WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR ENVIRONMENTAL QUALITY STUDY

SAINT JOHN HARBOUR
ENVIRONMENTAL QUALITY STUDY

SUBMITTED TO: TRI-LEVEL COMMITTEE CONSISTING OF:
CITY OF SAINT JOHN
PROVINCE OF NEW BRUNSWICK
GOVERNMENT OF CANADA

SUBMITTED BY: WASHBURN & GILLIS ASSOCIATES LTD.
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1.0 INTRODUCTION

Over the past 20 years public concern for the environment has increased dramatically in New Brunswick, Canada, and throughout the world. In Canada, this trend is reflected in the growth in the number, types, and strength of federal and provincial environmental regulations. Governments at all levels are responding to citizen pressure to clean up and protect air, water, and natural resources. Increasingly higher standards are being set for all phases of environmental management. The City of Saint John, in step with municipalities elsewhere, is embarking on a multi-year effort to clean up its environs. Through the process of developing its 1989 Strategic Plan, the City determined that Saint John "must achieve a higher quality and more desirable environment". Towards achieving this goal, the City administration concluded that all forms of pollution must be reduced.

A report completed in May, 1990 (A View of the City), by the Environmental Consultation Committee identified a need to quantify the extent of contamination, identify the sources of such contamination, provide appropriate water and sediment quality objectives and outline cost-effective rehabilitation and maintenance procedures to attain an appropriate level of water and sediment quality in Saint John Harbour. The City of Saint John and the Province of New Brunswick are also developing a strategy for implementation of a municipal wastewater treatment program. Part of the overall strategy to reduce pollution in Saint John will focus on the City's Harbour. Concern for the Harbour stems from the knowledge that effluent from numerous point sources, including pulp and paper mills, oil and sugar refineries, breweries, power generating plants, and sewage outfalls, have had an effect on water quality.

A Committee formed by the Federal Government, the Province of New Brunswick, and the City of Saint John, and referred to as the Tri-Level Committee, is responsible for determining management-oriented environmental quality objectives for the Saint John Harbour and a wastewater treatment strategy for the City of Saint John. The Tri-Level Committee consists of:

- City of Saint John.
- New Brunswick Department of the Environment.
- Environment Canada.
- Atlantic Canada Opportunities Agency.
- Saint John Port Corporation (observe status only).

The Tri-Level Committee has commissioned a study consisting of two components:

- Component A - A Study of the Saint John Harbour Environmental Quality.
- Component B - A Study of Wastewater Treatment for the City of Saint John.

The study results are reported in two separate reports. This report addresses Component A. A separate report has been prepared by Godfrey Associates Ltd. and provides specific information on the wastewater treatment strategy for the City of Saint John (Godfrey Associates Ltd., 1993).

1.1 Study Boundaries

The overall area to be studied includes the area within the City boundaries from Lorneville and the Spruce Lake Highway in the West, to the Saint John Airport and the First Loch Lomond Lake in the East; from the Kennebecasis and St. John Rivers in the North, to the Bay of Fundy in the South.

The Saint John Harbour is situated within the Bay of Fundy bordering New Brunswick. The specific Harbour study area is bounded on the north by Cedar Point just downstream of Grand Bay while the southern limit of the Harbour extends from Lorneville to Mispec Point (see Figure 1-1).

1.2 Objectives For Study of Saint John Harbour Environmental Quality

The overall objective of the Component A study was to assess the extent and types of chemical and physical contamination of Saint John Harbour and determine priorities for the

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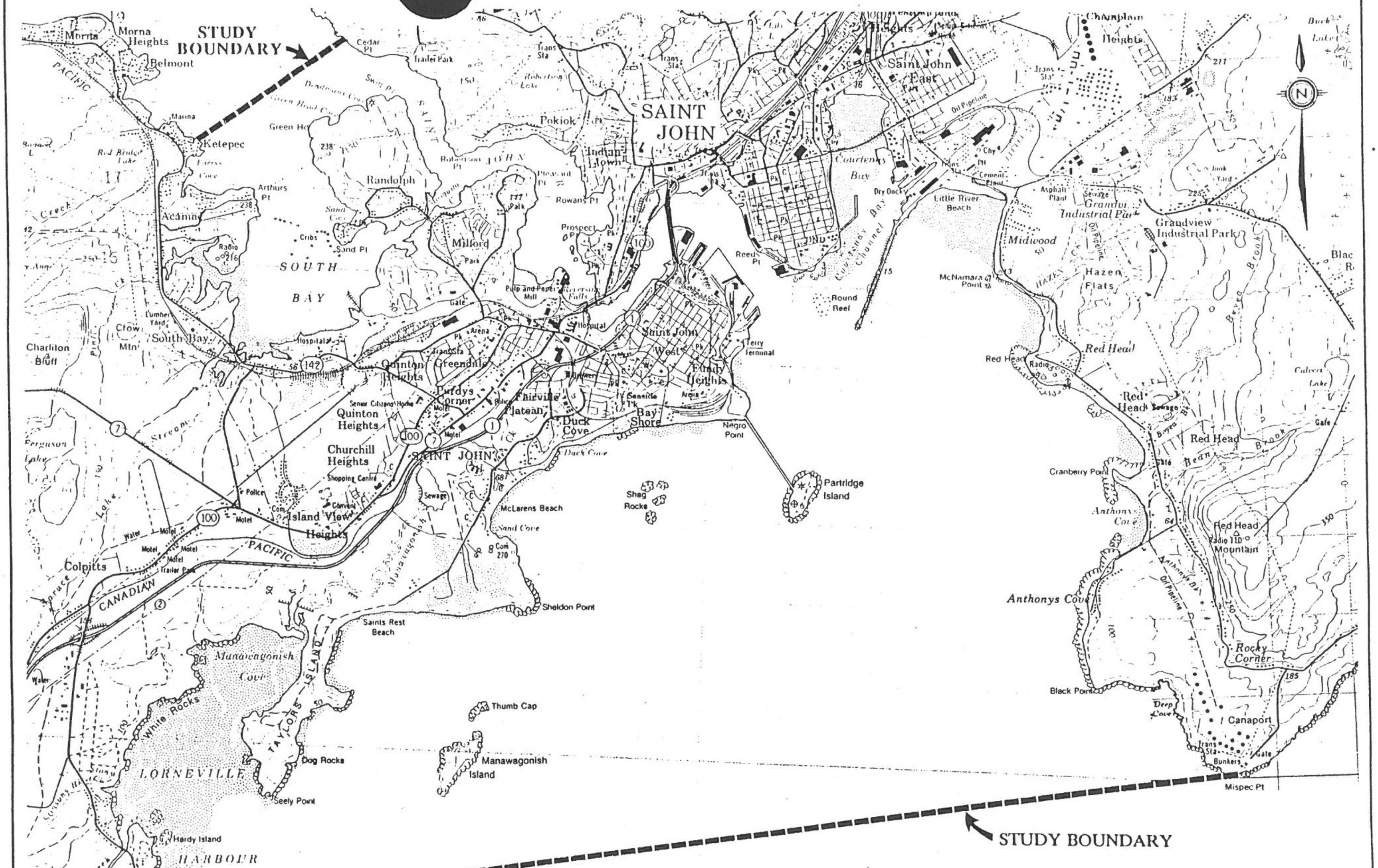

FIGURE 1-1
STUDY BOUNDARIES

rehabilitation and maintenance of an acceptable level of environmental quality. Tasks required to meet the objective are listed below.

Determine Environmental Characteristics of The Harbour

This task involves review of available information to provide descriptions of the physical, biological, and land use setting of the Harbour. Components of this task includes:

- hydrography description;
- description of sedimentological processes of the Harbour, including existing levels of sediment contamination;
- description of biological resources of the Harbour, including benthic invertebrates and fishery resources and existing levels of contamination; and
- historical, present, and projected future land use descriptions around the Harbour.

Prepare Environmental Profile

This task involves establishment of an inventory and characterization of sources of contamination entering Saint John Harbour, including:

- municipality of Saint John;
- industry;
- streams discharging into the Harbour; and
- assessment of their potential contributions to the pollution of the Harbour in the context of associated environmental concerns.

Identify Environmental Concerns

This task focuses on identification of contaminants of concern, based on contributions from known pollution sources, preliminary prioritization of contaminants of greatest concern, and includes determination of the level of pollution (residues and effects) existing in the Harbour.

Establish Environmental Quality Objectives

This task includes recommending environmental quality objectives for the Harbour, along with a monitoring program for the priority parameters.

1.2.1 Milestone Report Objectives

The overall Component A study consists of three milestone phases. The first phase provides a presentation and discussion of the results and findings related to the environmental setting and the environmental profile and gives an overview of the sources and fates of contaminants discharged into the harbour, as well as recommendations for assessment of these contaminants within the Harbour itself.

The second phase provides a description of the sampling program conducted to identify the potential effects of contaminants of concern in the Harbour and includes a presentation and discussion of the approach to establishing environmental quality objectives.

In the third phase, recommendations for the Harbour quality objectives are presented along with recommendations on parameters to be considered for these objectives.

1.3 Report Methodology

This section of the report provides a more detailed review of the approach used to achieve the objectives for the study.

1.3.1 Environmental Characteristics of the Harbour

The Saint John Harbour environment has been characterized based on a description of the physical, chemical, biological, and land use setting. This task was accomplished through the extensive use of available background documentation and discussions with resource managers, government and academic researchers, resource users, and personnel with the City of Saint John and private industry. Available maps, charts, drawings, and various photographic materials have been utilized in conjunction with the other data sources. Existing information has been obtained from sources such as the Bedford Institute of Oceanography, the Biological Research Station at St. Andrews, and various regulatory agencies.

1.3.1.1 Hydrography/Sedimentology

Saint John Harbour and the St. John River estuarine complex comprise a unique system. The hydrographic conditions are extremely complex, being dominated by the outward flow from the St. John River system and the high tides of the Bay of Fundy (Bezanson, 1983; Thomas, 1983). The area has been the subject of various hydrographic and sedimentological studies since the late 1890's (Matthew, 1894; Hachey, 1935, 1939 a, b; Rogers, 1936; Neu, 1960 a, b; Trites 1960; Sprague, 1964; Hansen, 1970; Metcalfe et al., 1976; Bezanson and Krank, 1981, 1982; ADI Limited, 1986; W.F. Baird et al., 1987).

The available information has been reviewed and evaluated to provide interpretation and documentation of the hydrographic characteristics associated with the St. John River estuary/Harbour system. This has included hydrodynamic aspects such as inflows and outflows, the effect of the St. John River and other tributaries on circulation patterns, and sediment dispersion characteristics. The existing data base has been evaluated with reference to the levels of hydrodynamic and water quality models that could be applied to the Saint John Harbour.

Data have also been reviewed to describe the sedimentology of the Harbour, and to identify locations of contaminated bed materials (Bezanson and Krank, 1981, 1982; Yurick, 1982; Ray, 1983; Ray and McKnight, 1984; ADI Limited, 1986). This, combined with data for contaminant source locations and hydrodynamic characteristics has been used to describe possible source-fate pathways in the Harbour.

1.3.1.2 Biology

Biological features of the study area have been characterized through description of the benthic faunal communities and fisheries resources.

Benthic studies conducted to date have been related to investigations for academic reasons and/or to determine if industrial activity at the mouth of the St. John River, particularly dredging and spoil disposal, has affected the benthic fauna. Both natural and anthropogenic influences have been related to impoverished benthic communities in the Harbour area.

Available information on benthic biota has been reviewed and evaluated to characterize composition, distribution, and diversity. Emphasis has been placed on those attributes which can be clearly related to environmental impacts resulting from the release of pollutants and anthropogenic disturbance, as opposed to natural phenomena.

Commercial fish species have been exploited in Saint John Harbour since the area was first settled, with landing statistics dating to the 1800's (Dadswell, 1983). Historically, the major species exploited in the Harbour included a variety of groundfish, sturgeon, striped bass, shad, gaspereau, eels, Atlantic salmon, herring, and lobster (Marine Research Associates Ltd., 1977; Dadswell, 1983).

Hildebrand (1980) reported that fishermen in the Saint John area expressed concern over a reduction of fishing potential in the Saint John Harbour and surrounding area. This was believed to be related to fish habitat degradation resulting from industrial pollution, dredging and spoil disposal. A workshop initiated by Environment Canada brought together concerned parties and jurisdictions in 1981 (Lindsay et al., 1983). Analysis of sediment distribution and dredging-related activity indicated that Harbour dredging was not the major, or perhaps even a significant, source of pollution. Natural siltation processes accelerated by onshore development, industrial growth, disposal of untreated sewage, and modifications to flow patterns and flushing action in the Harbour resulting from causeway and wharf construction, were all seen as being more likely sources of environmental change.

Existing information on fisheries resources has been compiled and reviewed to determine current resource utilization in the Harbour area, historical trends in species composition and landings, and distribution of fishing activity.

1.3.1.3 Land Use

The area immediately surrounding the Harbour has been characterized based on existing municipal, commercial, industrial, domestic, and natural environment distribution patterns. Past and future trends in area land uses, Harbour uses, and industrial profiles have been investigated for the study area.

In order to achieve these tasks, a land use survey has been conducted in the study area and discussions have been held with planners at the Community Planning Branch of the City. Historic records have been reviewed to determine past trends in uses. Future trends have been determined through discussions with planning, engineering and economic development officials with the City of Saint John regarding industrial profiles.

1.3.2 Environmental Profile of Harbour

An environmental profile has been developed based on sources of contaminants entering the Saint John Harbour. This profile has involved a combination of literature searches and personal consultations (to identify and characterize sources), and a field sampling program (to fill data deficiencies and provide a better overall understanding). As part of this task, the results of the environmental profile have been integrated with the description of the environmental setting to develop a Harbour environmental sampling program.

1.3.2.1 Identification and Characterization of Contaminant Sources

Many of the contaminants entering the Harbour are typical of those that have been associated with environmental impairment. Their significance is dependent on their relative quantity, potential to result in environmental degradation, and the ability of the receiving environment to assimilate them. Their relative quantity in the mixed Harbour environment is dependent on both the quantity of effluent and the concentrations of parameters of interest within that flow.

A combination of literature review and consultation strategy has been employed to identify and characterize the potential sources of contaminants entering the Harbour. Several categories of sources have been investigated: municipal (storm runoff, sanitary sewage, combined sewer overflows, treatment plants, and outfalls), industrial (sewer users, private outfalls and treatment works), and Harbour tributaries.

The contaminant sources have been characterized with respect to their potential to cause environmental degradation in the Harbour. Data obtained from literature review and personal consultations have been scrutinized with respect to the parameters of interest. The contaminant sources characterization has been used to provide the basis for designing the effluent field sampling program.

1.3.2.2 Effluent Sampling Program

An effluent sampling program has been designed and implemented with the goal of filling primary data deficiencies. The sampling program has been developed in consultation with, and implemented after approval by, the Tri-Level Committee.

Nine major industries were sampled. These included Moosehead Breweries Ltd., Lantic Sugar Ltd., T.S. Simms & Co. Ltd., NB Power Coleson Cove and Courtenay Bay Generating Stations, Irving Tissue Ltd., Irving Pulp and Paper Ltd., Irving Paper Ltd., and the Irving Oil Refinery.

Harbour tributaries have also been identified as potential sources of contaminants. Unlike the industrial effluents, tributary flows and loadings may vary widely with season. Therefore, the tributaries were sampled once in a low flow and once in a high flow period. Four main tributaries were sampled: Marsh Creek, Hazen Creek, Little River, and the St. John River.

A municipal wastewater quantity and quality study was undertaken to determine wastewater flows at various locations throughout the City. A total of 17 locations were flow monitored during the study, including four wastewater treatment facilities. The locations were selected to fill gaps in existing information and provide representative flow data for various areas and types of development in the City. In addition to the municipal wastewater quantity monitoring, wastewater quality sampling was also carried out at five locations. The sampling locations were selected from the fourteen flow monitoring sites in order that the data could be related to flow.

1.3.3 Potential Effects of Sources Entering the Harbour on the Harbour Environment

The preliminary Harbour quality evaluation consisted of reviewing characteristics of the industrial, municipal, and tributary effluents and reviewing the environmental setting with respect to the potential effects of contaminant sources. Parameters of interest were identified for sources entering the Harbour on the basis of generic concerns related to Harbour uses. A Harbour sampling program was then developed to determine the specific effects on the Harbour environment for the identified parameters of interest. These tasks are described below.

1.3.3.1 Identification of Parameters of Interest

The literature searches, personal interviews, and sampling and analyses have provided an extensive data base of the characteristics of effluent and other discharges to the Harbour. The data have been reviewed with respect to loadings of contaminants, and also with respect to the potential for specific contaminants to cause environmental degradation.

1.3.3.2 Review of Environmental Setting and Harbour Uses

The description of the environmental setting has been related to the characterization of effluent discharges in the Harbour. The description of the environmental setting has provided information about locations of contaminated sediments and biota in the harbour, what the contaminants comprise, and possible pathways of contamination (sources and distribution). This information has been related to the effluent parameters of interest and potential effects on Harbour uses. A preliminary evaluation describing possible sources and fates of contaminants in Saint John Harbour has been prepared.

1.3.3.3 Harbour Environmental Sampling Program

The Harbour environmental sampling program has been developed by reviewing characteristics of the industrial, municipal, and tributary effluents and identification of parameters of interest and by reviewing the environmental setting with respect to the contaminant sources and loadings.

The goal of this task is to relate the description of the environmental setting to the characterization of effluent discharges in the Harbour. The description of the environmental setting provides information about locations of biota and contaminated sediments in the Harbour, what the contaminants consist of, and possible pathways of contamination (sources and distribution). This information has been related to the effluent parameters of interest and has been used to develop a specific sampling program to assess the effects of water quality on the Harbour environment including: contaminant levels in sediments, contaminant levels in biota, and biotic responses to contaminant levels.

The Harbour sampling program has been directed at determining the effect of sources entering the Harbour on the Harbour environment as a whole from a literature review and determining the occurrence of contaminants of interest as identified in the environmental profile sampling results.

Contaminants in Sediments

Levels of selected contaminants in the sediments of the Harbour have been investigated in the past (Bezanson and Krank, 1981; Yurick, 1982; Ray, 1983; Ray and MacKnight, 1984; ADI Limited., 1986). Sediment sampling has been conducted to fill data deficiencies.

Sampling was conducted to determine the levels of selected contaminants in depositional areas. Parameters for analyses, location, and timing of sampling were determined in consultation with the Tri-Level Committee.

Contaminants in Biota

Contaminant levels in the Harbour biota have been investigated to a much lesser degree than levels in the sediments. However, several species are known to accumulate various contaminants and, therefore, are indicators of contaminant occurrence in the environment (Yurick, 1982; Bacon, 1983).

Biota sampling has been conducted in conjunction with sediment sampling to allow the potential link in contaminant transfer between these ecosystem components to be assessed. Invertebrate (mussels) and groundfish (flounder) were sampled at selected locations. Details of the program were developed in consultation with the Tri-Level Committee.

Physiological Responses to Contaminant Levels

Physiological responses of biota to contaminants were evaluated in order to assess the magnitude of the impacts of contaminant accumulation or exposure. The mixed-function-oxidase (MFO) test was conducted using resident flatfish (flounder).

MFO's are a group of enzymes found in the livers of most animals. Their main function is to metabolize (detoxify) certain contaminants which the animal has been exposed to. When the animals are exposed to certain groups of chemicals, their hepatic microsomal MFO's are induced. Increased hepatic MFO activity in wild organisms may, therefore, indicate contamination of their habitat and induction may be a sub-lethal bioassay of environmental contamination by certain chemicals. Among the organic contaminants known to induce MFO's in fish are PAH's, PCB's, dioxins and furans.

The work was performed by capturing live fish from the survey area, immediately removing their livers and preserving livers for shipment to the laboratory. In the laboratory, the enzymes are extracted from the liver tissue and measured using biochemical techniques. Dr. Richard Addison of the Bedford Institute of Oceanography implemented the MFO testing, analyzed the samples, and interpreted the results. The flatfish were sampled at several locations throughout the Harbour.

1.3.3.4 Identification of Contaminants of Concern

The environmental quality data generated and compiled through sampling programs and literature reviews during this study have been used to identify contaminants of concern.

The level of concern associated with particular contaminants is dependent on known or potential deleterious effects on human health or biotic aquatic resources. Where possible, available Harbour use information has been used to determine concerns. Concerns have been established based on known exposure pathways to human receptors, potential deleterious human health effects, effects on aquatic resources, levels occurring in various environmental components, and potential for bioaccumulation.

A discussion on the approach to establishing contaminant priority and environmental quality objectives is also provided.

1.3.4 Environmental Quality Objectives

Development of environmental quality objectives has been undertaken interactively with the Tri-Level Committee. Environmental quality objectives for Saint John Harbour have been developed with consideration of appropriate guidelines for parameters measured in the study area and the characteristic physical, chemical, and biological conditions in the Harbour. Due to the diversity of environments within the study area, site-specific variations in environmental conditions have been recognized when formulating objectives. The complex hydrographic conditions result in high flushing in some areas, and/or retention and deposition in other areas.

Objectives have been developed to be consistent with sustainable development in the study area. They reflect the most sensitive habitats and/or harbour uses. The implications for future land/harbour uses have been discussed relative to recommended objectives.

A monitoring program has been designed for the previously determined priority parameters and includes recommendations for additional parameters which are indicative of local environmental conditions.

1.4 Project Team

Washburn & Gillis Associates Ltd., has drawn upon the specialist input of several consultants and laboratories to complete the study. Specific areas of expertise are summarized as follows:

- ADI Limited/Godfrey Associates Ltd. - municipal effluent characterization.
- Fiander-Good Associates Ltd. - land use history, patterns and trends.
- J.E. Edinger Associates Inc. - hydrographic and bathymetric interpretation.
- Philpott Associates Coastal Engineers Limited - sedimentation and circulation patterns.
- Beak Consultants Limited - laboratory analysis related to toxicity testing.
- Fenwick Laboratories Limited - laboratory analysis for water quality, sediment and biota.
- Bedford Institute of Oceanography (Dr. Richard Addison) - MFO testing.

2.0 PHYSICAL ENVIRONMENTAL CHARACTERISTICS

The Harbour study area is characterized by three hydrographic sub-areas. Each sub-area has a distinct physical environment. The following sections describe the physical environment of the Harbour study area and sub-areas in terms of hydrography and sedimentology.

2.1 Hydrography

The hydrodynamics of Saint John Harbour from its boundary with the Bay of Fundy to above the study area is comprised of three major sub-areas (see Figure 2-1):

- Outer Bay
- Harbour Bay
  - City Harbour
  - Courtenay Bay
- Above Reversing Falls

These unique sub-areas are defined in terms of exchanges that take place across hydrodynamic boundaries and the circulation within the portions of the waterbodies between those boundaries. The major hydrodynamic boundaries are between the Bay of Fundy and Outer Saint John Bay, between the Outer Bay and Harbour Bay and at Reversing Falls.

The major source of basic hydrographic information available for the study area is the Neu (1960a) report. Although, little new hydrographic information has become available since 1960, the Neu report is, however, still very significant because of the amount of data collected and the interpretation of that data. The interpretation of the data was state of the art at the time and is still considered to be invaluable.

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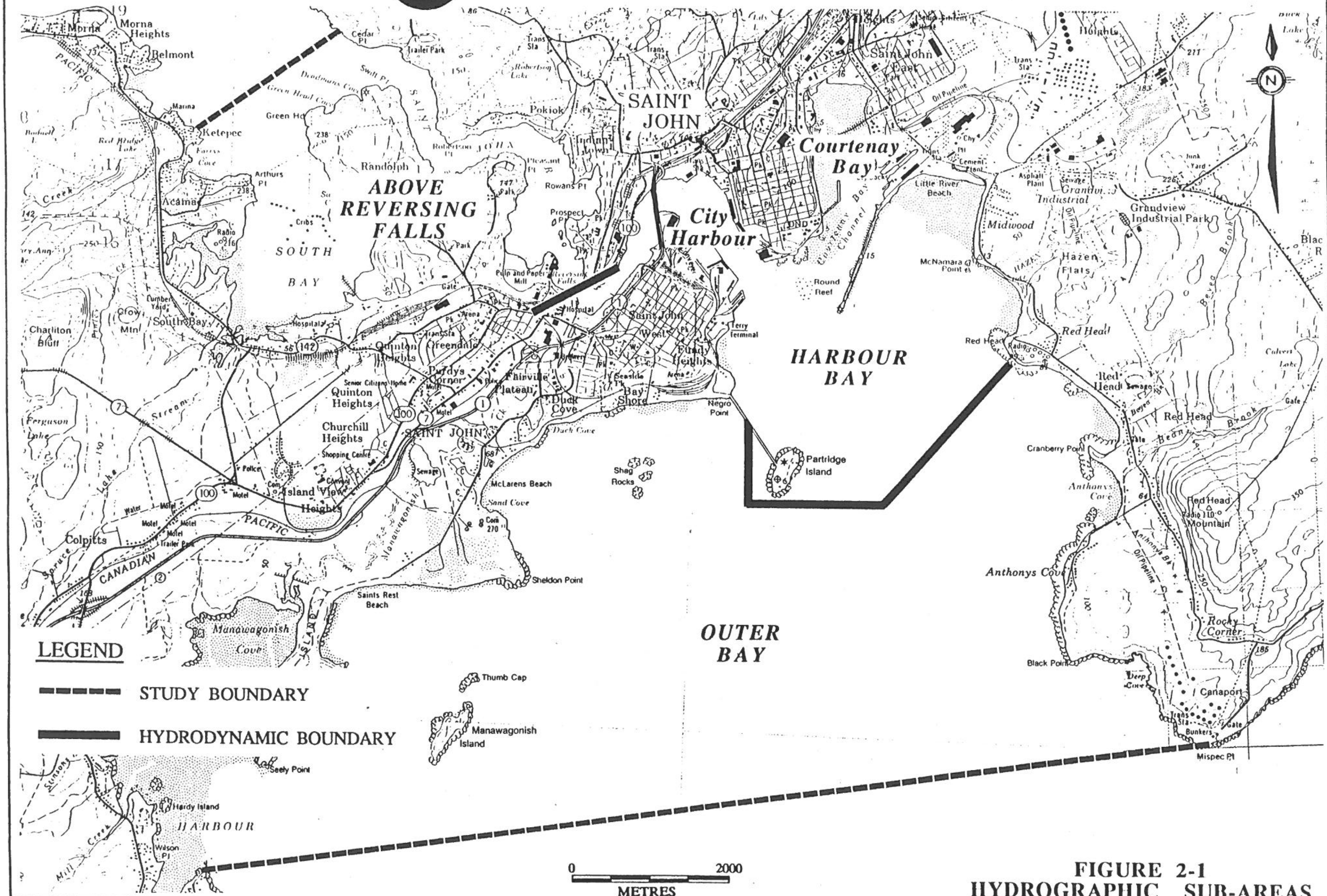

FIGURE 2-1
HYDROGRAPHIC SUB-AREAS

The work of Neu (1960a) has served as the basis for establishment of the three major Harbour sub-areas defined above. Note, however, that the boundaries shown in Figure 2-1 are not exactly as those described by Neu (1960a). Rather, these boundaries have been modified somewhat to co-ordinate with the overall project study area, Harbour uses, and other available data.

The Neu (1960a) report results have been reinterpreted in this study to describe what is known about exchange at the boundaries. This section of the report also provides descriptions of some of the processes within the portions of waterbody that are important in describing flushing and sediment transport processes.

2.1.1 Exchange With the Bay of Fundy

The boundary between the Bay of Fundy and the Outer Bay has been taken as that defined by Neu (1960a) (see Section I-I in Figure 2-2). However, this boundary may be somewhat arbitrary relative to larger scale processes in the Bay of Fundy.

The mean tide and maximum tide range in the vicinity of Saint John is 6.5 m and 8.7 m, respectively. Over the study area, the mean tide has been determined by mass volume calculations to result in an overall tidal exchange rate of 77,000 cubic meters per second (CMS). The exchange is filled from both the River and the outer boundary. However, the maximum mean monthly flow of the St. John River is 3271 CMS and is a small portion of the overall tidal exchange rate. The majority of the 77,000 CMS therefore crosses the boundary between the Bay of Fundy and the Outer Bay. The overall tidal exchange rate does not give a direct estimate of flushing, since a large fraction of the water leaving on falling tide will re-enter on rising tide and is not "new" dilution water.

The effect of the St. John River is, however, detectable at the outer boundary. This is illustrated on Figure 2-3 which shows the lower density (freshwater) St. John River on the surface and having a gradually greater influence on falling tide. The cross-sections referred to on Figure 2-3 are shown on Figure 2-2.

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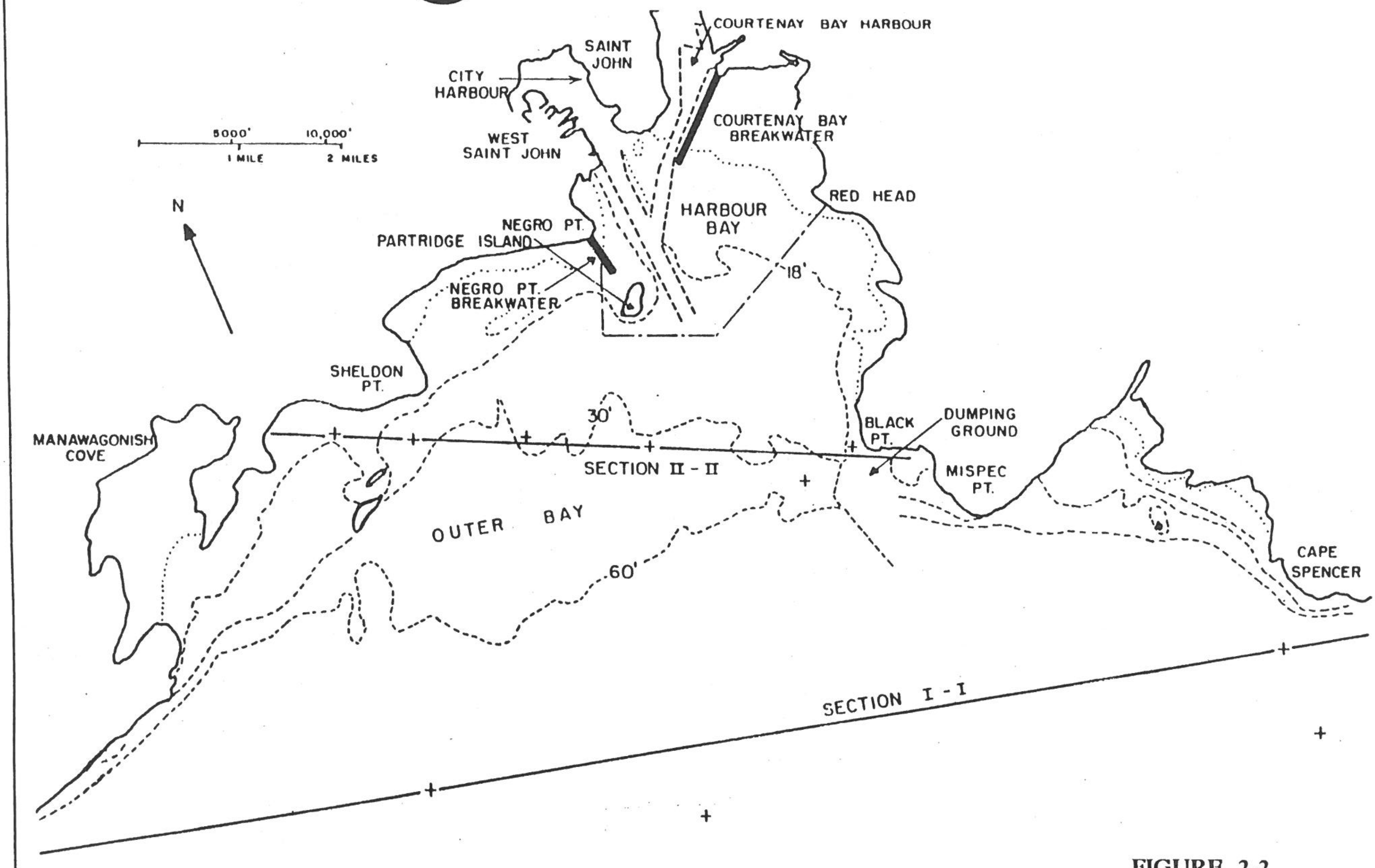
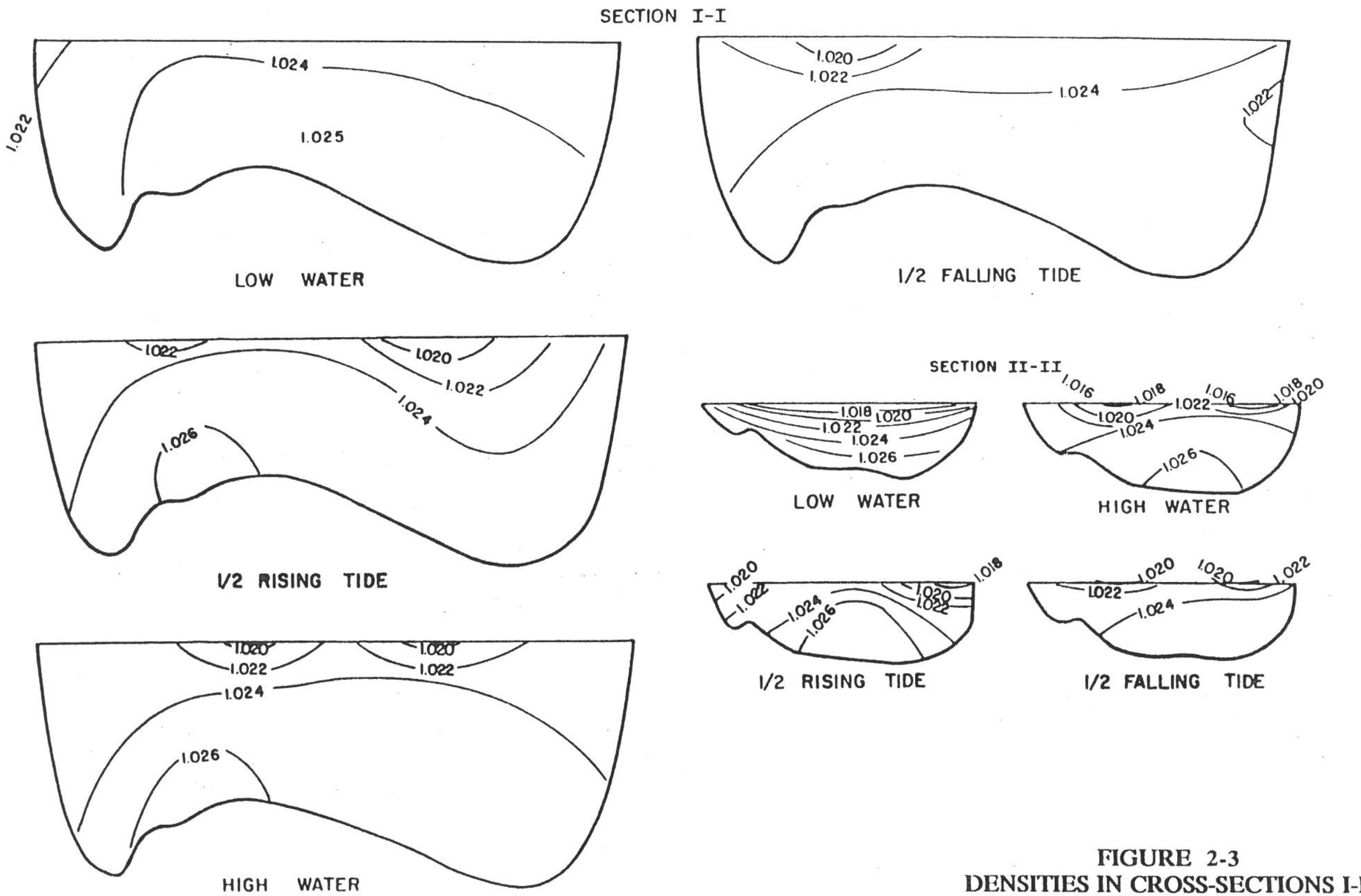


SOURCE: NEU, 1960.

FIGURE 2-2
HYDRODYNAMIC REGIONS OF SAINT JOHN HARBOUR AREA



SOURCE: NEU, 1960.

FIGURE 2-3
DENSITIES IN CROSS-SECTIONS I-I AND II-II DURING THE FOUR MAIN TIDE STAGES

The velocities inferred by Neu (1960a) across the boundary of the Outer Bay at different sets of tide are shown in Figure 2-4. These results show a complex boundary condition at any given tide with inflows along one part of the boundary and outflows along another part of the boundary. Both cross-sections (I-I and II-II) show most of the flow entering the bay on rising tide along the western end of the boundary. The range of velocities on flood and ebb tide are near that which would be estimated from the overall exchange rate.

2.1.2 Circulation in the Outer Bay - Influence of St. John River

The two known dominant features of the circulation within the Outer Bay are the boundary tidal induced circulation shown in Figure 2-4 and the stratified outflow of the St. John River shown in Figure 2-3. As shown in Figure 2-4, the tidal induced circulation tends to produce a clockwise circulation on rising tide and a less intense counter-clockwise circulation on falling tide.

The tidal currents along the southwest boundary of the Outer Bay near Sheldon Point have tidal amplitudes of 40 to 60 cm/s but mean values of only 5 to 10 cm/s. The tidal currents in the deeper water (beyond 10 m MLW depth) follow the typical pattern of a standing-wave tidal current which are up-bay on rising tide and down-bay on falling tide with slack water at high and low tide. The deeper water mean currents tend to be down-bay in response to the St. John River inflow. Nearer to shore, the tidal currents deviate from this pattern and tend to become radial over time with strong onshore-offshore components.

The St. John River acts as a flow superimposed on the tidal circulation. The less dense river flow is held back in the Harbour Bay on rising tide and extends outward in the Outer Bay on falling tide. The extent of the St. John River plume in the Outer Bay is determined by the river flow and varies seasonally. The plume also spreads laterally due to density effects. This flow would carry suspended sediment into the Outer Bay which would be deposited as the river plume widened and its horizontal velocities slowed.

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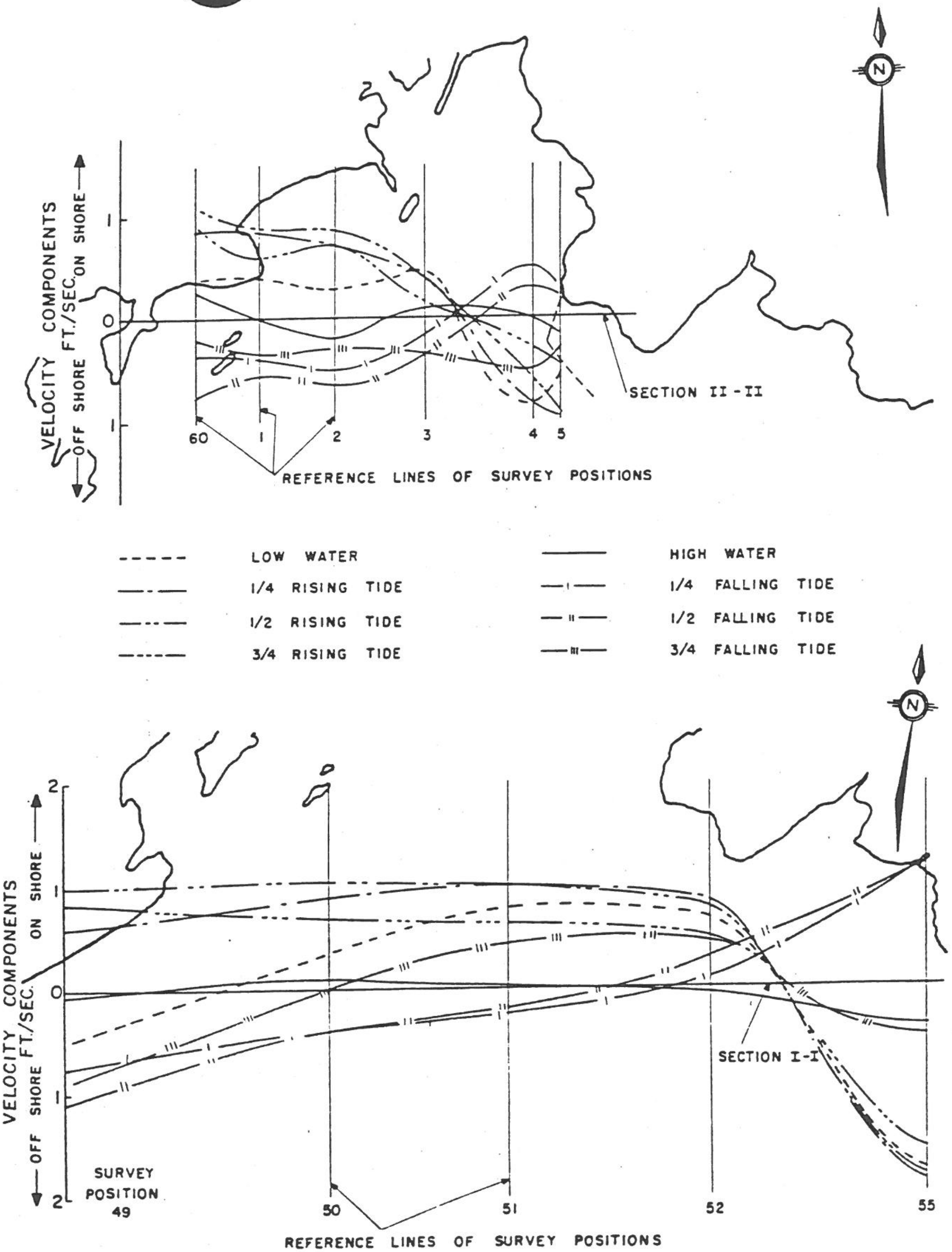


FIGURE 2-4
ON AND OFF SHORE COMPONENTS OF MEAN VELOCITIES IN SECTIONS I-I AND II-II OVER A TIDE PERIOD

SOURCE: NEU, 1960.

The average (over many tidal cycles) St. John River current is expected to turn south outside Partridge Island due to Coriolis acceleration and stay outside Manawagonish Island. This motion should produce a northerly return eddy between the island and the mainland.

There has been no discussion of wind-driven circulation in the Outer Bay in any of the documentation reviewed. However, short-term wind conditions can produce bottom currents that also result in shifts of sediment distribution.

2.1.3 Exchange Between Outer Bay and Harbour Bay

The boundary between the Outer Bay and the Harbour Bay is shown in Figure 2-1. The Harbour Bay boundary is one of the more significant boundaries in the overall system.

Overall tidal exchange across the Harbour Bay boundary is calculated to be approximately 3550 CMS and is almost the same as the mean monthly flows of the St. John River in the spring. Filling of the overall exchange in the spring is therefore mostly due to the St. John River and in other months more due to filling from the Outer Bay. As previously indicated, the overall exchange does not all represent "new" water for flushing and dilution, and a large portion of it would be the plume of the St. John River being pushed back into Harbour Bay on rising tide.

Flushing and sediment transport is related to the "net non-tidal" exchange across the boundary rather than the overall tidal exchange. Hachey (1939) determined that salinities near the Harbour Bay boundary were stratified and presented relationships for the surface and bottom salinities as a function of the St. John River flow. These relationships suggest that a two-layered circulation model can be used to estimate the net non-tidal exchange across the Harbour Bay boundary.

The developed relationships have been used to compute the mean monthly upper and lower transport at the Harbour Bay boundary. The results are given in Table 2-1.

TABLE 2-1
Estimates of Two Layered Flows Into and Out of Saint John Harbour*

Month	Mean Monthly St. John River Flow in Cubic Metres Per Second (CMS)	Outward Surface Layer Flow (Dilution Flow), Rounded to Nearest CMS	Positive Inward Bottom Layer Flow, Rounded to Nearest CMS
January	585	2382	1797
February	620	2441	1821
March	875	2718	1843
April	3271	486	-2784
May	3059	824	-2234
June	1034	2786	1752
July	584	2380	1796
August	557	2330	1773
September	534	2285	1751
October	846	2698	1852
November	1010	2780	1770
December	936	2752	1816

*Results are based on salinities as a function of flow given in Hachey (1939).

The results in Table 2-1 show that the baroclinic density exchange at the Harbour Bay boundary in most months has a bottom inflow and a surface outflow where the bottom inflow is two to four times the river flow and the surface outflow is three to five times the river flow. In the high River flow months of April and May, the flow in both layers is outward and equal to the River flow. During these months, there is little salt intrusion across the boundary. Significant storm events may alter the relationships shown in Table 2-1; however, the values given here could be considered as "normal" or "average" conditions.

2.1.4 Circulation and Flushing Within Harbour Bay

The Harbour Bay area (as defined by Neu (1960a)) is also shown on Figure 2-2. It incorporates the City Harbour, Courtenay Bay, and their channels. The baroclinic bottom flow entering across the Harbour Bay boundary, given in Table 2-1, diminishes as it moves up the Harbour and the net flushing subsequently decreases towards the head of the Harbour. At the Reversing Falls, a portion of the higher salinity bottom water is carried over the falls on rising and high tide to become bottom water in the Saint John Estuary. The Harbour Bay area has a volume of approximately 75 million m^3, resulting in a short flushing time for the given flows.

2.1.4.1 City Harbour

The City Harbour is quite narrow and has large net non-tidal velocities for the two layered flow taking place within it. It is expected that conditions are varying from week to week between net deposition and resuspension of sediments within the City Harbour depending on the St. John River flow.

Hachey (1939) shows that waterbodies are stratified in the City Harbour in the area above Navy Island, and that salinities are higher along the southerly shore than along the northerly shore at the same depth. This could be due to the Coriolis acceleration of the surface outflow, but possibly is due to there being more freshwater runoff from one shoreline than another.

2.1.4.2 Courtenay Bay

There is limited freshwater inflow in Courtenay Bay channel. However, baroclinic inflow is estimated to be four or five times the freshwater inflow rate and would move sediment up the channel. McGrath (1983) reports that the generating station on Courtenay Bay recirculates approximately 4.4 m^3/s at 10°C rise. Its pumping from deeper waters and its discharge of less dense water back to the surface will increase the baroclinic flow into Courtenay Bay at a long-term steady rate.

2.1.5 Circulation and Flushing Above Reversing Falls

The study area extends from Reversing Falls about 6 km up the Saint John estuary to Cedar Point and includes South Bay (see Figures 1-1 and 2-1). The circulation in this area is governed by the exchange across Reversing Falls.

The flows through Reversing Falls are adequately described by Neu (1960a). In summary, the Reversing Falls is both a ledge and narrow constricted channel. The channel constriction can result in a drop in water surface from the Harbour end of about 6 m at high tide. This constriction limits the amount of tidal flow up river. During the spring, the St. John River flow can be high enough that the flow does not reverse at Reversing Falls.

High density water from the Harbour flows into the basin above Reversing Falls and sinks to the bottom. It mixes with the river outflow on falling tide to return as brackish water to the Harbour. Stratification develops within the basin between Reversing Falls and the Kennebecasis Sill. Internal seiching develops at the interface in response to the surface tides (Thomas, 1983).

2.2 Sedimentology

The estuary which includes Saint John Harbour is unusual. In terms of the very large tidal range and the comparatively large river discharge, it would be classified as well mixed. However, because of its peculiar configuration it is not well mixed, but only partially mixed below the Reversing Falls and substantially unmixed above the Falls. To understand this behaviour it is necessary to consider the two segments below and above the Reversing Falls separately. Below the Falls the large tidal range and generally high river discharge are confined within a very small volume. This creates unusually intense density gradients and local mixing, but because of the small volume of the lower harbour the process does not proceed very far. This has two consequences.

- Well defined salinity gradients extend well beyond the inner City Harbour, throughout the Outer Bay (Neu 1960a), and can be traced for a considerable distance in the nearshore waters of Fundy, beyond the Saint John Harbour.
- During each high tide (except at freshet) a large but discrete slug of brackish to saline water pours over the sill of the Reversing Falls. The area above the Reversing Falls acts as an almost independent waterbody with a considerably smaller tide, a large volume, deep water and a relatively large fresh water input.

The salinity gradients are likely to be largest near the Harbour Bay boundary. A major process that takes place at the salinity interface is sediment flocculation and heavy metals uptake on sediment due to electrochemical processes and sedimentation. What appears to be happening to sediment and other constituents transported with the St. John River flow over an annual cycle is that they are carried out beyond the Harbour Bay boundary with the high St. John River flows in April and May and deposited as the flow spreads and slows over Outer Bay near the Harbour mouth. Sediment is returned (at least partially) to the Harbour with the baroclinic flows shown in Table 2-1 during the remaining months.

Thus, the estuary above the Reversing Falls can be classified as unmixed, as shown by the results of Thomas (1983). The estuary below the Reversing Falls has very high flushing capacity and is usually saturated with dissolved oxygen. In the narrower City Harbour the channel is generally swept clear of loose sediment, even though there may always be a significant concentration of suspended sediment in the water column.

2.2.1 Sediment Distribution

A general sediment distribution for the whole Bay of Fundy is given by Loring (1979). Sediment sampling and textural analysis were carried out at 60 locations in Saint John Harbour and the Outer Bay by Neu (1960a). Sampling was also done at 145 sites to obtain data and is variously reported in Bezanson and Kranck (1981), Ray (1983), and Ray and

McKnight (1984). These investigations extended varying distances above the Reversing Falls into Grand Bay. Metcalfe et al. (1976) mapped bottom sediments throughout the upper St. John River estuary, above the Reversing Falls. In addition, particle size distributions were determined from several pre-dredging investigations along the Courtenay Bay channel for Public Works / Transport Canada, most recently those of ADI Limited (1986), Seatech Investigation Services Ltd. (1989) and Land & Sea Environmental Consultants Ltd. (1991).

The sediment distribution data from Bezanson and Kranck (1981), are reproduced as Figures 2-5 and 2-6. Figure 2-5, provides the best overall view of sediments over most of the study area. Figure 2-7 provides bathymetric information for comparison purposes.

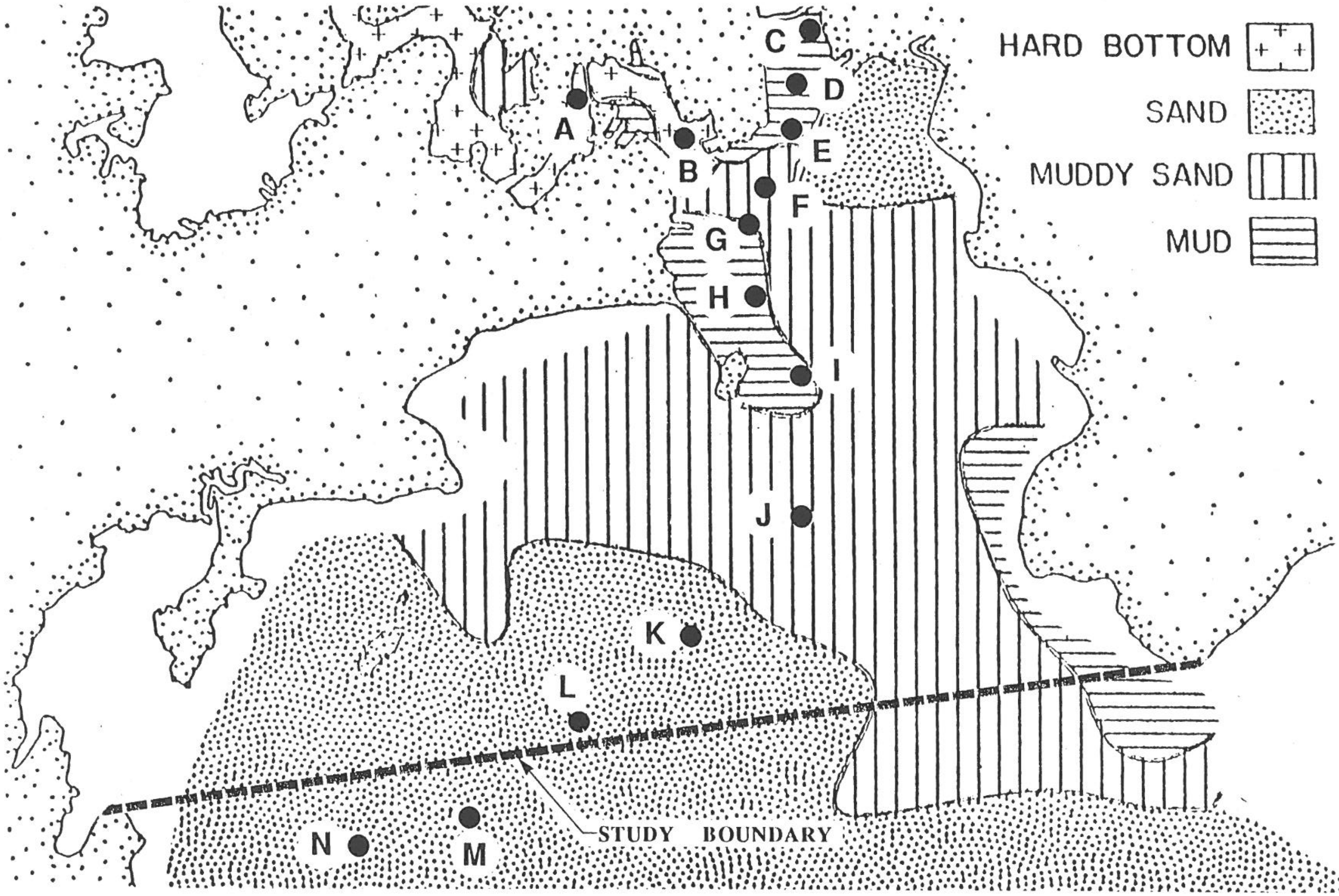
2.2.1.1 Above Reversing Falls to the Mouth of City Harbour

From above the Reversing Falls down to near the mouth of the narrow City Harbour channel, the bed is generally swept clear of loose sediment by the swift currents which, due to the very large tides, are usually many times greater than the net discharge of the River.

It is expected that circulation is limited in the deeper more saline portions of the basin and that this region could act as a sediment trap which is scoured during the spring freshet. As found by Neu (1960a) and demonstrated by the Port dredging records, a substantial amount of suspended sediment is circulated in the lower part of the water column, and is deposited anywhere that there is a sheltered indentation along the shoreline or a berth dredged below the natural equilibrium depth at the side of the channel. Also, according to Neu, there is a net transport of sediment upstream over the Reversing Falls into the Grand Bay area.

2.2.1.2 Harbour Bay

The Harbour Bay is subdivided into two areas. These are the City Harbour area including Courtenay Bay, and the Harbour Bay east of the breakwater.



SOURCE: BEZANSON & KRANCK, 1981.

FIGURE 2-5
SEDIMENT DISTRIBUTION

WASHBURN & GILLIS ASSOCIATES LTD.

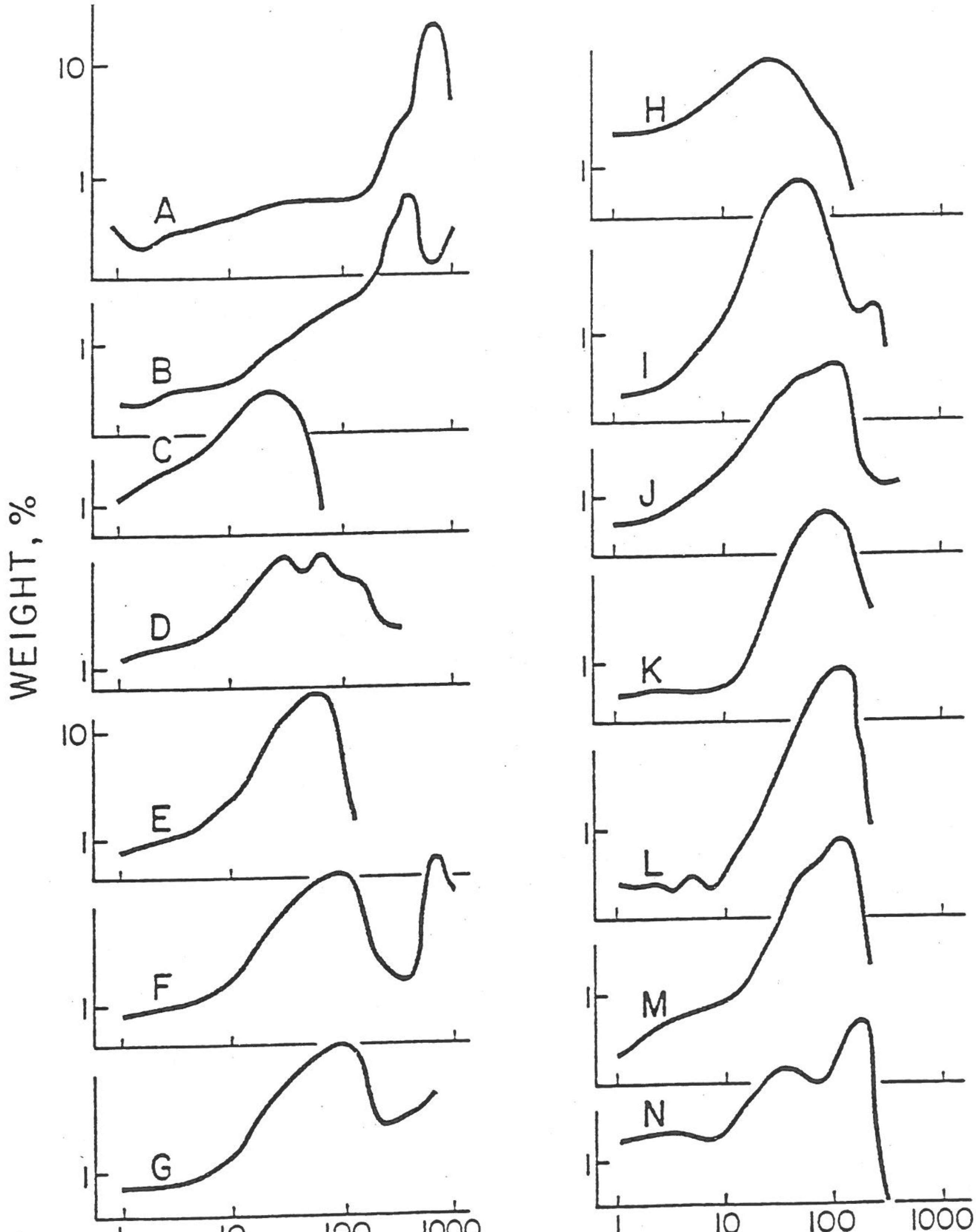
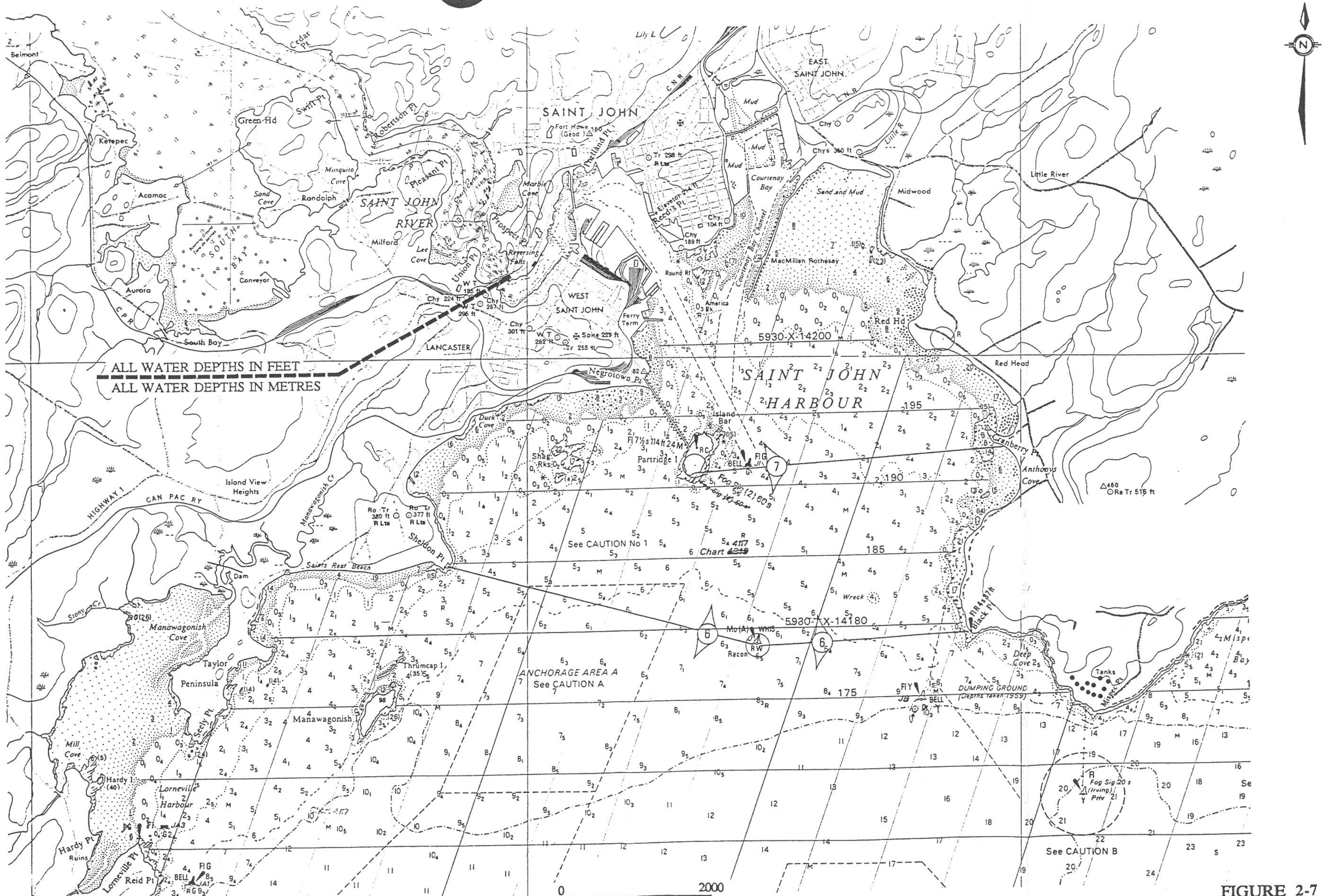


FIGURE 2-6
SEDIMENT GRAIN SIZE DISTRIBUTION

SOURCE: BEZANSON & KRANCK, 1981.



SOURCE: CANADIAN HYDROGRAPHIC SERVICE, CHART # 4117 & # 4141

FIGURE 2-7
STUDY AREA BATHYMETRY

Lower City Harbour Area and Courtenay Bay

These areas are partially sheltered by the Partridge Island and Courtenay Bay breakwaters, respectively and are the shallowest areas of Saint John Harbour. The bottom sediments consist of fine grained soft mud over most of the area. Two channels have been dredged for navigational purposes. The main channel generally follows the thalweg of the natural channel to the City Harbour. The Courtenay Bay channel and turning basin are wholly artificial. The upper part of Courtenay Bay channel is sheltered by the Courtenay Bay breakwater, while the main channel is protected from southwesterly seas by the Partridge Island breakwater.

Neu (1960b) found that the salinity gradients and mixing are most intense in this area and that almost stationary internal standing waves are formed on both rising and falling tides under most combinations of tide and river discharge. Also near-bottom currents are usually directed upstream during both rising and falling tides. Since relatively high concentrations of suspended sediment are present, siltation of the dredged channels occurs.

W.F. Baird et al., (1987) have documented the perennial buildup of sediment in the Courtenay Bay channel. The explanations given are qualitative descriptions based on maximum tidal velocities similar to those given by Blair (1959). Schubel (1968), however, has shown by direct measurement that sediment is suspended during maximum tidal velocities and settles during minimum velocities and that there is little horizontal transport of sediment due to tidal velocities. Rather, the transport of sediment is more related to the long term net non-tidal flows in the particular portion of the waterbody being examined.

The baroclinic bottom inflows into Courtenay Bay will result in an upwelling at the head of the bay and may be a source of sediment buildup in the headwater regions shown in Figure 2-5.

Harbour Bay East of Breakwater

The Harbour Bay (Neu, 1960a), to the east of the Courtenay Bay breakwater, is a very shallow area which is partially uncovered at low tide and has a sand bottom. It is presumably sandy because it lies outside the main salt/fresh water exchange area and because it is subject to high energy due to wave action which prevents the deposition of fine grained material.

2.2.1.3 Outer Bay

Beyond the areas discussed above, the bottom of the Outer Bay consists mainly of muddy sand, except close to shore where wave energy intensity generally prevents fine grained sediment deposition. The other exception is close to the east shore of the Outer Bay offshore from the coast between Anthony Cove, Black Point and Mispec Point where there is an area of mud. This area includes the Black Point dredge spoil disposal area, which is expected to be partially responsible for the presence of mud.

