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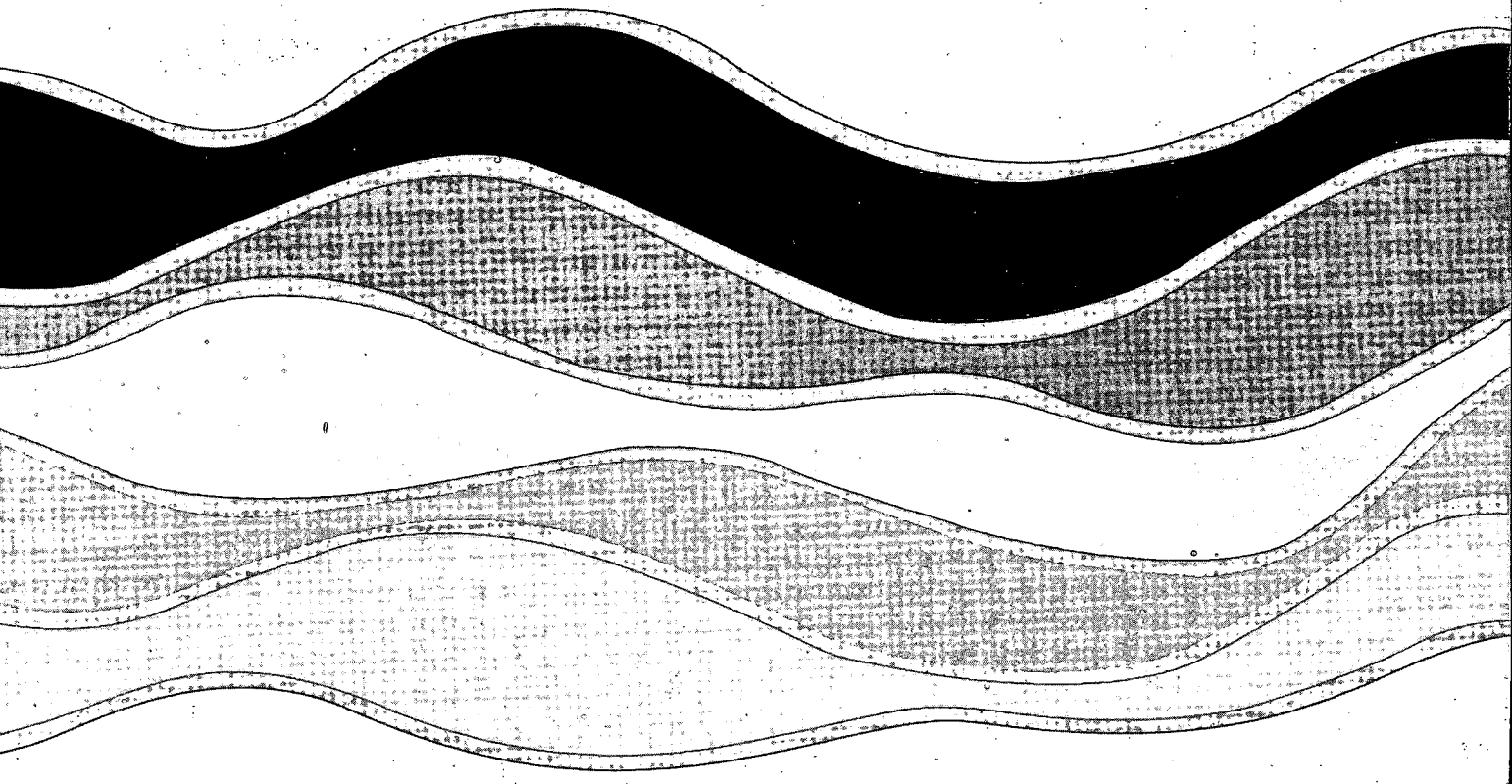

CONTAMINANTS IN VEGETATION, EARTHWORMS AND DREDGED SEDIMENT IN CONFINED DISPOSAL FACILITIES ON THE CANADIAN GREAT LAKES

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Contaminants in Vegetation, Earthworms and Dredged Sediment in Confined Disposal Facilities on the Canadian Great Lakes

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Management Perspective

Sediments dredged for navigational purposes from the Great Lakes have been evaluated using the 1976 Ontario Ministry of the Environment guidelines for open water disposal of dredged material. Sediments with concentrations of contaminants exceeding these guidelines have been considered unsuitable for open water disposal and placed in confined disposal facilities (CDFs) constructed along the Great Lakes shoreline.

Since the early 70s about 56% of sediments dredged from Great Lakes harbours and navigational channels have been placed in CDFs. Present management of CDFs in Ontario usually results in the development of aquatic (i.e. marsh) habitat, which gradually changes into terrestrial habitat as the sediment dewaters. Once the disposed sediment has dried out it should be considered soil for which the Ontario Ministry of Environment has soil guidelines for comparison. Consequently, contaminated dredged sediments which have been confined with all precautionary measures to eliminate contaminant mobility become terrestrial soils that could be acceptable for agricultural, parkland or residential land use because the concentrations of contaminants in the soil guidelines are 3 to 40 times greater than those in the sediment guidelines.

