. One parameter, zinc, suffices to show the two general characteristics (Figure 16). For cores taken in the shipping lanes, there is evidence of disturbance of the sediments and no clear trend over the

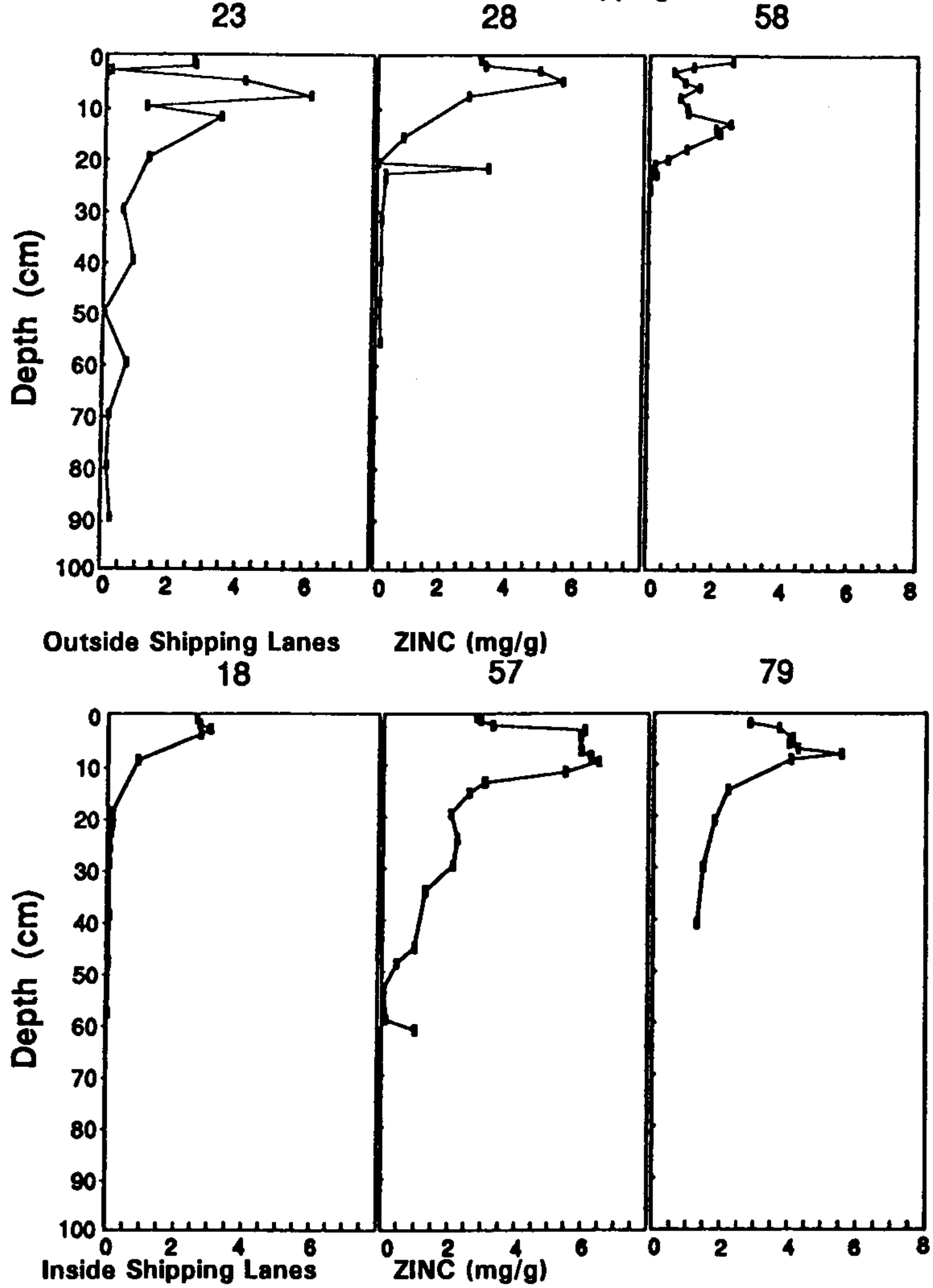
TABLE 9: **Spatial Analysis of Hamilton Harbour surficial sediments (all data, all years) and a comparison with Provincial Sediment Quality Objectives.**

	% > Lowest Effect Concentration	% > Severe Effect Concentration
Arsenic	88	16
Cadmium	100	64
Chromium	99	82
Copper	98	52
Lead	98	55
Mercury	90	Insufficient data
Nickel	85	Insufficient data
Zinc	99	84
Note: Data Summary by S. Painter (personal communication).		
Source: Draft Provincial Sediment Quality Objectives, 1991.		

TABLE 10: **Trace metals in suspended solids and surficial sediments (1980 and 1986). Iron and manganese in mg/g, all others in μg/g.**

	Suspended Particulates		Surficial Sediments	
Metal	1980	1986	1980	1986
Iron	35	53	68	74
Manganese	20	9.6	1.9	2.1
Zinc	1050	1797	2700	2180
Lead	192	307	310	281
Copper	103	105	130	158
Cadmium	-	6.3	5.7	14.1
Nickel	50	52	66	55

Figure 16: Zinc in Hamilton Harbour Sediment Cores from Stations Located Outside and Inside Shipping Lanes.



Source: 1987 Rukavina Cores, Murphy/Brouwer Data.

years. For cores outside the shipping lanes, the concentration of contaminants shows a peaking that corresponds to a time about 20 years age, followed by improvement (reduced zinc concentrations) in the sediment at the surface that are being laid down at the present time.

III.3.2 Sediment Sources

Suspended sediment loads to the Harbour were estimated to average 140,000 kg/day in 1977, diminishing to 66,100 kg/day by 1985 (MOE, 1985) and 50,150 kg/day in 1987. This apparently large decrease will be confirmed during future investigations as part of a regular surveillance program.

The Ministry of Environment (West-Central Region) has carried out a study to determine sources and loadings of suspended sediments and total phosphorus from tributary inputs to Hamilton Harbour. A weekly sampling program was initiated on June 16, 1987 at seven locations on five tributaries: Grindstone, Redhill, Spencer, Borer's and Indian/Rambro Creeks. Sampling was completed in the spring of 1989. Further studies are planned.

The most likely erosional areas and estimated suspended sediment inputs from the various land uses in the basin have recently been determined. These two studies will allow revision of the present estimates of suspended sediment loadings to the Harbour, the contribution of different land uses and the areas which are most prone to instream erosion. Abatement scenarios can then be determined with greater precision.

III.3.3 Eutrophication-Related Conditions

Sediment sampling in the Harbour over the period 1975 to 1982 identified concentrations of nutrients throughout the Harbour which are higher than the disposal guidelines or the newly drafted Provincial Sediment Quality Guidelines (MOE, 1991). Concentrations of total phosphorus (TP) and total Kjeldahl nitrogen (TKN) were consistently above existing MOE guidelines for open water disposal of dredged material. TKN and TP averaged 3.1 and 2.9 mg/g respectively (Table 11). The loss on ignition (LOI) of the surficial sediments from 1975 to 1980 was approximately 10% compared to the MOE guideline for disposal of sediments in the open Lake of 6%.

During the summer and fall, the low dissolved oxygen concentrations in the hypolimnion and the high organic loadings to the sediments result in low redox potentials within the sediment. Manganese release from the sediments to the overlying water occurs frequently during summer and fall and iron release occurs less frequently towards the end of the summer. As a result of the reducing conditions, phosphorus release has been observed in the past. However, since the phosphorus appears to be associated with iron and the reducing conditions are not severe enough to release iron, very often, phosphorus release from the sediments rarely occurs.

III.3.4 Trace Contaminants
III.3.4.1 Persistent Organics

The highest concentration of organic solvent extractables are found in the deep basin (720,000 μg/g) and in the Randle Reef area (730,000 μg/g)(Murphy et al., 1992a).

Sediment samples in the confined disposal facility contain up to 2,000 μg/g of organic solvent extractables (Mudroch and Sandilands, 1980). Elevated levels of PCBs have been observed in the sediments from Windermere Basin due to STP and storm water discharges. Elevated PCB concentrations have also been observed along the north shore, particularly around the LaSalle Park Pier; the source is unknown. The mean concentration of PCBs in the Harbour sediments is 0.2-0.44 μg/g (MOE, 1985,1986a) which is within the range for sediments of other harbours on Lake Ontario (0.01-0.62 μg/g), but well above the levels in sediments offshore (0.058 μg/g). The MOE guidelines for open water disposal of sediments contaminated with PCBs is 0.05 μg PCBs/g. Some samples from the deepest areas and along the industrial shoreline exceeded 0.5 μg/g (MOE, 1986a). In one study, the highest value (1.27 μg/g) occurred near the Burlington shoreline, and the lowest value was in Windermere Basin (MOE, 1986a). In other studies, the concentration of PCBs in Windermere basin was 10 μg/g (MOE, 1976) and 1 μg/g (MOE, 1982). The most recent distribution map was supplied by Dr. T. Murphy (personal communication) in Figure 17. Most of the PCBs are found in the deep hole with more PCBs at the northern edge.

Non-point sources such as atmospheric deposition and urban runoff via tributaries and storm sewers are likely to be significant sources of organic contaminants such as pesticides.

The distribution of PAHs indicates that the steel mills were the main source and that the Hamilton STP was a minor source (MOE, 1986a). Concentrations of PAH compounds measured in samples collected in 1985 and 1988 are plotted in Figure 17.

PAH contamination in the Randle Reef area is elaborated in greater detail in a recent report (Murphy et al., 1990) as this is an area that probably will require treatment or removal/treatment in order to reduce the spread of the material and to eliminate an area of severe toxicity (see also Section III.4.4.1).

The levels of pesticides in sediments are low. DDT averages about 6 ng/g dry weight compared to 2-30 ng/g in other Lake Ontario harbours. Other frequently occurring pesticides were α- and ß-chlordane (5 and 7 ng/g respectively) and α-hexachlorocyclohexane (α-BHC, 2 ng/g) which were found in 50-65% of the samples. HCB (<1 ng/g), op-DDT (<5 ng/g), pp-DDE (<1 ng/g), and ß-BHC were found in 15-25% of the samples (MOE, 1986a).

TABLE 11: Summary of chemistry of surficial sediments from 1975 to 1986, compared with the Guidelines for Open Water Disposal. All values in $\mu g/g$ unless otherwise stated.

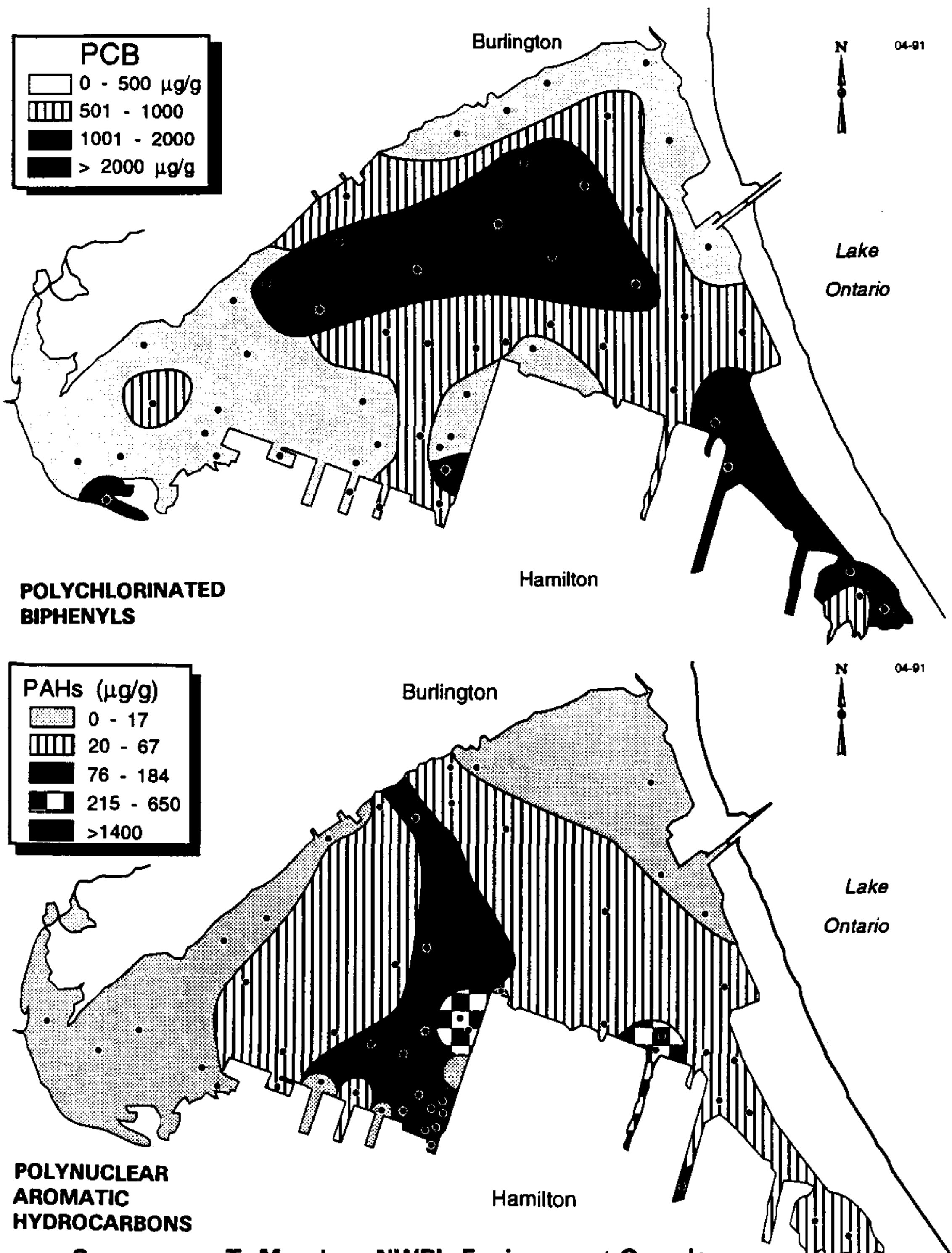
						Guidelines	
	1975	1976	1977	1980	1986	Lowest Effect Level	Severe Effect Level
LOI (%)	10.5		9.5	9.8			
BOD (mg/g)	3.9		2.6				
SOD (mg/g)	152	140	150				
NH_3			30				
TKN (mg/g)	3.5	2.7	2.9	3.5		.55	4.8
TP (mg/g)	3.4	2.4	2.9	3.2		0.6	2.0
Ether Ext. (mg/g)			12.5				
Iron (mg/g)	68	70	88	68	74	20	40
Copper	101		110	130	158	16	110
Chromium	206	200	220	204		26	110
Nickel	45	39	52	44	55	16	75
Zinc (mg/g)	3.1	2.0	2.6	2.7	2.2	.12	0.82
Lead	320	260	310	310	281	31	250
Cadmium	7.8	5.0	6.3	5.7	14.1	0.6	10
Manganese	1670			1900	2100	460	1100
Mercury	2.4	0.4	1.7	0.3	2	0.2	2
Cobalt	15		12	10	20		
Arsenic			22		40	6	33

III.3.4.2 Metals

Metal levels in the surficial sediments from six stations from 1975 to 1986 and the guidelines for open-water disposal of dredged material are shown in Table 11. Data on the spatial variability in trace metal concentrations in the Harbour sediments are presented in Figure 18a and 18b, as an illustration of such distributions.

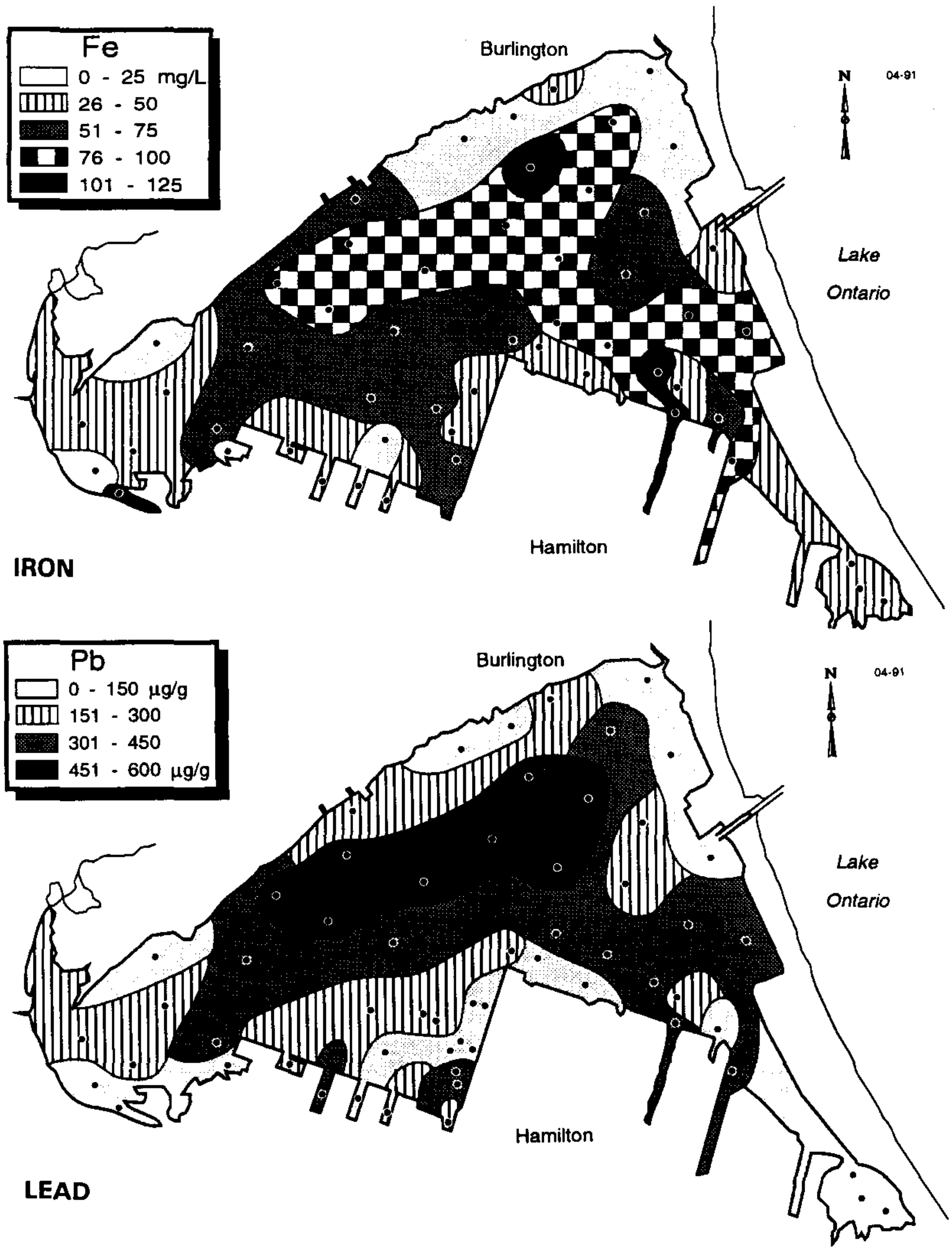
Lum and coworkers (McIsaac et al., 1982) found that the most important chemical phase for metals was the iron-manganese oxides. These oxides controlled the solubility of manganese, zinc, and occasionally lead. These elements can be released into solution and become more bioavailable and toxic if the water becomes anoxic. Most of the copper was associated with

Figure 17: Trace Contaminant distribution in sediment.



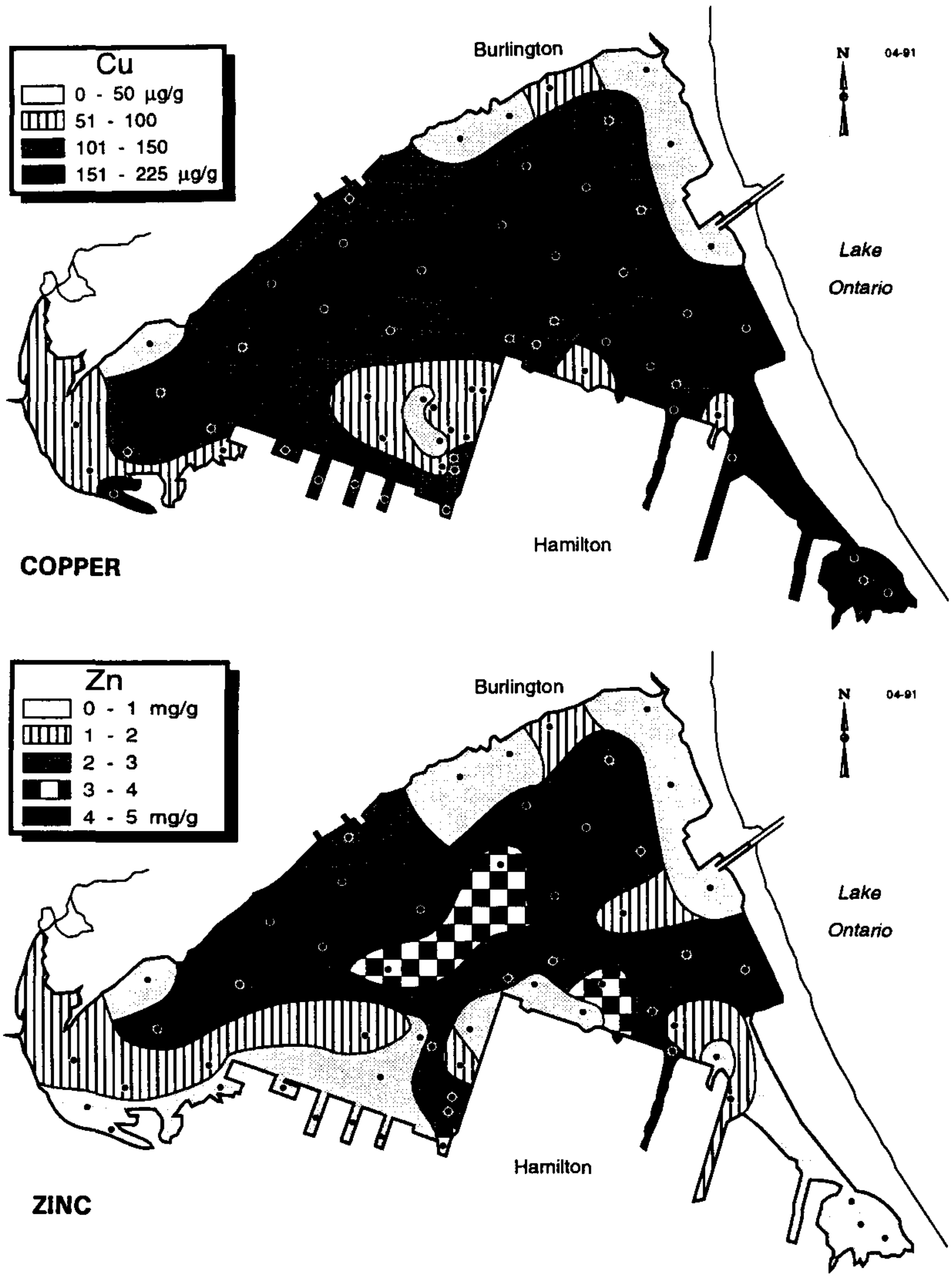
Source: T. Murphy - NWRI, Environment Canada.

Figure 18a: Metal distribution in sediment.



Source: T. Murphy - NWRI, Environment Canada.

Figure 18b: Metal distribution in sediment.



Source: T. Murphy - NWRI, Environment Canada.

organic matter; chromium, lead, nickel and zinc were also often associated with organic matter (McIsaac et al., 1982). In many samples, a large portion of the metals was refractory; thus, the metals were not bioavailable or toxic. Mudroch (1980) found that cadmium, chromium, mercury, and arsenic were not released into solution when sediment samples were shaken with Lake water. Preliminary results from an ongoing study by MOE indicate that sediment toxicity is far more pronounced in the fall than the spring, and that biological available metals appear to be involved at locations in the main Harbour (Krantzberg pers. comm.). It appears that the annual variation in the oxygen conditions at the sediment-water interface is both directly and indirectly involved.

With the exception of the area near the Dundas STP, the concentration of metals in most of Cootes Paradise is much lower than in Hamilton Harbour. Concentrations of zinc, lead, and copper are 1/8, 1/5, and 1/2 respectively, of those in the Harbour sediments (MOE, 1975, 1977b). Moreover, the concentrations of zinc, copper, lead and cadmium in the surface sediment near the outlet of Cootes Paradise decreased greatly from 1975 to 1980 (MOE, 1986b). The improvements to the Dundas STP are responsible for the improvements in water quality and presumably in sediment quality of Cootes Paradise.

III.3.5 Dredging Operations

Dredging activity in the Harbour has gradually diminished since the late 1950s. Maintenance dredging, which is carried out by Public Works Canada, has removed a total of 341,573 m^3 since 1980. Capital dredging projects are undertaken by the Hamilton Harbour Commissioners as needed. Most of the recent activity has been in the approach channel and turning basin to the Dofasco and Strathearne Avenue slips. In addition, some slips, which had been dredged regularly in the past, are being filled in to form piers.

Since 1970, disposal of the dredged material has been confined to prevent the entry of pollutants back into the watercourse. The exterior berm of the CDF was constructed in three stages, creating a 50 ha facility with an approximate total capacity of 3.0 million m^3. Since 1972, all material dredged from the Harbour has been deposited into this site. It became apparent in 1981 that the site required better management to make it work better and construction of interior berms was carried out to create a cell structure.

This permitted a staged development of the site, improved control of dredge slurry deposition and improved containment of pollutants. Simple overflow weirs were constructed for each cell in order to enhance settling of fine sediments. As the present cells are filled, future cells will be constructed in a similar fashion.

Monitoring of dredged slurry indicates excellent particle retention, with the water quality in the last cell comparable to ambient water conditions in the area (IJC, 1986). Therefore, the dredging and disposal operations probably have little negative effect on water chemistry and sediment chemistry. Additional monitoring around the CDF is planned. The dredging operations are removing contaminated sediments and therefore could be viewed as improving the Harbour sediment contaminant conditions. However, the amount of sediment dredged during the past decade is minor relative to the total amount of contaminated sediment in the Harbour.

The Hamilton Harbour Commissioners have advised that the capacity of existing CDFs for dredgeate disposal for navigational needs is adequate until the year 2010. No plans have been finalized for adequate capacity beyond that date.

III.3.5.1 Impact of CDF on Wildlife

Recent data (Dobos et al., 1990) suggest that the use of CDFs in Hamilton Harbour should be reviewed carefully in light of the high PCB concentrations. The depth of the cap isolating the contaminated sediments may need to be thicker than normal and rooting of the vegetation through the cap should be prohibited. The cap will have to be designed in such a way as to discourage shrews and moles from burrowing through the cap into the dredged "soil".

The real concern for the impact of CDFs on wildlife, however, comes from the exposure of shoreline and mudflat areas and from the shorebird and waterfowl species which feed in these areas. The Hamilton CDFs have been receiving contaminated sediments for over 20 years (see above). When water levels in those CDFs recede in the autumn, as they almost always do, those sediments become exposed or available as mudflats or as shallow water littoral areas. Shorebirds will probe and feed in the mud; ducks will "tip-up" and feed in the bottom sluice. In both cases, the birds have access to or are being exposed to the accumulated contaminants from over the years. Several recent studies, both right in Hamilton Harbour (Section III.4.8.4), and elsewhere in North America, have shown that birds feeding in these situations can accumulate significant levels of contaminants (especially PCBs) in as little as a few days. Clearly CDFs can be major sources of contaminants to littoral/shoreline feeding birds.

III.4 Biology
III.4.1 Bacteria
III.4.1.1 Coliforms (Objectives for Swimming)

Bacterial counts are higher in the south and east areas of the Harbour compared to the north and west. During the past decade, frequent sampling was conducted at the central (#258) and western (#270) stations in mid-Harbour, and the faecal coliforms were consistently below the objective for swimming (geometric mean= 57/100 ml). Faecal coliform counts recorded in 1986-87 indicate moderate increases over those of a decade earlier. Mean faecal coliform counts based on just six samples for each station all exceeded the level set for swimming (100/100 ml). More intensive sampling would be required to reliably test the suitability of Hamilton Harbour for body contact recreation. The geometric mean faecal coliform counts (#'s/100 ml) were 114 and 175 at stations #270 and #258, respectively. Climatic conditions in 1987 (dry and hot) may have been responsible for the elevated faecal coliform counts.

Total coliforms were not determined in 1987. Previous estimates from 1975 indicate that the Harbour exceeds the total coliform objective for swimming (1,000/100 ml). The geometric mean for stations #270 and #258 for 1975 was 1,475/100 ml. The south and eastern areas of the Harbour had higher levels of total coliforms.

The first beach reconnaissance sampling for faecal coliforms was done in 1988 along the northern and western shores. The results are shown in Table 12 (Painter, NWRI, pers. comm.). Samples were collected in 1-1.5 m water depth by NWRI, and were analyzed by the Hamilton-Wentworth Region Laboratory. The higher values observed are related to rainfall events, either during or just before the sampling date.

This experiment was repeated in 1990 at five locations around LaSalle Park, at two locations on either side of Willow Point and at five locations around the Lax property (proposed site of a new Hamilton park). Sites were sampled on three consecutive days in five weeks of July, August and September (15 days altogether) - (Boyd, 1991). Tests at two stations indicated that E. Coli was constituting 34 and 42% of the faecal coliform count.

In addition, data collected on the same day at open beaches on Lake Ontario on 12 of these sampling days shows "...that Harbour geometric mean densities are not significantly different from those at existing bathing beaches" (on Lake Ontario).

Further, it was concluded that: "These findings provide no evidence to preclude further efforts to establish bathing beaches within the Harbour. Of the three zones examined, the former Lax property was the least suitable having an overall geometric mean of 204 organisms 100 ml^{-1} with similar bacterial densities at all five stations. In contrast, the Willow Point zone was the best with an overall geometric mean of 110 organisms 100 ml^{-1}. Within this zone the western location was the most favourable. Results from the LaSalle Park area, currently the most promising zone in terms of public access, fell between the other two zones with an overall geometric mean of 141 organisms 100 ml^{-1}. The second most easterly location had the best results in this zone.

Whichever Harbour zone, or zones, are considered for future development as public bathing beaches, successful management will depend largely upon the application of a policy regarding the reduction of the health risks associated with swimming following rainfall (confirming earlier work).

Health and environment officials have followed up this work with studies in 1991 that include regular sampling of Harbour sites as is done at existing swimming beaches on Lake Ontario. Preliminary examination of these results indicates that conditions in the Harbour are not as good as those out in the open Lake. However, there appears to be potential for future restoration pending further assessment following remedial actions associated with combined sewer overflows, and other non-point sources.

TABLE 12: Faecal coliform counts in Hamilton Harbour, 1988 (counts/100 ml).

	July				August				
	4	11	18	25	2	8	15	22	29
Hager/Rambro	68	152	>2400	180	24	44	56	48	200
LaSalle E.	44	84	220	320	116	24	84	60	72
LaSalle W.	124	272	320	440	12	68	128	12	100
West RR	4	68	>2400	1000	80	32	64	52	36
Lax Canal opening	64	32	>2400	720	68	36	220	56	28
Lax Canal middle	104	84	>2400	280	72	76	200	20	240
Lax Canal back	248	432	>2400	400	80	136	1200	64	160

Source: S. Painter, NWRI

III.4.1.2 Bacteria Involved in Chemical Cycles

Annual, Harbour-wide, geometric mean densities of sulphur oxidizing bacteria have changed dramatically, but irregularly, since 1975. This suggests that the significance of these bacteria and the sulphur oxidizing processes to oxygen depletion may vary from year to year. In general, densities decrease with depth and from the eastern to the western end of the Harbour. This suggests a strong link between bacterial numbers and the point source inputs. The last source of reduced sulphur was eliminated in 1984, and therefore, sulphur oxidation is probably no longer important in the Harbour.

Nitrification is a two step bacterially-mediated process which converts ammonia (NH_3) to nitrate (NO_3): first, ammonia to nitrite by Nitrosomonas; and then, nitrite to nitrate by Nitrobacter. Nitrification requires oxygen. The seasonal contribution of nitrification to the total water column oxygen demand ranges from 10% to 45%. Population densities of nitrifiers show extremely high fluctuations not just seasonally, but also on a weekly basis. The presence of significant concentrations of ammonia in the Harbour throughout the year indicates that these bacteria are not substrate limited. Populations of nitrifiers were highest in the west end of the Harbour which is geographically distant from the point source loadings of ammonia.

III.4.1.3 Heterotrophic Bacteria

Heterotrophs are a heterogeneous group of organisms requiring organic carbon for growth. Densities are greatest in the eastern end of the Harbour. Levels are elevated in the surface waters where temperature, dissolved oxygen, algal biomass and dissolved organic carbon concentrations are the highest. Heterotrophic bacteria are most abundant in the spring and autumn and least in summer, suggesting that densities are not strictly controlled by temperature. In addition, the presence of high concentrations of dissolved organic carbon throughout the year would suggest that they are not substrate-limited. The major factors limiting growth and metabolic activity during the summer would appear to be low dissolved oxygen concentrations or zooplankton grazing.

III.4.2 Phytoplankton

The production of organic carbon by phytoplankton in the Harbour is up to 1.5 times greater than the organic carbon loadings from municipal and industrial sources (MOE, 1985). Much of this algal biomass settles into the hypolimnion where it decays and consumes oxygen. Together with ammonia oxidation, the oxidation of decaying algae can keep the hypolimnion anoxic (MOE, 1985).

The algal biomass in the Harbour is lower than would be expected from nutrient loadings (Haffner et al., 1980). Although Haffner proposed that physical factors regulate phytoplankton growth, others have thought that toxic compounds may inhibit algae. Algae isolated from Hamilton Harbour were not affected by zinc concentrations about 100 times higher than those observed in the Harbour (Piccinin, 1977). Wong et al., (1978) found that mixtures of metals in concentrations equivalent to the Water Quality Objectives were inhibitory to four species of algae. The metal concentrations (μg/L) used were: arsenic 50; cadmium 0.2; chromium 50; copper 5; iron 300; lead 25; mercury 0.2; nickel 25; selenium 10; and zinc 30. Current metal concentrations (μg/L) in Hamilton Harbour are listed in Table 8, but they were all less than the concentration tested. Goudey (1983) found that copper and mercury at concentrations found in the Harbour could inhibit photosynthesis; but again, metal concentrations have decreased since Goudey did his study. Metals are largely detoxified by precipitation and adsorption to cell debris (Goudey, 1983). Moreover, some Harbour algae (i.e. Scenedesmus and Coelastrum) are more tolerant to copper and zinc than are similar laboratory strains (Goudey, 1983).

Analyses of algae suggested elevated levels of copper, chromium and nickel relative to sediment concentrations. However, these metals may be regulated as nutrients, i.e. they may be actively scavenged from water or excessive levels may be excreted. Concentrations of cobalt, zinc, and lead in algae were lower than in sediments.

Physical factors are probably more important in restricting algal growth. Light limitation by coloured organic material (Harris, 1976; Harris et al., 1980a) and self-shading (Harris, 1976) is a major factor regulating macrophyte and phytoplankton growth. Light limitation favours the growth of larger algae which can optimize light utilization (Harris, 1976).

Phytoplankton are sensitive to rapid fluctuations in light regime, such as those brought about by turbulence in the mixed layer (Harris et al., 1980b). Incursions of Lake Ontario water through the Ship Canal, and direct wind stirring cause vertical mixing and rapid changes in mixing depth.

Phytoplankton are adaptable to fluctuations in the ratio of light penetration to mixing depth (Haffner et al., 1980). Physiological adaptations such as altered chlorophyll content or photosynthetic enzymes are seen during the summer in green algae. Some species, such as Cryptomonas, utilize heterotrophic processes rather than relying on photosynthetic carbon uptake. Small coccoid cells such as Chlamydomonas lose their flagella and pigment as the ratio of light penetration to mixing depth decreases and cells spend less time in the euphotic zone.

During periods of stable light and mixing depth, large cells such as Oocystis borgei predominate. This species persisted in the summer once a thermal gradient was established, but declined when lake mixing increased (Haffner et al., 1980). Changes in the mixing depth can give the impression of multiple growth peaks. Near monospecific phytoplankton blooms occur most commonly under conditions of relatively stable physical parameters (Harris et al., 1980b).

Diatom growth is related to vertical mixing. Without vertical turbulence, the heavy silica shells tend to sink out of the water column. The persistence of diatoms throughout the year is evidence of vertical turbulence during the stratified period (Haffner et al., 1980). The survival of Stephanodiscus also depends directly on its resuspension by vertical mixing (Harris et al., 1983). Diatoms are also favoured because they can utilize energy from green light more efficiently than can green algae. Since green light penetrates water three times farther than blue light, diatoms are less stressed when light penetration is poor.

The seasonal succession of Hamilton Harbour phytoplankton includes diatoms and small phytoflagellates early in the year, during periods of homogeneous mixing. These are followed by the predomination of coccoid green algae for a short period of time, and then by a mixture of diatoms and green algae when the maximum summer temperature is reached. Diatoms and flagellates later return as the dominant species. Blue-green algae were noticeably absent from the Harbour despite the eutrophic conditions (Harris and Piccinin, 1980).

Algal primary production is responsible for the fixation of 6.5 to 58 tonnes of organic carbon per day which is 0.2 to 1.7 times the estimated external load in 1979. In addition, 4.6 to 41 tonnes per day of organic nitrogen is similarly produced which is 0.2 to 1.6 times the estimated external load for 1979. Both organic carbon and nitrogen are responsible for a significant portion of the oxygen demand in the Harbour, and algal biomass is a major contributor to these reservoirs.

III.4.3 Zooplankton

The few studies that have been done on Hamilton Harbour zooplankton communities have established that the zooplankton fauna is typical of a eutrophic lake where the food chain is largely based on detritus (Piccinin and Harris, 1980; Harris, 1976). Large rotifer populations dominate the zooplankton community in the Harbour for most of the year. A cladoceran, Bosmina longirostris, is also common at certain times of the year, while some other cladoceran species (e.g. Daphnia) and copepods are less common than might be expected based on observations from other eutrophic lakes.

The seasonal succession of zooplankton in Hamilton Harbour includes an early spring peak made up almost entirely of the rotifer Keratella quadrata (Harris, 1976). During summer in the stratified Harbour, epilimnetic species are dominated by B. longirostris and Brachionus angularis. Few species can survive in the anoxic bottom layers. During fall turnover, zooplankton numbers increase as hypolimnetic reoxygenation opens up new habitats. Piccinin and Harris (1980) have found B. longirostris abundance to be positively correlated to oxygen tension during the summer. In 1976, MOE aerated two sites in the Harbour, creating an oxic hypolimnion, leading to an increased zooplankton biomass when compared to the previous year (Piccinin, 1977).

Zooplankton biomass has been positively correlated to phytoplankton biomass in the epilimnion of Hamilton Harbour (Harris, 1976). Fluctuations in zooplankton numbers and dry weights were found to correspond to changing phytoplankton biomass, and to the thermal structure of the water. Grazing, however, had little effect on total algal biomass (Harris, 1976). It is believed that the zooplankton in the Harbour feed mostly on bacteria and detritus (Piccinin and Harris, 1980).

Rotifer distribution was shown to be associated with both seasonal and depth components (Piccinin and Harris, 1980). Rotifer abundance was correlated with ammonia and silica distribution which vary with the season and with depth. Rotifers generally occur throughout the entire water column.

In general, zooplankton populations are similar in composition to populations in the Bay of Quinte, with the exception of the presence of moira bractiata.

III.4.4 Benthos

Johnson and Matheson (1968) sampled the benthic community of Hamilton Harbour in 1964. Their results indicated a severely degraded ecosystem dominated by pollution-tolerant oligochaetes (worms). Limnodrillus hoffmeisteri occurred at all of the sites sampled and represented 50% of the total mature population of oligochaetes. Tubifex tubifex was found at 85% of the sites and contributed 30% to the population. More sensitive species such as Quistadrillus multisetosus made up less than 5% of the population and occurred at less than 30% of the sample sites. Oligochaete abundance was highest in the area adjacent to the Burlington Ship Canal suggesting a positive effect of Lake Ontario on Hamilton Harbour water and/or sediment quality. Low abundance in the rest of the Harbour, particularly in a 2 km^2 "toxic zone" close to the Ottawa Street slip, supported the hypothesis that poor water quality and/or sediment toxicity was inhibiting the abundance and distribution of oligochaetes in the Harbour.

The Harbour was resampled in 1984 to determine the response of the benthic community to remedial actions implemented between 1964 and 1984. The Harbour was again dominated by oligochaetes. Abundance ranged from absent at the south end of the Ottawa St. slip to 450,000 m^{-2} in Windermere Basin and in the deep central basin. Average biomass was between 10,000 and 100,000 oligochaetes m^{-2} (Figure 19). Q. multisetosus, a pollution-sensitive oligochaete was 42% of the total benthic invertebrate population. L. hoffmeisteri and T. tubifex, pollution-tolerant oligochaetes, were 32 and 10% of the population. Chironomids, of which four genera were reported in 1964, occurred at all of the littoral sites sampled. Mean abundance at the littoral sites was 302 m^{-2}. Visual surveys conducted in 1988 indicate the presence of extensive clam beds in the shallow water between LaSalle Marina and the north east corner of the Harbour.

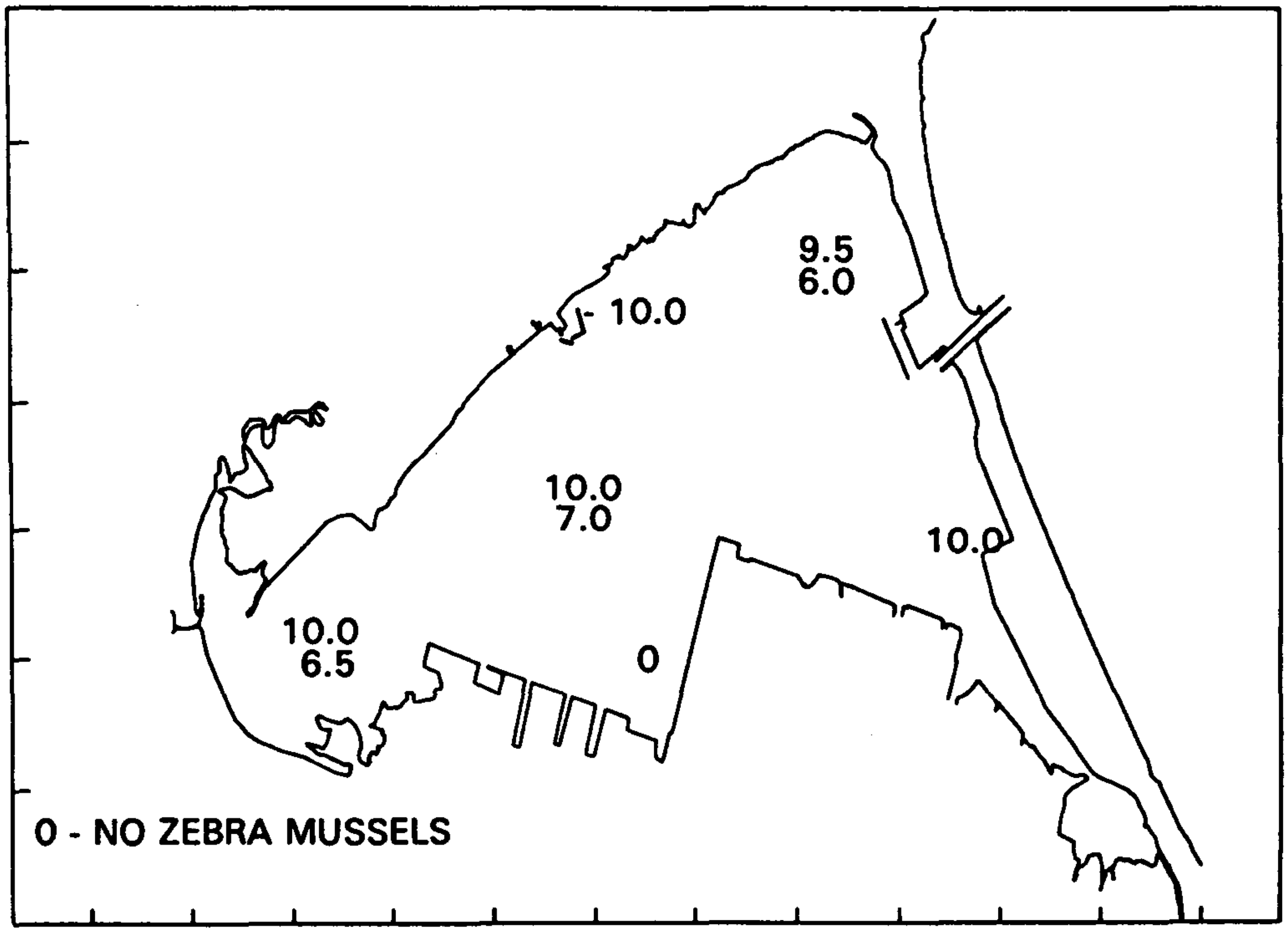
Although the benthic community in Hamilton Harbour is indicative of a highly eutrophic environment, substantial improvements have occurred in the abundance and community composition since 1964. The "toxic zone" described in 1964 has been reduced from 2 km^2 to a small area at the south end of the Ottawa St. slip. Biomass throughout the Harbour has increased between 5 and 20 fold and the community composition has shifted away from pollution-tolerant species towards more pollution-sensitive species. An additional four genera of chironomids were found in 1984. Sphaerids, which were not found in the 1964 survey, occurred at 11 sites in 1984.