The sediment distribution (Figure 2-5) shows the outermost areas of the Outer Bay generally beyond the 10 m depth contour composed of sand sized particles. Energies in these areas are relatively high due mainly to the stronger currents of the Bay of Fundy, (Canadian Hydrographic Service, 1981).

2.2.1.4 Bay of Fundy

Figure 2-8 shows the larger scale sediment distribution for the whole Bay of Fundy. There is some local discrepancy with Loring's interpretation of the sediment distribution in the vicinity of the Saint John Harbour Outer Bay. This is probably due to the much more widely spaced sampling points used. However this does not detract from the broader picture, which shows a wide area of relatively finer grained sediment extending from Saint John Harbour south west towards Passamaquoddy Bay.

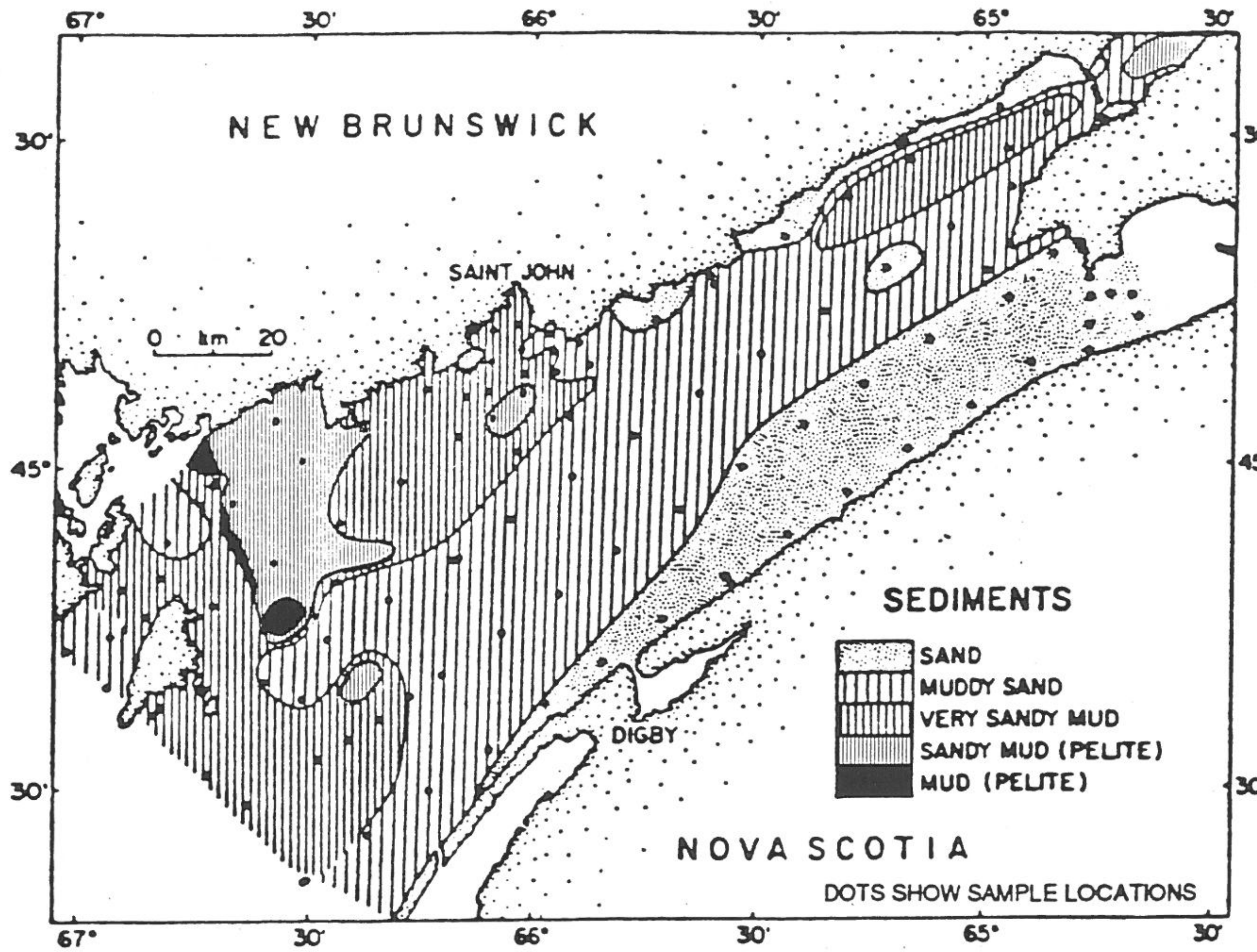


FIGURE 2-8
SEDIMENT DISTRIBUTION OF MATERIAL
<2mm IN THE BAY OF FUNDY, NOMENCLATURE
OF LORING AND NOTA, 1973

SOURCE: LORING, 1979.

2.2.2 Sedimentation and Erosion Processes

Neu (1960a) provided suspended sediment profiles at more than sixty stations in the Harbour and Outer Bay, along with velocity, salinity and density profiles for a representative range of tidal and river discharge conditions. These data have been applied in several detailed studies to examine specific issues such as the stability of the dredge spoil disposal area at Black Point (Bezanson, 1983).

There has never been a comprehensive analysis of these data to quantify the overall sedimentation and erosion processes in the estuary. On the other hand, the dredged channels and berths have been observed for nearly a century, and fairly complete dredging records have been assembled (W.F. Baird et al., 1987) for nearly half of that time. These records and the accompanying surveys and investigations, therefore, provide the only detailed data available on estuarine sedimentation processes.

2.2.2.1 Sedimentation and Dredging

The dredging records assembled by W.F. Baird et al., (1987) and Saint John Port Corporation (SJPC, 1991) indicate that average annual maintenance dredging volumes for navigation purposes amount to about 556,000 m^3 (in-place measure). This amount consists of 440,000 m^3 in Courtenay Bay, 46,000 m^3 in the Saint John Harbour Main Channel, and 70,000 m^3 for the "Inner Main Saint John Harbour" (the City Harbour area). The latter figure comprises dredgings at some eighteen berths, terminals and approaches under the administration of the SJPC.

In its natural state, the bed of Saint John Harbour would tend to develop a dynamic-equilibrium form in response to the pattern of shear stresses exerted by the river and tidal currents. Under these conditions over time, substantially equal amounts of sediment would be deposited and removed as conditions varied. Although there might well be slow long-term trends, there would be no major areas of rapid accretion, such as are now experienced in the dredged channel in Courtenay Bay, and (to a lesser extent) in the main navigation channel (W.F. Baird et al., 1987).

The following principles apply to describing sedimentation and erosion in the study area. Generally speaking, where water depths have been increased by dredging, or where indentations of the shoreline or sheltered areas have been created by construction, rapid sediment deposition will occur, or if already naturally occurring, will be accelerated. An increase in flow width or depth will cause flow deceleration and induce siltation and depth reduction. Conversely, if the sediment-bearing flow can be smoothly constricted, to increase the velocity, then sedimentation may be reduced, or, under suitable conditions, channel deepening by bottom scouring may be induced.

The foregoing principles can be applied to the main channel and Courtenay Bay channel to explain the difference in sedimentation and maintenance dredging rates between the two areas. The main channel appears to closely follow the alignment of the natural channel, which tends to concentrate the flow. The Partridge Island breakwater which is parallel to the dominant flow also helps guide and concentrate the flow. The dredged depth of 9.1 m below datum requires a dredged cut 3 m deep at the maximum, and averaging less than 2 m below the natural dynamic equilibrium depth. The foregoing factors combine to moderate the extent of siltation and maintenance dredging in the main channel.

The Courtenay Bay channel, though only dredged to 6.1 m depth, is angled obliquely to the flow at its lower end where it is cut through the shallow sand flats area. It is dredged to a depth of 5 - 6 m below the equilibrium depth. These factors both encourage more rapid siltation in the outer Courtenay Bay channel.

The middle and upper parts of the Courtenay Bay channel are contained in the large, coastal indentation created by the Courtenay Bay breakwater, thus forming an efficient settling basin. Also, because Courtenay Bay has a very wide entrance located in the area where salt/fresh water mixing is most dynamic, it is exposed to a very large amount of suspended sediment, much of which is carried into the Bay by the complex three-dimensional current pattern in the adjoining main channel area. Finally, wave energy from the south transports sand from the eastern Harbour Bay around the tip of the

Courtenay Bay breakwater and possibly also projects sand over the top. These factors contribute to the high sedimentation and dredging rate in the middle and upper parts of the Courtenay Bay channel.

From the foregoing it can be estimated that anthropogenic-influenced sedimentation contributes to as much as 555,000 m^3 per year and most of it occurs in Courtenay Bay. However, it is not possible to estimate what "natural" sedimentation rates would exist in these areas should existing port development not be completed. There could also be additional anthropogenic-influenced sedimentation in the undredged portions of Courtenay Bay which could very well be of comparable magnitude.

In order to better understand this sedimentation process it is necessary to identify the source(s) of the sediment as well as the rate of deposition.

2.2.2.2 Sources of Deposited Sediment

W.F. Baird et al., (1987) deduced from published sediment data that the annual suspended sediment load of the St. John River amounts to about 1.1 million m^3 (in-place measure). From this and other sources including Neu (1960a), W.F. Baird et al. (1989) concludes that the river is one potential source of navigation channel sedimentation.

Recirculation of silt from the Black Point dredge spoil disposal site has been investigated as another potential source. Bezanson (1983), Bezanson and Kranck (1981, 1982), Wildish and Thomas (1985), and Science Applications International Corporation (SAIC, 1986) investigated, in various ways, the potential for erosion, resuspension, dispersion, and/or recirculation of sediment from the dredged material disposal area near Black Point back to the dredged channels.

Although Bezanson (1983) found that the area is erosional at half rising tide and half falling tide, sediment tracing indicates a net transport towards the south-east, away from the Harbour. This finding is also consistent with the dominant tendency for a pronounced clockwise circulation throughout the Outer Bay (Neu, 1960a). Therefore, all investigators concluded that the disposal area is not, in a direct sense, a significant source of the sediment which deposits in the dredged channels.

The third potential source for the observed sedimentation is the Bay of Fundy itself. Bezanson (1983), noting the dominant upstream motion of near-bottom sediment in the Harbour mouth, suggests that "it may well constitute the source for the sediment which is deposited constantly in Courtenay Bay."

3.0 HARBOUR USES

The establishment of Harbour environmental objectives will ultimately depend on the potential effect of Harbour water quality on existing and future usage. Land use within the Harbour study area also contributes to the types and quantities of inflow. This section of the report reviews existing land use, identifies Harbour inflows, and Harbour uses for the study area.

The land use setting is described according to the distribution of selected land use categories within the study area. The land use categories have been developed by adapting those used in previous studies (Proctor and Redfern, Bousfield & Bacon, 1968; Fenco Consultants Ltd., 1979) to reflect the potential for certain uses to influence the environmental quality of the Harbour. The terrestrial spatial bounds for the distribution of land uses include the area immediately surrounding the Harbour within the study area boundaries, and the area sufficiently removed from the shoreline to include certain uses with potential to influence the Harbour environmental quality due to location of effluent discharges or local topographic features. The present distribution of land use patterns was delineated on mapping (1:4,800 scale) based on the results of a ground-truthing survey conducted in the study area.

Harbour uses are discussed in terms of the port facilities from a historical perspective and with respect to future development plans. Documents pertaining to the historical development of the Harbour were reviewed and future development concepts were determined from the Harbour Master Plan (Fenco Consultants Ltd., 1979) and through discussions with Saint John Port Corporation authorities.

3.1 Historical Harbour Development

Samuel de Champlain, to whom the credit is given for discovering Saint John, entered the Harbour on St. John the Baptist's Day June 24, 1604. Prior to this, Native groups had been harvesting the fisheries at that location for generations. Several factors account for

European settlement at Saint John. The site was found to provide good anchorage and a natural harbour, as well as an important transportation link to the interior. This factor made Saint John a strategic location as a military post and trade centre. The availability and value of fur, fish, and later timber, were also vitally important and soon recognized by traders such as La Tour, and later by Simonds, Hazen, and White.

During the eighteenth and early nineteenth centuries, the importance of fishing was confirmed by the number of wharves and weirs in the areas of Portland Point and the Straight Shore. During the nineteenth century however, the dollar value of the timber trade surpassed that of the fisheries. Areas formerly occupied by fishing wharves and weirs were transformed into areas for storage and shipment of timber products and shipbuilding. Sawmills and dams appeared to the extent that fishermen complained to city officials about refuse, pollution, and the formation of sawdust and mud shoals (MacKay, 1983). As one of the world's leading shipbuilding centres, and with Britain's requirement for colonial timber as a result of the Napoleonic Wars, the port activities and facilities at Saint John developed further. Construction of rail lines to Saint John in the late nineteenth century also facilitated the development of the port.

By 1900 the Harbour and river, from below the Reversing Falls up to Indiantown, was dotted with wharves and piers. Finger piers on piles, and wharves constructed of rock filled timber cribs lined the Straight Shore and were also found across the river in the area of Riverside Drive and further down river at the Pugsley Terminal area. These facilities primarily catered to the commercial fishery (Phinney, 1983). In the early part of the century Federal funding prompted the development of wharves, warehousing and a dredging program. This coupled with a drop in rail rates resulted in an increase of rail freight to the port.

By 1923 the Courtenay Bay Channel had been created along with a large turning basin. Construction on the drydock was under way, as was construction of the Courtenay Bay breakwater. At this time, Piers 11, 12, 13, and 14 were developed and the configuration of wharves throughout the older section of the Harbour changed (Phinney, 1983).

In 1931 a fire on the west side of the Harbour destroyed much of the dock facilities. Funding from the Federal Government resulted in a modern port being reconstructed. By the end of 1931, Navy Island was no longer an island. Through the use of a coffer dam, work on the Navy Island Complex was soon completed and Piers 1, 2, and 3 were created between 1931-35. New wharves were increasingly of the solid face arch type rather than a pier or cribwork structure. Increased activity and construction along the river resulted in the channel becoming constricted. In East Saint John infilling around the drydock took place, and construction of the Courtenay Bay breakwater had begun. By 1937 both the east and west banks of the St. John River below the falls were entirely developed, eliminating any remaining natural shoreline (Phinney 1983, MacKay 1983).

As a response to wartime requirements Saint John once again became a shipbuilding centre in the 1940's. Other World War II developments included the construction of two berths to handle war munitions and supplies, the Burma Wharf and the Broad Street Wharf in 1945 (Phinney, 1983). Pugsley A and B were completed in 1947, and by 1953 the Pugsley Terminal and Piers 2 and 3 were extended. This construction lead to further constriction of the Harbour.

In 1960 the Courtenay Bay Causeway was built, along with the completion of the Negro Point Breakwater (initiated in 1874-75). Construction on the Partridge Island breakwater was carried out between 1961 and 1965 (Phinney, 1983). Pier 1 was further extended in the late 1960's and the development of Rodney Terminal took place between 1970 and 1975. By the mid-1980's, Lower Cove had been filled, Long Wharf extended, and the Potash Terminal constructed. Each of these projects further constricted the Harbour.

During the 1960's and 1970's cargo volumes continued to increase. Most of this volume is attributed to crude oils, petroleum products, grain and raw sugar. Over this same period non-bulk cargoes were increasingly shipped by container. As a result, vessel turn around times while in port were reduced from weeks to hours. The quantity of petroleum products shipped through Saint John had risen and forest products exports continued to grow.

In the late 1970's a study was conducted to develop an overall Master Plan for the Port of Saint John and included a comprehensive port development plan to 1990 (Fenco Consultants Ltd., 1979). During the period of time since then, several redevelopments and development of new port facilities have been completed. These include the Rodney Container Terminal, Navy Island Forest Products Terminal, the Long Wharf Terminal, the Lower Cove Terminal, and the Barrack Point Potash Terminal with its two sheds shared by Potash Company of America and Potacan Mining Company.

3.2 Current Land Use Patterns

Five land use categories have been used for delineating land uses in the study area. These categories are described below:

Heavy Industry

Heavy industry is generally found grouped in blocks of land and includes pulp and paper mills, oil and sugar refineries, shipbuilding facilities, power generating stations, heavy manufacturing sites, breweries and storage of bulk petroleum products.

Light Industry/Commercial

Light industry-commercial is often found in linear strip commercial developments and highway commercial developments and industrial park settings or bordering the Harbour. Included in light industry-commercial are: quarries, light manufacturing industries, service industries, light industries, assembly plants, warehouses, storage, transport terminals, dock terminals and port facilities, storage garages, commercial establishments with large indoor or outdoor storage (i.e., lumber yards, scrap yards, coal yards, freight and express sheds), concentrations of railway lines, large scale agriculture and forestry operations.

Municipal Sewage Treatment/Waste Disposal

Municipal sewage treatment/waste disposal includes a series of point sources identifiable by sewage lagoons and treatment plants, and municipal sanitary landfill sites and dumps.

Urban

Urban includes houses, apartments, motels, hotels and cottages whether they be on a municipal system or septic tank system. Also retail and service stores, offices, automotive garages, institutional facilities and municipally owned buildings such as rinks, halls, and armouries.

Green Spaces

Green spaces includes parks and open spaces, golf courses, cemeteries, watershed lands, small scale farming or forestry operations, forest, marsh, beaches and other natural areas.

3.2.1 Distribution of Land Uses

The distribution of land uses in the study is described in the section below and is illustrated in Figure 3-1.

Heavy industry within the study area is predominately restricted to the older sections of the city that have traditionally become known as industrial areas. Over the past decades the land use in these areas has not changed from industrial to another category. However, in some cases there have been changes within industries such as upgrading, expansion and improved waste treatment facilities. Major industries on the West Side include Irving Pulp and Paper and the Moosehead and Labatts breweries. Ocean Steel on the Straight Shore Road and the Sugar Refinery and bulk petroleum storage facilities in the south end of the Central Peninsula are other heavy industrial sites.

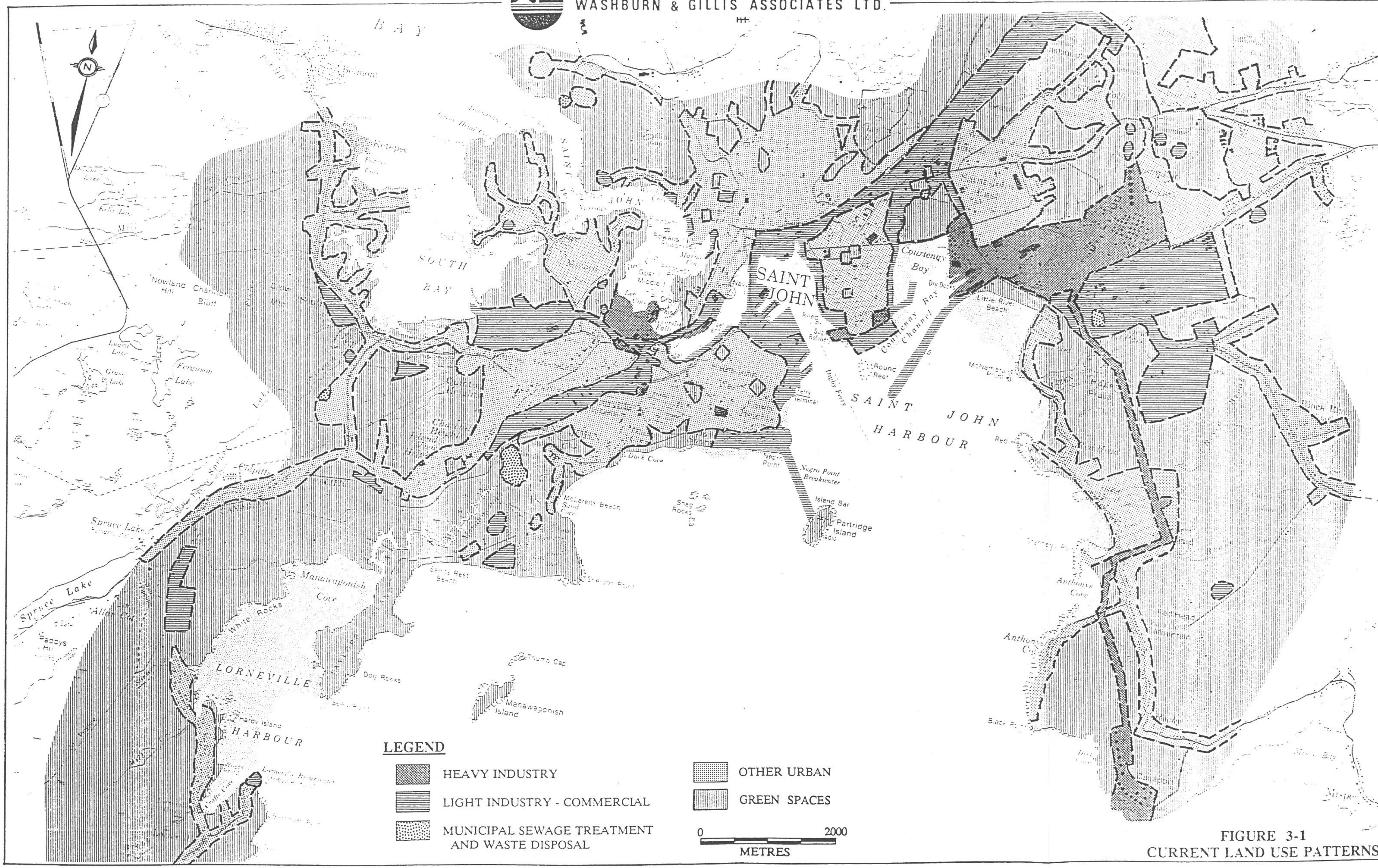


FIGURE 3-1
CURRENT LAND USE PATTERNS

The largest area of industrial complexes is that area extending from the east shore of Courtenay Bay to Little River Beach and inland to the Irving Oil Refinery. Industries in this block include Saint John Shipbuilding Limited, the Irving Oil Refinery, the NB Power Courtenay Bay Generating Station and storage of petroleum products. The Canaport development at Mispec Pt. is the final heavy industrial complex.

The light industry-commercial category contains a broader range of land uses than heavy industry, and is found throughout the study area. Light industry-commercial areas can be further sub-divided into several components.

Light industry-commercial land uses relating to port activities are concentrated along the water front of the West Side and the Central Peninsula, as well as the Bay Shore and the potash terminal areas.

Strip and highway commercial developments are found along transportation routes leading into the western and eastern core sections of the city. Typically this land use is recognized as a combination of concentrated commercial establishments, storage lots, and light industry. These include the Golden Mile, Rothesay Avenue, Russell Street-Bay Side Drive area, Haymarket Square through to the Harbour Bridge, and the Straight Shore Road.

Industrial parks include Spruce Lake Industrial Park, McAllister Industrial Park, and Grandview Industrial Park. Other light industry-commercial areas are found around the commercial development at South Bay and the Canadian Pacific depot on the Dever Road between Greendale and Milford. Quarries and scrapyards are found scattered over the study area.

Municipal sewage treatment and waste disposal sites form the smallest land use category within the study area and are located at the Spruce Lake landfill site, and sewage treatment facilities at Manawagonish Road, Cedar Point, the head of Courtenay Bay, Grandview Industrial Park and off the Gault Road. Additional sites that were formerly, or are still, used by Saint John exist just outside the study area.

Urban land use areas are situated throughout the study area. The most densely packed urban areas occur in the older sections of the city, and the least densely settled areas occur along outlying roads and highways leading into the city.

The central area of the West Side exhibits a relatively dense residential community with an assortment of businesses throughout. This block extends to the MacLaren's Beach area thinning out in the eastern areas. The area around the community of Lorneville and along the Route 810 to Seaview is classified as urban and is relatively sparsely populated.

A large block consisting of sections of the former City of Lancaster and subdivisions constructed as much as 30 years ago extends through Fairvale, Greendale, Purdy's Corner west past Quinton and Islandview Heights as far as the new housing along the Gault Road. This block is pinched off from the urban land use at Milford by the CP depot, a sparse strip of wooded area, and the industrial complex near Simms Corner/Reversing Falls.

Another dense area of urban land use is found in the older part of the city on the Central Peninsula. Situated on upland areas back from the Harbour shore, it extends north to Hay Market Square. Urban land use areas are also found in the North End from Hay Market Square to the northern boundary of the study area including the area from Indiantown to Lily Lake.

On the east side of Courtenay Bay urban land uses are found in East Saint John, Westmorland Heights, Silver Falls, Forest Hills and Champlain Heights. The remaining urban areas are found along the highways leading into the central parts of the city. Some of these areas have substantial development.

The remainder of the study area has been classified as green spaces, which in total area, is the largest category.

3.3 Current Port Facilities

A description of the current port facilities has been prepared from information presented in literature produced by the Saint John Port Corporation (undated).

The Navy Island Terminal is a forest product handling facility with features including Piers 1, 2 and 3 with a combined berthage of 1,000 m, and 37,000 m^2 of shedded space. An additional 5 hectares of open area with wide aprons provide open storage space. Cargo handling is maintained through the use of two roll-on roll-off (ro-ro) notches for quarter ramp vessels and two ro-ro notches for axial ramp vessels.

The Rodney Container Terminal has three Portioner container cranes with the capability of 30 lifts per hour per crane. The berth margin exceeds 600 m in length and handles vessels up to the Panamax size. The facility also has a 294 m slip berth.

Long Wharf Terminal facilities include 15,600 m^2 of heated shed, a salt storage shed with a capacity of 26,000 tonnes, and six hectares of open area. Long Wharf handles salt, general cargo including knocked down automobiles and heavy lifts.

Lower Cove Terminal is an 18 hectare common user open area terminal with 245 m of marginal berth and a notch for quarter ramp vessels. Vessels loading cargo from the adjacent Pugsley Terminal also use the open area.

Pugsley Terminal exports forest products as well as importing and exporting general cargo. This facility has 520 m of marginal berth, 18,000 m^2 of shedded space, and a half hectare of open space is also available for port use.

Pier 12 is a general cargo common user facility. Pier 13 was a general cargo common user facility with a heated shed. Pier 14 was a two-hectare open area used for general cargo such as lumber. This facility is connected to the nearby petroleum bulk storage tanks and Crosby Molasses bulk storage tanks by manifolds.

The Broad Street Wharf was built as a temporary structure during World War II. This facility has a 200 m marginal berth used by small tankers discharging petroleum products.

Private facilities at the port include Irving's four tanker berths at Courtenay Bay, and Canaport in the outer Harbour area at Mispec, all of which serve the oil refinery. Also located in Courtenay Bay is the Irving Paper ro-ro barge loading facility.

Saint John Shipbuilding Ltd. on Courtenay Bay has the largest graving dock in Canada. The shipyard has wide experience in all types of marine structures including drilling rigs and icebreakers. The yard is currently working on the Canadian Patrol Frigate Program.

Other current port facilities include the Lantic Sugar berth on the inner Harbour, and Marine Atlantic's ro-ro ferry terminal. The port is also home to a Canadian Coast Guard Base which provides navigational aid service in the Bay of Fundy and the Bay of Fundy Traffic Control Centre.

3.3.1 Future Development of the Harbour

Development of the Harbour has largely been consistent with that proposed in the Master Plan of 1979. The Master Plan is still considered to be valid and future developments are also anticipated to be consistent with concepts in that plan. The Saint John Ports Corporation considers potential development projects to have the same relative priority as indicated in the Master Plan. However, there is no firm schedule in place to establish the time frame within which outstanding projects will be undertaken (E. Vye, Saint John Ports Corporation, personal communication, 1992). It is likely that additional projects will be undertaken as current needs and funding dictate.

For a detailed review of projects considered relevant to the future development of the Harbour, the reader is referred to the Port of Saint John Master Plan (Fenco Consultants Ltd., 1979). The remainder of this section contains a discussion of the future trends in Harbour use and planning as outlined in the Master Plan.

In 1979, the future of the Port at Saint John was associated with providing the link or being an intermediary between sea transportation and land shipment of a range of goods. Receiving, storage and dispersal of petroleum products were to be major components in the development scheme. To fulfil the goal of continued growth at the port, several objectives had to be fulfilled. These objectives were developed after a review of emerging trends in port planning.

Examination of those trends indicated that greater efficiency would be realized through the integration of sea and road transportation networks and systems as one total system, rather than two separate industries. At the time of the Master Plan it was predicted that there would be increased container traffic, and therefore, the appropriate changes at the port would be required to handle the changing trend to containerization.

It was anticipated that the use of roll-on roll-off (ro-ro), lift-on lift-off (lo-lo) and combo vessels, would increase as shipping lines looked for ways to reduce operating costs. Other cost reduction measures would include using ports where loading, handling and ship turn around times were kept to a minimum. Similarly, improved or more efficient methods of storage, retrieval and handling of cargo and a more efficient lay out of wharves to reduce port tie-up time was desirable. Marginal rather than finger wharves were preferred as they allow loop layouts for ground traffic, and provide more manoeuvrability for ships. Marginal wharves are also more adaptable than finger wharves to future needs with respect to ships, cargo, and ground transportation.

It was foreseen that these emerging trends would eventually become requirements if the Port of Saint John was to remain competitive. This would necessitate alterations to the existing port facilities.

As a result of these and other findings the direction of future developments at the Port of Saint John were presented in the 1979 Master Plan. Although all the suggestions of the Master Plan have not been implemented, it is anticipated that the recommendations will have a shelf life into the foreseeable future.

The generalized concept of recommendations detailed in the Master Plan involved the reorganization and improvement of existing facilities, the expansion of the West Side port area, and the construction of new terminals. Major projects suggested in the Master Plan include the development of the Courtenay Bay bulk terminal, the staged expansion of Rodney Terminal, provision of ro-ro facilities, land reclamation at Long Wharf, reconstruction of Berths 13 and 14, acquisition of the Blue Rocks area with construction of outer port roads on the West Side, construction of three new berths south of the ferry terminal, construction of a breakwater extension at Partridge Island and construction of a groin south of Lantic Sugar.

The separation of the inner and outer Harbour into areas designated as normal-draft and deep-draft facilities is seen as a vital step. The inner Harbour facilities (Rodney Terminal, Navy Island Terminal, Berths 2 & 3, 10, 11, 12, 13 & 14, Long Wharf, Pugsley Terminal, Broad Street Wharf) were to be used as a shallow water or normal-draft facility with depths up to 12 m. The normal-draft facility would handle general cargo as well as some bulk cargo. The outer Harbour (Mispec, Bay Shore, Lorneville, Musquash, Red Head) was to be developed into several deep-draft facilities for bulk cargoes. Some bulk cargo loads would be transferred to smaller vessels and shipped to more restricted ports. Normal-draft facilities within the inner Harbour were to be developed to the full potential before development of that type of facility occurred outside the Harbour. Inside the Harbour, facilities would be designated for handling specific types of cargo such as break-bulk, liquid and dry bulk or containers.

The replacement and/or modernization of existing facilities, and efforts to increase the efficiency of existing facilities had priority to be carried out first. Only after this step has been completed were new facilities to be considered.

Because of the importance of the port municipally and nationally, adequate lands were to be made available for port related activities such as operations, communications, railway marshalling, parking and port services. This will be completed in part by defining the upland extent of the port to prevent conflicts between port and urban interests.

Provision of an efficient and updated road service to the port for the efficient transport of goods to and from the port area is also seen as part of the integrated system.

Conceptual plans for outer harbour areas are anticipated as playing a key role in future development plans. The Lorneville harbour and peninsula has been identified as the possible site of a coal unloading terminal in part because of its deep water and good navigational approaches. Other favourable qualities in the area include approximately 3,240 ha of provincially owned land, potential rail access, ample supplies of power and water, vast potential for major marine-related developments and excellent highway connections. Other deep water marine facilities considered for the Lorneville area include a regasification plant, and possibly oil trans-shipment terminal.

The Red Head area including the shoreline from Courtenay Bay to beyond Redhead was recognized as having considerable potential for industrial marine-related land creation.

Furthermore, the area is close to industrial zones and is serviced by rail and road corridors. However, the area is exposed to southwest winds and would require substantial breakwater protection.

The Bay Shore area was identified as having potential for long-term development west of the Partridge Island breakwater. This project would require substantial breakwater protection and dredging for conventional port use. Backup land would be available through landfilling.

The proposed development at Partridge Island included an extension of the existing breakwater towards the channel. This would provide protection for other facilities such as the Marine Atlantic ferry operation and Harbour traffic. As well, a series of berths between the ferry terminal and Partridge Island were proposed.

3.4 Harbour Fisheries

The fishery in the study area is supported by two different ecosystems: estuarial and oceanic. Commercial fish species have been exploited and reported in Saint John Harbour since early settlement by La Tour in the 1630's. Landing statistics dating to 1875 have been reviewed and compiled by Dadswell (1983) for statistical districts 48, 49, 55, 56, and 57 (Saint John Harbour and estuary). As well, a general overview of the historical changes of the fisheries in Saint John Harbour has been described by MacKay (1983).

Commercial landing statistics dating from 1977 to 1991 have been obtained from the Department of Fisheries and Oceans (DFO). The study area falls within DFO statistical districts 48 and 49 (see Figure 3-2). However, since these districts cover a larger seaward area than our study boundaries, only the inshore fishery data for these districts were considered. Landing statistics for the inshore fishery (district 48 and 49) are summarized in Table 3-1 and illustrated in Figure 3-3.

Current fishing activities in the study area were determined from responses to a questionnaire (including map of the study area) distributed to the members of the Saint John Harbour Commercial Fishermen Association during the spring of 1992. A total of 60 questionnaires were sent, and of these, approximately 40% were returned.

A description of the fishery for groundfish, pelagic and estuarial fish, and shellfish is presented in the following sections. Both historical and current trends are described as well as current distribution of fishing activity.

3.4.1 Groundfish Fishery

This fishery includes the gadoid or cod species (Atlantic cod, pollack, hake, tomcod, and haddock) the flatfish or flounder (witch, plaice, halibut, yellowtail, windowpane, smooth flounder, and winter flounder), the wolffish or catfish (*Anarhichas* sp.) and redfish (*Sebastes* sp.).

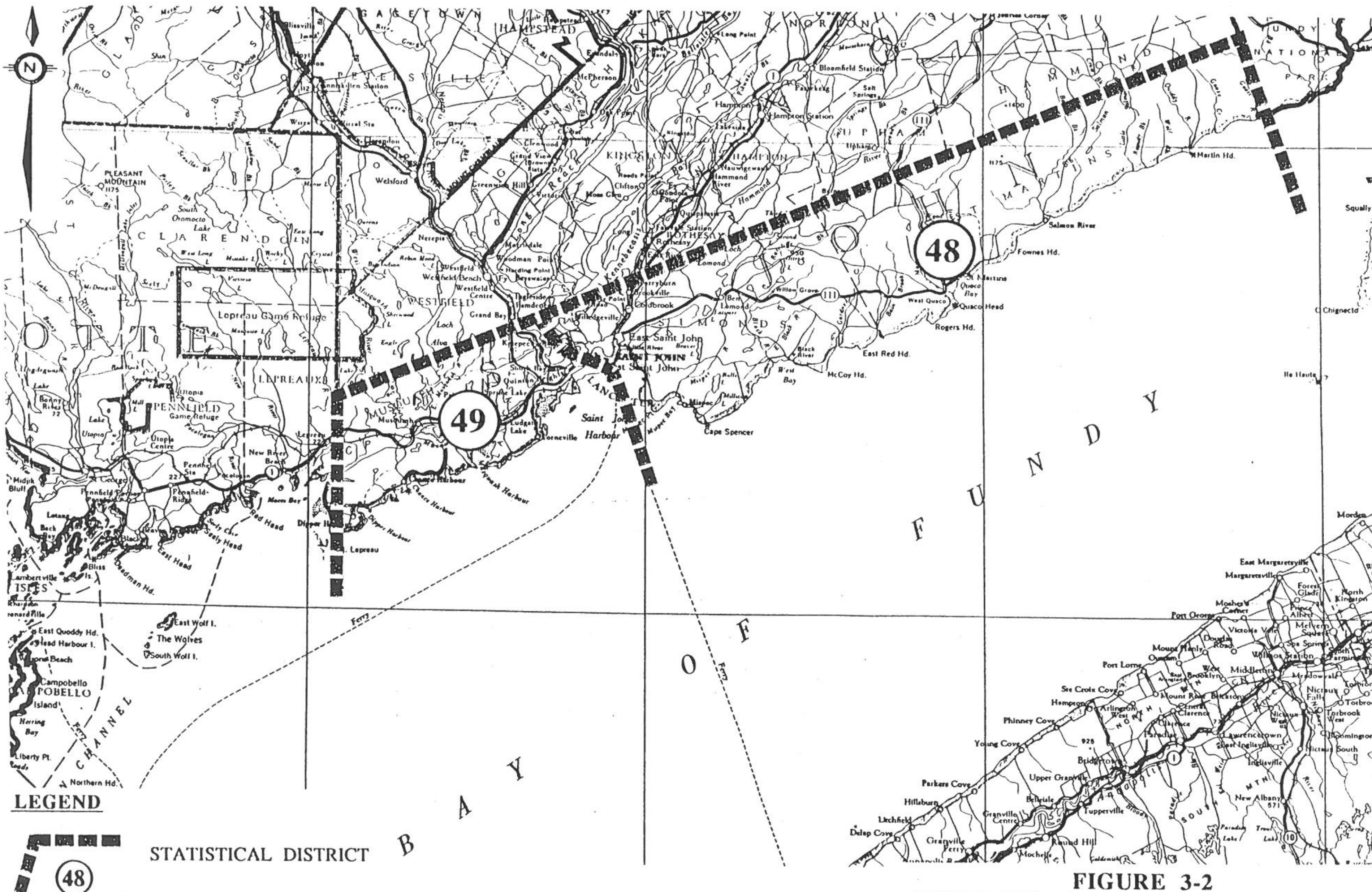
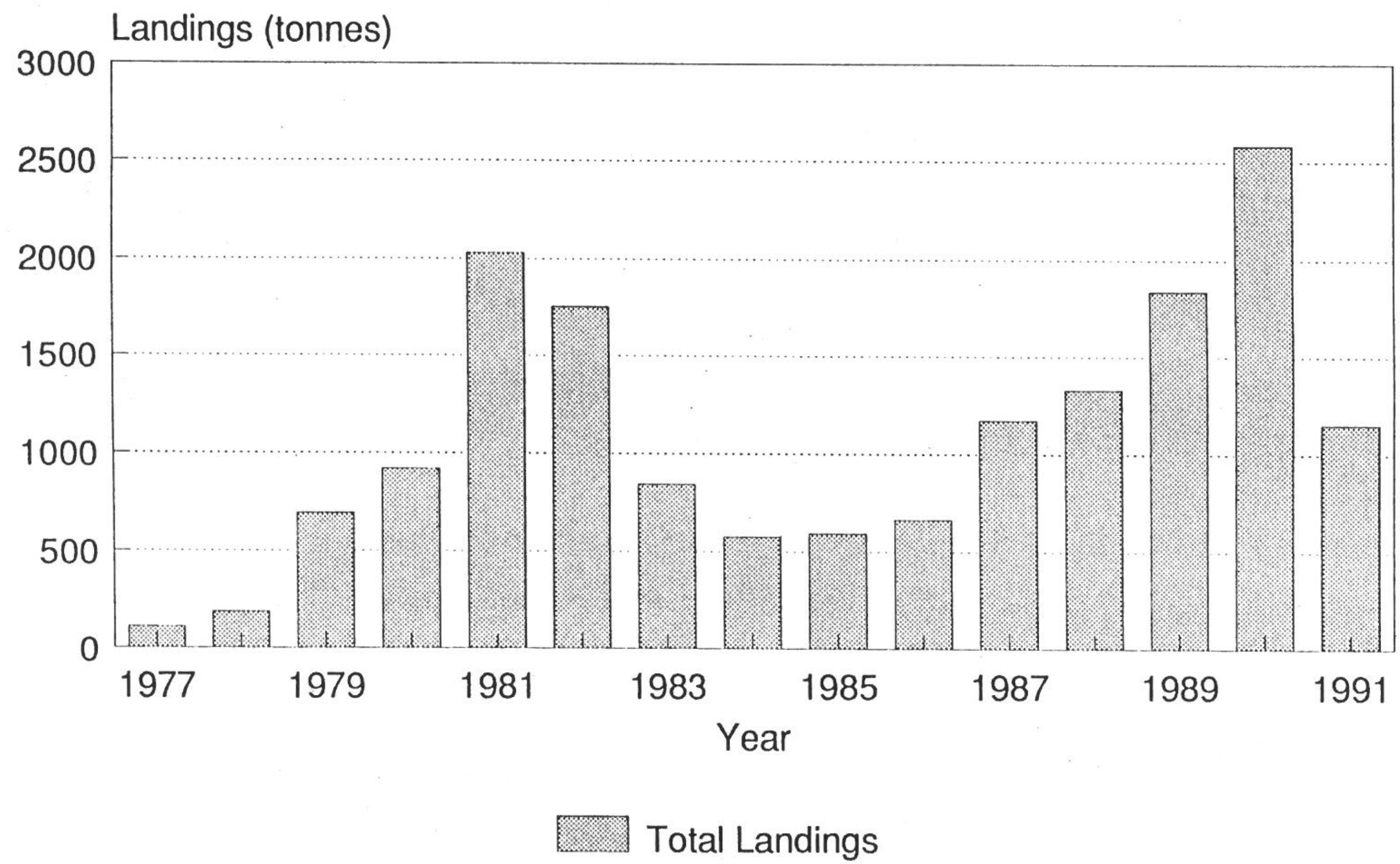


FIGURE 3-2
FISHERIES STATISTICAL DISTRICTS IN THE STUDY AREA

TABLE 3-1: Landing Statistics for the Inshore Saint John Harbour Fishery, District 48 and 49 (tonnes)

Years	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Groundfish															
- Cod	7	52		199	402	433	341	116	113	109	274	153	74	93	104
- Halibut		1		1	2	3	4	1		1	1	6		1	1
- Hake				3	3	3	1			1	1		2		
- Haddock						4	2					5	1		
- Pollock				1						3	1	3			4
- Plaice							1				1	9	2	2	
- Flounder (winter)						3	3					5		1	2
- Unspecified Flounder														2	4
- Unspecified Groundfish											1				
- Yellowtail Flounder															
- Grey Sole														1	1
SUBTOTAL	7	53		204	407	446	352	117	113	114	279	181	79	100	116
Pelagic and Estuarial															
- Shad	45	14		44	5	8	6	8	4	27	16	118	100	66	2
- Alewife	31	58		597	104	58	79	111	46	122	289	311	375	850	83
- Eel			47	8	4				6	5	2	65		8	15
- Sturgeon									9	2		10		2	
- Mackerel										5	6	12	2		
- Shark, Mackerel, Mako									1	1	1				2
- Herring		26	524				176	6	14		1	26			
- Smelt					1365	1064				9	5	16	1		
- Salmon		1		2	35	17	15								
- Stripped bass												1			
SUBTOTAL	76	99	571	651	1513	1147	276	125	80	171	320	559	478	926	102
Shellfish															
- Lobster	28	35	124	66	86	96	92	109	174	153	195	190	170	190	152
- Scallop					18	52	120	221	221	221	356	392	1101	1338	752
- Clam					1			1	3	2	19	4	8	27	28
- Periwinkle					5	1		2	3	3	1	1	3	1	2
- Crab						2		1	1						
- Squid					1										
SUBTOTAL	28	35	124	66	111	160	212	334	402	379	571	587	1282	1556	934
Dulse and Other Marine Plants						1	4	1	1	2					1
TOTAL LANDING	111	187	695	921	2031	1754	844	577	596	666	1170	1327	1839	2582	1153

SAINT JOHN HARBOUR AREA
TOTAL LANDINGS
Statistical Districts 48 and 49



Inshore Fishery Only

FIGURE 3-3

This is an important fishery in the Saint John area. However, this fishery becomes less important with increased distance into the Harbour. MacKay (1983) reported that groundfish were present in the Harbour but were restricted in their inward movement. Fishing areas for groundfish are depicted in Figure 3-4. Fishing areas are similar to those described by Marine Research Associates Ltd., 1987. The in-shore fishery for groundfish between 1977 and 1991 accounted for approximately 16% of total landings in Districts 48 and 49 (Figure 3-5). Groundfish landings were relatively low in 1989-1990 but an increase in landings occurred in 1990 (Figure 3-6). Over 80% of the annual groundfish catch for the period 1977-1991 is cod (see Appendix A).

Although landings for other groundfish are reported by DFO for the past few years, questionnaire respondents fishing in the Harbour indicated that cod was the main species caught (only one respondent mentioned that halibut was also caught in the Harbour). It is estimated that less than 10 fishermen are licensed for groundfish in the Harbour (D. Moyer, Saint John Commercial Fishermen Association, personal communication, 1992).

3.4.2 Pelagic and Estuarial Fisheries

Pelagic and estuarial fisheries include a variety of species, but the inshore Harbour fishery is limited mainly to herring, shad, gaspereau, smelt, and eel (Saint John Commercial Fishermen Association, personal communication, 1992). Historical trends for the Harbour fishery are initially discussed below, followed by more recent trends from 1977 to 1991. MacKay (1983) reported that in the early 1800's the weir fishery in the inner Harbour was very active. By 1937, the harbour had undergone extensive development and most of the habitat that could be used for weirs had been used for wharves. As a result, the fishing industry was practically excluded from the inner Harbour area (MacKay, 1983).

Changes in the shad and gaspereau fisheries over the years were thought to be related to loss of spawning grounds up the river (MacKay, 1983). Shad landings during the period 1870 to 1980 showed two cycles of high and low abundance with approximately a 30-year

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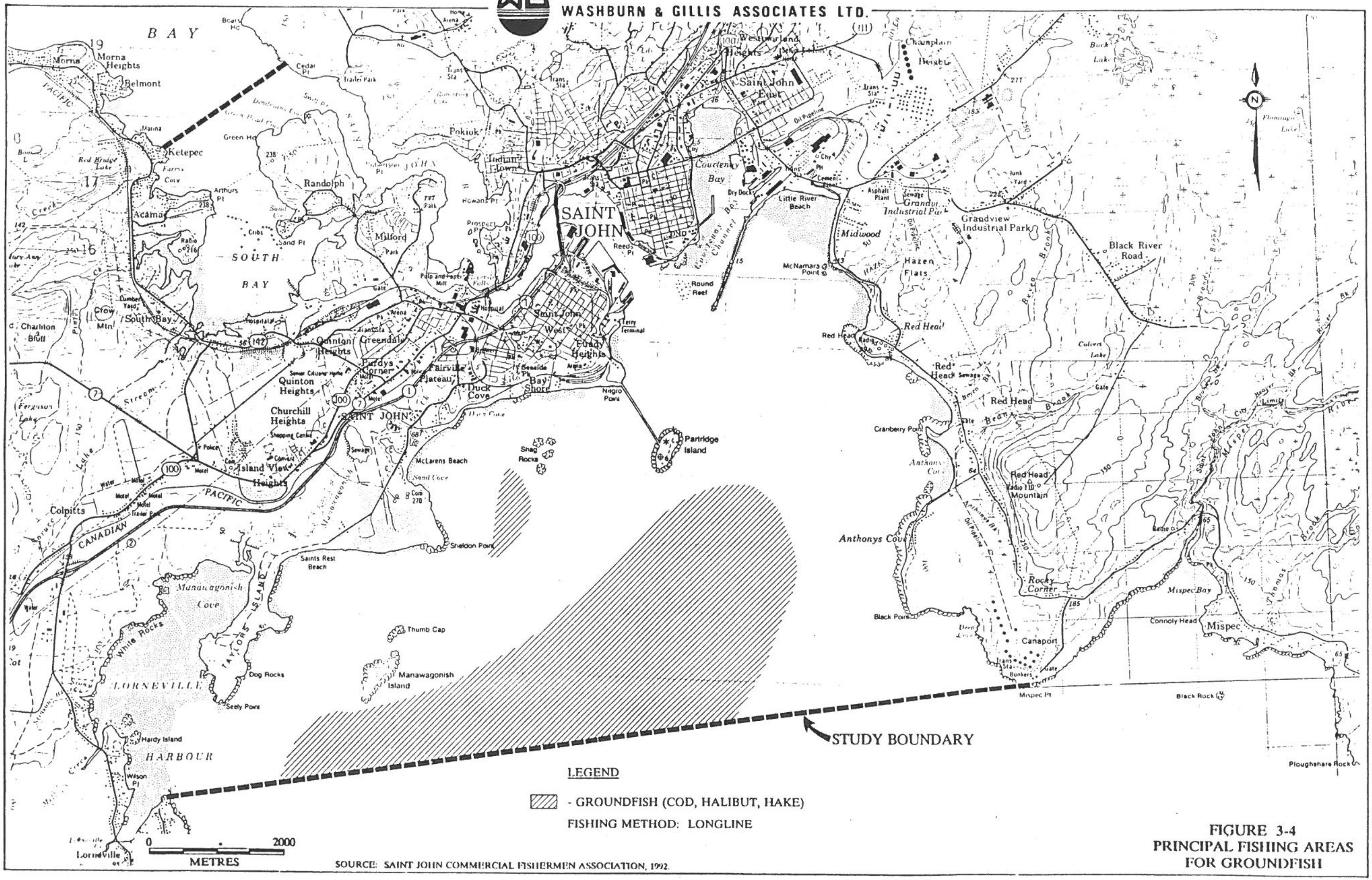

LEGEND

- GROUNDFISH (COD, HALIBUT, HAKE)

FISHING METHOD: LONGLINE

SOURCE: SAINT JOHN COMMERCIAL FISHERMEN ASSOCIATION, 1992.

FIGURE 3-4
PRINCIPAL FISHING AREAS
FOR GROUNDFISH

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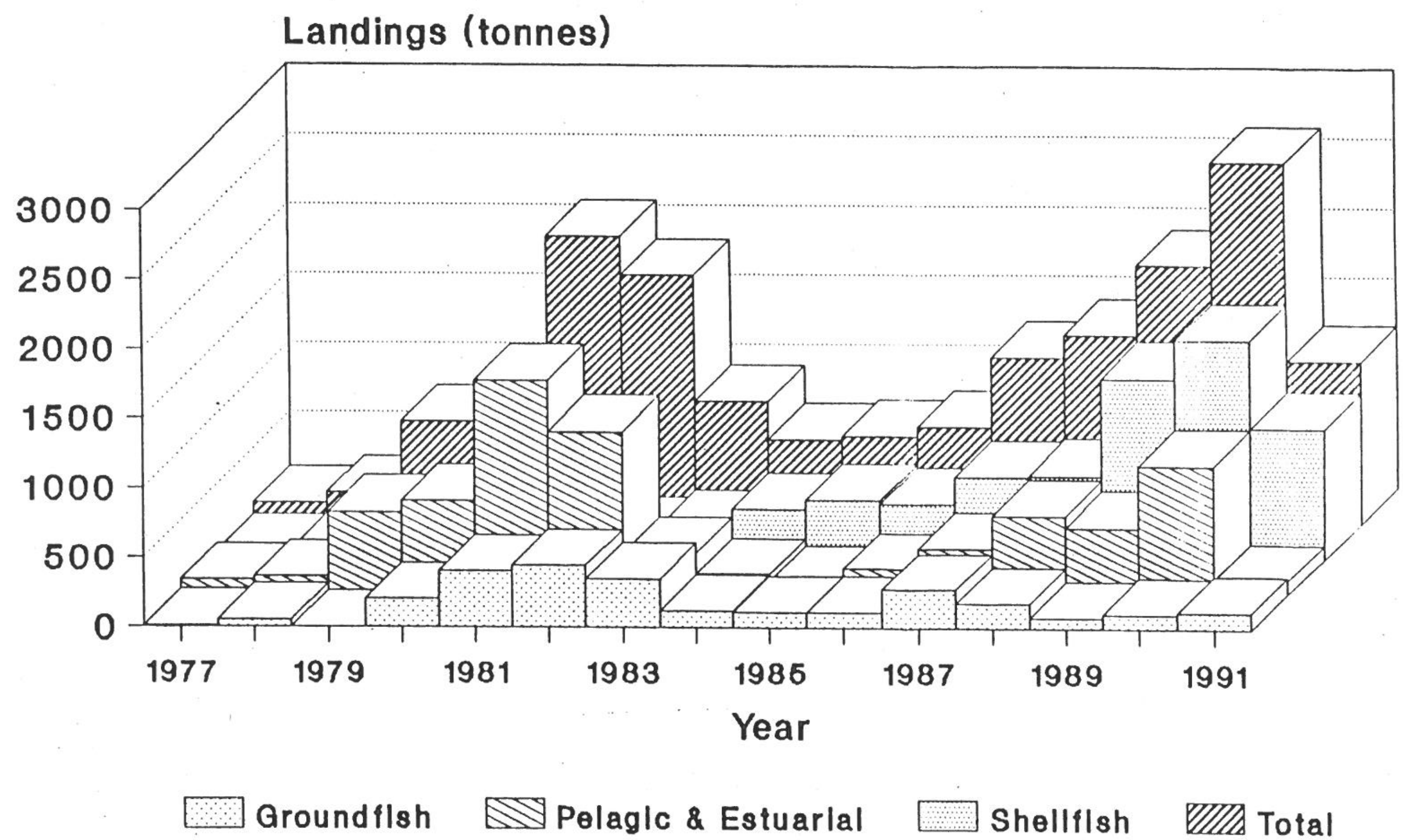
SAINT JOHN HARBOUR AREA
COMPARISON OF FISHERIES
Statistical Districts 48 and 49



Inshore Fishery Only

FIGURE 3-5

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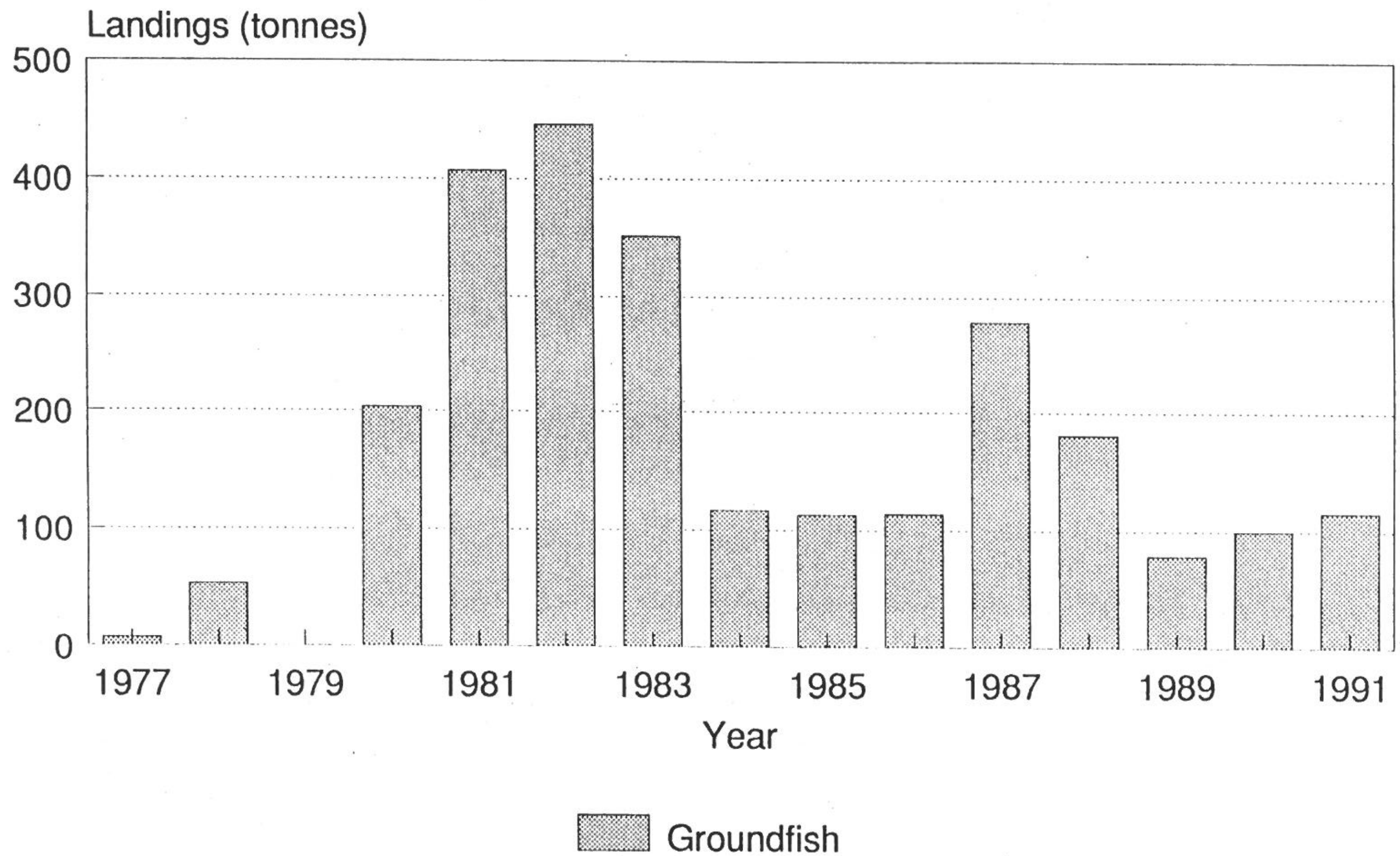
SAINT JOHN HARBOUR AREA
GROUNDFISH FISHERY
Statistical Districts 48 and 49



Inshore Fishery Only

FIGURE 3-6

phase between peaks and depressions (Dadswell, 1983). The decline in Harbour area landings for gaspereau after 1965 was assumed by Dadswell (1983) to be related to reduced efforts rather than lack of resource.

Eels were not fully exploited in the Saint John area prior to 1960 but exploitation increased drastically in 1970 due mainly to an increased market demand (Dadswell, 1983). The commercial salmon fishery in the Harbour was closed in 1972 because of reduced stock size. No historical data for smelt have been reported.

Herring fishing grounds are spread throughout the whole study area (Figure 3-7). Although herring and smelt are fished within the study area, no landings were reported for these species in the past two years (Appendix A). Fishing grounds for smelt and eels are depicted in Figure 3-8. Landings for eels were relatively high in 1988 while minimal landings were reported in the following years (Appendix A).

Shad and gaspereau are the main anadromous species presently fished in the study area. Approximately 85% of the questionnaire respondents fished these species. Fishing grounds for shad and gaspereau are shown in Figure 3-9.

It can be seen from landing data (Appendix A) that a decrease in shad landings occurred between 1981 and 1985 followed by an increase from 1986 to 1990. Shad landings in 1991 were considerably reduced, which may coincide with the beginning of the next depression in the landings cycle. While Dadswell (1983) described a 30-year period between low cycles, landings from 1977 to 1991 reflect a 10-year cycle. However, the 1991 data are considered preliminary at this time.

Gaspereau landings in the past 10 years remained lower than historical landings, with a good year in 1990, followed by lower landings in 1991 (Appendix A).