An environmental audit of present confined disposal facilities has been performed to determine if plants and wildlife colonizing the new habitat are at risk. Sediments/soils at most CDFs were determined to be no more contaminated than urban soils in Ontario. Some CDFs, however, were determined to be highly contaminated, the most notable being the one in Hamilton Harbour. Vegetation growing on the sediments/soils accumulated cadmium, copper and zinc to a larger degree than other metals. Generally, contaminants in vegetation were found at acceptable concentrations. Accumulation of contaminants in grasses and clover was less than in sedges suggesting that manipulating the vegetative cover and the depth of cap isolating the contaminated sediments/soils could minimize contaminant mobility.

Most significant, however, is the comparison between the sediment/soil and the provincial soil guidelines. Only three of the 12 CDFs had soils unsuitable for agricultural, parkland or residential land use. In two of the three, the soils were suitable for commercial/industrial land use and in the remaining one, at Hamilton Harbour, the soil was unsuitable for any land use due to the excessively high zinc concentrations.

Generally, the creation of confined disposal facilities for the dredged sediments and the creation of terrestrial habitat for parkland is an acceptable option for dredged sediments on the Canadian side of the Great Lakes except in Hamilton Harbour. In the near future, the confined disposal option will be evaluated for the remediation of contaminated sediment problems in the Areas of Concern. In light of this report, this option should be evaluated using the sediment guidelines during the first phase

after the CDF is created and the soil guidelines during the next phase after the sediment is dry and partly consolidated. If the contaminant concentrations in the sediment of interest are significantly higher than the sediment guidelines but below the soil guidelines, every effort should be made to minimize the length of time of the first aquatic phase and reach the second terrestrial phase as quickly as possible.

The use of confined disposal facilities in Hamilton Harbour should be reviewed carefully in light of the excessively high zinc concentrations making the "soil" unsuitable for any land use in Ontario. The depth of the cap isolating the contaminated sediments may need to be thicker than normal and rooting of vegetation through the cap should be prohibited.

Perspectives de la direction

On a évalué les sédiments dragués dans les Grands Lacs pour y faciliter la navigation au moyen des directives de 1976 concernant l'élimination des déblais de dragage dans les eaux libres du ministère de l'Environnement de l'Ontario. Les sédiments présentant des concentrations de contaminants excédant les valeurs présentées dans les directives ont été jugés impropres à ce mode d'évacuation et ont été transportés jusqu'à des décharges protégées, aménagées le long du rivage des Grands Lacs.

Depuis le début des années 1970, environ 56 % des sédiments dragués dans les ports et les chenaux des Grands Lacs ont été mis en décharge dans de tels lieux protégés. En Ontario, grâce aux techniques actuelles de gestion, des habitats aquatiques (c'est-à-dire, des marais) se forment habituellement dans ces décharges, puis les marais se transforment progressivement en habitats terrestres au fur et à mesure que les sédiments sèchent. Une fois qu'ils sont secs, les sédiments se classent parmi des sols dont les caractéristiques peuvent être comparées à celles des directives touchant les sols du ministère de l'Environnement de l'Ontario. En conséquence, les sédiments contaminés dragués, qui ont été mis en décharge avec toutes les précautions qu'il faut prendre pour empêcher la migration des substances contaminantes, pourraient être employés à des fins d'agriculture, de construction domiciliaire ou pour l'aménagement de forêts-parcs, car les concentrations de matières contaminantes précisées dans les directives au sujet des sols sont de 3 à 40 fois plus élevées que celles des matières contaminantes présentées dans les directives touchant les sédiments.

On a effectué une évaluation environnementale des décharges protégées actuelles afin de déterminer si les espèces floristiques et fauniques colonisant les nouveaux habitats étaient en péril. D'après les résultats, les sédiments-sols dans la majorité des décharges protégées ne sont pas plus pollués que les sols urbains en Ontario. Toutefois, dans certaines décharges, les sédiments sont fortement contaminés; le cas le plus notable est celui de la décharge située dans le port d'Hamilton. Les concentrations de cadmium, de cuivre et de zinc mesurées dans la végétation croissant sur les sédiments-sols de ce lieu étaient plus élevées que celles de tout autre métal. En règle générale, les concentrations des contaminants relevées dans la végétation étaient d'un niveau acceptable. L'accumulation des substances contaminantes chez les graminées et le trèfle était moins importante que chez les cypéracées, révélant ainsi que la manipulation du couvert végétal et la profondeur de la couverture isolant les sédiments-sols contaminés pourraient minimiser les mouvements des polluants.

Ce sont, cependant, les résultats de la comparaison des caractéristiques des sédiments-sols et des directives provinciales au sujet des sols qui étaient les plus significatifs. Parmi les douze décharges protégées examinées, seulement trois étaient impropres à l'agriculture, à l'aménagement de forêts-parcs ou à la

construction domiciliaire. Parmi ces trois décharges, deux pouvaient servir comme site commercial ou industriel. Dans le dernier cas, c'est-à-dire la décharge située dans le port d'Hamilton, le sol était impropre à tout type d'utilisation en raison des concentrations excessivement élevées de zinc.