III.4.4.1 Effect of Sediments on Benthos and Zooplankton

Sediments in the Harbour are contaminated. The levels of contamination are sufficiently high to require that dredgeate be disposed of in confined disposal facilities, rather than being dumped in the open Harbour or open Lake. In other words, if one must move the sediments, certain regulations must be followed.

But do the sediments left in place constitute a hazard? This question has been recently brought to a focus in a protocol for sediment assessment (Water Quality Board, 1988). While the suggestions in the Board's report are largely untested in both a practical and a research sense, agencies involved in the Hamilton Harbour RAP have developed information in line with these protocols.

Figure 24: Maximum depth (m) of zebra mussel accumulation on Hamilton Harbour moorings, 1991.



Paradise and Hamilton Harbour and the combined effects of eutrophication, agricultural expansion, and industrial development were reflected by the Harbour fisheries. Commercial catches of lake trout, whitefish, and herring peaked at 4,500, 13,600 and an impressive 114,000 kg per year, respectively, in the late 1800s. By 1950, annual catches of lake trout, whitefish and herring had dwindled to 0, 181, and 68 kg, respectively.

III.4.7.1.3 Stresses Affecting the Coldwater Fishery

The coldwater fishery in Hamilton Harbour responded to a number of stresses including overfishing, competition from newly introduced species, loss from physical habitat through infilling or silting of spawning beds and deteriorating water quality. Seining at the Canal during feeding and spawning migrations, combined with heavy gillnet fishing, substantially reduced lake trout, whitefish, and herring populations (Whillans, 1979). In addition, cold water species were unsuccessfully competing with smelt for benthic invertebrates (Pontoporeia and sphaerids). Smelt were first reported in Hamilton Harbour in 1865 (Whillans, 1979) and were thought to be an important factor contributing to the decline of whitefish populations in the eastern basin of Lake Ontario (Christie, 1973).

There are few historical references describing the effects of eutrophication and toxic chemicals on the coldwater fishery. Whillans (1979) cites references from Kerr and Kerr, the Fisheries overseers from 1860-1898, describing deteriorating water quality on lake sturgeon spawning beds along the south shore and other instances of dead fish in close proximity to industrial discharges. Although warmwater fisheries declined after the installation of the first collecting sewer in 1854, there were no data describing the effects of eutrophication on the hypolimnetic waters of the Harbour. Excessive nutrient inputs to the Harbour encourage algal production. The decaying algae and oxygen demanding sediments combine to deplete the dissolved oxygen in the hypolimnion during the summer months, effectively eliminating the deep water habitat necessary to sustain the coldwater fishery. Analyses of sediment core samples are underway to determine when this cycle of anoxia began in the Harbour and if this period of reduced oxygen coincided with the loss of benthic invertebrates and coldwater fisheries.

III.4.7.1.4 Stresses Affecting the Warmwater Fishery

The collapse of the coldwater fishery was quickly followed by a rapid decline in the number of warmwater fish and a transition from a predator-dominated fishery to one dominated by forage species. Overfishing, toxic discharges, introductions of exotic species (carp, alewife, and white perch) and habitat loss were the major factors responsible for reductions in the warmwater fishery. These changes paralleled the growth of Hamilton as an industrial and urban centre. The city's population increased from 3,000 in 1840 to 25,000 by 1857 and reached 155,000 in 1931 (Threader et al., 1989). Population increases were accompanied by rapid industrial expansion along the south shore of the Harbour. By 1880, Hamilton was already established as a major iron manufacturing centre and in 1910, the steel producers merged to become the Steel Company of Canada. International Harvester expanded in 1911 and Dofasco, the second steel mill to be built on the south shore of Hamilton Harbour, was established in 1912. The Harbour was now receiving effluents from three municipalities, two of Canada's largest steel producers, and textile, rubber, paint, and solvent manufacturers. The Fisheries Overseer reported many occurrences of dead and dying fish along the vegetated shoreline (Whillans, 1979).

The war years from 1915 to 1918 were accompanied by escalating steel and munitions production in Hamilton. Expanding industries required more land on the south shore and many of the shallow water marshes were filled to provide roads, docks, and factories. This trend continued in the post-war years and by 1959, approximately 22 percent of the open water area in the Harbour had been lost to landfilling (Threader et al., 1989). Although land reclamation along the south shore significantly reduced the open water area (and the retention time of the basin), the most significant impact was the loss of the shallow water marsh habitats that supported the warmwater fish community. Prior to industrial development, the 43 km south shore was a complex marsh ecosystem colonized by emergent and submerged vegetation. The irregular shore line had many inlets that in some cases created long bays extending more than 1 km inland. Landfilling reduced the total littoral shoreline from 65 km in 1,800 to 20 km by 1985 (Figure 1). Most of the south shore has been dredged to at least 8 m deep. The landfilled shore is separated from the Harbour by steeply sloped berms or by vertical pilings. There is no suitable fish habitat along the south shore of Hamilton Harbour east of the former Lax property.

The loss of marsh habitat significantly reduced the abundance and distribution of warmwater fish. Disappearing wetlands along the south shore restricted the fishery to the north and west shores of the Harbour and to Cootes Paradise.

III.4.7.2 Present State of Hamilton Harbour Fishery

III.4.7.2.1 Larval Fish

Larval and juvenile fish surveys were conducted in 1985 and 1987 by the Department of Fisheries and Oceans in littoral and open water areas of both Hamilton Harbour and Cootes Paradise. The most common larval fish are listed in Table 16 of the 42 species of larval fish identified (Table 17). Most species were caught in the west end of the Harbour and in Cootes Paradise (Figure 22).

Twenty-seven adult northern pike were observed in Grindstone Creek. Spawning was observed and pre- and post-spawning females and males were confirmed. Larval pike were not collected but this is normal since larval pike are particularly difficult to collect.

TABLE 16: Larval fish composition, 1985 and 1987.

Species	Percent Composition
Gizzard shad	50
Alewife	32
Yellow perch	5.1
Bluegill	2.8
Pumpkinseed	2.5
White perch	2.3
Total:	95
Source: J. Leslie, DFO	

III.4.7.2.2 Adult Fish

Hamilton Harbour supports a diverse fishery represented by 19 families, 42 genera, and 59 species (Table 17). Although diversity is high, community structure has shifted from the larger, long-lived species common in the late 1800s to smaller, short-lived species characteristic of eutrophic environments.

The Hamilton Harbour and Cootes Paradise fishery consists of two distinct species groups. The first group, represented by crappies, sunfish, gizzard shad, and brown bullheads, remain in the Harbour and marsh throughout the year. They tend to congregate in Cootes Paradise in the spring and move into the western end of Hamilton Harbour in the fall.

The second major group, represented by smelt, white sucker, yellow perch, brown trout, spottail shiners, herring, lake chubs, and Pacific salmon, migrate into Hamilton Harbour from Lake Ontario to feed and/or spawn. Abundance is highest in the spring and fall (Table 18) although small numbers of migrating species were found in the summer at the eastern end of the Harbour close to the Burlington Canal.

TABLE 17: **Fish species in Hamilton Harbour and Cootes Paradise, 1984-87.**

Scientific Name	Common Name	Larvae
Petromyzon marinus	sea lamprey	
Anguilla rostrata	American eel	
Lepisosteus osseus	longnose gar	
Amia calva	bowfin	
Alosa pseudoharengus	alewife	•
Dorosoma cepedianum	gizzard shad	•
Oncorhynchus kisutch	coho salmon	•
Oncorhynchus tshawytscha	chinook salmon	•
Salmo gairdneri	rainbow trout	
Salmo trutta	brown trout	
Salvelinus namaycush	lake trout	
Coregonus artedii	lake herring	
Couesius plumbeus	lake chub	
Osmerus mordax	American smelt	•
Umbra limi	central mudminnow	•
Esox lucius	northern pike	
Carassius auratus	goldfish	•
Cyprinus carpio	carp	•
Notemigonus crysoleucas	golden shiner	•
Notropis atherinoides	emerald shiner	•
Notropis hudsonius	spottail shiner	•
Notropis heterolepis	blacknose shiner	•
Notropis heterodon	blackchin shiner	
Notropis cornutus	common shiner	•
Notropis chrysocephalus	striped shiner	•
Notropis volucellus	mimic shiner	•
Pimephalus promelus	fathead minnow	•
Pimephalus notatus	bluntnose minnow	•
Semotilus atromaculatus	creek chub	•

Scientific Name	Common Name	Larvae
Rhinichtys astratulus	blacknose dace	*
Carpiodes cyprinus	quillback	
Catostomus catostomus	longnose sucker	
Hypentelium nigricans	northern hog sucker	
Ictiobus cyprinellus	bigmouth buffalo	
Ictalurus nebulosus	brown bullhead	*
Ictalurus punctatus	channel catfish	*
Ictalurus melas	black bullhead	*
Ictalurus natalis	yellow bullhead	*
Noturus gyrinus	tadpole madtom	*
Fundulus diaphanus	banded killifish	*
Labidesthes sicculus	brook silversides	*
Culaea inconstans	fivespine sickleback	*
Percopsis omiscomaycus	trout perch	*
Morone americana	white perch	*
Morone chrysops	white bass	*
Ambloplites rupestris	rock bass	*
Lepomis gibbosus	pumpkinseed	*
Lepomis macrochirus	bluegill	*
Micropterus dolomieui	smallmouth bass	*
Micropterus salmoides	largemouth bass	*
Poxomis nigromaculatus	black crappie	*
Poxomis annularis	white crappie	
Percina caprodes	logperch	*
Etheostoma nigrum	johnny darter	*
Etheostoma caeruleum	rainbow darter	*
Perca flavescens	yellow perch	*
Stizostedion vitreum	walleye	
Aplodinotus grunniens	freshwater drum	*
Source: V. Cairns, GLFAS, DFO		

TABLE 18: Seasonal changes in the numbers of fish caught in index gillnets in Hamilton Harbour from September 1984 to August 1985, and Cootes Paradise from April to August 1985.

Species	1984				1985				
	Sept.	Oct.	Nov.	Dec.	Apr.	May	June	July	Aug.
Hamilton Harbour									
White perch	284	293	414	25	227	447	356	556	513
Alewife	441	101	19	5	72	1285	3445	832	499
Carp	19	40	58	9	3	7	20	23	27
White sucker	15	29	28	37	67	73	33	33	20
Yellow perch	39	93	38	12	219	445	141	3	33
Brown bullhead	69	158	80	30	151	255	88	80	48
Brown trout	3	7	15	14	28	28	2	5	1
Cootes Paradise									
White perch	N.D.	N.D.	N.D.	N.D.	1158	929	911	608	1038
Alewife	N.D.	N.D.	N.D.	N.D.	5	297	3273	3350	184
Carp	N.D.	N.D.	N.D.	N.D.	82	76	53	86	64
White sucker	N.D.	N.D.	N.D.	N.D.	45	19	0	0	0
Yellow perch	N.D.	N.D.	N.D.	N.D.	80	10	4	2	10
Brown bullhead	N.D.	N.D.	N.D.	N.D.	271	169	78	67	98
Brown trout	N.D.	N.D.	N.D.	N.D.	3	1	2	0	2

N.D.: No data available

Source: V. Cairns, GLLFAS, DFO

The relative abundance (catch per unit effort) and distribution of fish in Hamilton Harbour were determined from gillnetting surveys conducted from September to December, 1984 and from April to September, 1985 (Portt, 1988). Additional data were obtained from an electrofishing survey of the Harbour by the OMNR in October, 1987.

The 1985 fish community in Hamilton Harbour and Cootes Paradise was dominated by warmwater planktivorous, herbivorous, and benthivorous species (Table 19). Alewife, white perch, and gizzard shad represented 92 percent of the total catch in Cootes Paradise (52, 32, and 8 percent respectively) and 71 percent of the Hamilton Harbour catch (56, 15, and 1 percent, respectively).

Differences in species composition reflected the presence of species that migrate between Lake Ontario and Hamilton Harbour and fewer carp and gizzard shad in the Harbour. Large piscivores such as pike, garpike, largemouth and smallmouth bass, channel catfish, and bowfin were rare. The total number of fish captured in Hamilton Harbour and Cootes Paradise was similar although Hamilton Harbour received 30 percent more fishing effort.

Total fish biomass (kg of fish captured between April and September, 1985) in Cootes Paradise was 1.5 times greater than the biomass in Hamilton Harbour (Table 19). Ninety-four percent of the fish biomass in Cootes Paradise was contributed by carp, gizzard shad, white perch, alewife, and brown bullhead. These species contributed only 60 percent of the total biomass in Hamilton Harbour. Apart from fewer gizzard shad and carp in the Harbour, the most significant difference between the two sites was the contribution of other species to the total biomass. Thirty-two percent of the Hamilton Harbour biomass represented Lake Ontario species migrating into the Harbour. The largest contributors included white suckers, yellow perch, brown trout, spottail shiners, and American smelt (10, 9.2, 7.3, 3.6, and 2.4 percent of the total biomass respectively). The remaining 21 species contributed only 2.5 percent of the fish biomass in the Harbour (Table 19).

The Ontario Ministry of Natural Resources conducted an electrofishing survey in October, 1987 to determine the abundance and distribution of sportfish in Hamilton Harbour. Fishing was confined to the littoral zone (1.3 m deep). Fish density (no. of fish per m^3) was determined from four 100 m runs in each habitat type (Table 19). Habitats were defined by the density of vegetation ranging from absent to dense. Acoustic surveys conducted in 1984 and 1985 indicate that fish were rarely found (densities never exceeded 0.1 fish/m^3) at depths greater than 10 m during the summer months. Fish abundance in the deeper water increased in December, possibly a response to improved oxygen conditions.

III.4.7.2.3 Health of Fish Communities in Nearshore Areas of Hamilton Harbour

Fish communities in nearshore areas of Hamilton Harbour show the effects of habitat stress. During 1990, electrofishing surveys were conducted in Hamilton Harbour, and in less stressed littoral habitats of Bay of Quinte (eastern Lake Ontario), and of Penetang, Hog and Matchedash Bays of Severn Sound (Georgian Bay). Electrofishing surveys were conducted along 100 m transects at the 1.5 m depth contour. Many transects were surveyed in each bay, such that replicate samples were obtained from a variety of habitats (presence/absence of macrophytes, substrate type, exposure etc.) in each study area. Comparisons of the fish data from the different areas confirmed that there were important differences in the biomass,

TABLE 19: **Total gillnet[1] catch, and biomass of fish in gillnet catch, in Hamilton Harbour and Cootes Paradise, April to September, 1985; and electrofish catch in Hamilton Harbour, October 1987.**

	1985				1987
	Hamilton Harbour		Cootes Paradise		Ham. Harb.
Species	Catch[2]	Catch[2]	Catch[2]	Biomass[3]	Catch[2]
Alewife	9075	275.0	8612	266.2	37
White perch	2449	298.3	5264	491.3	337
American smelt	1718	36.1	0	0	0
Spottail shiner	841	42.1	97	1.4	7
Yellow perch	746	138.3	124	10.2	75
Brown bullhead	458	53.9	725	94.4	666
White sucker	308	151.0	66	40.6	44
Gizzard shad	180	74.7	1309	554.5	36
Carp	99	262.1	370	758.3	27
Brown trout	78	108.6	9	16.8	13
Trout perch	45	0.6	17	0.2	0
Pumpkin seed	29	1.3	46	1.5	622
White bass	14	6.0	3	1.0	0
Freshwater drum	11	11.2	12	17.1	1
Carp X Goldfish	10	10.2	9	11.5	0
Rock bass	6	0.7	1	0.2	15
Lake trout	5	10.6	0	0	0
Channel catfish	4	1.3	10	8.9	1
Black crappie	3	0.6	9	1.7	2
Rainbow trout	2	0.4	5	6.9	2
Goldfish	2	1.2	17	7.3	5
Northern pike	2	7.4	3	2.1	0
Smallmouth bass	2	0.5	0	0	2
Lake chub	1	0.1	0	0	0

Species	1985				1987
	Hamilton Harbour		Cootes Paradise		Ham. Harb.
	Catch[2]	Catch[2]	Catch[2]	Biomass[3]	Catch[2]
Lake herring	1	0.1	0	0	0
Longnose gar	0	0	1	0.8	0
Chinook salmon	0	0	0	0	10
Largemouth bass	0	0	0	0	71
Bowfin	0	0	1	2.1	0
Emerald shiner	0	0	0	0	7
Brook silversides	0	0	0	0	5
Golden shiner	0	0	0	0	4
Bluntnose minnow	0	0	0	0	2
Total Number of Fish: Total Number of Species:	16091 27		16710 22		2005 27

1. Experimental gillnets (64 m long x 2 m deep) consisted of 8 m long panels of 2.5, 3.8, 5.1, 6.4, 7.6, 10.2, 12.7, and 15.2 cm stretch mesh. They were set six times from April to September, 1985, at six locations in Hamilton Harbour and four in Cootes Paradise.
2. Numbers of fish.
3. Kilograms of fish

Source: V. Cairns, GLLFAS, DFO

species composition and trophic structure between Hamilton Harbour and the less stressed littoral habitats of the Bay of Quinte and Severn Sound.

Significantly, community fish biomass was on average higher at the Hamilton transects than in the other bays. Biomass was estimated to average about 300 kg/ha in Hamilton Harbour, 230 kg/ha in Bay of Quinte and 120-160 kg/ha in the Severn Sound bays. Community fish biomass is often used by fish biologists as a surrogate index for production; thus the biomass data indicated that despite habitat deterioration, the productivity of the Hamilton Harbour sites has remained high. However, habitat deterioration has had a negative impact on the fish populations in other ways. Specifically, the distribution of the fish biomass was quite 'patchy' in Hamilton Harbour. High variability in biomass from one localized area to another reflected a patchy distribution of suitable habitat in the nearshore areas. Average species richness (i.e. the mean number of fish species captured per transect) was less in Hamilton (4 species) than in the other survey areas (up to 7 species in the more desirable habitats). Within the fish community of the Harbour, most of the biomass was comprised of a few pollution-tolerant species, particularly common carp, whereas in the healthier littoral habitats of Quinte and Severn Sound, biomass was distributed among a greater number of species, and thus reflected a more balanced and desirable community structure. Exotic (non-native) species of fish, like carp, alewife and white perch, comprised about 60% of the total fish biomass in Hamilton Harbour. In contrast, exotic species represented only 10 to 20% of the biomass in the other study areas. In the Bay of Quinte and in the three bays of Severn Sound, piscivores (top predators, such as pike, largemouth bass and walleye) made up a much higher proportion of the total fish biomass (20-25%) than in Hamilton Harbour (9%). Juvenile stages of the piscivore species were particularly rare in Hamilton Harbour. In summary, electrofishing data indicated key differences between the structure of the fish communities in Hamilton Harbour and the healthier littoral habitats of the reference bays, and confirmed that the nearshore fish communities of the Harbour reflected the eutrophic and degraded conditions.

In future, specific fish targets for a desirable and stable fish community in Hamilton Harbour will be identified by using reference data from the less stressed habitats. The fish targets will include many of the general elements identified above: i.e., specific targets for total biomass, percent native species, percent piscivores, mean species richness and coefficients of variation of biomass that reflect a less patchy distribution of fish. Target biomasses for specific species of fish such as pike, largemouth bass and yellow perch will also be identified. Progress in achieving the targets will be monitored by conducting standardized electrofishing surveys in a manner similar to the 1990 surveys. Current high levels of biomass in the Harbour, although comprised of a few less desirable non-native species of fish, nevertheless indicate that the productivity of the habitat is high, and thus the potential for restoring the habitat and for achieving the desirable fish targets in future is considerable.

III.4.7.3 Specific Concerns about Contaminant Levels in Fish

Until 1985, sport fish collected from Hamilton Harbour for contaminant analysis had usually been limited in numbers of specimens of any single species caught. In 1985, large collections were obtained, and analyses have been completed for most of the parameters specified. Review of these results enabled the consumption advice contained in the annual Guide to Eating Ontario Sport Fish to be upgraded (MOE, 1988a).

Five of the twelve species listed in the Guide have limitations on consumption of some sizes of those fish. One species is advised for restricted consumption of all sizes sampled, and seven species have no advised consumption limitations.

Consumption limitations arise from the presence of one or more of three contaminants: mercury, PCBs, and Mirex. Mercury levels in the edible portion of freshwater drum (sheepshead) were found to average 0.56 mg/kg (range 0.16 to 1.2). Statistical projection indicates that this species would exceed 0.5 mg/kg mercury in the 35 to 45 cm size range, and 1.0 mg/kg mercury in the 45 to 55 cm size range. Assessment of the organic contaminant data for this species showed Mirex levels exceeded the 0.1 mg/kg Federal guideline in the 45 to 55 cm size range of fish in this sample, resulting in further advised restrictions on the consumption of large freshwater drum.

In white perch, both PCB and Mirex were found to exceed the respective Federal guidelines of 2.0 mg/kg PCB and 0.1 mg/kg Mirex in the 25 to 30 cm length range. Mercury was calculated to exceed the 0.5 mg/kg guideline in the 30 to 35 cm size range, however this exceedence is over-ridden by the exceedences for PCB and Mirex.

Carp over 65 cm in length are advised for restricted consumption based on the projection that PCBs will exceed 2.0 mg/kg in specimens of this size.

While the sample of channel catfish was small, the PCB and Mirex levels in nearly all individuals exceeded the Federal guidelines. For this reason, all sizes of channel catfish from Hamilton Harbour are advised for restricted consumption only. This includes specimens in the length range from 20 to 65 cm.

Few brown trout were collected, and most of them exceeded the Federal guideline for Mirex. Calculations indicated that brown trout from 45 to 65 cm would exceed 0.1 mg/kg Mirex. Brown trout in the size range collected were calculated not to exceed the 2.0 mg/kg PCB or 0.5 mg/kg mercury guidelines.

The other seven species (rainbow smelt, brown bullhead, northern pike, black crappie, white sucker, yellow perch, and white bass) are considered suitable for consumption in regard to Federal guidelines for mercury, PCB, Mirex and DDT.

More recent data were collected in 1987 by Fisheries and Oceans. Composite whole fish (rather than edible portion data listed above) samples of carp, white perch, brown bullheads, and white suckers (two pooled samples of 10 large and 10 small fish of each species) were analyzed in 1987. The results indicate that carp and white perch in Hamilton Harbour have high PCB concentrations. Concentrations of Mirex, DDT, DDE, HCB, Chlordane, Dieldrin, and Endrin were below consumption advisory levels. PCB accumulation in carp occurs at several other sites on Lake Ontario and consumption advisories (based on PCB's, Mirex and pesticides) are in effect at five of the nine sites sampled in Lake Ontario and the St. Lawrence River (MOE, 1988a).

The levels of trace organics in edible portions (muscle) have declined steadily between 1972 and 1981. Table 20 illustrates the earliest record and the 1981 record for PCB concentrations in Hamilton Harbour fish. Major reductions in the PCB content have occurred.

The source of contaminants accumulating in Hamilton Harbour fish is complicated by seasonal movements between the Harbour and the Lake. At least 15 species, including Pacific salmon, lake trout, rainbow trout, brown trout, white perch, white suckers, yellow perch, American smelt, white bass, freshwater drum and carp, migrate into the Harbour and Cootes Paradise from Lake Ontario.

TABLE 20: **PCB concentrations in fish from Hamilton Harbour, in mg/kg wet weight. Consumption guide is 2 mg/kg.**

Fish	Earliest Record		1981
	Year	Concentration	Concentration
Pike		-	0.49
Carp	1976	8.9	0.02
Bullhead	1972	4.0	0.04
Yellow perch	1976	0.52	0.1
White perch	1978	1.13	0.42
Sunfish	1972	2.5	0.02

Some species, such as carp and white perch, remain in the Harbour (and Cootes Paradise) from May-November and contaminant burdens during this period of maximum feeding are strongly influenced by local conditions. Trout and salmon enter the Harbour for short periods in the spring and fall and contaminant burdens in these species are more representative of Lake Ontario exposure. Consumption advisories for salmon and trout are in effect at most sites on Lake Ontario.

Studies of blood lead levels have demonstrated little difference between Hamilton Harbour fish and those from other parts of the Great Lakes. In fact, fish from Toronto Harbour and other Lake Ontario locations were more contaminated. This was true even for benthic feeding species which generally accumulate more lead than pelagic feeders.

Tissue levels of PCBs and other organochlorines in white suckers from Hamilton Harbour were similar to levels in suckers from several sites along the north shore of Lake Ontario (Table 21). These data suggest that contaminants in Hamilton Harbour fish, particularly non-resident species, are strongly influenced by Lake Ontario. Tissue burdens in non-migratory Harbour predators such as pike and bass are also affected by Lake Ontario contaminants. Migrating alewife, smelt, white perch, and yellow perch, are important food for resident fish. Hurley (1986) reported that these species constituted 76% of the northern pike diet in the Bay of Quinte.

Concerns for an edible fishery in Hamilton Harbour must be addressed on a whole Lake basis. Many of the non-resident species such as smelt, alewife, salmon and trout accumulate contaminants Lake-wide and it is unlikely that reduced loadings in Hamilton Harbour alone will result in an edible non-resident fishery. Concerted action in the Harbour and at all western Lake Ontario loading sites is required.

TABLE 21: Organochlorine concentrations (mg/kg) in whole white suckers from several sites on Lake Ontario, 1983.

	Hamilton	Bronte	Humber	Ganaraska	Brockville
# of fish	18	5	9	5	5
PCB	1.52	1.92	3.39	1.24	1.88
	±0.42	±1.4	±1.22	±0.76	±1.77
ΣDDT	0.34	0.79	0.53	0.29	0.03
	±0.12	±1.26	±0.29	±0.16	±0.03
HCB	0.01	0.0	0.01	0.09	0.01
	±0.01	±0.01	±0.01	±0.09	±0.00
Mirex	0.06	0.05	0.04	0.06	0.09
	±0.05	±0.01	±0.03	±0.04	±0.07
Dieldrin	0.02	0.02	0.03	0.02	<0.01
	±0.02	±0.02	±0.02	±0.00	
αChlordane	0.004	ND	ND	ND	ND
	±0.002				

Note: Fish from Hamilton, Bronte, Ganaraska, and Brockville were 5-7 year old males. Humber River fish were 5-7 year old females.

Source: V. Cairns, Department of Fisheries and Oceans

As a monitor of contaminant conditions throughout the Great Lakes, a program has been carried out by the Ontario Ministry of the Environment that involves analysis of contaminant content in spottail shiners. The data for Hamilton Harbour are given in Table 22.

K. Suns (personal communication) advised that: "While PCB residues over the 3-year interval (1984-87) decreased significantly ($p < 0.05$) in the North Shore collections, residue levels in all other collections, except Grindstone Creek, were in excess of the IJC Aquatic

Life Guideline of 100 ng/g. However, care should be taken in data comparison, because of the possible mix of age classes."

Greatest confidence is placed in the Northshore (QEW) and Grindstone Creek samples.

TABLE 22: Organochlorine concentrations in young-of-the-year spottail shiners from Hamilton Harbour (1984-1989). Values are means +/- standard deviation.

Sampling Site	Year	n	Total Length (mm)	Fat (%)	PCB (ng/g)	DDT (ng/g)	Mirex (ng/g)	Chlordane (ng/g)	BHC (ng/g)	HCB (ng/g)	OCS (ng/g)
North Shore	1984	4	73-4	4.6-0.4	602-113	91-23	TR	12-5	1-1	2-1	ND
(near golf course)	1987	6	76-3	5.0-0.4	338-33	33-30	TR	11-8	3-1	ND	TR
North Shore (QEW)	1987	6	62-10	3.9-0.4	257-58	45-34	ND	3-2	ND	TR	-
Northwest Shore	1989	5	72-1	4.8-0.8	292-54	51-7	ND	3-1	2-1	2.1	3.1
Cootes Paradise	1987	6	75-3	3.8-0.3	368-54	48-21	ND	8-5	2-2	ND	-
Grindstone Creek	1989	5	39-3	6.7-1.0	ND	77-44	ND	5-1	1-1	ND	ND

Source: Data courtesy K. Suns, OMOE, personal communication.

III.4.7.4 Fish Health in Hamilton Harbour

Fish tumour surveys conducted in Hamilton Harbour between 1973 and 1976 reported the occurrence of tumours on bottom dwelling fish such as carp, carp X goldfish hybrids, goldfish, white suckers and brown bullheads (Table 23). These surveys were repeated in 1983-84 to determine if tumour prevalence had changed in the last 10 years, and to compare tumour frequency with other sites in the Great Lakes.

III.4.7.4.1 Gonadal Tumours in Carp and Carp X Goldfish Hybrids

Gonadal tumours occur in carp and carp X goldfish hybrids in Hamilton Harbour (Table 23). The tumours are benign and are found most frequently in older fish. Gonadal tumours are rare in carp (1%) but very common in the carp X goldfish hybrids (100% in older males). Tumoured carp and tumoured and non-tumoured hybrids are sterile.

There has been little change in the occurrence of benign gonadal tumours in carp X goldfish hybrids since 1975. Tumour frequency in five year old male hybrids changed from 60% in 1975 (Sonstegard, 1977) to 52% in 1983 (DFO, Burlington). Sampling at other locations revealed that gonadal tumours were common in hybrids from upper Lake Huron (Kincardin), Rochester, Long Point on Lake Erie, the Welland River, and the Detroit River. The appearance of tumours at all sample locations, including the relatively clean site in Lake Huron, suggests a non-chemical etiology. The presence of gonadal tumours in carp X goldfish hybrids in Hamilton Harbour is probably not related to contaminant exposure.

III.4.7.4.2 Lip and Body Papillomas on White Suckers

Sonstegard (1976, 1977) reported the occurrence of benign papillomas on the lips and bodies of white suckers. Although papillomas were found on suckers throughout the Lake, fish from Hamilton Harbour (35%) and Sixteen Mile Creek (50%) were the most severely affected. There has been little change in the prevalence of papillomas on white suckers from Hamilton Harbour and Sixteen Mile Creek between 1973 and 1983-87. Data for 1983-87 are reported in Table 23.

The frequency of occurrence in Lake Ontario ranged from 5 to 60 percent. Prevalence exceeded 30 percent at all sites west of Toronto and in the area of Port Hope (Ganaraska River and Gage Creek) (Table 24). There is no evidence that papillomas are caused by chemical exposure. However, the increased prevalence in suckers from western Lake Ontario suggests a local problem.

The cause of epidermal papillomas on white suckers is unknown. Sonstegard (1977) reported the presence of a C-type virus in the lip papilloma but was unable to induce papillomas by exposing fish to the virus. Papillomas tend to shrink when affected fish are moved to a laboratory environment, suggesting that continued exposure to a biological or chemical agent is necessary to sustain the tumour. Sustained tumour prevalence in Hamilton Harbour between 1973 and 1983 indicates long term continuing exposure to etiological agents. The widespread distribution throughout Lake Ontario and in Lake Huron indicates that Hamilton Harbour is not the source of papillomas (Figure 25). The occurrence of papillomas in relatively clean sites at levels less than 10 percent suggests a non-chemical etiology.

The papilloma has no noticeable effect on the biology of white sucker populations in Hamilton Harbour. Spawning migrations were monitored in Grindstone Creek from 1980 to 1983. All year classes were represented in the population and there was no significant difference in growth, fecundity, fertility, percent hatch, fry survival and growth, and reproductive behaviour between normal and papillomatous fish (Cairns and Fitzsimons, 1988).

TABLE 23: Summary of lesions reported in Hamilton Harbour fish.

Species	Lesions	% Occurrence (N)
White sucker		
lip	neoplasia	39.0 (1200)
skin	neoplasias:	
	hyperplasia	0.6 (1200)
	papilloma/carcinoma	1.7 (1200)
liver	neoplasias:	
	carcinoma	2.7 (113)
	granuloma	4.4 (113)
gonad	testicular lesions:	
	seminoma	1.4 (71)
	hypertrophy	2.8 (71)
bladder	fibrosarcoma	1 (113)
Brown bullhead		
lip	neoplasia	25.4 (480)
skin	body neoplasia[1]	7.0 (480)
	barbel asymmetry	72.0 (480)
	ulcer	5.0 (480)
liver	gross anomalies[2]	10.5 (380)
	chlorangiolar carcinoma	1.6 (124)
Goldfish		
skin	ulcer	50-80 (N/A)
kidney	granuloma	51 (29)
	polycystic	6.3 (80)
gonad	neoplasia	30.0 (13)
Carp		
gonad	neoplasia	0.9 (220)
Carp X Goldfish		
gonad	neoplasia	52.0 (79)
	hermaphrodism	6.3 (79)
White perch		
kidney	glomerular nephritis	100.0 (43)

1: Total number of raised papillomas/carcinomas.
2: A total of 380 livers were observed. One hundred and twenty-four were analyzed histologically. Two were diagnosed as cholangiolar carcinoma.

Source: V. Cairns, GLLFAS, DFO

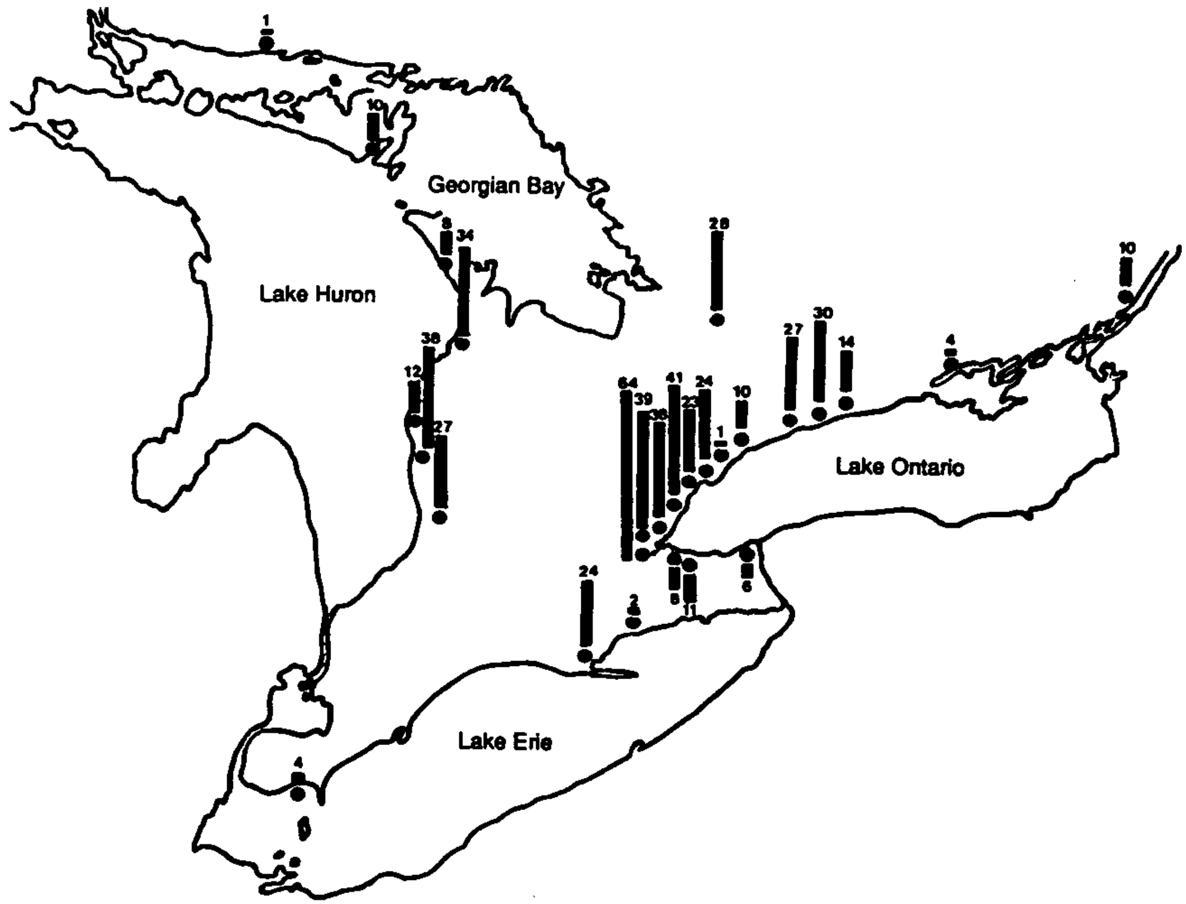
TABLE 24: **Percentage of occurrence of lip and body neoplasms[1] in white suckers from Lake Ontario. Data from 1981 to 1983.**

Site	Lip[2] (N)	Body[3] (N)
Vineland	9 (132)	0
Forty Mile Creek	23 (78)	2.5 (155)
Grindstone Creek	39 (1200)	1.4 (5284)
Spencer Creek	71 (146)	2.7 (146)
Bronte Creek	54 (109)	2.1 (147)
Sixteen Mile Creek	62 (111)	9.4 (160)
Credit River	34 (38)	2.5 (118)
Humber River	40 (58)	0.8 (335)
Rouge River	16 (96)	0.3 (347)
Graham Creek	19 (102)	5.0 (119)
Gage Creek	40 (99)	4.1 (192)
Coburg Creek	15 (102)	2.7 (146)
Bay of Quinte	5 (91)	2.7 (184)
Brockville	15 (177)	7.8 (192)
Lake Huron:		
Maitland River	40 (N/A)	(N/A)
South Bay	5 (280)	(N/A)

1: Neoplasms refer to single or multi-nodular growths. Not all of these lesions were confirmed histologically.
2: Mean percent occurrence for fish 7 years and older.
3: Mean percent occurrence for combined ages.

Source: V. Cairns, GLLFAS,DFO

Figure 25: The percentage of white suckers (Catostomus commersoni) 7 years and older from Lake Huron, Lake Erie and Lake Ontario with lip papillomas. Approximately 150-200 fish were collected from each site. Samples were collected between 1983 and 1987 by the Department of Fisheries and Oceans.



Source: Env. Cda., Dept. Fisheries and Oceans, Health and Welfare Canada, 1991.

III.4.7.4.3 Liver Tumours in White Suckers

White suckers from Hamilton Harbour are afflicted with liver lesions (Table 23) (Cairns and Fitzsimons, 1987). These included bile duct hyperplasia and low levels of hepatocellular carcinoma. The total prevalence of liver neoplasms in Hamilton Harbour was 3.4%, considerably less than the 7.4% found at Sixteen Mile Creek. Liver carcinomas were also found in white suckers from eight sites tested on Lake Ontario between Forty Mile Creek and the Ganaraska River (Figure 26). There were severe bile duct anomalies but no liver tumours in white suckers from the control site on Manitoulin Island. The occurrence of liver anomalies at all sites on Lake Ontario and also at the control site suggests a non-chemical etiology.

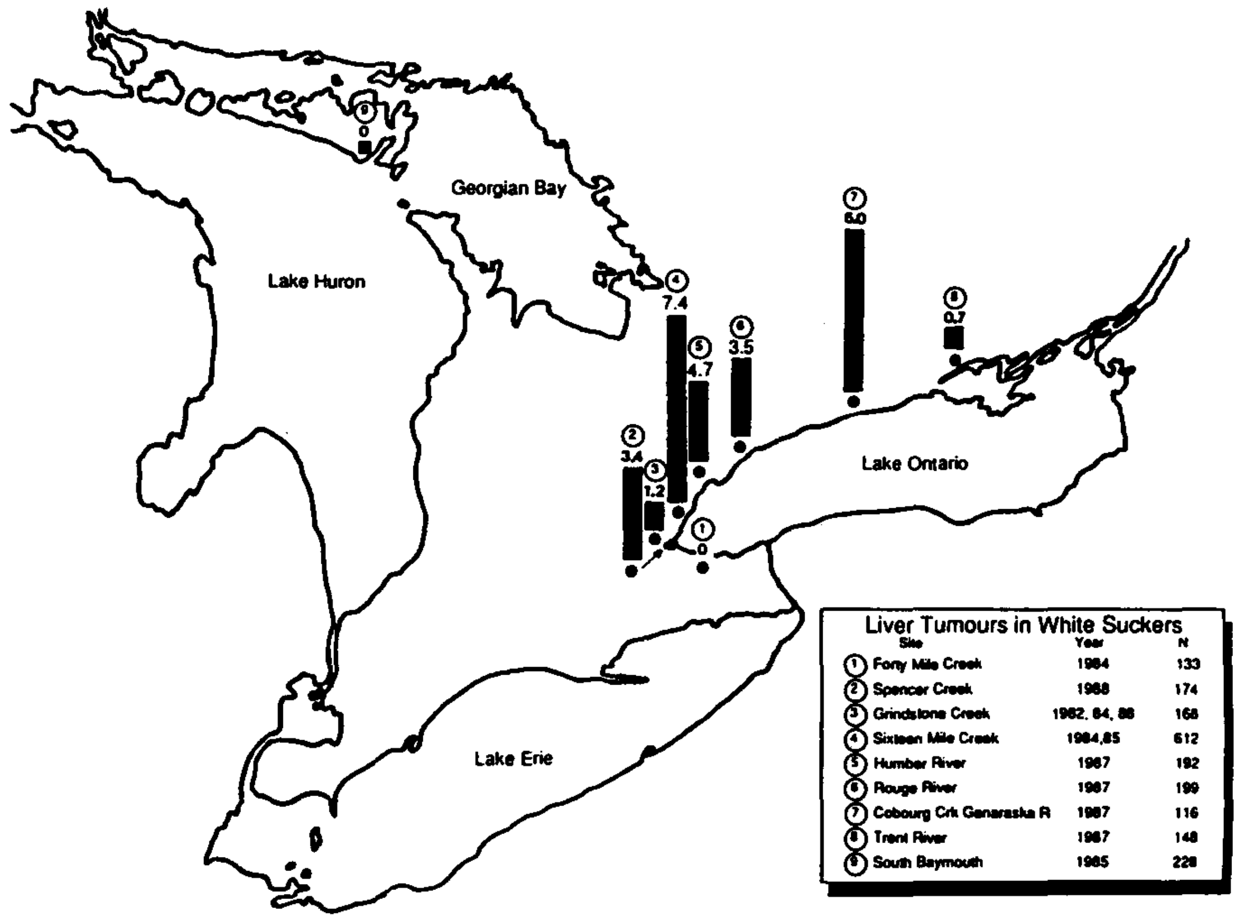
Hepatocellular tumours were found in white suckers from Hamilton Harbour, Sixteen Mile Creek, and the Humber River. They were not found in fish from the other sites. Hepatocellular tumours are often associated with contaminant exposure in laboratory induction experiments. The limited distribution of this tumour type strongly suggests a chemical association. The chemicals responsible are unknown but there are good data showing that some Hamilton Harbour sediments are heavily contaminated with mammalian carcinogens (PAHs). A tumour induction experiment in which Hamilton Harbour sediment extracts were injected into the yolk sacs of developing rainbow trout fry confirmed the carcinogenicity of the sediments. Twelve percent of the fry developed tumours within 14 months following a single exposure (Metcalfe et al., 1988).

III.4.7.4.4 Lip and Body Papillomas and Liver Lesions in Brown Bullheads

The prevalence of lip papillomas in brown bullheads from Hamilton Harbour declined from 80 percent in 1973-76 (sample size unknown) (Sonstegard, 1976) to 25 percent in 1983 (Table 23). This is similar to the percent occurrence reported by Baumann (1987) for bullheads from the heavily polluted Black River in Ohio and from Lake St. Clair.

Body lesions, which occur less frequently (7%) than the lip papillomas, appeared as flat, circular, black or brown plaques, or as raised growths. Fifty-eight percent of the body lesions examined histologically were invasive carcinomas (n=17). Only 1.6% of the brown bullheads had liver carcinomas. This is considerably less than the 80% reported for bullheads in the Black River (Baumann, 1987). Seventy-two percent of the barbels (used for sensory stimuli) were reduced to short stubby projections less than 5 mm in length. In some fish the barbel ended in a swollen mass. There are no data from other locations reporting the significance of this finding. However, the occurrence of ulcers and fin rot resulting from contact with contaminated sediments (by infectious or chemical agents) has been reported for marine species (Mearns and Sherwood, 1977).