Pelagic and esturial fisheries accounted for approximately 43% of the total in-shore fishery in the past 15 years (Figure 3-5). In 1991, these fisheries accounted for only 8% of the total

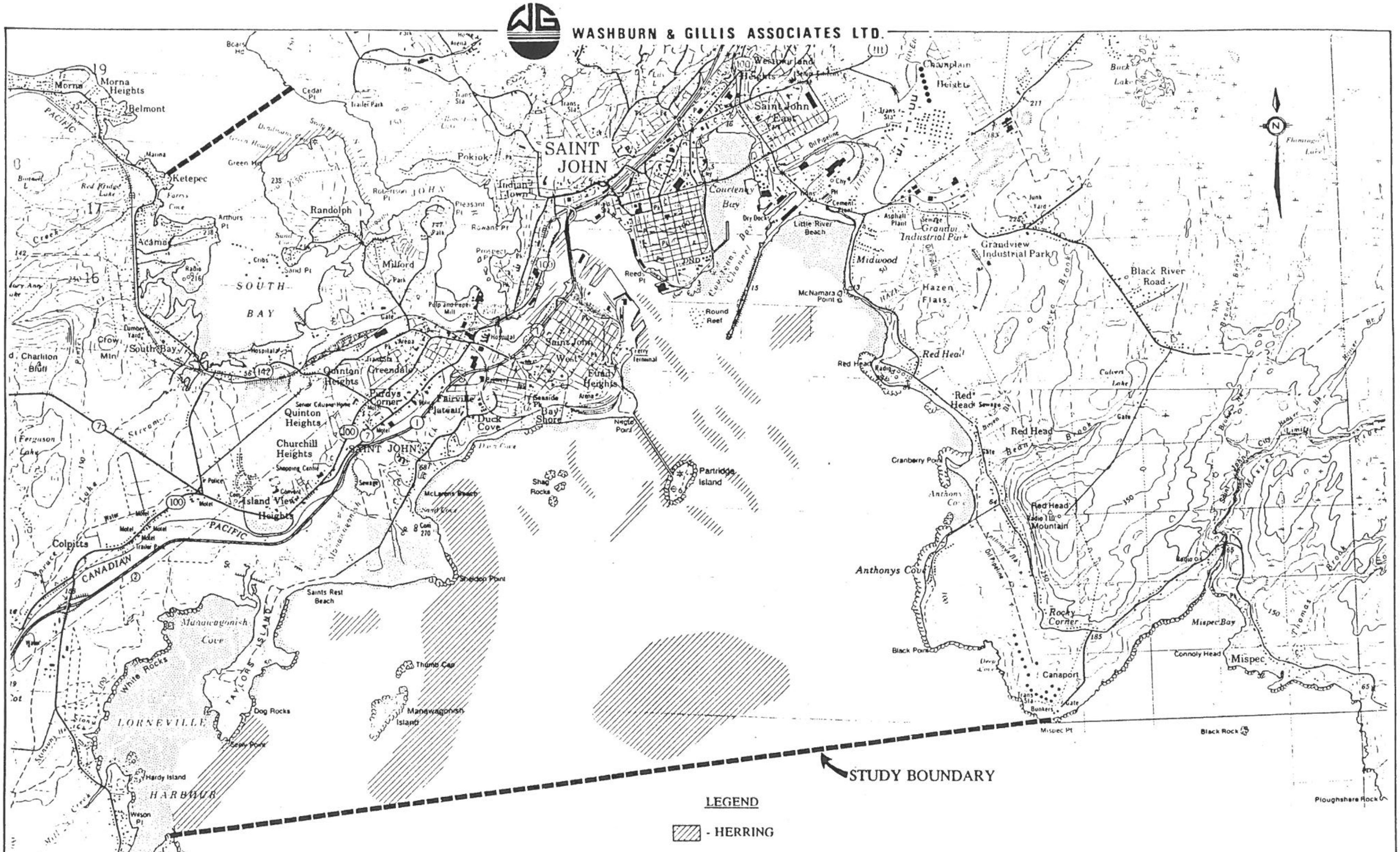


FIGURE 3-7
PRINCIPAL FISHING AREAS
FOR HERRING

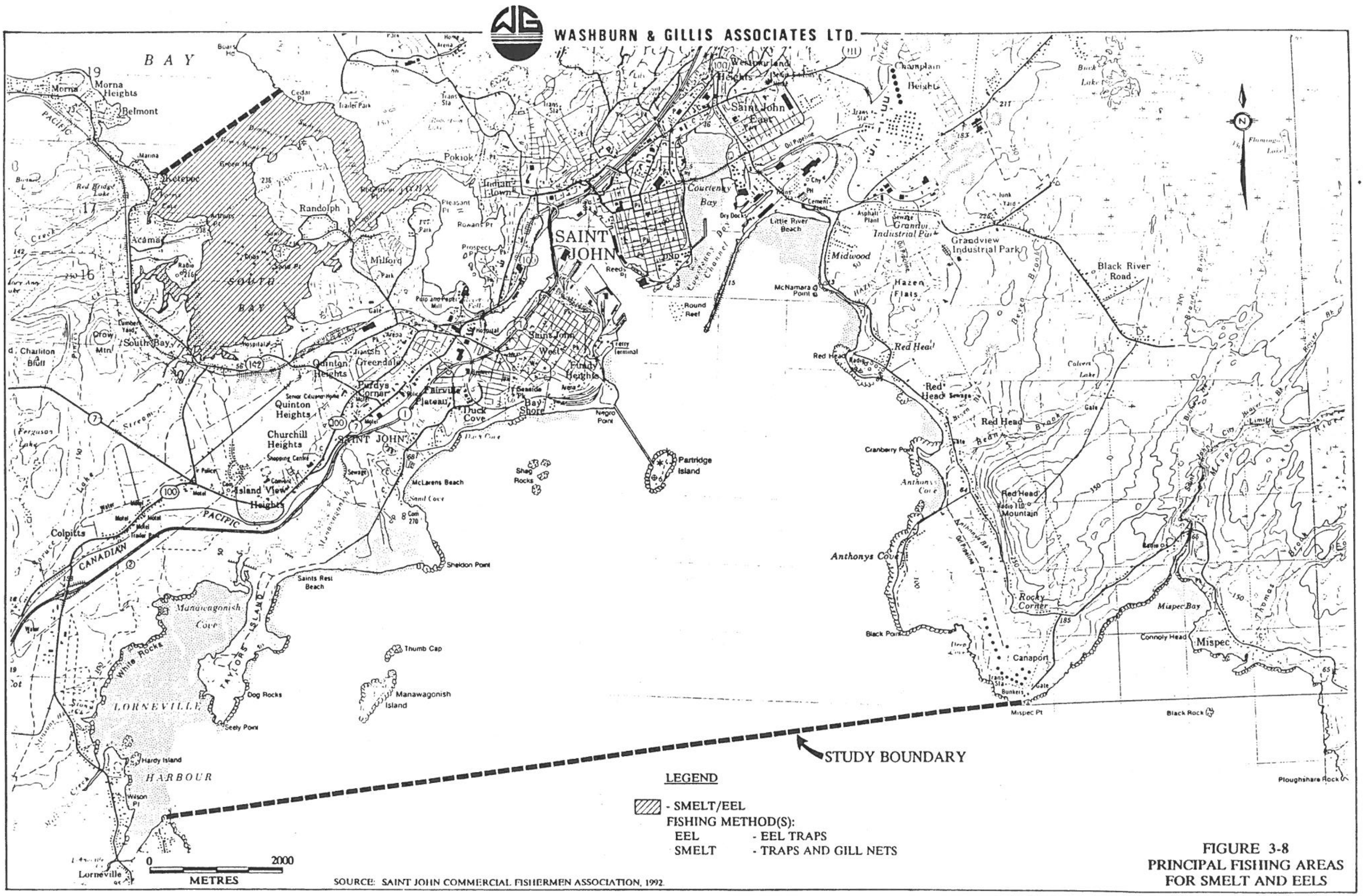


FIGURE 3-8
PRINCIPAL FISHING AREAS FOR SMELT AND EELS

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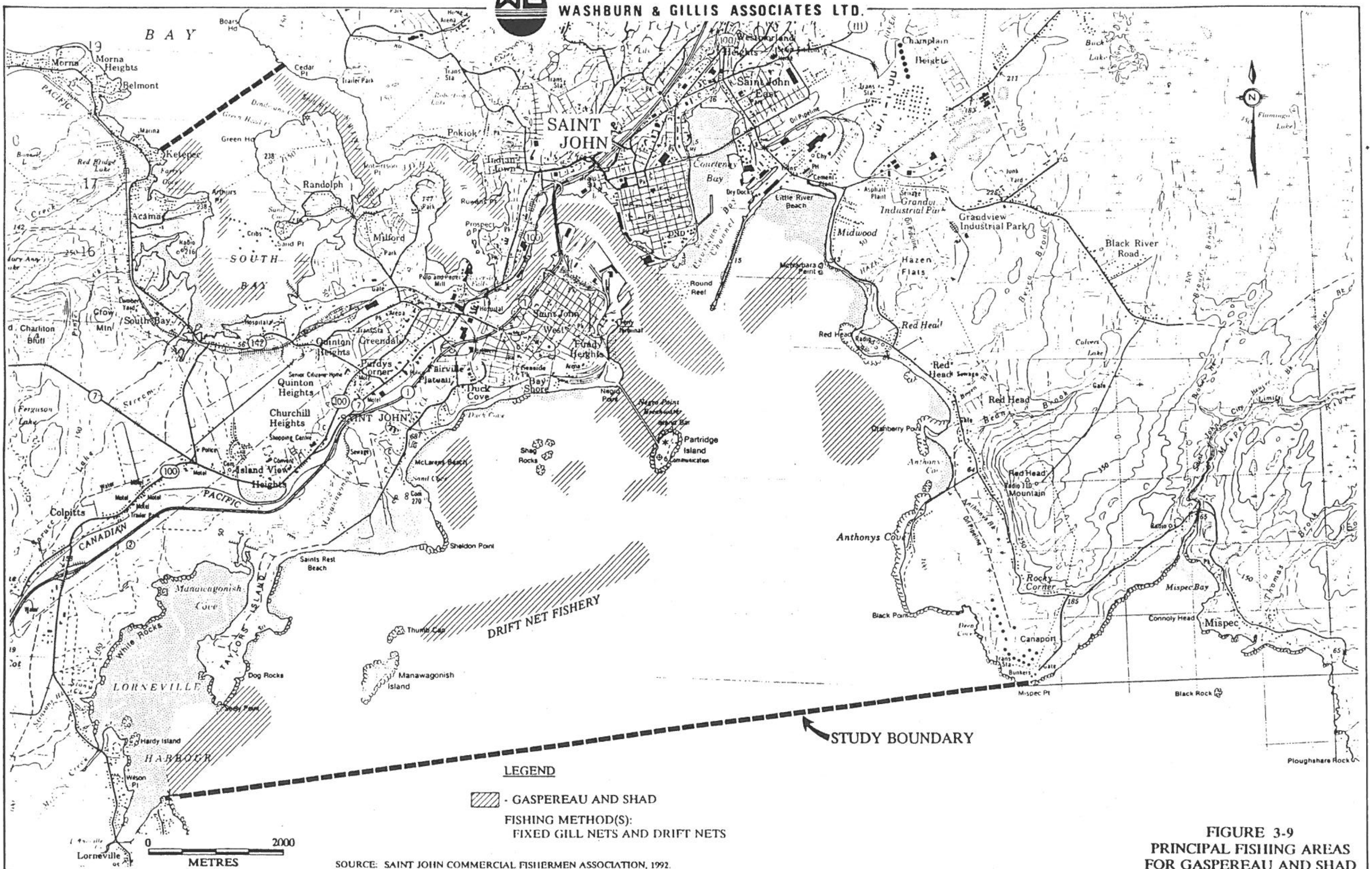

LEGEND

- GASPEREAU AND SHAD

FISHING METHOD(S):
FIXED GILL NETS AND DRIFT NETS

SOURCE: SAINT JOHN COMMERCIAL FISHERMEN ASSOCIATION, 1992.

FIGURE 3-9
PRINCIPAL FISHING AREAS FOR GASPEREAU AND SHAD

fishery. For the past 5 years over 57% of the pelagic and estuarial fish landed were alewives (Appendix A). The landings for pelagic and estuarial species is depicted in Figure 3-10.

Approximately 72 fishermen are licensed for gaspereau in the harbour area, 67 for shad, and 17 for herring (D. Moyer, Saint John Commercial Fishermen Association, personal communication, 1992). Fisheries for shad and gaspereau are therefore, considered important for the fishermen in the area.

3.4.3 Shellfish Fishery

Shellfish fisheries are typically composed of a variety of species of aquatic biota including crustaceans (lobster, crab, etc.) and molluscs (clams, mussels, scallops, periwinkles, etc.). In the study area a shellfish harvesting closure is in affect for the mollusc component. The closure has been in effect since 1958 as a result of bacterial contamination (Waller, et al., 1976).

Other than for lobster, historical trends in shellfish landings are unavailable for the study area. The high cycles of lobster in the past 80 years were phased with periods of warmer water (Dadswell, 1983). Landings for that period remained between 23 and 272 metric tonnes. For the past 10 years lobster landings fluctuated between 92 and 195 metric tonnes with 152 metric tonnes in 1991 (Appendix A). The shellfish fishery accounts for 41% of total landing for the harbour in-shore fishery (Figure 3-5).

In the past 10 years, lobster and scallops were the main species landed. Up to 1982, lobster dominated the landings but from 1983 to 1991, scallops were the dominant species landed. Shellfish landings are depicted in Figure 3-11. Fishing grounds for lobster within the study area are depicted in Figure 3-12.

Approximately 20 fishermen are licensed for lobster in the Harbour area (D. Moyer, Saint John Commercial Fishermen Association, personal communication 1992). Although, DFO statistical data show landings for shellfish species other than lobster, only lobster is currently fished in the Harbour. Other species are fished outside the study area and are landed in

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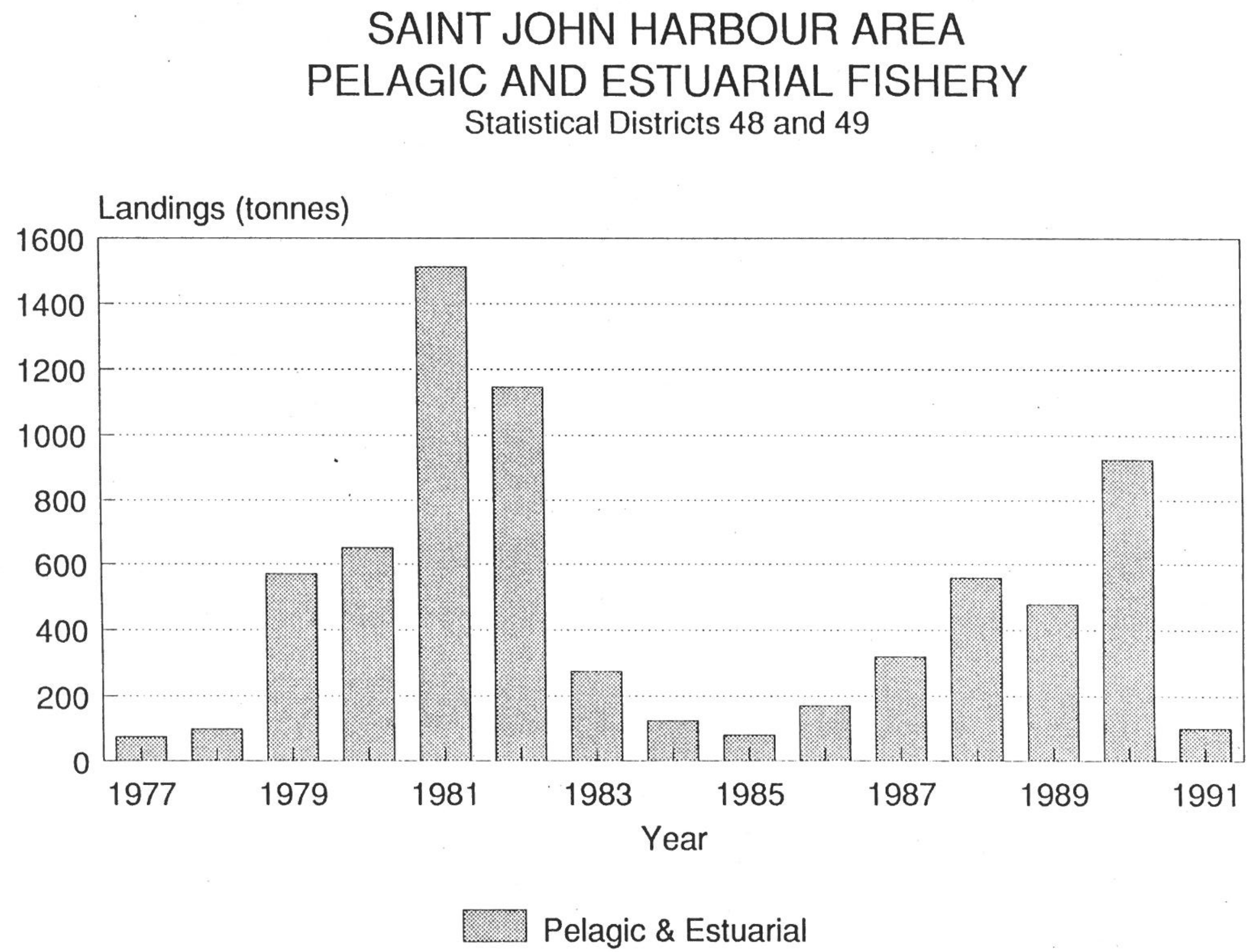
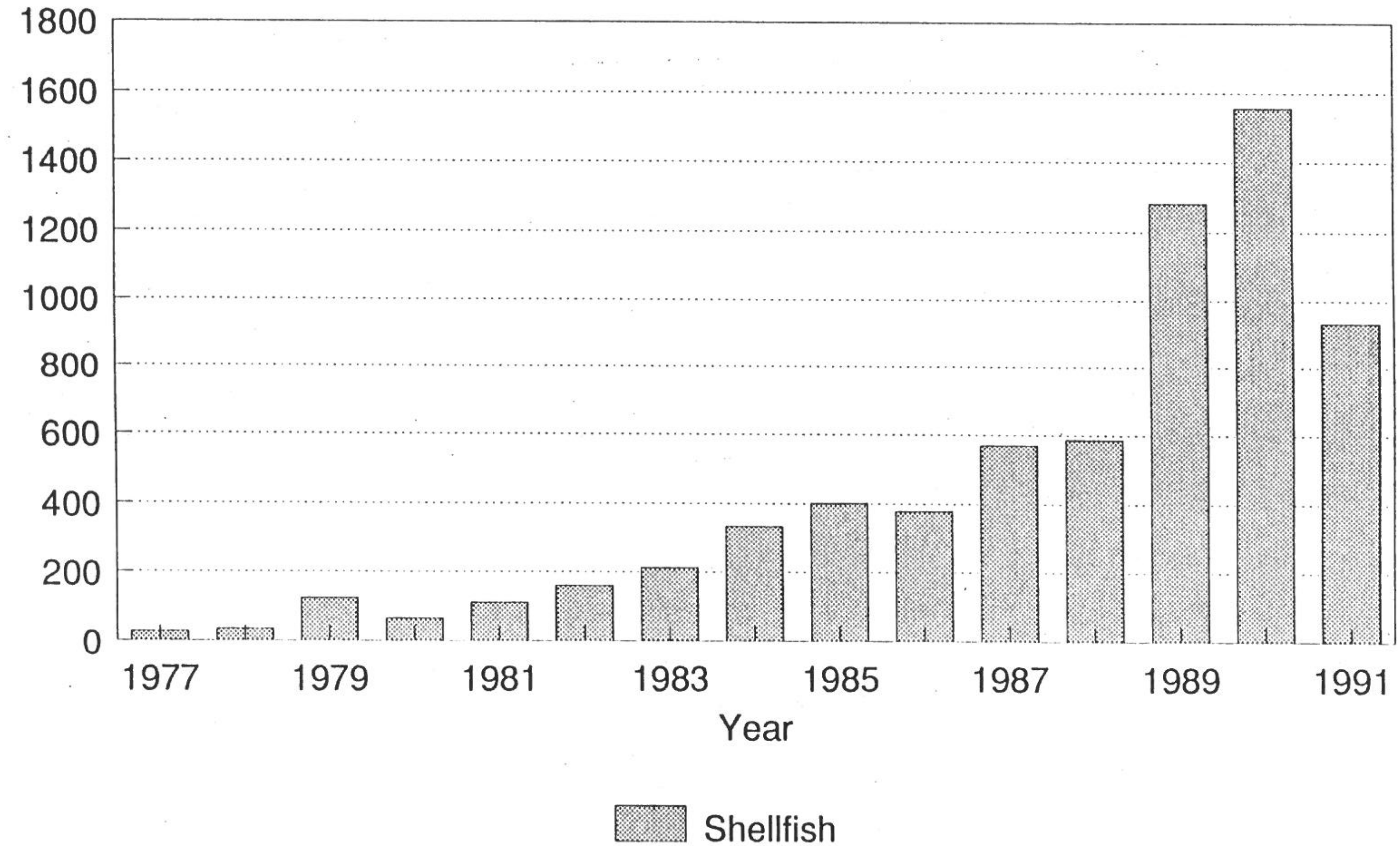


Inshore Fishery Only

FIGURE 3-10

SAINT JOHN HARBOUR AREA
SHELLFISH FISHERY
Statistical Districts 48 and 49



Inshore Fishery Only

FIGURE 3-11

WASHBURN & GILLIS ASSOCIATES LTD.

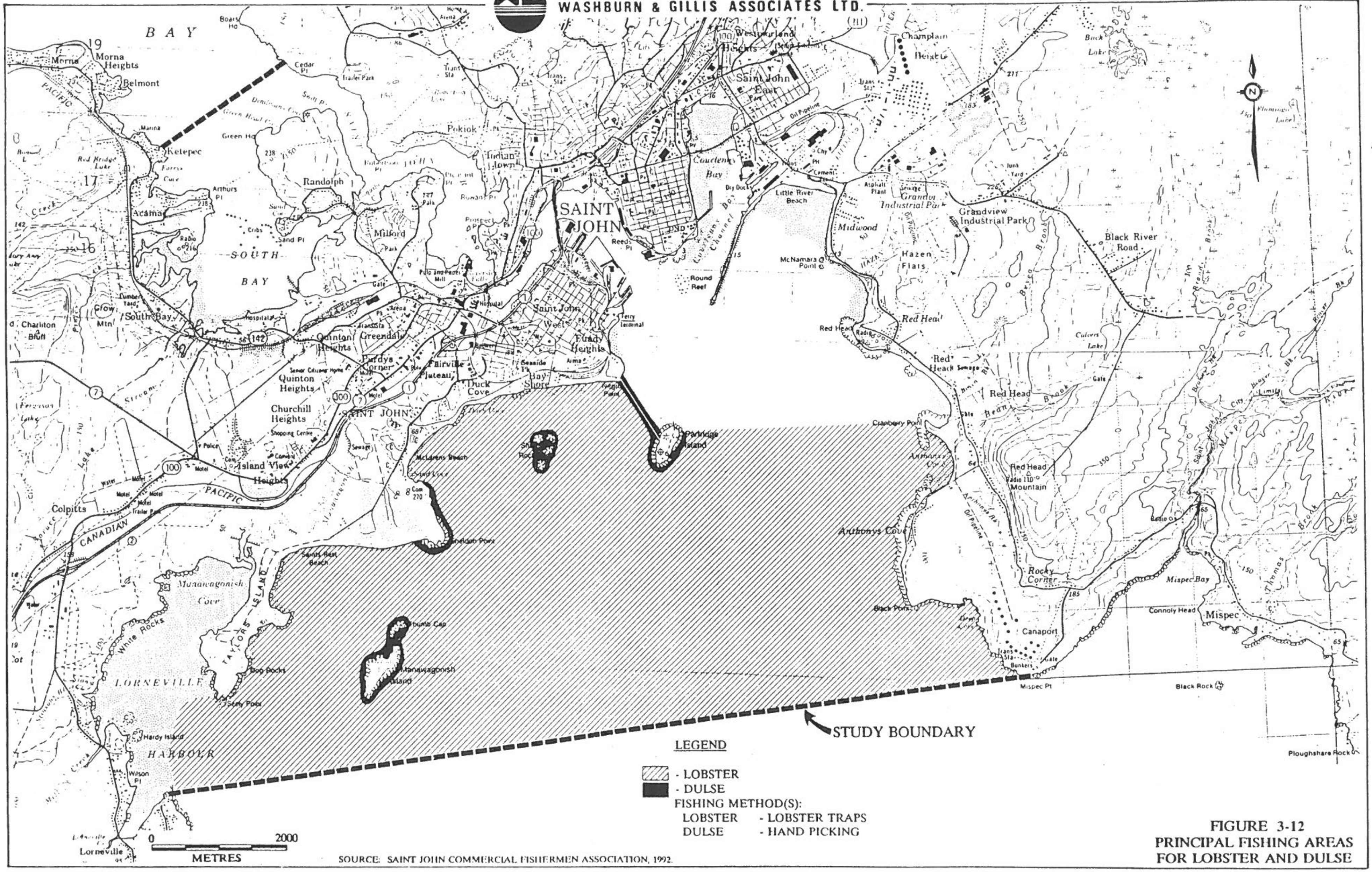


FIGURE 3-12
PRINCIPAL FISHING AREAS FOR LOBSTER AND DULSE

district 48 and 49. No fishing grounds for other shellfish species have been identified in the study area.

3.4.4 Other Commercial Fishery

Other than the fisheries described above, dulse harvesting is the only other type of commercial fishing activity occurring in the study area (Saint John Commercial Fishermen Association, personal communication, 1992). The areas of harvesting are also shown in Figure 3-12. The areas are limited and no significant landings have been reported by DFO for the past 15 years.

3.4.5 Overall Fishery Summary

Overall, the fishery in the study area increased steadily in the past 7 years (see Figure 3-3). However, in 1991 a drop in landings occurred. At the present time, it is impossible to determine if the decrease reflects the beginning of a period of low landings. The 1991 statistical data are considered preliminary.

It is interesting to note that the peaks in total landings in the 1981-82 the 1989-90 periods are strongly reflective of the influence of single species fluctuations in the fishery. The peak of 1981-82 reflects a slight increase in cod landings, but is largely due to significant increases in landings reported for alewife and smelt. The peak of 1989-90 also reflects an increase in reported landings of alewife, and a large increase in scallop landings during that period.

A general note of caution is also warranted, however, where interpreting landings statistics data. Landing statistics may not reflect the true importance of a fishery for several reasons (i.e., non-commercial catches for private consumption, poaching and/or misreporting). Also, fish landed in the statistical districts of the area of concern do not necessarily come from within the area.

The fishery in the Harbour is very important for the local fishermen. More than 40 boats could be seen in the Harbour from mid-March to mid-June (D. Moyer, Saint John

Commercial Fishermen Association, personal communication 1992). Most fishermen used fixed gill nets (herring, gaspereau, shad, and smelt), drift gill nets (gaspereau and shad) or traps (lobster). The fixed nets are in the water continuously except from Friday noon until Sunday morning when the fishery in the harbour is closed (D. Moyer, Saint John Commercial Fishermen Association, personal communication, 1992). Drift nets are approximately 1200 ft long and are put in the water (estuary) two hours before high water. Drift netting is done twice a day, for approximately 3 1/2 to 4 1/2 hours each time.

Fishing ground locations as identified by the respondents of the survey were compared with the fishing grounds identified by Marine Research Associates Ltd. (1977). The comparison shows that the general fishing grounds for species occurring in the Harbour did not change in the past 14 years.

3.5 Other Significant Study Area Uses

The Harbour study area is used, to varying degrees, for other activities such as recreational boating and fishing, swimming, and tourism.

It is not within the scope of this study to fully document such uses. However, their importance is well recognized. Relevant activities are summarized in Table 3-2.

TABLE 3-2
Summary of Major Study Area Uses

Activity	Outer Bay	Harbour Bay	Above Reversing Falls
Tourism	✓	✓	✓
Recreational Boating	✓	✓	✓
Recreational Fishing	✓		✓
Swimming	✓		✓
Nature/Scenic Appreciation	✓		✓

3.5.1 Outer Bay

The Outer Bay area has extensive recreational and tourist activities. The western area of the Outer Bay includes Partridge and Taylors Islands. Partridge Island is of significant historical interest and has increasing tourism potential. Taylors Island is a park that provides opportunities for nature/scenic appreciation. The Saints Rest marsh is a significant ecological area.

The western shore also includes coastal areas such as Saints Rest and McLarens Beaches which provide opportunities for recreational use, including some swimming.

The eastern shore of the Outer Bay area is impacted more by anthropogenic activities. The Mispec beach is located outside the study area. Significant recreational and tourist activities are generally in the area between Red Head and Black Point.

3.5.2 Harbour Bay

The Harbour Bay sub-area is not as diverse in terms of recreational and other uses as the other portions of the study area. Harbour uses in this sub-area are dominated by Port activities. There are no significant recreational or natural areas. However, the Harbour Bay sub-area is an important focal point for tourism.

3.5.3 Above Reversing Falls

The Reversing Falls area is a major tourist attraction. There is also significant additional recreational activity in the area. Recreational boating activities center around marinas located near Ketepec and the power boat club located just above the Falls. The Dominion Park beach is a significant recreational area on South Bay. Recreational fishing, primarily for striped bass, occurs in the lower end of the sub-area and smelt fishing during the winter is popular in the South Bay area.

4.0 ENVIRONMENTAL PROFILES OF SOURCES ENTERING THE HARBOUR

An environmental profile has been developed in terms of the potential sources of contaminants entering Saint John Harbour. Potential contaminants entering the Harbour are conveyed by a number of sources including tributaries, industrial effluents, and effluents from the municipal collection/treatment system. The contributing sources are summarized by hydrographic sub areas in Table 4-1.

Effluent characterization has been based on the results of analysis for selected physical and chemical parameters, for tributary, industrial, and municipal sources. In addition, toxicity testing of samples for the major tributary and industrial sources has also been undertaken.

4.1 Tributaries to Saint John Harbour

Major tributaries to the Saint John Harbour study area include Little River, Hazen Creek, Marsh Creek, and the St. John River. The comparative drainage areas for each of the Harbour tributaries are given in Table 4-2. The St. John River dominates tributary flows and is approximately 500 times all other tributary inflows combined.

In order to characterize each tributary, available background data were reviewed and water quality sampling was conducted. The list of parameters selected for analysis is presented in Table 4-3.

Tributary flows and loadings may vary widely in relation to seasonal precipitation. Therefore, tributaries were sampled during wet (December) and again during dry (March) periods. Water samples for characterizing dioxin and furan constituents during the low flow period, were collected in June 1992, due to sampling problems experienced in March. Water samples were collected, where possible, on low water spring tides at a point immediately upstream from the low water spring tide elevation contour to ensure that

TABLE 4-1
Summary of Contributing Sources Sampled

Source	LOCATION		
	Outer Bay	Harbour Bay	Above Reversing Falls
Major Tributaries			
St. John River			x
Marsh Creek		x	
Little River	x		
Hazen Creek	x		
Industries			
Irving Pulp and Paper Ltd.			x
Irving Tissue Ltd.			x
Irving Paper Ltd.	x		
Irving Oil Refinery	x		
Lantic Sugar Ltd.		x	
Moosehead Breweries Ltd.			x
T.S. Simms & Co. Ltd.			x
NB Power - Courtenay Bay	x		
NB Power - Coleson Cove	x*		
Municipal			
Untreated Effluent	x	x	x
Treated Effluent			
●Lancaster	x		
●Hazen Creek	x		
●Millidgeville			x

* Outside Study Area

TABLE 4-2
Harbour Tributary Drainage Areas

Tributary	Drainage Area (km^2)	Approx. Mean Annual Runoff (mm)	Approx. Mean Annual Flow (m^3/day)
St. John River	55,143	663	100×10^6
Marsh Creek	27.9	950	3,000
Little River	35.7	950	93,000
Hazen Creek	7.2	950	19,000

TABLE 4-3
List of Parameters Analyzed for Tributary Characterization

Parameters	Wet Sampling 1991 12 06	Dry Sampling 1992 03 04
BASE PARAMETERS		
Biochemical Oxygen Demand (BOD) (total)	x	x
BOD (soluble)	x	x
Total Suspended Solids (TSS)	x	x
Total Dissolved Solids (TDS)	x	x
Volatile Suspended Solids (VSS)	x	x
pH	x	x
Total Organic Carbon (TOC)	x	x
Chemical Oxygen Demand (COD)	x	x
Total Kjeldhal Nitrogen (TKN)	x	x
Ammonia (-NH-N)	x	x
Total phosphorus	x	x
Soluble phosphorus	x	x
Copper (Cu)	x	x
Lead (Pb)	x	x
Zinc (Zn)	x	x
Mercury (Hg)	x	x
Cadmium (Cd)	x	x
Total Coliform	x	x
Fecal Coliform	x	x
E. coli	x	x
Oil and grease (total)	x	x
Mineral oil and grease (petrogenic)	x	x
Chloride		x
Sodium		x

Parameters	Wet Sampling 1991 12 06	Dry Sampling 1992 03 04
ADDITIONAL PARAMETERS		
Phenolics (as phenols)	x	x
Cyanides	x	x
Hydrogen Sulphide	x	x
Chlorinated Organics		
Adsorbable Organic Halide (AOX)	x	x
Polychlorinated Biphenyl (PCB)	x	
Extractable Organic Chlorine (EOX)		x
Pesticides		
Organochlorinated	x	
Organophosphorous & triazines	x	
Phenoxy acid/neutral herbicides and carbamates (ppb)	x	
Polynuclear aromatic hydrocarbons (PAH)	x	x
Dioxins and furans	x	
Resin and fatty acids	x	x
Toxicity Testing		
Acute toxicity testing		
Daphnia magna	x	x
Fathead minnow	x	x
Rainbow Trout		x
Chronic toxicity testing		
Fathead minnow 7-day Larval survival and growth	x	x
Genotoxicity		
SOS Chromotest *E. coli*	x	x

samples were not diluted by intruding seawater. The St. John River was sampled on a low water spring tide to minimize saltwater/freshwater mixing. The location of each point sampled for the respective tributaries is shown in Figure 4-1.

4.1.1 St. John River

The St. John River headwaters originate from Little St. John Lake on the boundary between Maine and Quebec. The river flows north and east, then turns to flow mainly south and east before emptying into the Bay of Fundy at Saint John. The total length is approximately 700 km, with a drainage area of 55,143 km^2.

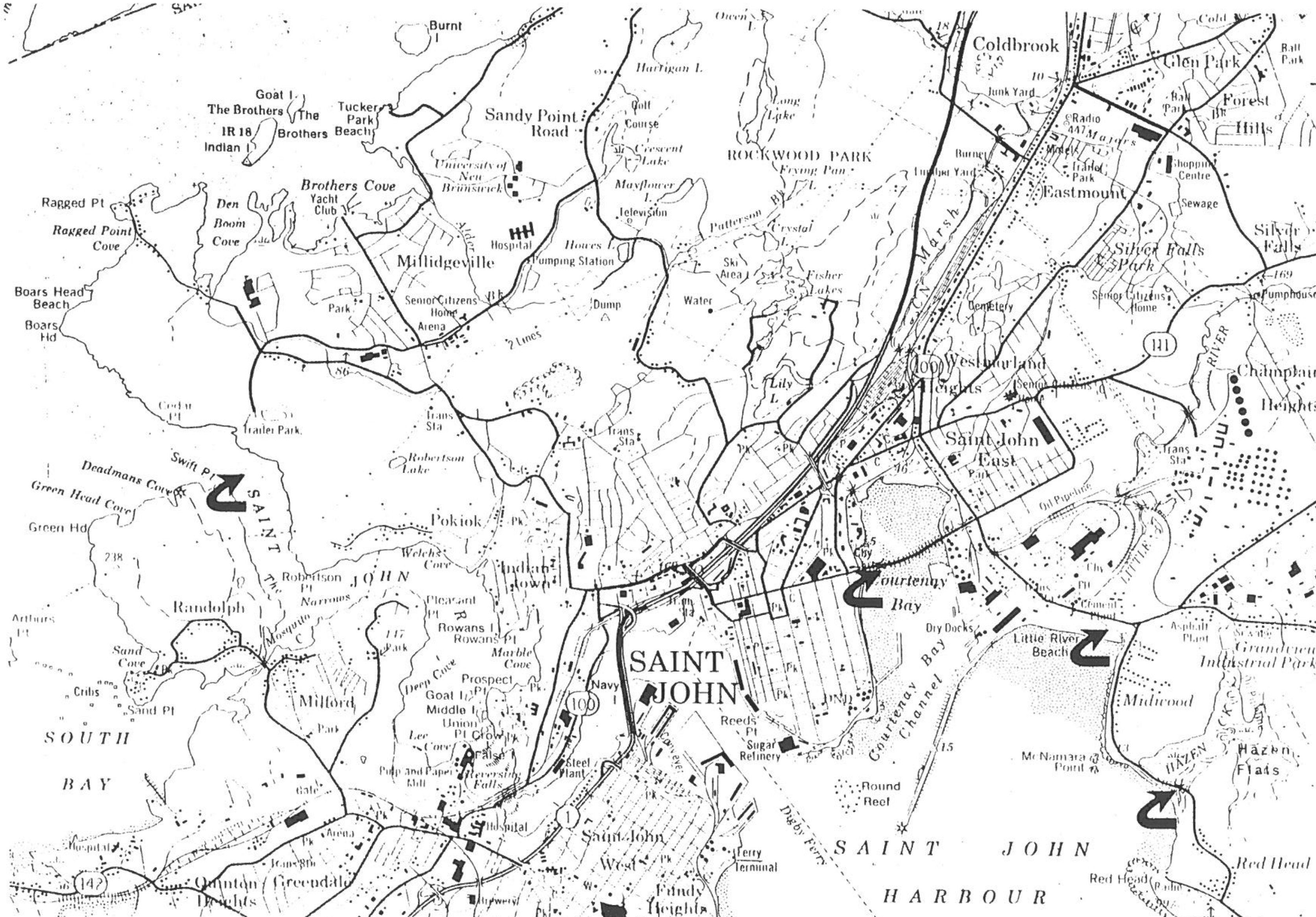
Major tributary streams include the Aroostock, Presque Isle and Meduxnekeag from Maine, the Saint Francis and Madawaska from Quebec and the Tobique, Nashwaak, Oromocto, Salmon, Canaan and Kennebecasis in New Brunswick (Washburn & Gillis Associates Ltd., 1985). Three mainstream hydro-electric dams are located in the middle portion of the river, at Grand Falls, Beechwood, and Mactaquac.

The average annual discharge of the St. John River 1159 m^3/sec. Monthly maximum and minimum discharges are 3271 m^3/sec (April) and 534 m^3/sec (September), respectively.

The principal industries along the St. John River include agriculture, food processing and pulp and paper. Food processing plants in the valley are largely associated with vegetable processing. No major industries are located on the St. John River between Fredericton and Saint John.

Historically, heavy metal concentrations are low in the waters of the St. John River and are mainly determined by the bedrock geology of the basin. Typically concentrations reported for cadmium are 0.001 mg/L, copper 0.015 mg/L, lead 0.05 mg/L and zinc 0 to 0.03 mg/L (Washburn & Gillis Associates Ltd., 1985). Values for PAHs and PCBs have been reported from sediments at Mactaquac as 0.591 mg/kg and $<$0.013 mg/kg, respectively (Bailey & Howell, 1983).

WASHBURN & GILLIS ASSOCIATES LTD.



LEGEND

SAMPLING STATION LOCATION

0 2000
METRES

FIGURE 4-1
TRIBUTARY SAMPLING STATIONS

The study sampling station on the St. John River was approximately 500 m downstream of Cedar Point, located above Reversing Falls. Sampling was conducted in mid-channel directly opposite Swift Point. Results from both wet and dry sampling periods are presented in Table 4-4. Data show little variation in concentrations of parameters between wet and dry sampling periods. The water pH remained neutral (7.0-7.1) and most parameters, (especially pesticides, PCBs, PAHs, resin & fatty acids, and dioxins and furans) were below detectable limits.

4.1.2 Marsh Creek

Marsh Creek has a drainage area of approximately 27.9 km^2. This tributary discharges directly into Courtenay Bay and flows through both a highly developed residential area in its upper reach and a light industry commercial area in the lower reaches. Bordering this watercourse are a large railyard, lumber yard, scrapyard and a concrete prefabrication plant.

Historically, Marsh Creek has been reported to have sewage and oil wastes clearly visible on the water surface (National Health and Welfare, 1964). Historical data indicate that Marsh Creek has had median coliform counts of 400,000 / 100 ml, with an average of 1,100,000 / 100 ml (National Health and Welfare, 1964). Phenols in Marsh Creek were reported as averaging 0.029 mg/L in 1964.

The tributary was sampled approximately 10 m downstream of the tide gates at the Courtenay Bay Causeway. Analytical results are presented in Table 4-5. Contamination by parameters, including coliform bacteria, suspended solids, dioxins and furans, and AOX was detected. Metal contamination was low.

4.1.3 Little River

Little River has a drainage area of approximately 35.7 km^2 making it the second largest tributary sampled. Little River is the most heavily industrialized of the smaller tributaries entering Saint John Harbour. The upper reach of the river is bordered by a residential area

TABLE 4-4
Water Quality Data - Saint John River

Parameters	High Flows 1991 12 06	Low Flows 1992 03 04
BASE PARAMETERS		
BOD (total) (mg/L)	3	<2
BOD (soluble) (mg/L)	<2	<2
TSS (mg/L)	4.4	2.8
TDS (mg/L)	3450	4440
VSS (mg/L)	1.3	1.2
pH	7.1	7
TOC (mg/L)	4.4	2.9
COD (mg/L)	45	135
TKN (mg/L)	3.3	0.1
-NH-N (mg/L)	0.17	0.05
Total phosphorus (mg/L)	<0.1	<0.1
Soluble phosphorus (mg/L)	<0.1	<0.1
Cu (μg/l)	7	2
Pb (μg/l)	3.4	0.6
Zn (μg/l)	12	9
Hg (μg/l)	0.08	0.8
Cd (μg/l)	<0.5	<0.5
Total Coliform (/100 mL)	400	112
Fecal Coliform (/100 mL)	89	100
E. coli (/100 mL)	0	40
Oil and grease (total) (mg/L)	<1.0	<1.0
Mineral oil and grease (petrogenic) (mg/L)	<1.0	<1.0
Chloride (mg/L)	n/a	3220
Sodium (mg/L)	n/a	1740
ADDITIONAL PARAMETERS		
Phenolics (as phenols) (mg/L)	0.002	<0.002
Cyanides (mg/L)	<0.005	<0.005
Hydrogen Sulphide (mg/L)	<0.1	<0.1
Chlorinated Organics		
Adsorbable Organic Halide (mg/L)	0.08	0.03
Polychlorinated Biphenyl (PCBs) (ppb)	<1.0	n/a
Extractable Organic Chlorine (ppb)	n/a	2.4
Organochlorinated pesticides (ppb)		
Heptachlor	<0.5	n/a
Aldrin	<0.1	n/a
Heptachlorepoxide	<0.5	n/a
Gamma chlordane	<0.1	n/a
Alpha chlordane	<0.1	n/a
Dieldrin	<0.1	n/a
DDT	<0.1	n/a
DDD	<0.1	n/a
DDE	<0.1	n/a
Organophosphorous & triazines (ppb)		
Glyphosate	<1.0	<1.0
Naled	<0.50	n/a
Mevinphos	<0.50	n/a
Acephate	<0.50	n/a
Terbufos	<0.50	n/a
Fonofos	<0.50	n/a
Methyl parathion	<0.50	n/a
Chlorpyrifos	<0.50	n/a
Fenthion	<0.50	n/a
Chlorfenvinphos	<0.50	n/a
Methidathion	<0.50	n/a
Phosalon	<0.50	n/a
Atrazine	<0.50	n/a
Cyanazine	<0.50	n/a
Simazine	<0.50	n/a
Propazine	<0.50	n/a
Phenoxy acid/neutral herbicides and carbamates (ppb)		
Dicamba	<0.10	n/a
MCPA	<0.10	n/a
2,4,-D	<0.10	<0.10
2,4,5,T	<0.10	<0.10
2,4,5,T,P	<0.10	<0.10
Treflan	<0.10	n/a
Bromoxynil	<0.10	n/a
Triallate	<0.10	n/a
Tordon	<0.10	n/a
Diclofop-methyl	<0.10	n/a
Aldicarb	<1.0	n/a
Methomyl	<1.0	n/a
Carbofuron	<1.0	n/a
Carbaryl	<1.0	n/a
Methiocarb	<1.0	n/a
Polynuclear aromatic hydrocarbons (ppb)		
Naphthalene	<0.01	<0.01
Acenapthylene	<0.01	<0.01
Acenaphthene	<0.01	<0.01
Fluorene	<0.01	<0.01
Phenanthrene	<0.01	<0.01
Anthracene	<0.01	<0.01
Fluoranthene	<0.01	<0.01
Pyrene	<0.01	<0.01
Benzo (a) anthracene	<0.01	<0.01
Chrysene	<0.01	<0.01
Benzo (b,j,k) fluoranthene	<0.01	<0.01
Benzo (a) pyrene	<0.01	<0.01
Dibenz (a,h) anthracene	<0.01	<0.01
Indeno (1,2,3-cd) pyrene	<0.01	<0.01
Benzo (g,h,i) perylene	<0.01	<0.01
Dioxins & furans (pg/L)		
1,2,3,7,8-P_5CDD	<1.5	n/a
1,2,3,4,7,8-H_6CDD	<1.6	n/a
1,2,3,6,7,8-H_6CDD	<1.4	n/a
1,2,3,4,6,7,8-H_7CDD	<2.7	n/a
O_8CDD	<4.8	n/a
2,3,4,7,8-P_5CDF	<1.0	n/a
1,2,3,7,8-P_5CDF	<1.3	n/a
1,2,3,4,7,8-H_6CDF	<1.1	n/a
2,3,4,6,7,8-H_6CDF	<1.0	n/a
1,2,3,6,7,8-H_6CDF	<1.0	n/a
1,2,3,7,8,9-H_6CDF	<2.3	n/a
1,2,3,4,6,7,8-H_7CDF	<1.7	n/a
1,2,3,4,7,8,9-H_7CDF	<3.5	n/a
O_8CDF	<4.3	n/a
Resin and fatty acids (ppb)		
Myristic acid	<1.30	<0.63
Palmitic acid	2.5	<0.63
Oleic acid	<1.30	<0.63
Linoleic acid	<1.30	<0.63
Stearic acid	5.8	<0.63
Linolenic acid	<1.30	<0.63
Pimaric acid	<1.30	<0.63
Arachidic acid	1.3	<0.63
Sandaracopimaric acid	<1.30	<0.63
Levopimaric acid / Isopimaric acid	<1.30	<0.63
Palustric acid	<1.30	<0.63
Dehydroabietic acid	<1.30	<0.63
Abietic acid	<1.30	<0.63
Neoabietic acid	<1.30	<0.63
9, 10 - Dichlorostearic acid	<1.30	<0.63
14 - Chlorodehydroabietic acid (#1)	<1.30	<0.63
12 - Chlorodehydroabietic acid (#2)	<1.30	<0.63
12,14 - Dichlorodehydroabietic acid	<1.30	<0.63

n/a - not analyzed

TABLE 4-5
Water Quality Data - Marsh Creek

Parameters	High Flows 1991 12 06	Low Flows 1992 03 04
BASE PARAMETERS		
BOD (total) (mg/L)	4	7
BOD (soluble) (mg/L)	2	13
TSS (mg/L)	17	106
TDS (mg/L)	14300	12100
VSS (mg/L)	0.4	26
pH	7.0	6.6
TOC (mg/L)	2.1	1.0
COD (mg/L)	244	306
TKN (mg/L)	2.0	6.4
-NH-N (mg/L)	0.09	3.7
Total phosphorus (mg/L)	<0.1	0.6
Soluble phosphorus (mg/L)	<0.1	0.4
Cu (µg/l)	5.0	60
Pb (µg/l)	1.5	36
Zn (µg/l)	10.0	67
Hg (µg/l)	0.08	0.05
Cd (µg/l)	<0.5	0.5
Total Coliform (/100 mL)	46000	110000
Fecal Coliform (/100 mL)	1100	7500
E. coli (/100 mL)	400	1100
Oil and grease (total) (mg/L)	<1.0	4.4
Mineral oil and grease (petrogenic) (mg/L)	<1.0	<1.0
Chloride (mg/L)	n/a	7590
Sodium (mg/L)	n/a	3730
ADDITIONAL PARAMETERS		
Phenolics (as phenols) (mg/L)	0.010	0.039
Cyanides (mg/L)	<0.005	<0.005
Hydrogen Sulphide (mg/L)	<0.1	<0.1
Chlorinated Organics		
Adsorbable Organic Halide (mg/L)	0.12	0.28
Polychlorinated Biphenyl (PCBs) (ppb)	<1.0	n/a
Extractable Organic Chlorine (ppb)	n/a	n/a
Organochlorinated pesticides (ppb)		
Heptachlor	<0.5	n/a
Aldrin	<0.1	n/a
Heptachlorepoxide	<0.5	n/a
Gamma chlordane	<0.1	n/a
Alpha chlordane	<0.1	n/a
Dieldrin	<0.1	n/a
DDT	<0.1	n/a
DDD	<0.1	n/a
DDE	<0.1	n/a
Organophosphorous & triazines (ppb)		
Glyphosate	<1.0	<1.0
Naled	<0.50	n/a
Mevinphos	<0.50	n/a
Acephate	<0.50	n/a
Terbufos	<0.50	n/a
Fonofos	<0.50	n/a
Methyl parathion	<0.50	n/a
Chlorpyrifos	<0.50	n/a
Fenthion	<0.50	n/a
Chlorfenvinphos	<0.50	n/a
Methidathion	<0.50	n/a
Phosalon	<0.50	n/a
Atrazine	<0.50	n/a
Cyanazine	<0.50	n/a
Simazine	<0.50	n/a
Propazine	<0.50	n/a
Phenoxy acid/neutral herbicides and carbamates (ppb)		
Dicamba	<0.10	n/a
MCPA	<0.10	n/a
2,4,-D	<0.10	n/a
2,4,5,-T	<0.10	<0.10
2,4,5,-T,P	<0.10	<0.10
Treflan	<0.10	n/a
Bromoxynil	<0.10	n/a
Triallate	<0.10	n/a
Tordon	<0.10	n/a
Diclofop-methyl	<0.10	n/a
Aldicarb	<1.0	n/a
Methomyl	<1.0	n/a
Carbofuron	<1.0	n/a
Carbaryl	<1.0	n/a
Methiocarb	<1.0	n/a
Polynuclear aromatic hydrocarbons (ppb)		
Naphthalene	<0.01	13
Acenapthylene	<0.01	<0.01
Acenaphthene	<0.01	<0.01
Fluorene	<0.01	1.0
Phenanthrene	<0.01	<0.01
Anthracene	<0.01	1.4
Fluoranthene	<0.01	1.1
Pyrene	<0.01	<0.01
Benzo (a) anthracene	<0.01	<0.01
Chrysene	<0.01	<0.01
Benzo (b,j,k) fluoranthene	<0.01	<0.01
Benzo (a) pyrene	<0.01	<0.01
Dibenz (a,h) anthracene	<0.01	<0.01
Indeno (1,2,3-cd) pyrene	<0.01	<0.01
Benzo (g,h,i) perylene	<0.01	<0.01
Dioxins & furans (pg/L)		
2,3,7,8-T_4CDD	<1.9	<1.0
1,2,3,7,8-P_5CDD	<2.2	<1.0
1,2,3,4,7,8-H_6CDD	<2.2	<1.0
1,2,3,6,7,8-H_6CDD	<1.7	<1.0
1,2,3,4,6,7,8-H_7CDD	<3.4	7
O_8CDD	27.0	49
2,3,7,8-T_4CDF	<1.3	<1.0
2,3,4,7,8-P_5CDF	<1.3	<1.0
1,2,3,7,8-P_5CDF	<1.6	2
1,2,3,4,7,8-H_6CDF	<1.1	<1.0
2,3,4,6,7,8-H_6CDF	<0.9	<1.0
1,2,3,6,7,8-H_6CDF	<1.0	<1.0
1,2,3,7,8,9-H_6CDF	<1.6	<1.0
1,2,3,4,6,7,8-H_7CDF	<1.7	<1.0
1,2,3,4,7,8,9-H_7CDF	<3.7	<1.0
O_8CDF	<6.5	<1.0
Resin and fatty acids (ppb)		
Myristic acid	<1.30	37
Palmitic acid	3.7	290
Oleic acid	7.7	120
Linoleic acid	8.7	4.3
Stearic acid	7.0	280
Linolenic acid	<1.30	<0.63
Pimaric acid	<1.30	0.79
Arachidic acid	1.3	17
Sandaracopimaric acid	<1.30	<0.63
Levopimaric acid / Isopimaric acid	<1.30	0.75
Palustric acid	<1.30	<0.63
Dehydroabietic acid	<1.30	2.1
Abietic acid	<1.30	11
Neoabietic acid	<1.30	<0.63
9, 10 - Dichlorostearic acid	<1.30	<0.63
14 - Chlorodehydroabietic acid (#1)	<1.30	<0.63
12 - Chlorodehydroabietic acid (#2)	<1.30	<0.63
12, 14 - Dichlorodehydroabietic acid	<1.30	<0.63

n/a - not analyzed

with the lower reach running through an area with a number of heavy industries. Both Irving Paper Ltd. and the Irving Oil Refinery discharge effluents into this tributary. In addition, untreated municipal sewage is discharged directly into the stream.

The sampling station was near the intersection of Bayside Drive and Red Head Road, located approximately 25 m downstream from the road. The discharge was estimated to be 0.006 m^3/sec for the high flow sampling period in December. March and June were estimated to have comparably low flow discharges of 0.0015 m^3/sec and 0.0018 m^3/sec, respectively. The Irving Oil Refinery was shutdown during the June sampling period.

Analytical results are presented in Table 4-6. Concentrations of base parameters were among the highest recorded in any of the tributaries and tended to increase during low flow periods. Values for oil and grease (total) were the highest found in any of the tributaries.

Resin and fatty acid concentrations were among the highest recorded at any of the tributaries.

4.1.4 Hazen Creek

Hazen Creek has a drainage area of approximately 7.2 km^2, making it the smallest tributary sampled. Discharge rates varied from high flows in December of 0.006 m^3/sec to low flows of 0.001 and 0.002 m^3/sec in March and June, respectively. Situated along the tributary are a residential area, industrial park and an asphalt plant. In addition, Hazen Creek is bordered by an oil pipeline running from Canaport to the Irving Oil Refinery. No historical water quality data are available for Hazen Creek.

The sampling point for the present study was located approximately 10 m downstream of the bridge crossing on the Red Head Road.

Data for low and high flow sampling periods are presented in Table 4-7. Water quality for this tributary is comparable with that from the St. John River. Base parameters were not found in excessively high amounts.

TABLE 4-6
Water Quality Data - Little River

Parameters	High Flows 1991 12 06	Low Flows 1992 03 04
BASE PARAMETERS		
BOD (total) (mg/L)	270	375
BOD (soluble) (mg/L)	236	487
TSS (mg/L)	230	230
TDS (mg/L)	716	1830
VSS (mg/L)	218	182
pH	5.9	5.9
TOC (mg/L)	178	245
COD (mg/L)	900	1060
TKN (mg/L)	4.5	3.4
-NH-N (mg/L)	<0.05	<0.05
Total phosphorus (mg/L)	1.0	2
Soluble phosphorus (mg/L)	<0.1	1.2
Cu (µg/l)	7.0	13
Pb (µg/l)	1.4	3.8
Zn (µg/l)	50	13
Hg (µg/l)	0.11	<0.05
Cd (µg/l)	<0.5	0.5
Total Coliform (/100 mL)	46000	160000
Fecal Coliform (/100 mL)	2300	130
E. coli (/100 mL)	400	17
Oil and grease (total) (mg/L)	10.0	21
Mineral oil and grease (petrogenic) (mg/L)	1.3	1.2
Chloride (mg/L)	n/a	131
Sodium (mg/L)	n/a	405
ADDITIONAL PARAMETERS		
Phenolics (as phenols) (mg/L)	0.700	0.34
Cyanides (mg/L)	<0.005	0.008
Hydrogen Sulphide (mg/L)	<0.1	5.7
Chlorinated Organics		
Adsorbable Organic Halide (mg/L)	0.09	0.08
Polychlorinated Biphenyl (PCBs) (ppb)	<1.0	n/a
Extractable Organic Chlorine (ppb)	n/a	8.1
Organochlorinated pesticides (ppb)		
Heptachlor	<0.5	n/a
Aldrin	<0.1	n/a
Heptachlorepoxide	<0.5	n/a
Gamma chlordane	<0.1	n/a
Alpha chlordane	<0.1	n/a
Dieldrin	<0.1	n/a
DDT	<0.1	n/a
DDD	<0.1	n/a
DDE	<0.1	n/a
Organophosphorous & triazines (ppb)		
Glyphosate	<1.0	<1.0
Naled	<0.50	n/a
Mevinphos	<0.50	n/a
Acephate	<0.50	n/a
Terbufos	<0.50	n/a
Fonofos	<0.50	n/a
Methyl parathion	<0.50	n/a
Chlorpyrifos	<0.50	n/a
Fenthion	<0.50	n/a
Chlorfenvinphos	<0.50	n/a
Methidathion	<0.50	n/a
Phosalon	<0.50	n/a
Atrazine	<0.50	n/a
Cyanazine	<0.50	n/a
Simazine	<0.50	n/a
Propazine	<0.50	n/a
Phenoxy acid/neutral herbicides and carbamates (ppb)		
Dicamba	<0.10	n/a
MCPA	<0.10	n/a
2,4,-D	<0.10	n/a
2,4,5,-T	n/a	<0.10
2,4,5,-T,P	n/a	<0.10
Treflan	<0.10	n/a
Bromoxynil	<0.10	n/a
Triallate	<0.10	n/a
Tordon	<0.10	n/a
Diclofop-methyl	<0.10	n/a
Aldicarb	<1.0	n/a
Methomyl	<1.0	n/a
Carbofuron	<1.0	n/a
Carbaryl	<1.0	n/a
Methiocarb	<1.0	n/a
Polynuclear aromatic hydrocarbons (ppb)		
Naphthalene	n/a	<0.01
Acenapthylene	n/a	<0.01
Acenaphthene	n/a	<0.01
Fluorene	n/a	<0.01
Phenanthrene	n/a	<0.01
Anthracene	n/a	<0.01
Fluoranthene	n/a	<0.44
Pyrene	n/a	<0.01
Benzo (a) anthracene	n/a	<0.01
Chrysene	n/a	<0.01
Benzo (b,j,k) fluoranthene	n/a	<0.01
Benzo (a) pyrene	n/a	<0.01
Dibenz (a,h) anthracene	n/a	<0.01
Indeno (1,2,3-cd) pyrene	n/a	<0.01
Benzo (g,h,i) perylene	n/a	<0.01
Dioxins & furans (pg/L)		
2,3,7,8-T_4CDD	<2.5	<1.0
1,2,3,7,8-P_5CDD	<2.3	<1.0
1,2,3,4,7,8-H_6CDD	<4.0	<1.0
1,2,3,6,7,8-H_6CDD	<3.1	<1.0
1,2,3,4,6,7,8-H_7CDD	6.9	<1.0
O_8CDD	260.0	20
2,3,7,8-T_4CDF	<2.0	<1.0
2,3,4,7,8-P_5CDF	<1.8	<1.0
1,2,3,7,8-P_5CDF	<1.7	<1.0
1,2,3,4,7,8-H_6CDF	<2.1	<1.0
2,3,4,6,7,8-H_6CDF	<2.1	<1.0
1,2,3,6,7,8-H_6CDF	<1.9	<1.0
1,2,3,7,8,9-H_6CDF	<3.2	<1.0
1,2,3,4,6,7,8-H_7CDF	<2.8	<1.0
1,2,3,4,7,8,9-H_7CDF	<6.9	<1.0
O_8CDF	<12.0	<1.0
Resin and fatty acids (ppb)		
Myristic acid	13	14
Palmitic acid	150	210
Oleic acid	260	300
Linoleic acid	500	1200
Stearic acid	27	100
Linolenic acid	730	<0.63
Pimaric acid	160	250
Arachidic acid	24	22
Sandaracopimaric acid	300	470
Levopimaric acid	840	1100
Palustric acid	1000	1500
Dehydroabietic acid	1100	1300
Abietic acid	<1.3	12000
Neoabietic acid	1000	170000
9, 10 - Dichlorostearic acid	<1.3	<0.63
14 - Chlorodehydroabietic acid (#1)	<1.3	<0.63
12 - Chlorodehydroabietic acid (#2)	<1.3	<0.63
12, 14 - Dichlorodehydroabietic acid	<1.3	<0.63

n/a not analyzed

TABLE 4-7
Water Quality Data - Hazen Creek

Parameters	High Flows 1991 12 06	Low Flows 1992 03 04
BASE PARAMETERS		
BOD (total) (mg/L)	<2	<2
BOD (soluble) (mg/L)	<2	<2
TSS (mg/L)	0.8	4.8
TDS (mg/L)	177	577
VSS (mg/L)	<0.4	2.8
pH	7.3	6.9
TOC (mg/L)	5.0	3.3
COD (mg/L)	17	18
TKN (mg/L)	1.7	0.4
NH_3-N (mg/L)	<0.05	0.13
Total phosphorus (mg/L)	<0.1	<0.1
Soluble phosphorus (mg/L)	0.6	<0.1
Cu (µg/l)	2	2
Pb (µg/l)	0.4	0.6
Zn (µg/l)	6	10
Hg (µg/l)	0.07	<0.05
Cd (µg/l)	<0.5	<0.5
Total Coliform (/100 mL)	400	46000
Fecal Coliform (/100 mL)	0	700
E. coli (/100 mL)	0	0
Oil and grease (total) (mg/L)	<1.0	<1.0
Mineral oil and grease (petrogenic) (mg/L)	<1.0	<1.0
Chloride (mg/L)	n/a	293
Sodium (mg/L)	n/a	170
ADDITIONAL PARAMETERS		
Phenolics (as phenols) (mg/L)	<0.002	<0.002
Cyanides (mg/L)	<0.005	<0.005
Hydrogen Sulphide (mg/L)	<0.1	<0.1
Chlorinated Organics		
Adsorbable Organic Halide (mg/L)	0.04	0.03
Polychlorinated Biphenyl (PCBs) (ppb)	<1.0	n/a
Extractable Organic Chlorine (ppb)	n/a	7.9
Organochlorinated pesticides (ppb)		
Heptachlor	<0.5	n/a
Aldrin	<0.1	n/a
Heptachlorepoxide	<0.5	n/a
Gamma chlordane	<0.1	n/a
Alpha chlordane	<0.1	n/a
Dieldrin	<0.1	n/a
DDT	<0.1	n/a
DDD	<0.1	n/a
DDE	<0.1	n/a
Organophosphorous & triazines (ppb)		
Glyphosate	<1.0	<1.0
Naled	<0.50	n/a
Mevinphos	<0.50	n/a
Acephate	<0.50	n/a
Terbufos	<0.50	n/a
Fonofos	<0.50	n/a
Methyl parathion	<0.50	n/a
Chlorpyrifos	<0.50	n/a
Fenthion	<0.50	n/a
Chlorfenvinphos	<0.50	n/a
Methidathion	<0.50	n/a
Phosalon	<0.50	n/a
Atrazine	<0.50	n/a
Cyanazine	<0.50	n/a
Simazine	<0.50	n/a
Propazine	<0.50	n/a
Phenoxy acid/neutral herbicides and carbamates (ppb)		
Dicamba	<0.10	n/a
MCPA	<0.10	n/a
2,4,-D	<0.10	n/a
2,4,5,-T	n/a	<0.10
2,4,5,-T,P	n/a	<0.10
Treflan	<0.10	n/a
Bromoxynil	<0.10	n/a
Triallate	<0.10	n/a
Tordon	<0.10	n/a
Diclofop-methyl	<0.10	n/a
Aldicarb	<1.0	n/a
Methomyl	<1.0	n/a
Carbofuron	<1.0	n/a
Carbaryl	<1.0	n/a
Methiocarb	<1.0	n/a
Polynuclear aromatic hydrocarbons (ppb)		
Naphthalene	<0.01	<0.01
Acenapthylene	<0.01	<0.01
Acenaphthene	<0.01	<0.01
Fluorene	<0.01	<0.01
Phenanthrene	<0.01	<0.01
Anthracene	<0.01	<0.01
Fluoranthene	<0.01	<0.01
Pyrene	<0.01	<0.01
Benzo (a) anthracene	<0.01	<0.01
Chrysene	<0.01	<0.01
Benzo (b,j,k) fluoranthene	<0.01	<0.01
Benzo (a) pyrene	<0.01	<0.01
Dibenz (a,h) anthracene	<0.01	<0.01
Indeno (1,2,3-cd) pyrene	<0.01	<0.01
Benzo (g,h,i) perylene	<0.01	<0.01
Dioxins & furans (pg/L)		
2,3,7,8-T_4CDD	<1.4	<1.0
1,2,3,7,8-P_5CDD	<1.5	<1.0
1,2,3,4,7,8-H_6CDD	<2.1	<1.0
1,2,3,6,7,8-H_6CDD	<1.6	<1.0
1,2,3,7,8,9-H_6CDD	<1.8	<1.0
1,2,3,4,6,7,8-H_7CDD	<3.8	<1.0
O_8CDD	<8.8	<2.0
2,3,7,8-T_4CDF	<0.9	<1.0
2,3,4,7,8-P_5CDF	<1.2	<1.0
1,2,3,7,8-P_5CDF	<1.4	<1.0
1,2,3,4,7,8-H_6CDF	<1.4	<1.0
2,3,4,6,7,8-H_6CDF	<1.2	<1.0
1,2,3,6,7,8-H_6CDF	<1.2	<1.0
1,2,3,7,8,9-H_6CDF	<1.7	<1.0
1,2,3,4,6,7,8-H_7CDF	<2.2	<1.0
1,2,3,4,7,8,9-H_7CDF	<4.1	<1.0
O_8CDF	<7.9	<2.0
Resin and fatty acids (ppb)		
Myristic acid	<1.30	<0.63
Palmitic acid	<1.30	<0.63
Oleic acid	<1.30	<0.63
Linoleic acid	7.0	<0.63
Stearic acid	<1.30	2.3
Linolenic acid	1.6	<0.63
Pimaric acid	<1.30	<0.63
Arachidic acid	<1.30	<0.63
Sandaracopimaric acid	<1.30	<0.63
Levopimaric acid / Isopimaric acid	<1.30	<0.63
Palustric acid	<1.30	<0.63
Dehydroabietic acid	<1.30	<0.63
Abietic acid	<1.30	<0.63
Neoabietic acid	<1.30	<0.63
9, 10 - Dichlorostearic acid	<1.30	<0.63
14 - Chlorodehydroabietic acid (#1)	<1.30	<0.63
12 - Chlorodehydroabietic acid (#2)	<1.30	<0.63
12, 14 - Dichlorodehydroabietic acid	<1.30	<0.63

n/a - not analyzed

Phenolics, pesticides, organophophorous, and triazines, phenoxyacid/ neutral herbicides and carbomates, polyaromatic hydrocarbons, PCBs, and dioxins, and furans were below detectable limits. Some resin and fatty acids were detected but most were also below detectable limits.

4.2 Industrial Characterization

Saint John is the largest city in the Province of New Brunswick and is also New Brunswick's main industrial centre. Pulp and paper mills, breweries, oil and sugar refineries and many small secondary industries are located in the city. In addition, Saint John has one of the world's largest ice free ports which permits cargo handling and drydocking operations throughout the year. Effluent discharge into Saint John Harbour has long been a cause for concern, not only with respect to declining aesthetic quality in the Harbour, but also by possible coastal resource impacts.

Characterizations for each industry are based on historical information obtained through literature searches and compliance reports obtained from the Environment Canada and the New Brunswick Department of Environment. In addition, information on production rates was furnished by the respective industries. Estimated flow rates for each industry at the time of sampling are summarized in Table 4-8.

An industrial sampling program was undertaken to provide current information and to fill in data deficiencies identified from previous literature searches. Sampling was conducted at most industries over a 24-hour period (sampling at T.S. Simms & Co. Ltd. was conducted over a 12-hour period corresponding to the typical work cycle) and composite samplers were utilized where possible. Where no composite sampler was available grab sampling was conducted every 3 hours and the samples were composited at laboratory facilities at the Chemistry Department of the University of New Brunswick in Saint John. For organic parameters sampling was done in glass to prevent potential interference associated with reactions between contaminant parameters and plastic collection vessels.

TABLE 4-8
Estimated Flow Rates at the Time of Sampling

Industry	Flow Rate (m^3/day)
Irving Pulp and Paper Ltd.	75,000
Irving Tissue Ltd.	9,630
Irving Paper Ltd.	39,840
Irving Oil Refinery	16,910
Lantic Sugar Ltd.	22,000
Moosehead Breweries Ltd.	2230
T.S. Simms & Co. Ltd.	<10
NB Power - Courtenay Bay	1,580
NB Power - Coleson Cove	1,890

All samples were refrigerated prior to being shipped to an independent laboratory for analysis. A list of parameters submitted for analysis for each of the respective industries is presented in Table 4-9.

4.2.2 Results of Industrial Effluent Characterization

This study directly investigated nine industries as point source contributors of contaminants to Saint John Harbour. These included Moosehead Breweries Ltd., Lantic Sugar Ltd., T.S. Simms & Co. Ltd., NB Power Coleson Cove and Courtenay Bay generating stations, Irving Tissue Ltd., Irving Paper Ltd., Irving Pulp and Paper Ltd., and the Irving Oil Refinery. It is understood that the industries investigated in this study do not represent an exhaustive list of industrial discharges to the Harbour. These industries have been identified by past studies and regulatory agencies as having the greatest potential for significant contamination of the Harbour.

Moosehead Breweries Ltd.