En général, la création de décharges protégées pour l'élimination de sédiments dragués, où se forment ultérieurement des habitats terrestres se transformant en forêts-parcs, est une méthode acceptable d'évacuation des sédiments extraits dans les zones canadiennes des Grands Lacs, sauf dans le port d'Hamilton. Dans un avenir proche, on entend évaluer la possibilité d'avoir recours aux décharges protégées pour régler la question des sédiments contaminés dans les zones à risques. À la lumière de ce rapport, on devrait, dans un premier temps (après la création des décharges protégées), se servir des directives concernant les sédiments, puis, dans un deuxième temps, une fois que les sédiments sont secs et partiellement consolidés, des directives au sujet des sols. Si les concentrations de polluants dans les sédiments d'intérêt sont notablement plus élevées que celles présentées dans les directives qui leur sont propres, mais qu'elles sont inférieures aux concentrations précisées dans les directives au sujet des sols, on devrait déployer tous les efforts possibles pour minimiser la durée de la première phase "aquatique", de manière à obtenir des habitats terrestres dans les meilleurs délais.

Il faudra examiner de façon minutieuse la possibilité de créer des décharges protégées dans le port d'Hamilton, car ces "sols" ne pourraient servir à aucune utilisation en Ontario, en raison de leur teneur excessive en zinc. La couverture isolant les sédiments contaminés devrait peut-être être plus profonde que la normale, et il faudrait interdire la pénétration des racines de la végétation dans les sédiments sous-jacents.

ABSTRACT

The placement of contaminated dredged sediments into confined disposal facilities (CDFs) has been practiced on the Canadian Great Lakes since the early 1970s. Depending on the management of these sites, aquatic and terrestrial habitats may develop which support diverse biotic communities. The potential exists for the re-entering of contaminants from the confined sediments into plants and wildlife utilizing these habitats. A study was initiated in 1987 to determine if vegetation growing on 12 contaminated CDFs and earthworms in these sediments were bioaccumulating contaminants, and if their contaminant concentrations were hazardous to wildlife.

Sediments from Hamilton Harbour were found to be highly contaminated with chromium, copper, lead, zinc, mercury, cadmium, PCBs and PAHs. Several other sites had metal concentrations which would classify them as waste material. However, the sediments at most of the sites were determined to be no more contaminated than other urban soils.

The coarse sediment fraction was found to contain a considerable proportion of the contaminants of the bulk sediment. However, the coarse material may largely be composed of flocculated fine particles. Dredging practices which separate the fine and coarse fractions and dispose of the coarse material in open water may be unsuitable in the Great Lakes if the coarse separation does not result in a relatively uncontaminated coarse (sand) sediment.

Vegetation bioaccumulated cadmium, copper and zinc to a larger degree than the other metals. Sedges accumulated metals more readily than did grass, clover or smartweed. Several metals were found at concentrations in vegetation and leaf litter which would be hazardous to wildlife consuming them. Organics were generally found at low concentrations in vegetation.

Earthworms contained concentrations of metals and organics which may be hazardous to wildlife consuming them, but the concentrations were similar to those reported in other studies. Earthworms accumulated greater proportions of the higher chlorinated biphenyls, although the lower chlorinated biphenyls were more abundant in the sediments.

The results indicate that CDFs should be managed so that vegetation, which does not accumulate contaminants to a large extent, such as clovers, be allowed to develop as a suitable ground cover. An appropriate thickness of capping material should be placed over the contaminated sediments to prevent the roots of vegetation from reaching the sediments.

RÉSUMÉ

Dans les Grands Lacs canadiens, le transport de sédiments dragués contaminés jusqu'à des décharges protégées s'effectue depuis le début des années 1970. Selon les méthodes de gestion employées, des habitats aquatiques et terrestres où croissent diverses communautés fauniques et floristiques peuvent s'y créer. Les matières polluant les sédiments mis en décharge risquent de contaminer la faune et la flore dans ces habitats. En 1987, on a amorcé une étude afin de déterminer s'il y avait bioaccumulation de ces contaminants dans la végétation et les vers de terre dans douze décharges protégées contaminées, et si les concentrations mesurées étaient dangereuses pour les espèces fauniques.

Dans les sédiments du port d'Hamilton, on a mesuré de fortes concentrations de chrome, de cuivre, de plomb, de zinc, de mercure, de cadmium, de BPC et d'HPA. Le sol dans plusieurs autres lieux pourraient être classés comme matériel de rebuts en raison des fortes concentrations qui y ont été relevées. Toutefois, dans la majorité des décharges, les sédiments analysés n'étaient pas plus contaminés que ne le sont les sols urbains.

La fraction de sédiments grossiers contenait un important pourcentage des contaminants par rapport à l'ensemble des sédiments. Cependant, les matériaux grossiers peuvent être constitués, dans une large mesure, de particules fines floculées. Les techniques de dragage qui permettent la séparation des fractions fines et grossières et d'évacuer les matériaux grossiers dans les eaux libres ne se prêtent peut-être pas aux conditions des Grands Lacs, si le sable (matériaux grossiers) qu'on obtient n'est pas relativement peu contaminé.