Figure 26: **The percentage of white suckers (Catostomus commersoni) from Lake Ontario with liver tumours. Samples were collected between 1982 and 1987 by the Department of Fisheries and Oceans.**



Source: **Env. Cda., Dept. Fisheries and Oceans, Health and Welfare Canada, 1991.**

The cause of epidermal papillomas and carcinomas in brown bullheads is unknown. However, there is some information suggesting that exposure to contaminated sediments may induce papillomas (Black, 1982) and that papillomas increased in fish exposed to sewage effluent (Grizzle and Melitus, 1983). There are good relationships from other sites in Canada and the United States between high occurrence of liver tumours and elevated levels of PAHs in sediment. The low level of tumours in Hamilton Harbour bullheads is surprising given the amount of PAH contamination along the south shore. Bullheads tend to remain in the west end of the Harbour and exposure to contaminated sediments may be reduced because of limited movement into the most contaminated sites.

III.4.8 Wildlife

III.4.8.1 Introduction

Historically, the wetlands of Cootes Paradise and Hamilton Harbour provided a haven for thousands of migrant and resident waterbirds and a wide variety of marsh-dependent wildlife, including many commercially important species such as muskrat. However, documentation of this is largely restricted to passages in diaries, newspaper clippings and other writings, many unpublished. Dundas resident Charles Durand (1893) wrote that in 1818-19, Cootes Paradise " ....was a paradise for game of all kinds. Immense flocks of ducks and wildfowl, and wild animals innumerable in old times were seen there. It was also the resort of wild fur animals, such as the otter, perhaps beaver, fisher, minks and especially muskrats; snakes were abundant there of all kinds". In 1861, Thomas McIllwraith, a prominent Hamilton area ornithologist, described flocks of waterfowl in Hamilton Harbour "....so great as frequently to darken the light of the sun by day, and make the night hideous with their discordant cries".

Though superficial, these accounts do give an indication that wildlife in the area was of very different character than it is today. The most comprehensive attempt to define those changes, with particular reference to waterbirds, was recently prepared by the Canadian Wildlife Service (Gebauer et al., in prep. a). Trends have emerged from the analysis which indicate that more species were common residents of the Harbour before 1948.

Undoubtedly, the loss of marsh habitat has had a profound effect on the composition, distribution and/or abundance of wildlife communities in Cootes Paradise and Hamilton Harbour. Waterfowl, rails, grebes, muskrats, and bullfrogs are all highly dependant on wetland vegetation for food, shelter, loafing and nesting. By 1979, an estimated 74% of shoreline marshes of Hamilton Harbour and Cootes Paradise had disappeared in the previous 150 years (Whillans, 1982). A further reduction in marshes has occurred since 1979 to an estimated 50 hectares in 1985 of the original 500 hectares. While the impact of these habitat reductions on wildlife in both Cootes Paradise and Hamilton Harbour is currently only partially understood and documented, the available information shows that many marsh-dependant wildlife species have either declined or have died out completely.

Geographically the Cootes Paradise/Hamilton Harbour area lies within two broad and overlapping life zones: the Great Lakes-St. Lawrence and the Carolinian. Consequently, the flora and the fauna reflect elements of both of these major biomes.

The Stakeholders have identified the open water area of Hamilton Harbour and 5 shoreline areas within the basin as having significant wildlife associations and therefore requiring protection/enhancement in the RAP (Hamilton Harbour Stakeholders, 1986). The current status of the wildlife communities will be discussed in detail for each sub-area within the Harbour.

III.4.8.2 Sub-area Physical Descriptions

III.4.8.2.1 Cootes Paradise

Cootes Paradise is an 840 hectare wildlife sanctuary located at the extreme western end of Hamilton Harbour. The sanctuary is managed and almost wholly owned by the RBG. It has been classified by OMNR as a Class I wetland (MNR, 1987), an Area of Natural and Scientific Interest (ANSI) and is a Hamilton Region Conservation Authority Environmentally Sensitive Area (ESA). The Canadian Wildlife Service has described the western end of Lake Ontario including Cootes Paradise as an important waterfowl staging area in Lake Ontario (Dennis et al., 1984). This use of the Great Lakes is important on a regional, provincial, national and international scale.

Cootes Paradise is comprised of roughly 50% terrestrial upland habitat and 50% wetland habitat. The vegetation of the uplands is primarily climax forest with maple and oak predominating. Marsh vegetation comprises approximately 20% of the total wetland area, the remainder being open water. The shoreline is deeply indented, particularly on the south shore where numerous wooded ravines terminate in small coves or inlets. There are four major hydraulic inputs (Hopkins Creek, Chedoke Creek, Spencer Creek, and the town of Dundas STP).

III.4.8.2.2 Hendrie Valley/Carrolls Point

Hendrie Valley/Carrolls Point is an area of approximately 150 ha located in the lower reaches of Grindstone Creek. The creek is a major watercourse whose headwaters originate above the escarpment in Flamborough and flow south from Waterdown. The Royal Botanical Gardens owns and manages the area, including the Carrolls Point water lot. This area has been designated an ESA in Halton Region. The vegetation is mixed deciduous forest on the slopes, with a small portion of open wet meadow and marshy bottomland where several small ponds vegetated with cattail and manna grass are located.

III.4.8.2.3 Pier 27 (Tollgate Ponds)

Pier 27 is an area of approximately 28 hectares in the southeast corner of Hamilton Harbour currently utilized for contaminated Harbour dredgeate disposal by the Hamilton Harbour

Commissioners. It is composed of two large ponds surrounded by rubble berms, and is gradually being filled with dredgeate. The berm at the less disturbed north end is vegetated with shrub willows (Salix sp.) and young eastern cottonwood trees (Populus deltoides). This area has been designated an ESA in Hamilton-Wentworth Region.

III.4.8.2.4 Hydro Islands

The Hydro Islands are located in the northeast corner of Hamilton Harbour and consist of two stone islands originally constructed to provide foundation for large hydro transmission towers. The towers have been removed from the islands. The islands provide breeding habitat for colonial waterbirds. The Hydro Islands have been designated an ESA in the Hamilton-Wentworth Region.

III.4.8.2.5 Windermere Basin

Prior to dredging in 1989, Windermere Basin was a 40 hectare, shallow (0.7-1.0 m) water basin, located at the southeast corner of the Harbour. It receives hydraulic inputs from Redhill Creek, Stelco, and the Hamilton STP. After dredging and the creation of berms, the water surface area decreased to about 18 ha with an increase of the mean depth overall to about 2.5 m for an average summer.

III.4.8.2.6 Van Wagner's Ponds

The area known locally as the Van Wagner's Ponds (or Van Wagner's Marsh) is a significant natural wetland in the Hamilton area. It includes the marsh area near the mouth of Redhill Creek on the south side of the QEW, and the two ponds on the north side of the QEW, and is one of few remnants of the once extensive shoreline marshes of Lake Ontario.

III.4.8.3 Birds
III.4.8.3.1 Cootes Paradise

Though detailed information exists at RBG for terrestrial bird species, the present discussion is confined to waterbirds. It is sufficient to point out that breeding bird densities and species diversity are higher in the terrestrial habitats of the north shore when compared with those of the wetland habitats.

The marshes that border the west end of Cootes Paradise contain breeding rails, coots and marsh wrens in small numbers, some species of which breed rarely in this region. West Pond is also frequented by several species of dabbling ducks, principally, American black duck (Anas rubripes), common merganser (Mergus merganser), and in the deeper Canal, hooded merganser (Lophodytes cucullatus) during migration. There is also some evidence that wood ducks, (Aix sponsa) blue-winged teal (Anas discors) and Canada geese (Branta canadensis) still breed in this area in small numbers and in 1977 the last known breeding attempt of the black tern (Chlidonias niger) reportedly occurred here. Herons and egrets regularly feed in West Pond. The remnant marsh which borders the south side of the Spencer Creek willow line still provides breeding habitat for small numbers of bitterns, rails and marsh wrens. A small pond formed by a break in marsh vegetation contains concentrations of waterfowl especially during spring migration, and affords good feeding areas for herons particularly the black-crowned night-heron, (Nycticorax nycticorax).

On the north side of the Spencer Creek willow line, heavy autumn concentrations of dabbling ducks, principally, green-winged teal, (Anas crecca), mallard (A. platyrhynchos), gadwall (A. strepera) and wood duck occur. In addition osprey (Pandion haliaetus), herons and egrets are frequently seen feeding during migration.

At the end of the willow line, during low water years, an extensive mudflat is created. During 1984/85 a total of 27 species of shorebirds was recorded. This is considered one of the best areas in southern Ontario to observe shorebirds in the fall. In addition, it is an excellent feeding area for herons, egrets and all species of dabbling ducks, especially green-winged teal and northern pintail (A. acuta). The mudflats are also known for large concentrations of loafing terns and gulls. Seven species of the latter were recorded in 1984/85.

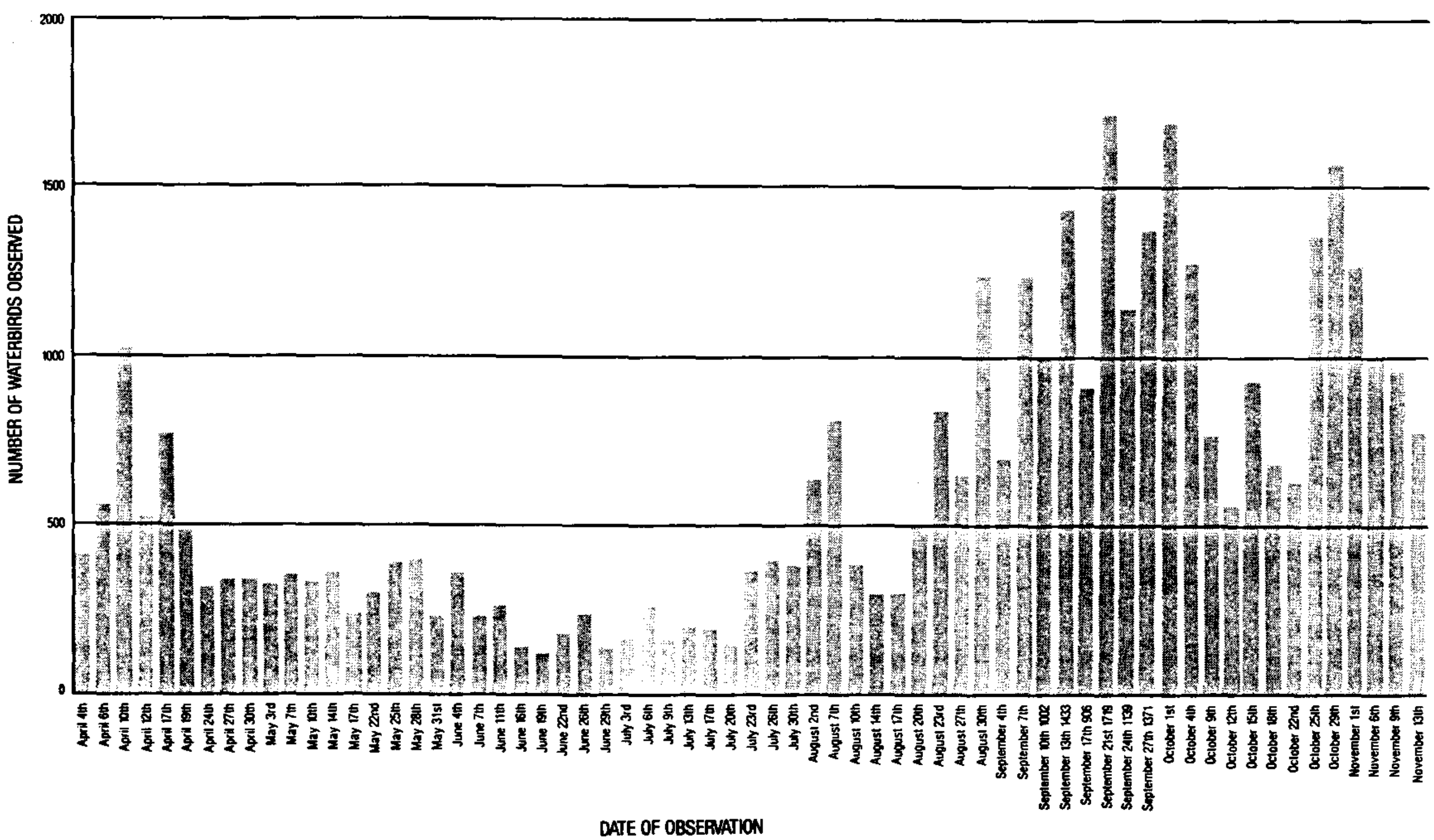
The central open water area of Cootes Paradise is principally used by migratory ducks, especially diving ducks. This is the only area in Cootes Paradise that common loons, (Gavia immer), red-necked grebes (Podiceps grisegena) and horned grebes (P. auritus) are recorded. During the fall and early winter, large numbers of common mergansers are observed feeding in this area until Cootes freezes. The old Desjardins Canal pilings provide an important preening location for double-crested cormorants (Phalacrocorax auritus), common terns (Sterna hirundo), herring gulls (Larus argentatus) and great black-backed gulls (Larus marinus).

The aquatic areas at Princess Point/Chedoke Creek mouth are important waterbird concentration areas. In early spring, open water attracts early migrant waterfowl. In the fall, when water levels are lower, there are large numbers of dabbling ducks, especially gadwall and American black duck. As well, gulls and a variable number of Canada geese congregate during the fall.

There are a number of smaller remnant marshes which rim Cootes Paradise shoreline and they provide limited breeding habitat for a small number of regionally rare species such as the sora rail (Porzana carolina) and least bittern (Ixobrychus exilis).

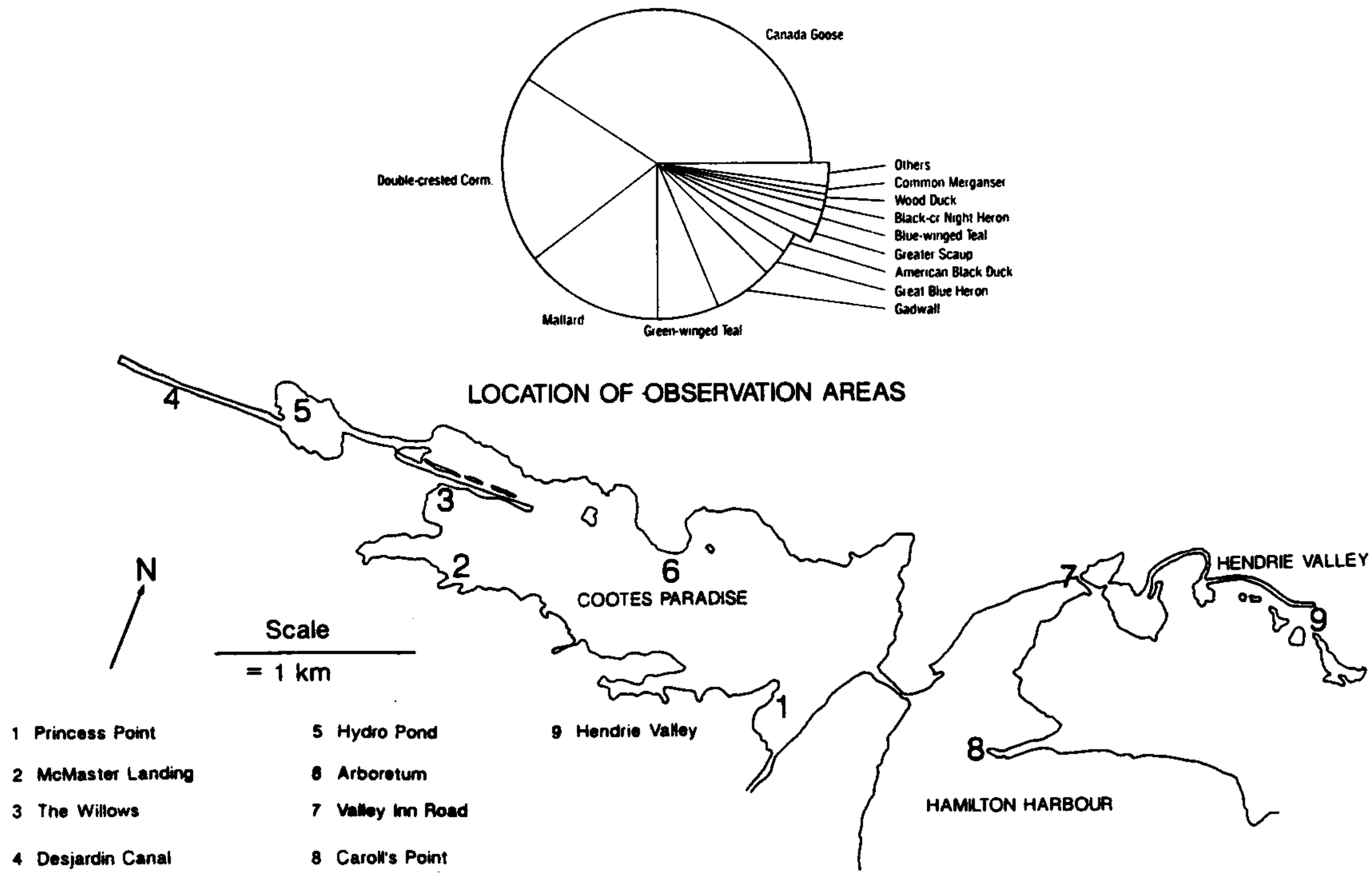
During the open water season of 1990, waterbird usage of Cootes Paradise and the surrounding western end of Hamilton Harbour was surveyed (Simser et al., 1991). Of the total of 38 species which were recorded, 75% were represented by three species (Canada Goose 40%, Double-crested Cormorant 20%, Mallard 15%). Twenty-nine of the species had totals which represented less than 1% of the total community composition (Figure 27 and Figure 28).

Figure 27: Graph of the number of waterbirds observed in Cootes Paradise and the Hendrie Valley during the spring, summer and fall of 1990.



Source: L. Simser <u>et al</u>., 1991.

Figure 28: **Graph of the composition of the waterbird population of Cootes Paradise and the Hendrie Valley observed during the spring, summer and fall of 1990.**



Source: **L. Simser <u>et al</u>., 1991.**

III.4.8.3.2 Hendrie Valley/Carrolls Point

Waterbird usage of this area has three principal concentration points. A small patch of cattail near the Desjardin Canal supported two species of breeding birds in 1984: the mute swan (Cygnus olor) and common moorhen (Gallinula chloropus). Both species are rare in the region. The open water in Carrolls Point bay is heavily utilized by nesting and migrating waterfowl. Diving ducks are very common here during spring and fall. During the winter, loafing gulls, particularly greater black-backed gull, and glaucous gull (Larus hyperboreus) are associated with this area. At the mouth of Grindstone Creek, when low autumn water levels expose mudflats, many species of shorebirds, such as the common snipe (Capella gallinago), congregate. This area is heavily utilized for feeding by black-crowned night-heron, osprey, and dabbling ducks, particularly gadwall (Simser et al., 1991).

III.4.8.3.3 Pier 27

The most outstanding feature of this area is the density and diversity of nesting colonial birds (Dobos et al.,1988). The cottonwood trees provide nesting sites for a large colony of black-crowned night- herons. The night-heron colony has been expanding steadily since 1975 when six nests were discovered (Dobos et al., 1988)). In 1987, the colony contained 212 active nests, but it has since decreased to 44 nests in 1991. The first cormorant nest was found on the ground in 1984. Since 1985, they have increased dramatically in the cottonwood trees to 405 nests in 1991. The first nesting of the snowy egret (Egretta thula) in Canada occurred here in 1986 (Curry and Bryant, 1987). It has not returned in subsequent years.

The berms and filled cells of the containment area support a large ring-billed gull (Larus delawarensis) colony, which numbered over 21,000 nests in 1991. This is one of the largest gull colonies on the lower Great Lakes. About 300 herring gull nests and 200 Caspian tern (Sterna caspia) nests are located around the gull colony. The Caspian tern is considered to be a rare species in Ontario and Canada (Cadman et al., 1987). Common Terns have nested here in recent years as well.

Other species which nest on the berms around the ponds are Canada goose, mallard, gadwall, spotted sandpiper (Actitus macularia) and killdeer (Charadrius vociferus). Species which have nested in the past include green-winged teal, marsh wren (Tetmatodytes palustris), common moorhen and American coot (Fulica americana); all are regionally significant breeding species.

The ponds are used for staging by large numbers of migratory waterfowl in the autumn. Many species of shorebirds feed at the mudflats along the shores of the ponds during late summer and autumn, including several species rare to Ontario, such as the American avocet (Recurvirostra americana) and willets (Catoptrophorus semipalmatus) in 1987 (Jennings, 1987).

III.4.8.3.4 Hydro Islands

Until recently, Common Terns have nested on these two islands, with up to 402 pairs in 1987 (Dobos et al., 1988). During the late summer and early fall double-crested cormorants use the islands for resting and preening. However, they have been displaced by nesting Ring-billed Gulls since 1989. Black-crowned night-herons have started nesting in the shrubs on Farre Island in 1990, and there were 14 nests in 1991.

III.4.8.3.5 Windermere Basin

Local naturalists know this area to be regionally significant for waterfowl during the autumn and winter. Waterbird surveys of the Basin were conducted by CWS in the autumn of 1986. The average number of birds present per count was 1867, with the most numerous species being scaup (Aythya sp.), American black duck, mallard, and bufflehead (Bucephala albeola) (Gebauer et al., in press). Average numbers of waterbirds during winter surveys increased to 4,648 birds per count. Regionally significant species of waterfowl, which overwintered at the Basin, include green-winged teal, northern pintail, northern shoveler (Anas clypeata), redhead (Aythya americana), hooded merganser and ruddy duck (Oxyura jamaicensis).

In 1989 Common Tern started nesting at Windermere Basin on the newly constructed berms. By 1991 approximately 600 pairs nested at this site.

During low water periods in the late summer and autumn, migrating shorebirds, including species rare in Ontario, are attracted to the exposed sludge bank in large numbers. In 1990, shorebird species were found during regular surveys at Windermere Basin (Gebauer et al., in prep. b). Recent rare sightings include a piping plover (Charadrius melodus) (Jennings, 1986a), an endangered species, an American oystercatcher (Haematopus palliatus) (Jennings, 1986b), and a Wilson's Plover (Charadrius wilsonia) (McLaughlin, 1990) (only the second record for Ontario).

Areas of marsh vegetation along the shore of Windermere Basin are the only remnants of the once extensive marshes of Hamilton Harbour. These areas provide nesting habitats for several bird species including mallard, gadwall, American black duck, green-winged teal, and common moorhen. At least 30 broods of waterfowl were observed there during the summer of 1987 (CWS, unpublished data).

III.4.8.3.6 Van Wagner's Ponds

This area has substantial areas of emergent aquatic vegetation (mostly cattail) which provide nesting habitat for a number of regionally significant bird species. It also has extensive submergent aquatic vegetation (pondweed and water lilies) which provides food for a large number of waterbird species (Dobos, 1989).

The black tern, a provincially rare breeding species, has nested here for many years. The last recorded nests were in 1989. Since 1978, this area has been the only nesting site in the region. The least bittern, another provincially rare breeding species, has also nested here in recent years. This area was one of two regional breeding sites. The green-backed heron, common moorhen and pied-billed grebe, all regionally significant breeding species, have nested at Van Wagner's Ponds. Other marsh birds regularly use the area as a feeding site, such as great blue heron, great egret, black-crowned night-heron, Virginia rail, sora rail, American coot, Caspian tern, common tern, belted kingfisher, and marsh wren. Some of the rare marsh birds seen here include eared grebe, snowy egret and Forster's tern.

The Van Wagner's Ponds are an important staging area for migratory shorebirds and waterfowl. During periods of low water levels, exposed mudflats attract at least 25 species of shorebirds, including rare species such as willet, Hudsonian godwit, western sandpiper, and piping plover (an endangered species). Waterfowl which regularly use the ponds include all of the regular puddle duck species, plus redhead, lesser scaup, and hooded merganser.

The Van Wagner's Ponds area is a migration point for landbirds as well. This area provides an island of habitat for birds which migrate along the shore of Lake Ontario. Several rare species, including bald eagle, merlin, peregrine falcon, little gull, yellow-billed cuckoo, snowy owl, black-backed woodpecker and western kingbird, have been observed there. The terrestrial habitat around the ponds also provides breeding habitat for many common species of birds.

III.4.8.3.7 Hamilton Harbour

Hamilton Harbour has a diverse and abundant waterbird population associated with it. CWS waterbird surveys in the autumns of 1985 and 1986 recorded approximately 1200 birds per count composed of up to 43 species (Gebauer et al., in press). Birds were generally concentrated in groups at specific locations around the Harbour. The LaSalle Park Marina, the Hamilton marinas, and the northeast shoreline areas had the greatest numbers of birds per survey. The western end, Lax landfill, LaSalle Park Marina and the northeast shoreline areas had the greatest number of species of waterbirds. The steel factory shoreline, the centre of the Harbour, the Burlington residential shoreline, and the highway and railway shorelines had the fewest numbers and species.

One of the best spring and fall concentrations of waterfowl, namely scoters (Melanitta sp.), tundra swans (Olor columbianus) and mergansers, is located directly below the Woodland Cemetery near the northwest shore.

III.4.8.4 Contaminants in Birds

The earliest studies of contaminants in birds from Hamilton Harbour date from 1970 when Gilbertson (1972) reported HCB, dieldrin, DDE and PCBs in common tern (Sterna hirundo) eggs from the Hydro Islands. This was the first reported instance of HCB in avian tissue.

In 1971, Gilbertson (1974) conducted further investigations which showed that the terns which nested on the Hydro Islands returned in the spring relatively free of contaminants but the residue levels in their eggs increased with later dates of laying. Eggs laid in June had higher contaminant burdens than those laid in May. He also discovered deformities, suspected of having been mediated by contaminants, among terns nesting on those islands (Gilbertson et al., 1976).

Few studies were conducted within the Harbour itself during the remainder of the 1970s. Herring gull eggs from the Harbour were sampled in 7 years between 1981 and 1991. In 1981, DDE, PCBs (1:1, Aroclor 1254:1260) and Mirex levels were 11, 79 and 1.9 mg/kg (wet weight), respectively, whereas in 1991, those same contaminants were 3.0, 17 and 0.50 mg/kg, a reduction of 73 - 79% (CWS, data files).

In 1981/82, a Lake Ontario-wide survey was done of contaminant levels in herring gull eggs. Eggs from 8 Lake Ontario sites, including Hamilton Harbour, showed no significant variation in contaminant levels among sites (except for one compound at one site) (Weseloh and Struger, 1985). In other words, contaminant levels in herring gull eggs from Hamilton Harbour were neither significantly higher nor lower than those from other Lake Ontario sites. In a 1983 study of lead, cadmium and mercury levels in herring gulls from four Great Lakes sites, adult gulls from the eastern Harbour had the highest levels in 25% of the cases. Kidney levels of lead and cadmium were 6.90 and 2.16 mg/kg (wet weight), respectively, and liver levels of mercury were 1.36 mg/kg. Eggs and young of herring gulls nesting at Pier 27 had elevated levels of both organics and heavy metals, when compared to Great Lakes samples (CWS, data files; Struger et al., 1987).

However, the recent breeding success of several colonies of fish-eating birds in the Harbour, including common and Caspian terns, is cause for guarded optimism. In 1991, Caspian terns at the main colony in Hamilton Harbour produced 1.61 young per active nest. This productivity was the highest measured among Caspian terns on seven colonies in Lake Ontario, Huron and Michigan. It should also be noted that levels in gulls probably represent the integration of levels in food from distances within 5 to 10 miles from the colony site. Thus levels in Hamilton Harbour gulls are not indicative of only Hamilton Harbour.

It is paradoxical that some populations of water birds congregate in the east end of Hamilton Harbour where the sediments are known to be contaminated with organics and heavy metals, and the habitat has deteriorated to a point where it is substandard at best. Many birds breed in the area during the spring and are attracted to the area for migrational staging and overwintering. Wildlife in this area has been shown to accumulate high levels of contaminants and to suffer significant health problems. Many of the birds ingest highly contaminated food. In a 1986 study, flightless domestic ducks were released into Windermere Basin and two other sites. Those at Windermere accumulated PCB residues almost 50 times greater than ducks at the other locations. Lead levels were also greatly elevated in Windermere Basin birds compared to those from the other sites. There are strong suggestions that lead was the prime causative factor in the die-offs of both the domestic ducks and an earlier case involving wild ducks at Windermere (CWS and MOE, unpub. data). This area produces or has the potential to produce contaminated birds and other wildlife, and this condition could not be allowed to persist. For this and other reasons Windermere Basin sediments have been dredged and are now being confined behind berms along the shores on either side of the remaining channel (1991).

Young and adult mallard ducks from Hamilton Harbour were surveyed for contaminants in 1988 by the Ontario Ministry of Natural Resources (Glooschenko et al., 1989). Analyses included octachlorostyrene, 7 PCB congeners, hexachlorobenzene and pentachlorostyrene. Liver and muscle tissues were both investigated and data from 5 sites around the Great Lakes were compared. The specific site from which the Hamilton Harbour ducks were taken was Windermere Basin. The data of greatest concern were PCB data for the Windermere Basin ducks. PCB congeners 138, 153, and 180 were significantly higher (up to 433 ppb in liver) for Hamilton Harbour mallards than any other area (Welland R., Amherst Is., Detroit R., and Cornwall Is.). While no statement has been issued in Canada regarding acceptable daily intake levels of PCBs in waterfowl at this time, the levels are a concern.

In 1989, CWS conducted a survey of contaminants in six species of birds nesting at Pier 26 to 27 (Table 24). DDE levels ranged from 0.23 to 5.0 ppm (wet weight) and were well below levels known to cause eggshell thinning in those species. PCB levels in Canada Geese were very low, comparatively, 0.91 ppm, but for the other five species they ranged from 11 to 25 ppm. On a lipid weight basis, PCB levels in the eggs of those five species were approximately 200 to 800+ times higher than the human consumption guidelines for poultry (0.5 ppm in fat). While humans do not eat eggs of any of these species on a regular basis, other wildlife do. These eggs would appear to be a highly contaminated food source for other wildlife of the Hamilton Harbour area.

In a 1990 study, the Canadian Wildlife Service released captively-raised Mallards at the Pier 26-27 CDFs and analyzed them at subsequent intervals. At Day 0, the Mallards has lipid weight values of 0.43 ppm PCBs and 0.29 ppm DDE. At the 10 to 30 day interval, levels in control birds were 0.63 and 0.21 ppm while those in ducks from the CDF had increased to 11.7 ppm and 1.5 ppm, respectively (arithmetic means, N=10). This represents a nearly 20-fold increase over levels in the control birds for PCBs and a 7-fold increase for DDE. When it is considered that Canadian guidelines for total PCBs in poultry fat is 0.5 ppm (lipid weight)(Wong, 1985), the levels in the released ducks become quite significant. If these results can be applied to the wild situation, they suggest that Mallards which stop over and feed in these CDFs, even for a few days during autumn migration, may accumulate PCB levels which exceed human consumption guidelines for poultry.

With the completion of the sediment remedial work in Windermere Basin in 1991 or 1992, follow-up work will be required to confirm its efficacy.

TABLE 25: Results of a survey of DDE and the total PCB levels in pooled egg samples of six nesting bird species from Pier 26 and 27.

	DDE	PCBS	
	Wet Weight	Wet Weight	Lipid Weight
Double-crested cormorant	3.90	20.0	(435)
Black-crowned night-heron	2.60	25.0	(446)
Canada goose	0.23	0.91	(6.5)
Herring gull	5.00	24.0	(273)
Common tern	1.80	11.0	(118)
Caspian tern	3.80	21.0	(244)
Source: Canadian Wildlife Service, 1989			

III.4.8.5 Specific Concerns for Bird Populations

Migratory bird species, in addition to being exposed to the cumulative effects of contaminants, must cope with a dwindling but vital food supply during migration. Surveys by CWS indicate that the remaining marshes along the Lake Ontario shoreline are extremely valuable as waterfowl concentration areas in spring and fall (Dennis and Chandler, 1974). Therefore, any efforts to expand food production in the remaining marshes will have a beneficial effect on waterbirds. Some adaptable birds, mainly scavengers, have benefitted from habitat alterations, and now numerically dominate the resident wildlife community structure.

The major concerns for wildlife in the eastern Harbour area are: 1) the occurrence of heavy metals and toxic organics in the sediments of Windermere Basin, in the surficial sediments of the Harbour, and in the confined disposal facilities (CDFs) of the Hamilton Harbour Commissioners; 2) the impact of these contaminated sediments upon wildlife; 3) the future development plans (resulting in habitat loss) for Windermere Basin and areas known locally as the Hydro Islands and Pier 27.

The dredging plan for Windermere Basin is evolving in a manner that may provide for wildlife concerns. At Pier 27, property owned by the Hamilton Harbour Commissioners, the future is not yet assured. The Commissioners have said that they have no plans for the area for the immediate future, i.e. 10 to 15 years. However, eventually they may want to put warehouse facilities, or some similar development, on the site. That development would displace the nesting colony of some 25,000 pairs of gulls, terns, herons and cormorants which currently breed there. The question is, given the long lead time before development is to take place, could the birds be encouraged to move to some other nearby, man-made or natural, nesting area? And if so, where, when and how? Less desirable species, like ring-billed gulls, will almost certainly move with little or no problem. However, for other species which are more sensitive to disturbance, e.g. Caspian terns, there is no known precedent for "moving" them from one site to another.

III.4.8.6 Herpetofauna
III.4.8.6.1 Cootes Paradise

Significant concentrations of frogs and turtle species still occur in many localized wetland habitats. Frogs are especially abundant wherever vegetation remains flooded throughout spring and fall. The northern leopard frog (Rana pipiens) and American toad (Bufo americanus) are the most common species and are well distributed in all marshy areas, but especially abundant in the old Spencer Creek bed. The green frog (Rana clamitans melanota) also occurs here. The western chorus frog (Pseudacris triseriata) is uncommon and found in small patches of marsh vegetation.

Turtle populations in Cootes Paradise are high in species diversity and abundance. The preferred areas of concentration are those which provide good basking sites and readily available food such as in the old Spencer Creek bed, Westdale Inlet and backwater ponds at the extreme western end. One of the latter ponds rivals other sites in North America as the highest estimated density of the midland painted turtle (Chrysemys picta marginata). Similarly, snapping turtle (Chelydra serpentina) densities in the western end of Cootes are considered very high, when compared to other sites, especially during breeding season in early June, when many females seek a suitable substrate for egg laying. The shoreline in this area provides good opportunities for this activity, and it is likely that the largest segment of the population in the western end resides there. Small populations of turtles such as Blanding's (Emydoidea blandings), found only in the old Spencer Creek bed, have quite restricted distribution, while a regionally uncommon species of the map turtle (Graptemys geographica) occurs in fair (20-30) numbers in Westdale Inlet.

III.4.8.6.2 Hendrie Valley/Carrolls Point

Reptile and amphibian populations of the area are characterized by species which are local or regionally significant. For example, both bullfrog (Rana catesbeiana) and pickerel frog (R. palustris) still occur in backwater ponds bordering the lower Grindstone Creek, albeit in restricted numbers. In addition, there is a large population of map turtles present, and an eastern spiny soft shell turtle (Trionyx spiniferus spiniferus) was sighted on two occasions in

1984 and one specimen was caught in 1982. This latter species is considered extremely rare and, at one time, was thought to have been extirpated from Lake Ontario (Campbell, 1977).

III.4.8.6.3 Windermere Basin

Wildlife known to occur in the Basin include muskrat, eastern cottontail (Sylvilagus floridanus), ring-necked pheasant (Phasianus colchicus), midland painted turtle and common snapping turtle.

III.4.8.6.4 Van Wagner's Ponds

The abandoned railway bed which bisects the ponds provides nesting sites for common snapping turtles and midland painted turtles.

III.4.8.7 Contaminants in Turtles

In a study of organochlorine levels in snapping turtle eggs from 10 sites in southern Ontario, eggs from Hamilton Harbour had the highest levels of PCBs (8.59 mg/kg, wet weight), oxychlordane (0.074 mg/kg), trans-nonachlor (0.02 mg/kg) and dieldrin (0.06 mg/kg) (Struger et al., in prep.). Dioxins (PCDD) and furans (PCDF) were detected in eggs in 1984 from Cootes Paradise (Struger et al., in prep) and again 1988 (Bishop et al., 1991). In 1988, three PCDDs and one PCDF were detected in eggs from Cootes Paradise while six PCDDs and four PCDFs detected in eggs from Lynde Creek (near Whitby). PCDD and PCDF levels were also present at higher levels in Lynde Creek eggs than those from Hamilton Harbour eggs.

The significance of those contaminants in the common snapping turtle has been examined in Cootes Paradise, through comparison with four other sites (Bishop et al., 1991). "The hypothesis that elevated incidences of egg death and/or deformities of hatching turtles would occur in populations with high concentrations of organochlorine contaminants in eggs was tested" using epidemiological criteria for data collected from 1986 to 1989. The combined rates of egg deaths and deformity rates for Cootes Paradise, Lynde Creek and Cranberry Marsh (all on Lake Ontario) were as high as 60%, 38% and 32% respectively (Bishop et al., 1992). This was in marked contrast to Big Creek Marsh on Lake Erie and Lake Sasajewun in Algonquin Park where turtle eggs have maximum combined rates of egg deaths and deformities of 12% and 5% respectively (Bishop et al., 1991). Also, incidences of ill health and deformities in adult snapping turtles in Cootes Paradise have been documented (Bishop et al., 1991). "This study indicates that a link between exposure to contaminants and developmental success exists" although the specific mechanism of action and the specificity of any single chemical needs further investigation.

III.4.8.8 Mammals
III.4.8.8.1 Cootes Paradise

Sixteen species of large mammals occur here. They range from a small mobile herd of less than 20 white-tailed deer (Odocoileus virginianus), which roam freely in distinct travel corridors between the north shore of Cootes Paradise and the Niagara Escarpment, to a large and well distributed population of raccoon (Procyon lotor), which intermixes with high density housing on the south shore. The principal semi-aquatic mammals are mink (Mustela vison), muskrat (Ondatra zibethica) and beaver (Castor canadensis). One beaver was recorded living in a bank den in the lower reaches of Spencer Creek in 1984. The muskrat population, estimated at less than 100 individuals, is confined to small localized pockets of emergent vegetation, primarily cattail (Typha sp.) and manna grass (Glyceria maxima), which rim the Cootes Paradise basin. Muskrats are concentrated in West Pond and in bank dens along Spencer Creek. Mink are present in unconfirmed numbers and are commonly associated with the streams of the north shore.

III.4.8.8.2 Hendrie Valley/Carrolls Point

Muskrats are found along the Grindstone Creek wherever suitable habitats exist. Bank dens and lodges in the ponds are currently utilized. In 1984, 30 individuals were counted and in 1985, 17 individuals were live-trapped along the creek. Mink were confirmed in 1984 but not quantified.

III.4.9 Fish and Wildlife Habitat, and Wetlands

The two previous sections on fish and wildlife describe aspects of the habitat changes that represent a major stress on these populations. It is hard to overestimate the significance of shallow waters and shoreline conditions on the biological characteristics and productivity of Lake Ontario in general, and of Hamilton Harbour and Cootes Paradise in particular (see, for example Dalziel, 1988). Aquatic birds, wildlife and fish depend critically on shallow and marshy zones for spawning/nesting habitat for nursery areas and for food.

In the case of many fish species, submerged weed beds are needed to supplement the shallow marshes or natural shore zones and beaches. Colonial water birds need cleared land close to water for nesting. Finally, many amphibious and land animals need the close linkage of natural land habitat adjacent to natural shoreline. There are necessary links to be maintained to ensure the existence of a range of habitats and their connectivity.

Wetlands bordering the Great Lakes are a matter of common interest for fisheries and aquatic birds. The planning for their restoration will require close collaboration. Recent developments that could assist in this collaboration and in the restoration of suitable habitat include:

1. Ontario Ministry of Natural Resources (MNR) - Cambridge District Fisheries Management Plan, 1989-2000 (published, 1989).

   This plan recommends management emphasis on rehabilitating fish habitat in Cootes Paradise and Hamilton Harbour through cooperation with other agencies and implementation of structural habitat improvements as outlined in the final RAP.

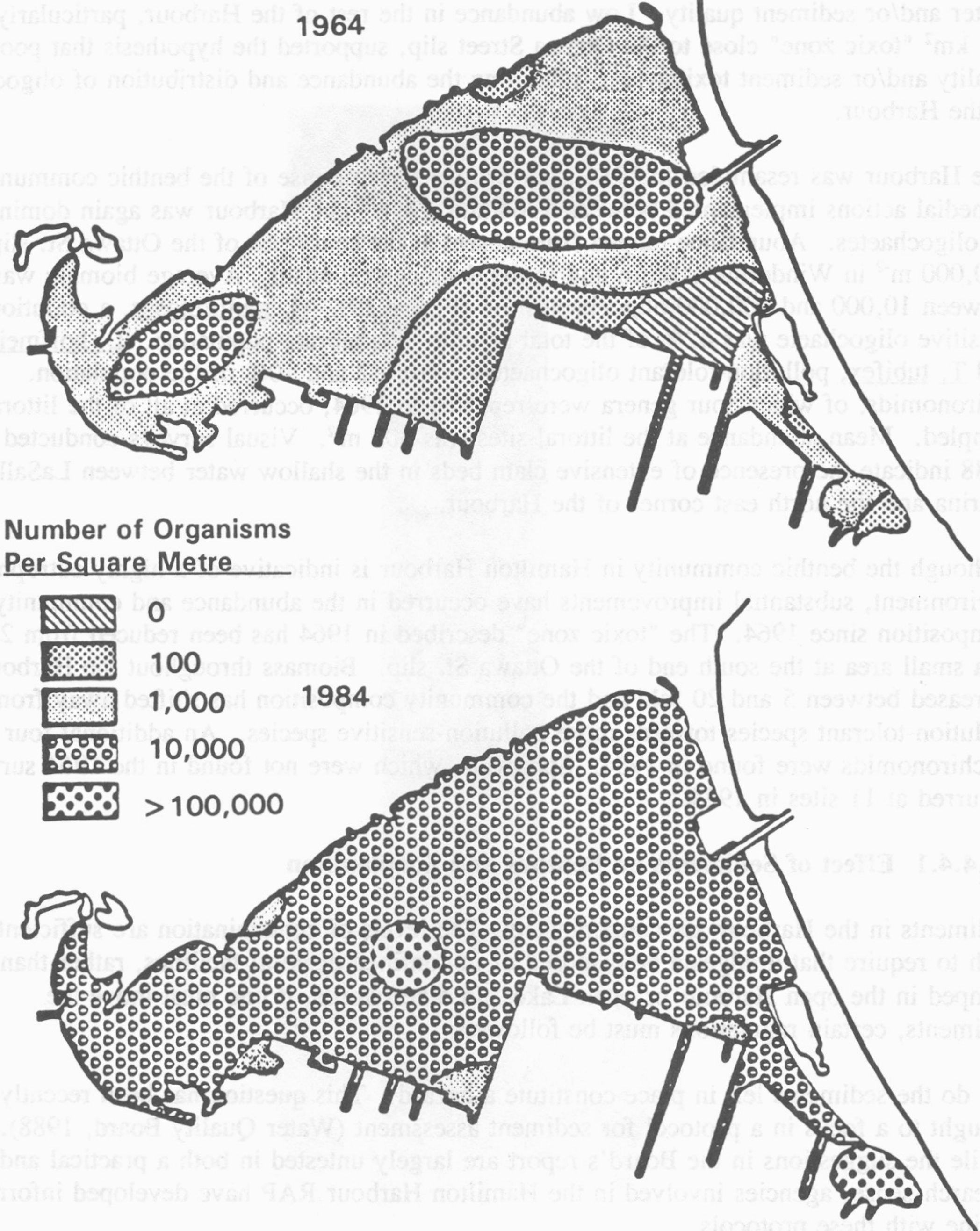
2. Ontario Ministry of Natural Resources (MNR) - Wetlands Planning Policy Statement and Implementation Guidelines (1989).

   This policy and the related guideline reflect that component of the wetlands management program which falls under the jurisdiction of the Planning Act, and addresses wetlands from a land use perspective.

3. Department of Fisheries and Oceans (DFO) Policy for the Management of Fish Habitat.

   This policy has as its objective a <u>net gain</u> of the productive capacity of fish habitats through conservation, restoration and development of new habitats, in cooperation with other government agencies, industry and non-government groups.

Figure 19: Abundance of oligochaetes in Hamilton Harbour



Source: 1964 data from Johnson et al., 1968; 1984 data supplied by M. Johnson - personal communication.