Moosehead Breweries Ltd. produces approximately 80 million litres of beer annually. Approximately 10 times the volume of beer produced annually is discharged as liquid effluent. This accounts for all brewery processes. No on-site treatment facilities exist,

TABLE 4-9
Sampling Parameters for Industrial Effluent Characterization

Parameter	IP&P	IT	IP	IOR	LS	MB	TSSCL	NBP1	NBP2
Base(1)	X	X	X	X	X	X	X	X	X
Chlorophenols	X	X	X	X					
Resin & Fatty Acids	X	X	X						
Cyanides				X					
Dioxins and Furans				X					
TPH				X			X	X	X
PAHs	X	X	X	X			X		
PCBs	X	X	X	X			X		
Sulphides	X	X	X	X	X		X		
AOX	X	X	X	X					
Phenols	X	X	X	X			X		
Toxicity Testing (3)	X	X	X	X	X	X	X	X	X

IP&P Irving Pulp and Paper Ltd.
IT Irving Tissue Ltd.
IP Irving Paper Ltd.
IOR Irving Oil Refinery
(2)LS Lantic Sugar Ltd.
MB Moosehead Breweries Ltd.
TSSCL TS Simms & Co. Ltd.
(4)NBP1 NB Power Courtenay Bay Generating Station
(4)NBP2 NB Power Coleson Cove Generating Station

(1) Base includes all base parameters analyzed for tributary (see Table 4-3).
(2) Toxicity testing for this industry includes 96 hr LC_{50} Rainbow Trout only.
(3) Toxicity testing includes 48 hr LC_{50} Daphnia magna; 96 hr LC_{50} Rainbow Trout; 7-day larval survival and growth Fathead Minnow; and SOS Chromotest.
(4) Heavy metal analysis includes Vanadium.

although the brewery has recently installed a state-of-the-art caustic regeneration system. Much of the raw product used to produce beer is recovered and sold for use as feed for livestock. Yeast is recovered and the spent grain is sold to farmers.

Brewing typically starts on Sunday night and a batch is ready to run off by Thursday. Each of the processes including brewing and fermentation take approximately one week to complete. Following primary and secondary storage the product is packaged and bottled. In addition, the quality of effluent from the bottleshop will vary depending on whether domestic or export beer is being produced. Domestic beer is bottled in reusable bottles which generates more sludge during the cleaning process. Export beer is bottled in new bottles. Liquid effluents are discharged into the City of Saint John sewage system. Ultimate discharge is via a pipe near Reversing Falls.

Sampling was conducted by means of grab samples from a manhole located downslope from the property. Samples were taken every three hours over a 24-hour period. Production normally is constant over a 24-hour period except at certain times of the year when a general shut-down occurs. Beer is produced on a batch system and consequently effluent quality varies from very concentrated with high suspended solid loads to dilute as a batch is completed and equipment cleaning occurs. Data obtained from sampling of Moosehead Breweries is summarized in Table 4-10.

The present study utilized a 24-hour composite sampling period. Previous work utilized grab sampling over a five- to seven-hour period and possibly sampled a direct batch runoff and ignored effluent reduction on an interim basis.

Sampling showed this effluent to be high in BOD, organic carbon and solids, and coliform bacteria. Evaluation of historical effluent data from this industry suggests an improvement in effluent quality in recent years.

Lantic Sugar Ltd.

Lantic Sugar processes raw sugar into various table-ready products at a plant located on the east side of Saint John Harbour. The plant is approximately 1 km south of Saint John City centre and receives its water for process operations from the municipal water system. The plant discharges untreated effluent from two main sewer systems (termed north and south sewers) directly into Saint John Harbour. The refinery utilizes saltwater pumped from the harbour for cooling water. This cooling water supply is transferred through the north sewer, a closed system where it is utilized for the cooling of a series of condensers. Occasionally wastewater is added to this system as operating conditions vary and consequently discharge quantity and quality varies. Wastewater, principally from the flume station and batch tanks, is discharged directly from the south sewer.

TABLE 4-10
Effluent Sampling Data - Moosehead Breweries Ltd. Sampled 1992 06 10/11

BASE PARAMETERS	
BOD (total) (mg/L)	657
BOD (soluble) (mg/L)	562
TSS (mg/L)	170
VSS (mg/L)	158
TDS (mg/L)	279
pH	4.5
TOC (mg/L)	245
COD (mg/L)	66
TKN (mg/L)	19.0
-NH-N (mg/L)	<0.05
Total phosphorus (mg/L)	2.9
Soluble phosphorus (mg/L)	1.6
Cu (μg/l)	170
Pb (μg/l)	10
Zn (μg/l)	210
Hg (μg/l)	<0.05
Cd (μg/l)	<0.5
Total Coliform (/100 mL)	$\geq$2400000
Fecal Coliform (/100 mL)	$\geq$2400000
E. coli (/100 mL)	$\geq$2400000
Oil and grease (total) (mg/L)	5.7
Mineral oil and grease (petrogenic) (mg/L)	<1

Sugar is refined in batches. The majority of the effluent results from this process. On average 10 batch tank loads are released in a 24-hour work period with an average volume of 4200 US gallons each. Approximately 250,000 tonnes of sugar are produced per year or approximately 1,000 tonnes per day.

Both the north and south sewers were grab sampled every 3-hours over a 24-hour period. Samples from both sewers were composited based on flow proportioned information. Flows from the north sewer have been estimated as approximately 20,500 m^3/day and flow from the south sewer comprises approximately 1,900 m^3/day.

Data obtained from 1992 sampling is presented in Table 4-11. Sampling of this effluent showed high levels of BOD, COD, organic carbon, solids, and coliforms.

TABLE 4-11
Effluent Sampling Data - Lantic Sugar Ltd. - Sampled 1992 06 11/12

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	355
BOD (soluble) (mg/L)	335
TSS (mg/L)	123
TDS (mg/L)	19100
VSS (mg/L)	51
pH	6.1
TOC (mg/L)	270
COD (mg/L)	980
TKN (mg/L)	2.7
-NH-N (mg/L)	<0.05
Total phosphorus (mg/L)	3.9
Soluble phosphorus (mg/L)	4.3
Cu (μg/l)	13
Pb (μg/l)	1.5
Zn (μg/l)	12
Hg (μg/l)	<0.05
Cd (μg/l)	0.5
Total Coliform (/100 mL)	≥240 000
Fecal Coliform (/100 mL)	≥240 000
E. coli (/100 mL)	≥240 000
Oil and grease (total) (mg/L)	2.9
Mineral oil and grease (petrogenic) (mg/L)	<1
Hydrogen sulphide (mg/L)	<0.1

T.S. Simms & Co. Ltd.

T.S. Simms & Co. Ltd. manufactures paint brushes, paint rollers, and other items. Fabrication and assembly proceed from raw materials to the finished product. T.S. Simms & Co. Ltd. distributes its goods worldwide and employs approximately 213 people. Typical water usage during peak production is 9,400 L/day.

Sampling was conducted over a 12-hour period during a typical work day. Grab samples were obtained from two sewer lines on the property, one carrying sewage and any wastewater generated in the plant; the other handling storm runoff from the property and receiving a small discharge of cooling water from the air compressors used in plastic moulding.

A summary of values obtained for the analytical parameters is presented in Table 4-12. This effluent sample showed high coliform levels and trace concentrations of PAHs. Other potential contaminants of interest such as petroleum hydrocarbons, sulphide and PCBs, were below detection limits.

NB Power Generating Station - Coleson Cove

The Coleson Cove Thermal Generating Station is located on a 46.9 ha site on the western border of the City of Saint John. Station design capacity is 1050 megawatts (MW) making Coleson Cove the largest thermal generating station in Eastern Canada. Coleson Cove operates 24-hours per day, 365 days per year with a staff of 150. Three generators are in operation, the last commissioned in 1977 with each unit capable of producing 350 MW.

The station utilizes condensing water from the Bay of Fundy. Cooling water is conveyed via a high pressure closed system within the plant from the Bay of Fundy at a rate of 1.4 x 10^6L/min and returned to the Bay of Fundy unaltered except for a 5°C increase in temperature. Water used in the steam cycle comes from Saint John's Spruce Lake water reservoir and is demineralized before use.

Samples from Coleson Cove were obtained over a 24-hour period from a composite sampler set by the industry to obtain a given volume over a 3-hour interval. Effluent sampled consisted of final discharge from the wastewater treatment plant, which ultimately reaches the Bay of Fundy via the cooling water discharge. Cooling water was not sampled due to the presence of a high pressure system and associated difficulties in sampling an enclosed system.

Historical data furnished through monthly summaries submitted to Environment New Brunswick cite yearly averages for pH at 8.41, suspended solids 9.49 mg/L and oil and

TABLE 4-12

Effluent Sampling Data - T.S. Simms & Co. Ltd. - Sampled 1992 06 11

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	4.0
BOD (soluble) (mg/L)	<2
TSS (mg/L)	14.4
TDS (mg/L)	7520
VSS (mg/L)	6.4
pH	6.9
TOC (mg/L)	3.7
COD (mg/L)	340
TKN (mg/L)	8.1
-NH-N (mg/L)	7.70
Total phosphorus (mg/L)	0.6
Soluble phosphorus (mg/L)	0.6
Cu (μg/l)	84
Pb (μg/l)	2.8
Zn (μg/l)	23
Hg (μg/l)	0.13
Cd (μg/l)	<0.5
Total Coliform (/100 mL)	35000
Fecal Coliform (/100 mL)	0
E. coli (/100 mL)	0
Oil and grease (total) (mg/L)	<1
Mineral oil and grease (petrogenic) (mg/L)	<1
Polychlorinated Byphenyls (PCBs)	n/d
Phenolics (mg/L)	0.011
Hydrogen sulfide (mg/L)	<0.02
Polynuclear aromatic hydrocarbons (PAHs) (μg/L)	
Naphthalene	<0.02
Acenophthylene	<0.02
Acenaphthene	<0.02
Flourene	<0.02
Phananthrene	0.020
Anthracene	<0.02
Fluoranthene	0.040
Pyrene	0.030
Benzo (a) anthracene	0.040
Chrysene	0.020
Benzo (b) flouranthene	<0.02
Benzo (a) pyrene	<0.02
Dibenz (a,h) anthracene	<0.05
Ideno (1, 2, 3 - cd) pyrene	<0.05
Benzo (g, h, i) perylene	<0.05
Total Petroleum Hydrocarbons (mg/L)	
Benzene	<0.002
Toluene	<0.002
Ethyl Benzene	<0.002
Xylenes	<0.002
Gasoline	<0.01
Fuel oil/Diesel	<0.05
Other Hydrocarbons	<0.05

grease < 10 mg/L. Flow from the wastewater treatment plant was given as 1886.1 m^3/day. Heavy metals were low, with the exception of vanadium (8.67 mg/L) and iron (1.11 mg/L).

A summary of data obtained in the current study is presented in Table 4-13. The sample from Coleson Cove showed high coliform, copper, and vanadium levels, while all other parameters were low. Coleson Cove personnel have indicated that these high levels appear to be very unusual and inconsistent with their own sampling results. The measured copper value of 0.97 mg/L was higher than that historically reported (average of 0.036 mg/L with a maximum of 0.64 mg/L). Analysis showed low concentrations of petroleum hydrocarbons.

NB Power Generating Station - Courtenay Bay

The Courtenay Bay Thermal Generating Station is located on the eastern side of the City, just off Bayside Drive. Station design capacity is 265 MW. Operation occurs 24-hours a day throughout the entire year. There are 4 generators in operation, the last commissioned in 1969.

The station utilizes condensing water from Courtenay Bay which is conveyed via a high pressure closed system. Cooling water is transported and returned to Courtenay Bay unaltered except for a 15°C increase in temperature. Water used in steam generation comes from Saint John's Loch Lommond water reservoir and is demineralized before use.

Samples at Courtenay Bay were obtained at 3-hour intervals from a hose which supplies water from the wastewater treatment system to the composite sampler. Cooling water was not sampled due to high pressure problems previously described for Coleson Cove.

Historical data furnished through monthly summaries submitted to Environment New Brunswick cite yearly averages for pH at 7.97, suspended solids 14.3 mg/L and oil and grease <10 mg/L. Flows were estimated at 1248.9 m^3/day. Heavy metals were 1.10 mg/L for iron and 1.96 mg/L for vanadium.

TABLE 4-13

Effluent Sampling Data - NB Power Coleson Cove - Sampled 1992 06 10/11

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	6.0
BOD (soluble) (mg/L)	<2.0
TSS (mg/L)	9.5
VSS (mg/L)	5.0
TDS (mg/L)	2860
pH	7.4
TOC (mg/L)	2.8
COD (mg/L)	21
TKN (mg/L)	0.7
-NH-N (mg/L)	0.28
Total phosphorus (mg/L)	<0.1
Soluble phosphorus (mg/L)	<0.1
Cu (μg/l)	970
Pb (μg/l)	14
Zn (μg/l)	40
Hg (μg/l)	0.09
Cd (μg/l)	<0.5
V (μg/l)	9200
Total Coliform (/100 mL)	330
Fecal Coliform (/100 mL)	50
E. coli (/100 mL)	0
Oil and grease (total) (mg/L)	<1
Mineral oil and grease (petrogenic) (mg/L)	<1
Total Petroleum Hydrocarbons (TPH) (mg/L)	
Benzene	<0.002
Toluene	<0.002
Ethyl Benzene	<0.002
Xylenes	<0.002
Gasoline	<0.01
Fuel Oil/Diesel	<0.05
Other Hydrocarbons	<0.05

A summary of data obtained in the current study is presented in Table 4-14. Courtenay Bay sample results showed all parameters to be in low concentration, except for vanadium which was 2 mg/L.

Irving Tissue Ltd.

Irving Tissue, formerly Kimberley-Clarke (Canada Ltd.), is located on the west side of Saint John near Reversing Falls. The company produces bulk tissue products from raw materials. Cutting and packaging of the product is completed at a plant in Moncton. Paper products are produced by two paper machines. Annual production of tissue products was 42.1 x 10^3 tonnes in 1991.

Wastewater treatment consists of filtering effluent for removal of suspended fibre and effluents are discharged directly to Reversing Falls. Effluent pH is approximately 6.6. Suspended solids averaged 7.50 kg/tonne/day in 1991, a reduction by half from 1990 values of 15.33 kg/tonne/day. Resin acids at 0.1 mg/L and fatty acids were all below 0.03 mg/L. BOD ranged between 25 and 60 mg/L and COD was 310 mg/L. Heavy metals were all below 0.25 mg/L, TKN was 11.36 mg/L,and suspended solids were 148.3 mg/L.

Sampling at Irving Tissue was from a composite sampler set to deliver the required volume within a 24-hour period. Discharge flow rate at time of sampling was about 9,630 m^3/day. Production was approximately 157 tonnes/day. Analytical results are given in Table 4-15.

The composite samples of this effluent showed high COD, solids, and coliforms. Phenols, sulphides, AOX, PCBs, PAHs, resins and fatty acids, and chlorophenols all showed concentrations that were low or below the level of detection.

Irving Paper Ltd.

Irving Paper, formerly Rothesay Paper, is located on the east side of Saint John off Bayside Drive. The company produces approximately 825 tonnes/day of newsprint. A typical work cycle is 7-days per week throughout the entire year.

TABLE 4-14
Effluent Sampling Data - NB Power Courtenay Bay - Sampled 1992 06 11/12

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	3
BOD (soluble) (mg/L)	3
TSS (mg/L)	24.6
TDS (mg/L)	15200
VSS (mg/L)	5.5
pH	7.7
TOC (mg/L)	2.0
COD (mg/L)	<100
TKN (mg/L)	0.2
-NH-N (mg/L)	<0.05
Total phosphorus (mg/L)	<0.1
Soluble phosphorus (mg/L)	<0.1
Cu (µg/l)	12
Pb (µg/l)	1.5
Zn (µg/l)	6
Hg (µg/l)	<0.05
Cd (µg/l)	<0.5
V (µg/l)	2000
Total Coliform (/100 mL)	0
Fecal Coliform (/100 mL)	0
E. coli (/100 mL)	0
Oil and grease (total) (mg/L)	<1
Mineral oil and grease (petrogenic) (mg/L)	<1
Total Petroleum Hydrocarbons (TPH) (mg/L)	
Benzene	<0.002
Toluene	<0.002
Ethyl Benzene	<0.002
Xylenes	<0.002
Gasoline	<0.01
Fuel Oils	<0.05
Others	<0.05

TABLE 4-15

Effluent Sampling Data - Irving Tissue Sampled 1992 06 23/24

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	68
BOD (soluble) (mg/L)	22
TSS (mg/L)	120
TDS (mg/L)	133
VSS (mg/L)	113
pH	6.7
TOC (mg/L)	21.5
COD (mg/L)	215
TKN (mg/L)	1.1
-NH-N (mg/L)	<0.05
Total phosphorus (mg/L)	<0.1
Soluble phosphorus (mg/L)	<0.1
Cu (μg/l)	17
Pb (μg/l)	1.4
Zn (μg/l)	10
Hg (μg/l)	<0.05
Cd (μg/l)	<0.5
Total Coliform (/100 mL)	1700
Fecal Coliform (/100 mL)	0
E. coli (/100 mL)	0
Oil and grease (total) (mg/L)	3.1
Mineral oil and grease (petrogenic) (mg/L)	3.1
Phenolics (mg/L)	0.006
Hydrogen sulfide (mg/L)	<0.1
AOX (mg/L)	0.51
Polychlorinated Biphenyls (PCB) (mg/L)	<0.0001
POLYNUCLEAR AROMATIC HYDROCARBONS (PAH) (μg/L)	
Naphthalene	0.050
Acenaphthylene	<0.02
Acenaphthene	<0.02
Fluorene	<0.02
Phenanthrene	0.020
Anthracene	<0.02
Fluoranthene	<0.02
Pyrene	<0.02
Benz(a) anthracene	<0.02
Chrysene	<0.02
Benxo(b) Flyoranthene	<0.02
Benzo (a) pyrene	<0.02
Dibenz (a,h) anthracene	<0.05
Indeno (1, 2, 3, - cd)pyrene	<0.05
Benzo (g, h, i) perylene	<0.05

Parameters	
RESIN ACIDS AND FATTY ACIDS (mg/L)	
Abietic acid	n/d
14-Chlorodehydroabietic acid #1	n/d
12-Chlorodehydroabietic acid #2	n/d
Dehydroabietic acid	n/d
Isopimaric/Levopimaric/Palustric acid	n/d
Neoabietic acid	n/d
Oleic acid	n/d
Pimaric acid	n/d
Myristic acid	n/d
Palmitic acid	n/d
Linoleic acid	n/d
Stearic acid	n/d
Linolenic acid	n/d
Arachidic acid	0.015
Sandaracopimaric acid	n/d
9,10-Dichlorostearic acid	n/d
12,14-Dichlorodehydroabietic acid	n/d
CHLOROPHENOLS (μg/l)	
2-Chlorophenol	n/d
2,4-Dichlorophenol	n/d
2,4,6-Trichlorophenol	n/d
2,3,4,6-Tetrachlorophenol	n/d
Pentachlorophenol	n/d
4-Chlorocetechol	n/d
3,4-Dichlorocatechol	n/d
3,5-Dichlorocatechol	n/d
4,5-Dichlorocatechol	n/d
3,4,5-Trichlorocatechol	n/d
3,4,6-Trichlorocatechol	n/d
Tetrachlorocatechol	n/d
4-Chloroguaiacol	n/d
3,4-Dichloroguaiacol	n/d
4,5-Dichloroguaiacol	n/d
4,6-Diohloroguaiacol	n/d
3,4,5-Trichloroguaiacol	n/d
3,4,6-Trichloroguaiacol	n/d
4,5,6-Trichloroguaiacol	n/d
Tetrachloroguaiacol	n/d
4,5-Dichloroveratrole	n/d
3,4,5-Trichloroveratrole	n/d
Tetrachloroveratrole	n/d
4,5-Dichlorovreatrole	n/d
4,5,6-Trichlorosyringol	n/d

n/d - not detected

Detection Limits = 0.10 - Chlorophenols

= 0.010 - Resin and Fatty Acids

There are three sewers within the mill. The main sewer carries waste from the paper making process. Floor drains carry waste from around the mill in addition to sanitary sewage. All plant effluents are channelled to a primary clarifier system for suspended solids removal, with the final effluent discharged to Little River.

Average yearly flows for Irving Paper were 38343 m^3/day in 1990, and 33,190 m^3/day in 1991. Suspended solid discharges averaged 9.59 tonnes/day and 9.99 tonnes/day for the same years (New Brunswick Department of the Environment files). Compliance audits are annually conducted on selected industries by Environment Canada and NBDOE. Based on a review of these files the following parameters have been tested and recorded. BOD ranged from 119 mg/L to 480 mg/L, suspended solids 85 to 160 mg/L, COD 580 to 968 mg/L, pH 6.5, TKN 1.8, and DO was 6.3 mg/L. Heavy metals were <0.3 mg/L with the exception of aluminum at 710 mg/L. Resin acids were 9.5 mg/L and chlorophenols were not detected.

Sampling for the present study was from a composite sampler set to deliver the required volume over a 24-hour period. Results are presented in Table 4-16. The effluent sample was high in BOD, COD, solids and coliform bacteria. Heavy metals, AOX, sulphides, PCBs, PAHs, and chlorophenols were all low or below the level of detection.

Irving Pulp & Paper Ltd.

Irving Pulp and Paper operates a bleached kraft market pulp mill located at Reversing Falls on the St. John River. Up until 1977, a 300-ton per day sulphite mill was also operated on the same site. The mill uses freshwater purchased from the City for the pulping process and river water drawn from the St. John River for its condensers (Hildebrand, 1980). There are a total of seven effluent sources on the Irving Pulp & Paper property. These are designated as the machine room, oil recovery, main chemical, contaminated condensates, kraft brown stock, new recovery and the demineralizer. Wastewater treatment consists of internal spill recovery systems which result in solids removal. Discharge is directly to Reversing Falls.

TABLE 4-16
Effluent Sampling Data - Irving Paper Ltd. Sampled 1992 06 23/24

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	648
BOD (soluble) (mg/L)	217
TSS (mg/L)	175
TDS (mg/L)	630
VSS (mg/L)	170
pH	5.7
TOC (mg/L)	221
COD (mg/L)	1250
TKN (mg/L)	2.8
-NH-N (mg/L)	<0.05
Total phosphorus (mg/L)	2.3
Soluble phosphorus (mg/L)	1.8
Cu (μg/l)	7.0
Pb (μg/l)	1.1
Zn (μg/l)	65
Hg (μg/l)	0.05
Cd (μg/l)	<0.5
Total Coliform (/100 mL)	92000
Fecal Coliform (/100 mL)	≥24000
E. coli (/100 mL)	≥24000
Oil and grease (total) (mg/L)	12.0
Mineral oil and grease (petrogenic) (mg/L)	1.1
Phenolics (mg/L)	0.500
Hydrogen sulfide (mg/L)	<0.1
AOX (mg/L)	0.1
Polychlorinated Biphenyls (PCB) (mg/L)	<0.0001
POLYNUCLEAR AROMATIC HYDROCARBONS (PAH) (μg/l)	
Naphthalene	<0.02
Acenaphthylene	<0.02
Acenaphthene	<0.02
Fluorene	<0.02
Phenanthrene	0.020
Anthracene	<0.02
Fluoranthene	<0.02
Pyrene	<0.02
Benz(a) anthracene	<0.02
Chrysene	<0.02
Benxo(b) Flyoranthene	<0.02
Benzo (a) pyrene	<0.02
Dibenz (a,h) anthracene	<0.05
Indeno (1, 2, 3, - cd)pyrene	<0.05
Benzo (g, h, i) perylene	<0.05

Parameters	
RESIN ACIDS AND FATTY ACIDS (mg/L)	
Abietic acid	0.018
14-Chlorodehydroabietic acid #1	n/d
12-Chlorodehydroabietic acid #2	n/d
Dehydroabietic acid	1.6
Isopimaric/Levopimaric/Palustric acid	1.3
Neoabietic acid	0.61
Oleic acid	0.94
Pimaric acid	0.69
Myristic acid	0.038
Palmitic acid	0.36
Linoleic acid	1.3
Stearic acid	0.025
Linolenic acid	0.051
Arachidic acid	n/d
Sandaracopimaric acid	0.64
9,10-Dichlorostearic acid	n/d
12,14-Dichlorodehydroabietic acid	n/d
CHLOROPHENOLS (μg/L)	
2-Chlorophenol	n/d
2,4-Dichlorophenol	n/d
2,4,6-Trichlorophenol	n/d
2,3,4,6-Tetrachlorophenol	n/d
Pentachlorophenol	n/d
4-Chlorocetechol	n/d
3,4-Dichlorocatechol	n/d
3,5-Dichlorocatechol	n/d
4,5-Dichlorocatechol	n/d
3,4,5-Trichlorocatechol	n/d
3,4,6-Trichlorocatechol	n/d
Tetrachlorocatechol	n/d
4-Chloroguaiacol	n/d
3,4-Dichloroguaiacol	n/d
4,5 Dichloroguaiacol	n/d
4,6 Diohloroguaiacol	n/d
3,4,5-Trichloroguaiacol	n/d
3,4,6-Trichloroguaiacol	n/d
4,5,6-Trichloroguaiacol	n/d
Tetrachloroguaiacol	n/d
4,5-Dichloroveratrole	n/d
3,4,5-Trichloroveratrole	n/d
Tetrachloroveratrole	n/d
4,5,6-Trichlorosyringol	n/d

n/d - not detected
Detection Limits = 0.10 - Chlorophenols
= 0.01 - Resin and Fatty Acids

Historical data are available for this industry from compliance reports submitted to various regulatory agencies. Yearly averages for total suspended solids were 7,011 kg/day in 1990 and 5,669 kg/day in 1991. BOD values were 15,553 and 20,327 kg/day respectively. Total flow averages 78.27 x 10^3 m^3/day. Daily discharges of selected parameters can be summarized as follows: pH ranged from 7.9 to 8.5 with a low of 3.7; BOD values were 320-580 mg/L; COD was 940-1600 mg/L and suspended solids were from 25-140 mg/L. AOX has been recorded at 51.1 mg/L but recent values are 25.8 or lower. Sulphate was 0.16 mg/L with TKN at 1.82 mg/L. Heavy metal values for zinc were 0.96 mg/L and 0.76 mg/L for aluminum. Resin acids were <0.1 mg/L to 8.0 with chlorophenols at <0.03 mg/L.

Irving Pulp and Paper was the only industry not directly sampled or toured by WGA personnel. Samples were based on 24-hour flow proportioned composite sampling and were collected by Irving personnel. WGA received the samples at the end of the 24-hour sampling period. At the time of sampling discharge flows were about 75,000 m^3/day for 860 tonnes of production. Analytical results are given in Table 4-17.

As with Irving Paper, this combined effluent sample showed high BOD, COD, and solids. High levels of zinc and AOX were detected in this sample. Other parameters of interest showed concentrations that were low or below the level of detection.

<u>Irving Oil Refinery</u>

The Irving Oil Refinery was originally designed to process 45,000 barrels of crude oil per day. By 1975, the capacity of the refinery was expanded to 280,000 barrels per day (Hildebrand, 1980). It is presently the largest refinery in Atlantic Canada. The refinery operates 24 hours per day, throughout the year, except during scheduled shutdown periods. Approximately 410 people are employed.

Effluent is subjected to secondary treatment with final discharge directly into Little River. The refinery produces oil, gas, lubricants, and other by-products from the refining of crude oil. Total flow averaged 20,000 m^3/d in 1990 and 21,000 m^3/d in 1991.

TABLE 4-17
Effluent Sampling Data - Irving Pulp & Paper Ltd. Sampled 1992 06 23/24

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	470
BOD (soluble) (mg/L)	231
TSS (mg/L)	82
TDS (mg/L)	1680
VSS (mg/L)	78
pH	7
TOC (mg/L)	283
COD (mg/L)	1350
TKN (mg/L)	3.4
-NH N (mg/L)	<0.05
Total phosphorus (mg/L)	0.4
Soluble phosphorus (mg/L)	0.2
Cu (µg/l)	12.0
Pb (µg/l)	1.9
Zn (µg/l)	77.0
Hg (µg/l)	0.05
Cd (µg/l)	0.8
Total Coliform (/100 mL)	170
Fecal Coliform (/100 mL)	120
E. coli (/100 mL)	120
Oil and grease (total) (mg/L)	21.0
Mineral oil and grease (petrogenic) (mg/L)	11.0
Phenolics (mg/L)	2.00
Hydrogen sulfide (mg/L)	<0.1
AOX (mg/L)	12.3
Polychlorinated Biphenyls (PCB) (mg/L)	<0.0001
POLYAROMATIC HYDROCARBONS (PAH) (µg/l)	
Naphthalene	<0.02
Acenaphthylene	<0.02
Acenaphthene	<0.02
Fluorene	<0.02
Phenanthrene	<0.02
Anthracene	<0.02
Fluoranthene	<0.02
Pyrene	<0.02
Benz(a) anthracene	<0.02
Chrysene	<0.02
Benzo(b) Flyoranthene	<0.02
Benzo (a) pyrene	<0.02
Dibenz (a,h) anthracene	<0.05
Indeno (1, 2, 3, - cd)pyrene	<0.05
Benzo (g, h, i) perylene	<0.05

Parameters	
RESIN ACIDS AND FATTY ACIDS (mg/l)	
Abietic acid	1.1
14 Chlorodehydroabietic acid #1	n/d
12-Chlorodehydroabietic acid #2	0.017
Dehydroabietic acid	n/d
Isopimaric/Levopimaric/Palustric acid	0.26
Neoabietic acid	0.14
Oleic acid	n/d
Pimaric acid	0.11
Myristic acid	n/d
Palmitic acid	n/d
Linoleic acid	n/d
Stearic acid	n/d
Linolenic acid	n/d
Arachidic acid	n/d
Sandaracopimaric acid	0.11
9,10-Dichlorostearic acid	n/d
12,14-Dichlorodehydroabietic acid	0.80
CHLOROPHENOLS (µg/l)	
2-Chlorophenol	n/d
2,4-Dichlorophenol	0.50
2,4,6-Trichlorophenol	n/d
2,3,4,6-Tetrachlorophenol	n/d
Pentachlorophenol	n/d
4-Chlorocatechol	n/d
3,4-Dichlorocatechol	n/d
3,5-Dichlorocatechol	n/d
4,5-Dichlorocatechol	n/d
3,4,5-Trichlorocatechol	0.80 n/dr
3,4,6-Trichlorocatechol	n/d
Tetrachlorocatechol	0.30 n/dr
4-Chloroguaiacol	2.0
3,4-Dichloroguaiacol	0.80
4,5-Dichloroguaiacol	7.6
4,6-Dichloroguaiacol	n/d
3,4,5-Trichloroguaiacol	4.8
3,4,6-Trichloroguaiacol	n/d
4,5,6-Trichloroguaiacol	1.0
Tetrachloroguaiacol	2.7
4,5-Dichloroveratrole	n/d
3,4,5-Trichloroveratrole	n/d
Tetrachloroveratrole	n/d
4,5,6-Trichlorosyringol	n/d

n/dr = not detected due to ratio. This is a conservative estimate of the total amount present in the sample.

n/d = not detected
Detection Limits = 0.10 ppb - Chlorophenols
Detection Limits = 0.010 ppm - Resin and Fatty Acids

Historical effluent data for the refinery has resulted from testing conducted by Environment Canada and New Brunswick Department of the Environment. Values for pH ranged from 6.7 to 7.9. In general ammonia, oils, and total suspended materials were high with ranges from 55-64 kg/day, 272-344 kg/day and 391-422 kg/day, respectively (1990-1991 EC Data). Petroleum hydrocarbons concentrations, based on a 24-hour composite were 131 μg/L for benzene, 145 μg/L for xylene, and >5000 μg/L for gasoline. The total hydrocarbon concentration was 11,873 μg/L (1990 NBDOE data).

Analytical results of the current study are presented in Table 4-18. Many parameters of interest compared favourably with the historic data. For example, ammonia, oil and grease, and total suspended solids were approximately 34 kg/d, 169 kg/d, and 440 kg/d, respectively. The analysis indicates high concentrations of total dissolved solids and COD. The concentrations of PAHs were below detection limits, with the exception of naphthalene. It is interesting to note that all petroleum hydrocarbons were below detection limits. The dioxin/furan analysis indicates that most congegers are at low concentrations or below detection limits with the exception of OCDD.

4.2.3 Municipal Characterization

The Tri-Level Committee has estimated that there are approximately 135 municipal outfalls entering the Harbour. These outfalls vary significantly in size and water quality. Major outfalls are summarized by sub-area in Table 4-19.

A continuous wastewater quantity study was undertaken by ADI Limited in 1992 to determine wastewater flows at various locations throughout the city. Detailed information is provided in a separate report (Godfrey Associates Ltd., 1993). A total of 17 locations were monitored during the study, including four wastewater treatment facilities. The locations that were selected were to fill gaps in existing information and provide

TABLE 4-18
Effluent Sampling Data - Irving Oil Ltd. Sampled 1992 08 20

Parameters	
BASE PARAMETERS	
BOD (total) (mg/L)	16
BOD (soluble) (mg/L)	5
TSS (mg/L)	26
TDS (mg/L)	7360
VSS (mg/L)	22
pH	6.8
TOC (mg/L)	8.1
COD (mg/L)	330
TKN (mg/L)	5.4
-NH-N (mg/L)	2.02
Total phosphorus (mg/L)	0.8
Soluble phosphorus (mg/L)	0.4
Cu (μg/l)	2
Pb (μg/l)	1.2
Zn (μg/l)	70
Hg (μg/l)	<0.05
Cd (μg/l)	<0.5
Total Coliform (/100 mL)	170
Fecal Coliform (/100 mL)	22
E. coli (/100 mL)	5
Oil and grease (total) (mg/L)	10.0
Mineral oil and grease (petrogenic) (mg/L)	1.8
Phenolics (mg/L)	0.080
Hydrogen sulfide (mg/L)	0.16
Cyanide (mg/L)	<0.005
AOX (mg/L)	0.27
Polychlorinated Biphenyls (PCB) (mg/L)	<0.0001
POLYAROMATIC HYDROCARBONS (PAH) (μg/l)	
Naphthalene	2.04
Acenaphthylene	<0.02
Acenaphthene	<0.02
Fluorene	<0.02
Phenanthrene	<0.02
Anthracene	<0.02

Parameters	
Fluoranthene	<0.02
Pyrene	<0.02
Benz(a) anthracene	<0.02
Chrysene	<0.02
Benzo(b) Fluoranthene	<0.02
Benzo (a) pyrene	<0.02
Dibenz (a,h) anthracene	<0.02
Indeno (1, 2, 3, - cd)pyrene	<0.02
Benzo (g, h, i) perylene	<0.02
Total Petroleum Hydrocarbons (mg/L)	
Benzene	<0.002
Toluene	<0.002
Ethyl Benzene	<0.002
Xylenes	<0.002
Gasoline	<0.01
Fuel Oil/Diesel	<0.05
Other Hydrocarbons	<0.05
dioxins & furans (pg/L)	
2,3,7,8-T_4CDD	1.9 n/dr
1,2,3,7,8-P_5CDD	<1.8
1,2,3,4,7,8-H_6CDD	<4.6
1,2,3,6,7,8-H_6CDD	<3.6
1,2,3,4,6,7,8-H_7CDD	14 n/dr
O_8CDD	83
2,3,7,8-T_4CDF	2.6 n/dr
2,3,4,7,8-P_5CDF	<1.5
1,2,3,7,8-P_5CDF	<1.3
1,2,3,4,7,8-H_6CDF	5.2
2,3,4,6,7,8-H_6CDF	<2.7
1,2,3,6,7,8-H_6CDF	<2.0
1,2,3,7,8,9-H_6CDF	<3.6
1,2,3,4,6,7,8-H_7CDF	18 n/dr
1,2,3,4,7,8,9-H_7CDF	<7.9
O_8CDF	9.9

n/dr - Not detected due to incorrect isotope ratio. Value indicates concentration if ratio were correct.

TABLE 4-19
Summary of Major Municipal Sources by Sub-Area

Sub-Area	Approximate No. of Major Untreated Sources*	Approximate No. of Treated Sources*	No. of Sampling Locations
Outer Harbour	3	2	4
Harbour Bay	39	1	9
Above Reversing Falls	13	1	4
TOTALS	55	4	17

*There are approximately 135 total outfalls in the study area.

representative flow data for various areas and types of development in the City. The flow data obtained would be later used in combination with other data to size future collector sewers, pumping stations and, wastewater treatment facilities based on population and development growth.

The wastewater quantity study began on February 25, 1992 and continued through to April 4, 1992. During this time period, flow data were obtained for a period of one week per location. The only exception was additional flow monitoring which was carried out for a twenty-four hour period at three of the existing wastewater treatment plants.

In addition to the wastewater quantity monitoring, wastewater quality sampling was also carried out at five locations. The sampling locations were selected from the fourteen flow monitoring sites in order that the data could be related to flow. In each case, samples were taken at hourly intervals and combined into one 24 hour composite sample. Before combining the hourly samples, each one was combined into a two hour sample which was analyzed for BOD, pH and SS. This sampling procedure provided a diurnal analysis of wastewater strength. The 24 hour composite sample was then analyzed for numerous other parameters. Results are summarized in Table 4-20.

TABLE 4-20
Composite Municipal Wastewater Sample Results[1]

Sample Date Collected	Location #2 1992 03 10/11	Location #5 1992 03 5/6	Location #11 1992 03 18/19	Location #13 1992 03 9/10	Location #14 1992 03 4/5
Approximate Dry Weather Flow (m^3/day)	1060	5230	4410	1940	1760
pH	7.4	7.2	6.8	7.2	NA
SS (mg/L)	123	127	82	57	118
VSS (mg/L)	70	47	74	47	100
BOD (mg/L)	63	40	120	40	103
Sol BOD (mg/L)	22	5	70	10	19
COD (mg/L)	125	110	272	125	218
TKN (mg/L)	17	14	23	22	33
NH3-N (mg/L)	7.4	13	20	16	28
Tol-P (mg/L)	1.4	1.2	2.4	1.8	3.4
Sol P (mg/L)	0.61	0.82	1.4	0.54	2.1
FOG (mg/L)	8	8	20	7	16
DOC (mg/L)	16.1	10.8	26.8	12.9	21.0
Cd (ppm)	<0.01	<0.01	<0.01	<0.01	<0.01
Cu (ppm)	0.11	0.10	0.11	0.10	0.08
Pb (ppm)	<0.02	0.02	<0.02	<0.02	<0.02
Zn (ppm)	0.07	0.08	0.05	0.06	0.06
Hg (ppm)	<1	<1	<1	<1	<1
Tol Coliform/100 ml	4600000	4600000	2400000	2100000	4600000
F Coliform/100 ml	390000	75000	150000	1500000	46000
E. Coli/100 ml	29000	20000	150000	36000	15000

(1) see ADI Limited, 1992

Twenty-four hour composite samples were also collected when the additional flow monitoring was carried out at the three treatment plants. These samples were analyzed for BOD and SS only. Results are summarized in Table 4-21.

4.3 Guide to Toxicity Results Interpretation

The term "toxicity" refers to a wide range of biological responses, all of which represent impairment to the normal functioning of an organism or a community. A toxic response in

TABLE 4-21
Composite Test Results from Influent Sampling at Wastewater Treatment Plants

Sample Date Collected	Lancaster W.T.P. April 21/22	Millidgeville W.T.P. April 23/24	Hazen Creek W.T.P. April 27/28
Average Daily Flow (m^3/day)	5430	3630	3760
Suspended Solids SS (mg/L)	89.3	66.8	82.0
Volatile Suspended Solids VSS (mg/L)	66.0	39.2	67.2
Biochemical Oxygen Demand BOD (mg/L)	250	119.0	154.0

organisms results from a critical exposure to chemicals, compounds or a change in the physical environment. Typically, sources of effluent discharges may contain a number of contaminants, some of which may exceed their known individual toxic level. However, in a complete effluent mixture, the presence of one contaminant can increase or decrease the toxic effect of another contaminant. The potential interactions among toxicants will be as numerous as the number and combinations of contaminants in a mixed effluent. Therefore, knowing toxicant concentrations and the period of exposure alone is insufficient to precisely predict final effluent toxicity, since the interactions of toxicants can rarely be quantified. On the other hand, exposing biological organisms to complex effluent takes the guessing out of estimating the toxicity of individual compounds and the interaction with other contaminants.

The simplest way to estimate the toxicity of a liquid effluent in a receiving water is to conduct a laboratory toxicity test using standard test organisms and test protocol. The organisms used are representative of those expected to inhabit the receiving water (e.g., fish, invertebrates, and algae). The organisms responses monitored to determine toxicity include lethality, impaired growth, impaired reproduction or impaired physiological function.

The most frequent first-evaluation of an effluent is the determination of the LC50, a measure of acute lethality. This is the concentration which causes lethality in 50% of the exposed test organisms. Usually, a 96-hour test is used to determine the "acute" or short-term effects on fish, while a slightly shorter period, typically 48 hours, is used for smaller organisms (e.g., Daphnia). "Chronic" tests are used to measure long-term effects on organisms, and show effects on growth, reproduction, behaviour, etc. and, while not directly lethal to individuals, would contribute to the demise or lack of competitive vigour of a community, and therefore result in ecosystem impairment. When responses other than lethality are measured, the effluent exposure concentration which results in an impairment to 50% of the test organisms is called the EC50 (concentration which will affect 50% of exposed organisms).

The results of effluent toxicity tests are normally expressed as a percent volume of effluent (i.e., % v/v). Acute and chronic toxicity tests are used to quantify the combined toxicity of individual effluent contaminants, and to estimate the overall effect of this effluent on the receiving water ecosystem. Toxicity test results expressed as percent effluent can be used, together with hydraulic characteristics of the receiving water, to estimate the area of receiving water or distance downstream of a discharge pipe that may be toxic to aquatic life.

In addition to whole organism responses described above, toxicity can also be determined at the genetic level. Effluents from urban-industrial complexes may contain contaminants which have the ability to induce hereditary genetic defects and cancer. The presence of such genotoxic activity may be determined through biotesting with a genetically engineered strain of the bacteria, E. coli, using the SOS Chromotest System. This system detects genotoxicity in the effluents by measuring DNA damage colorimetrically. Genotoxic agents (carcinogens and mutagens, e.g. chemicals, irradiations) cause lesions in the bacterial DNA. Immediately thereafter the cell attempts to restore the DNA to its original condition by activating a repair system called SOS. The result of SOS repair efforts will determine the future of the cell. In a successful complete repair, the cell will resume its normal cycle and activities. In the case of an impossible repair, the damage will be too extensive and the cell will die. An incomplete repair will cause permanent changes in the genetic structure of the cell and may result in transmissible mutation or cancerous transformation of the cell.

In the SOS Chromotest System an unrelated enzyme gene, Lac Z (encodes for B-galactosidase), normally absent from these bacteria, is linked to an SOS parameter gene. When the SOS response is induced by genotoxic assault, the enzyme is synthesized and easily detected by a simple colour reaction. In the SOS Chromotest the production of B-galactosidase is the direct outcome of a genotoxic assault, and even the cells that do not divide would give a positive result.

4.3.1 Tributary Sources

Toxicity testing was conducted on tributary source samples collected during each of the wet and dry sampling periods. Initially (wet), testing included acute toxicity testing with Daphnia magna (48 hr exposure period) and chronic/sublethal testing (seven day exposure period) with the fathead minnow. Acute toxicity testing (96 hr exposure period) using rainbow trout was incorporated into the testing program conducted later, for the dry sampling period. Genotoxicity was tested using standard SOS Chromotest analysis. The results of toxicity testing are summarized in Table 4-22.

4.3.1.1 Wet Period

The sample from the St. John River is considered non-acutely toxic to Daphnia magna, but it did display slight toxicity. There was 20% daphnid mortality observed in the full strength sample only, during the test period. This sample displayed no toxicity and had no detrimental effect on larvae fish survival and growth over the exposure period.

The sample from Marsh Creek was acutely toxic, resulting in an LC_{50} of 45.5% for daphnids and an LC_{50} of 70.7% for fathead minnow.

Little River proved to be most toxic of the tributaries sampled. An acute LC_{50} of 30.3% and 12.8% was determined for daphnids and fathead minnow, respectively. A Chronic LC_{50} of 11.1% was determined for fathead minnow.

The Hazen Creek sample was not acutely toxic to daphnids and there was no mortality or sublethal effect observed. The sample displayed no toxicity and had no detrimental effect on larvae fish growth or survival.

TABLE 4-22 - Toxicity Test Results - Tributary and Industrial Sources

Location	Toxicity Testing										[3] SOS Chromotest for Genotoxicity
	[1] Acute Toxicity Testing (LC_{50}(%v/v))			[2] Chronic Toxicity Testing Using Fathead Minnow							
	Daphnia magna	Fathead minnow	Rainbow Trout	7-day LC_{50} (%v/v)	NOEC (%v/v)	LOEC (%v/v)	TEC (%v/v)	Ch.V. (%v/v)	IC_{25} (%v/v)	IC_{50} (%v/v)	
St. John River											
High Flows 1991 12 06	>100[a]	N.L.	-	N.L.	100	-	-	>100	-	>100	n/d
Marsh Creek											
High Flows 1991 12 06	45.5	70.7	-	70.7	50	100	-	70.7	-	70.0	n/d
Low Flows 1992 03 09	32.9	63.2	N.L.	55.5	25	50	35	-	57.7	71.8	n/d
Little River											
High Flows 1991 12 06	30.3	12.8	-	11.1	3.13	6.25	-	4.4	-	10.0	n/d
Low Flows 1992 03 09	15.5	5.0	7.2	3.9	0.39	0.78	0.55	-	2.4	4.2	n/d
Hazen Creek											
High Flows 1991 12 06	N.L.	>100[b]	-	>100[b]	100	-	-	>100	-	>100	n/d
Low Flows 1992 03 04	N.L.	>100[c]	N.L.	>100[c]	25	50	35	-	>100	>100	n/d
Moosehead Breweries Ltd.											
Sampled 1992 06 10/11	15.9	39.9	53.6	22.7	1.56	3.13	2.2	-	3.1	11.0	n/d
Lantic Sugar Ltd.											
Sampled 1992 06 11/12	35.4	34.7	26.8	21.9	6.25	12.5	8.8	-	9.5	17.0	n/d
T.S. Simms & Co. Ltd.											
Sampled 1992 06 11	100	>100[d]	N.L.	>100[d]	100	-	>100	-	>100	>100	n/d
NB Power Coleson Cove											
Sampled 1992 06 10/11	4.1	14.5	21.8	7.0	-	1.56	<1.56	-	2.2	4.2	n/d
NB Power Courtenay Bay											
Sampled 1992 06 11/12	42.1	67.1	N.L.	57.3	6.25	12.5	8.8	-	10.6	48.4	n/d
Irving Tissue											
Sampled 1992 06 23/24	>100[a]	>100[d]	N.L.	>100[d]	25	50	35	-	65	>100	n/d
Irving Paper Ltd.											
Sampled 1992 06 23/24	16.5	9.2	5.1	8.2	3.13	6.25	4.4	-	4.51	6.32	n/d
Irving Pulp & Paper Ltd.											
Sampled 1992 06 23/24	46.7	15.3	17.7	12.7	6.25	12.5	8.8	-	7.47	10.6	n/d
Irving Oil Ltd.											
Sampled 1992 08 20	>100[e]	>100[f]	N.L.	>100[f]	50	100	70.7	-	75.1	>100	n/d

1 Daphnia magna 48 hr; fathead minnow 96 hr; rainbow trout 96 hr.

2 NOEC - No Observed Effective Concentration
LOEC - Lowest Observed Effective Concentration
Ch.V.- Chronic Value (geometrical mean of NOEC and LOEC)
IC_{25}- Inhibition Concentration (estimated concentration where 25% of the population would be significantly affected)
IC_{50}- Inhibition Concentration (estimated concentration where 50% of the population would be significantly affected)
TEC - Threshold concentration

N.L. - not acutely lethal
n/d - not detected

a - 20% mortality in full strength sample
b - 15% mortality in full strength sample
c - 2.5 % mortality in full strength sample
d - 5% mortality in full strength sample
e - 10% mortality in full strength sample
f - 25% mortality in full strength sample

No evidence of genotoxicity was detected in any of the samples.

4.3.1.2 Dry Period

The St. John River was not tested for toxicity during the dry period.

The Marsh Creek sample did not affect rainbow trout survival, but was acutely toxic to Daphnia magna (LC_{50} of 32.9%). It was also determined that the tested sample did affect fathead minnow larvae survival and growth at concentrations above 25% (acute LC_{50} of 63.2%; chronic LC_{50} of 55.5%).

The Little River sample was toxic to both daphnids and fish. Acute LC_{50} values of 15.5%, 5%, and 7.2% were determined for daphnids, fathead minnow, and rainbow trout, respectively. This sample also had a detrimental effect on fathead minnow larvae growth at a concentration above 0.39% with a chronic LC_{50} of 3.9%.

The Hazen River sample was not acutely lethal to fish and invertebrates and did not have a significant effect on fish larvae survival and growth. However, during testing with fathead minnow, 15% mortality in the full strength sample occurred.

No evidence of genotoxicity was detected in any of the samples tested by standard SOS Chromotest analysis.

4.3.2 Industrial Sources

Toxicity testing for industrial sources was conducted once for each source sampled during the study. Sampling was conducted from June to August, 1992. A summary of the toxicity test results are presented in Table 4-22.

Samples exhibiting the lowest toxicities were from T.S. Simms & Co. Ltd., Irving Tissue Ltd., and Irving Oil Ltd. These were considered to be not acutely lethal to daphnids and fish, and to have no significant effect on fathead minnow larvae growth and survival.

An acute LC_{50} for daphnids was determined to be at 100% for T.S. Simms & Co. Ltd. Although this sample did not have a significant effect on fish larvae survival and growth, 5% mortality occurred in the full strength sample. The sample was non-lethal to rainbow trout.

The acute LC_{50} for daphnids was determined to be greater than 100% for the Irving Tissue Ltd. sample. However, 20% mortality occurred in the full strength sample. This sample had acute and chronic LC_{50} values for fathead minnow larvae greater than 100% (5% mortality in full strength sample). The sample had no effect on larvae growth at 25% concentration and lower. This sample was non-lethal to rainbow trout.

The acute and chronic LC_{50} values were determined to be greater than 100% for all test organisms in the Irving Oil Ltd. sample. However, in the full strength sample, 10% mortality occurred in daphnids and 25% mortality occurred in fathead minnow. The sample had no effect on fathead minnow larvae growth at 50% concentration and lower. The sample was non-lethal to rainbow trout.

All other effluent samples tested exhibited acute and chronic toxicity in all exposed organisms. Acute LC_{50} concentrations for daphnids ranged from 4.1% (NB Power Coleson Cove) to 46.7% (Irving Pulp & Paper Ltd.); for fathead minnow larvae ranged from 9.2% (Irving Paper Ltd.) to 67.1% (NB Power Courtenay Bay); for rainbow trout ranged from 5.1% (Irving Paper Ltd.) to 53.6% (Moosehead Breweries Ltd.). Chronic LC_{50} concentrations for fathead minnow larvae ranged from 7% (NB Power Coleson Cove) to 57.3% (NB Power Courtenay Bay).

No evidence of genotoxicity was detected in any of the industrial source samples.

4.3.3 Discussion of Toxicity Test Results

Several of the tributary sources are known to receive effluent directly from industrial sources or indirectly via the municipal collection system. The toxicity associated with the tributary sources showed an increase from the wet to dry sampling period. This suggests that constituents which induce toxic responses are more concentrated during the low flow period, as the natural runoff available for dilution is lower, and the municipal and industrial discharges remain high. This is reflected in the water quality data for the tributaries. Although there are varying fluctuations for several parameters, the trend is for increased concentrations of many parameters during the low flow period.

In addition to the toxicity associated with particular tributary sources, most of the industrial sources induced toxic responses in the tests conducted. Both tributary and industrial sources are located throughout the study area. Based on a review of the data presented above, it can be seen that the Harbour is receiving input from a variety of point sources which have the potential to result in toxicity to aquatic life in the receiving environment.

The combination of constituents in the respective sources vary widely and no attempt has been made to identify the causative agent in each which is responsible for the toxic responses measured. Similarly, because many of the effluents tested are subsequently mixed with other industrial and/or municipal effluents prior to entering the Harbour and they are entering a very dynamic estuarial/ marine environment, no attempt has been made to predict the magnitude or extent of the potential toxicity in the receiving environment. Toxicity to aquatic life may be modified significantly by the resulting interactions between constituents in various effluent streams and the bio-availability of toxicants resulting from the specific conditions in the receiving environment (i.e., temperature, dissolved oxygen, pH, hardness, solubility, complexation, etc.).

It is recognized that potential exists for harmful alteration of the Harbour environment as a result of the point source inputs. Therefore, it is important to identify impacts on the Harbour environment which are attributable to known inputs and uses. Aspects of impacts on the Harbour environment are considered and discussed in Section 5.0.

5.0 POTENTIAL EFFECTS OF SOURCES ENTERING THE HARBOUR ON HARBOUR ENVIRONMENT

The types of contaminants entering the Harbour have the potential to result in environmental degradation or change, which could adversely affect existing or future Harbour uses. The extent of degradation or change is dependent on the types of use, the contaminant types and loadings to the Harbour, and the assimilative capacity of the Harbour.

This section of the report identifies the types of concerns related to generic uses and describes a specific Harbour sampling program to determine the presence and extent of associated environmental problems. The Harbour Sampling Program was developed by reviewing characteristics of the industrial, municipal, and tributary effluents and identification of parameters of interest and by reviewing the Harbour environmental setting with respect to the contaminant sources and loadings. Features of the environmental setting are reviewed and discussed with respect to source-fate pathways and levels of contamination in sediments and biota of the Harbour.

The specific goal of this section is to relate the description of the Harbour environmental setting to the characterization of effluent discharges in the Harbour. The description of the environmental setting provides information about biota and sediments in the Harbour, what the contaminants consist of, and possible pathways of contamination (sources and distribution). This information was reviewed in the context of parameters of interest and was used to develop a sampling program to assess the effects of environmental quality on the harbour environment including: contaminant levels in sediments, contaminant levels in biota, and biotic responses to contaminant levels.

5.1 Environmental Quality Considerations

The data compiled to characterize point source discharges to the Harbour was reviewed relative to the current Harbour uses. Based on consideration of the general requirements for the specified uses and resulting interactions with discharges, several potential impacts have been identified:

- Recreational Health and Safety Risks

  The presence of coliform bacteria at elevated concentrations in the receiving environment could indicate potential risks for water contact activities and recreational harvesting of shellfish.

- Poor Aesthetics

  Several constituents in the identified effluents have potential to reduce the aesthetic appeal of the water column and beach zones due to presence of objectionable deposits of suspended materials, floating debris and oil, and changes to water clarity, odour, or taste.

- Habitat Disruption

  The occurrence of suspended solids and oxidizable constituents (indicated by BOD, COD) in effluents can results in harmful physical alteration of habitat (suspended and deposited material) and depletion of oxygen, for both benthic and pelagic biota. This may render natural areas of community development or zones of passage unsuitable for those uses.

- Toxicity

  Numerous effluent sources have been demonstrated to be toxic to aquatic biota and several constituents (inorganic and organic) have the potential to induce direct toxicity (acute and sublethal) in the receiving environment or to become toxic due to residue accumulated in body tissues.

- Tainting

  Objectionable taste, odour, or colour may be imparted to edible tissues of aquatic biota as a result of exposure to chemicals at concentrations lower than those which are directly harmful to the organisms, including those associated with organic compounds and metals found in discharges from a variety of industrial and municipal sources.

- Excessive Nutrient Enrichment

  The most common limiting factor for algal growth in the marine environment is the availability of nitrogen (and to a lesser degree, phosphorous); excessive amounts of these nutrients may result in blooms of algae leading to anoxic conditions or increases in the abundance of undesirable species responsible for the production of biotoxins, which may be accumulated in shellfish.

- Physical Nuisance

  Several effluent constituents which comprise suspended and floating solids and petroleum compounds may be present at sufficient levels to result in fouling of fishing gear or to constitute a nuisance to other water contact activities.

It is recognized that point sources have, at least, localized effects on the water quality in the receiving environment. Available information has been reviewed to determine the type and extent of effects which have occurred and/or have been documented in the study area.

5.1.1 Generic Environmental Quality Considerations

Generic environmental quality guidelines have been developed for Halifax Harbour by the Halifax Harbour Task Force (Fournier, 1990). The guidelines are based on consideration of sources entering the harbour and public input concerning present and future harbour uses. The Task Force recognized that establishing specific guidelines for Halifax Harbour would be a lengthy and complex process. The Task Force, therefore, reviewed environmental criteria and reported levels of contaminants in other urban harbours around the world, and compiled a table of recommended guidelines based on studies undertaken by groups convened by the United Nations, the United States Environmental Protection Agency, the United Kingdom Ministry of Agriculture and Fisheries, the Puget Sound Water Quality Authority, the US Office of Technology Assessment, the Fraser River Estuary Management Program, and a draft report on marine criteria prepared for Environment Canada.

Environmental quality objectives vary depending on the priorities established for various Harbour uses. Public input will be required to ensure that the use objectives for Saint John Harbour represent a cross-section of concerns and opinions. Rhode Island has developed a classification scheme for groups of water uses requiring different minimum levels of environmental quality. Identical or similar schemes are used by other municipalities (for example, Boston). Class SA would refer to areas with the most stringent environmental quality requirements. The classifications are summarized in Table 5-1. Generic environmental quality guidelines developed for Halifax Harbour are summarized in Table 5-2.

TABLE 5-1
Environmental Quality Classification: Rhode Island

Class SA	• Bathing and contact recreation • Shellfish harvesting for direct human consumption • Fish and wildlife habitat
Class SB	• Shellfish harvesting for human consumption after depuration • Bathing and other primary contact recreational activities • Fish and wildlife habitat
Class SC	• Boating and other secondary contact recreational activities • Fish and wildlife habitat • Industrial cooling • Good aesthetic value

TABLE 5-2

Proposed Environmental Quality Guidelines for Halifax Harbour Derived from Review of Literature

Variable	Water	Sediment	Biota
Dissolved oxygen	SA>[a]8.0 mg/L[b] SB>7.0 SC>6.0		
Fecal Coliform Bacteria	14 per 100 mL[c] 200 per 100 mL[d]		
Suspended Particulate Matter	10% above ambient[b]		
Metals			
Copper	2.9 µg/L	40.0 mg/kg[e]	20.0 µg/g[g]
Lead	5.6 µg/L	45.0 mg/kg[e]	2.0 µg/g[g]
Zinc	86.0 µg/L	40.0 mg/kg[e]	50.0 µg/g[g]
Cadmium	9.3 µg/L	0.6 mg/kg[f]	0.5 µg/g[g]
Chromium	50.0 µg/L		
Mercury	0.025 µg/L	0.75 mg/kg[f]	0.5 µg/g[g]
Manganese	100.0 µg/L		
Nickel	8.3 µg/L		
Organic Chemicals			
Total PCB	0.03 µg/L	100.0 µg/kg[f]	2.0 µg/g[g]
Total PAH	5.0 µg/L	2.5 µg/kg[f]	100.0 µg/g[i]
Oil and Grease	10.0 µg/L[h]	10.0 µg/kg[f]	
Total Pesticide		100.0 µg/kg[f]	
Total OHs		100.0 µg/kg[f]	

a. See Table 5-1.
b. Based on Fraser River Estuary recommended objectives.
c. Shellfish water quality standard (14 fecal coliform per 100 ml, 10% not >43).
d. Swimming water quality standard (200 fecal coliform per 100 ml, 10% not >400).
e. Based on Puget Sound apparent effects threshold.
f. CEPA levels for ocean dumping control.
g. For consumption normally judged by National Health and Welfare on individual situation.
h. To prevent tainting.
i. Recommendation in GESAMP review (the Joint Group of Experts on the Scientific Aspects of Marine Pollution, a body sponsored by several international organizations including UNEP, UNESCO, and FAO.

5.2 Potential Pathways

Potential pathways for effluent constituents from source to fate can be investigated by consideration of hydrographic and sedimentological characteristics of the Harbour, as well as the location of sources of effluent discharges.

Saint John Harbour has very complex hydrographic and sedimentological characteristics. Freshwater flows from the St. John River and seawater inputs from the Bay of Fundy combine to produce zones of varying current speed and direction, and salinity gradients. The area above Reversing Falls has been described as seasonally stratified, receiving inputs of seawater over the falls only at high tides and low river flow periods. It is also described as a potential sediment trap.

In the Harbour area below Reversing Falls, currents are reported to be very strong, with sediment accumulation occurring only in sheltered areas (small coves, wharves, berths, etc.). Surface flows in this area are down-harbour, while bottom flows of seawater up-harbour also exist, especially in the dredged channels. Courtenay Bay is a sediment depositional area. In the channel entrance to the Harbour, water flows are enhanced by dredging and the channelling-effect of the Partridge Island breakwater. Sediment deposition is limited in this area, although some does occur. Surface flows in the channel are outward. However, density gradients in this area result in a significant inward bottom flow along the channel.

In the outer Harbour area currents generally follow a clockwise gyre on the rising tide and a counter-clockwise gyre (less intense) on the falling tide. This area exhibits a definite influence of the St. John River, as surface salinities are lower than those at depth. Sediment accumulation in the outer Harbour occurs at the Black Point dredge spoil dump site, as well as the plume of the St. John River.

These complex patterns of hydrography and sedimentology suggest that clearly identifiable pathways of contaminant deposition are not prevalent in the Harbour, particularly if the assumption is made that contamination of sediments and biota by parameters of concern is coincidental with sediment deposition. Sediment deposition occurs in many areas at varying rates. In addition, dredging activities periodically alter current regimes and sedimentation patterns. Identification of potential pathways is made even more complex by the distribution of tributary, industrial and municipal effluent sources throughout the study area.

5.3 Review of Available Information

A review of available information was undertaken to investigate potential effects of point discharges (sources) on the Harbour environment. Information reviewed includes trace metal distributions, organic contaminants, benthic invertebrate communities, and fisheries resources.

5.3.1 Trace Metal Distributions in Harbour Sediments

Heavy metals were examined by Bezanson and Kranck (1981) as sediment tracers in Saint John Harbour. However, before examining their findings it is useful to look at the broader environment of the Bay of Fundy as a whole. For reference purposes, Figure 2-10 shows sediment distribution in the Bay of Fundy.

Baseline data for trace metals were mapped throughout the Bay of Fundy by Loring (1979). Figure 5-1 shows the distribution of Zn with values in the range 50-100 ppm in the vicinity of Saint John Harbour. Figure 5-2 shows a generalized mapping of the combined concentrations of elements considered by Loring. This figure is a composite of 12 trace metal distributions, each having different ranges of high, medium, and low concentrations. Figure 5-2 is Loring's composite interpretation of these concentrations, and should be used for comparison purposes only. Average concentrations of selected trace metals measured by Loring are (units of ppm, range in brackets): Zn 51(18-104); Cu 15 (5-32); Cd 0.22 (0.03-0.52); Pb 20(8-42); and Hg 0.03 (0.02-0.09). Loring's conclusion, which is readily appreciated from comparison of Figures 2-10, 5-1, and 5-2 is that "particle size is the main factor controlling the abundance and distribution of total trace metal concentrations in the

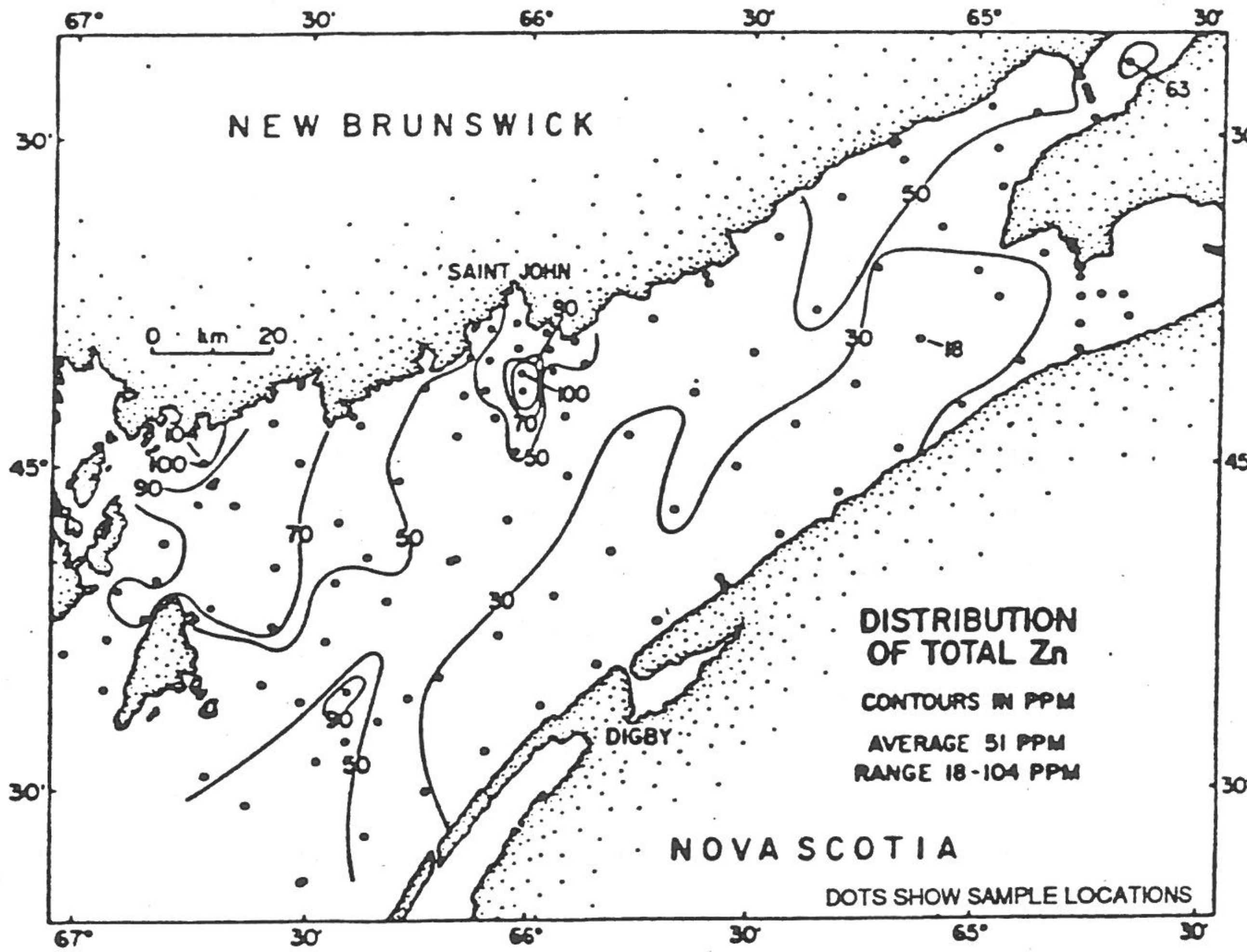


FIGURE 5-1
DISTRIBUTION OF TOTAL Zn IN THE SURFACE SEDIMENTS (< 2mm)

SOURCE: LORING, 1979.