La bioaccumulation du cadmium, du cuivre et du zinc était plus importante que celle des autres métaux dans la végétation. Les cypéracées accumulaient plus facilement les métaux que les graminées, le trèfle ou la renouée. Les concentrations de plusieurs métaux, mesurées dans la végétation et dans la litière, étaient dangereuses pour les espèces fauniques qui s'en nourrissent. En général, les concentrations de substances organiques étaient faibles dans la végétation.

Les vers de terre présentaient des concentrations de métaux et de substances organiques pouvant être dangereuses pour la faune, mais les valeurs étaient similaires à celles signalées dans d'autres études. Les concentrations de chlorobiphényles supérieurs étaient plus importantes chez les vers de terre, tandis que la teneur en chlorobiphényles inférieurs était plus élevée dans les sédiments.

Les résultats révèlent qu'on devrait gérer les décharges protégées de manière à favoriser la croissance d'une végétation pouvant constituer une couverture appropriée, c'est-à-dire une végétation qui n'accumule pas d'importantes concentrations de contaminants (par exemple, le trèfle). Une couverture d'une

épaisseur appropriée doit être placée sur les sédiments contaminés afin d'empêcher les racines de la végétation de pénétrer dans ceux-ci.

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1. INTRODUCTION

The practice of disposing of contaminated dredged material into confined disposal facilities (CDFs) has been carried out since the early 1970s on the Canadian Great Lakes. Before then, open lake disposal of all dredged materials was the common practice. With the increase in awareness of the impacts of contaminated sediments on the environment, emphasis shifted to the isolation and confinement of these materials in specially engineered containment facilities (Seawright 1986). In 1976, the Ontario Ministry of the Environment (OMOE) established guidelines indicative of contamination in sediments (Table 1). Sediment parameters must be lower than these guidelines to allow for open water disposal (OMOE 1987). During 1975-79, approximately 1.4 million m^3 or 56% of the total Canadian Great Lakes dredged material was disposed of in confined facilities (IJC 1982).

The isolation of contaminated sediments in CDFs usually involves the placement of the material into the facility, a dewatering period to allow the material to stabilize, then the capping of the site with clean fill material. These sites may then be used for purposes such as industrial development, recreation or open space. The OMOE has also developed guidelines for the land use of contaminated soils, which may be applied to sediments after their disposal and capping (Rinne 1988).

Depending on the planned use, these sites may develop a variety of vegetation communities both during the uncapped dewatering phase or after the site has been capped. Concern has developed over the possibility of contaminants re-entering the ecosystem via uptake by vegetation growing on the sites or ingestion by soil invertebrates and the implications to biota associated with CDFs. This has led to a study into the bioaccumulation of contaminants into vegetation growing on dredge disposal sites and into earthworms at these sites, by the Lakes Research Branch, National Water Research Institute, Burlington, Ontario.

Part 3 of this report summarizes the background information obtained on each confined disposal site on the Canadian Great Lakes. This information was used to select the sites which were sampled in the study. Part 4 of this report describes the sampling undertaken in the study, summarizes the results and discusses the biological significance of the results to biota utilizing dredge disposal sites.

2. BACKGROUND INFORMATION ON CONFINED DREDGE DISPOSAL SITES

Information on confined dredge disposal sites on the Canadian Great Lakes was obtained regarding location, size, age, disposal history, type of dredgate material, possible contaminant content, management status, vegetation status and planned uses. Sources of information included the Guidelines and Register for Evaluation of Great Lakes Dredging Projects (IJC 1982), and resource people from the following offices: the Lakes Research Branch, NWRI, Burlington; the Environmental Protection Service, Ontario Region, Toronto; Public Works Canada, Ontario Region, Toronto; and Small Craft Harbours, Fisheries and Oceans Canada, Burlington. The sites were visited in the summer of 1987 to determine the present status of vegetation communities. The information for confined dredge disposal sites at nine locations on the Canadian Great Lakes (Fig.1) are described below.

2.1 THUNDER BAY

The Mission Bay Disposal Facility (MBDF) is a long-term confined disposal facility located at the southern end of Thunder Bay's harbour, adjacent to Chippewa Park. It was built between 1978-81, and has a storage capacity of 5 million m^3. Four storage cells and a reservoir cell have been created by the construction of interior berms between 1981-84 (Fig. 2). Dredged material is initially placed into the reservoir cell, then hydraulically rehandled into the containment cells at a later date.

In 1981, the first rehandling of dredged material from the reservoir into cell 1 was carried out. The 173,000 m^3 of sediment filled most of cell 1 and part of cell 2. This sediment was originally dredged during two projects in the autumn of 1980. The material was comprised of fine sand, silt and clay from the Westfort Turning Basin (DPW ID code TBW8001) and McIntyre River (TBM8001) areas. The sediments from the Westfort Turning Basin exceeded OMOE open water disposal guidelines for copper and PCBs while the McIntyre River sediment exceeded chromium, copper and mercury guidelines (Table 2).

In 1982, the second rehandling of sediments from the reservoir to the containment cells was performed. Approximately 150,000 m^3 of material was used to fill all of cell 1 and most of cell 2. The sediment was originally dredged from the Westfort Turning Basin (TBW8101) and north (TBH8101) areas of the harbour during the latter part of 1981, and was comprised of sand, silt and clay. The north harbour sediment had concentrations of chromium, copper, mercury and nickel which exceeded the open water disposal guidelines (Table 2).