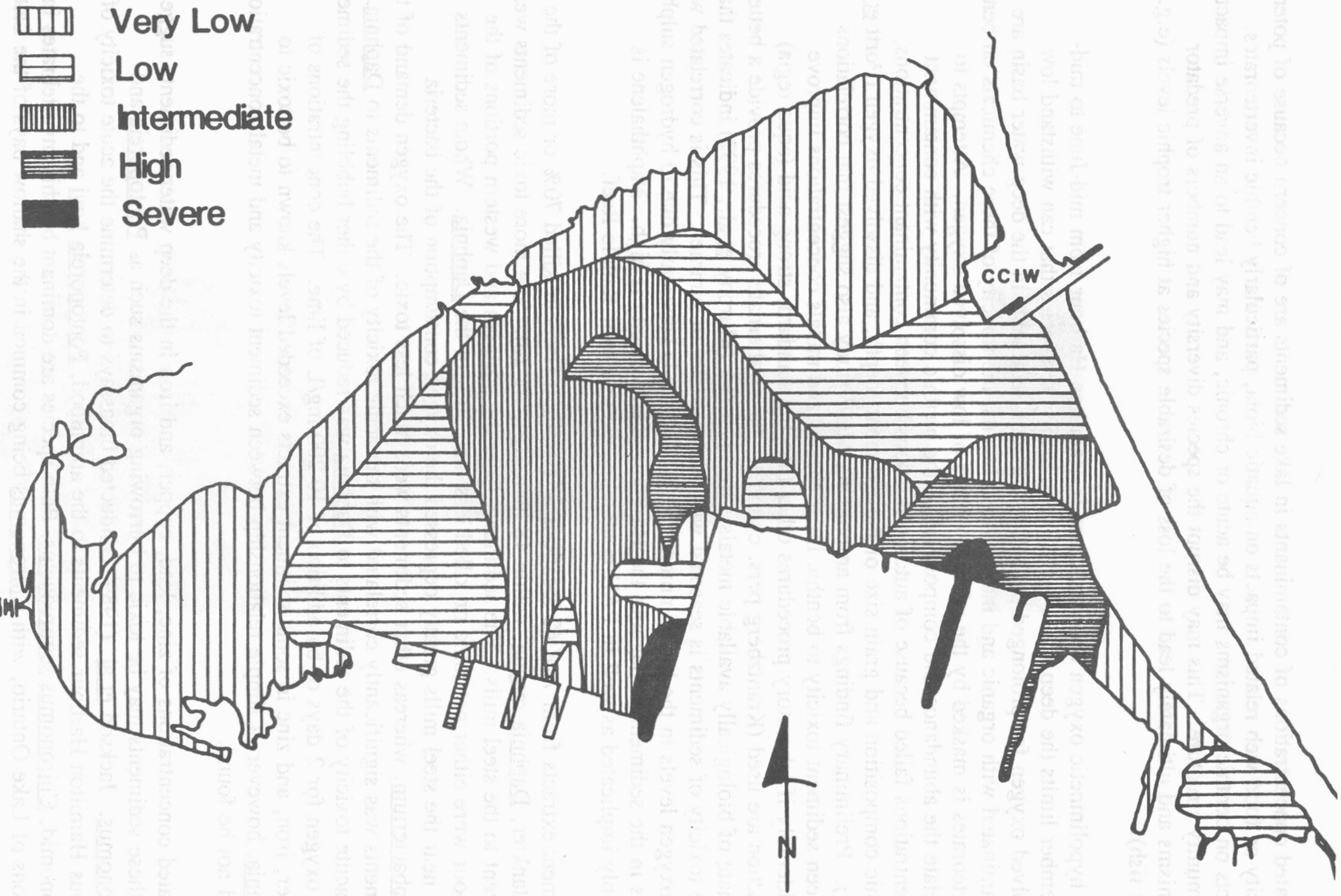
Elevated concentrations of contaminants in lake sediments are of concern because of potential toxicity or food web related impacts on aquatic biota, particularly benthic invertebrates. Effects on benthic organisms may be acute or chronic, and may lead to an adverse impact on community structure. This may disrupt the species diversity and numbers of predator organisms and ultimately lead to the loss of desirable species at higher trophic levels (e.g. sport fish).

Low hypolimnetic oxygen concentrations in Hamilton Harbour from mid-June to mid-September limits the deep water benthic community to species that can withstand low dissolved oxygen for prolonged periods. Although sediments in the deep water basin are contaminated with organic and inorganic pollutants, the toxicity of these chemicals on benthic invertebrates is masked by the adverse effects of low dissolved oxygen. Attempts to correlate the abundance and composition of the benthic community with contaminant concentrations failed because of auto-correlations between contaminant concentrations, organic composition and grain size of the sediment, depth, and dissolved oxygen (Portt et al. 1989). Preliminary findings from an ongoing MOE study also suggest that correlations between sediment toxicity to benthic invertebrates and metals concentrations improve considerably if laboratory procedures other than the standard, strong acid (aqua regia) extraction are used (Krantzberg pers. comm.). These alternate procedures provide a better estimate of biologically available metals. Recent work (Murphy et al., 1992) indicates that acute toxicity of sediments is seasonal with peak toxicity in summer. This is correlated with low oxygen levels in the hypolimnion. Acute toxicity is apparently due to hydrogen sulphide levels in the sediment throughout the Harbour where toxicity is high. Naphthalene is possibly implicated as well in PAH-contaminated areas near Randle Reef.

Sediment extracts from 7 of 62 locations in Hamilton Harbour killed 70% or more of the zooplankter, Daphnia magna, within 48 hours (Figure 20). The more toxic sediments were adjacent to the steel mills. The sediments from the northern and western portions of the Harbour were either not toxic or killed less than 30% of the Daphnia. Whole sediments from near the steel mills greatly depressed the oxygen consumption of the bacteria Photobacterium, whereas other sediments were much less toxic. The oxygen demand of the sediments was significantly correlated with the acute toxicity of the sediments to Daphnia. The acute toxicity of the sediments to Daphnia was reduced by either bubbling the sediments with oxygen for 2 days or by addition of 10-200 mg/L of lime. The concentrations of copper, iron, and zinc in some sediment extracts exceeded levels known to be toxic to Daphnia; however, a simple relationship between sediment toxicity and metal concentration could not be found.

Elevated concentrations of zinc, lead, copper, and iron in the deep water sediments suggest that these sediments may be toxic to burrowing organisms such as Pontoporeia and Chironomus. Jackson et al. (1989) conducted bioassays to determine the acute toxicity of various Hamilton Harbour sediments to the amphipod, Pontoporeia hoyi and to the chironomid, Chironomus semireductus. Both species are dominant benthic invertebrates in portions of Lake Ontario, with Chironomus being common in the shallow bays of the Lake.

Figure 20: Acute toxicity of Hamilton Harbour sediments February 1, 1989.



Source: T. Murphy - NWRI

Pontoporeia, an important food organism for whitefish, was abundant in Hamilton Harbour in the late 1800s.

Sediments from the deeper stations in Hamilton Harbour were acutely toxic to Pontoporeia within 168 hours (65-85%). Exposure to sediments from Cootes Paradise, Lake Ontario, the Bay of Quinte, and a shallow water site on the north shore of the Harbour caused less than 15 percent mortality in 168 hours, with no significant difference in mortality among these samples. Cause and effect relationships are difficult to establish from field bioassays. However, concentrations of zinc, lead, iron, and chromium were higher in the toxic sediments (Table 13).

Hamilton Harbour sediments were not acutely toxic to Chironomus. There was no significant difference in mortality of Chironomus exposed to sediments from a deep water station in Hamilton Harbour and those exposed to sediments from Cootes Paradise. The sublethal effects of Hamilton Harbour sediments on the feeding activity of Chironomus was determined by measuring the percent of gut filled with food. Chironomus exposed to Hamilton Harbour and Cootes sediments showed significantly lower feeding activity (24%) than those exposed to Lake Ontario or the Bay of Quinte sediments (72%).

Results from the acute Pontoporeia bioassay indicate that the deep water sediments of Hamilton Harbour are unsuitable for colonization by Pontoporeia. Cause and effect relationships are unknown and research is needed to identify the toxic agent(s) and develop remedial actions. Results from the Chironomus bioassay are more difficult to interpret. Low acute toxicity in all Harbour sediments suggests that Chironomus would be successful throughout the Harbour if dissolved oxygen were not limiting. However, reduced feeding activity in the short term assay (192 hours) has implications for growth and long term survival and it is not clear if Chironomus could successfully colonize the deep water sediments.

Biomagnification of contaminants by benthic organisms may also be of concern due to the potential for transmission to predator species and subsequent accumulation through the food web. Benthic macroinvertebrates (chiefly tubificid oligochaetes) in Windermere Basin and in Lake Ontario near the Ship Canal exhibit tissue concentrations of metals (Cu, Fe, Hg, Zn) and certain organochlorine compounds (PCBs, HCB, DDE, chlordane, heptachlor, aldrin, α-BHC) 2-6 times more than in their associated sediments (MOE, 1987a), which suggests that a transfer from sediments into the aquatic food web is taking place.

Interpreting tissue concentrations in benthic invertebrates and fish is difficult due to our lack of ability to separate the effects of present contaminant loadings to the water from the effects of high contaminant concentrations in the sediment as a result of past loadings. We have no confidence that abatement actions at the sources alone would be effective in reducing the contaminant content of the biota. Hence, remedial measures to deal with the deposits from past loadings may become necessary.

TABLE 13: Mortality of Pontoporeia and Chironomus exposed to sediments from four sites in Hamilton Harbour or three other sites. Also shown are the contaminant concentrations in the sediments from each site. Metals expressed as acid-extracted values, mg/kg unless otherwise stated.

	Location						
	Hamilton Harbour Site				Lake	Bay of	Cootes
	A	B	C	D	Ontario	Quinte	Paradise
Mortality (%):							
Pontoporeia	65	65	85	5	10	15	8
Chironomus	12	25	15	13	8	7	23
Depth (m)	11	23	19	5	125	5	2
Metals:							
Cadmium	3.9	5.2	0.2	2.9	2.0	1.4	1.0
Chromium	62.7	122.6	150.7	30.7	17.6	10.5	10.9
Copper	76.0	101.0	274.6	73.8	68.7	26.7	43.3
Iron[1]	14.2	23.2	25.4	10.7	10.4	10.5	10.3
Manganese[1]	1.5	2.0	2.0	0.6	1.6	0.6	0.7
Nickel	28.7	35.0	0.6	13.9	41.0	16.0	12.7
Lead	181.7	292.3	336.0	56.2	87.0	54.2	69.3
Zinc[1]	1.4	2.0	2.5	0.4	<0.1	0.1	0.3
1: mg/g							
Source: Jackson et al., 1989							

Mobility of contaminants in the sediment due to either physical resuspension of sediment particles, bioturbation, geochemical reactions, or biomagnification is poorly understood in Hamilton Harbour. Only manganese and occasionally iron release from the Harbour sediments has been documented. Biomagnification of contaminants in benthic invertebrates has been observed, but its significance to the warmwater fishery has not yet been estimated.

Sediment trap measurements of suspended sediment fluxes throughout the Harbour in 1987 suggest that resuspension of surficial sediments (and hence recycling of associated contaminants into the water column) appears to be occurring in deep areas of the Harbour as well as those boundary areas most obviously affected by ship traffic and wave action (Charlton, pers. comm.). Analysis of organic content and such physical properties as particle size will assist in the interpretation of the processes responsible for resuspension.

While the complete set of tests on Harbour sediments are not yet complete, it is clear that there are problems associated with the contaminants in this material. The scope of the problem can only be partially assessed. That is to say, the degree to which sediments contribute to contaminant issues in the Harbour (such as fish health, bird reproduction, and contaminants in fish fillets) is difficult to assess.

III.4.5 Macrophytes

III.4.5.1 Cootes Paradise Aquatic Vegetation

The present marsh flora of Cootes Paradise bears little resemblance to that described in pre-20th century writings. The memoirs of Charles Durand (1893), a former Dundas resident, provide some insight into that period's natural history. Durand implies that the marsh in the early 19th century, when he was a boy, was virtually filled throughout its length with emergent aquatic plants. Photographs currently on file at Royal Botanical Gardens (RBG) confirm that as late as 1928 there were, in fact, emergent aquatics growing as far east as the mouth of the Desjardins Canal at the High Level Bridge.

George North (1910-1983), an amateur naturalist and keen long-time observer of Cootes Paradise, described the marsh flora as it was during the 1920s and early 1930s (pers. comm. to J. Lord of RBG). According to North, the most abundant emergent plant was cattail (Typha sp.) and was associated with many other common wetland species such as burreed (Sparganium spp.) water lily (Nymphaea spp.) and water smartweed (Polygonum punctatum). North noted that manna grass (Glyceria maxima), which is currently the dominant emergent of the marsh, became evident much later. In addition to these emergent species, there were vast amounts of submergent aquatics. Wragg (1949), although he did not cite specific references, also described the marsh circa 1920, "Judging from reports of its condition, 30 years ago it must have been a remarkable place. In addition to the abundant growth of aquatic plants found there today, wild celery (Vallisneria americana) was common and wild rice (Zizania aquatica) so abundant that, in rowing through the marsh, one's boat would be covered with rice. Water was so clean and food so plentiful that ducks remained in thousands until ice formed." Wragg noted that a decline in waterfowl usage, concurrent with a decline in wild rice and wild celery stands, occurred in the ensuing 30 years.

Based on interpretation of historical writings and other sources, permanent reduction of wetland vegetation in Cootes Paradise appears to have begun sometime around the turn of the century and has accelerated rapidly since the 1940s (Table 14). Though documentation is fragmentary, several factors appear to have contributed to this decline. High water events

TABLE 14: Extent of emergent vegetation in Cootes Paradise.

Year	% of Total Area
1934	100
1946	41.6
1950	25
1953	12.6
1954	20
1959	40
1962	32
1971	27.9
1972	27
1974	9.3
1980	15
1985	16.9

Source: V. Cairns, GLLFAS, DFO, and the Royal Botanical Gardens.

have been correlated with a decrease in abundance and distribution of emergent plant communities in Cootes Paradise (Dept. of Fisheries and Oceans, unpub. data, 1986). However, based on historical descriptions, permanent reductions in marsh vegetation prior to 1900 were not experienced. Historical records from 1840 to the present show that Lake Ontario water levels have undergone wide fluctuations, including extended periods of high water, (during the 1800s,) without permanent damage to the macrophyte communities (Painter et al., 1988). Apparently the emergent vegetation recovered when water levels returned to normal. It would then appear that factors other than water level are involved in the marsh decline. Note also earlier comments on the effects of long term crustal movements on water depth (Section II.1.6.1). However, "the steepness of the shoreline slope and the timing of the peak water level (each year) in Lake Ontario are important factors influencing the distribution and extent of emergent vegetation.... The relationship between water level and recent marsh acreage would suggest that the current emergent plant area in Cootes Paradise is what would be expected under normal Lake Ontario water levels. For the emergent vegetation to return to 85% of the available area, the average water level of Lake Ontario would have to drop to 70 cm ...." (Painter et al., 1988) unlikely under the existing control orders for water level regulations.

The wetland vegetation of Cootes Paradise and Hendrie Valley/Carrolls Point area is currently dominated by a small number of hardy emergent species such as manna grass, cattail and giant burreed (Sparganium eurycarpum). There are still small localized stands of bulrush (Scirpus spp.) and sedges (Carex spp.) in the more protected inlets which fringe the basin. The present extent of emergent vegetation is approximately 15% of the total area, and is restricted to areas above the normal high water level.

The open water area of Cootes Paradise measures 250 hectares and is virtually devoid of aquatic plants. Around the edges, submergent communities are dominated by a small number of hardy species, for instance, sago pondweed (Potamogeton pectinatus). In 1946-48, 25 species of submerged aquatic plants were found in Cootes Paradise. In 1968-72 and in 1985, 11 species were observed; and in 1987, only 4 species.

Turbidity caused by algal blooms (in response to high nutrient loading) can cause inhibition of submergent plant growth, ultimately resulting in elimination of plant communities. The Dundas STP has been implicated as the primary source of excessive nutrient loadings to Cootes Paradise since its construction in 1919. It is postulated that the levels of nitrogen and other nutrients, discharged into the marsh, may also have led to the weakening and breaking of stems of some species of emergent macrophytes growing on floating root and rhizome mats (Boar and Crook, 1985). This mechanism can cause widespread loss of macrophyte stands. The extent of the marsh that was floating and therefore possibly affected by high nitrogen loading is unknown.

Turbidity derived from suspended sediments (erosion from urban storm water drainage) reduced light penetration to 14-38 cm throughout the summer of 1985 (Portt et al., 1989). Silt may also coat leaves, further inhibiting photosynthesis, and may physically damage stems and leaves. High silt loadings can also change substrate texture rendering it unsuitable for some plant species to colonize. Siltation in Cootes Paradise has changed bottom contours dramatically, resulting in a shallower basin particularly in the eastern portion (Painter et al., 1988). This shallowness has fostered wind-generated resuspension of bottom sediments and therefore has compounded the light penetration problems created by phytoplankton blooms.

A major role in the decline of the Cootes Paradise macrophyte communities must also be attributed to the spawning and feeding activities of carp (Cyprinus carpio) in the marsh. Carp were implicated by Wragg (1949) as responsible, in part, for the eradication of wild rice and wild celery from Cootes Paradise 30 years before he undertook his studies. Although he did not cite references, Wragg suggested that the apparent failure to re-establish these two plants, circa 1937, was again due to the destructiveness of carp. An ambitious programme of carp control was conducted by the Royal Botanical Gardens in 1952 and again in 1954-56. The latter effort removed 130,000 adult carp and resulted in dramatic improvement in the distribution and abundance of aquatic vegetation in the marsh (Lamoureux, 1961). However, the programme was discontinued and has not been repeated since that time.

There are a number of other minor factors which may have contributed to the decline of macrophyte communities in Cootes Paradise. For example, damage to replanted wild rice stands in 1951-56 was caused by larvae of an unidentified species of moth (Lamoureux, 1957). In addition, grazing by muskrats may have had some local effects, but whether permanent damage occurred is unknown.

It would appear that the major factors currently limiting recovery of the macrophyte communities in Cootes Paradise are turbidity, high water and carp. If marsh restoration is to be achieved, practical methods of controlling these factors must be sought.

III.4.5.2 Hamilton Harbour Aquatic Vegetation

The composition and abundance of warmwater fisheries in Hamilton Harbour is influenced by the type, density, and distribution of submerged and emergent aquatic plants. Apart from an obvious role in sediment stabilization, aquatic vegetation provides essential fish habitat. Submerged macrophyte cover influences phytoplankton and zooplankton populations, increases epiphytes and littoral invertebrates, and provides spawning, nursery, and adult habitats for largemouth bass, pike, bowfin, sunfish, longnose gar, and crappies. Fisheries production in the littoral zone appears to be optimum at intermediate plant densities. Sparsely vegetated areas offer little protection from predators while extremely dense vegetation impedes larger predators and reduces feeding success. Plant abundance is influenced by light, water levels, nutrients, substrate characteristics, ice scour, and lake morphometry (Duarte et al., 1986). Current and ideal conditions are illustrated in Figure 21.

Emergent vegetation provides spawning habitat for largemouth bass and northern pike. Pike prefer flooded sedges (Carex sp.), grasses (Spartina, Phalaris) and water plantain (Alisma). They will also spawn on flooded mats of broken cattails (Typha).

There are no data quantifying the extent of emergent marsh vegetation in Hamilton Harbour prior to 1900. Kerr and Kerr (1860-1898) reported that marshes extended along the entire south shore of the Harbour, in the north east corner (Brant's Pond), and in the mouth and lower reaches of Grindstone Creek. The entire 49.6 km south shore (from Desjardins Canal to the Burlington Canal) was restructured between 1900 and 1985 (Figure 1) resulting in a loss of 85 percent of the original vegetated shoreline. Whillans (1979) concluded that the loss of the south shore marsh was a major factor contributing to the decline of the warmwater fishery.

The emergent marsh in Grindstone creek declined from 37.8 ha in 1934 to 5.1 ha in 1985 (Table 15). Most of the loss (23 ha) occurred in the area of the Valley Inn Road. Possible factors responsible for marsh loss include ice scour, damage by carp, siltation, reduced light penetration, and increased water levels. Recent analysis of marsh losses since 1934 show a good correlation with elevated water levels (Cairns, DFO, pers. comm.).

Figure 21a: Hamilton Harbour - Present State.

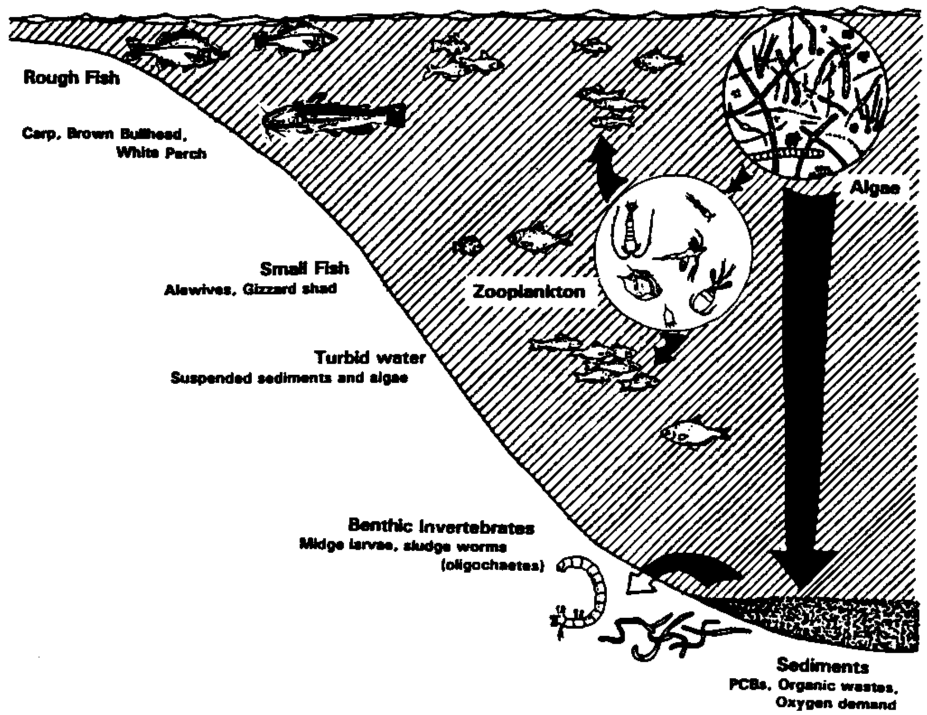
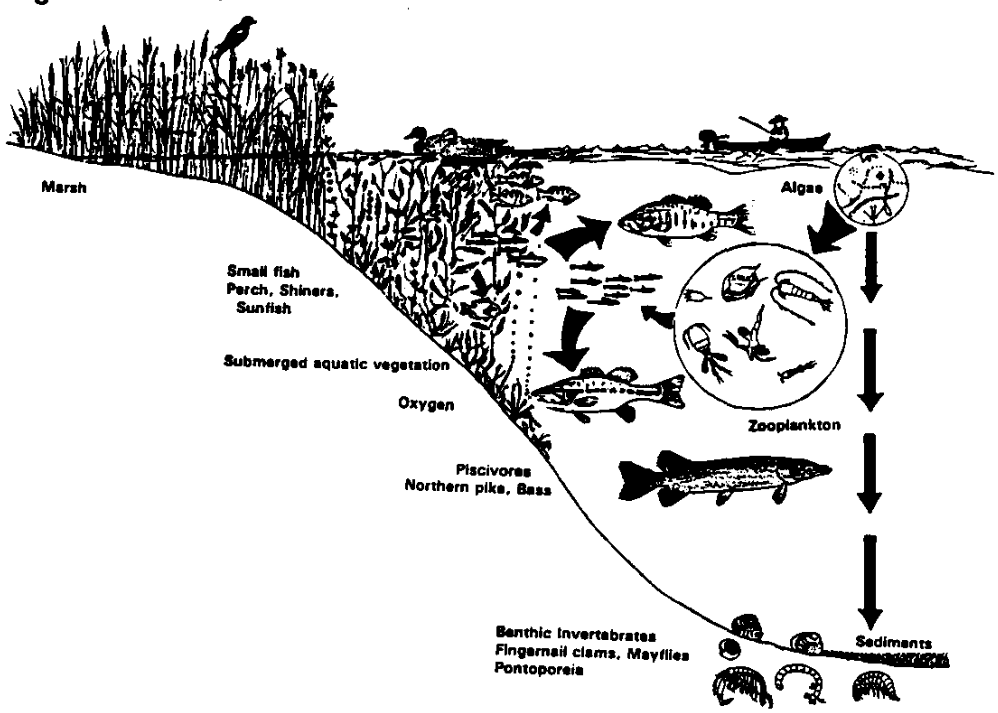


Figure 21b: Hamilton Harbour - Future State.



Source: Concept courtesy Green Bay, RAP report.

TABLE 15: **Area (ha) of emergent vegetation in the Grindstone Creek marsh from 1934 - 1985.**

Year	Area (ha.)			
	Valley Inn	Sunfish Pond	Lower Marsh	Boardwalk Marsh
1934	23.0	2.6	6.9	5.3
1939	3.5	2.6	7.9	5.7
1950	1.1	0.1	2.4	3.5
1954	3.0	0.5	1.2	4.2
1959	1.1	2.3	4.9	4.2
1961	0.7	0.9	3.5	5.0
1969	0.6	0.5	1.9	3.8
1972	10.2	0.6	3.4	3.6
1974	0	0.2	0	1.4
1980	0.4	0.4	1.4	3.5
1985	0.4	0.3	0.7	3.7

Source: V. Cairns, GLLFAS, DFO

The Grindstone Creek marsh is the last remaining stand of emergent vegetation in Hamilton Harbour and the only site suitable for pike reproduction. Eighteen adult pike were observed in the vicinity of the boardwalk marsh in 1985. Only 1 pair were spawning. There was no evidence of pike spawning in Cootes Paradise in 1985 or 1987.

There is insufficient spawning habitat (emergent marsh) in Hamilton Harbour to support a viable pike fishery (20-25 kg/ha). The ratio of spawning habitat to adult habitat is 0.06 in Hamilton Harbour (using 1987 data of 5 ha of suitable spawning habitat in Grindstone Creek and 64 ha of vegetated adult habitat in the Harbour). This is considerably less than the 0.3-0.4 ratio of spawning habitat to adult habitat recommended for productive marshes (Inskip, 1982). Based on these calculations, an additional 19-26 ha of suitable spawning habitat are required to sustain 64 ha of adult pike habitat.

The distribution and relative abundance of submerged vegetation was determined during 1987 from echosounding along the 1.3 m contour of the Harbour. Twenty-two transects perpendicular to shore were used to establish the maximum depth of macrophyte growth.

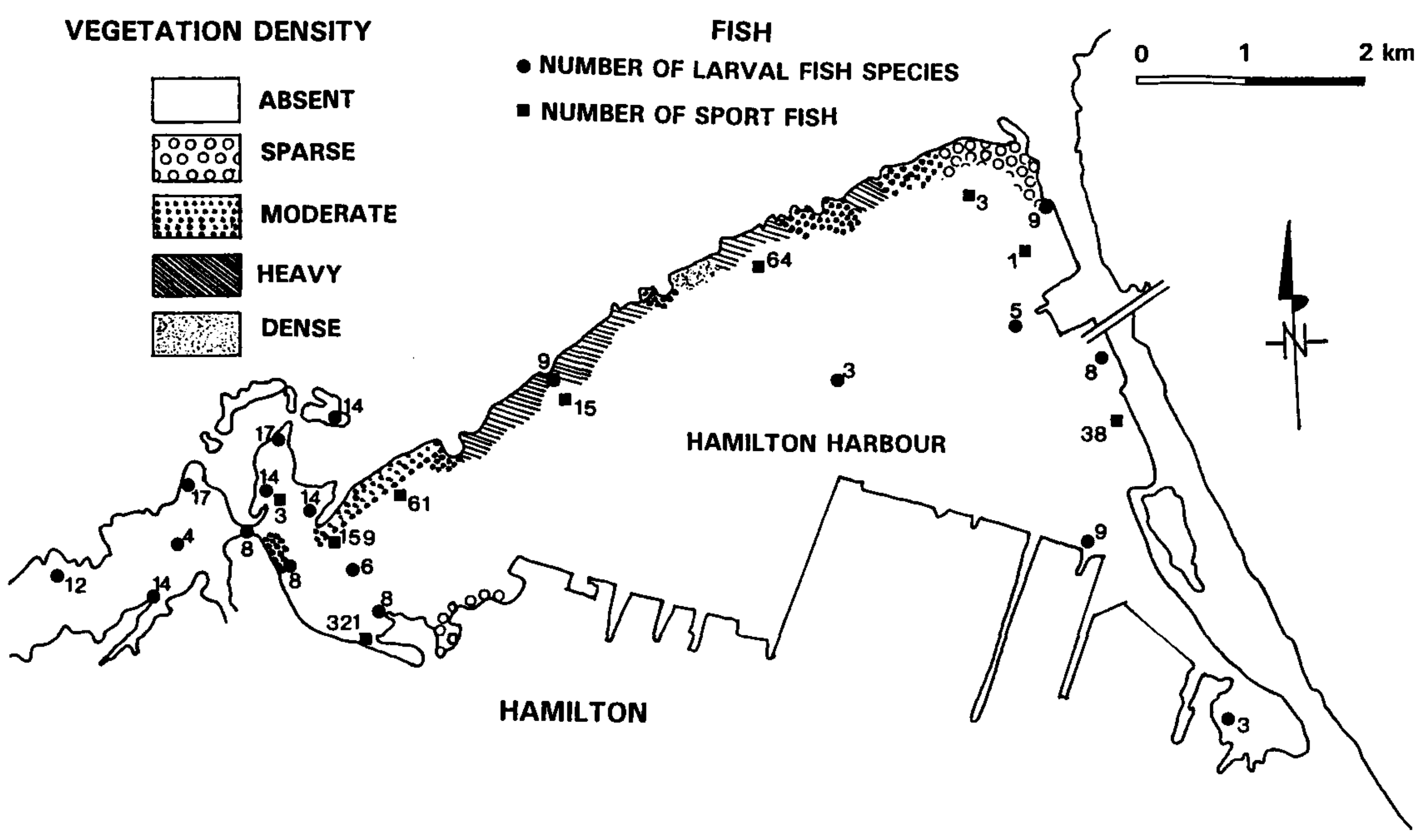
Plants were rarely found at depths greater than 2 m. Hence, the extent of littoral zone colonized by submerged plants was determined by measuring the area between the shore and the 2 m contour. However, plants rarely grew at depths less than 0.5 m. Therefore, the above method slightly overestimated the area of distribution of aquatic vegetation in the Harbour. Echolocating was used initially to identify areas of dense, heavy, moderate, and sparse vegetation. Species richness and density (number of plants/m^2) in these sites were subsequently measured by direct observation (SCUBA) at three locations in each vegetation type (Cairns, DFO, pers. comm.).

There are 199 ha of littoral habitat (less than 2 m deep) remaining in Hamilton Harbour. Only 45 percent of the total littoral area contained moderate to dense vegetation. Plant abundance in the remaining 55 percent of the littoral zone ranged from absent to sparse (3 plants/m^2). Submerged vegetation was confined to the north shore and to the west shore of the Harbour between the former Lax property and the Desjardins Canal (Figure 22). Plants did not grow at depths greater than 2.5 m, probably due to poor light penetration below that depth. Plants were absent along the south shore east of the Royal Hamilton Yacht Club. The littoral zone along the east shore of the Harbour is shallow enough to permit vegetation but plant growth is limited by almost constant wave action and poor light penetration. Prior to 1985, the east shore, south of the Burlington Canal, was moderately vegetated (Cairns, DFO, unpub. data). Shoreline restructuring to accommodate the West Service Road transformed this area into a high energy rubble shore that reflects wave action and inhibits plant growth.

With the exception of a small area (16 ha) of dense vegetation in the sheltered LaSalle marina, the majority of the north shore was moderately vegetated. Plant densities in areas of dense, moderate, and sparse vegetation were 400, 63, and 3 plants/m^2, respectively. Dense and sparse areas were represented by single species (Myriophyllum and Vallisneria, respectively). Maximum species richness in Hamilton Harbour occurred in moderately vegetated areas and was limited to only five species (Elodea canadensis, Vallisneria americana, Heteranthera dubia, Myriophyllum spicatum, and Potamogeton pectinatus). These plants are characteristic of eutrophic environments (Crowder and Bristow, 1986).

Crowder and Bristow (1986) reported that reduced light transparency was the most important factor limiting the distribution, abundance, and diversity of submerged aquatic plants in the Bay of Quinte. Secchi disk readings averaged 1.2 m in the Bay of Quinte and submerged vegetation did not grow at depths greater than 2 m (Crowder and Bristow, 1986). These data are consistent with the 2 m maximum depth of plant colonization for this Secchi depth predicted by Chambers and Kalff (1985). Similar relationships between light penetration and plant distribution appear to be occurring in Hamilton Harbour. In areas exposed to wave actions, it is likely that the clarity of water will decrease in the shore zone less than 2 m deep. Lower Secchi readings close to shore indicate that nearshore conditions such as suspended sediments may be limiting light penetration at depths less than 2 m. Secchi depth increased within the protected confines of the LaSalle Marina suggesting that the presence of

Figure 22: **Vegetation density and fish distribution in Hamilton Harbour.**



Source: V. Cairns, GLLFAS, DFO

docks and wave barriers reduced these nearshore factors. Not surprisingly, the sheltered area near the marina was also the only habitat in the Harbour characterized by dense vegetation (400 plants/m^2). The increased abundance of plants further dampened the effects of wave action and stabilized bottom sediments. Unprotected littoral habitat on both sides of the sheltered marina had moderate to heavy vegetation (Figure 22).

The source and fate of suspended sediments in Hamilton Harbour are not fully understood. Grindstone Creek, Indian Creek, Cootes Paradise, the STPs, combined sewer overflows, and erosion are obvious sources of suspended sediments to the Harbour. In addition, resuspension of existing sediments in the nearshore zone by wave action and possibly by the foraging action of carp also contributes suspended solids to the water column. Unfortunately there are insufficient suspended sediment data in the littoral zone of Hamilton Harbour to determine: 1) if suspended sediments are responsible for decreased light penetration close to shore; and 2) the relative importance of sediment inputs versus resuspension as factors limiting light penetration.

Breakwalls have been constructed along more than 5 km of the north shore leaving the area between Carrolls Point and Willow Point as the largest stretch of unprotected shoreline. The clay banks at this site show signs of recent extensive erosion by wave action confirming its role as a source of sediments to the Harbour. Although erosion along the north shore is minimized by the breakwalls, the restructured concrete shore reflects wave energy back into the littoral zone and increases sediment resuspension. The combination of reduced light penetration and unstable substrate limits plant abundance and distribution. It also reduces the diversity and abundance of benthic invertebrates and fish.

Light penetration is severely limited at the mouth of Grindstone Creek. Secchi depths at this site ranged from 14 to 38 cm throughout the summer of 1985 (Portt, 1986). Suspended sediments frequently exceed 80 mg/L (MOE, 1986b) and appear to be the most important factor limiting light penetration. Suspended clay and silt transported by Grindstone Creek during erosion events is deposited in Sunfish Pond and in the Valley Inn road area. The mean depth at both sites is now less than 0.5 and 1 m, respectively. The creek, Sunfish Pond, and the estuary are turbid during periods of runoff. However, Grindstone Creek is clear during dry periods but Sunfish Pond and the estuary remain turbid, suggesting that wind (and/or carp) are responsible for sediment resuspension.

III.4.6 Zebra Mussels

Zebra mussels (Dreissena polymorpha) (Figure 23a and Figure 23b) were first discovered in Lake St. Clair in 1988, believed to have been introduced to the Great Lakes by a ship discharging ballast water picked up in a freshwater European port. Since that time, mussels have been found in Lake Erie, the Niagara River, the Welland Canal, in Lake Ontario near Burlington, Mississauga, Bath and Picton, in the St. Lawrence River near Prescott and Cornwall, in Green Bay (Lake Michigan), in Duluth Harbour (Lake Superior), and recently in Hamilton Harbour.

Figure 23a: North American freshwater biofouling bivalve. Dreissena polymorpha (zebra mussel).

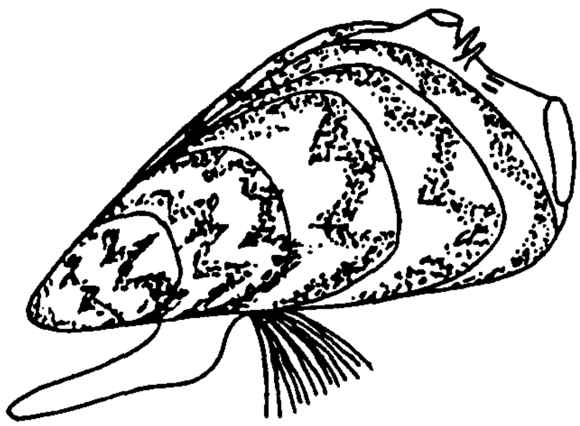
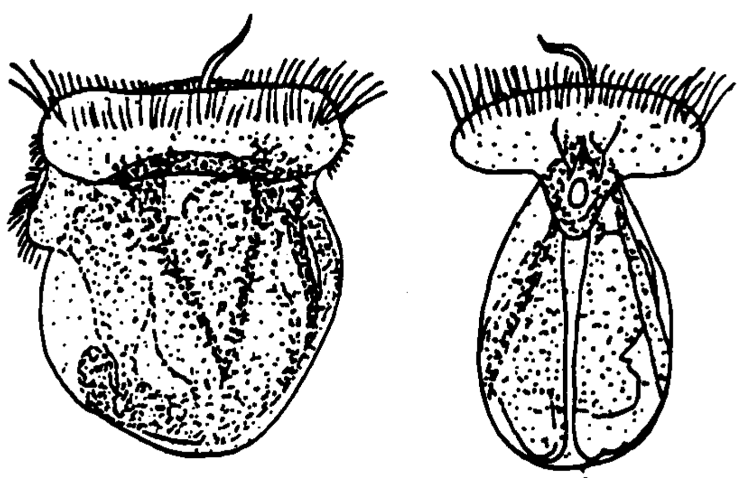


Figure 23b: Lateral and ventral views of viliger larvae of Dreissena polymorpha.



Source: The Zebra Mussel, Dreissena Polymorpha; A Synthesis of European Experience and a Preview for North America, 1989

Zebra mussels were first discovered in the Harbour in June 1990 when divers from the Ministry of the Environment examined the ship docks at CCIW. In August, they were found in the water intake pipe at Dofasco Inc. and on November 3, 1990 mussels were found on the floating tire breakwater at LaSalle Park Marina.

The rapid rate at which zebra mussels reproduce (30,000 eggs annually) coupled with their ability to adapt to the Great Lakes ecosystem have allowed them to disperse quickly throughout the lakes. It is predicted that zebra mussels will continue to spread throughout the basin and further into inland lakes and rivers.

Zebra mussels are already causing problems in the Great Lakes. Adult mussels firmly attach themselves to almost any hard underwater surface (boats, piers, breakwalls, water intake pipes, rocks, aquatic plants, clams and crayfish) at various depths. Once attached, they build up colonies several layers thick numbering upwards in the tens of thousands per square metre.

In cases where large concentrations of mussels have built up inside municipal and industrial water intake pipes, water flow is significantly reduced, sometimes by more than 50 percent. At this time, little information is known about the potential damage to the Great Lakes fisheries. Zebra mussels consume plankton which may impact on the young of some fish species who also rely on this food source. Adult zebra mussels also colonize spawning beds which can seriously harm fish populations by decreasing the survival rate of fish eggs.

Zebra mussels have few natural predators. Fish (whitefish, sturgeon, freshwater drum and carp) and waterfowl (diving ducks and gulls) will feed on the mussels but unfortunately are not present in sufficient numbers in the Great Lakes to keep the populations of mussels under control.

Research is underway to find ways to prevent or slow the spread of zebra mussels. To help prevent the introduction of additional exotic species, the Canadian Coast Guard introduced in May 1989, voluntary guidelines stating that all ships bound for the St. Lawrence Seaway and Great Lakes exchange their ballast water either at sea or in the St. Lawrence River before entering the seaway.

As of 1991 the mussels have established populations throughout Hamilton Harbour on the docks, pilings, rocks, and boats. Industrial water users now have to chlorinate their intakes to prevent disruptions due to mussels. Experience in Lake Erie has been that the mussels cleaned up the western basin by filtering algae out of the water. This effect will likely be less important in the Harbour due to the greater depth.

The mussels spawn at water temperatures above 12° Celsius. Two generations are produced in one season in the Harbour. When spawning temperatures occur the Harbour is stratified into an upper warm layer and a lower cold layer. In Europe it has been found that the largest concentrations of the immature larvae are present in the upper warm layer where they were spawned. This aspect of the mussel's ecology was exploited in experiments by NWRI designed to find the potential to avoid Zebra mussels in the Harbour, Lake Ontario and Lake Erie. Artificial substrates were provided for the mussels at many depths during 1991 (Figure 24). No recruitment of Zebra mussels occurred below the thermocline. It is not yet known whether the effect in the Harbour is due to temperature or lack of oxygen in the deep. The results mean that water users may avoid mussel problems and the use of chlorine by moving intakes to deeper colder water.

III.4.7 Fish

III.4.7.1 Trends in the Hamilton Harbour Fishery

Historically, Hamilton Harbour was one of the most diverse and important fish habitats in western Lake Ontario, supporting a coldwater fishery dominated by lake trout, whitefish, and lake herring. Prior to 1800, the fishery also included Atlantic salmon and lake sturgeon. Kerr and Kerr (1860-1898) reported seasonal feeding migrations of lake trout and whitefish into Hamilton Harbour in June and July. Summer feeding migrations were followed by spawning runs in October and November as millions of whitefish and lake herring entered the Harbour to spawn on gravel shoals along the north and west shores (Holmes and Whillans, 1984). The commercial catch of lake herring in the late 1800s represented 48 percent of the western lake fishery and made up 15 percent of Lake Ontario's total commercial catch.

Cootes Paradise and the south and west shores of Hamilton Harbour consisted of shallow water marshes that provided spawning, nursery, and adult habitats for the warmwater fish community. Pike and bass were the dominant recreational and commercial warmwater species. Approximately 12,270 kg of pike were taken by the commercial fishery in 1871 and bass fishing peaked in 1879 with a record catch of 5,400 kg (Holmes and Whillans, 1984). These catches do not include the large sport fishery (primarily spearing) for pike and bass in the north western end of the Harbour near Carrolls Point. Whillans (1977, cited in Holmes and Whillans, 1984) estimated the annual mortality from spearfishing at 18,000 kg/year. The diverse warm water fishery included pike, bass, yellow perch, sunfish, muskellunge, walleye, drum, burbot, channel catfish, brown bullhead, and white sucker.

III.4.7.1.2 Decline of the Fishery

By 1900, the coldwater fishery was responding to deteriorating water quality, competition from invading species (smelt), overfishing, and habitat loss associated with urban and industrial development. Tributaries used by Atlantic Salmon for spawning were blocked by mills in the last century. The gravel spawning beds in these tributaries and the Harbour were also covered by silt from erosion when the land was cleared for agriculture and urbanization. The first collecting sewer for the city of Hamilton was completed in 1854 (Threader et al., 1989). Prior to this, sewage disposal from water closets emptied directly into Cootes

IV DESCRIPTION OF POLLUTANT SOURCES

IV.1 Point Sources

Pollutant sources are commonly classified as point or non-point sources. For Hamilton Harbour, point sources include municipal STPs, direct industrial outfalls, and combined sewer overflows (CSOs). The non-point sources are urban and rural run-offs, atmospheric and agricultural loadings, contaminant spills, and leachate from landfill sites. In situ loadings which relate to the release of contamination from in-place sediments are also considered in this section. Municipal and industrial loadings of pollutants have been reduced by 60-95% since the early 1960s.

IV.1.1 Municipal

Four municipal sewage treatment plants (STPs) discharge treated wastes to Hamilton Harbour. All are conventional activated-sludge plants with chemical treatment for phosphorus removal. All four plants are well operated.

The Woodward Avenue plant in Hamilton is the largest, serving a population of about 360,000. Sewage from the cities of Hamilton and Stoney Creek and the Town of Ancaster is treated at the plant. It has a design capacity of 409,000 cubic metres per day and is now treating about 320,000 cubic metres per day. The treated effluent is discharged to Redhill Creek as it flows into Windermere Basin of Hamilton Harbour.

The Skyway plant in Burlington serves a population of about 120,000. The sewage from the total urban area of Burlington is treated at the plant. It has a design capacity of 93,000 cubic metres per day and is now receiving an average of about 71,000 cubic metres per day. The treated effluent is discharged into the northeast corner of Hamilton Harbour.