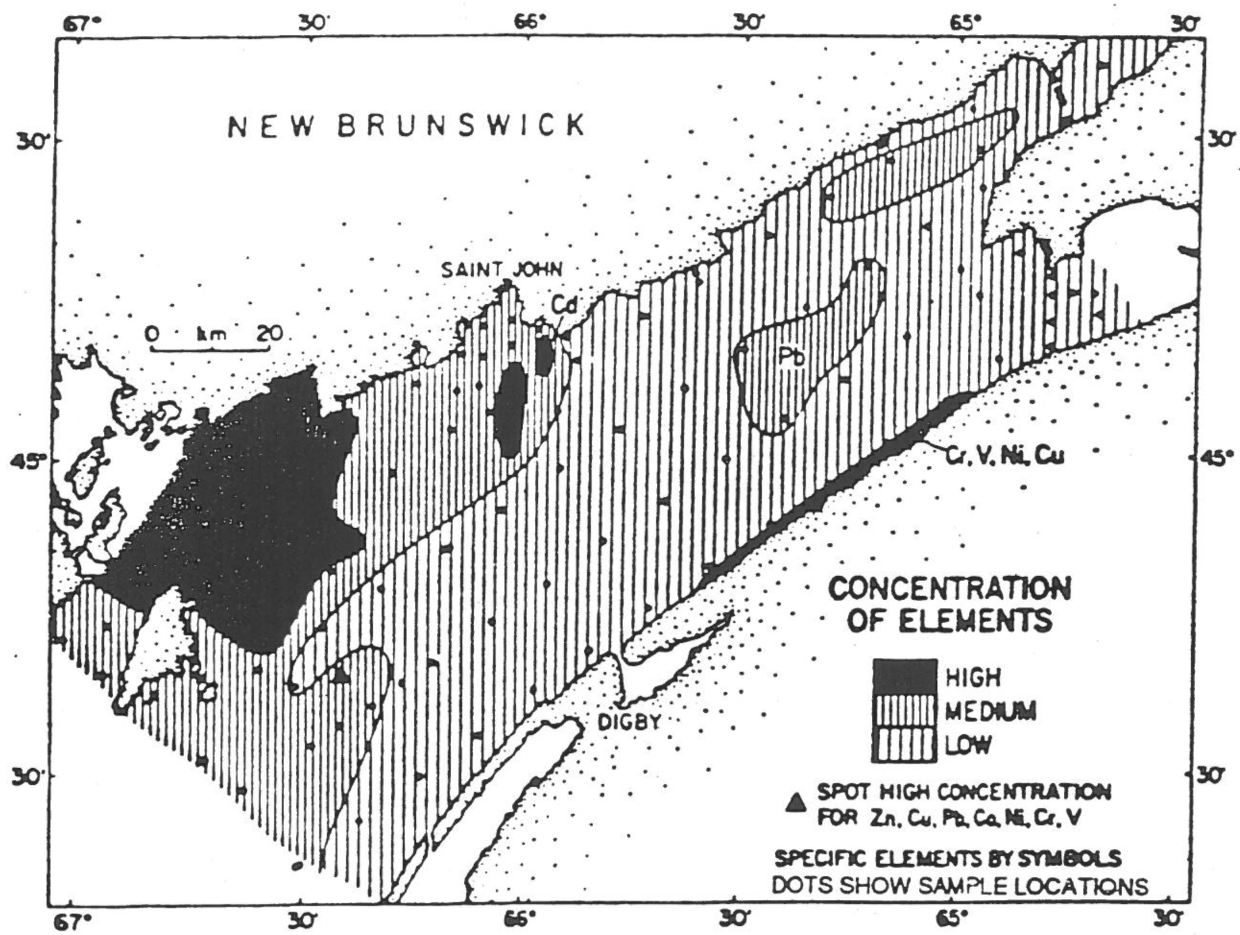


FIGURE 5-2
DISTRIBUTION OF THE RELATIVELY HIGH, MEDIUM AND LOW CONCENTRATIONS OF Zn, Cu, Pb, Co, Ni, Cr, V, Be, Ba, Se, Hg and Cd IN THE SURFACE SEDIMENTS (<2mm)

SOURCE: LORING, 1979.

Bay of Fundy." He also says that "at present the average levels of trace metals found in Fundy sediments, perhaps with the exception of Pb, are at or near natural levels found in unpolluted fine grained sediments."

Concentration contours for copper and zinc are shown in Figure 5-3 and Figure 5-4, respectively. The distribution patterns for concentrations of the two metals are similar. Bezanson and Krank (1981) make the following comments regarding these figures:

> "Over most of the outer Harbour bottom, zinc concentrations vary over a narrow range of values between 40 to 60 ppm. In Courtenay Bay, levels increase to a range between 70 and 180 ppm, with most values near 100 ppm. In sheltered backwaters in the dock area, values approach 100 ppm and a pocket of sediment below the Reversing Falls shows approximately 90 ppm. By far, the highest value in the entire Harbour area, 440 ppm, occurs at the mouth of Little River, to the east of the Courtenay Bay breakwater.
>
> Copper concentrations show a very similar pattern of variation with values between 7.9 and 13.1 ppm in the outer Harbour, up to 39.6 ppm in Courtenay Bay, a local high of 25.8 at Ocean Steel, and the highest value in the Harbour, 106.3 ppm, at the mouth of Little River.
>
> In the outer Harbour, values are elevated at the Black Point dump site. Copper values reach 27.0 ppm and zinc values 100.0 ppm. Concentrations return to background within 2 km of the dump site. Values of both zinc and copper rise again slightly in some nearshore regions".

For comparison purposes, ocean dumping guidelines for copper and zinc are 81 and 160 ppm (screening limits; Environment Canada, 1991), respectively.

It should be noted that all but the highest values found by these authors lie within the natural baseline values found by Loring. However, in order to eliminate the strong

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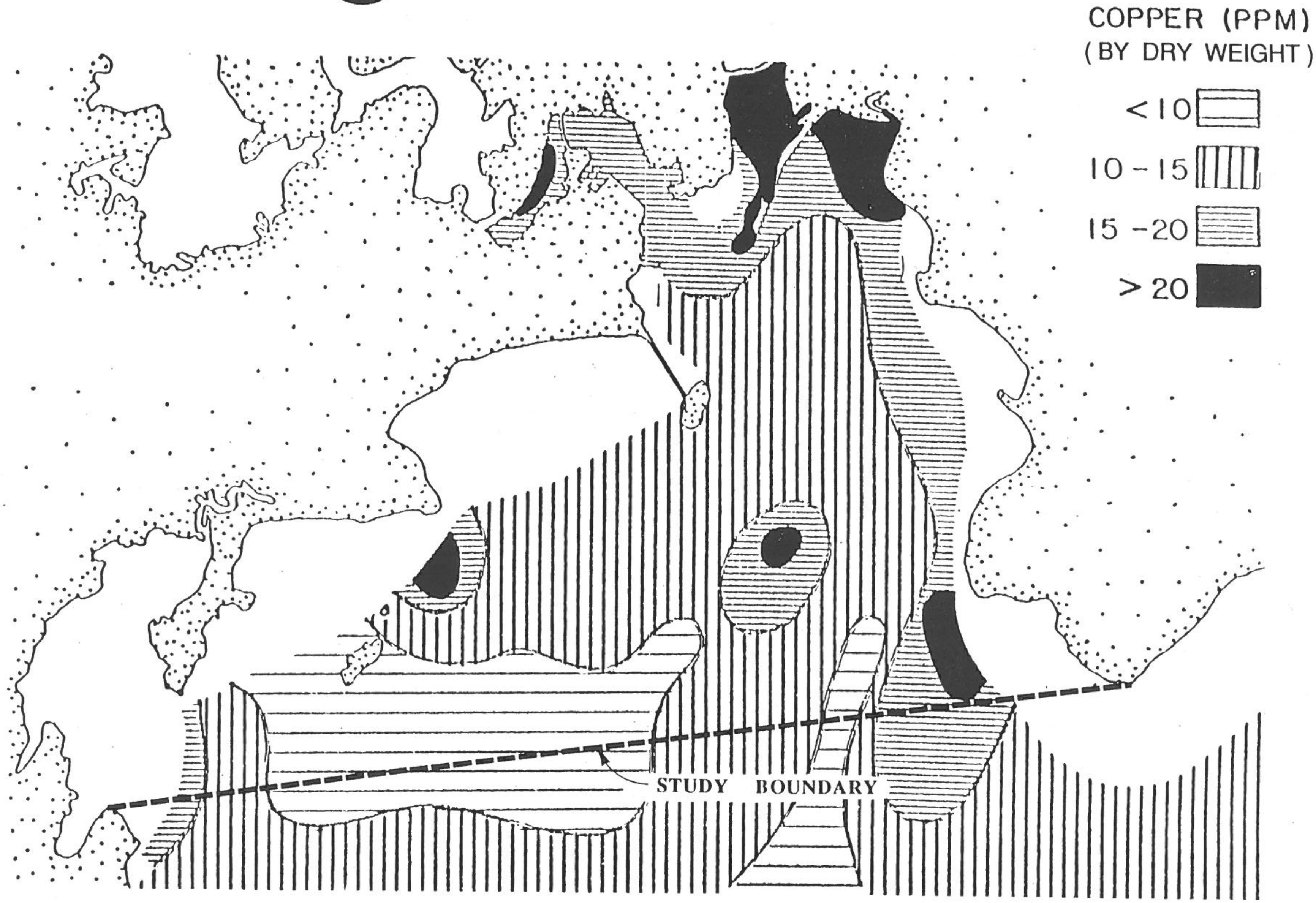

SOURCE: BEZANSON & KRANCK, 1981.

FIGURE 5-3
CONCENTRATION OF COPPER
IN SEDIMENT

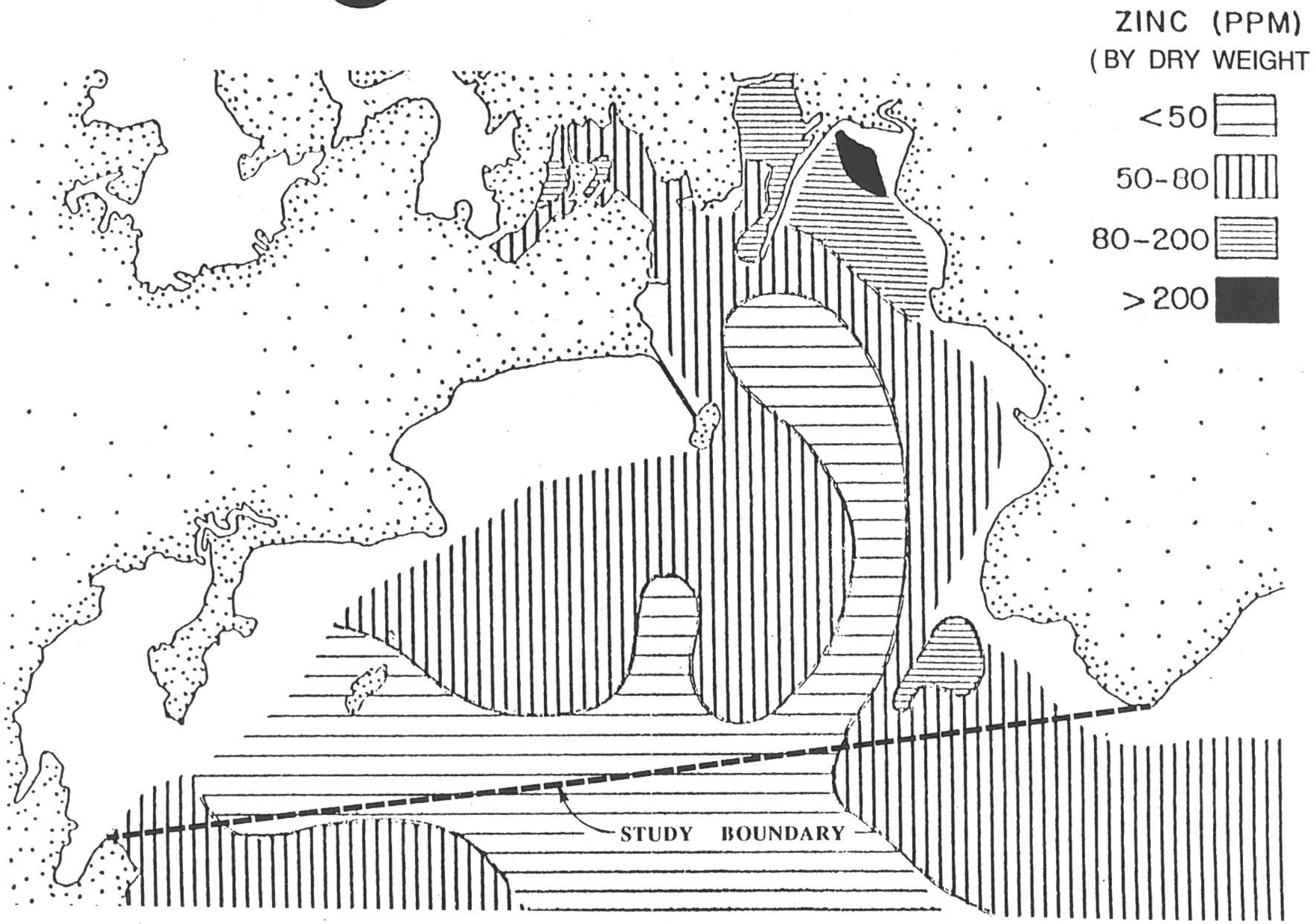

FIGURE 5-4
CONCENTRATION OF ZINC IN SEDIMENT

SOURCE: BEZANSON & KRANCK, 1981.

influence of sediment particle size on trace metal concentration, Bezanson and Kranck normalized the concentrations in terms of the specific surface area of the sediment particles, as computed from their grain size spectra. Normalized concentrations are expressed in units of micro-grams per square metre of particle surface. Bezanson and Kranck describe their normalized results, here shown in Figures 5-5 and 5-6, as follows.

> "For copper, numbers range between 50 and 100 $\mu g\ m^{-2}$ in the outer harbour area where background levels might be expected. In the dredging areas in the main harbour and Courtenay Channel, numbers rise to a range between 100 and 300 $\mu g\ m^{-2}$. Still higher values occur below the Reversing Falls and the highest values occur near the mouth of Little River, reaching 4600 $\mu g\ m^{-2}$. Values rise locally at the dump site to 260 $\mu g\ m^{-2}$.
>
> Normalized zinc values range in a similar pattern between 400 and 500 $\mu g\ m^{-2}$ in the outer harbour, up to 1200 in frequently dredged areas, 1500 to 3000 $\mu g\ m^{-2}$ below the Reversing Falls and to a high of 20,000 $\mu g\ m^{-2}$ near the mouth of Little River. Values rise locally at the dump site to over 1000 $\mu g\ m^{-2}$.
>
> Both normalized and non-normalized trace metal concentrations show an imprint at the Black Point dump site. This feature decreases to background levels within 2 km of the site and is probably an approximate indication of the local extent of physical disruption of bottom conditions by dumping operations. Courtenay Bay shows much lower relative trace metal loading in the normalized distribution than with respect to bulk concentrations."

Because they are of direct relevance to the purposes of this discussion, the conclusions of Bezanson and Kranck (1981) are reproduced here in full.

> "The distributions of zinc and copper concentrations normalized by particle surface area in the bottom sediments of Saint John Harbour show that the largest single influence on pollutant levels in the sediment distribution is the effluent of

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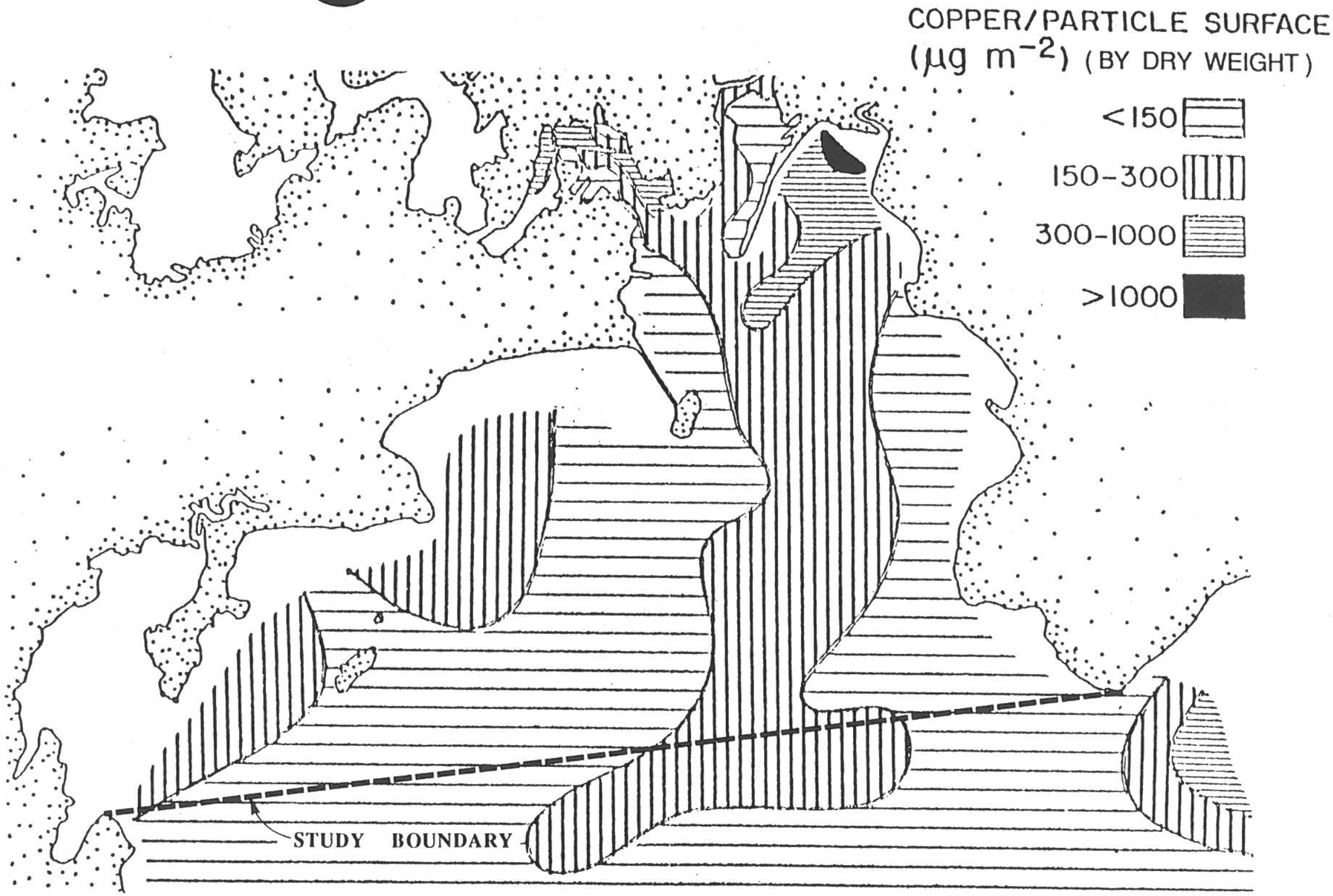


FIGURE 5-5
NORMALIZED CONCENTRATION OF COPPER IN SEDIMENT

SOURCE: BEZANSON & KRANCK, 1981.

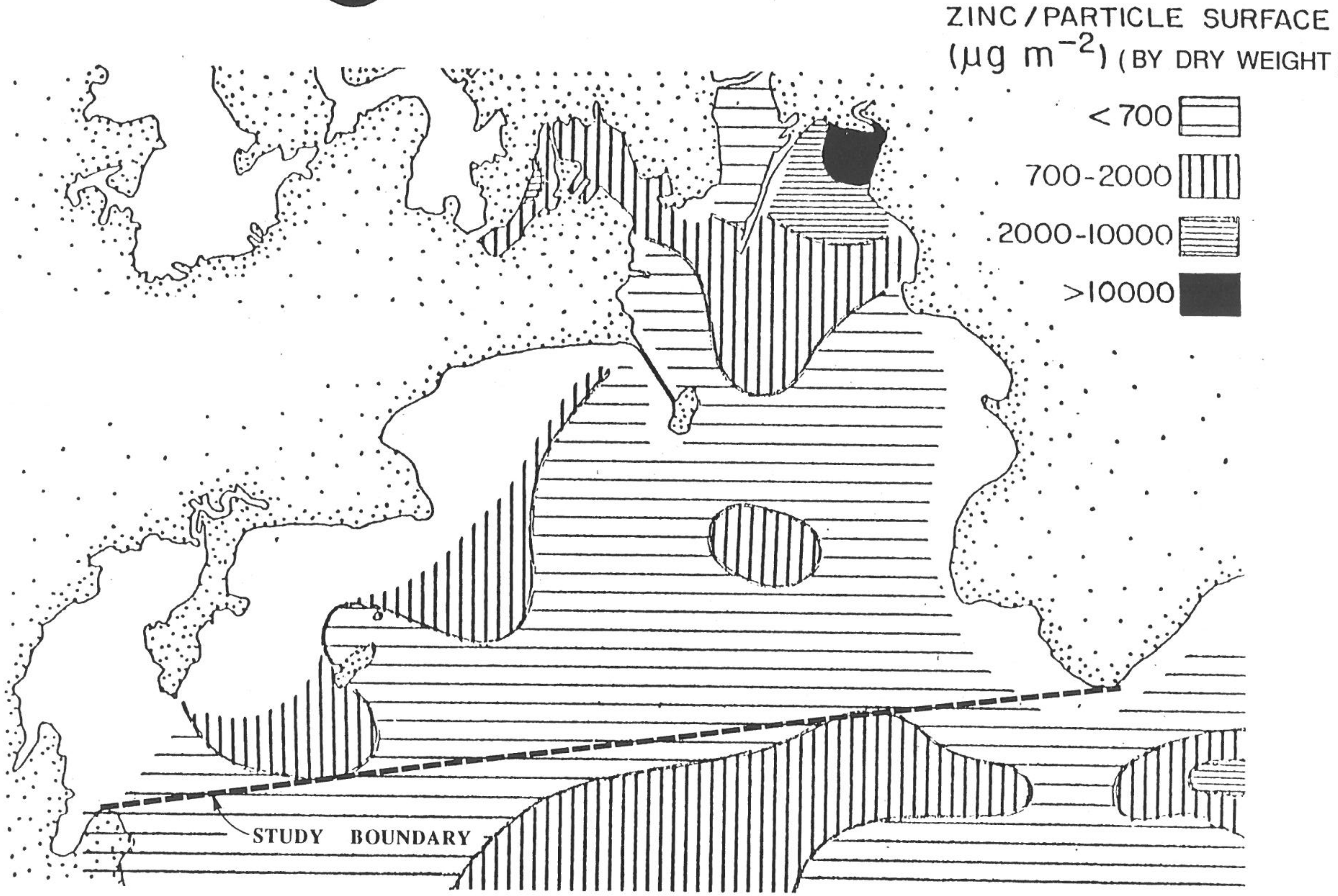


FIGURE 5-6
NORMALIZED CONCENTRATION OF ZINC IN SEDIMENT

SOURCE: BEZANSON & KRANCK, 1981.

Little River where fresh water flowing past major industries flows over an undredged tidal flat. Other sources within the harbour produce more limited effects in spite of the indications from effluent analysis that the largest source occurs at the Reversing Falls. The Black Point dump site produces only a minor perturbation of the outer harbour distributions. Within Courtenay Bay, where the drydock and sewage outfall are potential sources of effluent, there is a clear distinction between the elevated bulk concentrations and the normalized values, which approach background levels. The difference suggests that there is a significant effluent input here, but that the large yearly deposition and dredging of fine grained sediment carry pollutants away to the Black Point dump site in a manner which represents relatively little loading of particle surface area."

"If future work were to show that concentrations of heavy metals bound to fine grained sediments are innocuous, this would constitute an argument for the concentration of industrial activity around Courtenay Bay rather than in sedimentologically less active environments."

As a final comment, it should be noted that Saint John Harbour, and indeed almost all of the Bay of Fundy contain low concentrations of trace metals compared to comparable water bodies elsewhere in North America and Europe which are contaminated. This is demonstrated by tables of data given by Ray and McKnight (1984) for comparison with the estuary and by Loring (1979) for comparison with the Bay of Fundy. Thus, with the exception of the very localized areas, identified by Bezanson and Kranck (see above) the estuary of the Saint John is generally uncontaminated by anthropogenic trace metals.

5.3.2 Organic Contaminants in Harbour Sediments

Organic contaminants, oxygen demand, and pockets of wood waste/debris in the sediments have been reported for scattered locations within the Harbour. Information from Wildish and Thomas (1985), ADI Limited (1986), Science Applications International Corporation (1986), Seatech Investigation Services (1989), Land and Sea Environmental

Consultants Ltd. (1991), SJPC (1992) and most recently by Jacques, Whitford & Associates Limited (1992) suggests that there are significant localized areas with these types of contamination.

Elevated concentrations of PAHs, PCBs, and oil and grease have been reported at sites associated with maintenance dredging and spoil disposal. These include SJPC berths and wharves, the Courtenay Bay channel and turning basin, and the Black Point dredge spoil disposal site.

Testing conducted in association with dredging requirements at Saint John Port Corporation facilities have documented elevated levels of the following organic contaminants: PAHs at Berth 3 (4.18 mg/kg, 1991), Rodney Marginal (10.28 mg/kg, 1991), and Lower Cove (4.23 mg/kg, 1990); PCBs at Berth 2 (340 μg/kg, 1990) and Rodney Marginal (100 μg/kg, 1990); oil and grease at Berth 2 (22 mg/kg, 1988), Rodney Slip (10 mg/kg, 1987), Berth 12 (37 mg/kg, 1988), and Potash Terminal (22 mg/kg, 1986; 30 mg/kg, 1987; 10 mg/kg, 1988).

Recent work completed by Jacques, Whitford & Associates Limited gives results of sampling at 10 locations around the perimeter of Courtenay Bay (in undredged areas of potentially continual sediment accumulation). These results show average PAH, PCB, and oil and grease concentrations in exceedance of ocean dumping guidelines.

Other recent data available from testing conducted in Courtenay Bay show elevated levels of oil and grease in the range of 11.3 - 57 mg/kg (Seatech, 1989; Public Works Canada, 1990).

Monitoring of the Black Point dredge disposal site shows elevated levels of organic constituents to be: 2.93 - 4.44 mg/kg total PAHs (Public Works Canada, 1990; Land and Sea, 1991); 102 - 712 μg/kg PCBs; 15.0 - 66.1 mg/kg oil and grease (Public Works Canada, 1990; Land and Sea, 1991).

Wildish and Thomas (1985) and SAIC (1986) have reported the occurrence of pockets of wood waste/debris at several locations in and along the main dredged channel between the

Harbour bridge and Partridge Island, and at the Black Point dredge spoil disposal site. No quantitative data are available on the degree and extent of this type of contamination in the Harbour.

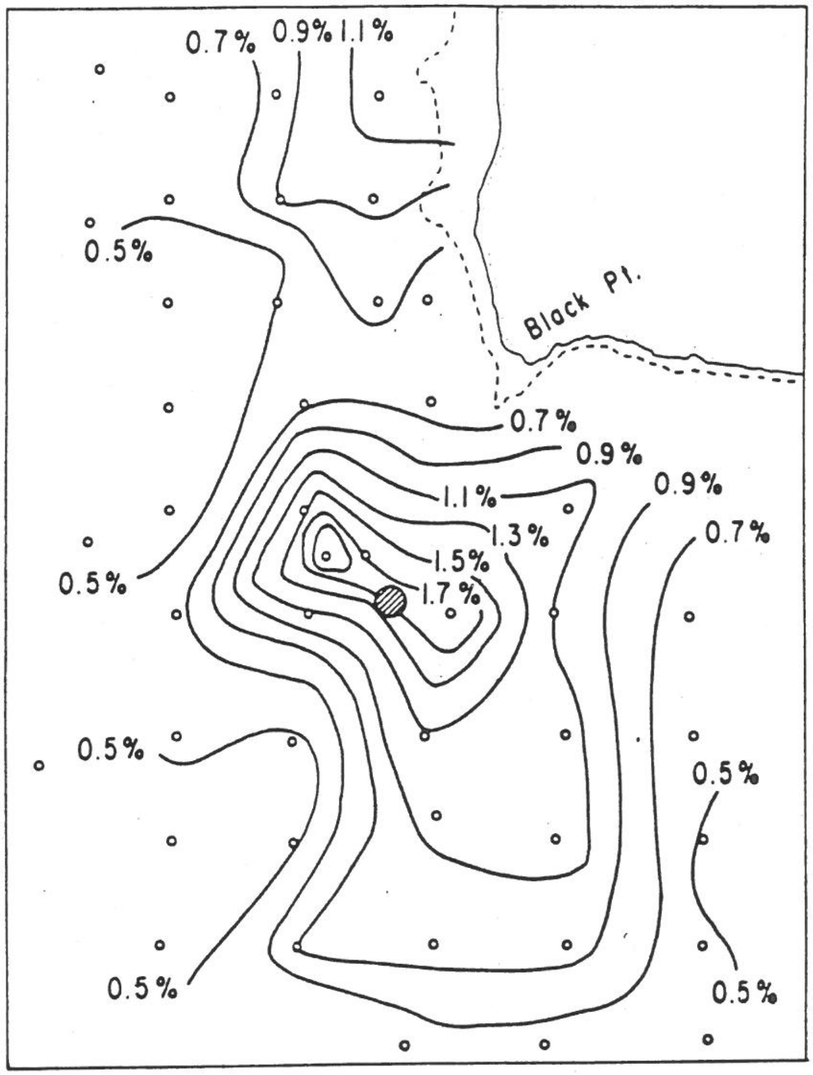
There has not been extensive sampling in the study area for organic contaminants in sediment and mapping has not been done at a level of detail to make it possible to trace these contaminants from known sources to areas of deposition. However, one area has been mapped in detail by the use of organic carbon as a tracer. This is the dredged spoil disposal site near Black Point, shown in Figure 5-7. Although the presence of organic carbon is of some interest in itself, W.F. Baird et al., (1987) suggest that it is not very satisfactory as a general purpose sediment tracer.

5.3.3 Benthic Invertebrates

Benthic community survey data for the study area are available for the period since 1959. Numerous studies of sublittoral benthic invertebrates have been conducted (i.e., MacLellan and Sprague, 1966; Wildish, 1976; Carter and MacGregor, 1978; Wildish and Kristmanson, 1979; McLeese and Ray, 1983; Yurick, 1982; Wildish and Thomas, 1985). A review of previous works provides a general overview of benthic invertebrate communities throughout much of the study area.

MacLellan and Sprague (1966) conducted the first quantitative benthic sampling program in the study area. They investigated a total of 13 stations from Cedar Point to the Black Point area (see Figure 5-8, which also serves as the general spatial distribution for benthic research in the study area). The study was conducted in two parts, the first in 1959 prior to the start-up of the Irving Oil Refinery. The second phase involved resampling of the original sites, approximately 16 months after the refinery began full production. This study provided the first detailed taxonomic list of benthic invertebrate species found in Saint John Harbour.

In 1973, Wildish (1976) resampled the station downstream of the Harbour bridge which had been sampled by MacLellan and Sprague in 1959 and 1961 (marked as "I" in Figure 5-8).



NOTE: HATCHED AREA INDICATES THE POSITION OF THE DUMPING SITE BUOY

SOURCE: WILDISH & THOMAS, 1985.

FIGURE 5-7
DISTRIBUTION OF "ORGANIC CARBON" NEAR BLACK POINT, SAINT JOHN HARBOUR

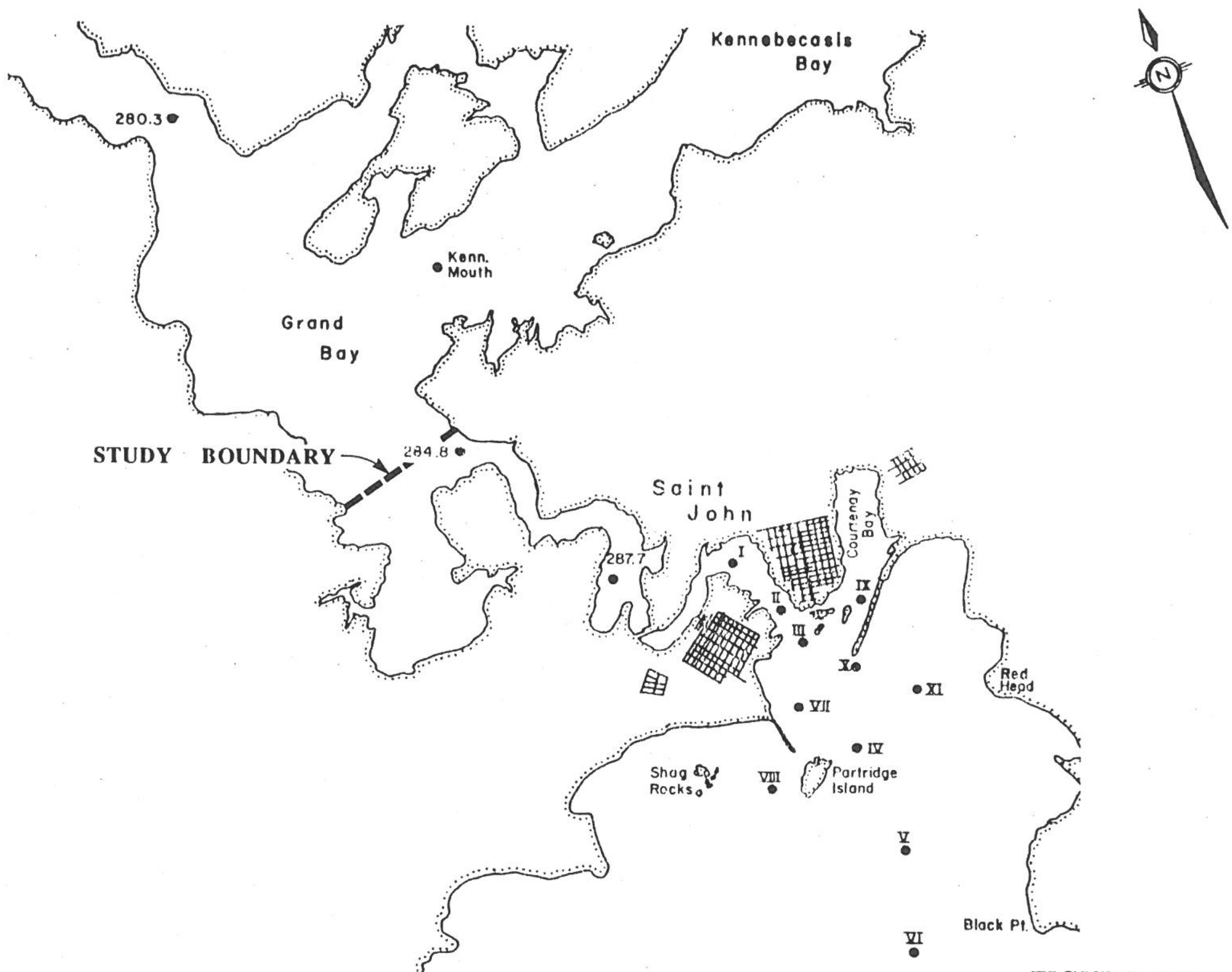


FIGURE 5-8
GENERAL SPATIAL DISTRIBUTION OF BENTHIC RESEARCH IN STUDY AREA

SOURCE: MacLELLAN AND SPRAGUE, 1966.

He noted that a change did occur in the benthic invertebrate population from that observed between 1959 and 1961, but it did not involve differences in species numbers or composition. A reduction in the number of individuals per species was recorded. MacLellan and Sprague (1966) sampled in late October to early December, where as Wildish (1976) sampled in March. Seasonal effects on invertebrate populations may, therefore, limit direct comparison of these results.

Carter and MacGregor (1978) conducted extensive sampling of benthos in the dredged area of Courtenay Bay and the channel and in the vicinity of the Black Point dump site. More than 65 species of invertebrates were recorded. They reported a considerable shift in community structure as compared to previous studies and general impoverishment in the two study areas.

Wildish and Kristmanson (1979) included a previously sampled station in Saint John Harbour (Wildish, 1976) as part of a study of seven estuaries in New Brunswick. Their research focused on physical parameters including sediment type and current regime, as limiting factors for benthic community development. Based on these considerations, it was suggested that communities are limited by the dominant effect of tidal energy.

Wildish and Thomas (1985) reported on the results of a study to determine the effect of dredging on the benthic macro fauna behind the Courtenay Bay breakwater and near the Black Point dump site. Data from their 1983 study and previous studies (Wildish 1976; Carter and MacGregor, 1978) were reviewed and analyzed. Based on selected biotic factors (trophic group analysis, species diversity and biomass dominant) the area of the harbour below the Harbour Bridge was divided into several zones, reflecting benthic community characteristics.

5.3.3.1 Benthic Communities

Limited data are available for the areas above the Harbour Bridge and to the west of Partridge Island. However, based on available data the study area has been divided into several zones (see Figure 5-9) reflecting sublittoral benthic community/habitat characteristics, as follows.

1) South Bay Area

No data are available for this part of the study area. However, it is anticipated that the species represented would not vary appreciably from those found in the Kennebecasis estuary (Steer, 1974; Metcalfe, et al.; Burns, 1976; Gillis, 1978; see below).

2) Cedar Point to Reversing Falls

Data for this zone were reported by MacLellan and Sprague (1966). The species assemblage is similar to that found in the Kennebecasis estuary. Typical biota consist of polychaetes (i.e., Nereis sp., Nepthys sp., Phyllodoca sp., Scolelepides viridis, Maldanopsis sp.), amphipods (Gammarus oceanicus), oligochaetes, isopods, and bivalve molluscs (Mya arenaria, Macoma balthica, Mytilis edulis).

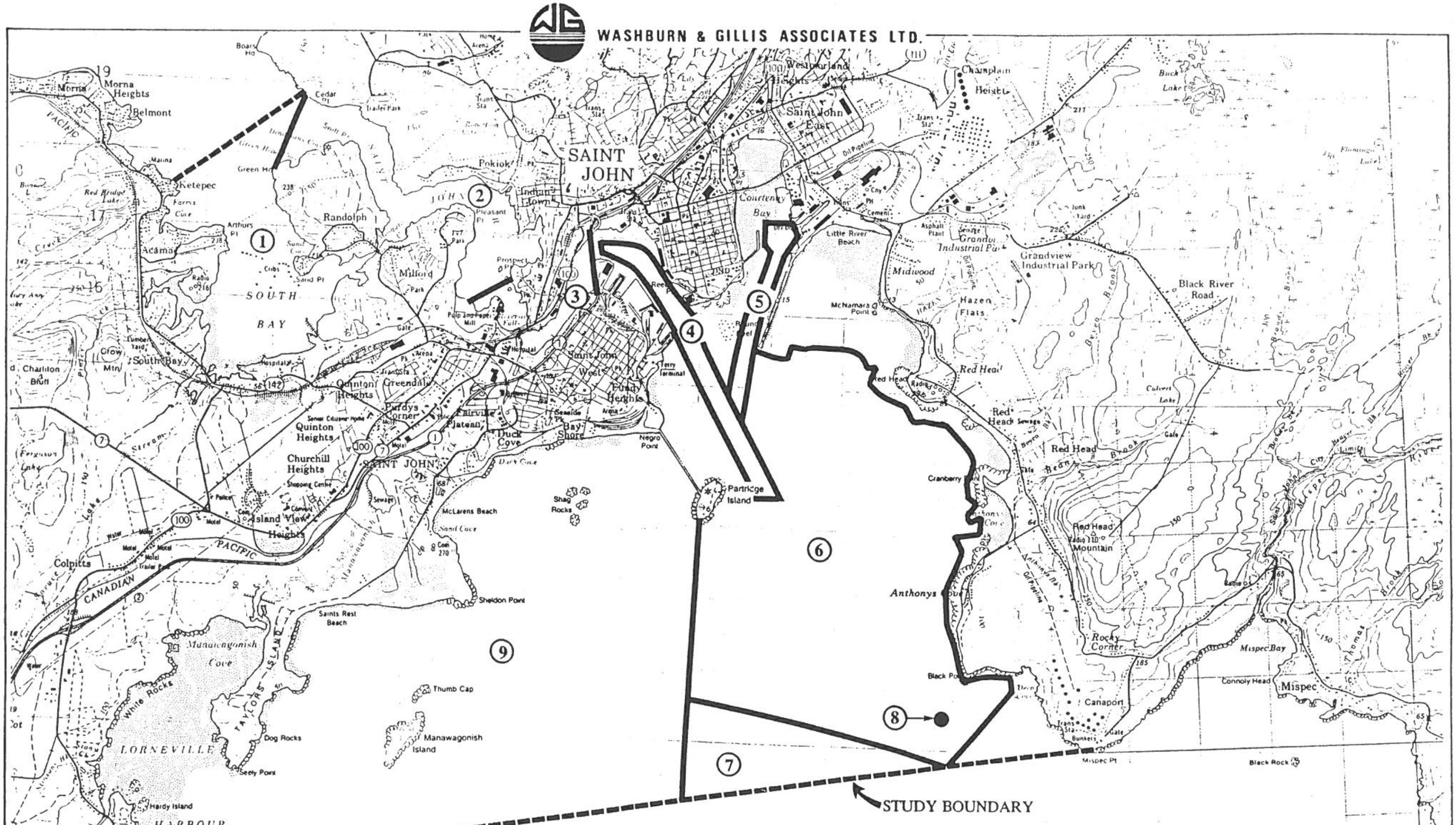
This area is subjected to a turbulent tidal regime leading to scouring of the substrate. Therefore, it is expected that the community can be classified as an impoverished hard substrate community along the main channel. Deep holes have been shown to have substrate consisting of a mixture of silt, gravel, and wood detritus. In areas such as these, an impoverished soft sediment community would be expected.

3) Reversing Falls to Harbour Bridge

No data are available for this area. However, due to the tidal scouring action, it is expected that an impoverished hard substrate community predominates.

4) Main Channel, Harbour Bridge to Partridge Island

The substrate is comprised largely of quantities of wood particles of sizes up to that of large strips of water-logged bark, 2-3 m in length. The wood surfaces are colonized by blue



LEGEND

① - BENTHIC INVERTEBRATE COMMUNITY ZONE

● - BLACK POINT DUMP SITE

SOURCE: ADAPTED FROM WILDISH AND THOMAS, 1985; MACLELLAN AND SPRAGUE, 1966.

FIGURE 5-9
DISTRIBUTION OF SUBLITTORAL MACROFAUNAL COMMUNITIES

mussels (Mytilus edulis) and barnacles (Balanus crenatus), and the interstitial spaces support the amphipod Gammarus oceanicus.

This area has been classified as having an impoverished hard substrate community (Wildish and Thomas, 1985). This area is subject to strong tidal currents and biota are firmly attached or burrow into the wood to avoid washout.

5) Courtenay Bay Turning Basin, Channel

Courtenay Bay, as well as Harbour berths, are hydrodynamically calm areas and as such, are depositional zones for sediment. Therefore, these areas require annual maintenance dredging for shipping purposes.

Dredged areas associated with Courtenay Bay are described by Wildish and Thomas (1985) as having impoverished soft sediment communities as a result of dredging activities. These areas typically have low biomass of a few species of deposit feeders (polychaete dominated) which are first colonizers of disturbed sediments (i.e., Capitella capitata, Nereis sp., Nepthys sp., Gammarus setosus).

The degree of faunal impoverishment due to dredging depends upon the timing of dredging activity and available recovery time. Similar dredging activity occurs at berths in the Harbour area and benthic communities in these areas would reflect the same type of soft substrate impoverishment.

6) Outer Harbour to Black Point/Below Harbour Bridge Adjacent to Main Channel

Communities in this area have been described as tidally impoverished soft sediment communities (Wildish and Thomas, 1985). In these areas impoverishment is due to a sediment erosion and deposition cycle resulting from strong tidal currents.

The majority of the invertebrate species are carnivorous or deposit feeding polychaetes (Sthenelais limicola, Nephthys sp., Goniada maculata, Ninoe nigripes). These species are tolerant of strong tidal currents and sediment erosion.

Wildish and Thomas (1985) point out that several locations in this zone exhibit characteristics indicating that in some situations it is difficult to separate tidally impoverished from climax communities in the soft sediments.

7) Outer Harbour

Species diversity and abundance increase in the outer harbour area. Much of the biomass (over 90%) consists of large suspension feeders. Dominant species include lamellibranchs, polychaetes, crustaceans, and a chordate (Bostrichobranchus pilularis).

This zone is described as having a climax soft sediment benthic community. The key to distinguishing zone 6 from zone 7 is the presence of the chordate, Bostrichobranchus.

8) Black Point Dump Site

In general, the area is very low in both species diversity and biomass. Carter and MacGregor (1978), found the polychaete Capitella capitata to be the dominant benthic organism of this area. Polychaetes, Nereis sp., Nepthys sp., and Eteone longa were also recorded along with the amphipods Unciola irrorata, Gammarus oceanicus, and Leptocheirus pinguis. Wildish and Thomas (1985) reported Capitella capitata as the dominant species with Ninoe nigripes and Ammotrypane aulogaster also present.

The species assemblage indicates a combination of biota transferred from other areas such as Courtenay Bay in spoil material, and survivors or colonists from adjacent areas. The dump site area is characterized as having an impoverished soft sediment community due to spoil disposal activity (Wildish and Thomas, 1985).

Biotic features which are characteristic of the spoil disposal area have an areal extent in the order of 1 km^2. Outside of this, the communities grade into those described for zones 6 and 7.

9) Harbour West of Partridge Island Breakwater

No data are available to describe the species assemblages in this portion of the study area. It is evident from the distribution of community characteristics in the adjacent zones that several of these may be represented in this area. Without having supporting data, it is not possible to delineate where these zones would be located. However, it is believed that the area would reflect characteristics representative of zones 6 and 7 in particular.

5.3.3.2 Contaminant Accumulation in Tissues

Descriptions of accumulation of selected contaminants in the tissues of benthic invertebrates are available from Bacon (1983). This work was conducted to determine the levels of various compounds, found in pulp mill effluents, in a variety of organisms found in and around the study area.

Results of the study indicate that all the compounds (e.g. chlorinated organics, resin acids, fatty acids) were detected in all invertebrates collected between the Harbour bridge and Manawagonish Island. A wide range of sublethal concentrations were measured, but no particular trend patterns were identified. No specific levels were given in this reference.

5.3.4 Fisheries Resources

Information dealing with potential impacts on the fisheries resources is available for commercial fisheries and fish body contaminant burden in the study area.

5.3.4.1 Commercial Fishery

Based on a review of available information (see Section 3.4 and Appendix A), it can be seen that changes have occurred in the commercial fishery in the study area over the period of record. It is evident that fishing activity has been physically displaced and largely excluded from selected areas due to Port development. This includes construction along the water front areas and use of a designated area of Black Point for dredge spoil disposal (MacKay, 1983).

Data reviewed by Dadswell (1983) and that discussed in Section 3.4 show that commercial fishery landings for statistical districts in the study area exhibit long-term cycles. Reported landings may be influenced by several factors including natural fluctuations in fish stocks, the level of effort expended toward target species and fishing locations, market conditions, the economic factors, and characteristics of the reporting system (catch location versus landing location; change in district boundaries). No data are available which establish that a reduction in biological potential in the study area has occurred or that actual alterations to fish populations have resulted from specific pollution sources (Hildebrand, 1980; Eaton, 1983).

5.3.4.2. Accumulation of Contaminants in Fish

As discussed in Section 5.2.3.2, Bacon (1983) determined the concentrations of selected compounds (principally chlorinated organics) in tissues of a variety of biota collected at several locations in the study area. Fish species collected included spiny dogfish, smelt, tomcod, winter flounder, and hake.

Some of all the compounds were detected in fish tissues collected at Manawagonish Island and most of the compounds were detected in fish captured at other sites (no specific values are given in this reference). A wide range of sublethal concentrations were determined, but no particular patterns were found.

Although fish in the study area have been determined to contain low levels of several chlorinated organic compounds, no data are available to indicate that fish from the study area have become tainted or that there are any potential health risks.

5.3.5 Summary of Available Information

Available information documents contamination of sediments in the study area by heavy metals and various organic constituents. Heavy metals throughout most of the area of study area are at close to natural background values, when sediment texture (i.e. particle size) organic carbon content is taken into account. One substantial point source of heavy metals was found at the mouth of Little River. In addition, a number of localized pockets of high normalized heavy metal concentrations were found below the Reversing Falls.

For organic contaminants (PAHs, PCBs, oils and greases, etc.) the situation is similar to that for heavy metals. Apart from isolated pockets, test values have been generally within acceptable limits. However, these parameters have not been mapped so that correlation of hot spots with known sources is not possible at this time. The same is true with regard to the mapping of deposits of organic debris such as bark and wood chips.

Data on benthic invertebrate communities suggests that impoverishment in the study area results from limiting natural factors such as tidal energy and physical habitat disruption resulting from dredging activities and disposal of dredge spoils.

Limited data show that benthic invertebrates in the study area have low level contamination of organic constituents. A wide range of concentrations were described, but no particular patterns are evident. The descriptions do not indicate that populations have been impacted by the presence of organic constituents in the environment.

Available commercial fisheries data indicate that cyclical fluctuations occur in the landings for the study area and that there has been physical exclusion of fishing activities from certain locations within the study area. Species which have historically comprised the fishery continue to be fished in the study area and data do not indicate exclusion of species from migratory zones of passage or areas previously frequented.

Information suggests that low level contamination of fish by organic compounds has occurred at sublethal concentrations. No data are available to indicate that tainting of fish has occurred (this usually happens at concentrations of contaminants below those harmful to fish), or that fish populations in the study area have been impacted by contaminants present. The exception to this is the closure of shellfish harvesting areas in the harbour due to potential for fecal coliform contamination and the potential effects on humans when consumed.

The available documentation indicates that several of the potential impacts identified in Section 5.1 have only localized occurrence and can be dealt with through the existing regulatory framework. However, due to the lack of conclusive data regarding the impact of contaminants accumulating in the receiving environment, additional information on contaminants from point sources accumulating in sediments and biota, is required.

5.4 Harbour Sampling Program

As per the Terms of Reference for the study, and based on the information presented in this report, a Harbour Sampling Program (HSP) was developed to assess existing levels of contamination of biota and sediments in the Harbour, as well as responses of biota to contamination. This program was directed to address deficiencies identified from the review of available information. Development and implementation of the HSP would, therefore, assist in the identification of contaminants of concern in the Harbour environment. The HSP consisted of the following components:

- Sediment Contaminant Burdens.
- Biota Contaminant Burdens.
- Biota Responses to Contaminant Exposure.

The three components of the HSP were developed to provide contaminant information relative to different sub-environment or trophic levels within the study bounds. Following is a brief rationale for each of the components in the HSP.

The sediment contaminant sampling program was used to provide an up-to-date characterization of sediment contamination within the study bounds. This information supplemented existing documentation. It was used in conjunction with data gathered from other components of the study (industrial and municipal outfall characterization, tributary sampling, and hydrodynamic and sedimentation processes reviews) to assist in determining if the Harbour is a sink for contaminants and to priorize contaminants. Previous studies completed to assess sediment contamination in the Harbour have been, for the most part, directed at specific areas, parameters, or Harbour uses. The sediment contaminant burden component of the HSP has been developed to provide geographic coverage of the study area, simultaneous determination of parameters of interest, as well as contamination at different sediment layers.

The biota contaminant burden program provided an indication of the level of bioaccumulation of contaminants. Two species were sampled to account for exposure to contaminants at different trophic levels. Sampling of blue mussels (Mytilus edulis) provided biota contaminant burden data for a species feeding directly from the water column. As the Harbour is subject to very complex hydrodynamic conditions that make direct water sampling and analysis impractical, sampling blue mussels provides an excellent platform to assess exposure to contaminants in the water column. Sampling of winter flounder (Pseudopleuronectes americanus) provided contaminant burden data for a species feeding in close contact with the Harbour sediments. The ecology of winter flounder is such that it is exposed to any contamination which may be occurring in the Harbour sediments (i.e. by feeding or body contact).

The mixed function oxidase (MFO) sampling program was undertaken in Saint John Harbour as a means of gaining insight into the physiological effects of certain contaminants (namely, hydrocarbons) in the Harbour on the biota residing there. The MFO program was developed and conducted with Dr. Richard Addison and his research team from the Bedford

Institute of Oceanography. Research undertaken by Dr. Addison (see Addison and Payne, 1986) has shown that several indices of winter flounder liver enzyme activity (hepatic mixed function oxidase) show variations directly proportional to exposure to certain hydrocarbons. Determination of MFO activity provides an indication of sub-lethal effects of hydrocarbon contamination in Harbour biota.

The HSP was developed and implemented according to protocols approved by the Tri-Level Committee.

5.4.1 Sample Sites

Eleven sample locations were selected to provide a thorough geographic representation of the study area (see Figure 5-10). These are described as follows:

- South Bay.
- Adjacent to Rodney Terminal and the Navy Island Terminal.
- Courtenay Bay.
- Between the Courtenay Bay breakwater and McNamara Point/Red Head.
- Between Partridge Island and the CN Ferry Terminal.
- Black Point Dump Site.
- Between Manawagonish Island and Saints Rest Beach.
- East of Mispec Point (reference site).
- Adjacent to Shag Rocks.
- Midway between the end of the Courtenay Bay Breakwater and Cranberry Point.
- Midway between Black Point and Manawagonish Island.

5.4.2 Sampling Techniques

Sediment samples were obtained by use of a diver-deployed corer. Cores were sub-divided into 0-5 cm, 5-10 cm and 10-15 cm sections. Each section was individually labelled, stored, and submitted for analysis.

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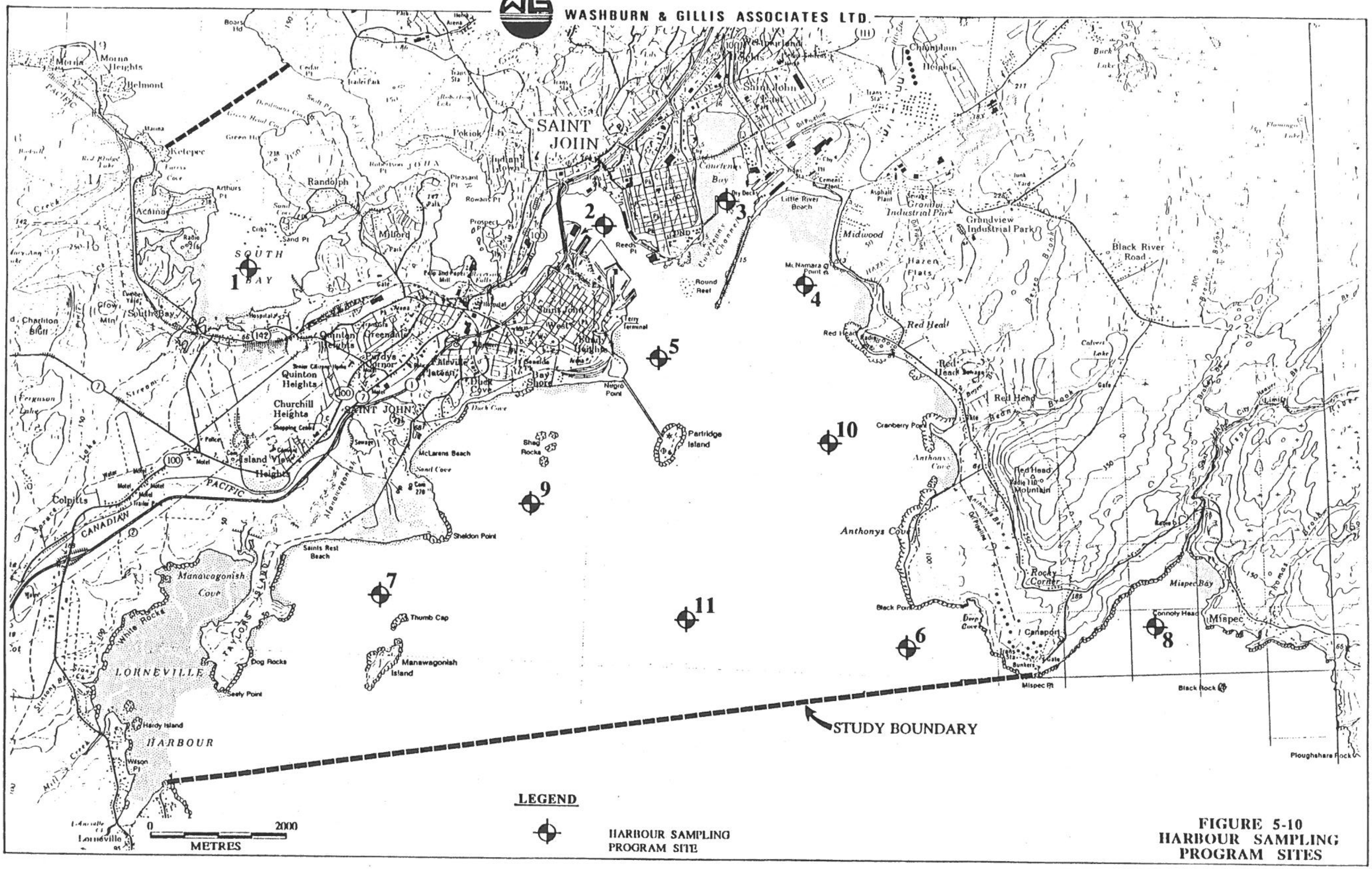

FIGURE 5-10
HARBOUR SAMPLING PROGRAM SITES

Biota samples for contaminant burden and MFO analysis were obtained by diver and/or beam trawl. Both techniques were utilized where site conditions permitted; however, hydrodynamic, weather or depth factors at some sites precluded use of one or the other. As biota samples were obtained, records of the number of individuals pooled together to make a sample, the sex and reproductive status of the individuals, the time and date of sampling, and other relevant information was made. Whole blue mussels were cleaned and rinsed with salt water and dissected to remove the soft tissue before pooling samples, storing, and submission for analysis. Livers were removed from winter flounder for both the contaminant burden and MFO programs. Carcasses of the winter flounder were maintained for weight analysis, although no contaminant burden measurements were made on the carcasses.

5.4.3 Sample Analysis Parameters

Sediment samples collected for the HSP were analyzed for the following parameters (as approved by the Tri-Level Committee):

- Heavy metals (Cd, Cu, Pb, Hg, Zn).
- Polychlorinated biphenyls (PCBs).
- Polyaromatic hydrocarbons (PAHs).
- Organo-chlorinated pesticides (including DDT,DDD,DDE).
- Extractable organic chlorine (EOX).
- Grain size.
- Oil and grease.
- Carbon content.

Analysis for these parameters was completed on each of the core sections from each sample site. In addition, vertically composited core samples from sites 1, 2, 3, and 4 were analyzed for dioxins and furans. These sites were considered most probable to be contaminated by these pollutants. It was not feasible, nor was there technical justification to analyze all sections of cores from all sites for dioxins and furans. Core samples from sites 1,2,3, and 4 were vertically composited to provide a suitable sample size for dioxin and furan analysis.

All blue mussel samples obtained (see Section 5.4.5) were analyzed for the suite of parameters given above (excluding grain size, oil and grease, and carbon content). Blue mussel samples from sites 2, 3, and 4 were analyzed for dioxin and furan contaminant burden.

Winter flounder liver samples collected (see Section 5.4.5) were analyzed for heavy metal contamination only. Analysis was limited to these parameters due to limited sample sizes.

The MFO program analysis consisted of three components:

- On-site measurement of EROD and CN-EROD enzyme activity from freshly caught and processed fish liver samples.
- Subsequent laboratory analysis of processed liver samples for levels of enzyme P450IA1.
- Sediment hydrocarbon contaminant burden.

5.4.4 Sediment Contaminant Burden Results

Results of the HSP are presented according to specific components as described above. Field sampling was completed according to defined protocols. Sediment samples were obtained at all samples sites. It should be noted that organo-chlorinated pesticides and extractable organic chlorine were not detected in any of the sediment samples (all sites and core layers, detection limits of 10-15 μg/kg and 20 mg/kg for organo-chlorinated pesticides and EOX, respectively).

5.4.4.1 Results of Grain Size, Carbon Content, Heavy Metals, Oil and Grease Analysis

Results of analyses for sediment contamination burden for the above parameters are presented in Table 5-3 to 5-5. Results are presented separately for each sediment core layer (0-5, 5-10, and 10-15 cm) to allow comparison between sites at a specific layer. Data are referenced against relevant ocean dumping disposal guidelines as specified in the Environment Canada document "Interim Contaminant Testing Guidelines for Ocean

TABLE 5-3
Sediment Sampling Data - Grain Size, Carbon Content, Heavy Metals, and Oil and Grease - 0-5 cm Core Sample. (Sampled 1992 08 10-12)

Parameter	Unit	Detection Limit	Reference Value[1]	Site										
				1	2	3	4	5	6	7	8	9	10	11
Grain Size														
Gravel	%	0.1	n/a	n/d	0.5	n/d	n/d	n/d	n/d	0.7	n/d	n/d	n/d	n/d
Sand	%	0.1	n/a	2.1	5.6	3.3	41.0	1.6	6.9	56.9	2.3	29.0	11.6	9.7
Silt	%	0.1	n/a	70.6	59.1	59.4	55.5	75.5	44.1	31.1	58.1	52.9	65.0	66.3
Clay	%	0.1	n/a	27.3	34.8	37.4	3.5	22.9	29.0	11.3	39.6	19.1	23.4	24.0
Carbon Content														
Total Organic Carbon	g/kg	1.0	n/a	24.8	28.6	29.9	2.9	17.2	27.9	11.3	28.3	10.8	12.6	15.2
Total Inorganic Carbon	g/kg	1.0	n/a	26.0	39.7	49.1	18.1	32.2	32.7	27.3	45.8	22.0	26.2	32.2
Total Carbon	g/kg	2.0	n/a	50.8	68.3	79.0	21.0	49.5	60.6	38.6	74.1	32.8	38.8	47.4
Heavy Metals														
Cadmium	mg/kg	0.05	0.6	0.13	0.08	0.13	0.02	0.07	0.15	0.03	0.03	0.04	0.05	0.04
Copper	mg/kg	0.5	81	19.7	18.1	21.9	10.0	14.2	21.0	11.6	18.1	12.0	13.5	15.4
Lead	mg/kg	0.5	66	26.3	30.2	29.1	12.7	18.8	28.5	19.0	34.6	22.5	19.5	19.2
Mercury	mg/kg	0.01	0.75	0.05	0.04	0.05	0.02	0.03	0.04	0.01	0.02	0.02	0.02	0.02
Zinc	mg/kg	0.5	160	83.7	72.5	84.2	40.8	58.9	70.2	49.7	73.5	47.6	59.8	61.1
Oil and Grease														
Total Oil and Grease	mg/kg	5	10	150	200	330	13	67	350	41	58	29	63	49
Mineral Oil and Grease	mg/kg	5	n/a	140	110	240	10	42	240	22	31	18	50	35

1. Reference Value: Refers to a regulated limit, interim rejection limit, or screening limit as defined in the Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991.

n/a: Not available or applicable.
n/d: Not detectable within the specified detection limits.