The third rehandling operation occurred in 1985 in which 336,000 m^3 of material from the reservoir filled cell 2 and most

of cell 3. This material was originally dredged during projects between late 1982 to late 1984 from the Westfort Turning Basin (TBW8201), upper Mission Turning Basin (TBU8301, TBU8401) and the central Kaministiquia River (TBK8301, TBK8401). It was comprised of sand, silt and clay. Concentrations of chromium, copper, mercury and nickel exceeded the OMOE open water disposal guidelines for most of the sediment (Table 2).

In 1985, cell 1 was covered with clean dredge material which was rehandled from the reservoir. The 50,000 m^3 of material had originally been dredged from the Mission River Entrance Channel during late 1984 and was comprised of sand, silt and clay. The cover material was spread over the cell to a uniform thickness of 0.3 m. Cell 1 was seeded with a grass and legume mixture of the following composition: Perennial rye grass (Lolium perenne) 25%, Timothy grass (Phleum sp.) 12.5%, Creeping red fescue (Festuca sp.) 12.5%, Reed canary grass (Phalaris arundinacea) 12.5%, Birdsfoot trefoil (Lotus corniculatus) 25%, and Red clover (Trifolium pratense) 12.5%.

In late 1986, clean material from an unused area of the reservoir was dredged and placed on cell 2 to provide a cap. The cover material was comprised of silt, sand and clay. A total of 80,000 m^3 of material was placed on cell 2 and a small part of cell 3. Cell 2 was to be seeded during the autumn of 1987 using the grass mixture described above.

In July 1987, cell 1 was approximately 80% covered with vegetation. Of this, 90% were grasses (Gramineae) and 10% were legumes (Leguminosae), sedges (Cyperaceae) and other minor forbs. Vegetation had been growing on the capped cell 1 for up to two years.

Cell 2 at that time was approximately 99% bare soil. Only sparse vegetation had established itself, being mostly grasses and legumes.

A dyke had been constructed in cell 3 dividing it into two sections. The west part of cell 3 was approximately 60% vegetated, 20% open water and 20% bare soil (clean fill overflow from cell 2). Some sparse aquatic submergent vegetation, including wild celery (Vallisneria americana) and pondweeds (Potamogeton sp.) were growing in the flooded section. The terrestrial vegetation was largely shrubs of sage-leaved willow (Salix candida) and blue-leaved willow (S. myricoides), a large area of manna grass (Glyceria sp.) and other plants. The east part of cell 3 was approximately 85% vegetated, largely with grasses, sedges, forbs and a large willow and speckled alder (Alnus incana) thicket. A small flooded pond and a semi-flooded mudflat area with some arrow arum (Peltandra virginica) growing on it were also present.

Cell 4 was almost entirely open water with a small shoreline mudflat in the northwest corner in 1987.

The planned future use of the disposal facility site is for recreation through the development of a park.

2.2 SEAWAY ISLAND

The South-East Bend Cut-Off Channel (SEBCOC) CDF is located at the south end of the St. Clair River where it enters Lake St. Clair (Fig. 1). Three containment facilities were built between 1977-78 along the shoreline of Seaway Island (Fig. 3) within the Walpole Island Indian Reserve. Each facility consisted of a large disposal cell with an adjoining cell for the decantation of supernatant overflow from the main cell during hydraulic dredging operations (Seawright 1986). The combined capacity of the facilities is approximately 500,000 m^3.

Dredging operations were carried out in the SEBCOC adjacent to Seaway Island between 1978-81. In 1978, 93,000 m^3 of sand and silt were placed into cell A and 87,300 m^3 were placed into cell B. In 1979, 3,000 m^3, 127,000 m^3 and 73,800 m^3 of sediment were placed into cells A, B and C, respectively. There were no chemical analyses reported for these dredging projects. In 1980, 78,000 m^3 of dredged material from the channel was deposited into cell A and 20,000 m^3 of material was placed into cell B. This material had mercury concentrations exceeding OMOE open water disposal guidelines (Table 2). In 1981, 27,000 m^3 of sediment was placed in cell A, then later trucked to cell B (Wilkins and Assoc., 1982).

In 1980, most of cell C had been covered with topsoil from Seaway Island and was seeded. During 1981-82, cells A, B and the rest of cell C were capped with imported topsoil. In September, 1982, all the cells were fertilized and seeded. The seed mixture used contained 50% wheat (Triticum sp.) with the remaining 50% made up of creeping red fescue, Canada bluegrass (Poa compressa), Kentucky bluegrass (P. pratensis), perennial rye grass, boreal bent grass (Agrostis borealis), and white clover (Trifolium repens).