The Dundas plant treats the sewage from a population of about 19,500. The plant has a design capacity of 18,000 cubic metres per day and is now treating a sewage flow of about 11,000 cubic metres per day. Sand filters were recently installed to further treat the final effluent. The treated effluent from the plant is discharged to Cootes Paradise.

The Waterdown plant serves a population of about 4,000 and is treating the sewage from the Community of Waterdown. The plant has a design capacity of 2,730 cubic metres per day and is now treating a sewage flow of 2,400 cubic metres per day. It operates in the extended aeration mode and has sand filters for polishing the final effluent. The treated effluent is discharged to Grindstone Creek.

IV.1.2 Industrial

The two steel mills discharge treated wastewaters to the Harbour. Small quantities of uncontaminated cooling water are discharged by several smaller industries located near the Harbour. All other industries discharge their wastewaters to the municipal sewers for treatment at the municipal sewage treatment plants. The details for such sources for the Hamilton-Wentworth system can be found in a recent report (Proctor and Redfern, 1991).

In 1986, Stelco discharged about 1,057,000 cubic metres per day of treated effluents to the Harbour through five outfalls, while Dofasco discharged about 655,000 cubic metres per day through five outfalls (MOE, 1987d). Control facilities installed by the steel mills include ion exchange for chromium removal, chemical treatment plants for oil and solids removal, steam distillation for ammonia removal, biological treatment for phenols and cyanide removal, clarifiers and dual-media filters for suspended solids removal, and recirculation to reduce flows and, therefore, effluent loadings. These control facilities have been found to be efficient in removing priority pollutants by controlling the conventional parameters.

IV.1.3 Combined Sewer Overflows (CSOs)

Sewage and storm water runoff are collected in a combined sewer system in most of the City of Hamilton. As a result, during periods of high runoff the combined sewer system becomes overloaded and raw sewage overflows into the receiving waters at 26 locations. The Regional Municipality of Hamilton-Wentworth has installed a holding tank at the largest of the combined sewer overflows to collect the sewage overflow. After the runoff event the collected sewage is diverted back into the sewer system for treatment at the municipal sewage treatment facility. The holding tank is designed to collect the total overflow during most summer storm events and to act as a primary clarifier during extended periods of runoff such as occur in the spring. This holding tank, which is located at the Greenhill Avenue combined sewer overflow, was placed in operation in 1988. Combined sewer overflows (86,000 m^3/day) are a source of ammonia and phosphorus, bacteria, suspended solids, industrial or commercial wastewater, and contaminants washed off streets. The estimated 1987 ammonia and phosphorus loading from combined sewer overflows are 200 kg/day and 90 kg/day, respectively. Somewhat lower estimates are given in a recent study (Theil et al., 1992). More direct measurements are required if greater precision is necessary.

IV.2 Non-point Source Loadings to Hamilton Harbour

IV.2.1 Atmospheric

The atmospheric loading was estimated using the deposition rates of various compounds ($kg/km^2/yr$) from Kuntz (1980) and IJC Great Lakes Science Advisory Report (1980) for Lake Ontario and the Harbour's water surface. Table 26 summarizes the estimated atmospheric loading and compares it to the loadings from point sources. The atmospheric loadings have been calculated for only the Harbour's water surface. Stormwater runoff from the watershed will increase the contribution of atmospheric loading reported in Table 26.

The relative importance of atmospheric loading to point source loading depends on the compound. Atmospheric loadings of inorganic compounds are insignificant, and of trace organics significant, relative to point source loadings.

TABLE 26: Estimated atmospheric loadings to Hamilton Harbour's water surface (kg/day), compared with an estimated percent of the point source loadings.

	Atmospheric Loading	Estimated % of Point Source Loading
Phosphorus	1.18	0.02
Ammonia	17.7	0.02
Copper	0.24	3
Iron	4.4	0.06
Lead	0.88	4
Zinc	3.5	2
PCBs	0.007	18
α-BHC	0.002	130
γ-BHC	0.011	180
PAHs	0.116	6
DDT	0.0004	10
Dieldrin	0.0004	>200
Endosulfan	0.006	-
HCB	0.001	15

Adapted from Kuntz (1980) and IJC Great Lakes Science Advisory Board (1980)

IV.2.2 Agricultural

Very little is known quantitatively of agricultural or other rural loadings to Hamilton Harbour. Relative to municipal and industrial loadings, agricultural loadings of contaminants are thought to be small. Loadings of suspended solids from the watershed are important but the relative contribution of agricultural, urban, and in-stream erosion sources is unknown. A land use survey was conducted in 1988 to provide the first step in developing this information (Ecologistics, 1988). Sediment loadings are greatest for agricultural areas in the Spencer Creek watershed below Christie Reservoir, for intensively cropped land south of Hamilton, and in the north part of the Grindstone Creek watershed.

IV.2.3 Dissolved Solids

The total loading of dissolved solids to Hamilton Harbour from all sources was estimated to be 607,000 kg/day in 1977 (Snodgrass, 1981). The use of road salt in 1976-77 was approximately 26 x 10^6 kg for Hamilton and Halton. Therefore, road salt represents approximately 12% of the annual load of total dissolved solids. Redhill Creek has the highest natural dissolved content of all the major streams due probably to solution of salts from limestone formations.

IV.2.4 Shipping and Spills

Spills in the Harbour are a relatively minor source of pollution. Between 1974 and 1986, there were only seven significant ship-related incidents reported. One was of bunker "C" and the rest were of light oil, ranging from 0.1 to 3 metric tonnes in size. In all cases, 60 to 90% of the oil was recovered by skimmers and adsorbents. Numerous slicks are observed on the water, but since oil spreads rapidly to a thin sheen, sometimes only one molecule thick, these slicks represent very small quantities.

Spills from other sources are more frequent. During the same 12 years, sixty-four incidents from land-based activities were reported. Half of these involved oil and the rest a wide variety of industrial liquids. More hydrochloric acid was released than any other product: a total of 950 metric tonnes in eight accidents. Acids and some other chemicals mix easily with water and cannot be recovered. Data on spills is included in Appendix I.

The spill records kept by DOE since 1974 indicate that the number and volumes of spill incidents are dropping in response to tougher regulations and preventive and educational programs. All spills from industries are investigated to determine the cause and to ensure that measures are taken to prevent a recurrence. As well, detailed hazardous operations analyses are being carried out to identify where things may go wrong so that preventive measures can be taken to minimize upsets.

IV.3 In Situ Loadings

Elevated concentrations of metals in the bottom waters of the Harbour due to release from the sediment has not been observed except for manganese and, occasionally, iron. Trace organic contaminants have a high affinity for sediment surfaces and are usually insoluble in water. Therefore, organic contaminants located in the sediments will also remain associated with the sediments and will not generally be released into the water column. However, sediments can be resuspended particularly in shallow areas subject to wind-wave action or disturbance by shipping. This is under investigation (Boyce et al., 1990 and Charlton, personal communication). Indications are that resuspension probably does not have a dominant effect on a Harbour-wide basis, but may be important for the quality of the water column in some restricted shallow areas near Randle Reef.

IV.3.1 Sediment Phosphorus Release

In many lakes, sediments release nutrients into the overlying water and this release can be the dominant nutrient flux (Ryding, 1985). However, the Hamilton Harbour sediments are not presently considered an important source of nutrients to the water column. Phosphorus release from the sediments has not been observed in the Harbour (MOE, 1986a), neither in short-term equilibrations with Harbour sediment (Mudroch and Sandilands, 1980), nor in long-term anoxic laboratory incubations with Harbour sediment (Burnison, NWRI, pers. comm.). Sediment phosphorus release was observed in sediment cores that were bubbled with nitrogen or oxygen. The phosphorus release rates measured over a two month period were equivalent to one to two weeks of external loading of phosphorus. Currently, sediment phosphorus release is assessed as a minor source of phosphorus.

The high concentrations of nitrate or iron in the Harbour may account for this lack of an anticipated release of phosphorus from anoxic sediments. High iron concentrations have been found to reduce phosphorus release in anoxic sediments (Nordin, British Columbia MOE, pers. comm.).

IV.3.2 Sediment Oxygen Demand

Mudroch and Sandilands (1980) found that ammonia was readily released from sediments into the Harbour water but this release is probably insignificant relative to the external loading of ammonia. However, if the sources of ammonia to the Harbour are treated with the best available technology, then the sediment release of ammonia will become important in delaying the oxidation of the hypolimnion. Bacteria consume oxygen to oxidize ammonia.

The sediment oxygen demand accounts for a small portion of the total oxygen demand; 40% in spring, 10-20% in summer, and 25% in the fall (MOE, 1985). As the restoration of the Harbour proceeds, sediment oxygen demand will delay the oxygen response of the Harbour. Eventually the sediments could become oxidized, but the period of time required for this to occur is unknown. An estimate of 10 years has been suggested.

IV.4 Summary of Loadings by Contaminant
IV.4.1 Hamilton Harbour
IV.4.1.1 Ammonia Loading

Major reductions in industrial discharges of ammonia have been achieved. The industrial loadings have been reduced from about 24,000 kg/day of ammonia as nitrogen in 1967 to about 352 kg/day in 1989. However, until recently there has been little change in the loadings of ammonia from the municipal STPs. In 1988-89 modifications were made to the operations of the municipal STPs to attain about a 50% reduction in ammonia loadings from the plants. Regular monitoring for ammonia in the effluents from the STPs was started in 1978.

Figure 29 shows the total loadings of ammonia as nitrogen from both industrial and municipal sources since 1978, including estimates of loadings in Hamilton's CSOs and the concentration of ammonia found in the Harbour. The concentration trend in the Harbour is cyclical with the highest concentration occurring in the early spring and the lowest in the summer. The nitrifying bacteria which oxidize the ammonia are inhibited by cold temperatures. As a result, ammonia builds up in the Harbour during the winter. In 1989, the concentration peaked at 1.5 mg/L. When the water temperature warms above 6°C in spring, the nitrifying bacteria become active again and very rapidly oxidize the accumulated ammonia. In so doing, the oxygen level in the Harbour water is reduced. The oxidation of each mg of ammonia, as nitrogen, requires about 4.6 mg of oxygen.

Not all of the ammonia discharged to the Harbour is oxidized. Ammonia is also flushed to the Lake through the Canal. As well, some ammonia is used by the aquatic biota as a nutrient. It is initially taken up by aquatic plants, including algae, and by bacteria. A small portion of this nitrogen makes its way through the food chain, ending up as protein in fish and water-fowl.

A plot of annual average ammonia loadings to the Harbour versus maximum early spring concentrations in the main body of the Harbour is shown in Figure 30. Extrapolation of the best fit straight line through the points in the plot to the 0 mg/L ammonia concentration indicates that during the winter about 3,300 kg/day of ammonia might be utilized by algae or is flushed out into Lake Ontario. Therefore, at the present rate of removal, a further 1,200 kg/day reduction in ammonia loading may prevent the build-up of ammonia in the Harbour during the winter. This would be, therefore, a first loading target.

Ammonia in the un-ionized form is toxic to some aquatic organisms. The percent of ammonia present in the un-ionized form is dependent on the pH and the temperature of the water (Table 27).

The Provincial Water Quality Objective for un-ionized ammonia is 0.02 mg/L. The concentration of un-ionized ammonia in the Harbour water is shown in Figure 31.

Exceedences of the objective occur in late spring and summer when the percentage of ammonia present in the un-ionized form increases ten-fold as a result of a rise in temperature and pH. The rise in pH from about 8 to 8.4 in the surface waters is believed to be caused by the removal of carbon dioxide from the water column as a result of algal photosynthesis. It appears that the initial target set for improvement of dissolved oxygen demand due to NH_3 (above) should also allow achievement of the objective for un-ionized ammonia.

Stelco completed the installation of indirect final coolers in 1987. In 1989, Stelco's loading was 195 kg/day, or about 4% of the total loading (Figure 32).

With the installation of a blast furnace water recycle system, the ammonia loading for Dofasco is 157 kg/day, or 3.5% of the total loading (Figure 32).

TABLE 27: **Percentage of ammonia in un-ionized form in water as a function of pH and temperature (°C).**

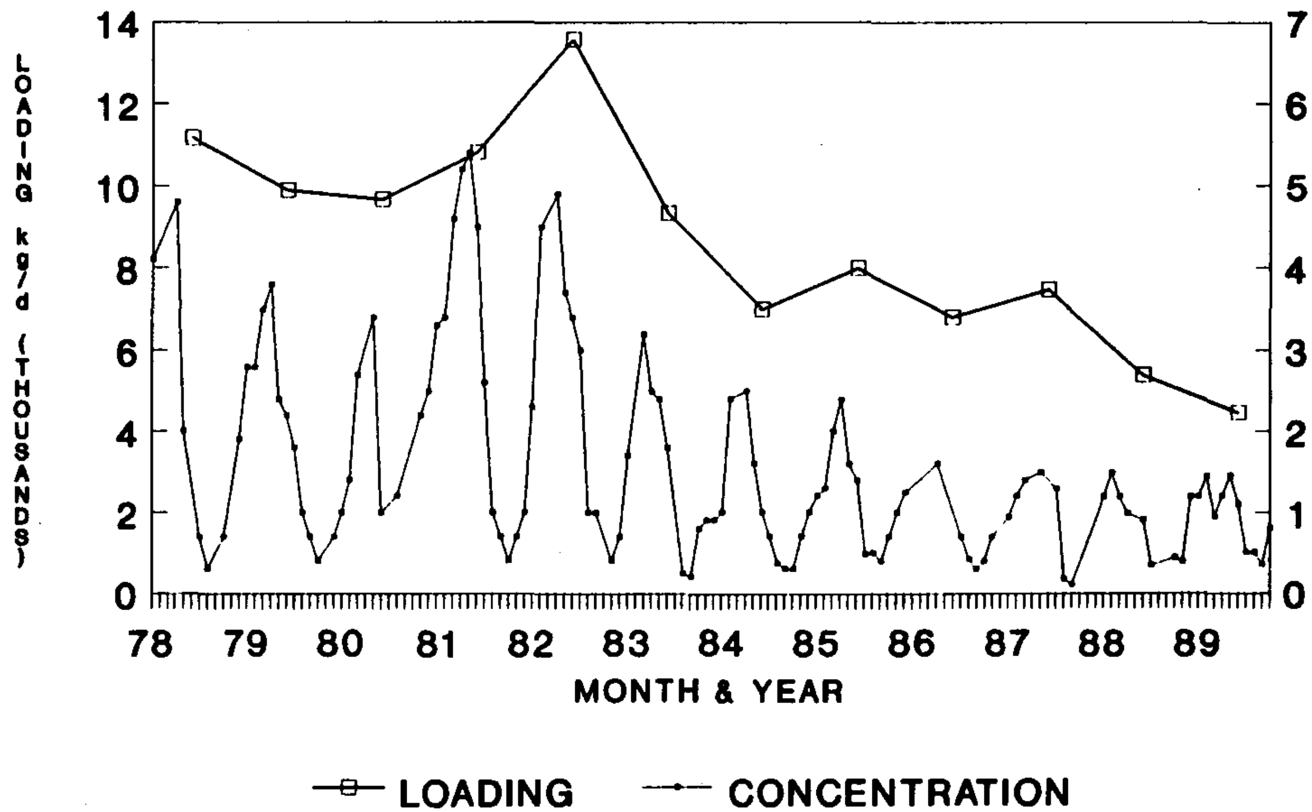
	pH								
Temperature	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	0.01	0.04	0.13	0.39	1.2	0.8	11	28	56
10	0.02	0.06	0.19	0.59	1.8	5.6	16	37	65
15	0.03	0.09	0.27	0.86	2.7	8.0	22	46	73
20	0.04	0.13	0.40	1.2	3.8	11	28	56	80
25	0.06	0.18	0.57	1.8	5.4	15	36	64	85
30	0.08	0.25	0.80	2.5	7.5	20	45	72	89

Source: MOE, 1978.

IV.4.1.2 Phosphorus Loading

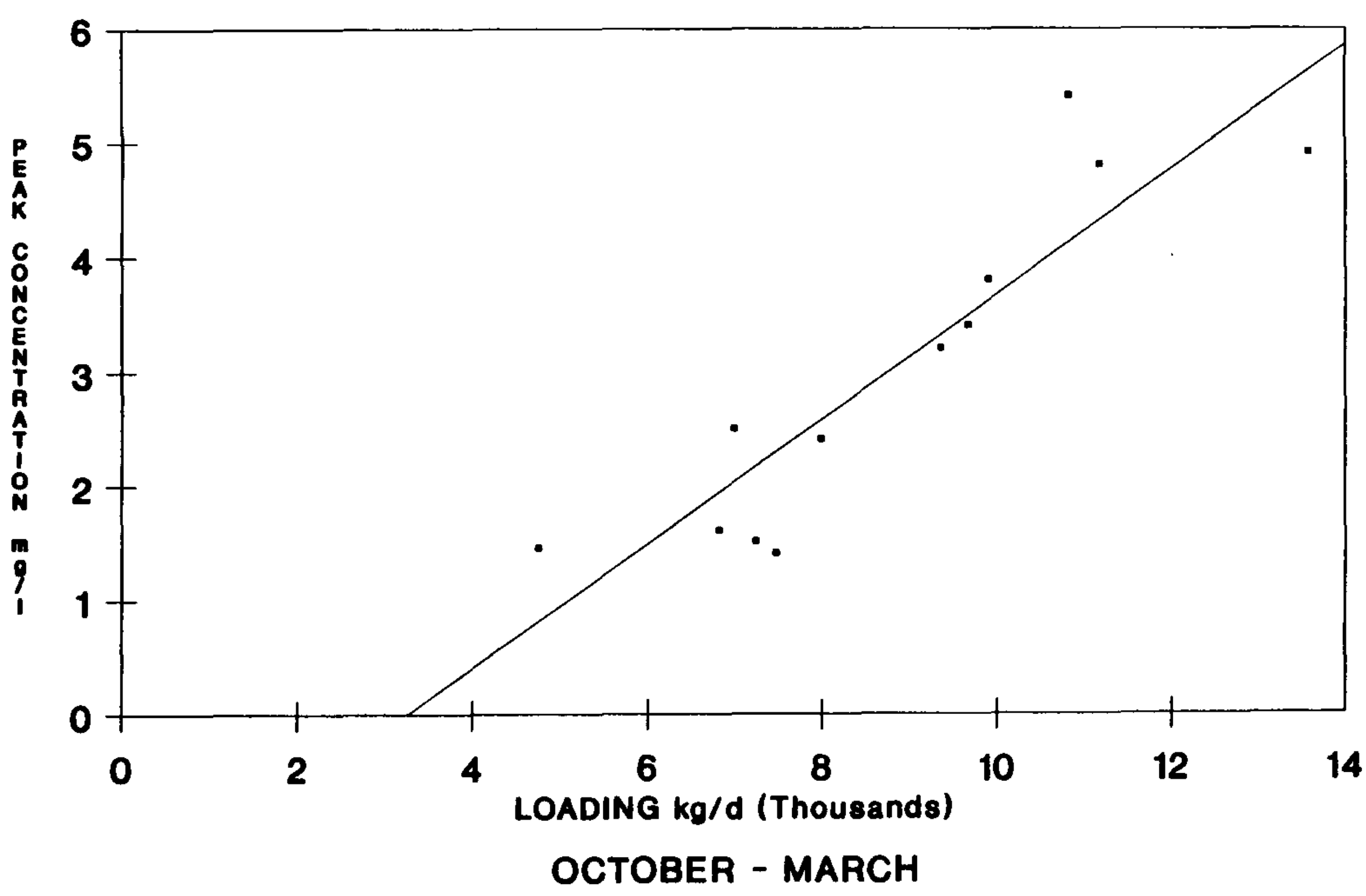
With the installation of wastewater treatment facilities at the steel mills, the industrial discharges of phosphorus to the Harbour have been reduced from about 1,200 kg/day in 1967 to less than 10 kg/day in 1989. The phosphorus loadings from the STPs have also been reduced through the use of chemical treatment.

Figure 29: Hamilton Harbour - Ammonia loading and concentration.



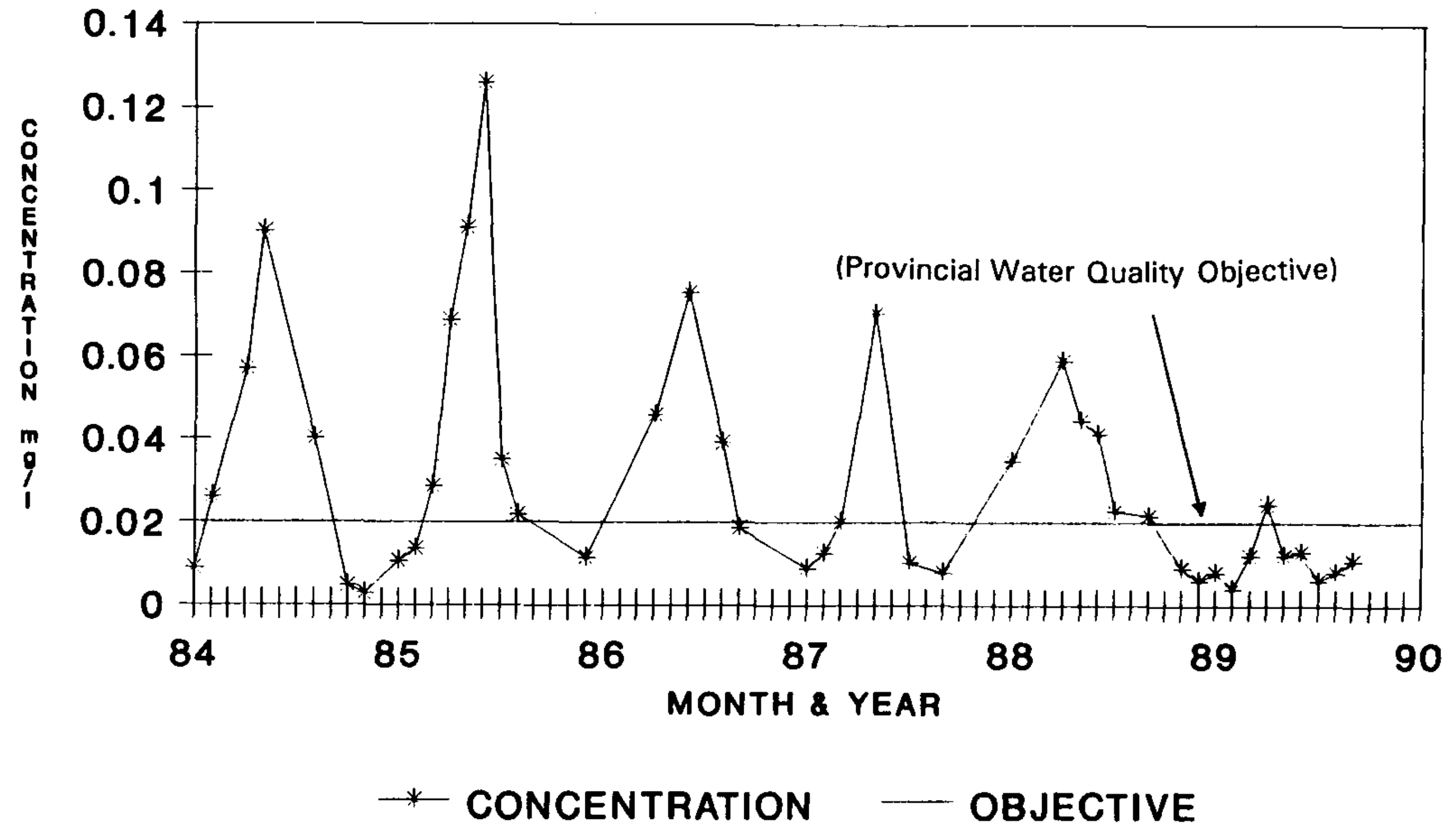
Source: J. Vogt, MOE/WCR

Figure 30: Hamilton Harbour - Ammonia peak concentration vs loading.



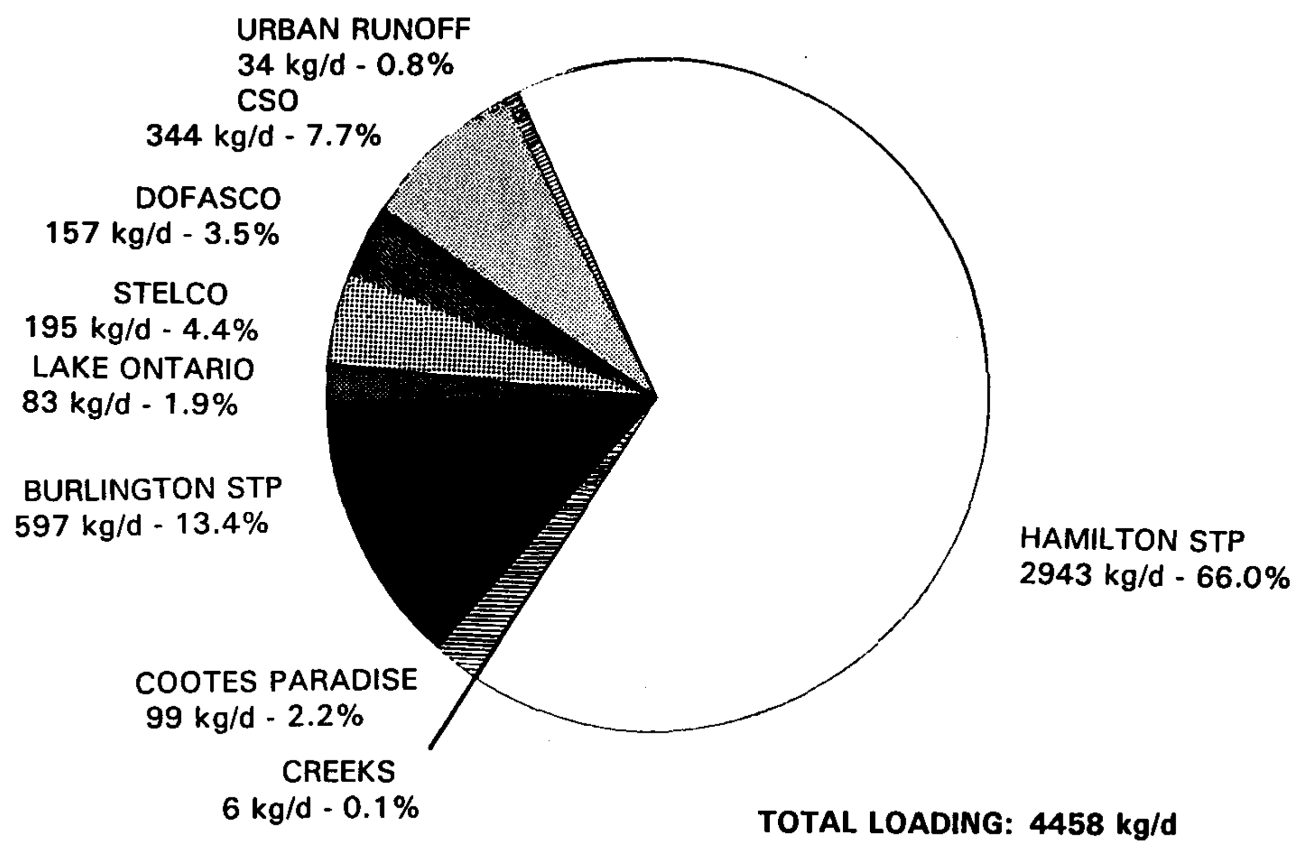
Source: J. Vogt, MOE/WCR

Figure 31: Hamilton Harbour - Un-ionized ammonia concentration.



J. Vogt, MOE/WCR

Figure 32: Hamilton Harbour - Percent of ammonia contribution by source (1989).



Source: J. Vogt, MOE/WCR

Total phosphorus loadings to the Harbour since 1974, including estimates of loadings from creeks and Hamilton's CSOs, are shown in Figure 33, along with the phosphorus concentrations in the Harbour. The total loading has been reduced from about 1,500 kg/day in the mid-1970s to about 330 kg/day in 1989.

In Figure 34, the annual average phosphorus loadings to the Harbour are plotted against the annual average total phosphorus concentrations found in the Harbour. Also included in Figure 34 is a plot of the phosphorus concentrations that would have been predicted using the Janus-Vollenweider model for annual average concentrations (Janus and Vollenweider, 1981).

The actual concentrations are lower than predicted by the model. This difference may be partly the result of "short circuiting" (flushing of phosphorus from the Harbour to Lake Ontario before it becomes completely mixed in the Harbour), but is more likely caused by the removal of phosphorus from the water column by the iron discharges from the steel mills, through precipitation and settling to the bottom sediments. When the Janus-Vollenweider prediction is modified to take iron inputs into consideration, the resulting model more accurately matches the actual concentrations. The iron-corrected model was used to predict the phosphorus concentrations in the Harbour at reduced phosphorus loading inputs (Figure 34).

In 1989, the major source of phosphorus loading into Hamilton Harbour was the Hamilton STP with a loading of 133 kg/day or 40% of the total loading. CSOs discharged about 63 kg/day (19%), the Burlington STP contributed 50 kg/day (15%), and the steel industries about 10 kg/day. Other sources of phosphorus loading include creeks. Phosphorus in the creeks is believed to be mostly due to soil erosion from construction sites, stream banks, and farm land.

The loading calculations above are based on the present sewage flows at the Hamilton and Burlington STPs. As the population grows, sewage flows and phosphorus loadings will increase unless treatment technology keeps pace.

IV.4.1.3 Zinc Loading

Annual average zinc loadings to the Harbour are shown in Figure 35, along with the zinc concentrations in the Harbour water. A major reduction in zinc loading to the Harbour occurred in the early 1980s when Stelco installed a system to recirculate blast furnace wastewaters. This improvement reduced the zinc loading from about 800 to 200 kg/day. Consequently, the zinc concentration in the Harbour dropped from about 0.05 to 0.018 mg/L. Since then, further improvements at the steel mills have reduced the total loading to the Harbour to about 110 kg/day in 1989, with the concentration in the Harbour water at about 0.017 mg/L. The zinc concentration is now within the Provincial water quality objective of 0.03 mg/L.

Figure 33: Hamilton Harbour - Phosphorus loading and concentration.

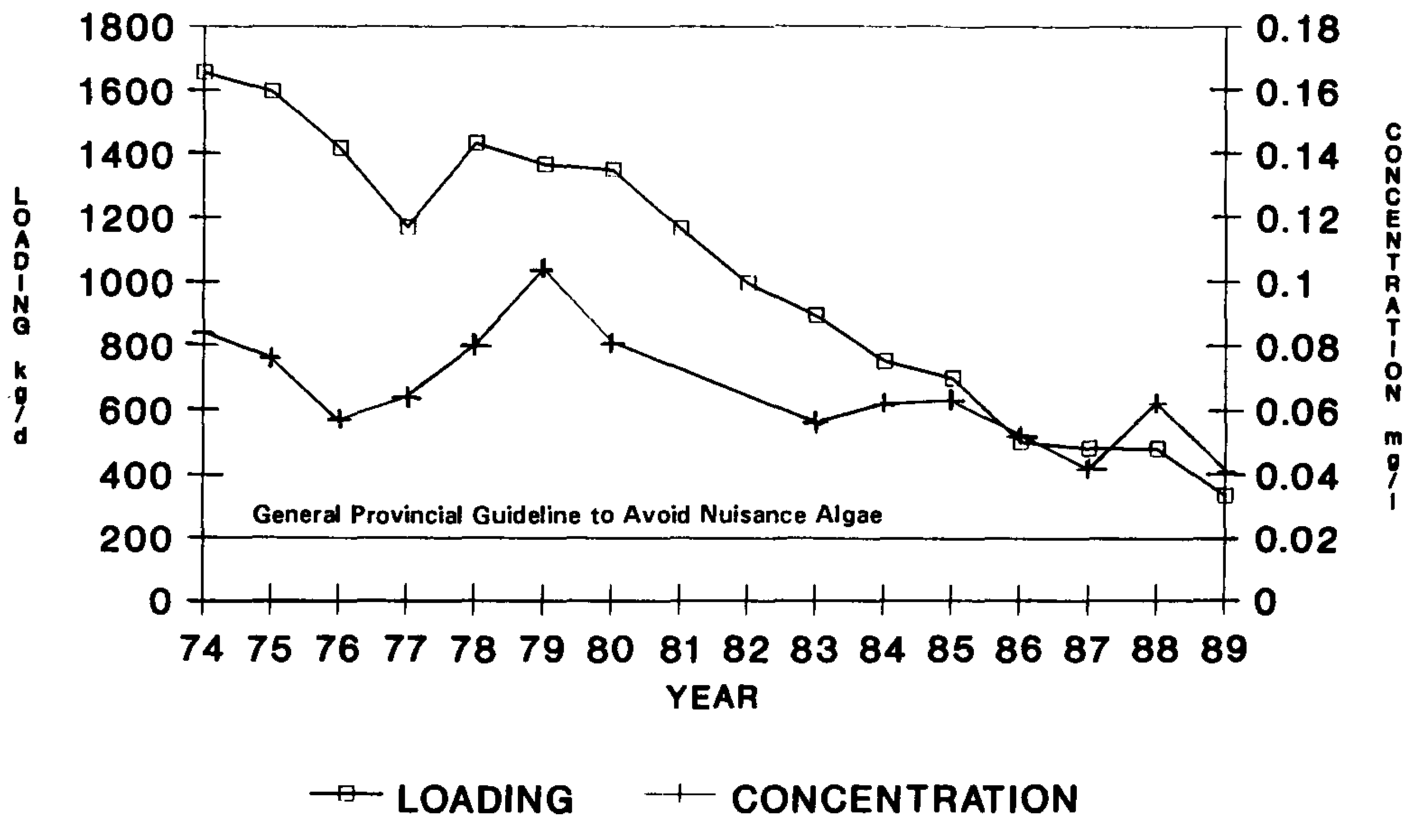


Figure 34: Hamilton Harbour - Phosphorus concentration vs loading.

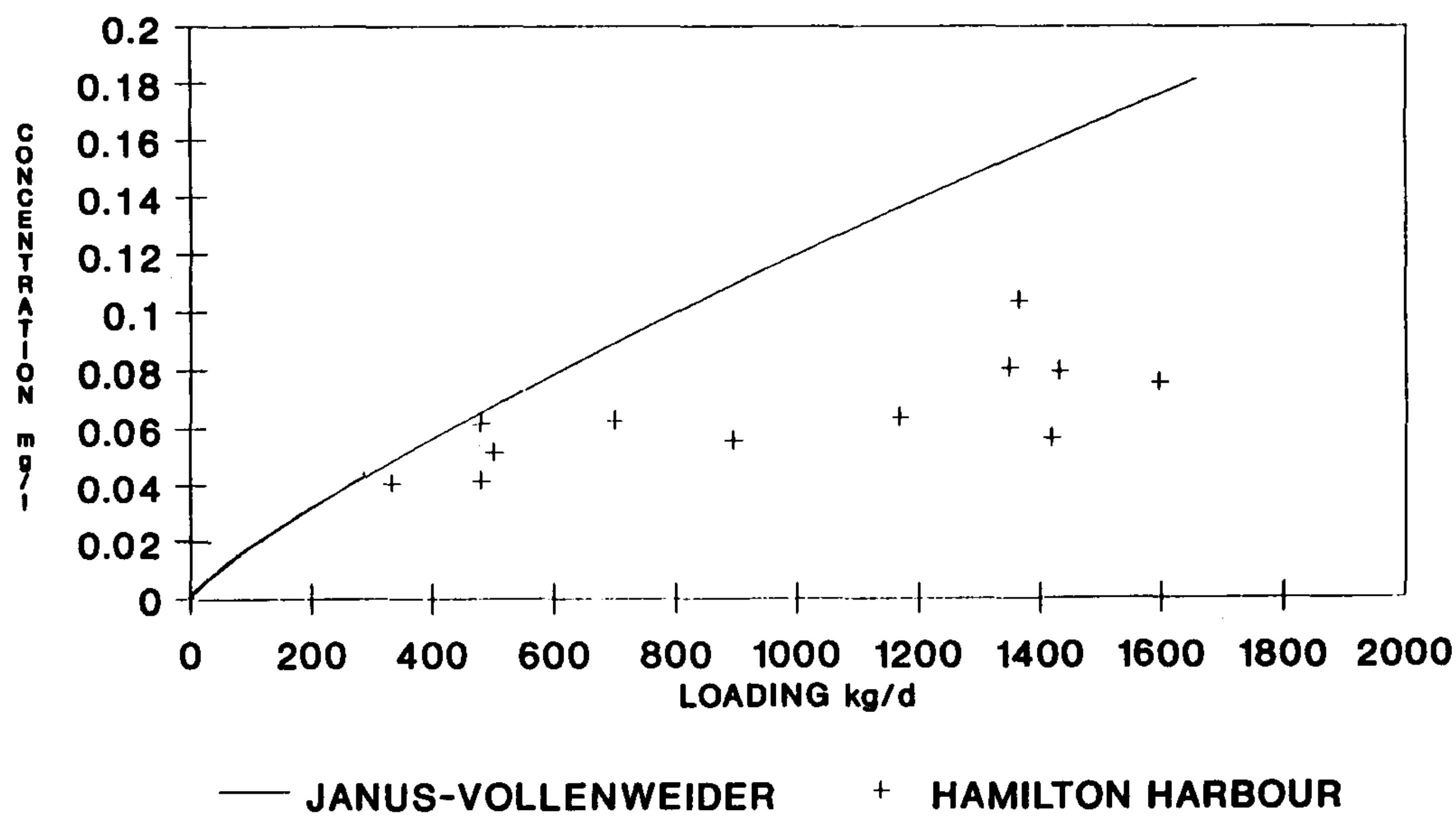
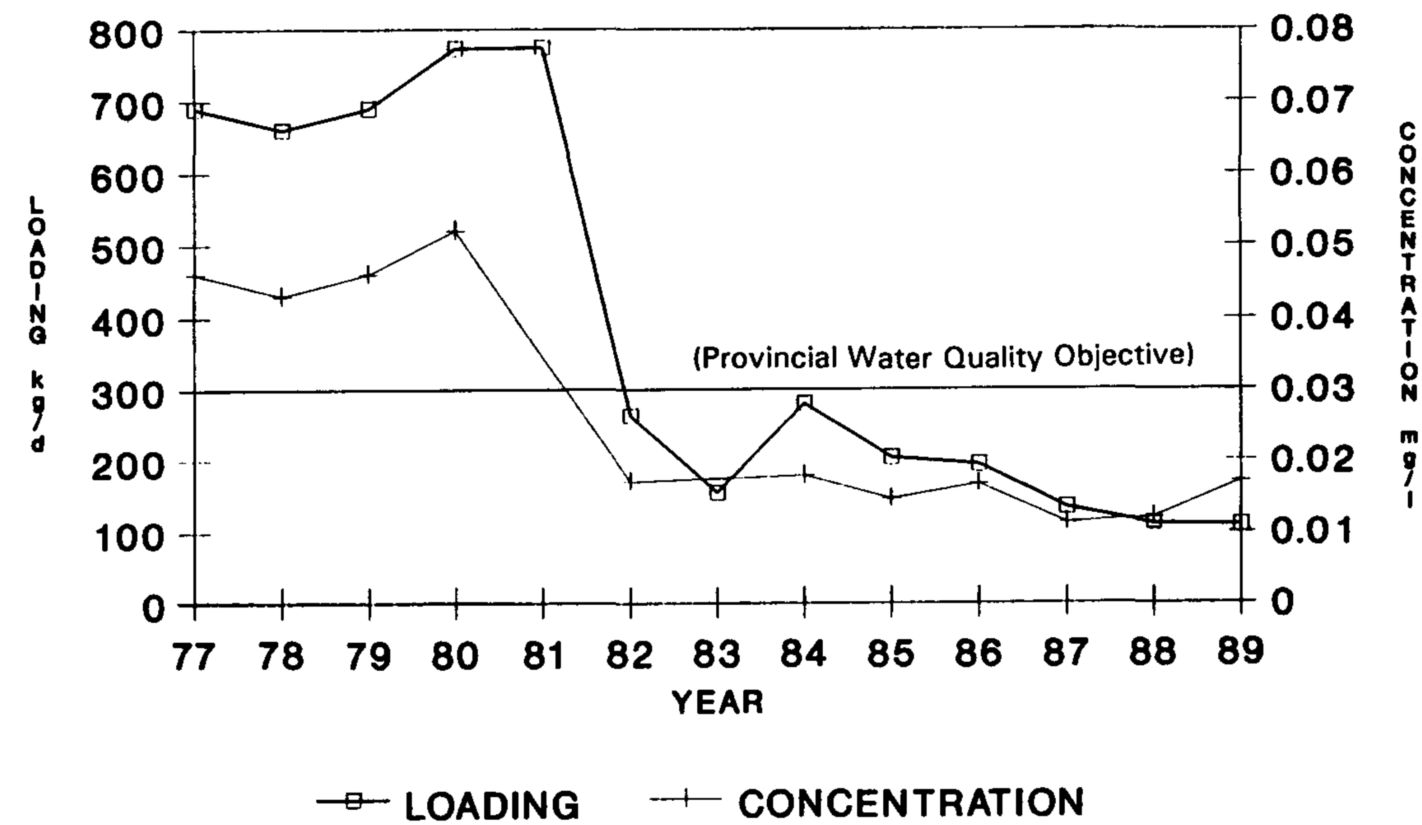


Figure 35: Hamilton Harbour - Zinc loading and concentration.



Source: J. Vogt, MOE/WCR

In 1987, Stelco discharged about 26 kg/day (24%) of zinc into Hamilton Harbour, and Dofasco discharged about 32 kg/day (29%).

IV.4.1.4 Phenols Loading

The annual average total loading of phenols discharged to Hamilton Harbour since 1974 is shown in Figure 36 along with phenols concentrations measured in the Harbour water. The loading has been reduced from about 2,600 kg/day in the early 1970s to about 15 kg/day in 1989 as a result of controls installed by the steel mills. The concentration of phenols in the Harbour water was less than 0.4 ug/L in 1987, well within the Provincial Water Quality Objective of 1 ug/L. Concentrations in 1988 and 1989 were reported to be 1.5 to 2.5 μg/L range. There is no explanation for these elevated levels since the loadings to the Harbour remained low. The concentration in 1990 was again reported to be less than 0.5 μg/L. The high values in 1988 and 1989 are unexplained. A preliminary examination of 1990 data indicates that it has dropped and met the objective again.

IV.4.1.5 Polynuclear Aromatic Hydrocarbon (PAH) Loadings

Knowledge of the historical loadings for PAHs is limited since technology for monitoring these chemicals in the concentrations found in the effluents (ng/L range) is a relatively recent development. The total PAH loading to the Harbour from point sources was found to be 1.8 kg/day in 1986, with the loading of benzo(a)pyrene being 0.068 kg/day.

The wastewater treatment facilities installed to control conventional parameters are also efficiently removing PAHs. The current PAH loading is probably a fraction of a percent of what it was 20 years ago. The control works installed by the steel mills in 1987 and 1988 have to reduce the PAH loading to the Harbour from point sources to less than 1 kg/day.