TABLE 5-4
Sediment Sampling Data - Grain Size, Carbon Content, Heavy Metals, and Oil and Grease - 5-10 cm Core Sample. (Sampled 1992 08 10-12)

Parameter	Unit	Detection Limit	Reference Value[1]	Site										
				1	2	3	4	5	6	7	8	9	10	11
Grain Size														
Gravel	%	0.1	n/a	n/d	n/d	n/d	n/d	n/d	n/d	0.2	n/d	n/d	n/d	n/d
Sand	%	0.1	n/a	1.0	2.0	0.1	71.1	5.2	4.1	71.1	4.6	24.3	1.8	18.1
Silt	%	0.1	n/a	68.2	60.2	63.6	26.2	79.6	63.5	21.5	60.9	60.5	59.6	63.9
Clay	%	0.1	n/a	30.8	37.7	36.3	2.0	15.2	32.4	7.2	34.4	15.2	38.6	18.0
Carbon Content														
Total Organic Carbon	g/kg	1.0	n/a	28.0	28.9	30.7	2.6	15.4	26.2	13.7	26.0	7.9	15.8	12.0
Total Inorganic Carbon	g/kg	1.0	n/a	26.6	43.0	47.6	17.2	26.7	40.3	30.8	40.1	20.5	28.3	28.3
Total Carbon	g/kg	2.0	n/a	54.6	71.9	77.6	19.8	42.1	66.5	44.5	66.1	28.4	44.1	40.3
Heavy Metals														
Cadmium	mg/kg	0.05	0.6	0.19	0.09	0.11	0.04	0.06	0.08	0.03	0.06	0.04	0.05	0.04
Copper	mg/kg	0.5	81	24.2	19.9	23.1	12.1	14.6	20.0	11.8	17.2	11.4	15.5	14.1
Lead	mg/kg	0.5	66	36.7	34.3	29.9	13.3	18.4	45.4	16.8	24.6	14.7	20.0	20.3
Mercury	mg/kg	0.01	0.75	0.08	0.06	0.05	0.02	0.02	0.03	0.02	0.03	0.01	0.03	0.02
Zinc	mg/kg	0.5	160	84.7	88.3	89.6	45.7	59.3	78.0	49.1	69.0	41.6	62.2	55.4
Oil and Grease														
Total Oil and Grease	mg/kg	5	10	220	300	350	6	68	240	21	70	10	48	36
Mineral Oil and Grease	mg/kg	5	n/a	200	250	290	5	48	160	13	47	8	48	27

1. **Reference Value:** **Refers to a regulated limit, interim rejection limit, or screening limit as defined in the Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991.**

n/a: Not available or applicable.
n/d: Not detectable within the specified detection limits.

TABLE 5-5

Sediment Sampling Data - Grain Size, Carbon Content, Heavy Metals, and Oil and Grease - 10-15 cm Core Sample. (Sampled 1992 08 10-12)

Parameter	Unit	Detection Limit	Reference Value[1]	Site										
				1	2	3	4	5	6	7	8	9	10	11
Grain Size														
Gravel	%	0.1	n/a	n/d	0.1	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Sand	%	0.1	n/a	2.0	4.1	1.6	50.5	5.8	6.6	36.7	3.2	6.1	11.1	21.9
Silt	%	0.1	n/a	63.6	53.7	67.9	47.8	75.8	63.8	49.9	68.4	69.1	80.9	63.7
Clay	%	0.1	n/a	34.4	42.0	30.5	1.7	18.5	29.5	13.4	28.4	24.7	8.0	14.4
Carbon Content														
Total Organic Carbon	g/kg	1.0	n/a	29.1	31.9	31.3	2.9	14.7	28.4	11.6	21.1	12.0	9.3	13.1
Total Inorganic Carbon	g/kg	1.0	n/a	33.9	46.0	43.8	16.2	28.4	41.1	24.5	34.3	26.1	23.2	28.7
Total Carbon	g/kg	2.0	n/a	63.0	77.9	75.1	19.1	43.1	69.5	36.1	55.4	38.1	32.5	41.8
Heavy Metals														
Cadmium	mg/kg	0.05	0.6	0.14	0.12	0.13	0.04	0.06	0.07	0.06	0.03	0.05	0.05	0.06
Copper	mg/kg	0.5	81	22.1	21.8	23.0	10.6	14.0	23.0	14.8	16.5	15.3	15.2	14.1
Lead	mg/kg	0.5	66	37.7	27.6	28.1	12.9	19.4	43.3	27.5	36.2	27.5	20.6	19.0
Mercury	mg/kg	0.01	0.75	0.08	0.05	0.06	0.01	0.02	0.04	0.02	0.02	0.03	0.02	0.02
Zinc	mg/kg	0.5	160	87.8	87.0	84.9	42.5	60.4	83.5	62.8	72.2	62.2	59.9	55.4
Oil and Grease														
Total Oil and Grease	mg/kg	5	10[2]	260	710	330	6	100	390	17	37	41	31	54
Mineral Oil and Grease	mg/kg	5	n/a	210	520	270	5	84	280	14	24	28	21	35

1. Reference Value: Refers to a regulated limit, interim rejection limit, or screening limit as defined in the Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991.
2. Reference value for oil and grease refers to a regulated limit (CEPA), but is not presently applied for ocean dumping screening purposes.

n/a: Not available or applicable.

n/d: Not detectable within the specified detection limits.

Disposal Atlantic Region, May, 1991." Results are discussed below by parameter group, core depth, and in comparison between sites, to ocean dumping guidelines, to previous studies, and to Harbour uses.

Grain Size

Grain size analysis of sediment samples provides an indication of hydrodynamic conditions of the sample sites. Larger grain sizes indicate high energy areas with low sedimentation potential, while small grain sizes indicate low energy areas with high sedimentation potential.

Results of the HSP sediment sampling are consistent with those of previous studies (e.g., Loring, 1979). At all core depths and sites, silt is the predominant sediment type. Known depositional areas, such as Navy Island (Site 2), Courtenay Bay (Site 3), and Partridge Island (Site 5) show high clay proportions at all core depths. Other areas, such as South Bay (Site 1), Black Point (Site 6), and Mispec (Site 8) also show high clay proportions. These sites, could also be considered as depositional areas. Small sized sediments at Black Point are resultant from dredge spoil dumping. McNamara Point (Site 4), Shag Docks (Site 9), and Manawagonish Island (Site 7) all show high sand content. These sites are subject to high wave and tidal energy. Observations of grain size in the sediment sample indicates hydrodynamic conditions similar to those described earlier in this report.

Carbon Content

At all core depths, sediment samples exhibited reductions in total carbon content with distance from the Harbour Bay area. Carbon content was observed to be similar at all core depths at each site.

South Bay (Site 1) exhibited almost equal proportions of organic and inorganic carbon. This is evidence of the influence of the Saint john River to the sediments at this site. Organic carbon in sediments typically is related to inputs of land runoff or anthropogenic sources such as forestry or agriculture. Organic carbon in sediments is a concern if decomposition of the material results in depletion of sediment or water oxygen levels.

Depositional areas such as Navy Island, Courtenay Bay, Partridge Island, Black Point, and Mispec exhibit some of the highest total carbon levels. In these samples, as in all samples, the proportion of organic to inorganic carbon decreased with distance from the Harbour Bay, indicating reducing River, anthropogenic, or land runoff influence.

Heavy Metals

Heavy metal contamination in the Harbour sediments was observed to be consistent with that described by Benzanson and Krank (1981) as elevated in areas of sediment deposition. Results of HSP sample analysis suggest higher metal concentration in the Harbour Bay and above Reversing Falls sites, than in the Outer Bay site (except Black Point). As suggested by Benzanson and Krank (1981), however, comparison of metal concentrations with grain size indicates normalization of concentrations against grain size would smooth the level of contamination throughout the Harbour. It is interesting to note that the HSP sediment samples indicate higher heavy metal concentrations in the deeper core samples at most sites, suggesting that contamination was higher historically than at the present.

Heavy metal concentrations as measured from the HSP sediment samples were never in exceedance of ocean dumping guidelines. Data supplied by the SJPC is in general agreement with these observations. Dredging applications submitted by the SJPC in recent years show an exceedance for copper in Courtenay Bay in 1989. No other exceedances were observed.

Oil and Grease

Concentrations of oil and grease in HSP sediment samples were measured to be consistently high at most sites and core depths. Concentrations of mineral oil and grease (relative to total oil and grease) suggest these to be the predominant component of this contamination;

therefore, the source is probably Harbour activities involving industrial or mechanical processes or transport of fossil fuels. Elevated levels of oil and grease throughout the study area were noted.

At all core depths, oil and grease concentrations were measured to be highest at sites in the Above Reversing Falls and Harbour Bay areas, as well as at Black point. Concentrations at South Bay (Site 1) are higher in deeper core depths than in the surface sediments, suggesting that historical contamination was greater then at the present. A similar trend is observed at Navy Island (Site 2). However, at Courtenay Bay (Site 3), oil and grease concentrations are consistent throughout the core layers. This observation suggests that historical contamination was similar to present day levels, or simply that sediments in all core depths were deposited in recent times with consistent contamination (i.e., possibly since the last dredging activity in Courtenay Bay).

Recent data given by the SJPC and by Seatech (1989) and Public Works Canada (1990) show high concentrations of oil and grease around several Port facilities and in Courtenay Bay. Concentrations reported for these sources are often an order of magnitude lower than those measured in HSP samples. This difference could be accounted for by sampling and/or sample compositing protocols.

5.4.4.2 Results of PCB and PAH Analysis

The results of PCB and PAH analysis are summarized in Tables 5-6 to 5-9. Data are referenced against relevant ocean dumping disposal guidelines as specified in the Environment Canada document "Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991". Results are discussed below by parameter group, core depth, and in comparison between sites, to ocean dumping guidelines, to previous studies, and to Harbour uses.

TABLE 5-6
Sediment Sampling Data - PCBs and PAHs -
0-5 cm Core Sample. (Sampled 1992 08 10-12)

Parameter	Unit	Detection Limit	Reference Value[1]	Site										
				1	2	3	4	5	6	7	8	9	10	11
Polychlorinated Biphenyl (PCB)	ug/kg	10	100	31	n/d	25	26	59	22	n/d	n/d	n/d	15	n/d
Polyaromatic Hydrocarbons (PAH)														
Naphthalene	mg/kg	0.05	6	0.06	n/d	n/d	0.13	0.06	0.10	0.09	0.07	n/d	0.07	0.06
Acenaphthylene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Acenaphthene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Fluorene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Phenanthrene	mg/kg	0.05	6	0.11	0.07	0.09	n/d	n/d	0.18	0.15	n/d	0.06	n/d	0.22
Anthracene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Fluoranthene	mg/kg	0.05	50	0.16	0.11	0.15	n/d	n/d	0.22	0.14	n/d	n/d	n/d	0/22
Pyrene	mg/kg	0.05	50	0.14	0.10	0.13	n/d	n/d	0.20	0.13	n/d	n/d	n/d	0.18
Benzo(a) anthracene	mg/kg	0.05	50	0.05	n/d	0.05	n/d	n/d	0.13	n/d	n/d	n/d	n/d	0.05
Chrysene	mg/kg	0.05	50	0.05	n/d	0.05	n/d	n/d	0.16	n/d	n/d	n/d	n/d	0.05
Benzo (b,j,k) fluoranthene	mg/kg	0.05	50	0.09	n/d	0.09	n/d	n/d	0.14	0.06	n/d	n/d	n/d	0.08
Benzo (a) pyrene	mg/kg	0.05	50	n/d	n/d	n/d	n/d	n/d	0.13	n/d	n/d	n/d	n/d	n/d
Dibenz (a,h) anthracene	mg/kg	0.05	50	n/d	n/d	n/d	n/d	n/d	0.08	n/d	n/d	n/d	n/d	n/d
Ideno (123cd)pyrene	mg/kg	0.05	50	n/d	n/d	n/d	n/d	n/d	n/a	n/d	n/d	n/d	n/d	n/d
Benzo (g,h,i) perylene	mg/kg	0.05	50	n/d	n/d	n/d	n/d	n/d	0.09	n/d	n/d	n/d	n/d	n/d
Total PAHs	mg/kg	n/a	2.5	0.66	0.28	0.56	0.13	0.06	1.43	0.57	0.07	0.06	0.07	0.86

1. Reference Value: Refers to a regulated limit, interim rejection limit, or screening limit as defined in the Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991.

n/a: Not available or applicable.
n/d: Not detectable within the specified detection limits.

TABLE 5-7
Sediment Sampling Data - PCBs and PAHs
5-10 cm Core Sample (Sampled 1992 08 10-12

Parameter	Unit	Detection Limit	Reference Value[1]	Site										
				1	2	3	4	5	6	7	8	9	10	11
Polychlorinated Biphenyl (PCB)	ug/kg	10	100	26	59	32	17	26	11	n/a	16	n/d	n/d	n/d
Polyaromatic Hydrocarbons (PAH)														
Naphthalene	mg/kg	0.05	6	n/d	0.06	0.06	0.08	n/d	0.06	0.09	0.09	0.07	n/d	0.07
Acenaphthylene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/a	n/d	n/d	n/d	n/d	n/d
Acenaphthene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/a	n/d	n/d	n/d	n/d	n/d
Fluorene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/a	n/d	n/d	n/d	n/d	n/d
Phenanthrene	mg.kg	0.05	6	0.11	0.12	0.14	n/d	0.06	0.11	n/d	0.09	n/d	0.05	0.06
Anthracene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Fluoranthene	mg/kg	0.05	50	0.17	0.20	0.21	n/d	0.07	0.16	n/d	0.10	n/d	0.06	0.05
Pyrene	mg/kg	0.05	50	0.15	0.17	0.17	n/d.	0.06	0.15	n/d	0.09	n/d	0.06	0.05
Benzo(a) anthracene	mg/kg	0.05	50	0.06	0.07	0.05	n/d	n/d	0.05	n/d	n/d	n/d	n/d	n/d
Chrysene	mg/kg	0.05	50	0.06	0.07	0.05	n/d	n/d	0.05	n/d	n/d	n/d	n/d	n/d
Benzo (b,j,k) fluoranthene	mg/kg	0.05	50	0.11	0.10	0.09	n/d	0.06	0.08	n/d	n/d	n/d	n/d	n/d
Benzo (a) pyrene	mg/kg	0.05	50	0.05	0.07	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Dibonz (a,h) anthracene	mg/kg	0.05	50	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Ideno (123cd)pyrene	mg/kg	0.05	50	0.06	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Benzo (g,h,i) perylene	mg/kg	0.05	50	0.05	0.05	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Total PAHS	mg/kg	n/a	2.5	0.82	0.84	0.77	0.08	0.25	0.61	0.09	0.37	0.07	0.17	0.23

1. Reference Value: Refers to a regulated limit, interim rejection limit, or screening limit as defined in the Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991.

n/a: Not available or applicable.
n/d: Not detectable within the specified detection limits.

TABLE 5-8
Sediment Sampling Data - PAHs Analyzed as Part of
MFO Program - 5-10 cm Core Sample. (Sampled 1992 08 10-12)

Parameter	Unit[1]	Site[2]									
		1	2	3	4	5	6	7	8	9	11
Naphthalene	ng/g	7.8	8.4	6.2	2.0	4.8	13.4	2.4	3.4	1.3	1.8
Biphenyl	ng/g	3.7	3.8	3.2	1.8	1.3	5.4	1.3	2.1	1.5	1.6
Acenaphthalene	ng/g	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Acenaphthene	ng/g	5.6	5.0	3.3	0.9	1.4	5.5	1.6	0.8	0.4	0.8
Fluorene	ng/g	11.1	10.8	10.8	2.3	5.7	16.8	3.6	4.0	1.3	2.6
Phenanthrene	ng/g	75.2	102.8	71.9	35.4	50.9	93.6	34.4	45.6	17.2	29.2
Anthracene	ng/g	22.1	23.4	22.9	1.8	28.9	27.1	7.1	3.9	3.8	7.3
Fluoranthene	ng/g	102.6	83.3	93.1	31.5	56.2	82.6	42.2	33.5	18.3	24.5
Pyrene	ng/g	86.5	61.1	66.4	27.7	45.3	65.1	36.5	24.8	14.8	21.1
Benz-anthracene	ng/g	37.6	36.1	27.1	11.0	16.3	23.8	16.9	11.0	5.8	10.3
Chrysene	ng/g	99.0	46.9	45.7	18.6	29.5	45.3	30.1	19.1	9.4	18.2
Benz-fluoranthenes	ng/g	177.3	110.5	88.7	29.7	38.9	78.9	36.8	28.2	14.1	22.6
Benz-a-pyrene	ng/g	45.6	35.3	17.3	8.5	24.3	21.2	18.3	14.6	3.6	10.4
Perylene	ng/g	25.2	15.1	18.8	9.3	8.0	16.6	8.5	7.9	5.8	5.6
Indeno (123cd)pyrene	ng/g	34.9	23.8	24.9	11.3	17.0	23.2	11.0	7.8	5.5	7.8
Dibenzanthracene	ng/g	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Benzo (g,h,i)perylene	ng/g	41.8	30.6	24.7	10.4	14.9	20.6	12.3	11.2	5.3	9.1
Total PAHs	ng/g	776.0	596.9	525.0	202.2	343.4	539.1	263.0	217.9	108.1	172.9

1. To convert ng/g to mg/kg, divide by 1,000.
2. Site 10 was not analyzed.
n/d: not detected.

TABLE 5-9
Sediment Sampling Data - PCBs and PAHs -
10-15 cm Core Sample. (Sampled 1992 08 10-12)

Parameter	Unit	Detection Limit	Reference Value[1]	Site										
				1	2	3	4	5	6	7	8	9	10	11
Polychlorinated Biphenyl (PCB)	ug/kg	10	100	89	45	31	18	n/d	n/d	n/d	n/d	10	n/d	n/d
Polyaromatic Hydrocarbons (PAH)														
Naphthalene	mg/kg	0.05	6	0.06	n/d	n/d	0.07	n/d	0.16	0.10	0.14	0.05	0.06	0.11
Acenaphthylene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Acenaphthene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Fluorene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Phenanthrene	mg.kg	0.05	6	0.09	0.05	0.11	n/d	n/d	0.18	0.05	0.08	0.05	0.05	0.07
Anthracene	mg/kg	0.05	6	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Fluoranthene	mg/kg	0.05	50	0.16	0.07	0.17	n/d	0.06	0.20	0.05	0.07	n/d	0.05	0.07
Pyrene	mg/kg	0.05	50	0.14	0.06	0.14	n/d	0.05	0.19	0.06	0.07	n/d	0.05	0.07
Benzo(a) anthracene	mg/kg	0.05	50	0.05	n/d	0.06	n/d	n/d	0.05	n/d	n/d	n/d	n/d	n/d
Chrysene	mg/kg	0.05	50	0.06	n/d	0.07	n/d	n/d	0.06	n/d	n/d	n/d	n/d	n/d
Benzo (b,j,k) fluoranthene	mg/kg	0.05	50	0.10	n/d	0.05	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Benzo (a) pyrene	mg/kg	0.05	50	n/d	n/d	0.05	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Dibonz (a,h) anthracene	mg/kg	0.05	50	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Ideno (123cd)pyrene	mg/kg	0.05	50	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Benzo (g,h,i) perylene	mg/kg	0.05	50	0.05	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
Total PAHS	mg/kg	N/A	2.5	0.71	0.18	0.65	0.07	0.11	0.84	0.26	0.36	0.05	0.21	0.32

1. Reference Value: Refers to a regulated limit, interim rejection limit, or screening limit as defined in the Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991.

n/a: Not available or applicable.
n/d: Not detectable within the specified detection limits.

Polychlorinated Biphenyls (PCBs)

Analysis of HSP sediment samples showed no exceedances of ocean dumping guidelines for PCBs at any site or core depth. As with other parameters, concentrations of PCBs were observed to be highest in depositional areas such as South Bay, Navy Island, Courtenay Bay, Partridge Island, and Black Point. Note McNamara Point (Site 4) exhibited relatively high PCB levels, whereas this high energy site is seen to be relatively low in other parameters. At some sites, a slight increase in PCB concentrations with core depth is observed.

The SJPC has reported PCB concentrations in exceedance to ocean dumping guidelines at Berth 2 and Rodney Terminal in 1990. Jacques, Whitford & Associates Limited (JWAL) (1992) recorded exceedances of ocean dumping guidelines for PCBs around the perimeter of Courtenay Bay. PCB levels measured from HSP samples taken at Black Point are in agreement with ranges reported by Public Works Canada (1990) and Land and Sea (1991). PCB contamination in HSP samples taken from Outer Bay area sites was observed to be very low.

Polyaromatic Hydrocarbons (PAHs)

Results for analysis of HSP sediment samples show no exceedances of ocean dumping interim rejection limits (individual PAHs) or screening limits (total PAHs) at any site or core depth. As with other sediment parameters, PAH levels were generally highest in deposition areas. Of note is Black Point (Site 6), where particularly in the surface sediment layer, PAH levels were amongst the highest of all measured. Levels are also generally higher in Above Reversing Falls and Harbour Bay areas than in the Outer Bay.

Concentrations in the 5-10 cm core layer measured as part of the MFO program by Dr. Addison's team are in general agreement with those measured by the contract laboratory for the HSP. No samples were seen to exceed ocean dumping guidelines.

Results of analysis of HSP samples do not agree with other data sources such as the SJPC, Public Works Canada (1990), Land and Sea (1991), and JWAL (1992). These sources show exceedances of ocean dumping guidelines around Port facilities, in Courtenay Bay, and at the Black Point Dump Site.

5.4.4.3 Results of Analysis for Dioxins and Furans

Results of analysis of HSP sediment samples for chlorinated dibenzo-p-dioxins and dibenzo furans are presented in Table 5-10. These results show very low levels of dioxin and furan contamination, with most congeners at most sites showing non-detectable levels. According to the classification scheme for dioxin and furan contamination given in the Trudel (1991) document "Dioxins and Furans in Bottom Sediments Near the 47 Canadian Pulp and Paper Mills Using Chlorine Bleach" published by Environment Canada, the following classifications are made for HSP sediment samples:

- South Bay (Site 1) - below detection limits for all dioxin and furan congeners except OCDD, which would be classed as "intermediate".
- Navy Island (Site 2) - as Site 1.
- Courtenay Bay (Site 3) - as Site 1.
- McNamara Point (Site 4) - as Site 1.

Results of the HSP sediment analysis for dioxins and furans are in agreement with those reported by Trudel (1991) for sites immediately up- and down-stream from Reversing Falls. This author reported contamination to be "slight" for HpCDD and OCDD.

Toxic equivalency factors may be used to provide an indication of the implications of the dioxin and furan level measured. Toxic equivalency factors are determined relative to 2378-TCDD (2378-tetrachlorodibenzo-p-dioxin, the most toxic dioxin and furan compound) which has a value of 1 (see Table 5-11). Toxic equivalency factors for HSP sediment samples are given in Table 5-12. These results show low toxic equivalency factors. For reference, the US EPA allows a final concentration of 10 TEQ pg/g (parts per trillion) for land application of pulp and paper mill sludge. Toxic equivalency factors measured for HSP sediment samples are all well below this level.

TABLE 5-10

Sediment Sampling Data - Concentration of Dioxins and Furans - Composite Core Sample.
(Sampled 1992 08 10-12)

Parameter	Unit	Detection Limit Range[2]	Reference Value[1]	Site			
				1	2	3	4
Dioxins							
2378-TCDD	pg/g	0.2 -1.1	n/a	n/d	n/d	n/d	n/d
12378-PeCDD	pg/g	0.3 -0.9	n/a	n/d	n/d	n/d	n/d
123478-HxCDD	pg/g	0.2 -2.5	n/a	n/d	n/d	n/d	n/d
123678-HxCDD	pg/g	0.2 -1.7	n/a	4.2	n/d	n/d	n/d
123789-HxCDD	pg/g	0.2 -1.9	n/a	n/d	n/d	n/d	n/d
1234678-HpCDD	pg/g	1.4 -7.9	n/a	26.0	26.0	20.0	4.2
OCDD	pg/g	15.0 -37.0	n/a	160.0	100.0	110.0	84.0
Furans							
2378-TCDF	pg/g	0.2 - 0.7	n/a	3.5	n/d	1.0	n/d
12378-PeCDF	pg/g	0.2 - 0.4	n/a	n/d	n/d	n/d	n/d
23478-PeCDF	pg/g	0.3 - 0.4	n/a	0.8	n/d	n/d	n/d
123478-HxCDF	pg/g	0.4 - 1.2	n/a	n/d	n/d	0.7	n/d
123678-HxCDF	pg/g	0.4 - 1.3	n/a	n/d	n/d	n/d	n/d
234678-HxCDF	pg/g	0.5 - 1.9	n/a	n/d	n/d	n/d	n/d
123789-HxCDF	pg/g	0.8 - 3.6	n/a	n/d	n/d	n/d	n/d
1234678-HpCDF	pg/g	0.9 - 2.4	n/a	6.1	5.3	4.3	n/d
1234789-HpCDF	pg/g	2.3 - 6.0	n/a	n/d	n/d	n/d	n/d
OCDF	pg/g	4.8 - 9.3	n/a	n/d	n/d	17.0	n/d

1. Reference Value: Refers to a regulated limit, interim rejection limit, or screening limit as defined in the Interim Contaminant Testing Guidelines for Ocean Disposal Atlantic Region, May, 1991. No specific levels for dioxins and furans are given in these guidelines. Levels to be determined on a site specific basis.

2. Detection Limit Range: Varied depending upon the sample size.

n/a: Not available or applicable.
n/d: Not detectable within the specified detection limits.

TABLE 5-11
Toxic Equivalency Factors of Dioxins and Furans.

Parameter	2378-TCDD Toxic Equivalency Factor
Dioxins	
2378-TCDD	1
12378-PeDDD	0.5
123478-HxCDD	0.1
123789-HxCDD	0.1
123678-HxCDD	0.1
1234678-HpCDD	0.01
OCDD	0.001
Furans	
2378-TCDF	0.1
23478-PeCDF	0.5
12378-PeCDF	0.01
123478-HxCDF	0.1
123789-HxCDF	0.1
123678-HxCDF	0.1
234678-HxCDF	0.1
1234678-HpCDF	0.1
1234789-HpCDF	0.01
OCDF	0.001

TABLE 5-12
Sediment Sampling Data - Toxic Equivalency Factors of Dioxins and Furans - Composite Core Sample
(Sampled 1992 08 10-12)

Parameter	Unit	Site			
		1	2	3	4
Dioxins					
2378-TCDD	TEQ pg/g	n/d	n/d	n/d	n/d
12378-PeCDD	TEQ pg/g	n/d	n/d	n/d	n/d
123478-HxCDD	TEQ pg/g	n/d	n/d	n/d	n/d
123678-HxCDD	TEQ pg/g	0.42	n/d	n/d	n/d
123789-HxCDD	TEQ pg/g	n/d	n/d	n/d	n/d
1234678-HpCDD	TEQ pg/g	0.26	0.26	0.20	0.042
OCDD	TEQ pg/g	0.16	0.10	0.11	0.084
Furans					
2378-TCDF	TEQ pg/g	0.35	n/d	0.01	n/d
12378-PeCDF	TEQ pg/g	n/d	n/d	n/d	n/d
23478-PeCDF	TEQ pg/g	0.008	n/d	n/d	n/d
123478-AxCDF	TEQ pg/g	n/d	n/d	0.07	n/d
123678-HxCDF	TEQ pg/g	n/d	n/d	n/d	n/d
234678-HxCDF	TEQ pg/g	n/d	n/d	n/d	n/d
123789-HxCDF	TEQ pg/g	n/d	n/d	n/d	n/d
1234678-HpCDF	TEQ pg/g	0.61	0.53	0.43	n/d
1234789-HpCDF	TEQ pg/g	n/d	n/d	n/d	n/d
OCDF	TEQ gp/g	n/d	n/d	0.017	n/d

5.4.5 Biota Contaminant Burden Results

Blue mussels (Mytilus edulis) and winter flounder (Pseudopleuronectes americanus) sampled as part of the HSP were analyzed according to protocols described in Section 5.4.3. Blue mussel samples for biota contaminant burden assessments were obtained at sites 2, 3, 4, 5, 6, and 9. Blue mussels were not found within reasonable proximity to the other sample sites. Winter flounder samples for biota contaminant burden and MFO testing were obtained at sites 3, 5, and 8, although attempts by diver and beam trawl were made at all sites. Results for analysis of blue mussels and with flounder are summarized below. Note organo-chlorinated pesticides or extractable organic halides were not detected in biota samples.

5.4.5.1 Blue Mussels

Blue mussels samples generally showed slightly higher heavy metal contamination from sites 3, 4, and 5 than Sites 2, 6, and 9 (see Table 5-13). This was particularly true for zinc, although other heavy metals did not show as pronounced differences. Concentrations of heavy metals in the blue mussel soft tissue were much less than those of sediment samples taken from similar sites.

TABLE 5-13
Biota Sampling Data - Heavy Metals in
Blue Mussel (Mytilus edulis) Soft Tissue.
(Sampled 1992 11 09)

Parameter	Unit	Site					
		2	3	4	5	6	9
Cadmium	mg/kg	0.23	0.26	0.39	0.34	0.34	0.25
Copper	mg/kg	1.5	1.8	1.6	1.8	1.3	1.6
Lead	mg/kg	0.26	0.44	0.53	0.77	0.34	0.44
Mercury	mg/kg	0.06	0.04	0.05	0.04	0.05	0.04
Zinc	mg/kg	13.6	24.5	27.5	23.9	13.2	18.5

The Shag Rocks (Site 9) location showed unanticipated high levels of heavy metal contamination. Individuals sampled at this site were smaller then those collected at other sites, suggesting that young, possibly fast growing individuals bio-accumulate metals at a higher rate than larger individuals.

Concentrations of PCBs measured in blue mussel samples were seen to be highest at sites 2, 3, and 4, and surprisingly at Site 9 (see Table 5-14). This latter site also showed high heavy metal contamination, and it is possible that the small individuals bio-accumulated PCBs at a faster rate than larger ones. The Courtenay Bay location (Site 3) showed the highest PCB concentrations.

TABLE 5-14
Biota Sampling Data - PCBs and PAHs in Blue Mussel (Mytilus edulis)
Soft Tissue. (Sampled 1992 11 09)

Parameter	Unit	Detection Limit	Site					
			2	3	4	5	6	9
Polychlorinated Biphenyl (PCB)	ug/kg	10	21	40	22	n/d	n/d	21
Polyaromatic Hydrocarbons (PAH)								
Naphthalene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Acenaphthylene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Acenaphthene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Fluorene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Phenanthrene	mg/kg	0.05	0.33	0.05	n/d	n/d	n/d	n/d
Anthracene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Fluoranthene	mg/kg	0.05	0.25	0.12	n/d	n/d	n/d	n/d
Pyrene	mg/kg	0.05	0.20	0.09	n/d	n/d	n/d	n/d
Benzo (a) anthracene	mg/kg	0.05	0.06	n/d	n/d	n/d	n/d	n/d
Chrysemes	mg/kg	0.05	0.09	n/d	n/d	n/d	n/d	n/d
Benzo (b,j,k) fluoranthene	mg/kg	0.05	0.07	n/d	n/d	n/d	n/d	n/d
Benzo (a) pyrene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Dibenz (a,h) anthracene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Idena (123cd) pyrene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Benzo (g,h,i) perylene	mg/kg	0.05	n/d	n/d	n/d	n/d	n/d	n/d
Total PAHs	mg/kg	n/a	1.00	0.26	n/d	nd/	n/d	n/d

n/a - Not available or applicable   n/d - Not detectable within the specified detection limits

PAHs were only detected from blue mussel samples taken at Navy Island (Site 2) and Courtenay bay (Site 3) (see Table 5-14). It is interesting to note that blue mussels from Navy Island showed higher total PAH levels then measured in the sediments from this site.

5.4.5.2 Winter Flounder

Heavy metal contamination in winter flounder livers was seen to be consistent for individuals taken from all sites where sampling was successful (Table 5-15). This observation may reflect the transitory nature of this fish, which is known to move in and out of coastal areas with the tides.

TABLE 5-15
Biota Sampling Data - Heavy Metals in
Winter Flounder (Pseudopleuronectes americanus) Livers.
(Sampled 1992 08 10-12)

Parameter	Unit	Detection Limit	Site		
			3	5	8
Cadmium	mg/kg	0.002	0.18	0.17	0.14
Copper	mg/kg	0.02	8.6	10.6	10.4
Lead	mg/kg	0.01	0.17	0.23	1.33
Mercury	mg/kg	0.01	0.08	0.09	0.08
Zinc	mg/kg	0.02	65.7	62.3	58.4

5.4.6 Biota Response to Contaminant Exposure

Biota responses to contaminant exposure was assessed by analysis of hepatic mixed function oxidase (MFO) activity in winter flounder sampled from HSP sites 3, 5, and 8. This testing was designed to assess biota responses to particular contaminants, namely hydrocarbons. Results of the MFO testing for the HSP are presented in Table 5-16.

Results of measurements of enzyme activity (Table 5-16) show little variation in EROD and CN-ECOD activity between Courtenay Bay (site 3) and Partridge Island (site 5), with a high level of activity at Mispec (site 8) as compared to these sites.

TABLE 5-16
Mixed Function Oxidase Testing - Winter Flounder (Pseudopleuronectesamericanus) Liver Enzyme Activity.
(Sampled 1992 08 10-12)

Site	Fish Weight (g)	Liver Weight (g)	Liver Size Index (% body weight)	Sex	Protein (mg/g liver)	EROD (p moles/mg protein/minute)	EROD (n moles/ g liver/minute	CN-ECOD p noles/mg protein/minute	CN-ECOD n moles/ g liver/minute	Microsomes	
										Protein (mg/g liver)	P-450 (n moles/mg protein)
3	386.0	9.0	2.33	F	137.09	23.11	3.17	0.00	0.00	2.40	2.62E-01
3	1284.0	25.0	1.95	F	145.66	11.97	1.74	0.02	0.00	0.75	1.34E-01
3	500.0	7.7	1.54	F	151.07	78.18	11.81	0.00	0.00	3.75	2.55E-01
3	184.0	0.8	0.43	F	297.96	39.06	11.64	0.00	0.00	6.56	3.03E-01
5	299.0	1.5	0.50	F	226.95	65.12	14.78	0.16	0.04	4.02	3.46E-01
5	358.0	3.9	1.09	F	163.67	39.10	6.40	1.04	0.17	2.92	3.74E-01
8	376.0	3.5	0.93	F	90.38	294.85	26.65	24.01	2.17	3.26	2.99E-01

The EROD and CN-ECOD enzymes are reported to increase in activity to enhance degradation of contaminants such as PAHs (Addison and Payne, 1986). Results of EROD and CN-ECOD enzyme activity shown in Table 5-16, therefore, suggests that exposure to PAH contamination is higher at Mispec than at the Harbour Bay sites. However, this observation is not reflected in sediment analysis or blue mussel contamination analysis results. Further, transient behaviour of winter flounders in Saint John Harbour and variations in winter flounder sample sizes collected for the HSP may impart some uncertainty to the MFO results (R. Addison, personal communication, 1992). In comparison, results of microsomal P-450 analysis (P-450 is considered to be a catalyst to the EROD and CN-ECOD enzymes) show uniform concentrations in all winter flounder livers analyzed. In review of these and other HSP results, Dr. Addison has commented that while results of the MFO testing do not strongly support or reinforce other HSP results, they do not refute them either.

5.5 Identification of Parameters of Concern

The effluent sampling program (Section 4.0) has identified several tributary, industrial and municipal sources that could potentially result in water quality or aquatic environment deterioration. Potential effects are discussed in Section 5.1 and include recreational health and safety risks, poor aesthetics, habitat disruption, toxicity, tainting, excessive nutrient enrichment and physical nuisance. The type and extent of the effects are dependent on the characteristics of the particular effluents and the general physical characteristics which define the respective area receiving the discharge. The quality of sources entering the Harbour are expected, and in some cases are known, to result in localized environmental impacts. It is outside the scope of this study to delineate mixing zones for the many point source discharges to the Harbour.

This study focused on the determination on the effects on the overall Harbour environment. The cumulative effects in the study area depend on several factors, including specific Harbour uses, contaminant loadings, the potential persistence and accumulation of contaminants in various compartments of the receiving environment, and the overall assimilative capacity of the aquatic system in the Harbour. The Harbour Sampling Program is discussed in Section 5.3 and provides information concerning sediment contaminant burdens, biota contaminant burdens, and biota response to contaminant exposure.

The Saint John Harbour is a dynamic system that is strongly influenced by the St. John River flow and the Bay of Fundy tides. These dominating influences increase the assimilative capacity of the Harbour and makes the identification of pathways and specific effects of contaminant loadings difficult. Many of the contaminants of interest are regulated at the source and it is not within the scope of this study to assess specific sources. The cumulative effect of Harbour environmental quality on Harbour uses is discussed in the following sections. This information will be used to identify parameters of concern and to develop an approach to establishing contaminant priority and water quality objectives.

5.5.1 Above Reversing Falls

The Above Reversing Falls sub-area is characterized by uses including commercial fisheries, tourism, recreation, and nature/scenic appreciation.

The South Bay area has been identified as depositional and contains noticeable levels of contamination of heavy metals, PAHs, PCBs, and oil and grease. Organic carbon levels suggest localized oxygen depletion may be possible, particularly since stratification of the water column regularly occurs. Also of potential concern in the aquatic environment of this sub-area are nutrients and biochemical oxygen demand.

Potential sources of the above-noted contaminants in the Above Reversing Falls sub-area include:

- St. John River and drainage, including the Kennebecasis River and drainage.
- Municipal sewer discharges and storm sewer discharges.
- Industrial discharges in the area of Reversing Falls.

- Harbour Bay sources that may transport contaminants over the Reversing Falls in baroclinic-induced bottom currents.

It should also be noted that historical activities may have contributed to much of the existing levels of contamination in the South Bay (Above Reversing Falls) sub-area. These include shipping and forestry operations.

5.5.2 Harbour Bay

Harbour uses for the Harbour Bay sub-area are discussed in Section 3.0. Uses for the sub-area, which includes the City Harbour and Courtenay Bay include commercial fishing, tourism and port activities.

Port operations are important to the Saint John area. Maintenance of Port activities require extensive dredging in areas of deposition. However, depositional areas have been found to have heavy metal and organic contamination levels that are of concern when the sediment is disturbed. Results of the HSP also indicate oil and grease contamination to be of concern.

Available hydrographic information suggests that potential sources of contamination are located within the Harbour Bay area, and within the St. John River drainage area above the Reversing Falls. Insufficient information is available to quantify specific loadings from the St. John River drainage, although the contribution could be significant. Potential sources in the Harbour Bay include:

- Little River and effluent discharges to it (including Irving Oil Refinery).
- Marsh Creek and small industry and non-point discharges to it.
- St. John River.
- Runoff and leachate from contaminated land, directly or via storm sewers or other municipal discharges.
- Port and shipping activities.
- Industrial discharges directly to the area.

A review of available information has not identified significant effects on commercial fisheries in the Harbour Bay sub-area. However, the potential for at least local concerns related to poor aesthetics, tainting, and physical nuisance, exist. Suspended solids and floating debris in the Harbour Bay sub-area could have some effect on tourism, although the extent is very difficult to quantify. Potential sources of suspended solids and floating debris include the St. John River drainage, Little River, Marsh Creek, and municipal outfalls, as well as industrial outfalls in the Reversing Falls area.

5.5.3 Outer Bay

Harbour uses of the Outer Bay sub-area include commercial fishing, shipping, recreation and tourism, nature/scenic appreciation, and dredge spoil disposal at Black Point.

Parameters of concern to these Harbour uses are identified from the review of available information and HSP results. These include oil and grease contamination of sediments throughout the sub-area; heavy metal and organic parameter contamination at Black Point; and, localized effects of suspended solids, floating debris, and coliforms in areas such as the Western Beaches. In terms of coliforms, this parameter also impacts commercial fisheries (and also recreational and tourism related fisheries activities) by closure of shellfish beds.

Sources of contaminants of concern in the Outer Bay sub-area include:

- Municipal sewer discharges and storm sewer discharges.
- Shipping activities.
- Dredge spoil disposal.
- Discharges of the St. John River and drainage, including increases in contaminants discharged to the Harbour Bay sub-area and Harbour tributaries.

6.0 ENVIRONMENTAL QUALITY OBJECTIVES FOR SAINT JOHN HARBOUR

This section provides recommendations for establishing environmental quality objectives, along with recommendations for a monitoring program to evaluate effectiveness and compliance with the objectives.

In various jurisdictions it has been recognized that it is not practical to treat all effluents to the level that they meet environmental quality objective concentrations at the point of discharge (Ontario Ministry of the Environment, 1984; British Columbia Ministry of Environment, 1986). Implicit in this concept is that some volume of water is required for dilution or modification of the waste effluent before objectives can be met. This involves consideration of two other concepts which are important in relation to the approach for development of environmental quality objectives for Saint John Harbour. These are assimilative capacity and initial dilution/mixing zones.

Assimilative capacity is the ability of an aquatic ecosystem to receive and transform contaminants such that environmental degradation does not occur to the point that sensitive designated uses are impaired. This capacity varies for particular contaminants and is a function of complex physical, chemical, and biological environmental factors. These factors influence the processes affecting the concentration of parameters in the environment and modify toxicity to aquatic organisms.

An initial dilution zone is considered to be a portion of a larger effluent mixing zone, the extent of which is typically relatively small, compared to the overall area being considered. This zone is essential to allow for the initial mixing between effluents and the receiving environment. Within the initial dilution zone there is potential for some degradation of the aquatic environment, and it is in this zone where localized effects on environmental quality (exceedance of guidelines) may be expected. However, effluent quality and dilution in the initial mixing zone should not result in immediately lethal conditions so that swimming organisms cannot evade the area, objectionable deposits and floating material, harmful bioaccumulation in biota, or nuisance conditions (British Columbia Ministry of the Environment, 1986). Outside of the initial dilution zone, the environmental quality should be suitable for designated resource uses, and should protect biota from sub-lethal effects.

Typically, environmental quality objectives do not apply within designated initial dilution/mixing zones, but are applicable to the remaining general area under consideration. It is beyond the intended scope of this study to delineate mixing zones and to determine specific effects of point sources. There is presently provision to address point source discharges through application of end-of-pipe guidelines and regulations which are administered and enforced by the New Brunswick Department of the Environment and Environment Canada. It is recommended that applicable requirements at end-of-pipe take into account generic environmental quality guidelines given in Section 5.1 in the context of the various Harbour uses that may occur in a mixing zone area.

A rationale for development of environmental quality objectives for the overall Harbour study area is provided in this section. Development of environmental quality objectives for Saint John Harbour is discussed relative to accepted definitions, applicable guidelines, and information presented in previous sections of this report. Recommendations for implementation of the objectives and further points of consideration are also provided.

6.1 Objectives Development Process

Rational resource management requires the integration of varied interests of resource user groups with detailed scientific information on the strength, sensitivity, and value of common property resources. Environmental quality managers require information on the environmental quality requirements of various resource uses under consideration in order to make rational decisions regarding the allocation of the particular resources.

6.1.1 Background and Definitions

In order to effectively assess environmental quality and potential contamination problems in a systematic and scientifically based manner, environmental quality managers require tools to define the acceptability of measured concentrations of parameters of concern. The use and interpretation of the tools available to environmental quality managers vary between jurisdictions and among agencies involved in regulating environmental quality. With respect to development of environmental quality objectives for Saint John Harbour, the definitions of the tools described below are consistent with those of MacDonald et. al. (1992):

- Criteria

  These are the scientific data that are evaluated to derive the recommended limits for the uses of the aquatic environment. For example, the 96-h LC_{50} of zinc to the mysid shrimp, Mysidopsis bahia, has been reported to be 0.499 mg/L^{-1} (Suter and Rosen 1988).

- Guidelines

  These are numerical concentrations or narrative statements recommended to support and maintain designated uses of the aquatic environment. For example, no harmful effects on mysid shrimp will result if the maximum concentration of zinc remains below 0.166 mg/L^{-1} (Suter and Rosen 1988); or the concentration of cadmium in sediments must not increase significantly with time (Commission of the European Communities, 1988).

- Objectives

  These are numerical concentrations or narrative statements that are established to support and protect the designated uses of the aquatic environment at a specified site. For example, the average concentration of zinc in the Fraser river estuary should not exceed 0.050 mg/L^{-1} to protect sensitive fish and aquatic life species and, in so doing, should ensure that other beneficial uses are not impaired (Swain and Holms 1985); toxic substances including metallic ions, phenolic compounds, oils, alkalies, and acids should be virtually eliminated from sewage effluents (McKee and Wolf, 1963).

- Standards

  These are objectives that are recognized in enforceable environmental control laws of a level of government. For example, the average concentration of zinc in the Columbia River basin shall not exceed 0.086 mg/L^{-1} (Oregon Department of Environmental Quality 1989).

Environmental quality guidelines are intended to provide the scientific information necessary to define conditions that will protect and maintain the environment in the context of designated resource uses. These uses may include those associated with aquatic life and their habitats, recreation and aesthetics, and the protection of human health. Other valid uses of the marine environment that are less sensitive than those described above may include power generation, dredge spoil disposal and waste assimilation, transportation, and industrial supplies.

Environmental quality guidelines for the protection of a given use are developed by following detailed formalized protocols which require extensive data bases with specified minimum data quality requirements.

In consideration of a particular parameter of concern, the guideline (and objective) developed for the most sensitive designated use at a specific location would govern the management/input of that parameter. For example, objectives for protection of recreational water uses are based on health and aesthetic considerations; with respect to aquatic life, objectives are set at levels to protect all forms of aquatic life and all aspects of the aquatic life cycles, found at the location of concern.

6.1.2 Factors to Consider in Developing Objectives

The environmental quality guidelines provide the scientific and technical information for the derivation of site-specific environmental quality objectives. In addition to identifying applicable guidelines, the information requirements on the specific environmental quality characteristics of the location for which objectives are developed have been described by MacDonald et. al. (1992) to include:

- the existing levels of particular parameters of concern;
- the temporal and spatial variability of water, sediment, and biota characteristics;
- the existing and potential aquatic life;
- the hydrographic features/circulation patterns and the relation to the quality of water, sediment, and biota;
- the existing and potential loadings of contaminants from point and non-point sources; and
- the existing and potential uses of the marine environment.

Socio-economic factors are also considered during the development of objectives for specific locations. This is necessary to determine if the objectives can realistically be attained, and may involve modifying effluent regulations to meet objectives. The socio-economic factors may be factored in by allowing sufficient time for the transition period, before deadlines must be met.

6.1.3 Types of Objectives

Generally, objectives may be classified as interim (or temporary) objectives or permanent objectives. Interim objectives may be considered to be those set where the information available about local conditions and/or the environmental quality guidelines for a parameter of concern are inadequate for the definitive establishment of scientifically defensible objectives. Objectives may also be considered as interim where the recommended approach for their development is tentative, and subject to revision as a formalized protocol is developed. For interim objectives, a monitoring program is specified that will provide additional information and lead to the development of permanent objectives.

Permanent objectives are established when the information available about the local conditions and environmental quality guidelines is considered adequate. A monitoring program is also specified with permanent objectives to determine how well they are attained. Both interim and permanent objectives should be widely reviewed (regulatory agencies, public consultation, etc.) before they are adopted. Permanent objectives need to be reviewed periodically and revised as necessary, as new information becomes available.

The Canadian Council of Ministers of the Environment (CCME, 1991) have established a policy regarding environmental quality objectives such that, as a minimum, the objectives should protect existing and potential uses of the aquatic system under consideration. Where a system supports valuable biological resources, further degradation of the system should be avoided.

6.1.4 Applicable Guidelines

MacDonald et. al. (1992) reported that in Canada, there are currently no nationally recognized, ecotoxicologically based guidelines to evaluate the quality of marine water or sediments. These authors have also indicated that although numerical limits for the assessment of marine sediments have been formulated for mercury and cadmium relative to dredge spoil disposal, no documented rationale for these limits is available.

Several other jurisdictions employ water and sediment quality guidelines as a means of assessing the quality of coastal and estuarine environments and as a scientific basis for the establishment of site-specific environmental quality objectives and standards. The approaches which have been or may be used to formulate quality guidelines, and thus objectives, for the marine environment have been reviewed and evaluated by MacDonald et. al. (1992). They have also compiled water and sediment guidelines for the protection of various resource uses which have been used by several jurisdictions.

For the purpose of developing marine environmental quality guidelines and objectives for water, MacDonald et. al. (1992) have recommended that the guidelines compiled from other jurisdictions, where they are suitable for Canadian conditions (they account for the sensitivities of Canadian species), be adopted as working interim guidelines until more detailed assessments can be conducted. They have also recommended that interim sediment quality guidelines should be established using the information which is currently available and in use in other jurisdictions. A three-tiered system approach for the selection of numeric interim sediment quality guidelines has also been suggested.

For the purpose of developing interim environmental quality objectives for Saint John Harbour, guidelines compiled from other jurisdictions by MacDonald et. al. (1992) and sediment management standards developed for Washington State (Washington State Department of Ecology, 1991) were reviewed to determine applicable guidelines for parameters of concern which may be adopted.

6.2 Environmental Quality Objectives

The environmental quality of Saint John Harbour is affected by localized problems related to point source discharges and cumulative effects in the general study area resulting from exposure to parameters of concern originating from a variety of sources. In order to determine the nature and extent of effects on Harbour environmental quality and identify the parameters of concern, the Harbour Sampling Program was undertaken (i.e., effects on biota and sediment). Information generated through this program has been used as a basis for developing environmental quality objectives for Saint John Harbour.

As indicated in Section 5.4, parameters of concern have been identified (specific to sediment concentration) for each of the previously designated hydrographic sub-areas within the study bounds. The particular parameters are of concern because of their known or potential effects and restrictions on the designated resource uses in each of the sub-areas.

Potentially, environmental quality objectives can be developed for the two principal compartments of the environment which are associated with resource uses, namely water and sediments. With respect to Saint John Harbour, environmental quality objectives specific to water are not being proposed for the parameters of concern. This is based on consideration of several factors which are important to the development of these objectives.

Data reviewed were inadequate to characterize water quality in the Harbour for the parameters of interest associated with municipal and industrial effluents specified in the study Terms of Reference. It was beyond the scope of this study to develop and conduct a program to supplement the paucity of data related to the parameters of interest and other water quality variables that have a modifying influence on the effect of these parameters.

As indicated in previous sections, it is recognized that effluents from various sources discharging to the Harbour (directly or indirectly through tributaries) are potentially lethal to aquatic life and contain parameters of interest which may have various effects on area uses, based on the samples collected at source. This is evident from the results of toxicity tests conducted on samples collected from tributaries such as Little River which receive effluent from a variety of sources. There are insufficient data to determine how the effects in the Harbour may be modified by site-specific water quality variables and to define the configuration and extent of the initial dilution zone associated with respective discharges. Delineation of the mixing zones is also outside of the scope of this study.

As such, water column quality was assessed indirectly through the biotic response and contaminant burden components of the Harbour Sampling Program. Based on the results of those components, no parameters of concern were identified with respect to water column quality in the general study area. Although water quality impairment associated with particular parameters of concern was not identified for the general study area, there are expected to be localized effects within initial dilution zones. However, based on the review of data generated and compiled during this study, cumulative effects on the environmental quality in the general Harbour area appear to be limited.

As discussed previously, environmental quality objectives typically do not apply within mixing zones. Therefore, an effective environmental management strategy for dealing with the localized effects would be to handle these on a point source by point source basis. This would involve application of appropriate end of pipe regulations to address problems associated with the localized impacts of particular point sources.

In the following sections, environmental quality objectives are discussed for the parameters of concern (as described in Sections 5.5) which include oil and grease, PAHs, and PCBs.

6.2.1 Parameters of Concern

As stated previously, the environmental quality objectives for Saint John Harbour must be established to protect the most sensitive uses in the areas under consideration. It is generally recognized that if the environmental quality is maintained to protect aquatic marine biota in a viable and healthy ecosystem, it will also be adequate for other uses of the marine environment (MacDonald et. al., 1992).

In each of the Harbour sub-areas, the parameters of concern were identified based on their concentrations in sediment. Elevated concentrations of contaminants in bottom sediments have the potential to result in a range of adverse effects on benthic biota.

As a result of the concentrations of the respective parameters, restrictions on Harbour activities such as dredging and dredge spoil disposal are imposed by regulatory sediment concentration limits administered by Environment Canada (set out in the Interim Contaminant Testing Guidelines for Ocean Disposal - Atlantic Region, 1991). Because these guidelines have established the limitation on activities necessary for the continued use of the Harbour for transportation associated with a major port, it is necessary that concentrations of the parameters of concern be reduced in sediments.

Numeric guidelines available from other jurisdictions were reviewed to identify guidelines for these parameters with relevance to Saint John Harbour. As discussed by MacDonald et. al. (1992), the actual concentrations recommended for various contaminants differ by up to three orders of magnitude. This is true with respect to different end point values generated using the same derivation approach.

This suggests that the approaches may be appropriate for specific applications but are not universally applicable. In determining guidelines which may be used to develop numerical objectives for an area under consideration, it is important that site-specific factors can be incorporated for generating these. Several guidelines have identified environmental characteristics, specifically organic carbon content of the sediment, which may be used in developing objectives on a site-specific basis.

Using factors such as organic carbon content of the sediment merits consideration in developing site-specific sediment quality objectives, due to the influence of organic carbon on adsorption and potential bioavailability of organic contaminants (Dragun, 1988). Although this approach may be employed in developing the site-specific sediment objectives, several uncertainties exist with respect to the relationship between the organic content of the sediment and the toxicological response resulting from exposure to particular compounds (S. Smith, Eco-Health Branch, Environment Canada, personnel communication, 1993).

Also, several projects are currently underway in several jurisdictions (Florida Department of Environmental Regulation; U.S. National Oceanic and Atmospheric Administration; S. Smith, personal communication) which are developing/modifying approaches for assessing marine sediment quality and the product of these should be reviewed upon completion for their relevance in modifying any objectives adopted. Environment Canada is currently developing environmental quality guidelines for contaminants in marine sediments (i.e., PAHs) which are expected to be released within a few months (S. Smith, personal communication).

In light of the considerations discussed above, it is inappropriate to propose specific numerical objectives for concentrations of the respective parameters of concern in sediments, in isolation of the ongoing efforts to prepare Canadian sediment quality guidelines. On an interim objective basis, guideline values which consider organic carbon content of the sediment, may be adopted. In this respect, the sediment management standards employed for Puget Sound (Washington State Department of Ecology, 1991) are applicable. However, these should be reviewed for implications relative to the current ocean disposal guidelines.

The effects associated with oil and grease, PAHs, and PCBs are not localized, but are common to depositional zones throughout the study area. Therefore, loadings of oil and grease, PAHs, and PCBs from potential sources to the Harbour should be reduced. This is necessary in order to reduce potential further contamination of sediments in depositional areas that may require dredging in the future. Also, for areas requiring ongoing maintenance dredging, this will help reduce the concentration of parameters of concern in sediments deposited from various source areas.

6.3 Potential Sources and Relative Loadings

Previous sections of this study reviewed historical data and reported results of sampling programs that described sources of contaminant loading (tributaries, industries, and municipal) to the Saint John Harbour. This information serves to provide an extensive qualitative description of contaminant sources; quantitative descriptions are not as well defined (nor was the aim of the study to undertake detailed quantitative descriptions). This section provides a review of these descriptions, and identifies potential sources of parameters of concern to the Harbour.

Tributaries discharging to Saint John Harbour include Marsh Creek, Little River, Hazen Creek, and the St. John River. The St. John River dominates flows entering the Harbour, not only of the tributaries but also of all potential contaminant sources. Sampling undertaken for this study indicated concentrations of parameters of concern below detection limits. However, given the high flow of this tributary and the resultant potential for significant loadings of contaminants (even if concentrations are low), this source can not be discounted. Little River exhibited detectable concentrations of oil and grease and some PAH compounds. Flow rates from this tributary, as well as the nature of industries discharging effluents to its catchment, warrant its consideration as a source of parameters of concern.

Industries examined as part of this study include several potential sources of loadings of parameters of concern to the Harbour. Detectable concentrations of oil and grease were observed in all industries examined, with the exception of T.S. Simms, NB Power Courtenay Bay, and NB Power Coleson Cove. Concentrations of PCBs and PAHs were measured on a less consistent basis than oil and grease. Results generally showed low concentrations in all industries where measurements were taken (T.S. Simms, Irving Pulp & Paper, Irving Tissue, Irving Paper, and Irving Oil Refinery). While results reported for this study do not provide a comprehensive quantitative analysis and ranking of industrial effluent quality, they do indicate potential sources.

Municipal wastewater sampling undertaken for this study provided information on potential loadings of several parameters from these sources. With respect to the identified parameters of concern, oil and grease was detected in all samples in similar concentrations to the industrial effluents. PCBs and PAHs were not measured for municipal samples.

Flow rates from the municipal sources were recorded to be of a similar order of magnitude as all but the larger industries. Given the large number of municipal outfalls to the Harbour, contributions from these sources must be considered in efforts to meet environmental quality objectives. Storm sewer discharges to the Harbour are also likely to be a potential source of loading of all parameters of concern.

Other potential sources of loadings of parameters of concern to the Harbour include uses of the Harbour itself. In particular, shipping and recreational boating activities probably contribute to the oil and grease contamination of the Harbour. This could be from discharge of ballast water or simply the operation of motors. Run-off from facilities located around the Harbour are also probable contributors.

This discussion of potential sources has been given with respect to the identified parameters of concern. It should also be noted that localized impacts have been identified as a concern in Saint John Harbour. Consideration must be given to the sources of contaminant loadings resulting in localized impacts, relative to attaining the environmental quality objectives and maintaining acceptable quality in the Harbour aquatic environment.

6.4 Recommendations

The following recommendations are provided based on information presented in this section and previous sections of the study:

- Delineate and assess localized effects of point sources on the Harbour environment, including the Little River, Marsh Creek, and western beaches areas.

- Implement the recommendations of the Component B study which identifies an overall wastewater treatment strategy for the City of Saint John (Godfrey Associates Ltd., 1993).

- Identify all cumulative sources and loadings of contaminants of concern, including industrial, municipal (including stormwater), and tributary sources.

- Develop and implement a strategy to reduce the loadings of oil and grease, PCBs, and PAHs from identified sources.

- Continue to monitor effluent sources under the existing regulatory framework initiatives, and undertake additional monitoring of sources, and the receiving environment, as required (with a program designed with consideration of factors outlined below).

- Review historical data and data collected from ongoing monitoring programs to identify changes in source loadings and potential effects on Harbour uses and attainment of environmental quality objectives.

- Consider development of new or re-defined regulations and guidelines with respect to environmental quality objectives and harbour uses. New information may provide for establishment of numeric environmental quality objectives that may lead to standards of environmental quality.

- Provide a forum for public consultation and review of present and future environmental quality objectives.

- Undertake to plan for harbour uses and activities based on information collected from implementation of the above recommendations.

6.5 Considerations for a Monitoring Program

Setting objectives for environmental quality requires establishment of a monitoring program to determine compliance. Design of the monitoring program must consider the same factors as were considered in setting the objectives. Such programs will yield results specific to the parameters of interest, and ensures resources are allocated in the most practical and cost effective manner.

The following sections describe design considerations and parameters of concern for an environmental quality objective monitoring program for Saint John Harbour. An environmental quality objective monitoring program for Saint John Harbour would have the following objectives:

- detect changes in the aquatic environment of Saint John Harbour, with particular reference to specific environmental quality objectives;
- detect changes in the mass loadings of contaminants to Saint John Harbour, with reference for potential to affect environmental quality objectives; and,
- determine the extent of localized effluent mixing and impact zones.

6.5.1 Design Considerations

Factors to consider in the design of the monitoring program must be similar to those employed in setting the environmental quality objectives (Valiela and Whitfield, 1988). Section 6.2.2 described factors to consider in setting objectives, including existing levels of contamination, temporal and spatial variability, existing and potential aquatic life, hydrographic features, existing and potential contaminant loadings, and existing and potential uses (MacDonald et al., 1992). Valiela and Whitfield (1988) provide an alternative view of these factors, but described more in relation to designing monitoring programs. Groups of factors described by these authors include:

- seasonal variability in flows and contaminant concentrations of all contributing sources, as well as dilution/dispersion waters;
- biologically critical periods;
- interactions of parameters of interest with other variables that may effect detection, mobility, biological availability and/or toxicity; and,
- cumulative effects and lags in functional responses that may effect detection.

Consistent through these factors is the need to consider spatial and temporal variability. In particular, consideration must be given to background variability, and the relation of parameters of interest to these patterns (Valiela and Whitfield, 1988). Monitoring programs must consider variability in harbour uses and constraints in these uses. The current and potential harbour uses must be considered on an ongoing basis as these may lead to future modifications in the choice of parameters to include in the program. Limitations due to variability and cost also define practical limitations in the monitoring program.

6.5.2 Special Considerations - Localized Impacts

Previous sections of this study have indicated areas of Saint John Harbour are subject to localized impacts from specific point sources and contaminant parameters. These localized impacts differ from widespread impacts in that they do not impose a general constraint on a harbour use. This does not preclude the fact that some localized impacts restrict harbour uses in localized areas.

Numeric environmental quality objectives are not generally applied to initial mixing zones. Some exceedance is allowed in these areas, provided that lethal conditions, objectionable deposits or floating materials, harmful bioaccumulation, or nuisance conditions do not occur (British Columbia Ministry of the Environment, 1986). Locations of initial mixing zones, or at least specific areas of localized impacts should be determined for Saint John Harbour.

6.5.3 Parameters of Concern and Monitoring Considerations

Parameters of concern for the environmental quality monitoring program should include those for which specific objectives have been established, as well as parameters that may interact with specific objective parameters, that have potential to impose restrictions on harbour uses, or that may effect the spatial or temporal variability of specific objectives.

6.5.3.1 Oil and Grease, PCBs, and PAHs

Environmental quality objectives have been established for the parameters of concern (oil and grease, PCBs, and PAHs). The objective is to reduce loadings of these parameters to the Harbour. Monitoring should therefore include these parameters with respect to point source discharges, tributary discharges, and contamination in the sediment.

Monitoring of point source discharges is incorporated in the existing regulatory framework. Data resulting from this monitoring must be examined for loadings information, as well as to determine temporal variations in loadings of individual point sources, and spatial variation between sources. Tributary discharges are not monitored under existing regulations; provisions should be made to monitor these as point sources. Municipal discharges must also be considered.

Monitoring of sediment contamination is presently achieved as requirements for dredging in port areas (this is the constrained harbour use). Monitoring of sediments to determine the status of contaminant accumulation should be conducted on a regular and more widespread basis, regardless of any immediate temporal or spatial requirement for dredging. This will allow collection of data that is related to spatial and temporal variability of the receiving environment.

There is no systematic program for monitoring biota contaminant burden currently in place. In addition to the monitoring program components described above, biota contaminant burden monitoring should be conducted on a regular basis, consistent with sediment monitoring. The target organisms should include mussels and flounder, in order to build on the existing data. This will assist in determining if the parameters of concern become problematical for resident biota.

6.5.3.2 Additional Parameters

Additional parameters which must be included in the environmental quality monitoring program are those which interact with specific parameters of concern, those with potential to impact existing or future harbour uses, those that describe spatial or temporal variability, or those that describe areas of localized impact.

Existing regulations pertaining to ocean dumping and sediment contamination have been acknowledged to be deficient in that they do not consider site specific mitigative conditions. In particular, organic carbon has been noted to interact with PAHs and other organic contaminants to reduce their mobility and/or bio-availability. This parameter should therefore be included in the monitoring program, particularly with respect to sediment contamination.

Parameters included in existing regulations for point source discharges have the potential to interact with identified parameters of concern or to impact on harbour uses. Monitoring of these parameters should continue at the point sources. Variations (positive or negative, spatial or temporal) in loadings of these parameters will identify requirements for further monitoring of water quality, sediment quality, or biotic contamination. As available information does not presently identify concerns other than for oil and grease, PCBs, and PAHs, specific planning to monitor the receiving environment for parameters apart from these is not presently justified.