In September 1983, cell A was covered with a good growth of vegetation dominated by wheat with some bluegrass and white clover. A low wet area was occupied by plants such as smartweeds (Polygonum sp.), bulrushes (Scirpus sp.), spiked loosestrife (Lythrum sp.), cattails (Typha sp.), old witch grass (Panicum capillare), yellow nut-grass (Cyperus esculentus), and reed grass (Phragmites communis). Cell B had similar growth to cell A, however it was less lush and had larger wet areas. Cell C had a very heterogenous vegetative cover with areas similar to that of cells A and B, some sparsely vegetated areas, and patches of Phragmites, Triticum and various mustards (Cruciferеae). This was attributed to cell C being thoroughly covered with good topsoil (MacLaren Ltd., 1984).

A post-dredging monitoring program was carried out at Seaway Island from 1981-83 to detect changes in mercury distribution in the environment which might result from mercury in the dredged sediments. The biological monitoring of 1983 involved collecting samples of terrestrial vegetation (white clover, wheat, Phragmites and cottonwood [Populus deltoides]) from the covered cells, aquatic macrophytes from sites adjacent to the cells and the decant portions of cells B and C, muskrats (Ondatra zibethicus) from Seaway Island near the cells, and voles (Microtus sp.) from Seaway Island adjacent to the cells. Results of the 1983 biological monitoring studies are presented in Table 3 (MacLaren Ltd., 1984).

In 1986, further dredging of the SEBCOC was carried out with the material being placed on the decant areas of cells A and B. They were covered with a layer of clean fill and seeded in the spring of 1987.

An additional disposal facility was built during the summer of 1987 by constructing a berm enclosing the space between the existing cells B and C. This facility will meet future dredge disposal requirements for the SEBCOC.

In July 1987, cells B and C were totally vegetated. Grasses were the dominant plants with interspersed white sweet clover (Melilotus alba), trefoil, and small cottonwood saplings. Low wet areas contained cattails, reed grass, bulrushes, sedges, and swamp milkweed (Asclepias incarnata). The wet areas were more extensive on cell C than on cell B. Cell A was not visited because of ongoing work relating to a current dredging project.

The planned future use of the disposal sites is for recreational use of the Walpole Island Indian Band. The site is presently used by Band members for hunting.

2.3 CHENAL ECARTE

Material was dredged from the Chenal Ecarte at the south end of the St. Clair River (Fig. 1) during the latter half of 1979. A total of 18,100 m^3 of silty sand and clay was removed and deposited on a piece of landfill property owned by Lambton Marina Ltd. adjacent to the channel (Fig. 4). This material was left piled at the site to dewater and consolidate until 1983 when it was spread evenly over the site. The material was not covered with clean fill. Chemical analyses of the material indicated that concentrations of mercury and PCBs exceeded OMOE open water disposal guidelines (Table 2).

In the summer of 1987, the property was totally vegetated. The vegetation was approximately 80% grasses (Phragmites sp. and others) and 20% forbs and other plants (goldenrods [Solidago sp.], dandelion [Taraxacum sp.], sedges, plantains [Plantago sp.], cottonwood and willow saplings). The vegetation at the site had

been cut by a mower shortly after the first visit in July 1987. The future use of the site is unknown.

2.4 WHEATLEY HARBOUR

Wheatley Harbour, located at the mouth of Muddy Creek on western Lake Erie (Fig. 1) underwent an expansion and dredging project during the mid 1970s. Dredging operations carried out between August 1976 to October 1977 removed 59,000 m^3 of material comprised of organic silt and sand. This material was disposed of at eight upland and confined sites (Fig. 5).

Contaminated sediments from dredging operations in Wheatley Harbour during late 1983 were disposed of at two upland sites, on private properties owned by the Pulley and Dust families. Approximately 9,000 m^3 of material composed of mostly silt and sand was placed in dugout reservoirs on each of the sites. Following consolidation of the dredged material, the Pulley site was covered by 0.3 m of clean fill. By August 1987, the Dust site had not fully consolidated and remained uncapped. Analyses of sediment samples taken in 1984 from the two sites indicated that concentrations of arsenic, chromium, copper, zinc and PCBs were higher than OMOE open water disposal guidelines (Table 2).

In 1987, the Pulley site was covered with a maintained lawn. The site was located between the roadway and a corn field. A portion of the southwest corner had slumped several inches and was partially flooded by surface water. The site remains as open space.

The Dust site, located at the back of a farm field adjacent to Muddy Creek, was almost entirely vegetated by successional plants such as cottonwood and willow saplings, cattails, Phragmites, nettles (Urticaceae), grasses, thistles (Compositae), wild carrot (Daucus carota) and white sweet clover. A small pond remained on the north side of the site. Fill material was stockpiled adjacent to the disposal site. After capping, the site is planned to be cultivated for agriculture.

2.5 PORT STANLEY

Dredging operations in the Port Stanley Harbour, located on the north shore of Lake Erie at the mouth of Kettle Creek (Fig. 1) removed 169,000 m^3 of contaminated material between October 1977 and June 1978. This material was disposed of in a confined facility on the east side of the harbour entrance (Fig. 6). The material was left uncapped. Pre-dredging sediment samples indicated that concentrations of copper, lead, zinc, and cadmium exceeded OMOE open water disposal guidelines (Table 2). At present, the disposal site is a municipal park for passive recreational use. It is covered by a maintained lawn. The west edge is bordered by a row of ornamental maple trees (Acer sp.) up

to 7 m in height. Some weed species are found scattered throughout the lawn.