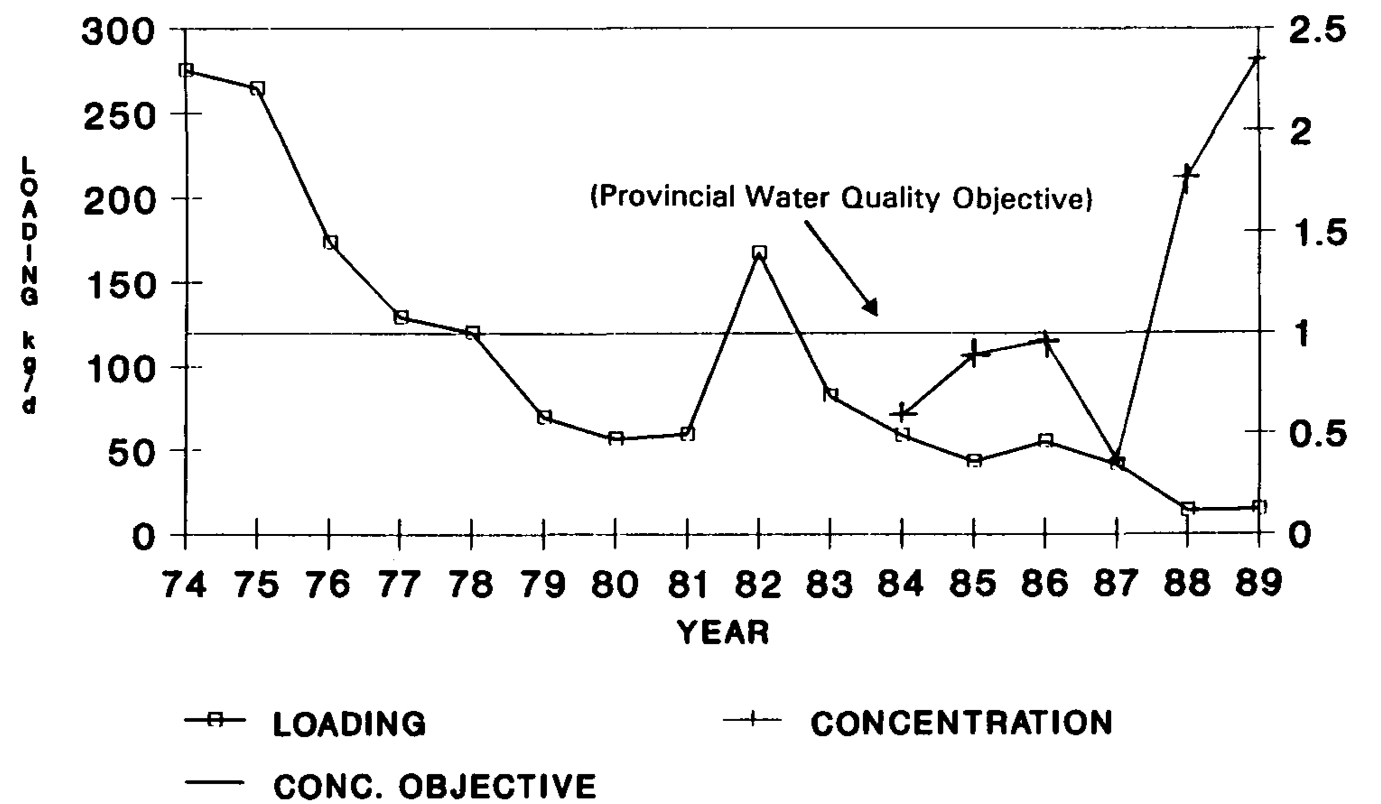
PAHs have only recently been detected in the Harbour water column at low levels. They are also found in bottom sediments. Historical sediments are found to contain greater than 1,400 μg/g of total PAHs as compared to 4 μg/g in sediment deposited in 1987.

IV.4.1.6 Cyanide Loading

Essentially all of the inputs of cyanide to the Harbour are from the steel mills. With installation of pollution control facilities, the cyanide loading to the Harbour has been reduced from about 700 kg/day in 1967 to about 50 kg/day in 1989. The total loadings of cyanide to the Harbour since 1974 are shown in Figure 37.

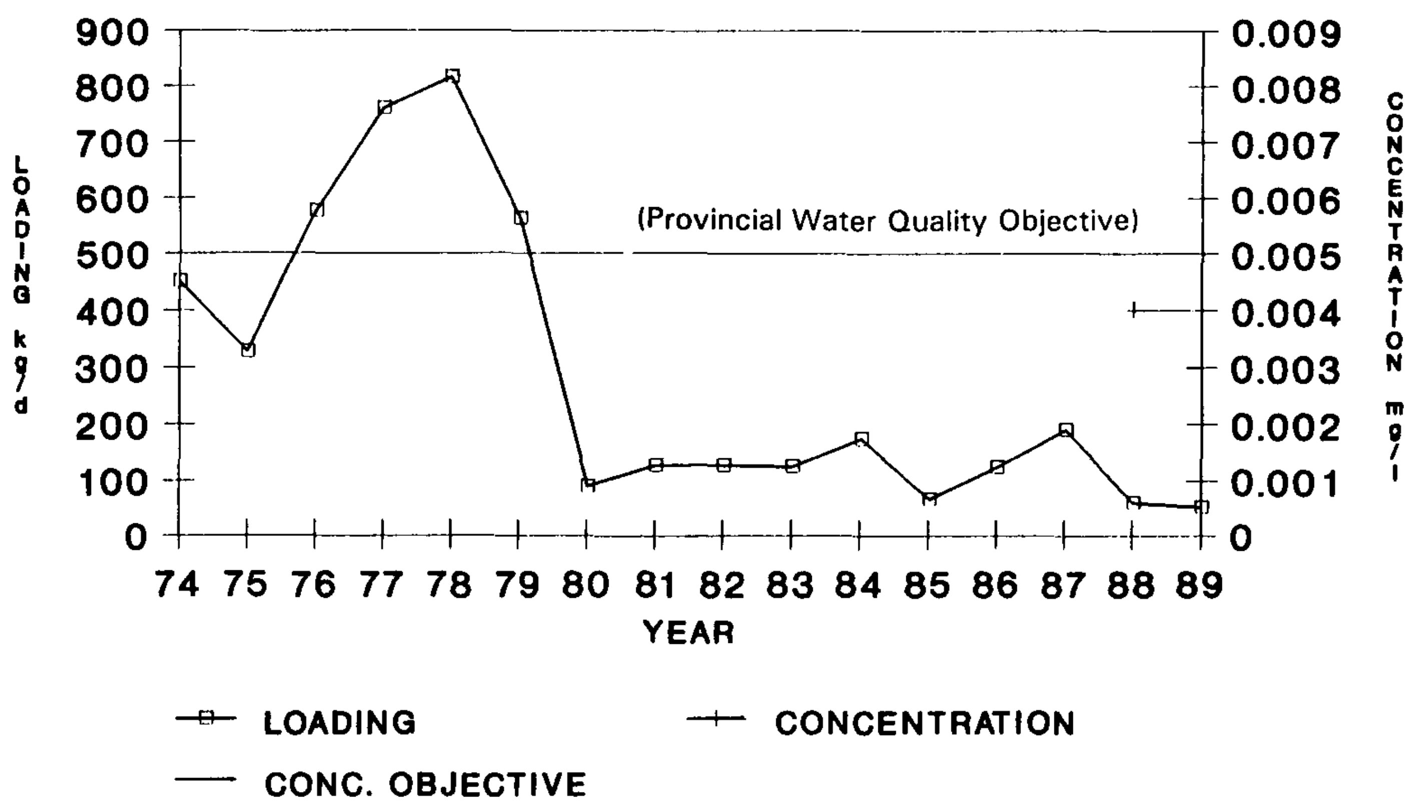
In 1989, Dofasco discharged 48.7 kg/day (98%) of cyanide into Hamilton Harbour. In the late 1970s, when the loadings to the Harbour were in the order of 700 to 800 kg/day,

Figure 36: Hamilton Harbour - Phenol loading and concentration.



Source: J. Vogt, MOE/WCR

Figure 37: Cyanide loading and concentration.



Source: J. Vogt, MOE/WCR

occasional exceedences of the 0.005 mg/L Provincial Water Quality Objective for cyanide were found in the Harbour water column. With the reduced loadings, no exceedences would now be expected.

IV.4.1.7 Iron Loading

The iron loading to the Harbour in 1989 was about 3,000 kg/day, compared to about 20,000 kg/day in the early 1970s. The reductions are the result of improved pollution control facilities installed by the steel mills. The total loading to the Harbour since 1974 is shown in Figure 38 along with the concentrations in the Harbour water column. In 1989, iron loading from Dofasco was 1,321 kg/day (42%) and from Stelco 455 kg/day (14%). CSOs, creeks, and the Hamilton STP contributed the remainder (20%).

In the late 1970s, occasional exceedences of the Provincial Water Quality Objective for iron (0.3 mg/L) were found. With the recent reductions of inputs, the Objectives are not now exceeded.

IV.4.1.8 Suspended Solids Loading

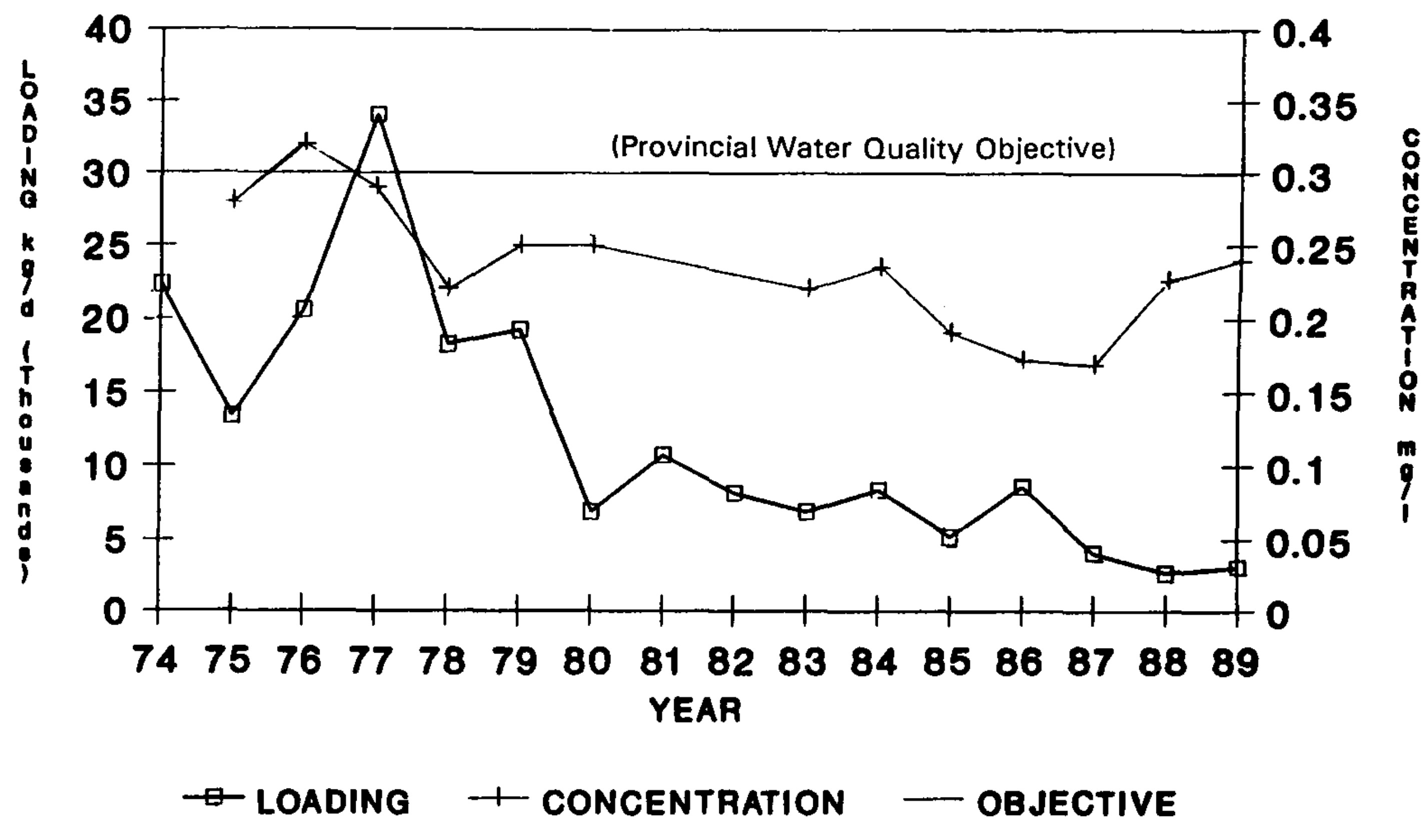
The suspended solids loadings to the Harbour from the steel mills have been reduced from about 150,000 kg/day in 1967 to about 8,450 kg/day in 1989. The total loading from all sources since 1978 are shown in Figure 39. The sources of suspended solids and their relative contributions to loadings in 1987 are shown in Figure 40.

At present, creeks are the largest source, delivering about two-thirds of the total suspended solids loading to the Harbour. A study is now underway to identify the sources of suspended solids in the creeks and to determine detailed abatement strategies. Initial study suggest that the largest input from streams comes from areas below the escarpment (i.e. not farmland). Construction activities for residential or industrial development, for highways and for railways are strongly indicated.

When considering the impact of suspended sediment loading on water clarity in the Harbour water, it is necessary to consider the resuspension processes at work. Both carp activity and wave resuspension are important factors, in addition to the loadings themselves. A second concern relating to suspended solids loading is the contaminants within or adhering to the particles being discharged into the Harbour.

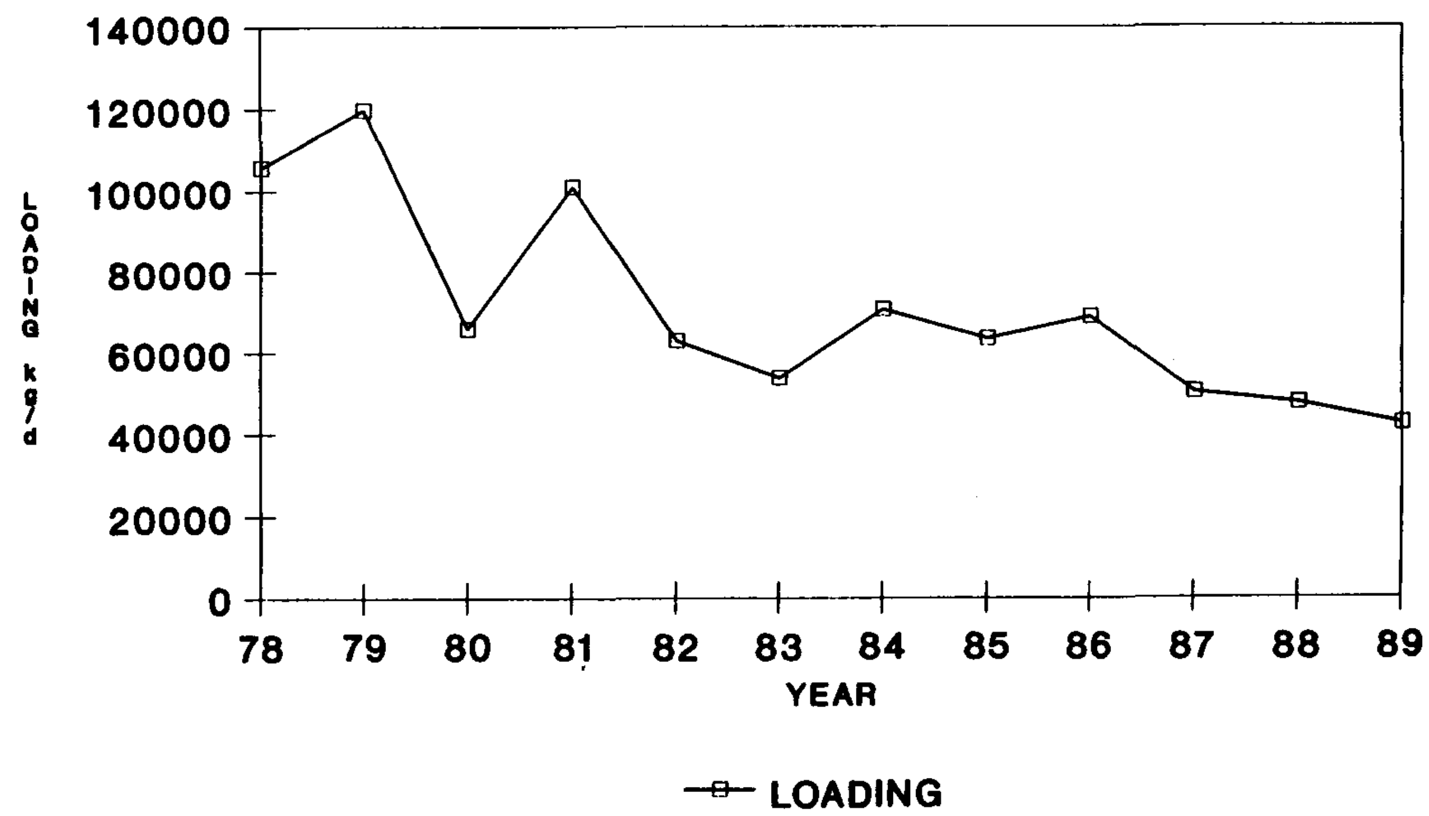
A final consideration is the impact of sediment loadings on the formation of mud banks and deltas where marsh develops or sensitive habitat requires maintenance. Suspended sediments also form a major part of the material laid down on the top of bottom sediments. Hence its quality and amount will determine the character of the future condition of Harbour sediments.

Figure 38: Hamilton Harbour - Iron loading and concentration.



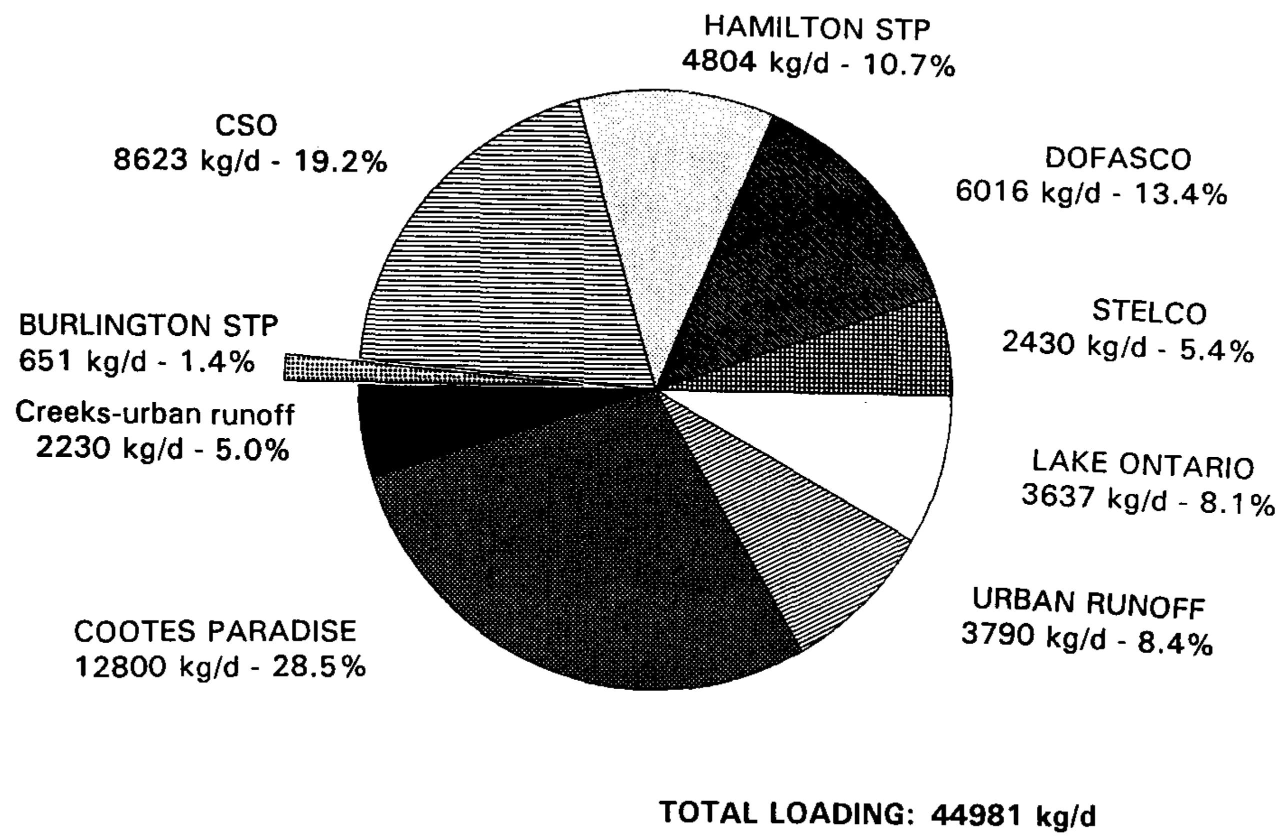
Source: J. Vogt, MOE/WCR

Figure 39: Hamilton Harbour - Suspended solids loading.



Source: J. Vogt, MOE/WCR

Figure 40: Hamilton Harbour - Percent of suspended solids contribution by source (1989).



Source: J. Vogt, MOE/WCR

IV.4.2 Cootes Paradise
IV.4.2.1 Phosphorus Loading

Phosphorus inputs must be reduced to reduce algal growth. The average retention time in Cootes Paradise is only 2.7 days averaged over the year. However, about a 20-day retention time occurs during the summer, low flow period. Control of available phosphorus inputs during the peak algal growing season of mid-April to mid-September is important.

The total loading of phosphorus to Cootes Paradise during the peak algal growing season has decreased from about 55 kg/day in the mid 1970s to about 42 kg/day in 1989 as a result of the expansion of the Dundas municipal STP. Figure 41 shows the average loadings of phosphorus to Cootes Paradise, from mid-April to mid-September, 1975 to 1989, and the concentrations of phosphorus measured in Cootes Paradise. In 1989, CSOs contributed 14.8 kg/day (35%), and creeks discharged 8 kg/day (19%) of phosphorus into Cootes Paradise.

IV.4.2.2 Suspended Solids Loadings

The largest source of all the suspended solids loading into Cootes Paradise is the creeks (4,858 kg/day in 1989, 49%) with the remainder primarily from combined sewer overflows (19%) and direct urban runoff (24%).

Soil erosion adds to turbidity in Cootes Paradise. The most common practice in the construction of subdivisions is to initially strip off the top soil. Sewers and water mains are then installed and the homes and streets constructed. The top soil is then replaced and the lots are sodded. Between the stripping of the top soil and resodding, erosion rates are very high. With development, the water retention capabilities are reduced, resulting in more rapid runoff of precipitation. The more rapid runoff, in turn, causes higher peak stream flows which result in increased erosion of stream beds and banks.

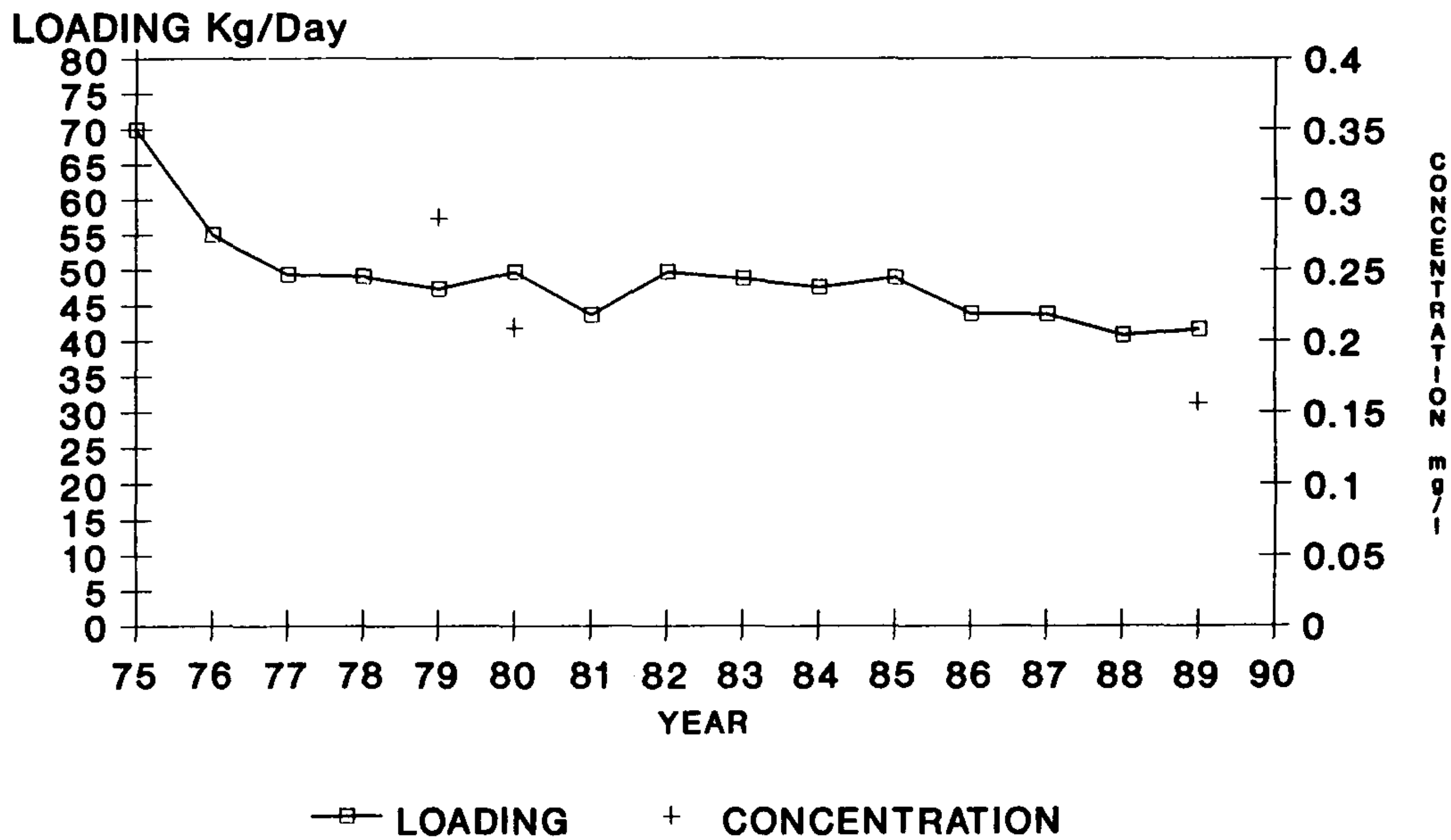
The trend in farming has been to plant more row crops such as corn. Soil is less protected from erosion with these crops.

Measures to control soil erosion include settling basins for runoff from construction sites, storm retention basins to reduce peak storm flows, installing riprap on creek beds and banks susceptible to erosion, and modifying farm practices to minimize soil loss. Two studies have been carried out demonstrating the potential for improvement in both types of erosion control. Elimination of combined sewer overflows is essential.

IV.5 Tabular Summary of Loadings

The preceding sections have described the trends and details of loading estimates. It was pointed out that current remedial programs were substantially lowering many of the contaminant loadings, and that several of the more diffuse loadings (creeks and CSOs), or

Figure 41: Cootes Paradise - Phosphorus loading and concentration.



Source: J. Vogt, MOE/WCR

intermittent loadings due to storms, have not been adequately sampled within a consistent time frame to provide a very accurate mass balance for the Harbour.

However, even approximate loadings are useful in establishing effective and efficient strategies to address the problems. In addition, efforts to account for the fate of the substances of concern in a comprehensive way provides greater confidence that we understand the situation more fully.

Hence we present here our third effort to develop data on loadings to the Harbour based on 1989 data and our earlier report (COA, 1989). The various estimating techniques are noted below.

Industrial and municipal loadings are based on direct measurements on file with OMOE/WCR. Urban runoff, creeks and CSO loadings are based on a mixture of streamflow measurements and generic information on contaminants in urban runoff (in the absence of direct measurements). The CSO loadings have been developed in a model study within the Pollution Control Planning Study for Hamilton-Wentworth Region.

The exchange between the Harbour and Lake Ontario was based on the estimated inflows and outflows (OMEO, 1985) annually with average values of the concentration of the substances inside and outside the Harbour. The exchange between Cootes Paradise and the Harbour uses the proportionality of the Lake/Harbour exchange with known runoff and the ratio of Harbour to Cootes Paradise areas.

In so far as adequate data existed, a comprehensive loading estimate was attempted for those substances of direct concern to Harbour conditions or to the priority list of the Lake Ontario Toxics Management Plan.

Apart from the very different types of data that have been melded into Table 28, the entries will give some indication of the potential for variability in estimates. One will note the discrepancy between total Cootes Paradise loadings and Cootes Paradise loadings to the Harbour. While not exact computational analogues, they indicate the degree of variability possible. Furthermore we do not believe that the PCB loading to Lake Ontario is negative. Representative PCB measurements at the low concentrations are difficult to obtain, whether due to variability of the parameter or lack of correspondence between analytical methods.

It is thought, also, that the high lead loading from CSOs to the Harbour arises because the estimate is based on urban runoff measurements made before the recent major reduction in lead in gasoline.

Additional studies have addressed estimates of loadings to the Harbour through groundwater in the industrial area of the waterfront (Table 29) and an examination of the drainage from old landfill sites. In both cases they have proven to be insignificant compared to known point sources or existing streamwater conditions, although additional investigations are being carried out.

Atmospheric contributions (Tables 28 and 30) have been updated by including dust fallout contributions. Its major impact is found in an increased iron loading (compared to Table 24 in the 1989 report).

Estimates of loading of organic substances has not altered from the 1989 report. Major new data will be available when the MISA monitoring results are published.

Table 28: Loadings to Hamilton Harbour as estimated for 1989. Values used to produce annual pie graphs in this report. All loadings in kg/d except PCBs loading which is in g/d. Flows are in $10^3 m^3 d^{-1}$.

HAMILTON HARBOUR

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Lead	PCBs
1989	Stelco (net)	1060	2400	200	0	6.3	0	26	450	1.1	1.3	0.2	0
	Dofasco (net)	660	6000	160	0	2.3	49	32	1320	0.4	5.0	0.8	0.7
	Hamilton STP	310	4800	2900	130	0.6	0	13	220	2.5	3.8	0.4	4.4
	Burlington STP	70	700	600	50	0.2	0	3	40	0.6	0.5	0.1	0
	Creeks		2800	10	10	0.2	0	1	60	0.2	1.6	0.1	0
	Cootes Paradise	300	15000	100	50	0.4	0	6	440	1.4	2.0	2.0	0.2
	CSO		8600	340	60	1.5	N.A.	12	400	2.9	2.5	7.5	7.1
	Urban Runoff		2300	30	10	0.3	N.A.	11	160	0.6	0.4	3.1	2.6
	Lake Ontario (inflow)	2700	3600	80	30	3.1	N.A.*	6	80	4.6	14.6	1.1	5.2
	Atmosphere	53	N.E.	N.E.	N.E.	N.E.	N.E.	5	110	0.7	0.3	0.9	7.0
	TOTAL:		46000	4400	340	14.9	51.7	115	3280	15.0	32.0	16.2	27.2
	Hamilton Harbour to Lake Ontario (outflow)	3000	16000	5400	280	8.9		103	650	15.0	15.4	3.0	1.0
	NET DISCHARGE TO LAKE	300	12000	5300	250	5.8		97	570	10.4	0.8	1.9	-3.3(?)
	COOTES PARADISE												
	Dundas STP		20	25	4	0.1	N.A.	.2	0	0.2	0.7	0.1	
	Creeks		5000	8	5	0.4	N.A.	8.0	639	1.0	8.9	2.2	
	CSO		2000	81	15	1.2	N.A.	7.0	93	0.7	0.6	1.8	1.7
	Urban Runoff		2300	34	7	0.3	N.A.	11.0	156	0.6	0.4	3.1	2.6
	Hamilton Harbour		800	85	8	0.2	N.A.	2.0	24	0.5	0.3	0.6	
	TOTAL		10100	233	39	2.2	0	28	912	3	10.9	7.8	

Note: N.E. - not estimated; N.A. - Not available

* Cyanide has not been detected at drinking water supply intakes in Lake Ontario.

TABLE 29: Estimated Loadings to Harbour in groundwater from industrial area.

Source	Total Loadings	
Phenols	0.01	kg/day
PAHs	0.05	mg/day
Zinc	0.01	kg/day
Cadmium	0.00005	kg/day
Chromium	0.002	kg/day
Copper	0.002	kg/day
Lead	0.01	kg/day
Source: J. Vogt, OMOE/WCR		

TABLE 30: Organic contaminant loadings by source to Hamilton Harbour (kg/d)(other than PCB's noted in Table 28).

	POINT SOURCES				NON-POINT SOURCES	
	Municipal STPs		Industrial			
	Hamilton	Burlington	Stelco	Dofasco	Storm Sewers, Creeks, CSOs	Atmospheric
Oil, Grease			4579	55	(*)	
α-BHC	0.003	0.007			(*)	0.002
γ-BHC	0.006	0.001			(*)	0.011
DDT	0.004	<0.0002			(*)	0.0004
Dieldrin		<0.0002			(*)	0.0004
Endosulfan					(*)	0.006
HCB	0.004	0.003			(*)	0.001
Mirex	0.005	0.002			(*)	
Chlordane	0.0001	0.0005			(*)	
Pesticides	0.02	0.007			(*)	
Volatiles			0.08	0.55	(*)	
PAHs	0.02		1.05	0.76	(*)	0.116

Note: (*) No reliable estimates available yet.

Source: Kuntz 1980; IJC 1980; MOE 1988.

V SUMMARY OF ISSUES AND CONCERNS

V.1 Introduction

For the present and future uses of Hamilton Harbour, concentrations of pollutants are to be brought below the levels set out in the Provincial Water Quality Objectives, Federal Objectives or Great Lakes Water Quality Agreement Objectives (whichever is most stringent). In accordance with the Great Lakes Water Quality Agreement (GLWQA), the virtual elimination of the discharge of persistent toxic substances is also required. In addition to water quality and sediment contamination problems, habitat is also a limiting factor for populations of fish and wildlife in the Harbour. All of these factors will need to be addressed in a balanced fashion in order to ensure the future integrity of the aquatic ecosystem.

For Cootes Paradise, more stringent objectives have been established by the Royal Botanical Gardens, which owns the area. The goal is to ensure that plant and animal life will survive and thrive in all parts of Cootes Paradise; and that, as a wildlife sanctuary, Cootes Paradise will be a high quality habitat complex for waterfowl and other marsh-dependent wildlife. Cootes Paradise is a key tributary and marsh zone for the Harbour.

The issues arise in different ways depending on whether one examines them on the basis of a single contaminant (or particular groups of contaminants); on the basis of the type of source (industry, STPs or rivers, rain, etc.); the use being impaired or type of impact. We shall start with summarizing the issues in a way which seems best suited to public concerns, followed by a table summarizing the situation in relation to the 14 beneficial uses listed in the 1987 Protocol to the GLWQA.

V.2 Issues

V.2.1 Water Quality/Eutrophication/Water Clarity

In early spring, the Harbour water is saturated with dissolved oxygen, which rapidly declines to 80% saturation in the epilimnion and only 10-20% saturation in the hypolimnion in the summer. In the hypolimnion, the dissolved oxygen fluctuates widely due to cold, oxygen-rich Lake Ontario water entering via the Burlington Ship Canal. If this inflow did not occur the depletion of oxygen could be even more severe. It is possible that without this inflow well mixed conditions would occur earlier in the summer.

This aspect of eutrophication has several causes. Large amounts of ammonia and phosphates enter the Harbour from the sewage treatment plants (STPs), creeks and combined sewer overflows (CSOs). The ammonia is nitrified to nitrates by bacteria, a process that requires about 40% of the total oxygen demand in the water column. The nitrates and phosphates are utilized by algae, producing an algal bloom. The algae die and decay, utilizing another 40% of the total oxygen demand. Oxygen demand at the sediment/water interface, from the

9% of the time for iron, 3% for zinc, and less than 1% for the more toxic metals. Only ten years ago exceedences were much more frequent. Most of the trace metals are discharged by the steel industries.

Organic pollutants of concern include polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), phenols, and pesticides (Mirex, DDT, Diazinon). PAHs are discharged mainly from the steel industries, and the PCBs and pesticides are found in rain, creeks, and the discharges from STPs. PAHs are rarely found in the water except bound to colloidal particles, but are present in the sediments, particularly the "historical" sediments.

PCBs in the water column require more thorough investigation in conjunction with analyses of sediments, rainfall, and biota to ensure that all possible remedial actions have been taken to eliminate local sources. Initial results (Fox, personal communication) indicate that PCBs in the Harbour are older, weathered components which have not been recently released to the environment.

Since the late 1970s and early 1980s, when treatment of sewage and industrial waste was improved, the concentrations of priority pollutants in the Harbour water and recently deposited sediments have decreased substantially. However, in earlier years, large quantities of heavy metals and organics were discharged. Some of those loadings still remain in the historic sediments, buried beneath recent deposits.

Bioassays have indicated a wide variability in the toxicity of the sediments. Certain areas of the Harbour are clearly indicated as urgent sites for remediation because of toxic sediments. One major variability that has been observed is seasonal. The greatest toxicity occurs when the dissolved oxygen in the hypolimnion is low in the summer. Test oxygenation of the bottom sediments also greatly reduces their toxicity.

More generally, the sediments in Hamilton Harbour have levels of contaminants that exceed acceptable limits for open water disposal of dredgeate under Provincial Guidelines and the more recent draft Provincial Sediment Quality Guidelines (MOE, 1991). Contaminated sediment, if it is moved, must be placed in a confined disposal facility. Current facilities are designed only for dredgeate from navigational dredging, and are only adequate to the year 2000. Thus, further disposal procedures will have to be developed, both for handling navigational dredgeate beyond 2000 and for dredgeate resulting from dredging undertaken to remediate the more contaminated areas.

The optimal method for dealing with contaminated sediments in areas other than those normally dredged for navigation purposes is not yet known. Dredging large parts of the Harbour is probably impractical, from the point of view of siting for disposal. Dredging on a large scale is also likely to have a severe environmental impact unless extensive controls are implemented. Some small areas of the most contaminated sediments might be dredged under suitable controls for both the dredging operation and the disposal of the dredgeate. As for other methods, the issue is the choice of chemical or physical treatments (or natural oxidation of methane and the production of nitrogen, can consume a further 20% of the oxygen. The hypolimnion is therefore virtually anoxic during the summer, and unable to support a coldwater fishery.

The algae themselves present an aesthetic problem as they reduce water clarity and cause an unpleasant nuisance growth that fouls beaches and rocks. Phosphorus control is the answer to excessive algal growth.

Generally speaking, the whole Harbour is affected by phosphorus loadings. However, the circulation in the Harbour is such that small, local phosphorus sources have an impact out of proportion to their contribution to the overall loading of the Harbour. These sources (the Dundas and Waterdown STPs) affect sensitive habitat in the shallower waters in the embayments and marshy areas at the west end of the Harbour and in Cootes Paradise.

Overall, preliminary loading targets of 3,600 kg/day of ammonia (Figure 30) and 200 kg/day of total phosphorus (Figure 33) for the Harbour are deemed necessary to correct the problem of anoxia, although this will need careful review (Marshal et al., 1988). Total phosphorus loading may have to be reduced to < 100 kg/day to relieve anoxia problems. Special attention will have to be given to phosphorus loadings in Cootes Paradise and to the western half of the Harbour to improve the algae problems in those areas.

Un-ionized ammonia itself has until recently exceeded the objective over 15 to 25% of the south-east and eastern parts of the Harbour in late winter and early spring. These levels may be acutely toxic to fish. The ammonia loading reductions have already improved this situation, although loading targets may have to be even lower to meet the need for improved oxygen conditions.

Water clarity affects light penetration to the bottom of littoral areas where submerged macrophytes could grow, thereby affecting the abundance of habitat necessary for certain species of fish. Suspended sediments are the major contributors to poor water clarity in Cootes Paradise and near the mouths of the creeks after rainfalls. In the central areas of the Harbour, the phytoplankton is the major obstacle to improved water clarity.

To improve water clarity, phosphorus loading needs to be reduced to the target noted above, and suspended solids loadings should be reduced by 50%. A better understanding of suspended sediment loads from creeks, from bank erosion below the escarpment, from the high yield rural areas, and especially from urban watersheds is essential. Carp activity is also a major cause of water clarity problems in shallow areas.

V.2.2 Contamination by Trace Metals and Trace Organics

The major heavy metals in the Harbour water are iron, zinc, copper, nickel, chromium, lead, and cadmium. The concentrations of these metals in the water column now exceed the Provincial Water Quality Objectives at the mid-Harbour monitoring stations no more than burial) that might be effective. Whatever the case, it is essential that we understand first whether the current loadings of the contaminants causing the sediments to be toxic have been reduced sufficiently to prevent re-occurrence of the problem. That information is being further developed and will be incorporated into the Stage 2 implementation process.

In the hypolimnion, conditions of low oxygen levels facilitate the release of manganese and iron, rendering these elements more bioavailable. Other metals may also be released. Biomagnification of contaminants by benthic organisms is of concern due to possible transmission to predator species and subsequent accumulation through the food web.

V.2.3 Bacterial Contamination

In the 1930s, the Hamilton Harbour Commissioners, acting on the advice of the Medical Officer of Health, enacted a by-law prohibiting swimming in the whole Harbour because of faecal contamination of the water. Windsurfing is restricted for the same reason, and some boating is more risky where capsizing might occur. Levels of faecal coliform bacteria (indicators of faecal contamination) vary throughout the Harbour with conditions ranging from suitable for swimming to completely unacceptable. Higher levels of bacteria are found after rain and in areas close to sources.

The sources of faecal coliform bacteria are combined sewer overflows, sewage treatment plant by-passes, sewage treatment plant effluent, runoff from urban (streets) and rural areas (animal sources), illegal sewer hookups, and malfunctioning septic tank systems. The relative importance of these sources has to be established for each affected area in the Harbour.

Since the sources of faecal coliform bacteria are widely distributed, no area in the Harbour is completely free of contamination. The least affected areas are along the north shore and at the west end. Given the existing use of the Harbour by recreational boating, open water areas must also be considered. Of course, any strategy which controls bacterial problems in nearshore areas would eliminate offshore problems which arise from the mixing of Harbour waters.

There is a provincial water clarity criterion for swimming, which the nearshore waters of the Harbour often fail to meet. Reduced water clarity is due to the combined effects of suspended sediment and algae. Sediment material enters the water column from creeks carrying eroded soil, shoreline erosion, bottom sediments stirred up by wave action, and resuspension caused by the feeding activities of carp. Algal growth cause water clarity and aesthetic problems throughout the Harbour (V.2.1 above).

Bacterial quality and water clarity are the parameters specified in current standards. New water quality standards for body contact are being considered, and these will have to be considered by health authorities in any future decisions regarding the designation of beaches.

V.2.4 Stresses on Fish and Wildlife

Historical documents reveal that Hamilton Harbour and Cootes Paradise supported abundant wildlife. A commercial fishery thrived, a commercial fur harvest existed, and waterfowl nested in the extensive marshlands in Cootes Paradise and along the south shore of Hamilton Harbour. In the spring and fall, the area was a staging ground for millions of migrating birds.

As industrial and urban development proceeded, the Harbour marshlands were either filled for industrial land or dredged for shipping. Urbanization of the drainage basin has also resulted in the loss of the Cootes Paradise marsh. The discharging of excessive nutrients and the resultant oxygen depletion of the hypolimnion, along with overfishing and the introduction of exotic species, destroyed the coldwater fishery. The fish population changed slowly from large, long-lived predator species to the smaller, short-lived, pollution-tolerant foraging species characteristic of eutrophic environments.

Ammonia is still present in sufficiently high concentrations to affect the fish and benthic populations as a toxic contaminant. The concern is documented in section V.4.

Fishing stress on the Harbour, while light at the present, could be a concern in the future. The one exception is carp, which could be selectively removed in order to alleviate the stress which it puts on fish habitat and water clarity.

While there appears to be adequate adult fish habitat for warm-water species, habitat for spawning and for juvenile stages of some key species is lacking. The areas with the most potential for habitat redevelopment are Cootes Paradise, the western and north shores of the Harbour, and the estuary of Grindstone Creek.

Neoplasms and other lesions have been reported on several species of fish. It is uncertain whether their origins are chemical or biological. Carcinogens are suspected, although standards for acceptable frequencies of lesions, and the exact cause of lesions, have not been established. Thus it is difficult to identify specific remedies or acceptable levels of their incidences. There is generally a higher prevalence of lesions on fish from urban areas such as Lake Ontario and Hamilton Harbour than on fish from Lake Huron or Manitoulin Island.

Due to the presence of contaminants in Ontario fish, a "Guide to Eating Ontario Sport Fish" has been published. Five of the twelve species listed for Hamilton Harbour have consumption limitations; one of these species is restricted for all sizes. Consumption limitations arise from the presence of one or more of Mirex, PCBs, and mercury.

Concerns for an edible fishery in Hamilton Harbour must be addressed on a whole-Lake basis. Many of the non-resident species accumulate contaminants Lake-wide, and it is unlikely that reduced loadings in Hamilton Harbour alone will result in elimination of fish consumption advisories for this Harbour.

PCBs and other organochlorine levels were higher in snapping turtle eggs from Hamilton Harbour than from nine other sites in Southern Ontario. Hatching deaths were also greatest at Hamilton Harbour and one other site, but deformities were highest elsewhere. Turtles in Hamilton Harbour may also be subject to contaminants in the Lake, because some of the fish they eat migrate between the Lake and the Harbour.

Colonial bird populations are in much better shape than in the mid 1970s. The concentration of contaminants in gull eggs, low hatching rates and the incidence of mutants have all declined. Reproductive rates are considered normal at present.

Present concerns for wildlife are: the heavy metals and toxic organics in the sediments of Windermere Basin and the confined disposal facilities and their impact upon wildlife; and the future development plans which could result in habitat loss in Windermere Basin, at the Hydro Islands, and at Pier 27 (north end of the existing CDF).

Redevelopment of marsh habitat in Cootes Paradise would add considerably to the wildlife potential in the area since much habitat has been lost through refilling, siltation, changes in the water level regime and carp infestation.

Algal production and species composition is affected by physical mixing processes and, very recently, by phosphorus concentrations as the phosphorus loading reductions have now reached levels that will make critical differences.

Zooplankton populations have not been sampled recently, so conclusions with respect to their species composition are not possible at this time.