Existing information provides an overall description of hydrographic and sedimentology conditions in Saint John Harbour. General patterns are known that describe spatial and temporal variations. Areas of high sedimentation (such as Courtenay Bay, the Harbour channels, and around the port facilities) are known and sediment sampling should be concentrated in these areas. In addition, it is known that patterns vary seasonally in the Harbour, and that during periods of high river flow there is a net loss of sediment from the Harbour. Environmental sampling during these periods would not be effective. Further sampling should be conducted to delineate zones of localized impact for inclusion of these areas in an effective environmental monitoring program.

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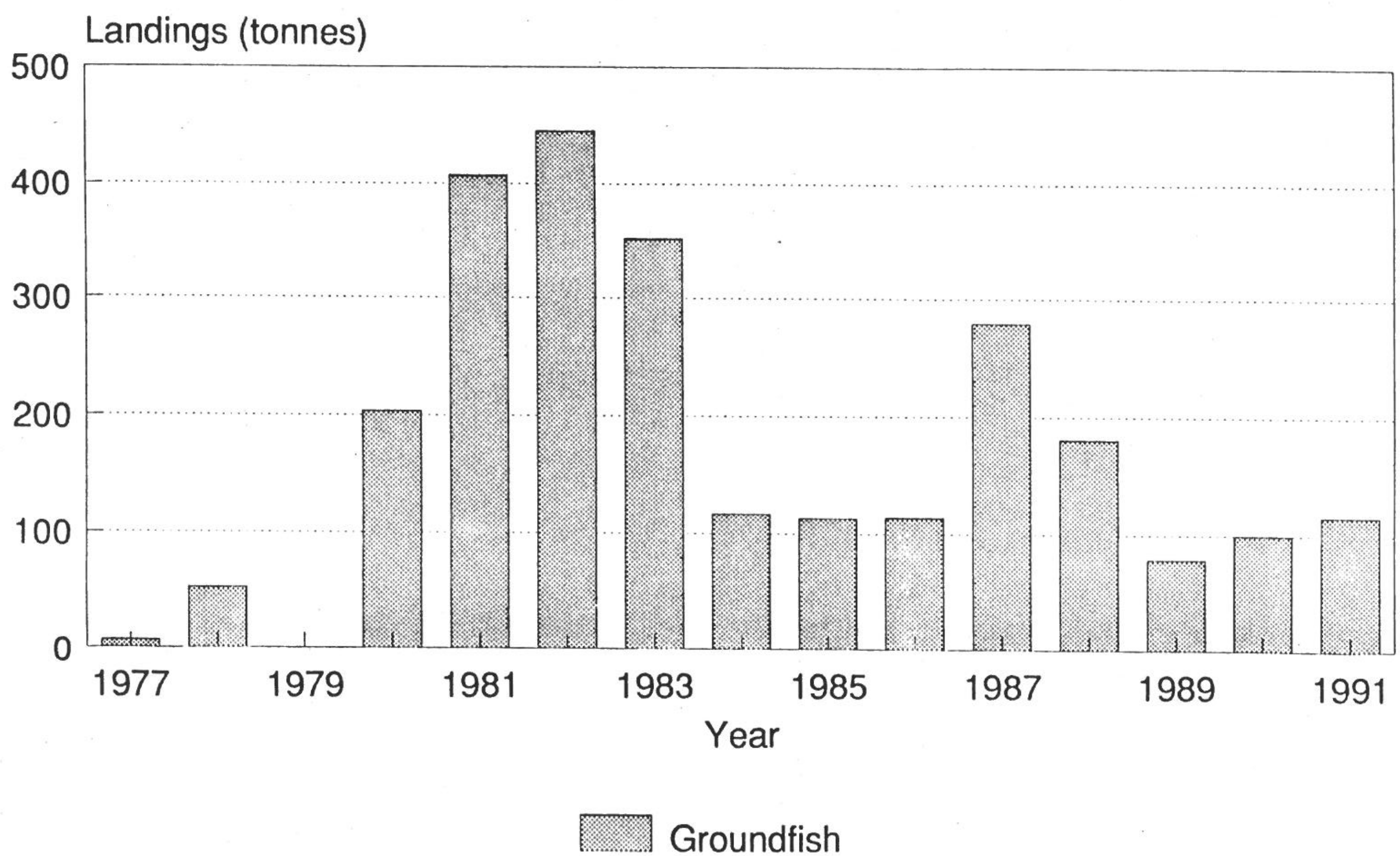
APPENDIX A

Commercial Fishery Landing Statistics

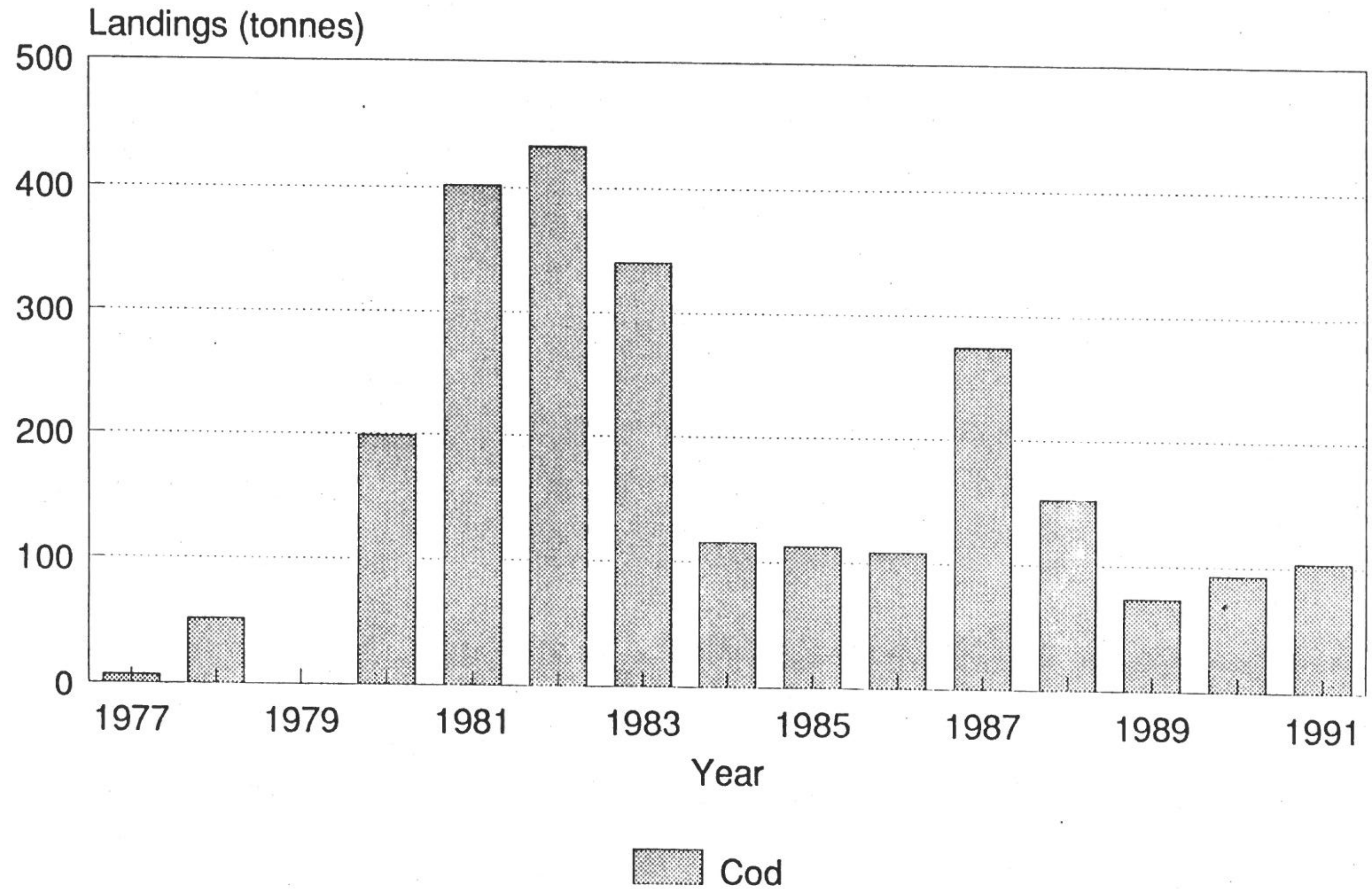
SAINT JOHN HARBOUR AREA
GROUNDFISH FISHERY
Statistical Districts 48 and 49



Inshore Fishery Only

SAINT JOHN HARBOUR AREA COD FISHERY

Statistical Districts 48 and 49

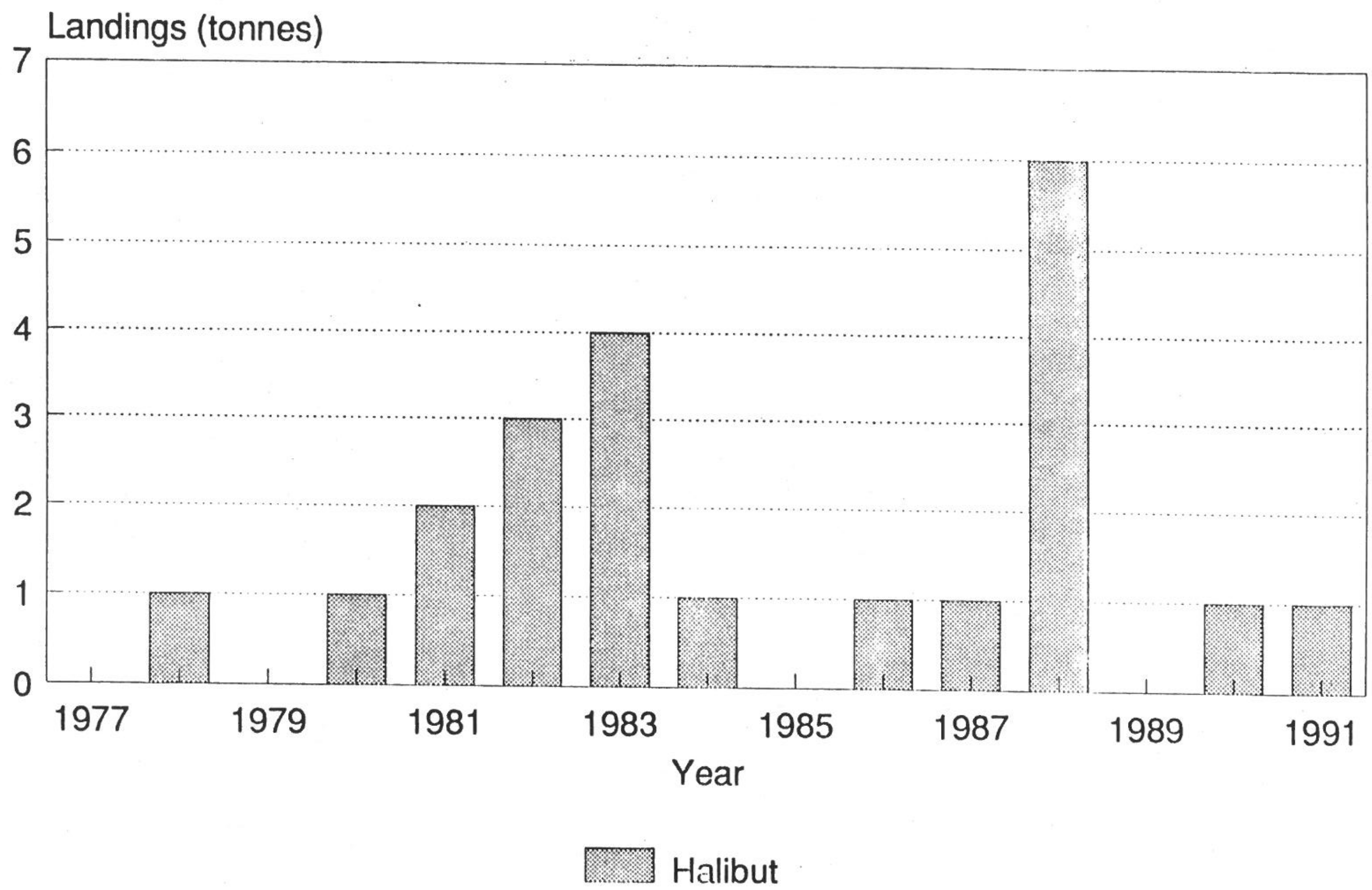


Inshore Fishery Only

WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA HALIBUT FISHERY

Statistical Districts 48 and 49



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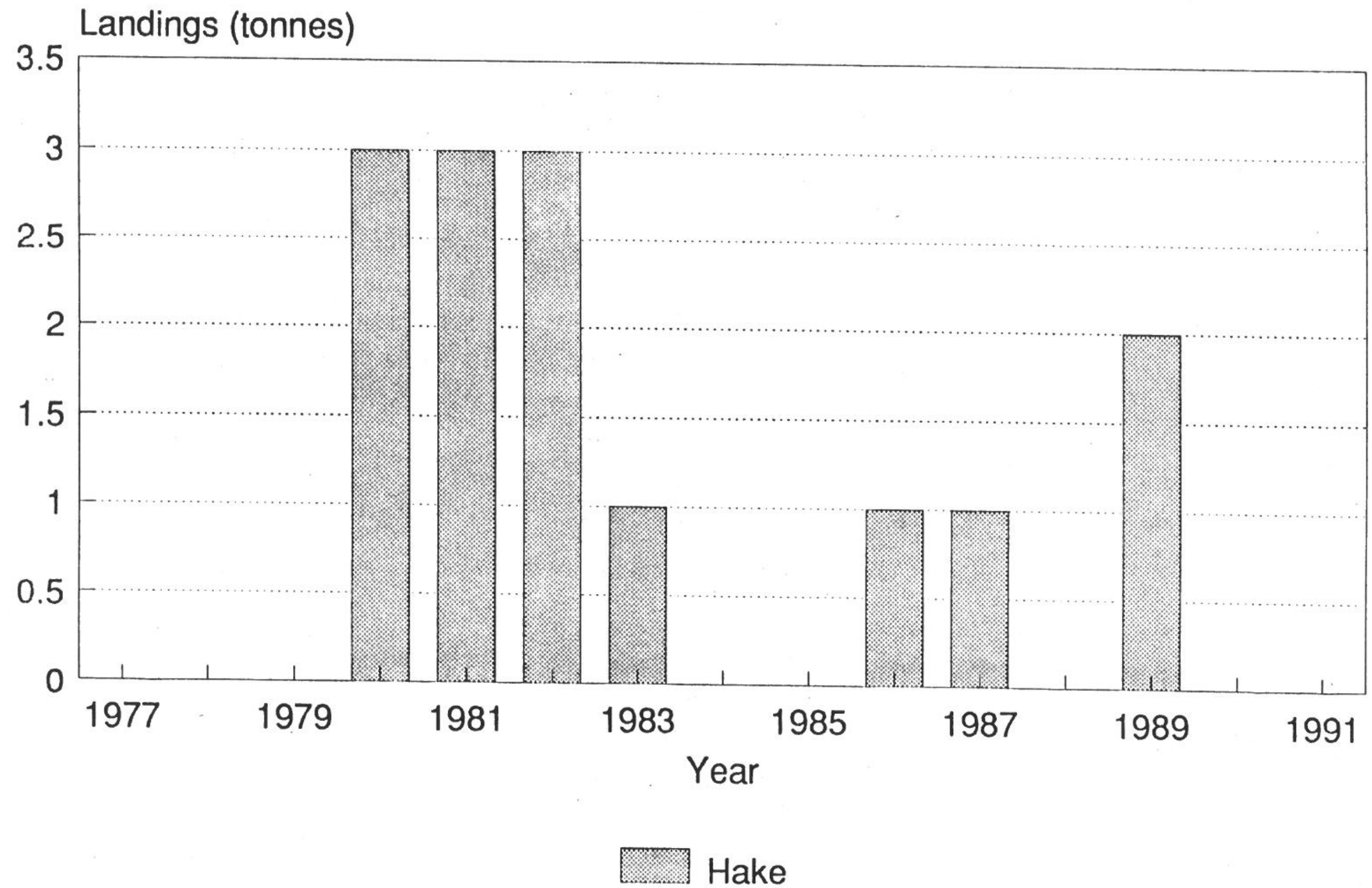
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA HAKE FISHERY

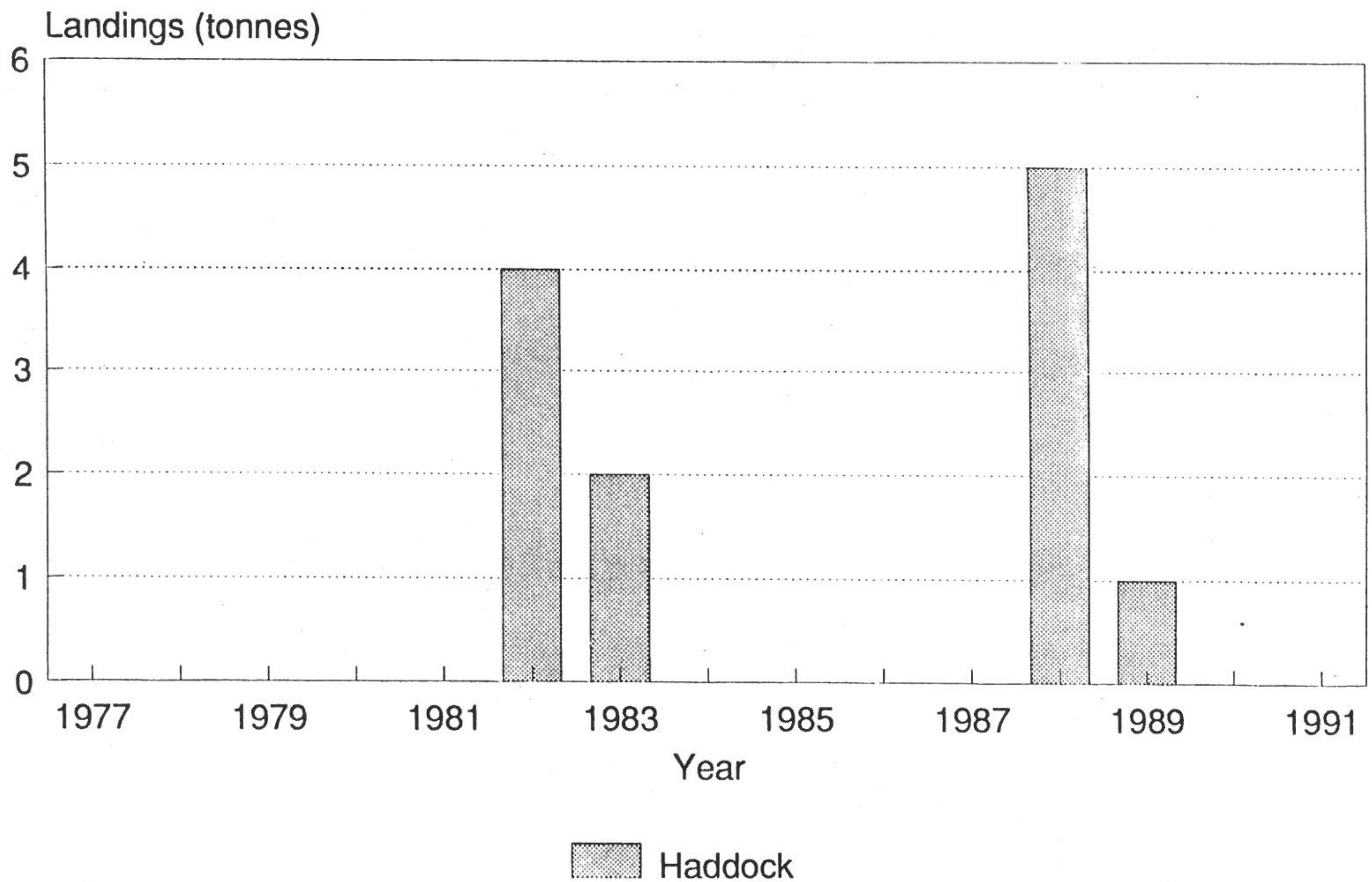
Statistical Districts 48 and 49



Inshore Fishery Only

SAINT JOHN HARBOUR AREA HADDOCK FISHERY

Statistical Districts 48 and 49



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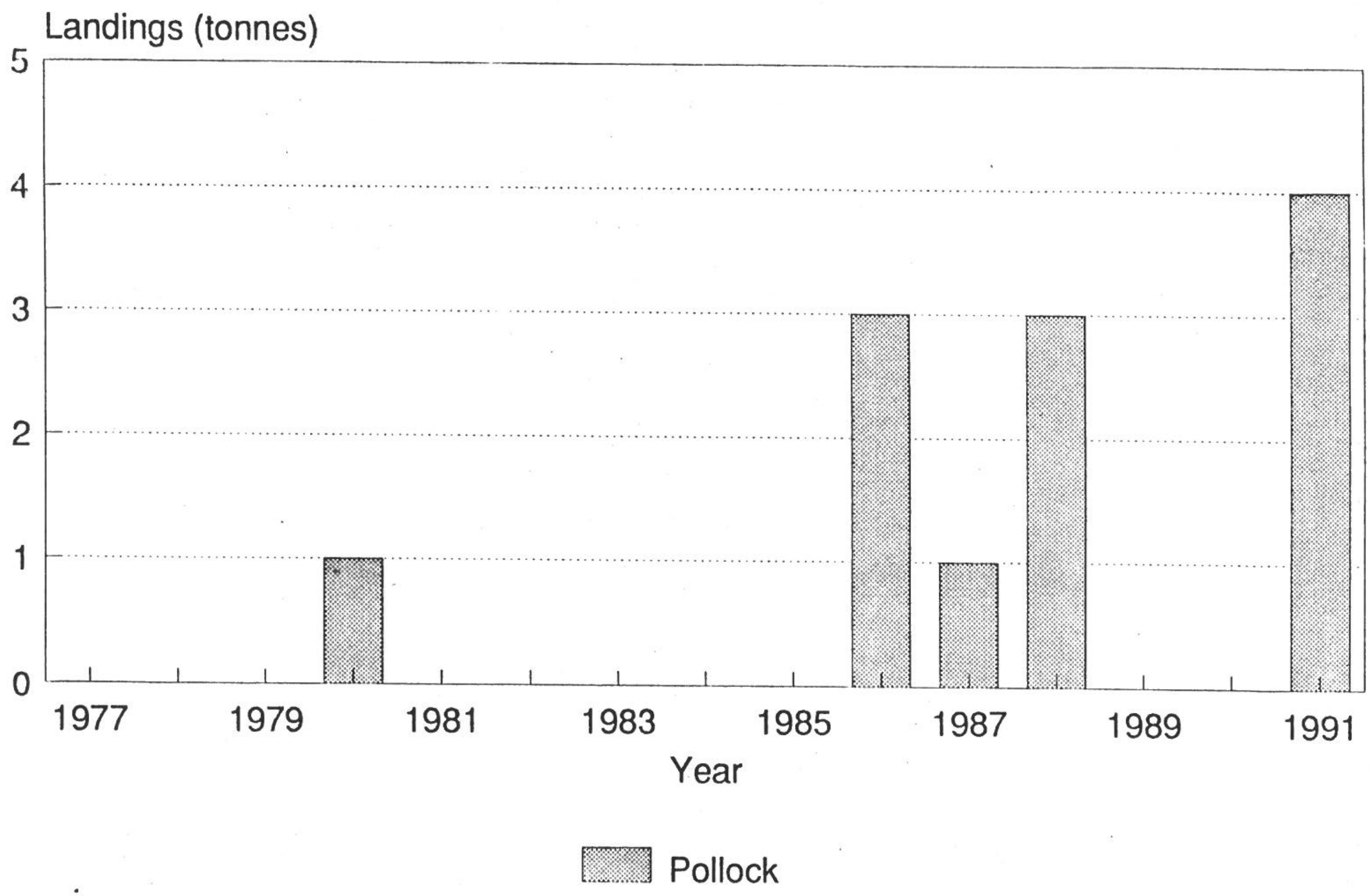
SAINT JOHN HARBOUR AREA POLLOCK FISHERY

Statistical Districts 48 and 49



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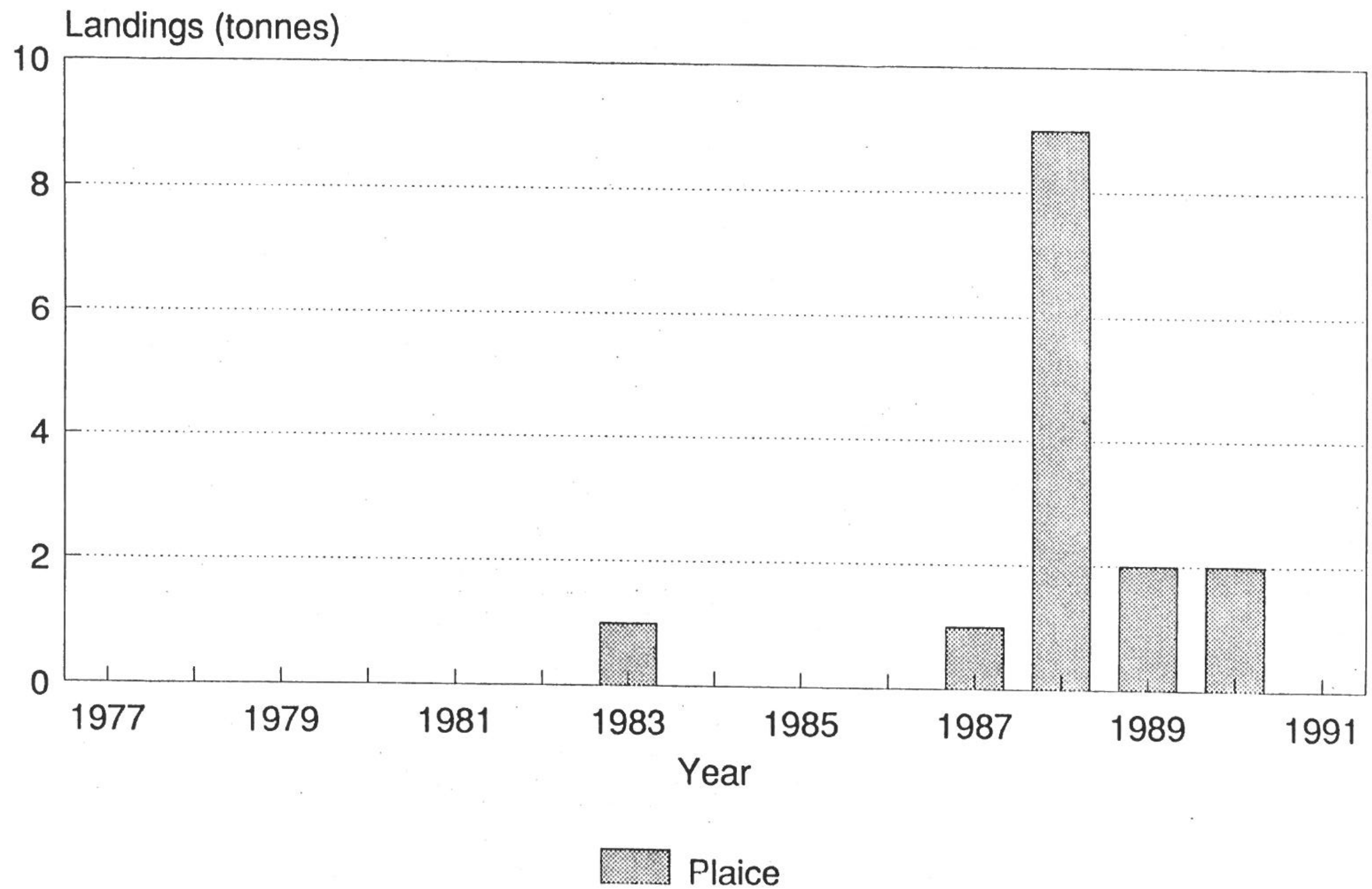
SAINT JOHN HARBOUR AREA PLAICE FISHERY

Statistical Districts 48 and 49



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SAINT JOHN HARBOUR AREA
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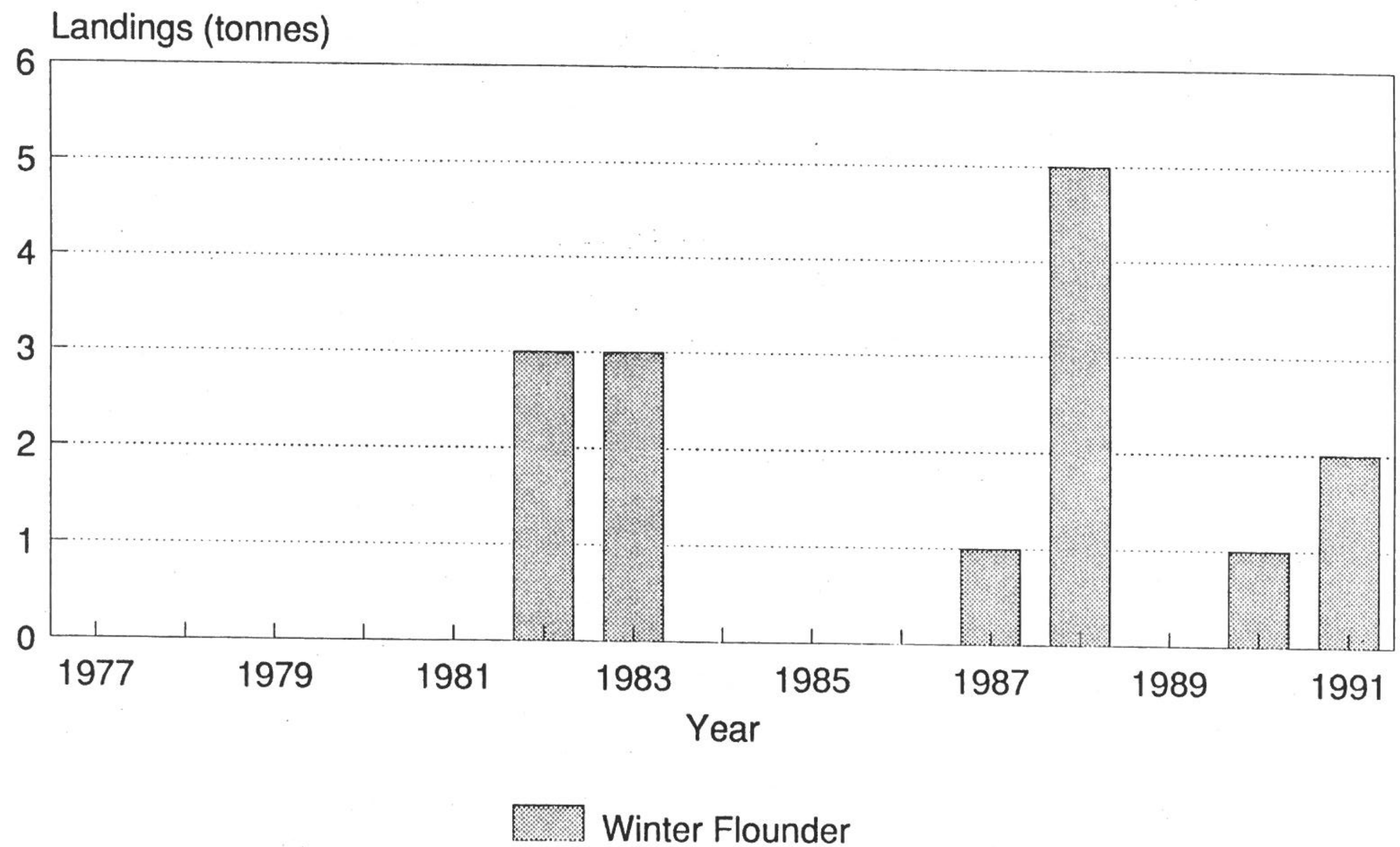
Statistical Districts 48 and 49



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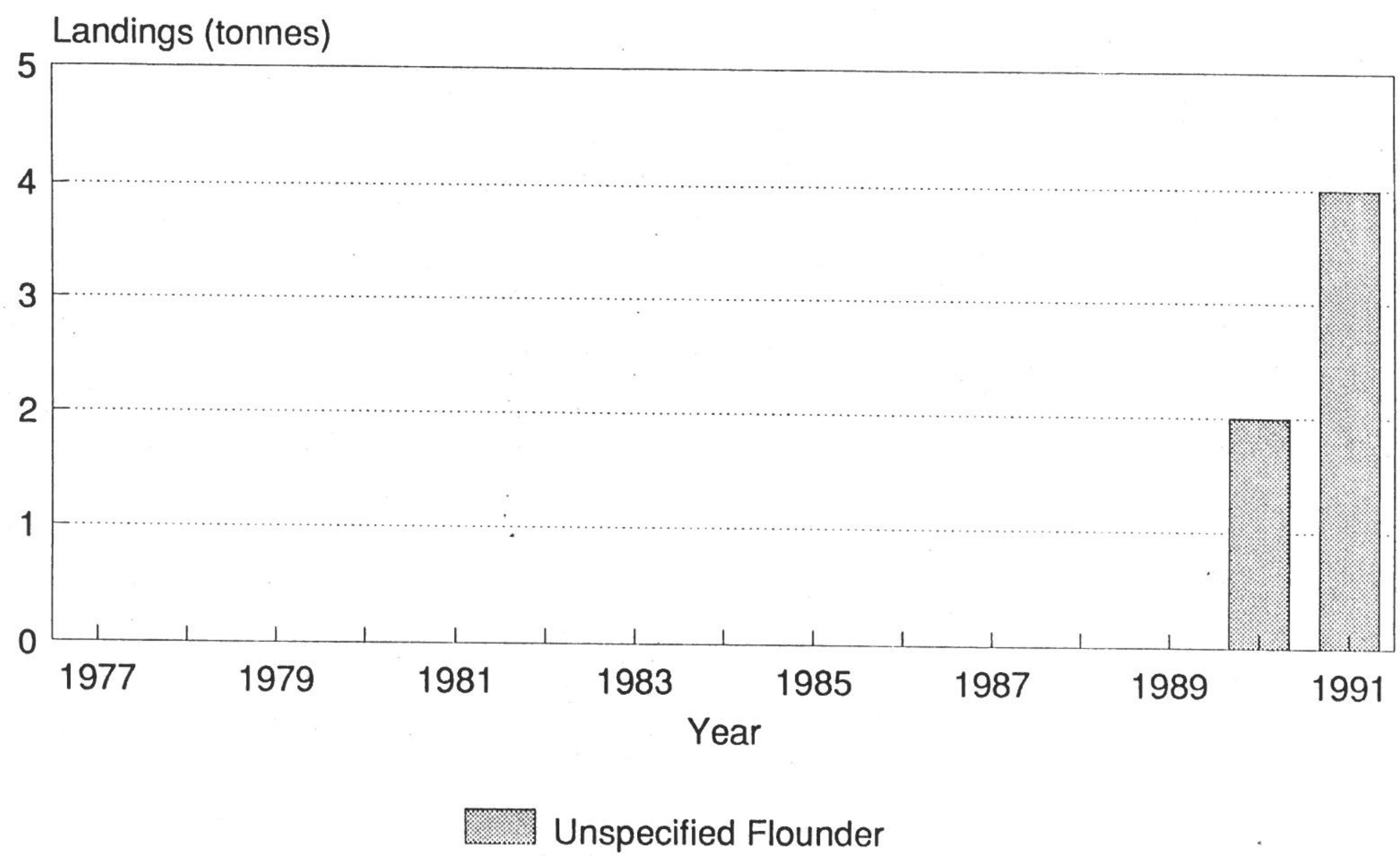
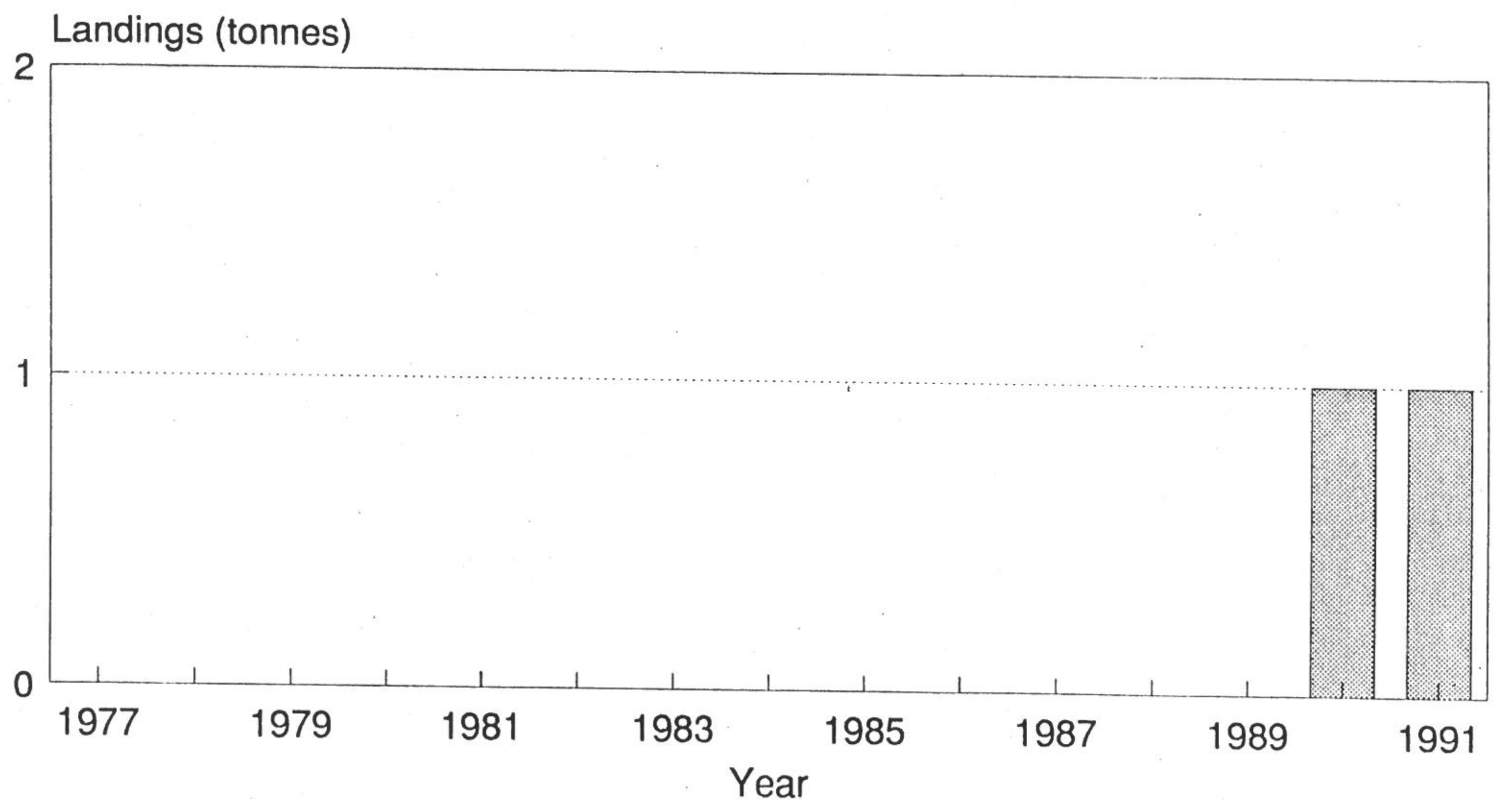
SAINT JOHN HARBOUR AREA
UNSPECIFIED FLOUNDER FISHERY
Statistical Districts 48 and 49



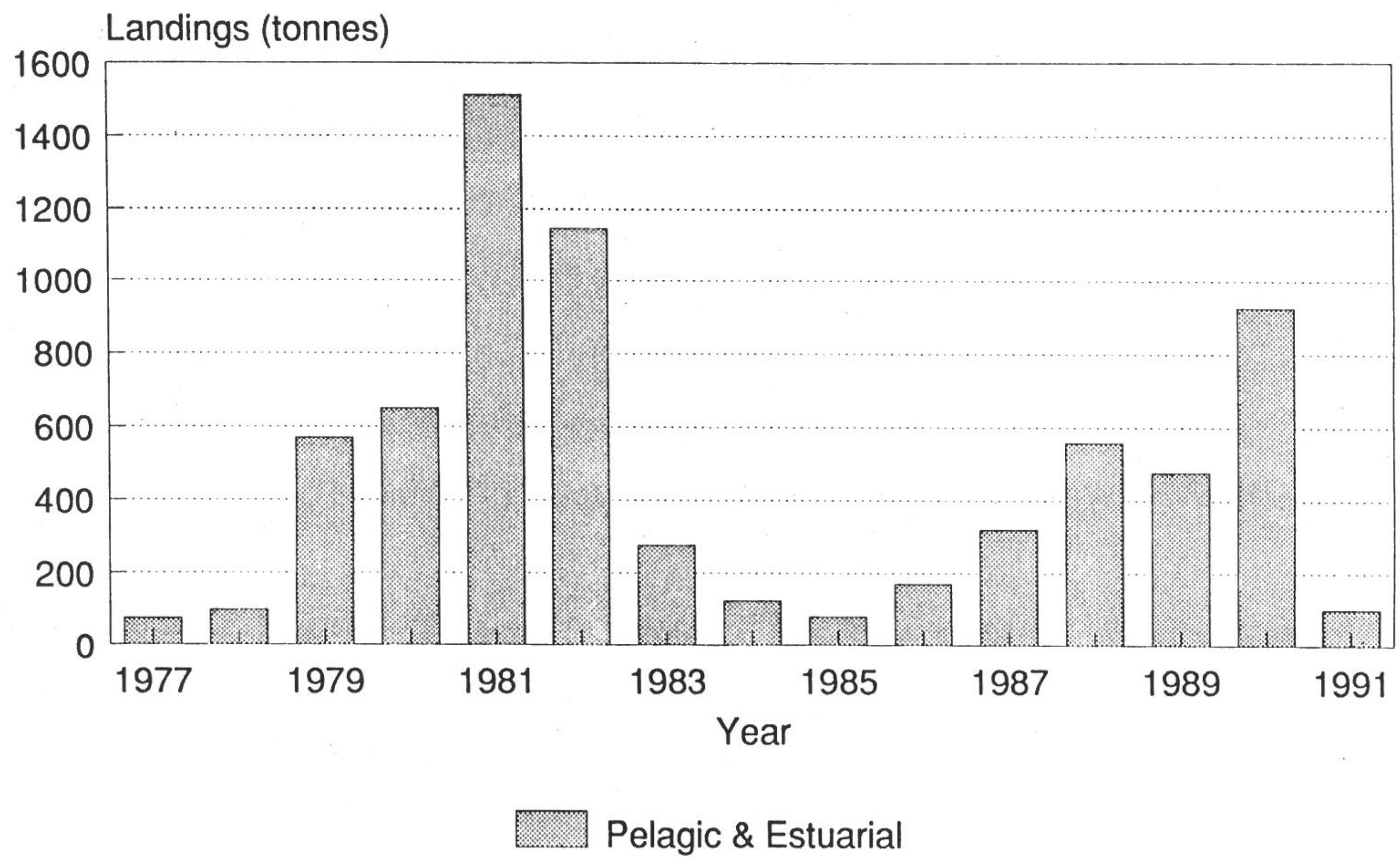
Inshore Fishery Only

SAINT JOHN HARBOUR AREA
GREY SOLE FISHERY
Statistical Districts 48 and 49



Inshore Fishery Only

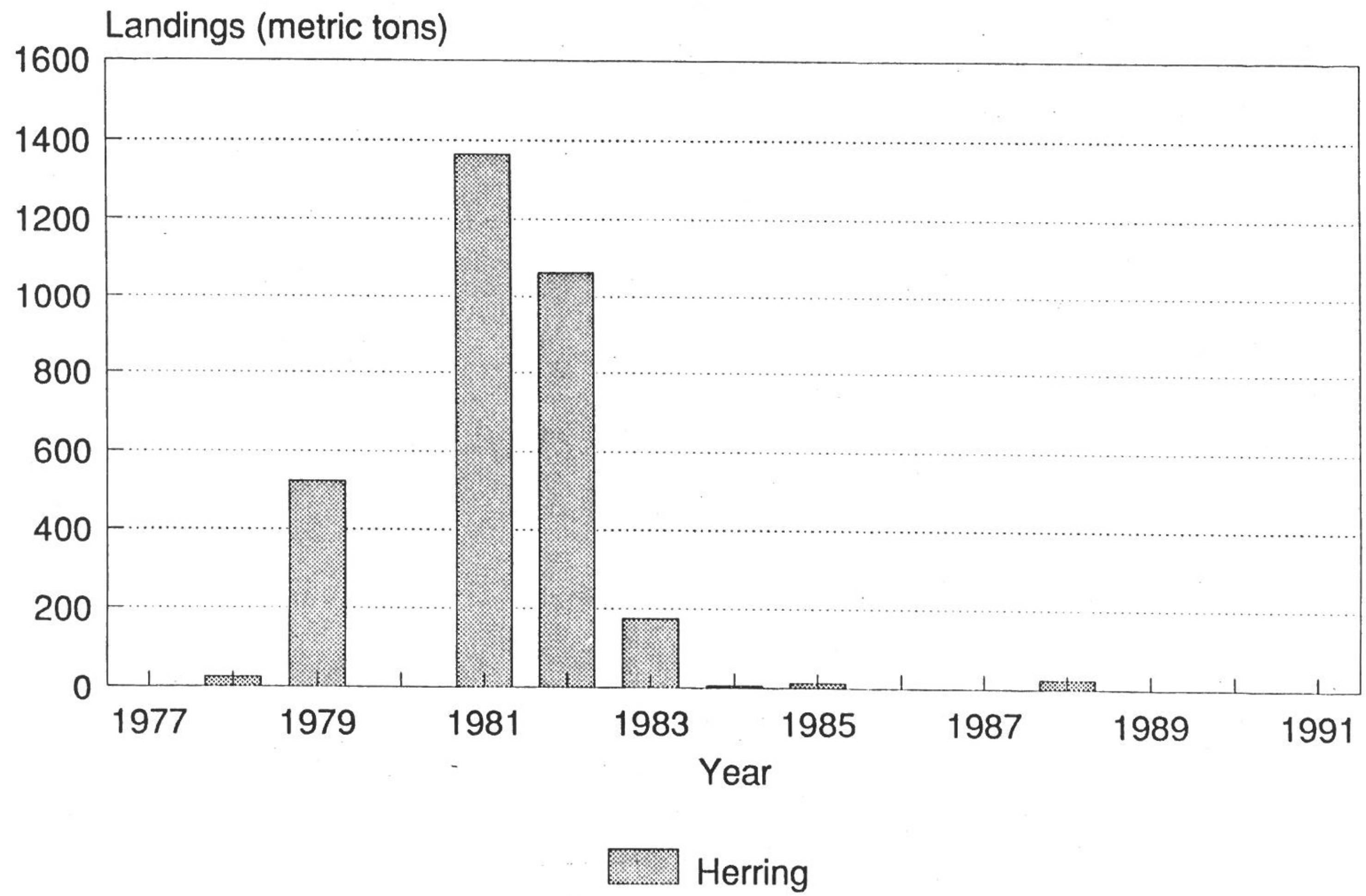
SAINT JOHN HARBOUR AREA
PELAGIC AND ESTUARIAL FISHERY
Statistical Districts 48 and 49



Inshore Fishery Only

SAINT JOHN HARBOUR AREA HERRING FISHERY

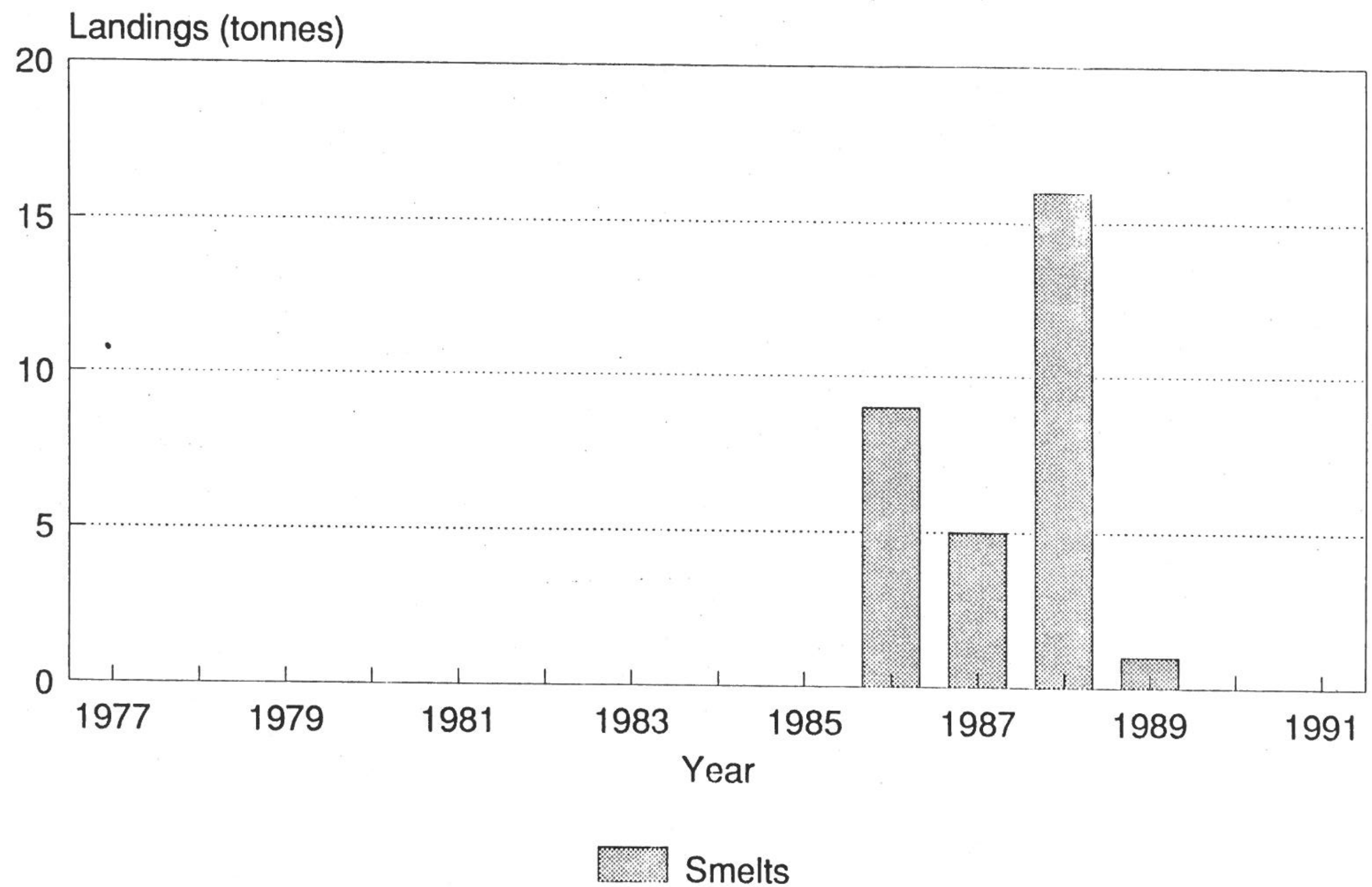
Statistical Districts 48 and 49



Inshore Fishery Only

SAINT JOHN HARBOUR AREA SMELT FISHERY

Statistical Districts 48 and 49



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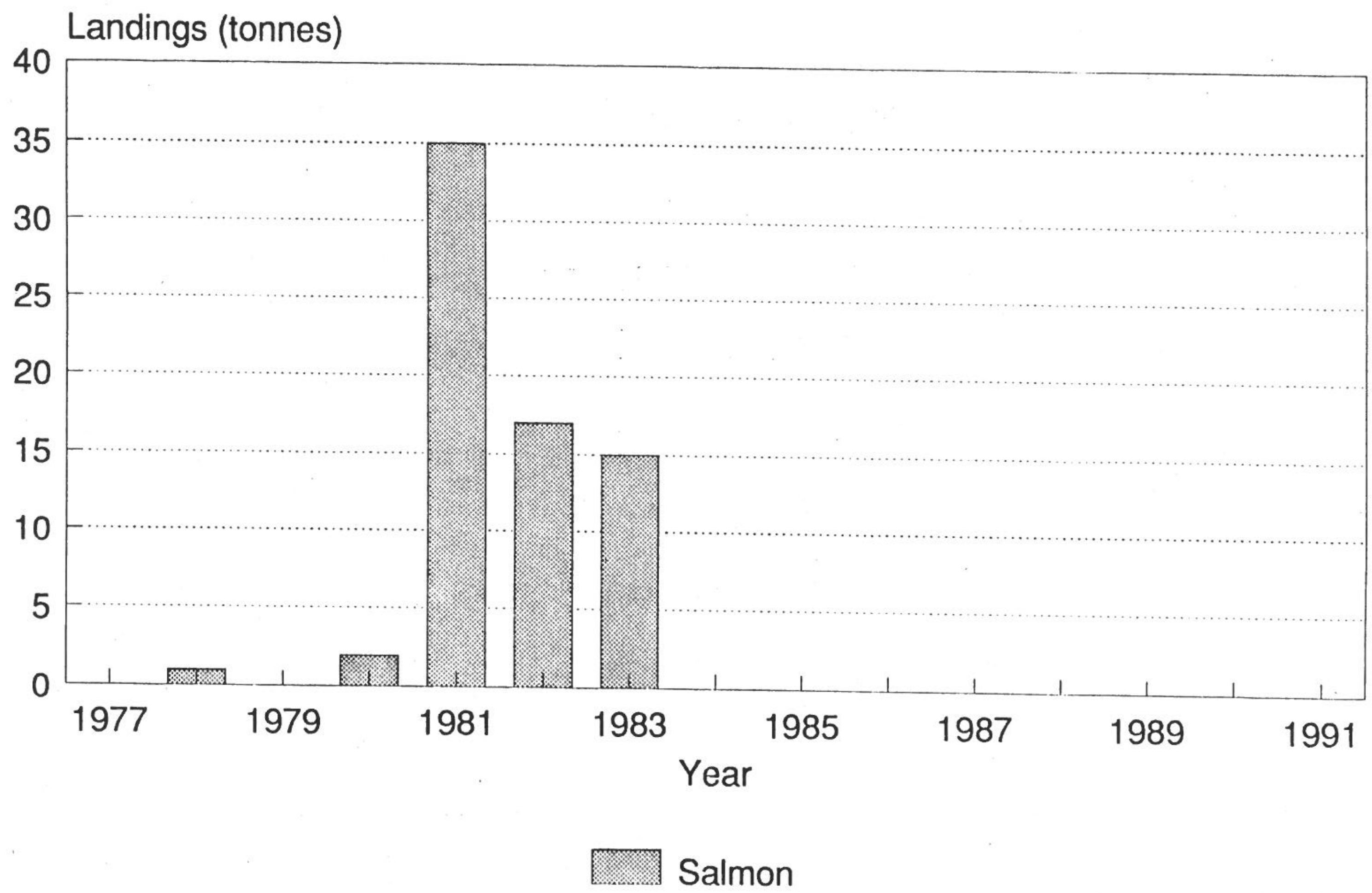
SAINT JOHN HARBOUR AREA SALMON FISHERY

Statistical Districts 48 and 49



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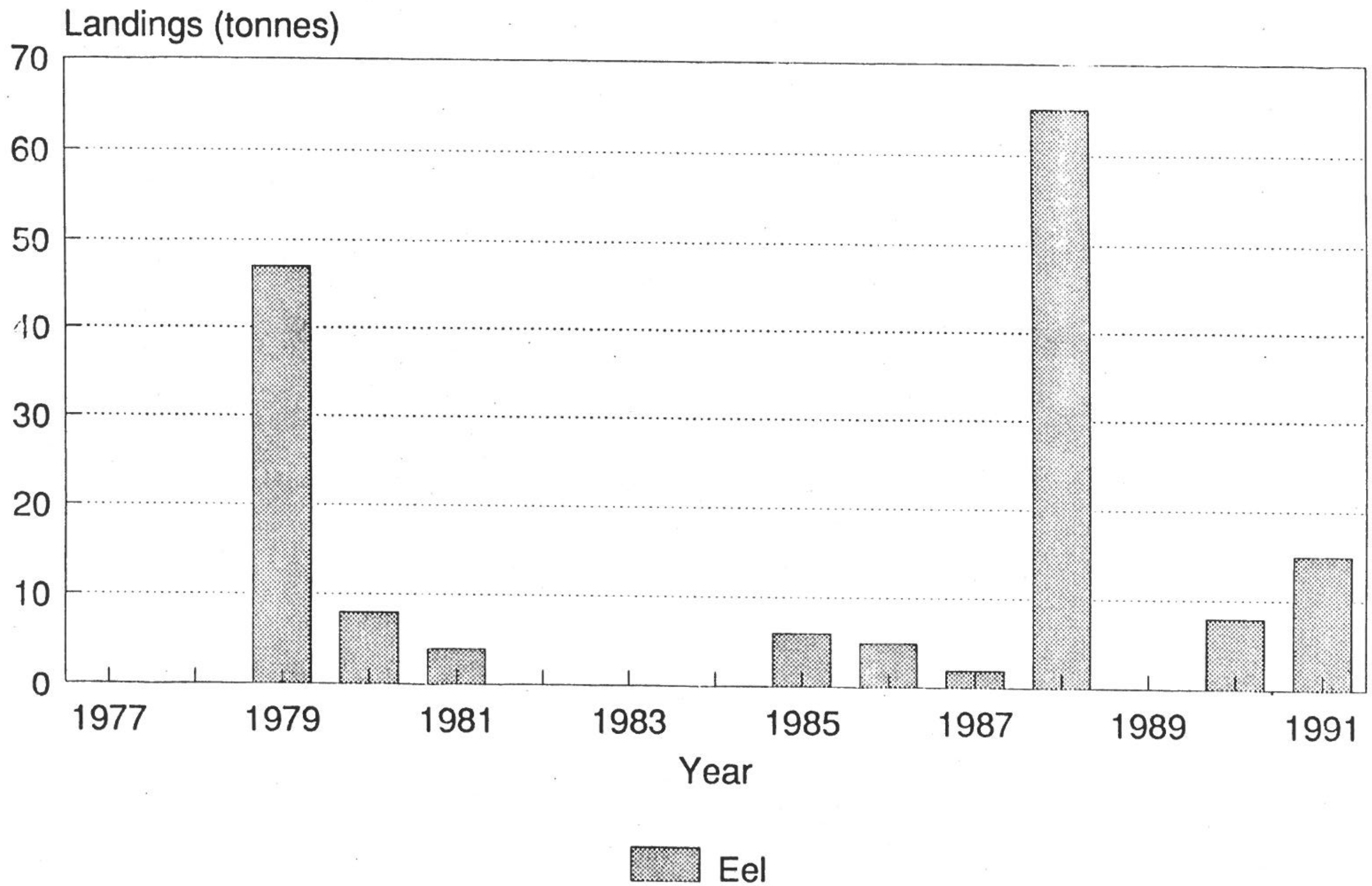
SAINT JOHN HARBOUR AREA EEL FISHERY

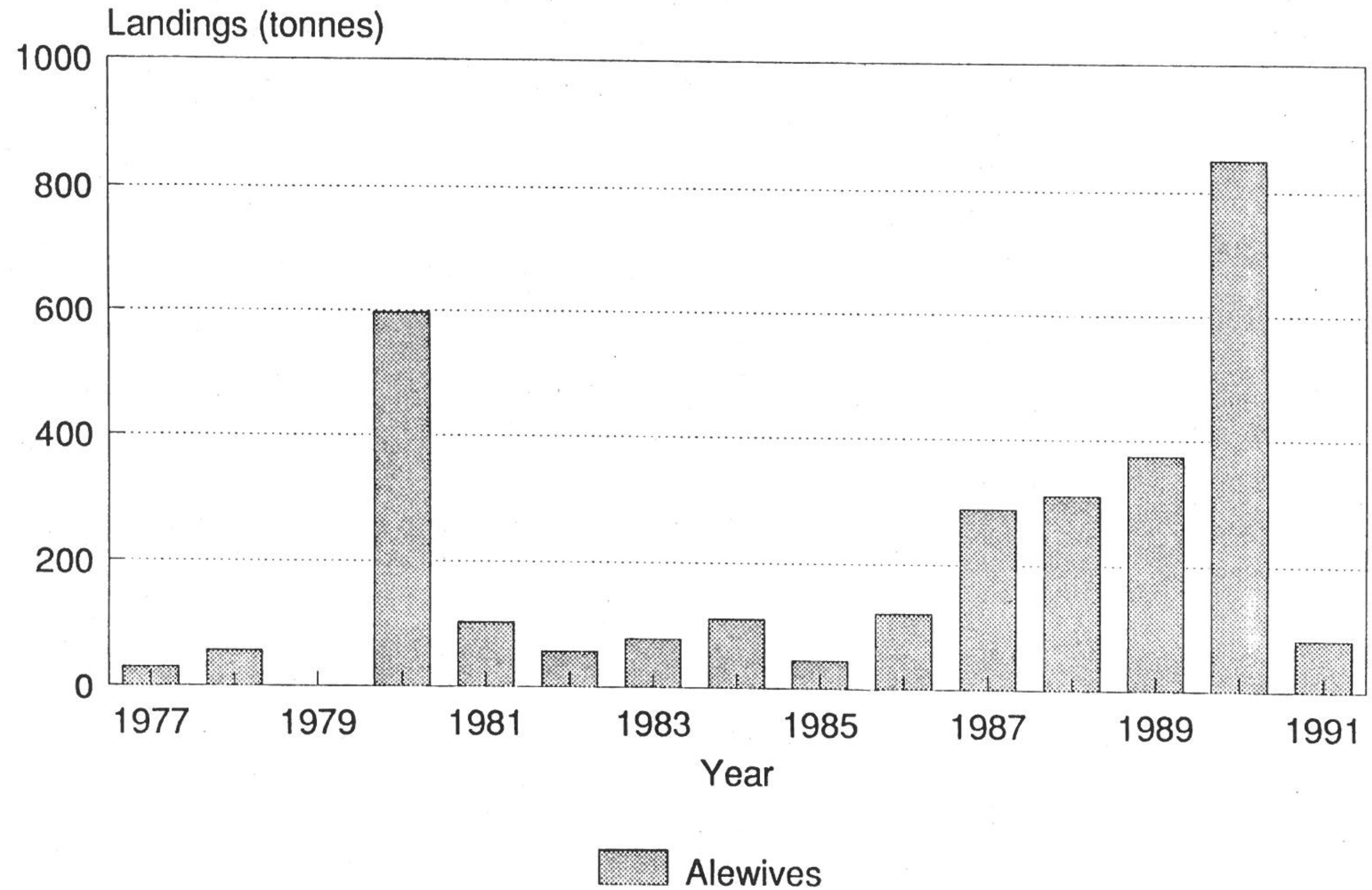
Statistical Districts 48 and 49



Inshore Fishery Only

SAINT JOHN HARBOUR AREA ALEWIFE FISHERY

Statistical Districts 48 and 49



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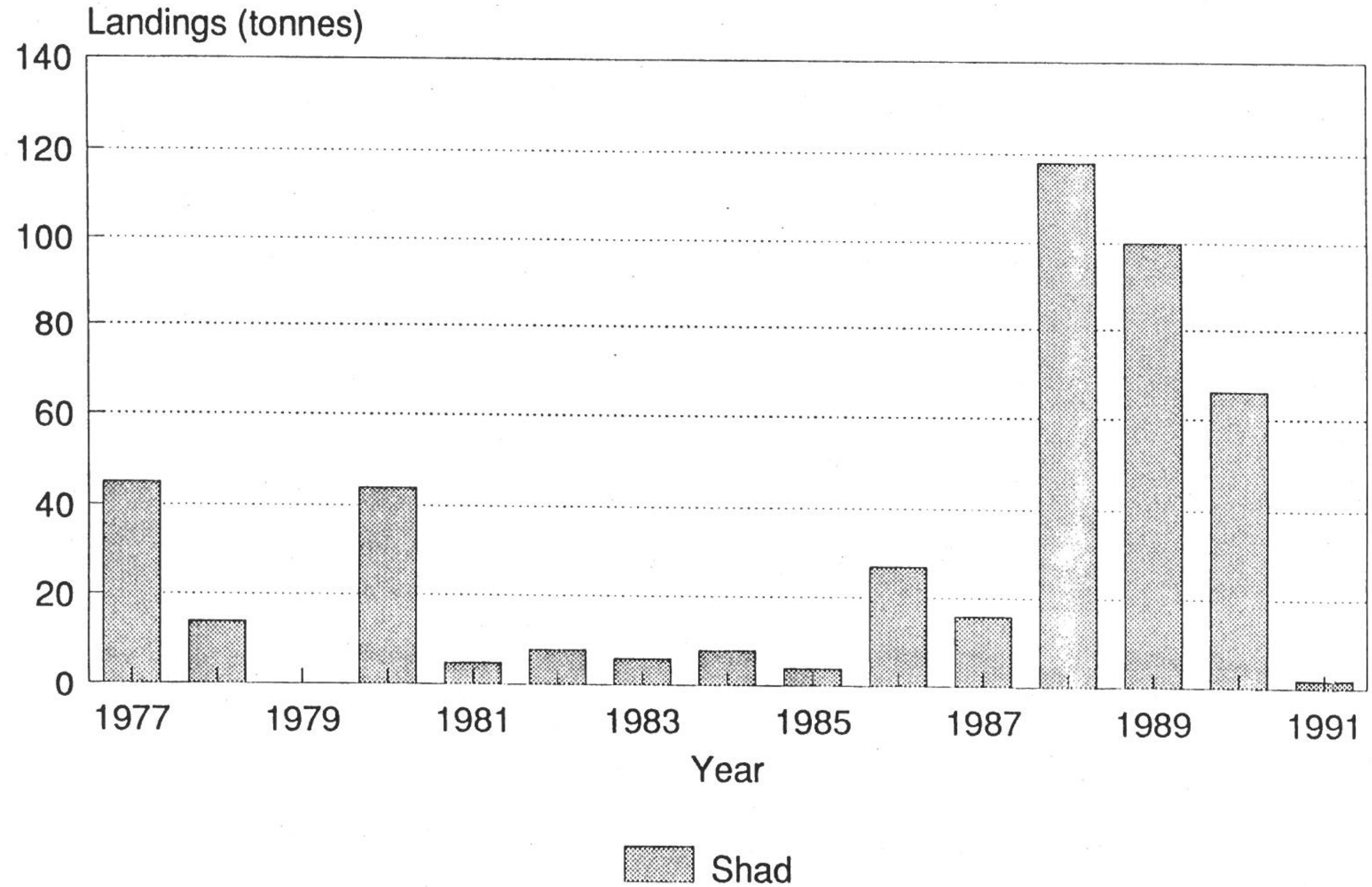
SAINT JOHN HARBOUR AREA SHAD FISHERY