2.6 HAMILTON HARBOUR

The Hamilton Harbour Bayside Disposal Facility is located in the eastern harbour along the Beachstrip, south of the Burlington Beach Canal (Fig. 7). Disposal of dredged material from the Harbour first occurred at the CDF in 1958 from work done on the development of the Strathearne Avenue wharves and turning basin. The first berm was constructed in that year to form Pier 25. In 1966 a second berm was built to form an additional cell. In 1972 a third berm was constructed forming parts of Piers 26 and 27 (Grossi 1986).

The 50 ha CDF has an approximate capacity of 3 million m^3. When filled to capacity, the site is designated for future industrial development. Since 1972, almost all of the material dredged from the harbour, which is highly contaminated, has been disposed of at this site. The facility has been filled from the southern end towards the north. As of 1985, the remaining capacity in the CDF was approximately 720,000 m^3 which is predicted to meet disposal needs for the next 15 years (Grossi 1986).

A history of the dredging operations in Hamilton Harbour from 1898 to 1979 was provided by Holmes (1986). A summary of dredging operations since 1976 is provided below.

In 1976 approximately 128,000 m^3 of material comprised of organic silt and sand was dredged during October and November and placed in the Bayside CDF. From April to May 1978, 105,000 m^3 of silt and organic silt was dredged and disposed of in the slip between Piers 12 and 13 in the west harbour. Also, approximately 42,000 m^3 of organic silty material was dredged from the Harbour between August and October 1978, and disposed of in the Bayside CDF. No chemical data were available for these operations.

In July and August of 1980 dredging operations in the Wentworth Street slip (HAM8001) removed 15,000 m^3 of material which was disposed of between Riers 12 and 13. Material dredged from the Emerald St. slip (HAM8002) between September and October 1980, amounting to 15,000 m^3 of silt and clay, was also placed between Piers 12 and 13. No chemical data were available for these operations.

In 1983, 47,500 m^3 of material comprised of class B sand, very fine sand, silt and clay were dredged from August to November (HAM8301) and placed in the Bayside CDF. The chemical analyses of these sediments indicated that cadmium, chromium, copper, mercury, nickel, oil and grease, lead, and PCB concentrations were in excess of OMOE open water disposal guidelines (Table 2). Dredging between December 1983 and August 1984 of 160,000 m^3 of class B material

from the Hamilton channel was carried out, with disposal in the Bayside CDF. Concentrations of arsenic, cadmium, chromium, copper, mercury, nickel, lead and PCBs were higher than OMOE open water disposal guidelines (Table 2). Dredging from the Burlington channel between October 1984 and January 1985 (BUR8401) removed 39,000 m^3 of sandy material, part of which was disposed of in the Bayside CDF and the remainder in the open lake. Sampling revealed that concentrations of heavy metals and PCBs were below OMOE open water disposal guidelines (Table 2).

Since 1982, a series of interior berms were constructed within the CDF to create four cells, permitting staged development of the site and improving control of dredged slurry deposition and the containment of pollutants by enhancing settlement of fine sediments (Grossi 1986). In 1983, rehandling of 120,000 m^3 of dredged material from the reservoir area of cell 4 filled all of cell 1, most of cell 2 and part of cell 3.

Most of the dredged material deposited at the Bayside CDF over the years has consisted of poor soils, organic muck, slurry, oil and grease, debris, sand, and gravel. This material is largely unsuitable for foundation purposes. In order for the site to be developed for industrial use, construction fill material was imported to surcharge the area to an acceptable soil bearing pressure. This material included iron and steel industry slag as well as construction material. The fill was spread over the dredged material to provide a cover layer with a minimum thickness of 1 m (Grossi 1986). At present, Piers 25 and 26 have been capped with fill material. Cells 1 and 2 of Pier 27 remain uncapped; however cell 1 is full to capacity and cell 2 is mostly full. Cell 3 is largely open water with some exposed sediment in the south end. Cell 4 is totally open water.

In August of 1987 cells 1 and 2 were completely vegetated with successional annual weed species. The dominant plant present was nodding smartweed (Polygonum lapathifolium).

2.7 WHITBY HARBOUR

Whitby Harbour is located on a bay at the mouth of Pringle Creek on the north shore of Lake Ontario east of Toronto (Fig. 1). The dredge disposal site is located on the west side of the harbour adjacent to the Whitby Yacht Club (Fig. 8). Dredged material has been disposed of at this site from two operations. In 1978 approximately 190,000 m^3 of material comprised of peat clay and silt was placed in the bermed area along the shoreline. The sediment sampling indicated that zinc, nickel, lead, copper, chromium, and PCB concentrations were above OMOE open water disposal guidelines (Table 2).

Material from dredging operations in 1983 was placed within a bermed section overlying a portion of the 1978 disposal site.

In August 1987 the site was totally vegetated, being dominated by a successional woodlot of mostly young willows and cottonwood, with an understory of grasses and many forb species. Some areas of the 1983 disposal site were very wet with cattail stands.