Benthos populations have improved in numbers and composition over the last 20 years. Bioassays suggest that they are affected by conditions in the sediment. Current research is trying to determine if mitigation of the benthic habitat can be achieved by improving the oxygen concentration in the summer hypolimnion, or by direct oxidation of the bottom sediments.

Approximately 90 hectares of submergent vegetation is present in Hamilton Harbour. The number of species of macrophytes is low, and typical of turbid water bodies with a low diversity of habitat types and with sediments of low organic content.

V.2.5 Aesthetics and Access

Persistent objectional loadings of oil and grease have been deposited in the deeper parts of the Harbour, but are not present now in the shallower areas. Oil sheens are observed infrequently and seem to be related primarily to shipping activities. Discharges from urban areas and combined sewer overflows result in periodic occurrences of objectionable turbidity. In small quiescent embayments or the upper ends of boat slips there can be found floating scum, debris, trash and putrid materials. Combined sewer overflows are probably the main concern in this regard. Water clarity, discussed above, is also an aesthetic concern.

The aesthetic quality of an area cannot be easily quantified. Hamilton Harbour is important in the life of the Hamilton and Burlington region; it provides jobs as well as recreation and scenery. However, the murkiness of nearshore waters, an unsightly shoreline, noise from highways, and the odours and dust from industrial operations all detract from enjoyment of the Harbour.

It is hard to suggest to citizens the importance of cleaning up a Harbour they can hardly see or get to. Views of the Harbour are blocked by industrial and marine facilities, and there are few paths or beaches where people can walk. What there is to see in the Harbour is not always worth the effort - little wildlife and few recreational activities. Often there is an unpleasant odour in the air.

Cleaning up the Harbour is required for many reasons unrelated to the public's access to it. However, the goals of the Stakeholders include making the Harbour swimmable and available for simple enjoyment. To some citizens this may mean passive recreational facilities such as boardwalks, while to others it may include more active recreation such as boating, swimming, or windsurfing. The Harbour and the RAP also provide opportunity for public education. Information programs, both at the site and in other settings, could contribute to public understanding of the specific needs of Hamilton Harbour and of the general need for all citizens to take responsibility for environmental problems such as we find in the Harbour.

Measures that reunite the citizens of the region and their waterfront can demonstrate how all citizens will share in the benefits of the remedial program.

V.2.6 Coordination and Forward Planning

The situation in Hamilton Harbour presents a challenging opportunity to demonstrate the willingness and capability of many people to work together to restore more uses for the Harbour and Cootes Paradise. It is customary to emphasize the diversity of interests that have a stake in a place like Hamilton Harbour. Nevertheless, a group of 42 Stakeholders have been drawn together to assist in the development of the Remedial Action Plan. And they have been very active in reviewing the results of the work of the Technical Team, as well as developing their own reports.

As the Plan moves forward, however, there is a need to develop a more viable institutional arrangement to oversee and monitor its implementation, and to monitor the inevitable changes that will have to accompany such long-term plans. This is not just a function of the diversity of political jurisdictions, regulatory powers and mandates, complicated though they are. It is also a matter of achieving an adequate ecosystem approach that ensures that decisions made in the watershed do not now, nor in the future, negate our collective efforts to improve Harbour conditions.

Many of the problems in the Harbour can be traced to activities that fall under the general heading 'land management'. The relatively rapid urban expansion in the region surrounding the Harbour has resulted in erosion from subdivision development and unwise stream management. Sewage treatment plants are unable to cope adequately with the urban expansion along with stormwater treatment. Road and highway construction destroys wildlife habitat. Industrialization has also contributed to the degradation of the Harbour in many ways in the past.

Dealing with complex issues like land use planning is complicated by the multiplicity of levels of government and their agencies who all function under different mandates and with different responsibilities. No overall plan exists that pulls together all these agencies and provides them with a common set of objectives. It will be a key requirement to incorporate the vision, the goals and the objectives of the RAP into official plans and regulations at all levels of government.

In an important sense, the condition of the Harbour and the conditions of the social and economic state of the communities around the Harbour are inextricably linked. In order to sustain development in an environmentally sound way, a broad consultative mechanism needs to be put into place along with adequate means to ensure that decision-making is made accountable for the broader social, economic, and environmental impacts. The Harbour can be a focus for such efforts because it receives all waterborne waste from the watershed. The Harbour is a mirror of how well we manage throughout the watershed.

V.3 Stakeholder Water Use Goals and the Factors that Affect Them

As indicated in the introduction, there are complex linkages amongst the various uses and the factors that affect them. Table 31 indicates the key factors limiting the more sensitive uses identified by the Stakeholder Group.

The functional relation amongst these same factors is illustrated in the following two figures. The first figure (Figure 42) addresses the complete range of influences in a qualitative way. The second (Figure 43) incorporates quantitative information for the elements involved in the eutrophication and water clarity of the main Harbour.

V.4 Summary of the Environmental Conditions as Expressed in the GLWQA

The GLWQA (1987 Protocol) spells out fourteen beneficial uses in Annex 2, to be addressed in a Remedial Action Plan. Listing and delisting criteria have been developed for these uses by both the Canadian government agencies (COA, 1991) and the International Joint Commission (IJC, 1991).

Preparatory to the Stage 2 report in which delisting criteria will be presented, the current status of conditions is summarized in Table A.

TABLE 31: Limiting Factors for Stakeholder Uses.

	STAKEHOLDER WATER USES					
LIMITING FACTORS	Swimming	Warm Water Fishery	Cold Water Fishery	Wildlife	Boating & Water Sports	Aesthetics
Reduced Oxygen		X	X			
Ammonia		X	X			X
Nutrients (Phosphorous)	X	X	X	X	X	X
Turbidity	X	X	X	X	X	X
Carp		X		X		X
Trace Metals		X	X	X		
Trace Organics	X	X	X	X		
Bacteria	X				X	
Temperature		X	X			
Water Levels		X	X	X		
Infilling	X	X	X	X		X

Notes: Turbidity influences all desired uses
Nutrients influence all desired uses, partly because it affects turbidity or the clarity of the water

Figure 42: General functional relation amongst control factors, water and sediment objectives, and targeted uses.

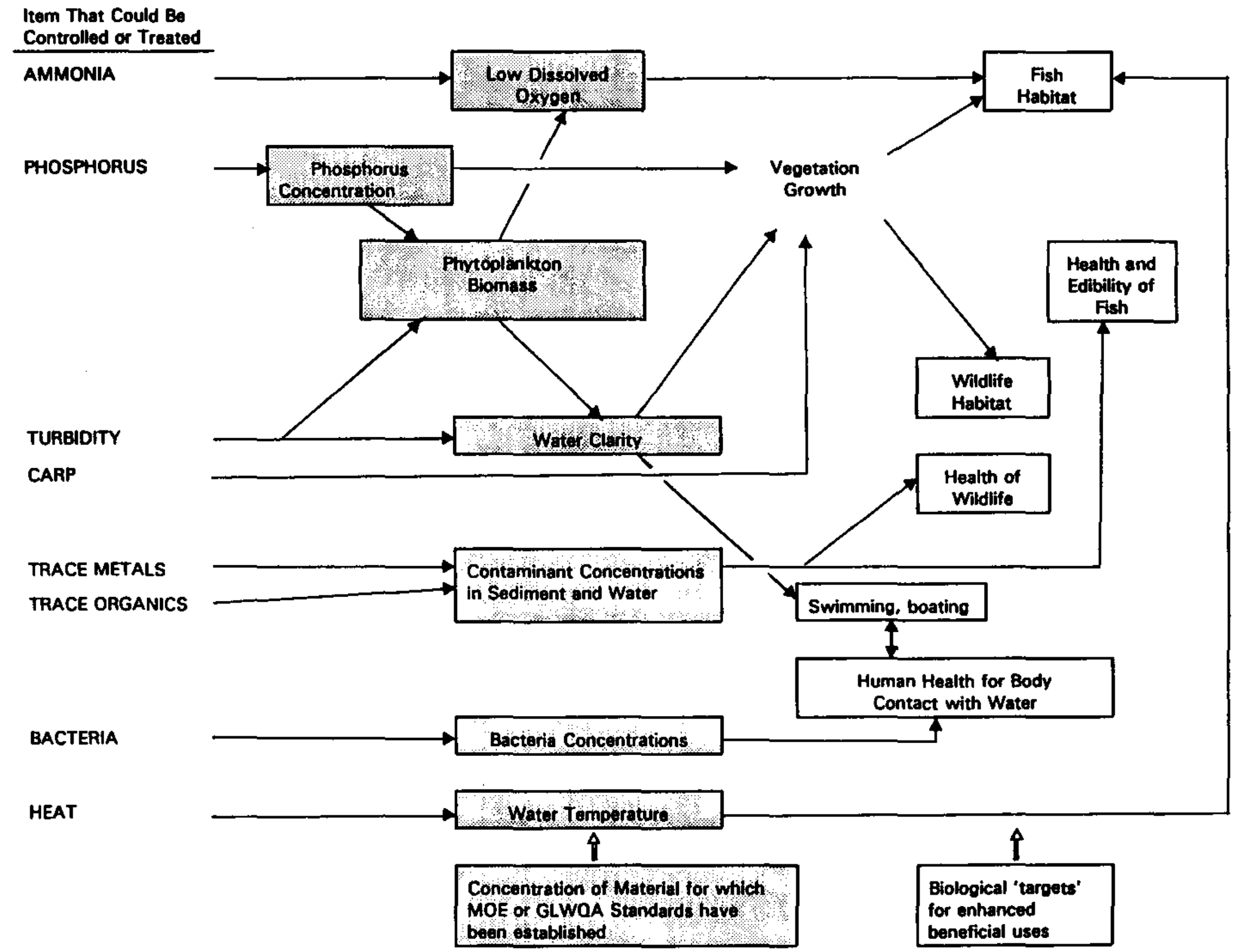
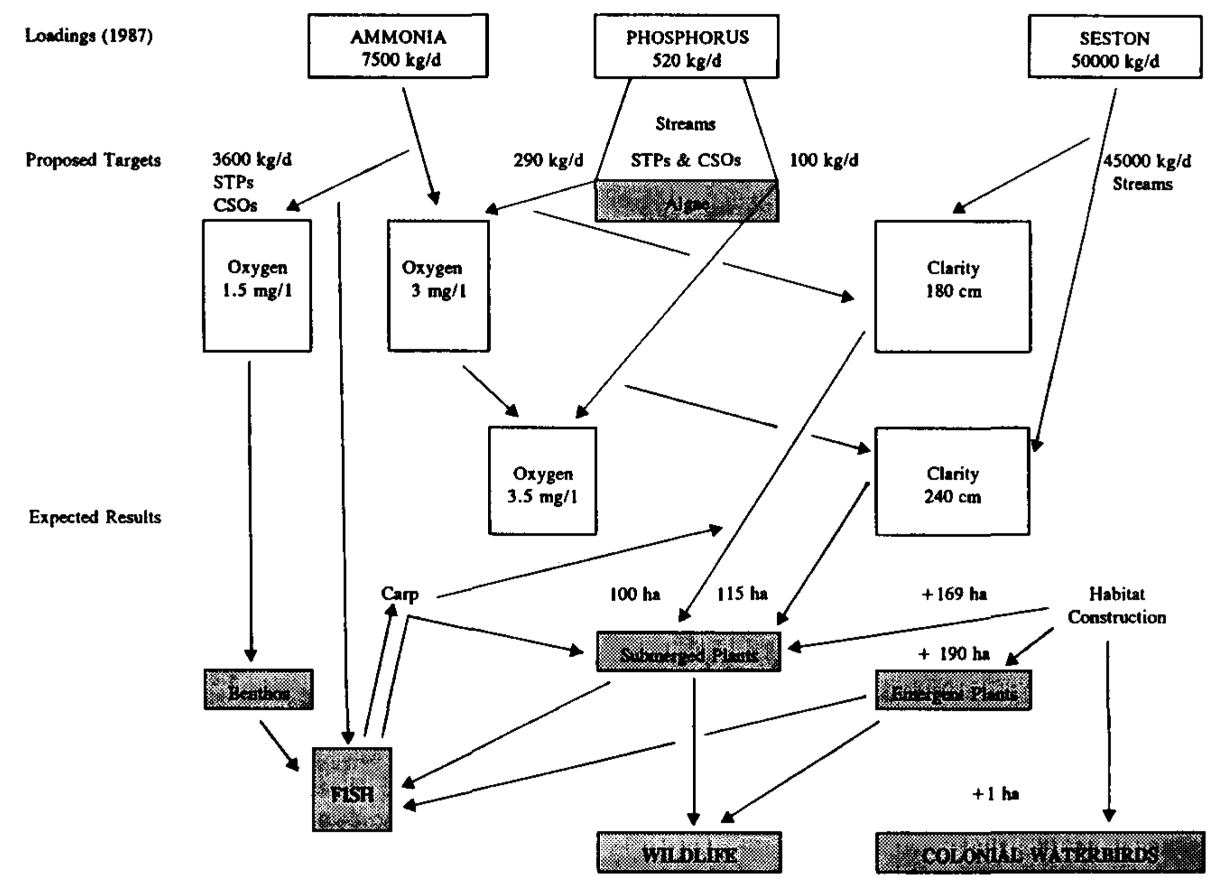


Figure 43: Quantitative relations in eutrophic conditions.



Source: S. Painter, 1988

TABLE A: Summary of the state of beneficial uses in Hamilton Harbour.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(i)	Restriction on fish and wildlife consumption	(a) Fish: Although there are current consumption advisories (mercury (Hg), Polychlorinated biphenyls (PCBs) and Mirex) on five of twelve fish species listed for the Harbour, four of the species accumulate contaminants Lake-wide because they migrate into the Harbour from Lake Ontario. It is unlikely that reduced loadings to the Harbour alone will result in elimination of fish consumption advisories since Lake Ontario conditions, atmospheric sources (not primarily local sources) as well as local contaminated sediment are all possible sources. In addition, smelt, alewife and gizzard shad - valuable food fish for harbour predators - also move contaminants from Lake Ontario into the Harbour and its food chain.	- Mercury (Hg), PCB, Mirex - Pesticides - very low levels of the insecticide DDT and DDE (breakdown of product of DDT).	- Sediments - Sewage Treatment Plants (STPs), (PCBs - origin may be by atmospheric and/or urban non-point sources). - Lake Ontario - in prey species and in top predators that move contaminants into the Harbour and its tributaries. - Atmospheric deposition	The connection between the many possible sources of the contaminants and the contaminants found in fish is unclear since current judgement is based on relatively weak circumstantial evidence.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		(b) Wildlife: Generally hunting is not permitted in the area. PCB concentrations in mallard ducks and snapping turtles are well above U.S. and N.Y. standards. There may be risk to hunters in other areas from migrating birds that spend time in this Harbour.	PCBs in food for birds.	Potentially PCBs in sediments in feeding areas or feeding on higher levels of the food chain that are contaminated from more general PCB distributions.	Wildlife should be examined more thoroughly. PCB and mercury distributions and links to local regional sources should be identified more precisely. Canadian standards for wildlife consumption are required. Standard methods for establishing more clearly that local sources are not significantly contributing to the problem need to be established and incorporated into the surveillance program.
(ii)	Tainting of fish and wildlife flavour	(a) Fish: No impairment is known to exist for fish. Fishing occurs in the Harbour but there have been no complaints regarding the tainting of fish flavour. (b) Wildlife: Tainting of wildlife flavour is not observed for Hamilton Harbour as hunting is not permitted in the area.			No formal study of tainting of fish and wildlife has yet been undertaken.
(iii)	Degraded fish and wildlife	a) Fish: Prior to initiation of the Remedial Action Plan (RAP) there were no objectives for desired fish population densities. A reduction in the carp	- Loss of spawning, nursery and adult habitats - Low dissolved oxygen (DO),	- Dense algal blooms - Contaminated sediments - Shoreline filling - Introduction of	Storm loadings of suspended solids from watersheds. Information on fish and wildlife regarding habitat requirements for various life stages of fish and wildlife (see (iv)).

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		population has been proposed in order to minimize the negative impact on the macrophyte communities and other species that depend on this type of habitat. Pike have been stocked in order to increase the population of top predators in the warmwater fishery. Fifty-nine species of fish have been found in the Harbour, forty-two of which are reproducing here. However, these populations indicate a highly degraded eutrophic system. (b) Wildlife: Two of the four recommended objectives for numbers of colonial waterbirds have been exceeded. Numbers of double-crested cormorants and black-crowned night herons are slightly below target levels. A reduction in the population of ring-billed gulls has been proposed.	ammonia toxicity - Degraded benthos (see (vi)) - Low aquatic plant diversity and abundance	exotic species - Poor light penetration	
(iv)	Fish tumours or other deformities	Liver and skin neoplasms and epidermal papillomas have been reported on several species of fish. Carcinogens	- Polyaromatic hydrocarbons (PAH) in contaminated sediment.	- Contaminated sediment from historical sources in	- Cause of tumours not clearly established. - Role of virus' not yet confirmed.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		are present in Harbour sediments. These sediments have induced liver tumours in fish in laboratory studies. Overall tumour frequency for Harbour fish is similar to the frequency of tumours found in fish from other sites in western Lake Ontario. The occurrence of hepatocellular carcinomas at low levels in white suckers strongly suggests chemical carcinogens in western Lake Ontario.	- Viruses may be responsible for epidermal papillomas.	the steel industry and general combustion products. - Urban runoff - Sewer system - Lake Ontario (perhaps)	
(v)	Bird or animal deformities or reproductive problems	To date, control sites have not been selected for bird or animal populations, and selection of sentinel wildlife species has not been made. There are no active bald eagle nests in the area although eagles have recently been sighted (1991). Reproduction rates for colonial bird populations are considered normal. Bird populations are being monitored. Higher levels of PCBs, organochlorines, and reproductive anomalies have been observed in snapping turtles in Cootes Paradise relative to a control site in Algonquin Park. The significance of this information is under study.	- Organochlorines, metals - DDT and its metabolites	- Historical deposits of contaminants in sediment - Contaminants in Lake Ontario	High concentrations of contaminants in turtles are poorly understood; other animals not yet studied. Acceptable control populations need to be better established.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(vi)	Degradation of benthos	The composition of the benthic community is characteristic of a highly eutrophic and urban/industrial contaminated environment. Both contaminants in sediment and low oxygen conditions (0.5-1.0 mg/1) in the hypolimnion in summer contribute to the problem.	- High nutrient levels - Decomposition of organic material in sediments releasing ammonia and hydrogen sulphide - Low dissolved oxygen - Trace contaminants in sediments	- STPs - Historical deposits of organic material in the bottom sediments.	Storm loadings of sediment. Time for end of sediment phosphorus reflux. Natural burial time for effective capping of contaminated sediments. Redistribution of sediment by ship traffic. Bioassays need to be standardized to define the end point.
(vii)	Restrictions on dredging activities	Hamilton Harbour sediments exceed acceptable limits for open water disposal of dredgeate under Provincial Guidelines. One cannot employ open water disposal for sediment dredged in the Harbour. Present CDF capacity is only adequate to the year 2010.	- PCBs in sediment - Metals, PAHs exceed guidelines in sediment	- STPs - Industry - Urban and rural runoff - Steel Industry - Combined Sewer Overflows (CSOs)	Quality of current deposits. Source control limits need to be set related to desired sediment quality.
(viii)	Eutrophication or undesirable algae	Ammonia and phosphorus concentrations exceed the requirements for the growth of algae at acceptable levels in the Harbour. The algae present an aesthetic problem as they reduce water clarity and foul beaches and rocks.	- High Phosphorus - High ammonia	- CSOs - STPs - Steel Industry - Runoff	Non Point Source contribution not known accurately enough. Update estimates of impact from phosphorus and ammonia loadings.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		The ammonia and decomposing algae create an oxygen demand that lowers summer hypolimnetic dissolved oxygen to levels averaging 0.5-1.0 mg/1. This, in turn, reduces fish habit, interferes with the normal food chain operation and increases the release of some contaminants from the bottom sediments. Major improvements in water clarity, and in total phosphorus and chlorophyll concentrations have been observed in the past three years, apparently as the result of new phosphorus control measures. But little change in dissolved oxygen conditions has been recorded in this period.			
(ix)	Restrictions on drinking water consumption or taste and odour problems	The drinking water supply for the residents of the Hamilton area and Burlington is Lake Ontario, not the Harbour. No drinking water supply is taken from the Harbour. However, existing water quality conditions in the main body of the Harbour now meet all objectives for a potable water supply. The Harbour water discharges to Lake Ontario through the Burlington Ship Canal which is 4 to 5 km from both the Burlington and	Not used for drinking water.	Not used for drinking water.	

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
		Hamilton water supply intakes to the northeast and southeast of the Canal, respectively. Intake water quality data to date indicate no problems related to the Harbour discharge.			
(x)	Beach closings	In the 1940's, on the advice of the Medical Officer of Health, the Hamilton Harbour Commissioners enacted a by-law prohibiting swimming in the whole Harbour. The basis of the ban was unacceptably high levels of faecal bacteria. There may also be some risk to recreational boaters where capsizing of small sailing craft often occurs. Results of sampling carried out in 1988, 1990 and 1991 indicate that remedial programs might be effective in bringing some specific areas of the Harbour within bacterial standards. Further investigation is required if swimming is to be considered for the Harbour, in terms of bacterial contamination, water clarity, beach sediment contamination and water quality conditions.	- High faecal bacteria levels during and after storms	- Raw sewage overflows (CSOs, STPs) - Streams and related urban and rural runoff.	Detailed bacterial data. Other sediment and water quality standards for swimming requested of the health authorities if they deem this necessary.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(xi)	Degradation of aesthetics	Oil sheens are observed occasionally and, there are periodic occurrences of objectionable turbidity, floating scum, debris, and putrid material. Reduced water clarity persists in shallow areas particularly. This is due primarily to discharge of suspended solids from tributaries, resuspension of bottom sediments by waves and by carp, and to some extent, by algal production.	- Occasional oil sheens - algal blooms - suspended solids - debris and putrid matter.	- Spills - industrial, highway, shipping - Runoff - Resuspension of sediment - Inadequately treated sewage (STPs, CSOs)	
(xii)	Added cost to agriculture or industry	(a) Agriculture: Hamilton Harbour water is not used for agricultural purposes. Lawn watering using Harbour water probably benefits from the nutrient content. (b) Industry: Treatment of the Harbour water for industrial use is routine, and includes the addition of chlorine to rid pipes of algal build-up, travelling screens to remove debris and fish, water strainers to remove suspended material for some uses, and bacterial control for special uses. Industry considers this source of water to be adequate or good compared with other areas in the Great Lakes.	- Algae - Debris - Fish - Suspended material - Bacteria	- CSOs - STPs - Storm runoff	

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(xiii)	Degradation of phytoplankton and zooplankton	With the exception of one species (Moina brachiata), zooplankton populations are similar in composition to populations in the Bay of Quinte. Abundance is high, reflecting eutrophication and increased productivity. Moina brachiata populations are high in Cootes Paradise and lower in the Harbour. This species is absent from Lake Ontario and from the Bay of Quinte. Zooplankton sizes are small, indicating heavy predation by zooplankton and feeding fish such as alewife. A new investigation of the zooplankton and phytoplankton assemblage is planned. Earlier studies of the toxicity of Harbour water to phytoplankton and zooplankton indicated no unusual toxicity. This situation is under review through application of new bioassays.	- High organic carbon - Nutrients - Light limitation - Low dissolved oxygen in bottom layers - Contaminated sediment - Predation by alewife	- Self-shading - Municipal and Industrial sources, generally - STPs, CSOs - No submerged plants for habitat	Assess toxicity of Harbour water to phytoplankton and zooplankton. Target numbers and test protocols have to be established.

	USE IMPAIRMENT	SIGNIFICANCE TO THE HAMILTON HARBOUR RAP	CAUSES OF IMPAIRMENT	SOURCE OF PROBLEM	INFORMATION DEFICIENCIES
(xiv)	Loss of fish and wildlife habitat	Fish and wildlife management goals are being developed which will define the amount and quality of physical, chemical, and biological habitat. There are very obvious water-quality-related habitat problems for fish that must be addressed. These include the general loss of submerged vegetation due to the water clarity problems as detailed in (xi), and the low oxygen conditions observed in the summer hypolimnion. Other habitat problems relate to loss of marsh areas due to high water levels, poor water quality, the uprooting activities of carp and siltation in Cootes Paradise and in shallow stream estuaries in the Harbour. Infilling of key habitat through past industrial, transportation and urban development activities has destroyed major portions of the habitat (i.e. 26% of the surface area of the Harbour and 80% of the Harbour shoreline have been altered since the early 1800's). Wildlife marsh habitat has been both destroyed (marsh and creeks on south shore for animals and waterbirds) and created (CDFs serving as nesting habitat for colonial waterbirds).	- Low dissolved oxygen (DO) - Loss of submerged and marsh vegetation - Shoreline development and redevelopment - Turbidity in the water	- High lake levels - Filling from urban development - Heavy algal blooms caused by nutrients STPs and CSOs - Resuspension of bottom sediments from high energy shores or from carp activity.	The impact of shoreline development and redevelopment needs to be assessed and controlled.

VI REMEDIAL ACTION PLAN DEVELOPMENT ACTIVITIES

This report addresses the first two information requirements called for in elements (i) and (ii) of Section 4(a) of Annex 2 of the 1987 revised Great Lakes Water Quality Agreement, namely:

(i) A definition and detailed description of the environmental problem in the Area of Concern, including a definition of the beneficial uses that are impaired, the degree of impairment and the geographic extent of such impairment;

(ii) A definition of the causes of the use impairment, including a description of all known sources of pollutants involved and an evaluation of other possible sources;

It must not be thought that this presentation is the sole activity in the development of the Remedial Action Plan (RAP). The basic information in this report was submitted to the Canada-Ontario Agreement Review Board and the Hamilton Harbour Stakeholder Group in March 1988, along with progress reports on the development of other aspects of the RAP. That material has received considerable public and peer review, which is reflected in this report. The process has not waited upon the completion of this report. The Stakeholders presented their views, goals and principles soon after the initial Information Workshop as is appropriate for the direction of the development of remedial and preventative options. The March 1988 report contained the first set of technical options that it had been possible to assemble to that date, and these have been discussed within agencies, and between the Writing Team and Stakeholders. Eighteen major reviews of the March 1988 report have been received and considered for the development of this report (the Stage I report), and as direction for the development of materials and options for the next stage of our deliberations. The first formal Stage I report was completed in March 1989 and the current report updates the earlier one.

VI.1 Hamilton Harbour RAP Development Progress

In the complete RAP process, the milestones have been as follows:

The first step in developing the RAP was to prepare a technical summary of a number of recent investigations of the Harbour. This was published in August 1985 with general management options. Other technical reports were developed on the impact of the Harbour on western Lake Ontario and on trace contaminants in the Harbour.

Two principal public consultation processes have been employed. One is directed at the general population of the Hamilton-Burlington area. The other involves the principal 'Stakeholder' groups, including agencies, organizations, institutions, government bodies, industries and private citizen groups who make use of, wish to make use of, or in some manner have jurisdiction over the use of the Harbour water (Appendix G). Both sets of activities started in July 1986.

A RAP Team, made up of representatives of the Ontario Ministry of the Environment (Water Resources Branch and West Central Region Office), Environment Canada (Environmental Protection Regional Office and the National Water Research Institute), the Royal Botanical Gardens, the Department of Fisheries and Oceans and the Ontario Ministry of Natural Resources, was formed in May 1986. This team has worked closely with the Stakeholders throughout this process. A Team member from the Ontario Ministry for Agriculture and Food was added in 1987.

In June 1986, 60 potential Stakeholders were interviewed individually to assess their views on the future for the Harbour's water quality. Many of these individuals took part in a workshop July 10 and 11, 1986, where they were presented with the information on the Harbour situation. They met on July 25th to finalize their views on the use goals for the Harbour with accompanying principles and some specific recommendations on the direction of the action plan. The Interim Report of the Stakeholders was released in September 1986.

The Stakeholder group met in December 1986 to audit the first details of the work of the writing team. Subsequent meetings in January and February of 1987 dealt with specific issues and agency responses to the Interim Report. In March 1987, the first progress report of the RAP Team was discussed and recommendations were made to the Team.

Parallel with this activity was a program to involve a wider public through general meetings in July 1986 and February and March 1987. These were information sessions with opportunities for questions to be addressed to the RAP Team. Several formal briefs were also presented. Throughout these consultations, full records have been kept of comments, advice and critiques.

Concurrent with the consultative process, the RAP Team drafted about 85% of those sections of the report dealing with the environmental data base. Specific objectives were prepared for the goals recommended by the Stakeholders and several remedial action options were explored to achieve those objectives.

Additional studies were scheduled for 1987 to 1991 to assist in the development of the RAP. Their objectives were such things as: a) detailed surveillance to set the baseline for future improvements and for design of future surveillance; b) further assessment of the contaminated sediments; c) feasibility of new mitigation measures (e.g. ammonia control at the Hamilton sewage treatment plant (STP) and phosphorus treatment for 0.1 mg/L total phosphorus in effluent, etc.); d) identification of fishery rehabilitation requirements; e) detailing the likely impact of various remedial options; and f) development of a cost-benefit analysis of remedial options. Agencies involved include Ontario Ministry of the Environment, Environment Canada, Department of Fisheries and Oceans, Royal Botanical Gardens, Hamilton-Wentworth Region and Halton Region.

New remedial actions have been initiated as a result of the RAP. Several measures have recently been completed by Stelco Canada and Hamilton-Wentworth Region. There are no outstanding control orders regarding effluent to the Harbour. All STPs are within Ontario MOE guidelines. The steel industries are working towards new objectives under the MISA program. The Halton and Hamilton-Wentworth Regional Municipalities have improved treatment for phosphorus and ammonia that go beyond their current control orders.

The variety of activities are listed in the following table.

VI.2 RAP Timetable

DATE	ACTIVITY
Wastewater Treatment Works Completed or Underway:	
1984	Dofasco coke oven byproducts cyanide tower - wet oxidation treatment.
1984	Dofasco #1 acid regeneration plant upgrading.
1984	Dofasco upgrading of oil recovery in the Ottawa Street sewer.
1985	Stelco #2 byproducts final coke oven gas cooling - converted to indirect cooling.
1985	Hamilton STP upgrading of phosphorus removal to meet the Great Lakes Water Quality Agreement Objective (1 mg/L).
1986	Stelco #1 byproducts interceptor sump effluent - diverted to treatment system.
1986	Dofasco upgrading of cold mill wastewater treatment.
1987	Stelco #1 byproducts final coke oven gas cooling - indirect cooler.
1987	Stelco #2 byproducts interceptor sump effluent - diversion to treatment.
1987	Stelco diversion of oil treatment plant effluent to further treatment.
1987	Dofasco hot mill filtration plant upgrading.
1987	Dofasco diversion of biological treatment plant effluent to municipal STP.
1987	Hamilton STP Greenhill combined sewer overflow (CSO) retention basin installed.
1988	Dofasco blast furnace gas cleaning wastewater recirculation.
Strategy and Planning Completed:	
June 1986	Public consultation framework, key Stakeholders identification.
September 1987	Goals for environmental quality and uses to be restored based on jurisdictional objectives and public consultation.

DATE	ACTIVITY
December 1987	Optional remedial actions, potential implementation schedule, based on cost/benefit analyses and public consultation.
March 1988	Draft RAP with use goals, remedial actions, for agency and public review.
March 1989	Stage I Report.
January 1990	Draft Preferred Options Report.
July 1991	Preliminary Stage 2 Report.
Monitoring Activities:	
1986 - 1989	Intensive monitoring of Harbour and tributaries to establish new baseline for future monitoring and to assess impact of past remedial actions.
1987	Analysis of STP effluent for toxic contaminants (185 priority pollutants).
1987	Initiation of first phase of monitoring effluent for Iron and Steel Industry Sector under the Municipal/Industrial Strategy for Abatement (MISA) Program.
1988 - ongoing	Execution of the annual and intensive monitoring schedules designated in the plans noted above.
1988 - 1989	Specification of effluent and process monitoring for iron and steel industry (self monitoring), under the MISA program.
1989	Redesign of monitoring program for ambient water quality STP effluent, fish, wildlife, sediment, and tributaries.
Industrial and Municipal Sources:	
1987 - 1988	Establish technology for ammonia treatment and further nutrient removal in STPs compatible with toxic chemical remediation strategy/technology and with loading targets for Harbour.
1988	Implementation of first of CSO remediation for Hamilton.
1989	Pilot plan for computer-assisted storm event control system to optimize sanitary and storm sewer operation (no sanitary sewer overflow, and treating worst components of storm runoff).

DATE	ACTIVITY
1990	Established best available technology (MISA) to be applied to STPs or to industrial components of STP inputs for toxic chemical remediation, and set schedule for implementation.
1990	Establish best available technology (MISA) to be applied to the iron and steel industry for toxic chemical remediation, and set schedule for implementation.
1991	Plan for completion of CSO remediation program. (Pollution Control Planning Study - Hamilton-Wentworth Region).
Non-point Sources:	
1985	Evaluation of alternatives for cleanup of Windermere Basin.
1987	Funding remediation of contaminated sediment problem in Windermere Basin, initiating final engineering design and environmental assessment.
1989	Plan for control of suspended solids loading from major tributaries to the west end of Harbour.
1989	Refinement of estimates of tributary contributions of contaminants to Hamilton Harbour.
1989	Check on atmospheric contributions of contaminants to Hamilton Harbour.
1989	Cleanup of Windermere Basin completed (dredging).
1989	Completion of assessment of contaminants on main Harbour sediments.
1990	Task Force established to develop common manual and investigate key source areas.
Recent Major Reports:	
1985	Hamilton Harbour Technical Summary and General Management Options (MOE, 1985).
1985	Final Report: Windermere Basin Study (Envirosearch Ltd., for Windermere Basin Advisory Committee).
1986	Impact of Hamilton Harbour on Western Lake Ontario (MOE, 1986a).

DATE	ACTIVITY
1986	The Impact of Dredging and Spoils Disposal on Hamilton Harbour Fisheries: Implications for Rehabilitation. J.A. Holmes (for DFO).
1991	Operational Audit of the Regional Municipality of Halton's Burlington Skyway Water Pollution Control Plant. Prepared by CH2M Hill Engineering Ltd., for Supply and Services Canada, the Regional Municipality of Halton and Environment Canada.
1991	Sewer Use Demonstration Program: The Regional Municipality of Hamilton-Wentworth (Draft). Prepared by Proctor and Redfern Ltd.
1991	Regional Municipality of Hamilton-Wentworth Pollution Control Plan. Prepared by Paul Theil Associates Ltd., and Beak Consultants Ltd.
Current Study Program Objectives:	
1987 - 1992	Set new baseline for future remediation; assess contaminated sediments; identify fishery and wildlife rehabilitation requirements; and detail the likely impact of all possible remedial option scenarios, considering possible interactions of control technologies and aquatic ecosystems.
Public Consultation:	
June 1986	Survey of views of potential Stakeholders.
July 1986	Information workshop and follow up.
September 1986	Interim report of Stakeholders to Environment Canada and Ontario MOE on goals, principles and general strategy.
October 1986	Public information meeting.
December 1986 to February 1987	Stakeholders discussion of issues of Windermere Basin, recreation, access, infilling of Harbour, agency programs.
March 1987	Review of progress report by Stakeholders.
March 1987	Public meeting on Draft Interim Summary Report.
June 1987	Stakeholder meeting - progress report.
July 1987	Final Stakeholders report on goals and principles.
October 1987	Stakeholder meeting - progress report.

DATE	ACTIVITY
May 1988	Public meeting on draft RAP (goals, problems and options).
October 1988	Stakeholder meeting.
January 1989 to March 1989	Meetings of Stakeholder Sub-Committees.
June 1989	Stakeholder Workshop to review Stage I report, and to provide advice on the Preferred Options for Remedial Action.
September 1989	Stakeholder Meeting.
October 1989	Stakeholder participation in IJC Biennial Meeting.
1989	Completion of Preferred Options Report.
January 1990	Release of Preferred Options Report.
February 1990 to July 1990	• Stakeholder Meetings to finalize first set of recommendations. • Visions Workshop • Resolution of the Fish and Wildlife Habitat Objectives
1991	Release of the initial draft of the Stage 2A Reports in preparation for public consultation - agency review.
1992	• Public Consultation on draft Stage 2A Report • Finalization of Recommendations from Stakeholders • Submission of Stage 2A Report to COA Review Board

APPENDIX A: REFERENCES

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APPENDIX B: MEASUREMENTS & UNITS

Measurements and Units				
mg/L	=	milligram per litre	=	part per million (ppm)
μg/L	=	microgram per litre	=	part per billion (ppb)
μg/g	=	microgram per gram	=	part per million (ppm)
m^3/d	=	cubic metres per day		
cms	=	cubic metres per second		
kg/d	=	kilogram per day		

What do parts per million (ppm) and parts per billion (ppb) mean?

One part per million (ppm) - one inch in two miles
one minute in two years
one bad apple in 2,000 barrels

One part per billion (ppb) - one inch in 16,000 miles
one second in 32 years
one bad apple in two million barrels

As an example: Swimmers can detect chlorine in a pool at 1 ppm, sensitive noses can detect the odour of fuel at 1 ppb.

EQUIVALENT UNITS					
metre	=	m	1 m	=	3.28 feet
kilometre	=	km	1 km	=	0.621 miles
gram	=	g	1000 g	=	1 kg = 2.205 pounds
litre	=	L	1 L	=	0.22 gallons (Can)

APPENDIX C: CONVERSION TABLES

To Convert	Multiply By	To Obtain
acres	0.4047	hectares
acres	4047	square metres
feet	0.348	metres
grams	.002205	pounds
hectares	2.471	acres
kilograms	2.2046	pounds
kilometres	0.6214	miles
litres	0.2201	gallons
metres	3.281	feet
metres	1.094	yards
miles	1.609	kilometres
pounds	453.5	grams
square metres	0.000247	acres
temperature °C	(°C x 9/5) + 32	temperature °F
temperature °F	(°F - 32) x 5/9	temperature °C
yards	0.9144	metres

APPENDIX D: GLOSSARY

Absorption	The incorporation of a substance into the body of another.
Accumulation	Storage and concentration of a chemical in tissue to concentration higher that taken in. May also apply to the storage and concentration of a chemical in aquatic sediments to levels above those that are present in the water column.
Acid extractables	Organic compounds, such as phenols, that can be extracted from a sample under acidic conditions.
Acidity	The ability of an aqueous media to react with hydroxyl (OH-) ions.
Acute toxicity	Mortality that is produced in a short period of time-exposure, usually 24 to 96 hours.
Adsorption	The surface retention of solid, liquid or gas molecules, atoms or ions by a solid or liquid.
Aerobic	The condition associated with the presence of free oxygen in the environment.
Algae	Simple one-celled or many-celled micro-organisms, usually free-floating, capable of carrying on photosynthesis in aquatic ecosystems.
Algal blooms	Excessive growths of algae and aquatic plants that form unsightly scums and layers of turbid water, impairing the water for recreational, domestic and aesthetic uses.
Algicide	A specific chemical highly toxic to algae. Algicides are often applied to water to control nuisance algal blooms.
Alkalinity	A measure of the capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides.
Anoxia	The absence of oxygen necessary for sustaining most life. In aquatic ecosystems this refers to the absence of dissolved oxygen in water.
Anoxic	Without dissolved oxygen, or deprived of oxygen.
Areas of Concern	Geographic locations identified by the IJC where water, sediments, or fish quality are degraded and the IJC water quality objectives or jurisdictional criteria, standards, or guidelines are not met.
Assimilated capacity	The ability of a waterbody to transform and/or incorporate substances (e.g. nutrients) into the ecosystem, such that the water quality does not degrade below a predetermined level.
Base-neutral extractables	Organic compounds that can be extracted under basic or neutral conditions, such as naphthalene and dichlorobenzene.
Benthic	Of or living on or in the bottom sediment of a water body.
Benthivore	An animal (e.g. white perch) which consumes benthic organisms or benthic matter.

Benthos	Bottom dwelling organisms - the benthos comprise: 1. sessile animals such as sponges, some worms and many attached algae; 2. creeping forms such as snails and flatworms; and 3. burrowing forms which include most clams, worms, mayflies and midges.
Benzo (a) pyrene	A PAH which is a suspected carcinogen found in such things as cigarette smoke. It is a by-product of combustion and is released to the aquatic environment during steel and aluminum-making process.
Bioaccumulation	Uptake and retention of environmental substances by an organism from both its environment (i.e. directly from the water) and its food.
Bioassay	A determination of concentration (dose) of a given material (often suspected pollutant) necessary to affect living cells under stated conditions.
Bioconcentration	The ability of an organism to concentrate substances within its body to concentrations greater than in its surrounding environment or food.
Biomagnification	The increasing concentration of a chemical up the food chain.
Biomass	The total amount, by weight, of all organisms or of a specified type of organism in a given area.
Biota	Species of all the plants and animals occurring within a certain area.
Bioturbation	The physical disturbance of sediments by burrowing and other activities of organisms.
Carcinogen	Cancer-causing chemicals or substances.
Chlorophyll a	The photosynthetic green pigment present in most plants or algae.
Chronic toxicity	Toxicity marked by a long duration, that produces an adverse effect on organisms. The end result of chronic toxicity can be death although the usual effects are sublethal (e.g. inhibits reproduction or growth). These effects are reflected by changes in the productivity and population structure of the community of organisms that are affected.
Coliforms	Contaminating bacteria normally found in the gut of vertebrates and eliminated in the faeces (faecal coliforms). May cause gastric ailments in humans if they are swallowed.
Community	Group of population of plants and animals in a given ecological unit used in the broad sense to include groups of various sizes and degrees of integration.
Contaminant	A substance foreign to a natural system or present at unnatural concentrations in air, water, soil or food, causing use of those things to be limited. A naturally occurring substances may be found to exceed government guidelines or objectives, and thus be called a contaminant.

Contamination	The introduction of pathogenic or undesirable micro-organisms, toxins and other deleterious substances which render water, air, soils or biota unfit for use.
Conventional pollutants	A term which includes nutrients, substances which decompose using oxygen in the process, material which produce an oily sludge deposit, and bacteria. Conventional pollutants include phosphorus, nitrogen, chemical oxygen demand, biochemical oxygen demand, oil and grease, volatile solids, total and faecal coliform bacteria, and chlorides.
Conventional parameters	Parameters and pollutants that have been measured for many years, such as COD, phenols, cyanide, suspended sediments, nitrogen, phosphorus, sulphide, and organic carbon.
Criteria	Numerical limits of pollutants established to protect specific water uses.
Detention	When storm water is held in a facility prior to being treated in a sewage treatment plant.
Detritus	Decaying plant and animal matter.
Dieldrin	A restricted chlorinated pesticide that is persistent and bioaccumulates in all living organisms; causes reproductive disorders in wildlife and is a known carcinogen.
Dioxin	A group of approximately 75 chemicals of the chlorinated dibenzodioxin family. 2,3,7,8-TCDD is considered the most toxic form.
Dissolved phase	The dissolved phase referred in Section III.2.2.2 is defined as the water which has been filtered through a 0.45 micron filter, through which colloidal material and macromolecules will pass. Trace organics are hydrophobic and will become adsorbed to particulates such as soil particles and colloidal particles. Due to the low concentration of large particles in the water column, the majority of hydrophobic organic compounds will remain in the dissolved phase or become attached to colloidal material. Since colloidal particles will not settle out of the water column due to their small size, for all practical purposes colloidal material and any associated organic contaminants are considered to be in the dissolved phase.
Dissolved oxygen	The amount of oxygen dissolved in a given volume of water.
Dofasco	Steel industry situated on the south shore of Hamilton Harbour.
Dredgeate	The material removed from the river, lake or harbour bottom during dredging operations.
Ecosystem	The interacting complex of living organisms and their non-living environment; the biotic community and its abiotic environment.
Effluent	Contaminated waters discharged from facilities to either wastewater sewers or surface waters.
Environment	All biotic and abiotic factors that actually affect an individual organism at any point in its life cycle.