Statistical Districts 48 and 49



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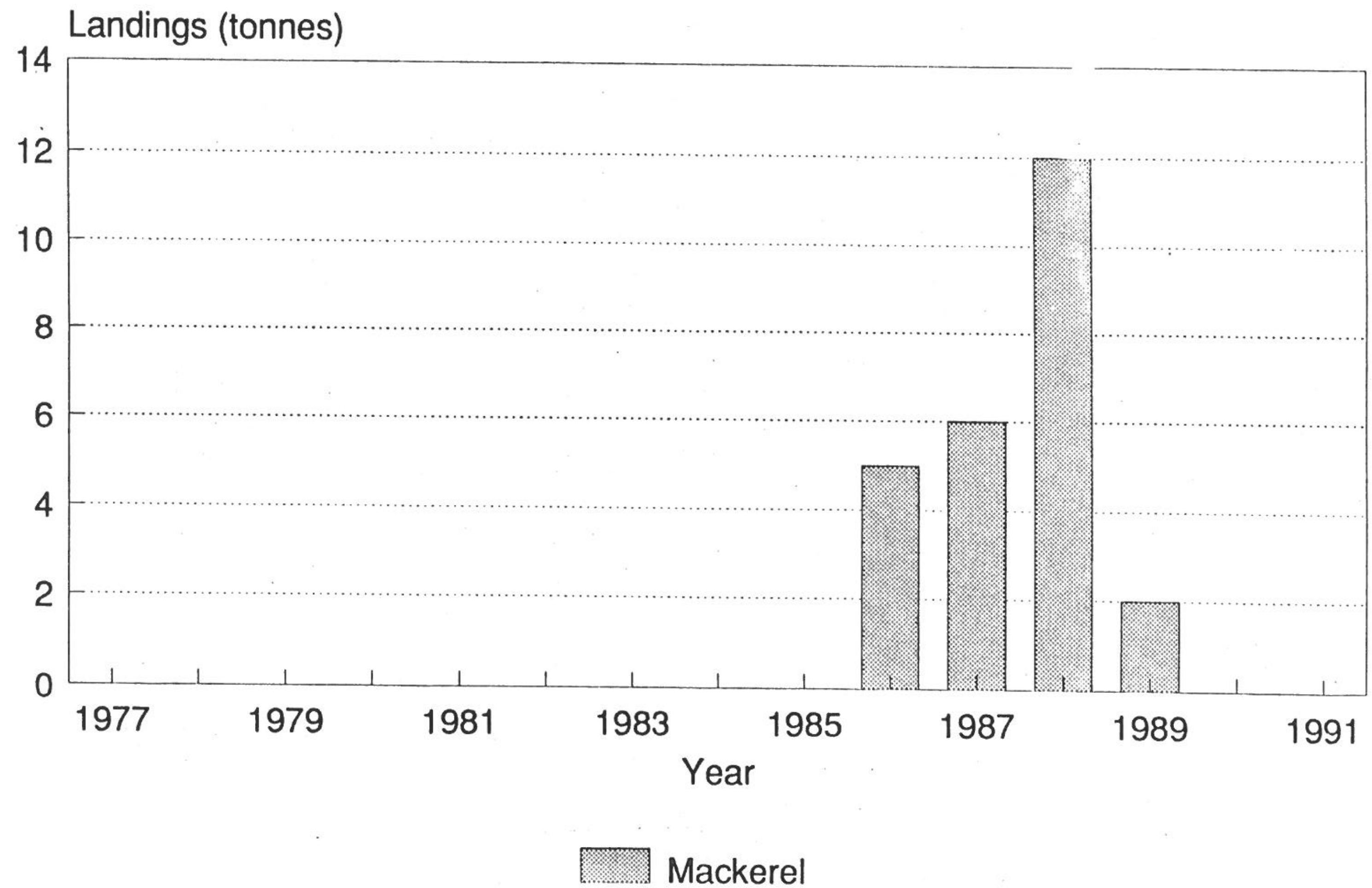
SAINT JOHN HARBOUR AREA MACKEREL FISHERY

Statistical Districts 48 and 49



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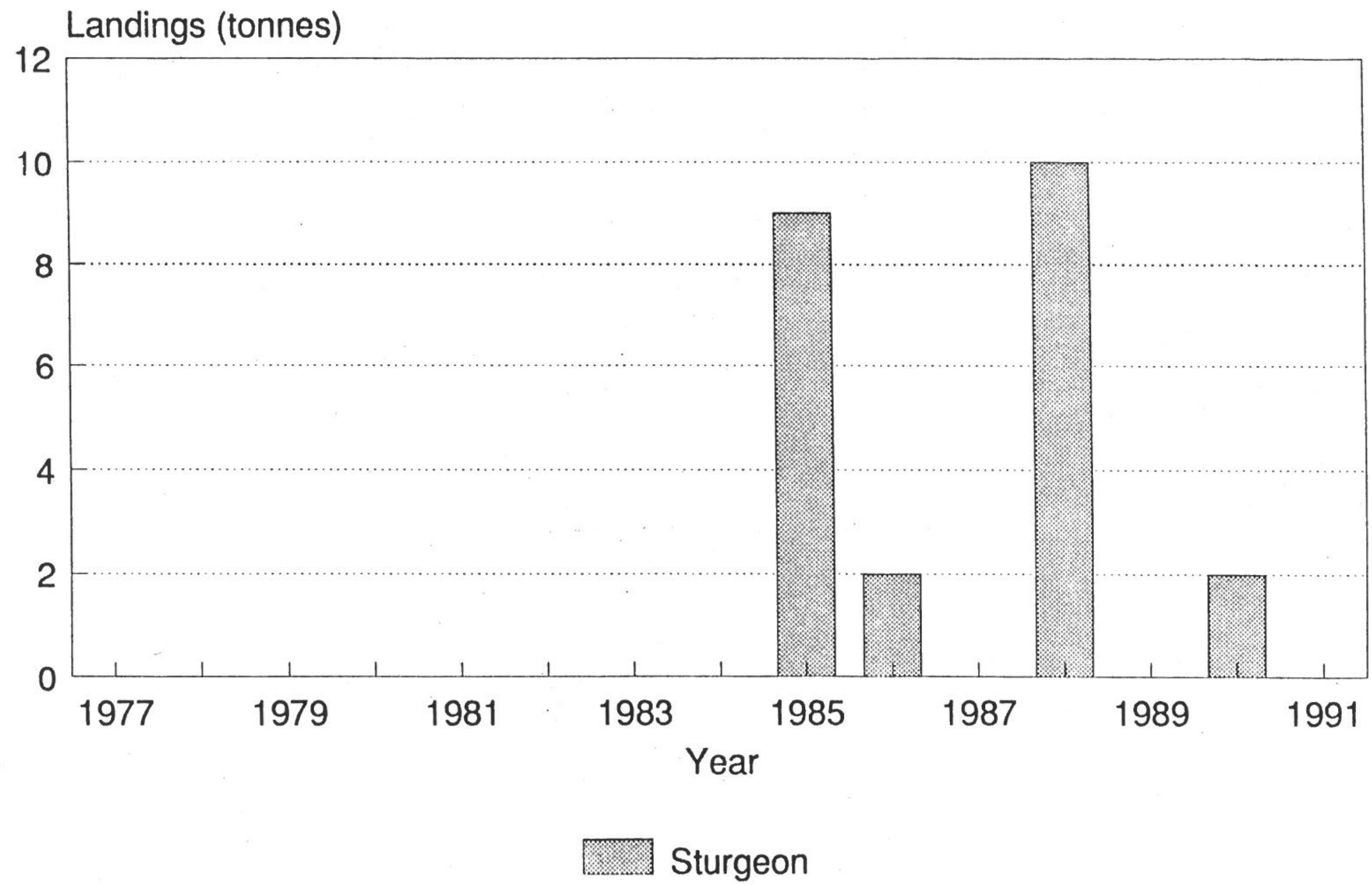
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA STURGEON FISHERY

Statistical Districts 48 and 49



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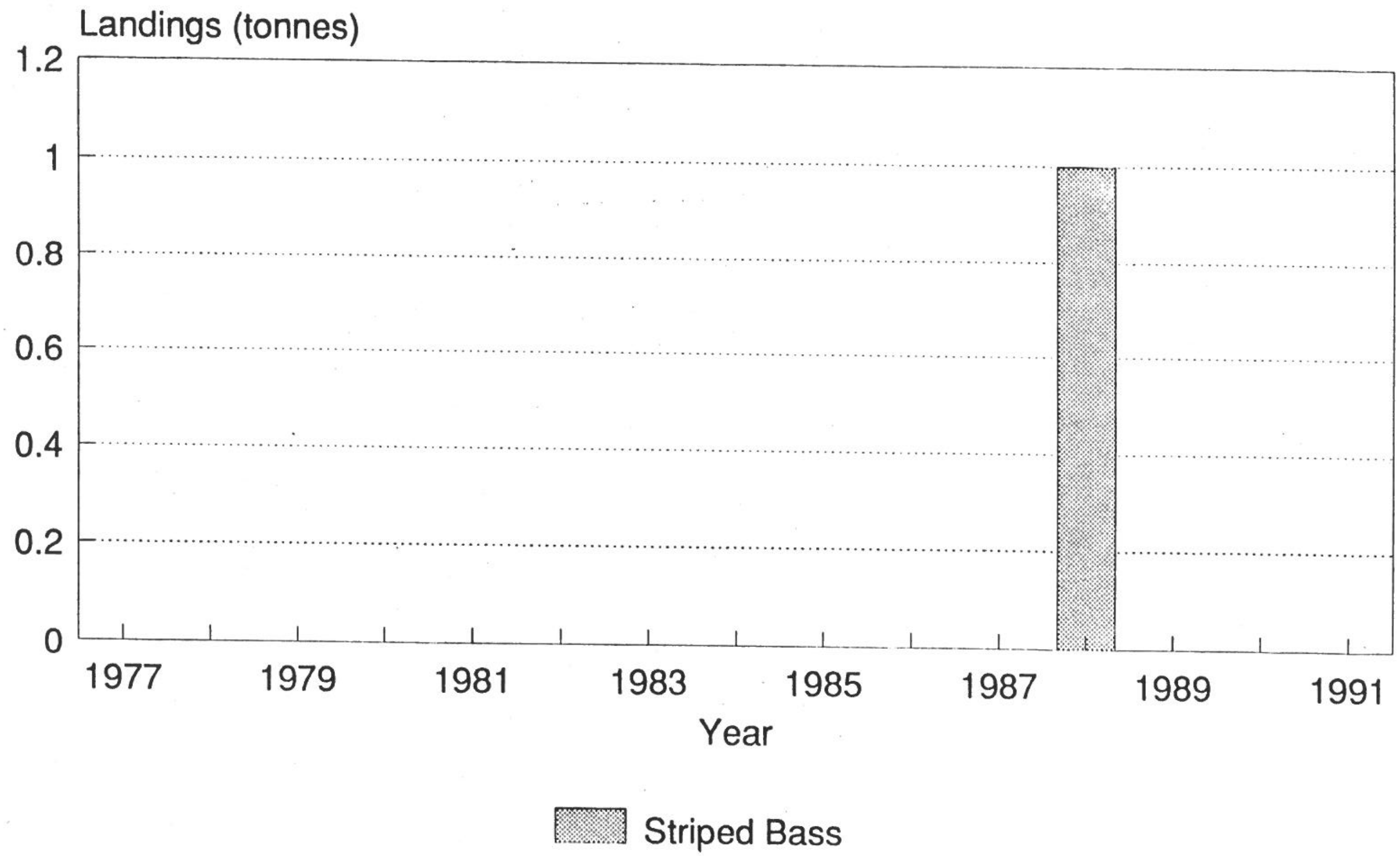
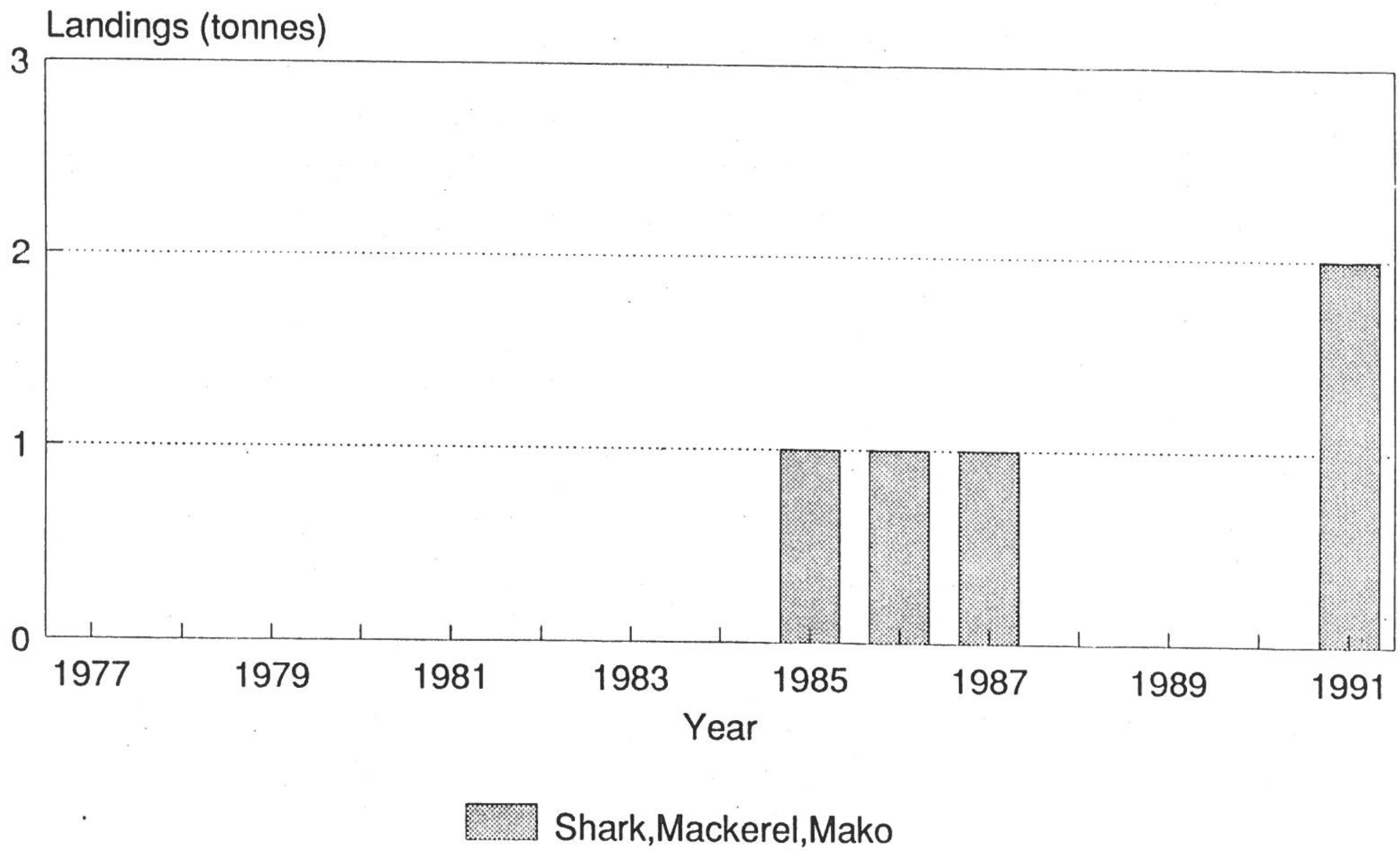
SAINT JOHN HARBOUR AREA
STRIPED BASS FISHERY
Statistical Districts 48 and 49



Inshore Fishery Only

SAINT JOHN HARBOUR AREA
SHARK, MACKEREL AND MAKO FISHERY
Statistical Districts 48 and 49



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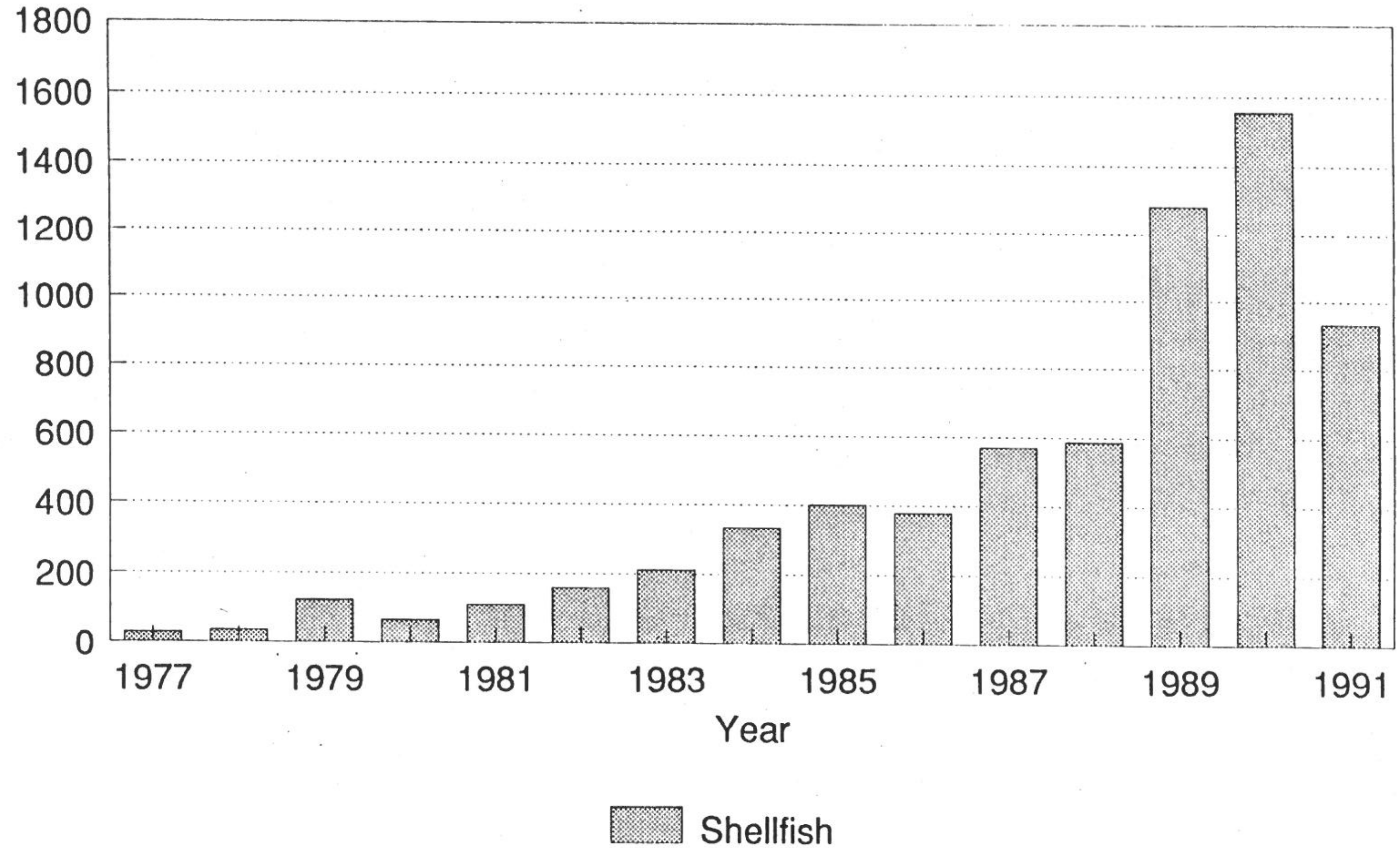
WASHBURN & GILLIS ASSOCIATES LTD.

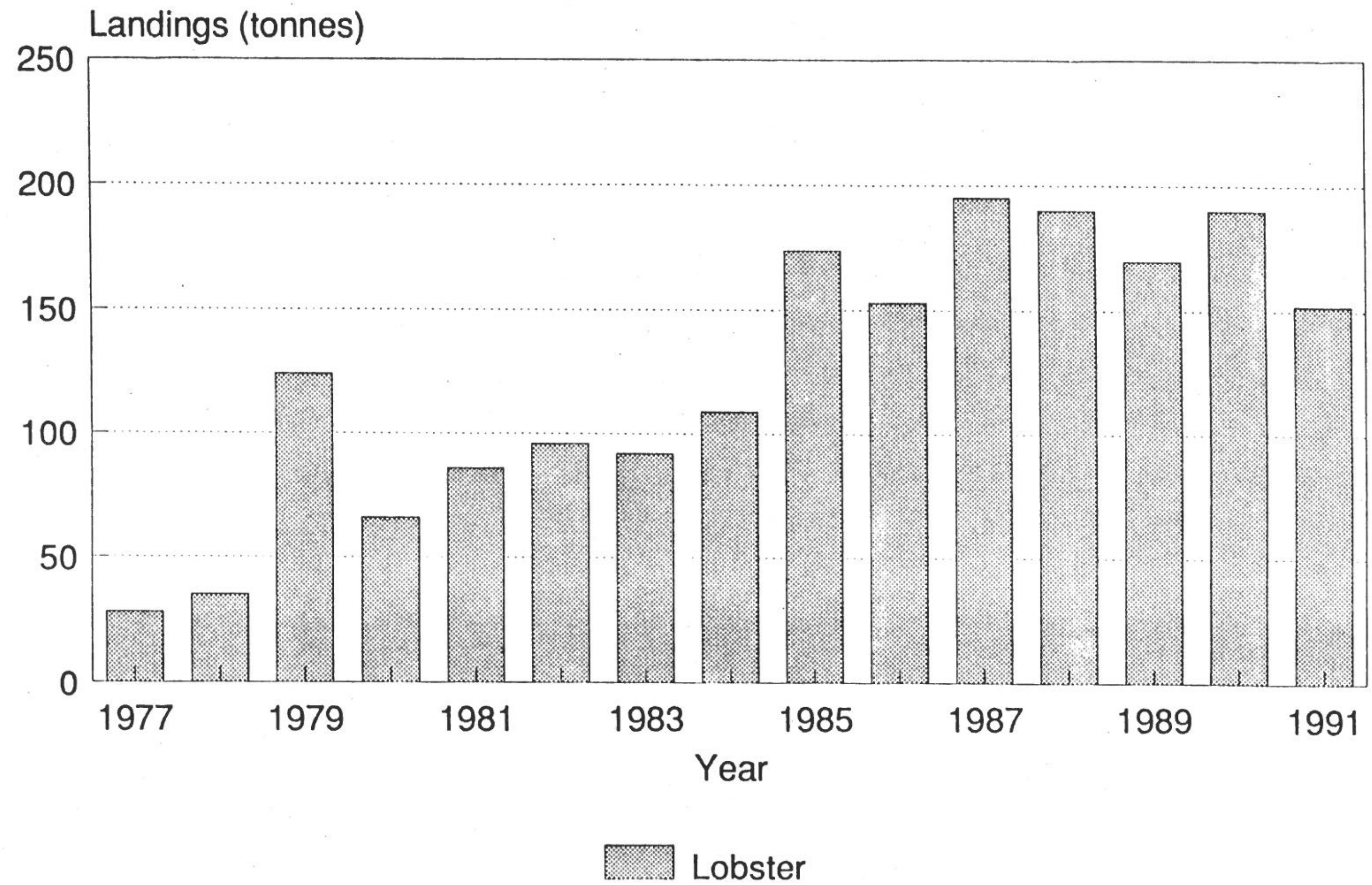
SAINT JOHN HARBOUR AREA
SHELLFISH FISHERY
Statistical Districts 48 and 49



Inshore Fishery Only

SAINT JOHN HARBOUR AREA LOBSTER FISHERY

Statistical Districts 48 and 49



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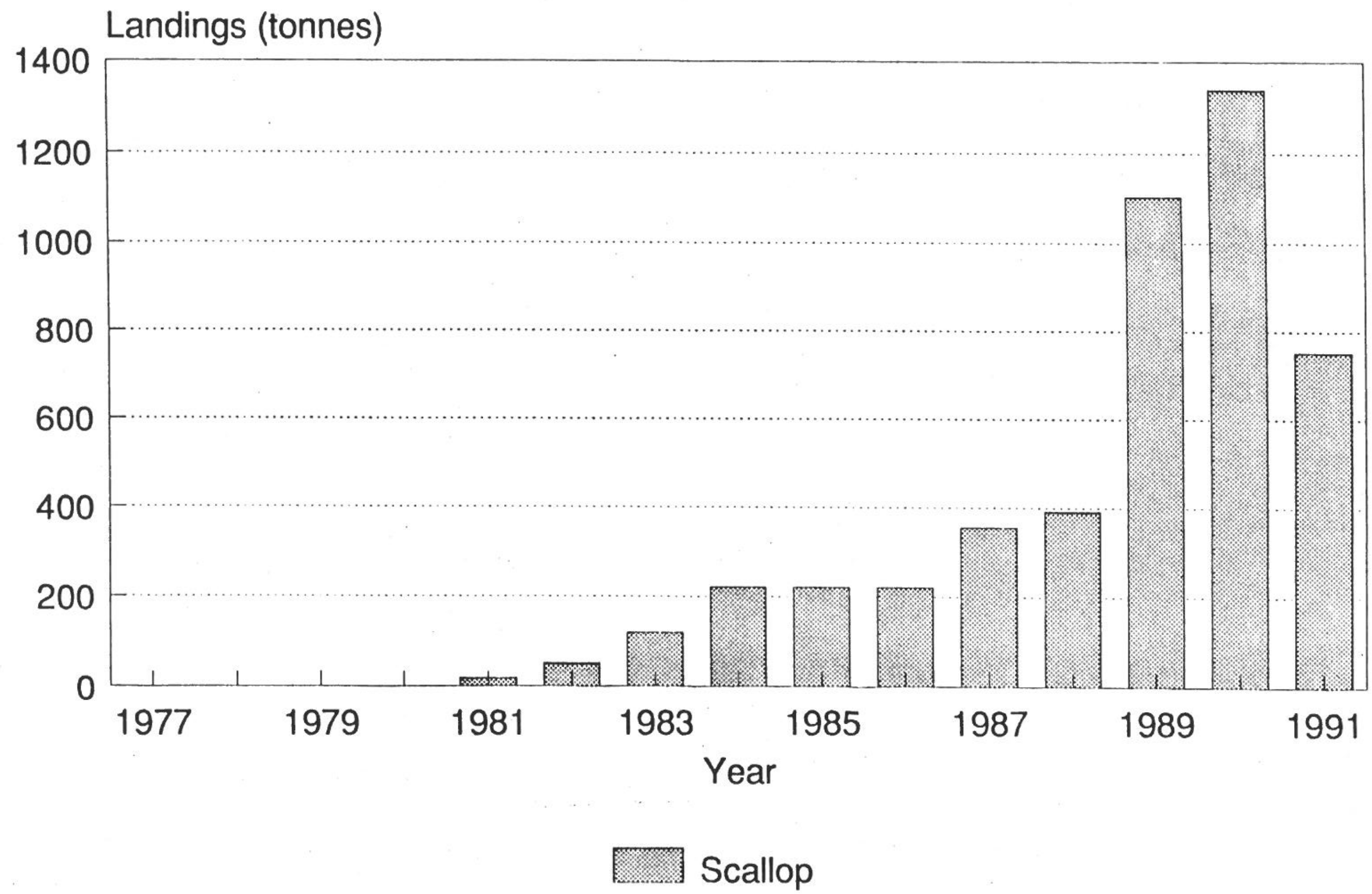
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA SCALLOP FISHERY

Statistical Districts 48 and 49



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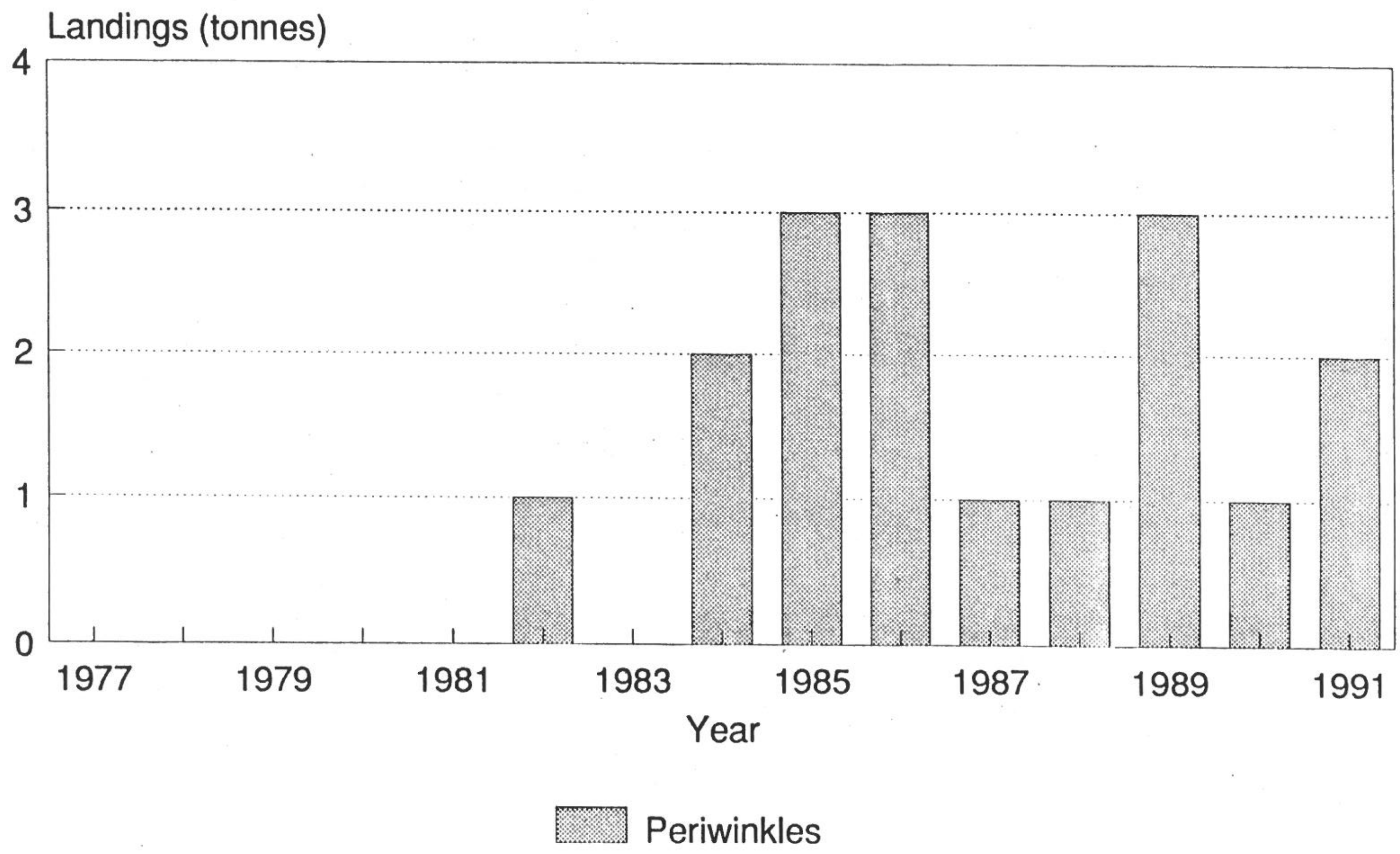
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA
PERIWINKLE FISHERY
Statistical Districts 48 and 49



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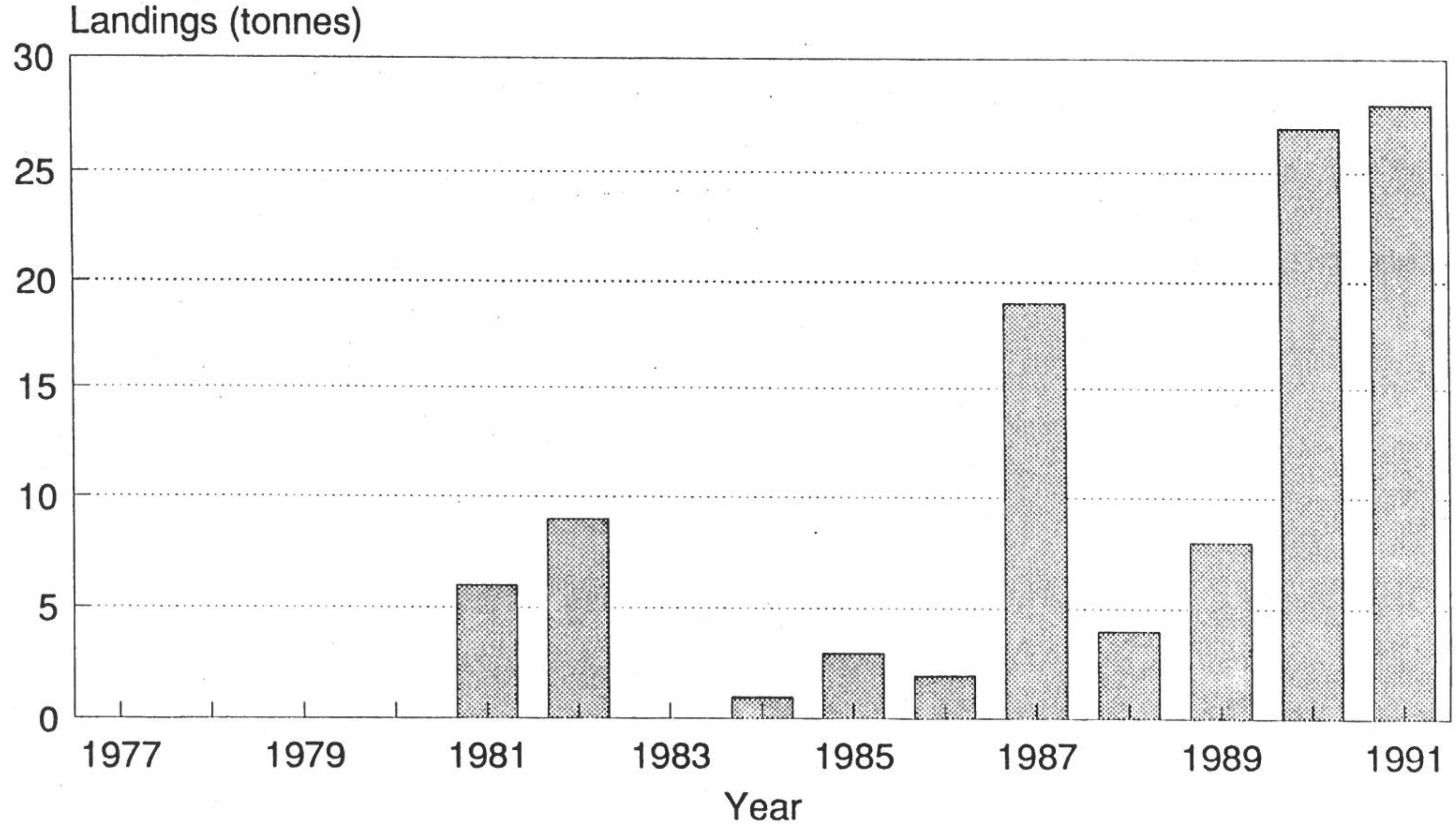
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA CLAM FISHERY

Statistical Districts 48 and 49



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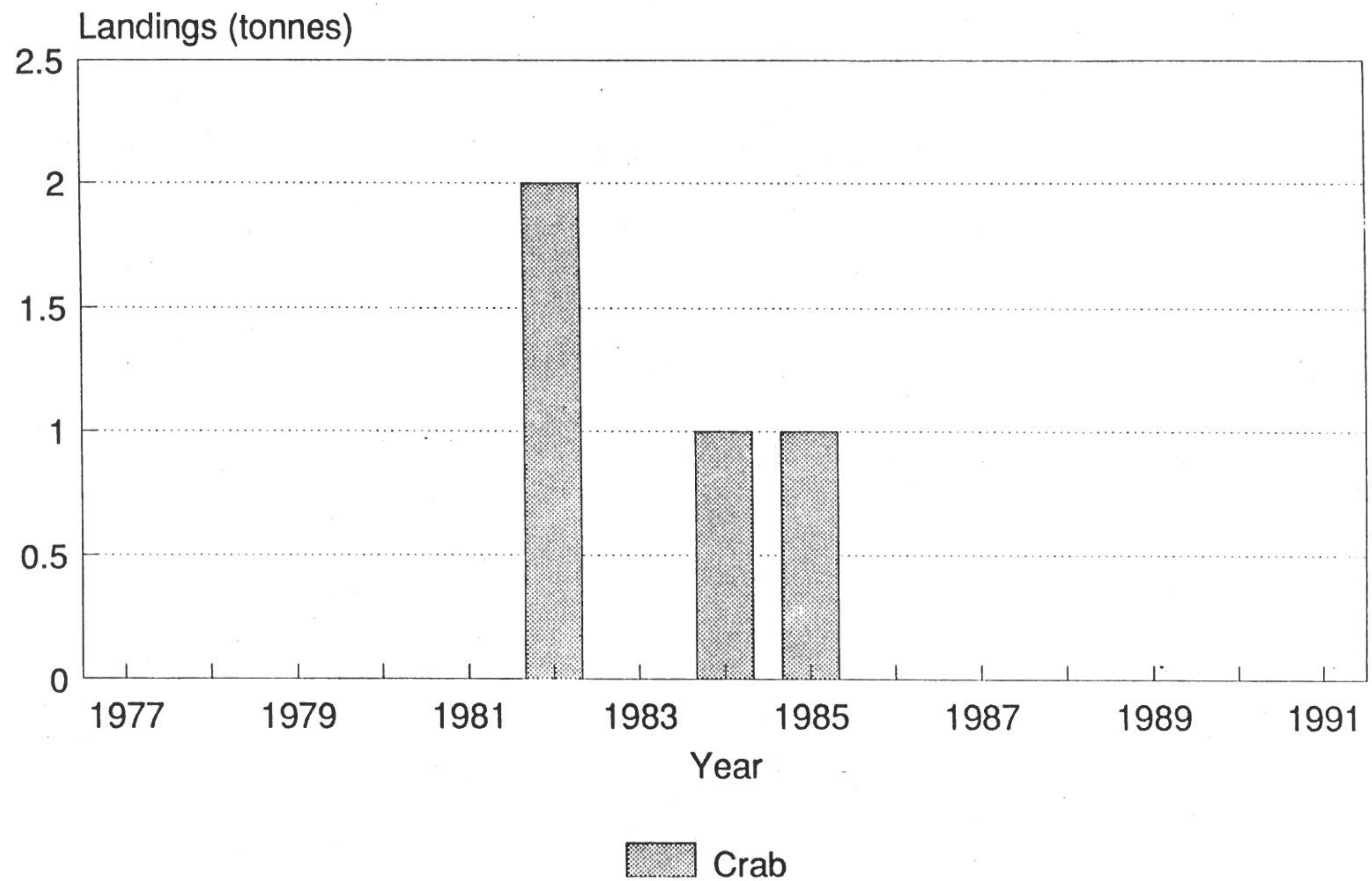
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA CRAB FISHERY

Statistical Districts 48 and 49



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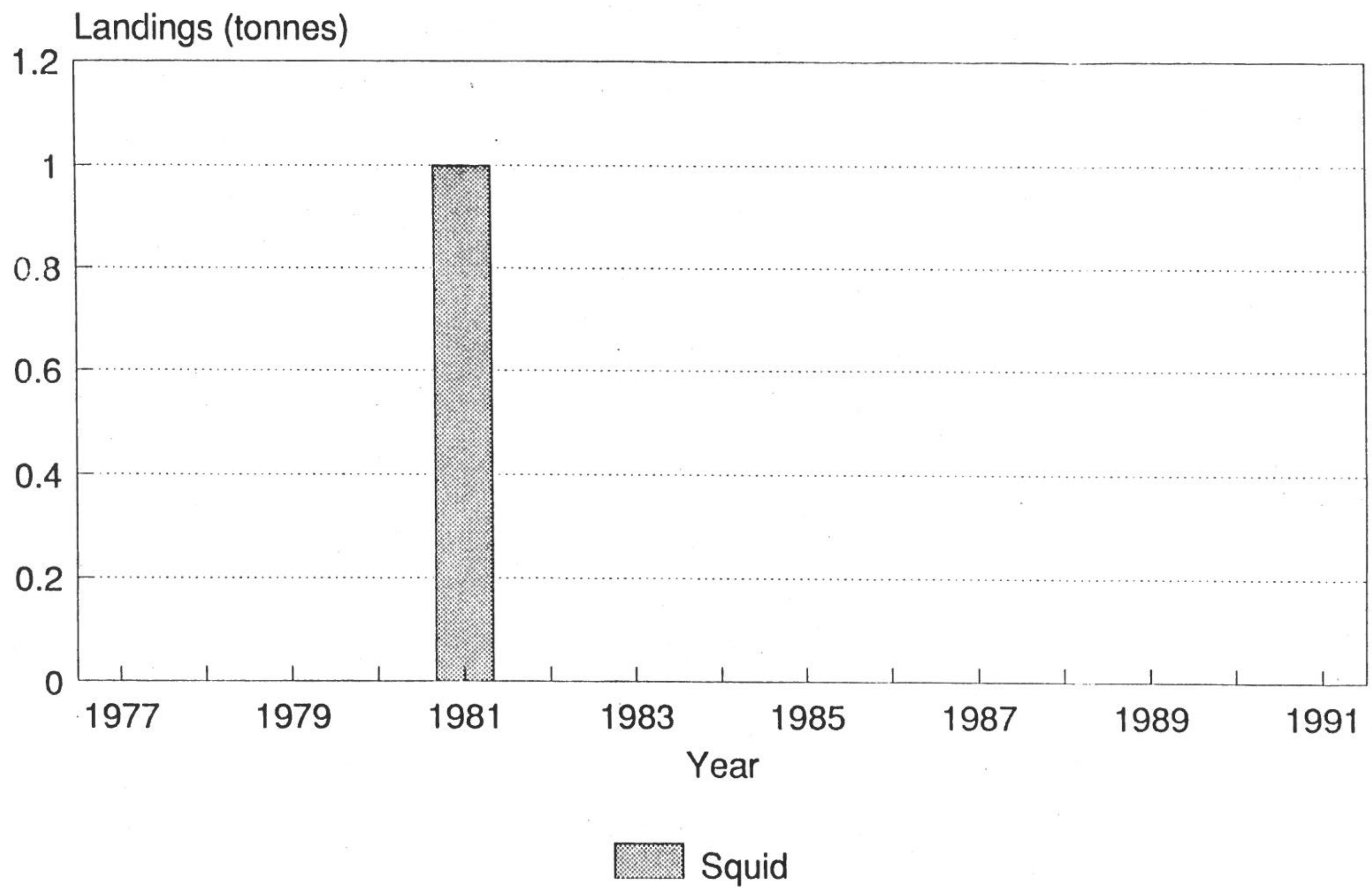
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA SQUID FISHERY

Statistical Districts 48 and 49



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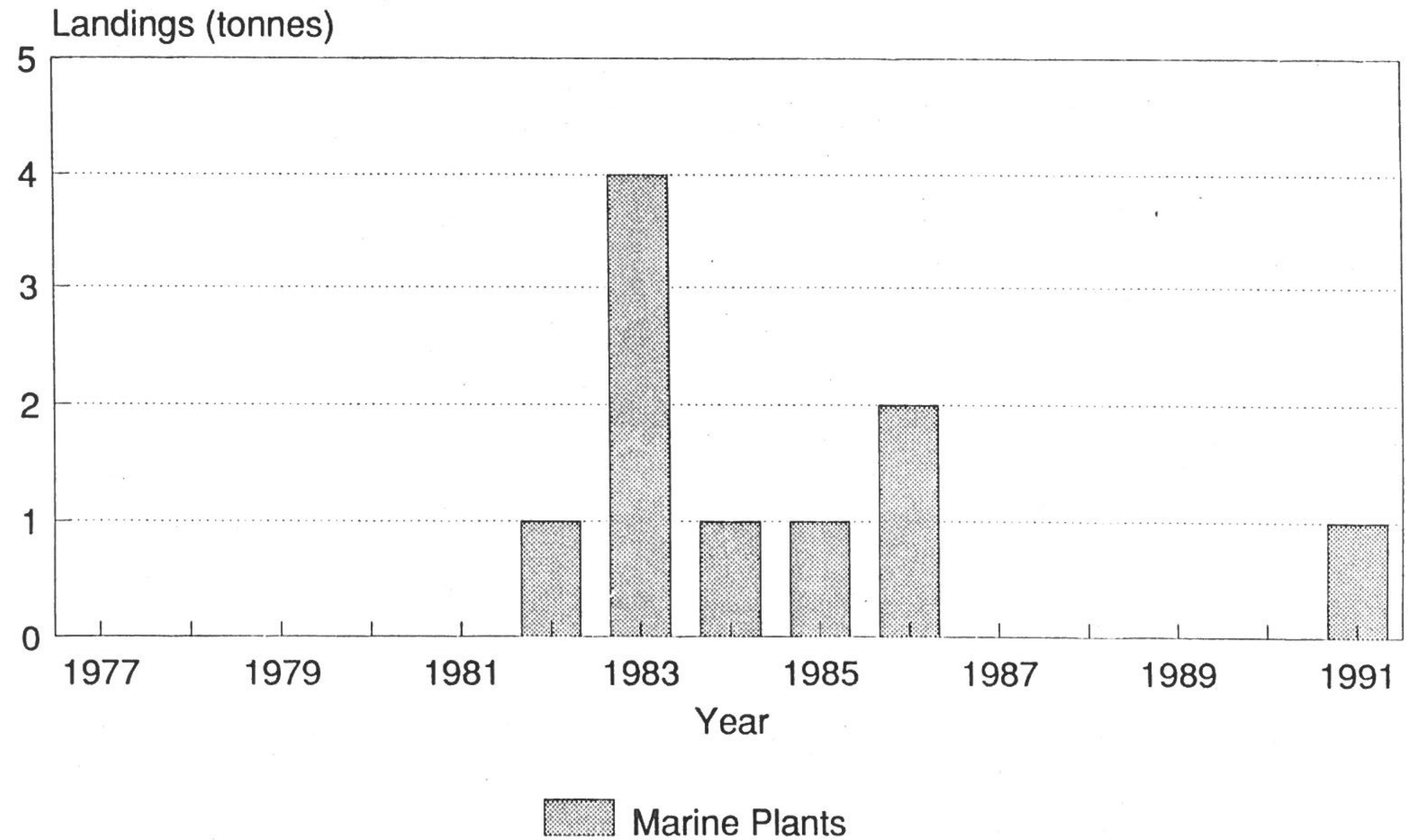
WASHBURN & GILLIS ASSOCIATES LTD.

SAINT JOHN HARBOUR AREA MARINE PLANT FISHERY

Statistical Districts 48 and 49



Inshore Fishery Only

APPENDIX B

Quality Assurance/Quality Control Information

Fenwick
Laboratories Limited

Client: Washburn & Gillis Associates Limited
123 York Street
Fredericton, New Brunswick
E3B 2N6

Attn: **Jamie Smith**

Project #: CSJ-91-1

Date Submitted: August, 1992
Date Reported: September, 1992

CERTIFICATE OF ANALYSIS

Sample Matrix: Water

Analysis Performed: As indicated below

Polynuclear Aromatic Hydrocarbons (PAH GC/MS) Method reference EPA 1625
Samples were fortified with per-deuterated PAH surrogates, extracted with methylene chloride and cleaned up on a silica gel column. The concentrated extracts were fortified with per-deuterated PAH internal standards and determined by capillary gas chromatography and mass spectrometry in the multiple ion mode.

Polychlorinated Biphenyls (PCB) Method reference EPA 608.
Samples were extracted with methylene chloride and cleaned up on a silica gel column. The concentrated extracts were analysed by dual column capillary gas chromatography and dual electron capture detection.

Total Petroleum Hydrocarbons by GCFID (TPHFID)
Samples were fortified with surrogate standards and extracted "in situ" with a carbon disulfide - n-pentane mixture. Recovered extracts were vialed and determined by high resolution capillary gas chromatography with flame ionization detection.

Total & Mineral Oil& Grease by Infra-Red Method Reference EPA 413/418
Samples were extracted with carbon disulfide and cleaned up with silica gel. Extracts were analyzed by infra red spectrophotometry.

Subcontracted Organic Analysis - Dioxins/Furans, Chlorophenols

Trace Metals by ICP-MS Method reference EPA 200.8
Metals analysed by Inductively Coupled Plasma-Mass Spectrometry

Total Organic Halides
Determined by combustion/microcoulimetric analysis.

General Inorganics - pH, Total Organic Carbon, Chemical Oxygen Demand, Ammonia (as N), Phosphorus (total), Phosphorus (soluble), Cyanide, Phenol, Sulphide all in accordance with Standard Methods for the Examination of Water & Wastewater Ed17.

Ross Kean

Certified by:
Ross Kean, MSc
Manager, Inorganic Chemistry

Certified by:
Dominique Levesque
Manager, Organic Chemistry

Suite 200
5595 Fenwick Street
Halifax, Nova Scotia
Canada, B3H 4M2
Fax: (902) 420-8612
Tel: (902) 420-0203

Fenwick
Laboratories Limited

Client:	Washburn & Gillis Associates Limited 123 York Street Fredericton, New Brunswick E3B 2N6
Attn:	**Jamie Smith**

Project #:	CSJ-91-1	**Date Submitted:**	Sept. 4, 1992
Fenwick #:	92-R023284 thru 92-R023316 October, 1992	**Date Reported:**	Oct 16, 1992

CERTIFICATE OF ANALYSIS

Sample Matrix: Sediment

Analysis Performed: Ocean Dumping Control Act (ODCA)

Total and Mineral Oil and Grease in Soil (OG IR) **Method reference 9070**

Samples were extracted with carbon disulfide and cleaned up with silica gel. Extracts were analysed by infra red spectrophotometry.

Polynuclear Aromatic Hydrocarbons (PAH GC/MS) **Method reference EPA 625**

Samples were fortified with per-deuterated PAH surrogates, extracted with methylene chloride and cleaned up on a silica gel column. The concentrated extracts were fortified with per deutereted PAH standards and determined by capillary gas chromatography and mass spectrometry in the multiple ion mode.

Polychlorinated Biphenyls (PCB) and OC Pesticides **Method reference EPA 8080.**

Samples were extracted with methylene chloride and cleaned up on a silica gel column. The concentrated extracts were determined by dual column capillary gas chromatography and dual electron capture detection.

Trace Metals by ICP-MS **Method reference EPA 200.8**
Inductively Coupled Plasma-Mass Spectrometry

Witnessed by:
Beth Herron, BSc
Customer Service

Certified by:
Dominique Levesque
Manager, Organic Chemistry

Suite 200
5595 Fenwick Street
Halifax, Nova Scotia
Canada, B3H 4M2
Fax (902) 420-8612
Tel. (902) 420-0203

Fenwick
Laboratories Limited

Client:	Washburn & Gillis Associates Limited 123 York Street Fredericton, New Brunswick E3B 2N6		
Attn:	**Jamie Smith**		
Project #:	CSJ-91-1	**Date Submitted:**	Nov 12, 1992
Fenwick #:	92-R023284 thru 92-R023316	**Date Reported:**	Nov 26, 1992

CERTIFICATE OF ANALYSIS

Sample Matrix: Mussels

Analysis Performed: As indicated below

Polynuclear Aromatic Hydrocarbons (PAH GC/MS) **Method reference EPA 625**

Samples were fortified with per-deuterated PAH surrogates, digested with methanolic KOH then extracted with methylene chloride and cleaned up on a silica gel column. The concentrated extracts were fortified with per deutereted PAH standards and determined by capillary gas chromatography and mass spectrometry in the multiple ion mode.

Polychlorinated Biphenyls (PCB) and OC Pesticides **Method reference EPA 8080.**

Samples were digested with methanolic KOH then extracted with methylene chloride and cleaned up on a silica gel column. The concentrated extracts were determined by dual column capillary gas chromatography and dual electron capture detection.

Trace Metals by ICP-MS **Method reference EPA 200.8**
Samples extracted with concentrated nitric acid and analysed by Inductively Coupled Plasma-Mass Spectrometry

Extractable Organic Halides
Samples extracted with ethyl acetate & determined by combustion/microcoulimetric analysis.

Witnessed by:
Beth Herron, BSc
Customer Service

Certified by:
Dominique Levesque
Manager, Organic Chemistry

Suite 200
5595 Fenwick Street
Halifax, Nova Scotia
Canada, B3H 4M2

Fax: (902) 420-8612
Tel: (902) 420-0203

beak consultants limited
14 Abacus Road
Brampton, Ontario
Canada L6T 5B7
Tel (416) 794-BEAK
Fax (416) 794-2338
INWATS (416) 1 800 361-BEAK

7-Day Fathead Minnow Survival and Growth Test

Client:	Washburn & Gillis Fredericton, N.B.
Sample Name:	Irving Oil Refinery
Sample Number:	92–08–43
Test Number:	1148

QUALITY ASSURANCE INFORMATION

Reference Toxicant Data

Chemical Used:	Potassium Chloride
Date of Test:	August 24/92
7–Day LC50:	813 mg/L
IC50:	987 mg/L

Warning limits are not calculated as sufficient data are not yet available.

Test Protocol

Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows.
Environment Canada Report EPS 1/RM/22.
February 1992

Test Conditions

Test Organism:	Fathead Minnow (Pimephales promelas)
Organism Age:	< 24 hours
Test Type:	Static renewal
Test Temperature:	25±1°C
Test Volume:	500ml
Photoperiod:	16 hours light/8 hours dark
Dilution Water:	Reconstituted water (moderately hard)
Stock Source:	in–house culture
Incidence of Disease:	none

Comments: All reported data were cross–checked for errors or omissions. Instruments used to monitor chemical and physical parameters were calibrated daily.

beak consultants limited

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7

Tel (416) 794-BEAK
Fax (416) 794-2338
INWATS (416) 1 800 361-BEAK

48–HOUR STATIC DAPHNIA MAGNA TEST

Client:	Washburn & Gillis Fredericton, N.B.	Sample Number:	92–08–43
		Test Number:	1149
Sample Name:	Irving Oil Refinery		

QUALITY ASSURANCE INFORMATION

Reference Toxicant Data

Chemical Used:	Sodium Chloride
Date of Test:	August 24/92
48–hour LC50:	5,857 mg/L
Historical Warning Limits:	3,011 – 8,570

Test Protocol

Biological Test Method: Acute Lethality Test Using Daphnia spp.
Environment Canada
July 1990

Test Conditions

Test Organism:	Daphnia magna
Test Type:	Static
Test Temperature:	20±1°C
Test Volume:	200ml
Photoperiod:	16 hours light/8 hours dark
Dilution Water:	Reconstituted Water
Organism Age:	in house culture
Time to First Brood:	< 12 days
Frequency of ephippia in culture:	0

Comments: The reference toxicant results show that test reproducibility and sensitivity of organisms were within established limits. All reported data were cross–checked for errors or omissions. Instruments used to monitor chemical and physical parameters were calibrated daily.

beak consultants limited

14 Abacus Road
Brampton, Ontario
Canada L6T 5B7

Tel (416) 794-BEAK
Fax (416) 794-2338
INWATS (416) 1 800 361-BEAK

96-HOUR STATIC RAINBOW TROUT TEST

Client:	Washburn & Gillis Fredericton, N.B.	Sample Number:	92-08-43
		Test Number:	1147
Sample Name:	Irving Oil Refinery		

QUALITY ASSURANCE INFORMATION

Reference Toxicant Data

Chemical Used:	Potassium Chloride
Date of Test:	August 11/92
96-Hour LC50:	4,483 mg/L
Historical Warning Limits:	2,884 – 5,111

Test Protocol

Biological Test Method: Acute Lethality Test Using Rainbow Trout
Environment Canada
July 1990

Test Conditions

Test Organism:	Rainbow Trout (Oncorhynchus mykiss)
Test Type:	Static
Test Temperature:	15±1°C
Test Volume:	15L
Photoperiod:	15 hours light/9 hours dark
Dilution Water:	Dechlorinated City of Brampton tap water
Stock Source:	Rainbow Springs Hatchery, Thamesford,Ont
Stock Number:	Rbt-15-92
Stock Acclimation Period (days):	17
Fish Lengths (mean±SD) (mm):	41.5±2.4
Fish Weights (mean±SD) (g):	0.71±0.14
Loading Rates (L/g/d):	0.53

Comments: The reference toxicant results show that test reproducibility and sensitivity of organisms were within established limits. All reported data were cross-checked for errors or omissions. Instruments used to monitor chemical and physical parameters were calibrated daily.

THE TOXI-CHROMOTEST

Version 3.0

INSTRUCTIONS FOR USE

May 1992

ENVIRONMENTAL BIO DETECTION INC.
14 Abacus Road
Brampton, Ontario, Canada
L6T 5B7

EBPI Toxi-Chromotest is a rapid bacterial-based colorimetric bioassay kit for the determination of toxicity. It is sensitive to a wide spectrum of toxic substances such as heavy metals, and organic and inorganic pollutants, and may be used to detect the presence of toxicants in water and soil/sediment extracts. The assay is based on the ability of substances (toxicants) to inhibit the *de novo* synthesis of an inducible enzyme - β-galactosidase - in a highly permeable mutant of *E. coli*.

The sensitivity of the test is enhanced by exposing the bacteria to stressing conditions, after which they are rehydrated in a cocktail containing a specific inducer of β-galactosidase, and essential factors required for the recovery of the bacteria from their stressed condition. The activity of the induced enzyme is detected by the hydrolysis of a chromogenic substrate. Toxic materials interfere with the recovery process and thus with the synthesis of the enzyme and the colour reaction.

WARRANTY

The Toxi-Chromotest kit or its components will be replaced if defective in manufacturing or packaging. Complete results of the control reactions should accompany all replacement claims.

2. HANDLING THE TOXI-CHROMOTEST KIT

Handle the Toxi-Chromotest Kit and your tested samples as you would any potentially hazardous material.

Although the bacterial strain is not a known pathogen, it is advisable to sterilize the remains of the Toxi-Chromotest Kit before disposal (use the included biohazard bag).

Due to the short incubation time and chemical configuration of the kit, sterile handling is not imperative.

The Toxi-Chromotest Kit should be stored under refrigeration (2 to 8°C), and should be protected from high temperatures and temperature changes.

3. LIST OF TOXI-CHROMOTEST COMPONENTS

Each Toxi-Chromotest package contains the components of four kits, including bacteria, media, microtitration plates and some accessories. The contents of the bottles in each kit are:

A) Reaction mixture - a cocktail containing an inducer for the enzyme β-galactosidase, and co-factors required for the recovery of the bacteria from their stressed condition.

B) The Toxi-Chromotest lyophilized bacteria - a highly permeable mutant of *E. coli*.

C) Rehydration solution - a solution to hydrate the bacteria.

D) Standard toxic substance - 4 μg/mL mercury chloride in water.

E) Diluent of yellow chromogenic substrate (yellow chromogen kit only).

F) Chromogenic substrate:
- blue chromogen cocktail, ready for use

OR
- yellow chromogen, dried, requires suspension in diluent.

G) Diluent for standard toxicant and samples.

I) Stop solution for colour reaction (for yellow chromogen only).

Hardware - frame, microwell modules, biohazard bags.

4. USING ONE TOXI-CHROMOTEST KIT

Each Toxi-Chromotest package contains four kits. Each kit can be used separately before expiry date if stored under refrigeration. One kit includes one bottle of each A, B, C, E and F. Discard remaining material from these bottles after the test. One bottle marked D containing standard toxicant, and two bottles G and I should be used with all the kits. Each kit also includes microwell modules and one biohazard bag. Each module consists of two columns of eight wells. For one kit, you may use at least six columns, e.g., 48 wells.

5. TOXI-CHROMOTEST PROCEDURE

This chapter describes the steps of the Toxi-Chromotest procedure. Figure 1 presents a suggested layout of the test microwell modules. This layout enables the testing of at least two materials in duplicate, each in seven dilutions. Be sure to include standard positive toxicant with each test.

For each kit, you received three microwell modules. The microwells fit into the frame which is marked with 12 columns numbered from 1 to 12 and eight rows marked A to H. You may insert from one to six microwell modules into the frame. One kit is designed for using three modules.

Insert three microwell modules into the frame from Columns 1 to 6. The first column of the first module is used for blank, and the second column for standard toxicant. The other two modules, e.g., other four columns are used with the samples to be tested and their dilutions. Row H, last well in each column, is used for control. These wells will contain no toxic material.

5.1 Dispense 100 microlitres of the diluent from Bottle G to all wells of the microwell modules except wells of Row A from A2 to A6.

5.2 Dispense 200 μL of the standard toxicant (Bottle D) to the first well of Column 2, Well A2. Mix well and transfer 100 microlitres of the solution to Well B2. Mix well and transfer 100 μL to Well C2.. Repeat this procedure along the wells. From Well G2, discard 100 microlitres of solution. You have now completed the two good dilutions of the positive known toxic material, mercury chloride.

5.3 Dispense 200 μL of the sample to be tested in the first wells of the second microwell module, Wells A3 and A4 and dilute as you have done with the standard toxic material.

5.4 Repeat for the second sample to be tested. Dispense 200 μL to Wells A5 and A6 and dilute two-fold serial dilutions until Wells G5 and G6. Discard 100 μL of solution from Wells G5 and G6.

5.5 Dispense 100 μL of the reaction mixture from Bottle A to wells of Column 1. These wells are used for blank.

5.6 Rehydrate the bacteria in Bottle B with the solution in Bottle C. Keep both bottles cold before mixing. Remove the seals and stoppers from the two bottles and immediately transfer the medium from Bottle C to Bottle B. Mix well by gently shaking. Leave at room temperature for 15 minutes, then transfer 1 mL of the bacterial suspension (now in Bottle B) in the reaction mixture in Bottle A.

5.7 Dispense 100 μL of the reaction mixture (Bottle A) including the bacteria to each well of Columns 2, 3, 4, 5 and 6.

5.8 Incubate the microwells at 37°C for 120 minutes.

5.9 Dispense 100 μL (0.1 mL) of the chromogenic substrate in Bottle F to all the wells. The blue substrate in Bottle F is in a ready for use solution. The yellow chromogenic substrate is in a dried form in Bottle F. To complete the yellow substrate solution, transfer the chromogen diluent in Bottle E to Bottle F. It is advised to warm chromogenic cocktail to 37°C before dispensing. After dispensing, mix well by tapping.

5.10 Incubate the microwells at 37°C for 20 minutes for yellow substrate and 90 minutes for the blue substrate. If colour is not well-developed in the wells, incubate for a longer period.

6.3 Toxicity of a tested material causes colour density below the OD values of the controls without the tested material. Toxicity is calculated by the equation:

% Toxicity = [0.1 - (OD* treated cells/OD control cells)] x 100

Minimal Inhibitory Concentration (MIC) is defined as the concentration of a chemical causing 20% toxicity.

* Treated cells are those incubated with a toxicant/tested material. Control wells are without tested material (wells of Row H).