Epilimnion	Surface layer of water, above the thermocline (cf.), warmer and more oxygenated than the hypolimnion (cf.).
Erosion	The wearing away and transportation of soils, rocks and dissolved minerals from land surface shorelines or river bottoms by rainfall, running water, wave or current actions.
Ether extractables	Organic compounds that can be extracted by ether.
Etiology	(ætiology) - An account of the cause of anything, assignment of a cause.
Euphotic Zone	The layer of a body of water down to the limits of effective light penetration for photosynthesis.
Eutrophication	Having abundant nutrients which leads to excessive productivity of plant and animal matter, frequently resulting in oxygen depletion in the lower layers of a body of water.
Exceedence	When the concentration of a pollutant exceeds the water quality guideline for that molecule.
Great Lakes Water Quality Agreement	A joint agreement between Canada and the Unites States which commits the two countries to develop then implement plans to restore and maintain the many desirable uses of the waters in the Great Lakes Basin. Originally signed in 1972 and reviewed in 1978, the Agreement was amended in 1987.
Groundwater	All subsurface water in the land portion of a watershed.
Halton Region	A political region which includes the city of Burlington and the north-east portion of the Hamilton Harbour watershed.
Hamilton-Wentworth Region	A political region which includes the City of Hamilton, the Town of Flamborough, Dundas, Ancaster, Stoney Creek and the west and south portions of the Hamilton Harbour watershed.
Heavy metals	Generic term for polluting metals such as lead, cadmium, mercury, zinc, etc. Usually does not include iron.
Hyperplasia	A tumour consisting of excessive tissue growth.
Hypolimnion	The deeper layer of a body of water, below the thermocline (cf.). Usually has less oxygen and is colder than the epilimnion (cf.).
In Situ	In place.
Jackson Units	A measurement of turbidity determined by comparing the amount of light seen through a certain length of the sample against a series of standards.
Kjeldahl Nitrogen	Total nitrogen content of a sample, determined by digesting the sample with concentrated sulphuric acid, and distilling the resultant NH_4SO_4 to produce ammonia.
Leachate	Contaminated liquid that derives it content by dissolving or carrying particles from the soil, wastes or rock layers through which it moves.

Littoral zone	A shallow area along the shore of a body of water with light penetration to the bottom, usually with emergent subaquatic plants.
Loadings	Total mass of pollutant to a water body over a specified time (e.g. tonnes per year of phosphorus).
Macrophytes	A member of the macroscopic plant life (i.e. larger than algae) especially of a body of water (i.e. water weeds or marsh vegetation).
Mirex	A pesticide which has been found in significant quantities in Lake Ontario. It accumulates in the food chain, causes reproductive problems and cancer.
Neoplasm	Tumour or abnormal tissue growth.
Non-point source	Source of pollution in which pollutants are discharged over a widespread area or from a number of small inputs rather than from distinct identifiable sources.
Nutrient	A chemical that is an essential raw material for growth and development of organisms.
Organochlorines	An organic compound which includes chemically bound chlorine. Many organochlorines are formed in industrial processes whenever chlorine or chlorine-based compounds are used. Thousands of chlorinated organic compounds exist, but only a small portion of those in industrial processes have been identified. Organochlorines include compounds such as PCBs (cf.) and pesticides.
Papilloma	A benign tumour, such as a polyp, on the skin.
Pelagic	Adjective, (in its reference to fisheries) pertaining to species of fish which inhabit the deeper regions of a lake (in depth of 10 m or more) where there is mud or ooze on the bottom and no vegetation.
Persistent toxic substances	Any toxic substance that does not break down to less than 50% of its original amount in a period of time less than eight weeks.
Pesticides	Any substance used to kill plants, insects, fungi or other organisms - includes germicides, insecticides, algicides and fungicides.
Phenolics	Any of a number of compounds with the basic structure of phenol but with substitutions made onto this structure. Phenolics are produced during the coking of coal, the distillation of wood, the operation of gas works and oil refineries, from human and animal wastes, and the microbiological decomposition of organic matter.

Phosphorus	Phosphorus occurs naturally in igneous and other types of rocks and may enter the aquatic environment through weathering of rock or precipitation. Some uses for phosphorus include soaps, detergents, fertilizer products, pesticides and insecticides. Domestic and livestock wastes, industrial effluents and agricultural drainage from fertilized land contribute phosphorus to waters. Phosphorus (total and soluble reactive) is an important nutrient utilized by plants and algae. Phosphorus is usually found in low concentrations in surface water because it is actively taken up by plants. High concentrations of phosphorus can promote nuisance levels of algal and plant growth.
Photosynthesis	A process occurring in the cells of green plants and some micro-organisms in which solar energy is transformed into stored chemical energy.
Phytoplankton	Minute, microscopic aquatic vegetative life; plant portion of the plankton; the plant community in marine and freshwater situations which floats free in the water and contains many species of algae and diatoms. They form the base of the natural food chain.
Piscivore	An animal (e.g. lake trout or salmon) which consumes fish.
Planktivore	An animal (e.g. alewife) that consumes plankton.
Pollution (water)	Anything causing or inducing objectionable conditions in the watercourses and adversely affecting the environment and use or uses to which the water thereof may be put.
Primary treatment	Mechanical removal of floating screenable, rackable or settleable solids from wastewater.
Priority pollutants	As defined by MISA, toxic chemicals that could pose a hazard to the receiving environment based on the chemical's persistence, potential to bioaccumulate, and acute and sub-lethal toxicity to organisms including humans. The list of about 150 pollutants includes heavy metals and pesticides.
Resuspension (of sediments)	The remixing of sediment particles and pollutants back into water by storms, currents, organisms and human activities such as dredging.
Retention	When stormwater is held in a facility prior to being released to the environment in a controlled manner.
Secchi Disc	A standard size metal disc is painted in black and white quarters and suspended by a rope from its centre. The secchi disc is used to estimate water clarity by lowering the disc beneath a lake's surface and noting the depth at which it becomes invisible to the naked eye.
Secondary treatment	Primary treatment plus bacterial action to remove organic parts of the waste.

Sewer (sanitary)	A municipal sewer for the collection and transmission of domestic, commercial and industrial waste not including land drainage or stormwater runoff.
Sewer (storm)	A municipal sewer for the collection and transmission of stormwater runoff, land surface water and water from soil drainage not including any industrial wastes other than unpolluted cooling waters.
Sludge	Solid removed from waste treatment facilities.
Solubility	Capability of being dissolved.
Stability	Absence of fluctuations in populations; ability to withstand perturbations without large changes in composition.
Stakeholder Group	A group comprising delegates from agencies, organizations, institutions, government departments, industries, and private citizen groups, all of which have an interest in Hamilton Harbour.
Stelco	Steel industry on the south shore of Hamilton Harbour.
Surficial sediments	The top layer of sediments.
Suspended sediments	Particulate matter suspended in water.
Suspended solids	Solids transported by water and held in suspension; the finer the solid the longer it is in suspension, the greater the distance it travels, and the greater the possibility of adsorbed pollutants.
Sustainable development	Development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs.
Thermocline	Abrupt change of temperature in the water column of a water body; the interface between the epilimnion (cf.) and the hypolimnion (cf.).
Toxic substances	As defined in the Great Lakes Water Quality Agreement, any substance that adversely affects the health or well being of any living organism.
Toxicity	Quality, state or degree of the harmful effect resulting from alteration of an environmental factor.
Trace contaminants	Toxic and other deleterious substances found in trace concentrations in the environment.
Trace element	A chemical element found naturally or required by living organisms in extremely small quantities.
Trophic level	Functional classification of organisms in a community according to feeding relationships - the first trophic level includes green plants, the second level includes herbivores (plant eaters), etc.
Tubificid	Of aquatic oligochaete or sludge worm which is tolerant to organically enriched waters.

Turbidity	A measure of the clarity of a water sample. Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble coloured inorganic compounds, plankton and other microscopic organisms. The clarity of a natural body of water is a major determinant of the condition and productivity of that system.
Volatiles	Organic compounds that can readily evaporate, such as chloroform or trichloroethylene.
Water Quality Objectives	Under the Great Lakes Water Quality Agreement, goals set by the Governments of Canada and the United States for protection of the uses of the Great Lakes as in allowable concentrations of individual chemicals.
Water Quality Standards	A criterion or objective for a specific water use standard that is incorporated into enforceable regulations.
Zooplankton	The animal portion of the community of small organisms that live suspended in the water column of a lake.

APPENDIX E: ACRONYMS

ANSI	Areas of natural scientific interest.
AOC	Area(s) of Concern
ARDA	Agricultural Rehabilitation and Development Directory (OMAF).
BATEA	Best available technology economically achievable
BHC	Benzene hydrochloride or hexachlorocyclohexane. There are three isomers: alpha, beta and gamma. Gamma BHC is the insecticide lindane.
BOD	Biological oxygen demand. The amount of oxygen necessary for the oxidation of water-borne oxidizable compounds by the micro-organisms present in the body of water.
CCIW	Canada Centre for Inland Waters.
CDF	Confined disposal facility for dredged material.
cfs	Cubic feet per second.
COA	Canada-Ontario Agreement respecting water quality in the Great Lakes.
COD	Chemical oxygen demand.
CSO	Combined Sewer Overflow. A municipal sewer for the collection and transmission of surface and ground waters and sewage; combined storm and sanitary sewer systems.
CWS	Canadian Wildlife Service (Environment Canada).
DDE	Dichlorodiphenyldichloroethylene. A natural breakdown product of DDT.
DDT	Dichlorodiphenyltrichloroethane. A widely used, very persistent chlorinated pesticide. Most uses of DDT were phased out by 1969, but persists in sediments and biota.
DFO	Department of Fisheries and Oceans (Federal).
EARP	Environmental Assessment and Review Process.
EPA	Environmental Protection Agency
ESA	Environmentally sensitive area.
GLLFAS	Great Lakes Laboratory for Fisheries and Aquatic Sciences
GLWQA	Great Lakes Water Quality Agreement (signed 1972 revised 1978 & 1987).
HCB	Hexachlorobenzene
HHC	Hamilton Harbour Commissioners.

IJC	International Joint Commission. A binational organization established in 1909 by the Boundary Waters Treaty. Through the IJC, Canada and the United States cooperatively resolve problems along their common border, including water and air pollution, lake levels power generation and other issues of mutual concern.
LOI	Loss on ignition.
MISA	The Municipal and Industrial Strategy for Abatement Program. The principal goals of this program is the virtual elimination of toxics discharged from point sources to surface waters in Ontario.
MOE	Ontario Ministry of the Environment.
MOH	Ministry of Health.
MTE	Ministry of Treasury and Economics (Ontario)
NWRI	National Water Research Institute (Environment Canada).
OECD	Organization for Economic Cooperation and Development.
OMAF	Ontario Ministry of Agriculture and Food.
OMNR	Ontario Ministry of Natural Resources.
OSCEPAP	Ontario Conservation and Environmental Protection Assistance Program
OWRA	Ontario Water Resources Act
PAH	Polynuclear aromatic hydrocarbons, some known to be carcinogens in mammals. Aromatic Hydrocarbons are composed of at least two fused benzene rings, many of which are potential or suspected carcinogens.
PCB	Polychlorinated Biphenyls. A class of persistent organic chemicals with a potential to bioaccumulate through the food chain, cause reproductive failure and is a suspected carcinogen. A family of chemically inert compounds, having the properties of low flammability and volatility and high electrical insulation quality. Past applications include use a hydraulic fluids, heat exchange, dielectric fluids, and plasticizers for plastics. They were banned in 1980, except for continued use in existing electrical equipment. As well as entering the Great Lakes from leaks and spills, PCB can be released by incineration and travel through the atmosphere.
pH	A measure of acidity of water on a scale from 0 to 14. 7 is neutral. Low numbers indicate acidic conditions, while high numbers indicate alkaline conditions.

RAP	Remedial Action Plan. A plan is developed with citizen involvement to restore and protect water quality at each of the 43 Areas of Concern in the Great Lakes Basin. The RAP will identify impaired uses, sources of contaminants, desired use goals, target cleanup levels, specific remedial options, schedules for implementation, resource commitments by Michigan and Ontario, as well as, by the federal governments, municipalities and industries, and monitoring requirements to assess the effectiveness of the remedial options implemented.
RBG	Royal Botanical Gardens.
SCUBA	Self Contained Underwater Breathing Apparatus.
SOD	Sediment oxygen demand.
STP	Sewage treatment plant.
TCDD	Tetrachlorodibenzo-p-dioxins.

APPENDIX F: CURRENT REGULATORY TOOLS

1. Spill Control

The ultimate responsibility for spill cleanup lies with the polluter, but Provincial, Federal and Municipal governments are charged with ensuring spills are dealt with promptly and adequately. In general, the Canadian Coast Guard (CCG) is responsible for all spills originating from ships, and the Ontario Ministry of Environment (MOE) is the lead agency for land-based incidents. The City of Hamilton Public Works Department may assume control for spills affecting roads and storm sewers, and Environment Canada deals with spills from federal facilities and operations. Legislation requires the immediate reporting and the control and cleanup of spills. The specific requirements are stated in the Federal Shipping Act.

The Ontario Ministry of Environment operates a 24-hour Spills Action Centre for coordination of environmental emergencies. Staff pass on reports to appropriate individuals and assist on-scene response people with information. The Port of Hamilton Spill Control Group operates on a voluntary basis. It is a cooperative consisting of local industries, the Harbour Commissioners and the Canadian Coast Guard, each committed to share equipment and expertise during spill incidents.

2. MOE Effluent Control Orders

The steel mills are required to control discharges to the natural environment. Orders have been issued under Section 6 of the Ontario Environmental Protection Act requiring such controls. The last Orders were served upon the steel mills in 1980-81. The last items were completed in 1989.

3. Municipal/Industrial Strategy for Abatement (MISA)

The Municipal/Industrial Strategy for Abatement is Ontario's new control program designed to systematically reduce the discharge of toxic contaminants.

The ultimate goal of the program is the virtual elimination of persistent toxic contaminants in municipal and industrial discharges to Provincial waterways. The program was announced in 1986 by the Environment Minister.

MISA is a regulatory program. For each of the eight major sectors of industry and the municipal sector, two regulations will be developed. Initially, discharges will be subject to a monitoring regulation which requires the industry or municipality to identify and measure concentrations of conventional and toxic contaminants in their effluents. This information will be used to formulate Effluent Limits Regulations. Following an analysis of these data, an abatement regulation will specify allowable concentrations, as well as amounts or loadings, of toxic pollutants for each discharger.

The MISA Program is being undertaken in full consultation with Environment Canada, municipalities, industries, interest groups and the general public. The MISA Advisory Committee is made up of independent technical and environmental experts. The purpose of the Advisory Committee is to review the draft regulations and provide advice and recommendations to the Environment Minister.

The two sectors of principal concern for Hamilton Harbour are the municipal sector and the iron and steel sector. The schedules for the monitoring phase and the phase specifying the "best available technology, economically achievable" (BATEA) are described below.

In the Iron and Steel industry, work began on the pre-regulation monitoring program in April, 1987, and the first sampling run was completed in November, 1987. A draft monitoring regulation was released for public review in February, 1989. Regulations are due in 1992.

The Iron and Steel Sector participants monitored specific water supply and waste streams. In Hamilton, DOFASCO monitored:

1. Biological Treatment Plant Influent
2. Biological Treatment Plant Effluent
3. Basic Oxygen Furnace slurry line
4. Hot Rolling Filter Plant location
5. Water Supply Intake

STELCO monitored:

1. Hilton Works - Water Intake #1
2. Hilton Works - Water Intake #2
3. Filter Plant Outlet
4. Blast Furnace Blowdown location
5. Oil Treatment Plant Effluent
6. Weak Ammonia Liquor (directed to Hamilton STP)

Both STELCO and DOFASCO are doing additional sampling at other locations as well.

The above documented work and schedules are based on the BATEA "track" for the MISA program. If the receiving water conditions call for more stringent controls, they will be addressed in the third phase of the MISA program.

In the municipal sector, a regulation writing team was formed in 1988. A proposed sewer use control program was released in September 1988. It is designed to reduce the loadings of toxic contaminants to the municipal STPs. Monitoring of STPs have been designed to cover periods when chlorination is and is not being used. One of five pilot studies for municipal bylaw systems has been carried out in Hamilton-Wentworth Region under MISA. A draft report has been tabled for discussion (Proctor and Redfern, 1991).

4. Air Emission Controls

Control orders under Section 6 of the Ontario Environmental Protection Act have been issued to industries requiring reductions of emissions to air. As a result, industrial air emissions have been reduced by about 86% since 1970. Current programs to control point source emissions were be completed in 1989.

Efforts to reduce wind-blown dust were started in the mid 1970s. As a result, extensive controls have been placed on the coal fields, and major roads within the steel mills have been paved and are frequently cleaned. As part of this program, the perimeters of the properties adjacent to the Harbour are being landscaped. This landscaping will not only reduce wind-blown dust but will also improve the appearance of the mill sites. An active liaison between industry and Hamilton beach residents has addressed dust and carbon fallout on a proactive way, with technical services supplied by OMOE.

Fugitive emissions from the steel mills are serious problems in matters of air pollution. Their impact on water quality is uncertain.

APPENDIX G: **HAMILTON HARBOUR RAP STAKEHOLDERS GROUP**

STAKEHOLDER*	AFFILIATION
Adamczyk, Adam	Steel Workers Area Office
Aikman, John	Council of Ontario Outdoor Educators
Anderson, June	West Burlington Citizens Group
Axon, Brenda (alt) Edmonson, Bob	Halton Region Conservation Authority
Brookfield, Jeff	Hamilton Harbour Commissioners
Cooke, Joe	Burlington Chamber of Commerce
Dowie, Don	Hamilton Beach Preservation Committee
Drewitt, Kathy	Hamilton & District Chamber of Commerce
Eisler, Hugh	Stelco Inc.
Fraser, Don	United Steel Workers of America, Local 1005
Gartner, John	Citizen at Large
Greenfield, Murray (alt) McGuire, Tom	Dofasco Inc.
Groves, David	Burlington Sailing and Boating Club
Hall, Ken	Executive Director, Bay Area Restoration Council (BARC)
Halliday, Jim	Director of Plant Operations, Regional Municipality of Hamilton-Wentworth
Hayes-Potter, Pat	NETforce
Herring, Pat	Regional Municipality of Halton
Joncas, Harry (alt) Leeson, Dennis	Golden Horseshoe Outdoors Club Inc.
Laforme, Mel (alt) Morreale, Mark	Leander Boat Club
Lang, Brian	Ministry of Agriculture and Food
Llewellyn, Simon (alt) Tseng, Tom	Environmental Protection - Ontario Region, Environment Canada
Luton, Bill (alt) Aitken, Bill	Hamilton Naturalists' Club

* Current Membership as of March 1992.

STAKEHOLDER*	AFFILIATION
McFadden, Jack	Ministry of Natural Resources
McLeod, Jeff	Burlington Golf and Country Club
Miller, Sarah	Canadian Environmental Law Association
Minns, Ken	Fisheries and Oceans Canada
Mitchell, Bill	Macassa Boat Club
Mulkewich, Walter (alt) Deloyde, Leo	Mayor, City of Burlington
Nichols, Jeff	City of Hamilton, Board of Education
Pollution Probe	
Redish, Anne	Representative, Town of Dundas
Rice, Peter (alt) Simser, Len	Royal Botanical Gardens
Simmons, Gil	Central Area Plan Implementation Committee, City of Hamilton
Smee, Ed	Conservers Society of Hamilton
Sproule-Jones, Mark	Professor of Urban Studies, McMaster University
Thompson, R.	Hamilton Yacht Club
Vallentyne, Jack	Citizen at Large
Vanderbrug, Ben	Hamilton Region Conservation Authority
Walker, Richard	Ontario Federation of Agriculture
Webb, Madelyn	Environment Canada, Great Lakes Tomorrow
Wong, Hardy (alt) Stewart, Ray	Director, West Central Region, OME

Murphy, K.L. (alt) Brown, Hugh	'Ex Officio' member for Hamilton-Wentworth Regional Chairman's Committee on Environmental Affairs

* Current Membership as of March 1992.

BAY AREA RESTORATION COUNCIL EXECTIVE (BARC) MEMBERSHIP

Anne Redish	President
Mark-Sproule Jones	Vice President
Hugh Eisler	Treasurer
Ken Hall	Executive Director (Staff)
Jack Vallentyne	Member
Gil Simmons	Member

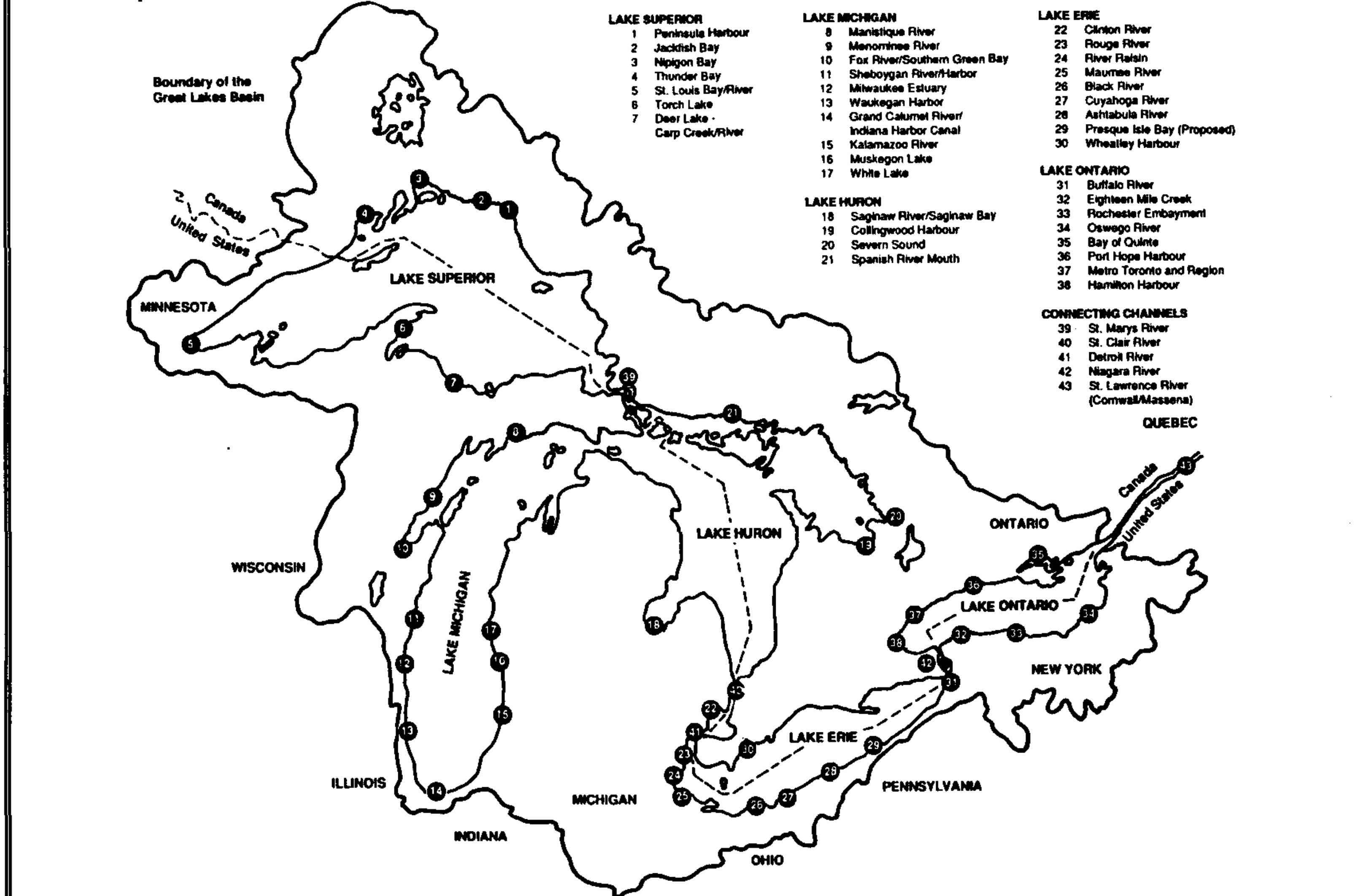
APPENDIX H: SUPPLEMENTARY MAPS

H-1 Great Lakes Areas of Concern

H-2 Point Sources for Hamilton Harbour and Surface Streams

H-3 Hamilton Sewer Layout

Map H-1: Great Lakes Areas of Concern



Map H-2: Surface Stream and Waste Water Treatment Plant (WWTP) Discharges.

STREAMS, WWTP & SEWER OUTFALLS ▲

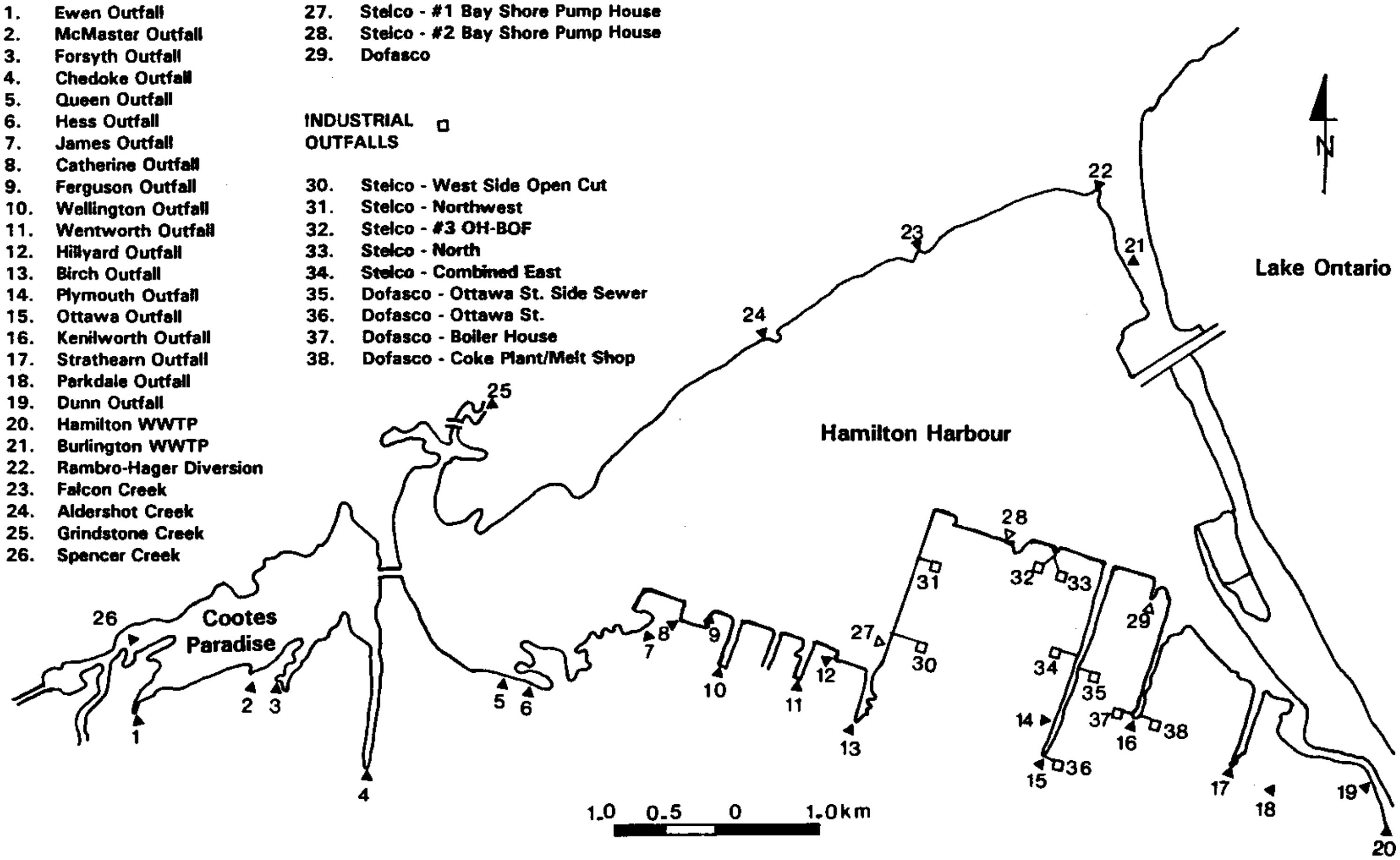
1. Ewen Outfall
2. McMaster Outfall
3. Forsyth Outfall
4. Chedoke Outfall
5. Queen Outfall
6. Hess Outfall
7. James Outfall
8. Catherine Outfall
9. Ferguson Outfall
10. Wellington Outfall
11. Wentworth Outfall
12. Hillyard Outfall
13. Birch Outfall
14. Plymouth Outfall
15. Ottawa Outfall
16. Kenilworth Outfall
17. Strathearn Outfall
18. Parkdale Outfall
19. Dunn Outfall
20. Hamilton WWTP
21. Burlington WWTP
22. Rambro-Hager Diversion
23. Falcon Creek
24. Aldershot Creek
25. Grindstone Creek
26. Spencer Creek

INDUSTRIAL OUTFALLS △

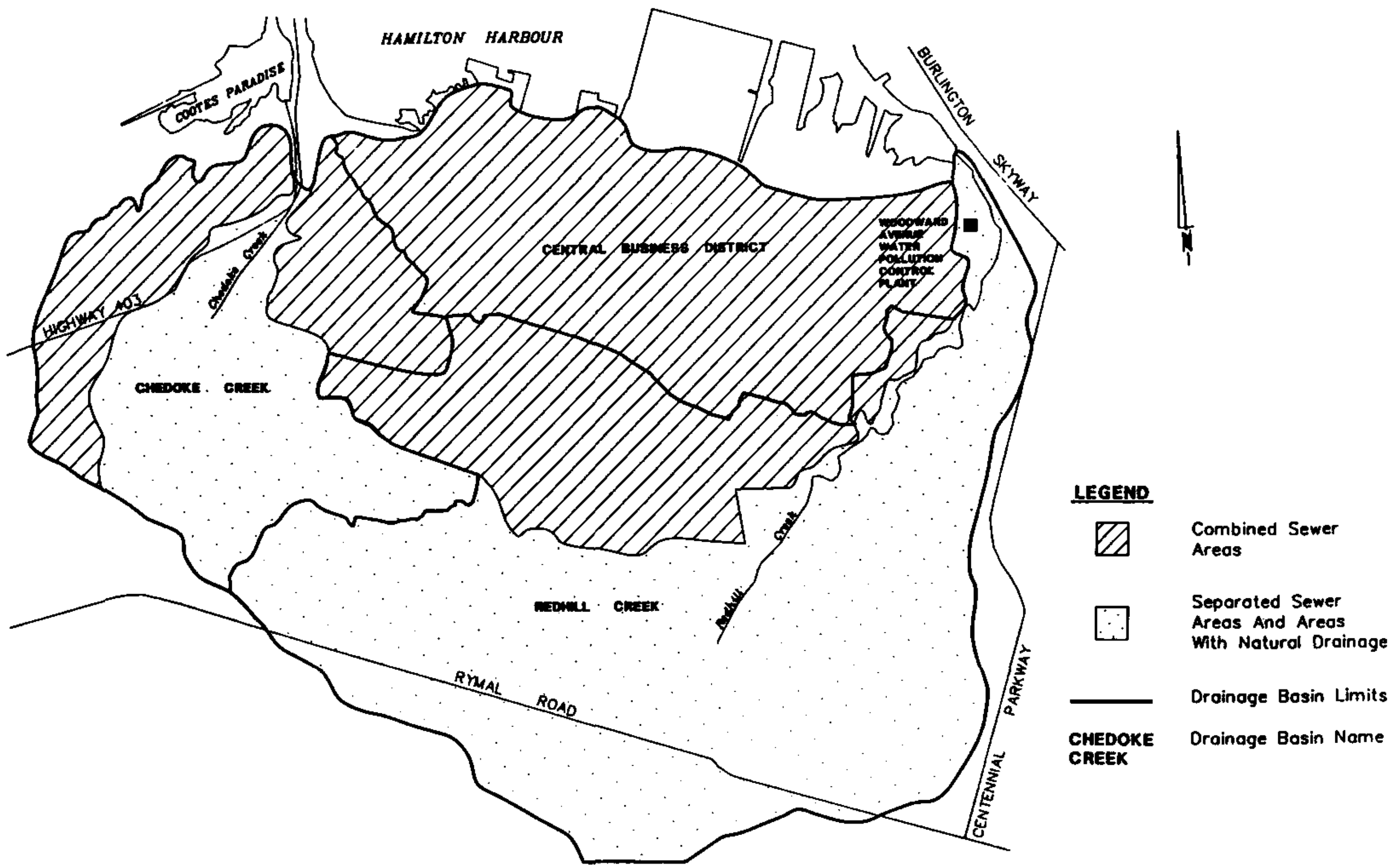
27. Stelco - #1 Bay Shore Pump House
28. Stelco - #2 Bay Shore Pump House
29. Dofasco

INDUSTRIAL OUTFALLS □

30. Stelco - West Side Open Cut
31. Stelco - Northwest
32. Stelco - #3 OH-BOF
33. Stelco - North
34. Stelco - Combined East
35. Dofasco - Ottawa St. Side Sewer
36. Dofasco - Ottawa St.
37. Dofasco - Boiler House
38. Dofasco - Coke Plant/Melt Shop



Map H-3: Major drainage basins and sewer system categories within the Hamilton area.



Source: Joint Study by Paul Theil Limited and Beak Consultants Limited, 1992.

APPENDIX I: SPILLS DATA

The Occurrences Information System (ORIS) provides a summary every year for Lake Ontario that details the total amount spilled of petroleum products, and of hazardous materials and solutions. The MOE occurrence reports provide to Environment Canada, supplemented by the more complete occurrence report computer database, provide estimates of the volume, description of the spill and its source.

Dofasco spilled more than 6,200,000 litres to water in 1991. The hot mills, blast furnace, and the byproducts plant were most frequently the source. Stelco spilled more than 1,700,000 litres to water in 1991. The blast furnace and caster machines were most frequently the source.

TABLE : Summary of spills to Lake Ontario for the 1989-90-91 period from MOE Occurrence Reports.

Date	Material	Amount	Controller of Material	Location
89.04.29	Phenol Spill from #2 Byproducts Plant	On-going	Dofasco	Hamilton
89.04.25	Tallow Spill	80,000 L	Petro-Canada	Mississauga
89.05.16	Bunker "C" Spill	400 L	Algoma Steel	Kingston
89.05.12	Calcium Hydroxide	100 L	Stelco Steel - Hilton Works	Burlington
89.06.28	Transformer Oil	<20 L at >50 ppm PCB	North York Hydro	Toronto East
89.08.16	Diesel fuel & water mixture	Sheen: 360' x 70'	Marine Vessel (NOS)	Kingston
89.09.06	Bunker "C" Oil	Unknown	Ajax Steam Plant	York/Durham
89.10.24	Oil Sheen	Unknown	Harbour Castle Hilton	Toronto
89.11.01	Oily Water - Tank/lagoon overflow (storm)	Unknown	Texaco	Toronto
89.11.14	Sulphuric Acid/Furnace Oil	1,200 L/6,500 L	Otonobee Trucking	Mississauga
89.11.27	Oily Sheen	Sheen: 220' x 100'	Unknown	Hamilton
89.12.11	Lubricating Oil (dyke failure of lagoon/pond)	Unknown	Ontario Hydro - Nanticoke	Nanticoke
90.03.05	Pulp Mill Effluent	Unknown (10 min.)	Noranda Paper	Thorold
90.03.09	Oil Sheen	Unknown	Stelco Steel - Hilton Works	Hamilton
90.04.25	Mineral Oil (50 ppm PCB)	675 L (50 ppm PCB)	Ontario Hydro	Toronto East
90.05.29	Diesel Fuel	200 L	Trillium Ship	Toronto Harbour
90.06.05	Water contaminated with coal dust/fly ash	912 L	Lambton Generating Station	Courtright
90.06.14	Oil Tar Code 2	Sheen: 800' x 40-60'	Unknown	Hamilton
90.06.15	Petroleum Gases N.O.S.	Unknown	C.N.R.	Oakville
90.06.21	Florescein Sodium	400 L at 10 ppm	Ontario Hydro - Darlington	Newcastle
90.06.28	Light Oil Sheen	Unknown	Unknown	Scarborough
90.06.30	Petroleum	Sheen: 100 m^2	Pleasure Craft	Hamilton
90.07.06	Calcium Hydroxide	Unknown	Dofasco	Hamilton
90.07.19	Wastewater Bypass (power interruption)	35,230,000 L	Stelco Steel - Hilton Works	Hamilton

Date	Material	Amount	Controller of Material	Location
90.07.29	Black Film	Film: 1,500 m x 30 m	Unknown	Ajax
90.08.20	Lubricating Oil	15 L	Dofasco	Hamilton
90.09.06	Oil Sheen, Oil Slick (N.O.S.)	Sheen: 6' x 1,000'	Unknown	Toronto
90.09.11	Diesel Fuel	Unknown	C.N.R.	Toronto
90.09.18	Waste Oil (4% Oil)	12 drums	Dehavilland	North York
90.01.01	Calcium precipitate (West Bay Front Sewer)	Unknown	Dofasco	Hamilton
90.10.02	Calcium precipitate (West Bay Front Sewer)	Unknown	Dofasco	Hamilton
90.10.03	Calcium precipitate (West Bay Front Sewer)	Unknown	Dofasco	Hamilton
90.10.07	Diesel Fuel	20 L	Brass Dolphin Sailboat	Whitby
90.10.09	Diesel Fuel	100 L	Motor Vehicle	Pickering
90.10.21	Overflow (tank, lagoon) due to electrical failure - Lime Slurry	Unknown	Stelco Steel - Hilton Works	Peterborough
90.11.01	Dirty/scale water from tank leak of slab cooling pit	Unknown (22 min,)	Dofasco	Hamilton
90.12.06	Oil Sheen from North Floor Drain to River	Unknown	Ontario Hydro-Lambton	Ambertsburg
90.12.06	Oil Sheen	Unknown	L. Rochette/Voxg Marine Vessel	Prescott
90.12.11	Diesel Fuel	Unknown	Toronto Island Ferry	Toronto Harbour
90.12.11	Petroleum (light blue oil)	Sheen: 60' x 200'	Unknown	Burlington
91.01.02	#1 Hot Mill Wastewater (overflow of tank/lagoon)	Unknown (150 ppm ss)	Dofasco	Hamilton
91.01.07	Light brown material/foam at Dofasco Outfall	Unknown	Unknown	Hamilton
91.01.08	#1 Hot Mill Filtration Plant Dirty Water	9,000 L (70 ppm ss)	Dofasco	Hamilton
91.01.09	East Side Filtration Wastewater	2,400,000 L	Stelco Steel - Hilton Works	Hamilton
91.01.09	Asphalt Sealer	5 L	Petro-Canada	Oakville
91.01.13	Machine Waste with Nitrates due to valve leak	1,400 L (500 ppm N02)	Stelco Steel - Hilton Works	Hamilton
91.01.22	Dirty Water (suspended solids) iron and carbon	112,500 L	Stelco Steel - Hilton Works	Hamilton
91.01.22	#2 Byproducts Plant - Clarifier Effluent (high phenol)	Unknown	Dofasco	Hamilton
91.01.22	Blast Furnace water (NAOH and phosphoric acid)	559,200 L	Stelco Steel - Hilton Works	Hamilton
91.01.24	#1 Hot Mill Filtration Plant dirty water	Unknown	Dofasco	Hamilton
91.01.31	Phenol from clarifier overflow at #2 Byproducts Plant	24,467,600 L (16-61 ppm)	Dofasco	Hamilton

Date	Material	Amount	Controller of Material	Location
91.02.02	Processed but unchlorinated sewage	Unknown (150 min.)	Main WPCP (Metro PUC)	Toronto
91.02.03	Processed but unchlorinated sewage	Unknown (85 min.)	Main WPCP (Metro PUC)	Toronto
91.02.03	#2 Byproducts Plant clarifier overflow (high phenols)	Unknown (14 hours) (5-11 ppm)	Dofasco	Hamilton
91.03.01	Gasoline from truck overturning	32,000 L	Power Tank Lines	Hamilton
91.03.15	Light Diesel Fuel (container leak)	Small Quantity	Marine Vessel (N.O.S.)	Hamilton Harbour
91.03.15	Fuel Oil	Unknown	Unknown - Wellington St. Slip	Hamilton
91.03.19	Calcium Carbonate precipitate	Unknown (few hours)	Dofasco	Hamilton
91.03.27	Oil and Grease/phenols/pentachlorophenolics	2,250 L	Domtar Wood	Trenton
91.03.27	#1 Hot Mill splinter box overflow - dirty water	2,000 conc. unknown	Dofasco	Hamilton
91.04.15	Ammonium Nitrate - 50% solution	900 kg	Ontario Hydro - Lakeview TGS	Mississauga
91.04.17	Petroleum - bilge pumping	Sheen: 900' x 10'	Marine Vessel - Vessel Winnipeg	Hamilton Harbour
91.04.17	Petroleum Oil Tar Code 2 and perhaps Tar Code 3	Unknown	Marine Vessel - Seaway Queen	Hamilton Harbour
91.05.15	Blast Furnace recirc. iron, ss, cyanide and ammonia	500 L	Stelco Steel - Hilton Works	Hamilton
91.05.22	Hydrochloric Acid	1,360 L	Richvale Block and Ready-mix	Toronto
91.05.16	Diesel fuel spilling to ground and sewer	100 L	Plaza 2 Hotel	Toronto
91.06.02	Dowtherm (1,500 ppb) - entered through service sewer	158 kg	Dupont	Kingston
91.07.05	Portland Cement Powder	Unknown	Chieftain Cement	Oshawa
91.07.09	Dirty Water (4,000 ppm suspended solids) - #1 Hot Mill	341,000 L	Dofasco	Hamilton
91.07.09	#2 Caster Machine Water (540 ppm nitrite conc.)	6,050 L	Stelco Steel - Hilton Works	Hamilton
91.07.10	Furnace Oil	135 L	Ontario Hydro - Lakeview TGS	Mississauga
91.07.25	Solvent spill in plant - entered storm sewer	Unknown	Lawson Graphics	Toronto West
91.08.02	Cyanide contaminated well overflow	Unknown	MFB Electrical Products	Toronto West
91.08.12	Blast Furnace - dirty water recirculation system	Unknown (912 L/minute)	Stelco Steel - Hilton Works	Hamilton
91.08.12	Paperboard Industrial Effluent Bypassing	Unknown (10 ppm solids)	Paperboard Industries Inc.	Belleville
91.09.10	Dirty water #1 Hot Mill recycle 35 ppm ss	Unknown (26 hours)	Dofasco	Hamilton
91.09.06	Hydraulic Oil (42% oil)	2,250 L	Stelco Steel - Hilton Works	Hamilton
91.09.06	East side filtration plant cooling water	3,050 L	Stelco Steel - Hilton Works	Hamilton

Date	Material	Amount	Controller of Material	Location
91.09.28	#2 Byproducts clarifier overflow - 30-151 ppm P	Unknown (14 day) 35 ppm	Dofasco	Hamilton
91.09.12	'E' Blast Gas Recycle Water (suspended solids)	5,000 L	Stelco Steel - Hilton Works	Hamilton
91.09.13	Orange coloured slick at Dofasco dock	Unknown	Unknown	Hamilton
91.09.15	Bypass of sewage (primary treatment/chlorination)	Unknown	Humber WPCP	Etobicoke
91.09.18	Chromate water - tin free steel electrolysis solution	5,500 L	Stelco Steel - Hilton Works	Hamilton
91.10.01	Blast Furnace Recycle Water - phenols, cyanide, ammonia	654,000 L	Stelco Steel - Hilton Works	Hamilton
91.10.01	#1 Steelbottom effluent wastewater discharge/bypass	Unknown	Dofasco	Hamilton
91.10.01	Dirty Water (176 ppm suspended solids) #1 Hot Mill	250 L	Dofasco	Hamilton
91.10.01	Dirty Water (4 ppm suspended solids - hot well overflow)	18,000 L	Dofasco	Hamilton
91.09.28	Diesel Fuel	45 L	Unknown	Toronto Harbour
91.10.02	NO2 contaminated machine cooling water - East Side Filtration	11,550 L (560 ppm NO2)	Stelco Steel - Hilton Works	Hamilton
91.10.31	Digested sludge (mostly foam) overflowed from digestors	10,000 L	Main WPCP	Toronto
91.11.07	Sodium Hydrochlorite (12% solution)	150 L	Pickering Nuclear Plant	Pickering
91.11.21	Dirty Water #1 Hot Mill (49 ppm ss average) - bypass	Unknown (24 hours)	Dofasco	Hamilton
91.11.22	Petroleum Oil	Unknown	Unknown	Toronto Harbour
91.11.22	Lubricating Oil/Grease	35 L	Petro-Canada	Mississauga
91.11.24	Paper Mill Effluent (100 ppm ss)	406,000 L	Domtar Fine Paper	St. Catherines
91.12.02	Petroleum Oil - planned pumping out of bilge	unknown	Steven Howard Tug Boat	Belleville
91.12.02	Blast Furnace Recycle Water H20 - ss, iron, phenol, ammonia, cyanide	1,600 L	Stelco Steel - Hilton Works	Hamilton
91.12.27	Blast Furnace Recycle Water H20 - ss, iron, phenol, ammonia, cyanide	40,000 L	Stelco Steel - Hilton Works	Hamilton

Source: MOE Occurrence Reports, 1989-1990-1991.