2.8 OSHAWA HARBOUR

Oshawa Harbour, located on the north shore of Lake Ontario east of Toronto (Fig. 1), was created through the dredging of the Oshawa First Marsh during the 1930s and 40s. Dredge spoils were dumped into the southern section of the adjacent Second Marsh (Environment Canada 1982).

Dredging operations during the early 1970s used an upland area east of the harbour as a disposal site (Fig. 9), however, no details about these operations were available.

In 1979, 61,000 m^3 of silt and clay dredged from the harbour during August to October was confined in a dyked area east of the east wharf. The chemical data revealed levels of zinc, nickel, lead, chromium, and PCBs in excess of OMOE open water disposal guidelines (Table 2).

During 1981-82 a long-term CDF was constructed on the east side of the east wharf of the harbour. The facility consists of one main disposal cell and an adjoining decant cell with overflow weir provisions in both cells and a total capacity of 90,000 m^3. The facility was designed with a life cycle of five years, but at present it is only 40% filled to capacity. The site is planned to be used for wharf or pier facilities when completely filled (Seawright 1986).

Approximately 14,000 m^3 of sand, silt and clay were dredged from the approach channel and west channel wharf (OSH8201) and placed in the CDF between October 1982 and June 1983. Concentrations of chromium, nickel, oil and grease, and PCBs were above OMOE open water disposal guidelines (Table 2). Another 8,000 m^3 of sand and silt from dredging of the inner harbour berth from July to September 1983 (OSH8301) were also disposed of in the CDF. The sediments had concentrations of cadmium, chromium, nickel, oil and grease, and PCBs which exceeded OMOE open water disposal guidelines (Table 2). From December 1984 to June 1985, 13,000 m^3 of silt, sand and clay was dredged from the harbour and placed in the CDF, however no chemical data were available for this operation.

In August 1987, the Oshawa CDF sediments were above the water level within one-half of the disposal cell. The edge of this sediment was thickly vegetated by cattails, grasses, sedges and other forbs. The majority of the sediment was sparsely vegetated with smartweed. The older upland disposal site was covered by a

young woodlot of willow and cottonwood trees with an understory of grasses, shrubs, and forbs.

2.9 TORONTO HARBOUR

Sediments dredged from Toronto Harbour, located on the northwest shore of Lake Ontario (Fig. 1), were first confined in 1975, when dredged material was placed in a polder inside Hardpoint #5 of the East Headland, then sealed off. Between 1976 and 1979, dredged material was placed into the polder of Hardpoint #5 by truck. Since 1980 material has been placed into the present disposal facility, the Endikement (Fig. 10). Located on the East Headland, the Endikement is formed of three cells of 280,000, 530,000 and 2,200,000 m^3 volumes, respectively (Fricbergs 1986). At present the facility is approximately 10% full, and is projected to fulfill disposal requirements until 2010. The proposed future use for the site is for recreation and wildlife (Seawright 1986).

A total of 64,500 m^3 of sediment from four dredging operations from undetermined dates between 1975 and 1979 was disposed of in the East Headland CDF. The material was comprised of silt and clay. In 1981, a further 103,000 m^3 of material was dredged from Toronto Harbour and confined in the CDF. The Toronto Harbour sediments had concentrations of lead, zinc, copper, chromium, oil and grease, and PCBs which exceeded OMOE open water disposal guidelines (Table 2).

As of the summer of 1987 the cells of the Toronto Harbour CDF were totally flooded with no emergent vegetation present.

2.10 Mercer's GLEN

Mercer's Glen is a pond on the property of the Royal Botanical Gardens at the west end of Hamilton Harbour (Fig. 1) and was used as a control site for this study. It is part of a buried valley which once connected Cootes Paradise to Hamilton Harbour (Fig. 11). It has been created through landfilling of the valley. In the 1850s the construction of an earth embankment for the crossing of a railway line created the present north shore of Mercer's Glen. Sometime later the south shore was created by the construction of Old Guelph Road (Lamoureux, 1962).

In 1961 this valley was again being filled during the construction of the Chedoke Expressway. The silty material at the bottom of the channel was not strong enough to support the embankment for the highway and was dredged out within the area where the highway embankment was to be built. This material was pumped into Mercer's Glen where the sediment settled out. At present coarse sand and gravel cover the area near the outlet of the pond and fine silts cover the rest of the Glen (Lamoureux 1962).

Mercer's Glen was considered to be a good control site because it contains previously excavated material similar to a dredge disposal site. The sediments in Mercer's Glen were expected to be relatively "uncontaminated" because of their origin in Cootes Paradise, a wildlife sanctuary which receives little industrial effluents. The only contamination in Mercer's Glen would be a result of atmospheric deposition.

In August 1987 the shore of Mercer's Glen was totally surrounded by vegetation of varying types, including a stand of mature trees on the east side, a thick growth of purple loosestrife (Lythrum salicaria), and scattered sedges, grasses, and shrubs.

3. BIOAVAILABILITY OF CONTAMINANTS AT CDFs

3.1 METHODS

3.1.1 Sampling

The use of the words "sediment" and "soil" may mean different things to different people; sediment usually referring to depositional material in waterbodies and soil referring to terrestrial substrate. After sediments have been removed from their aquatic phase and placed on land or allowed to dewater, they become soils. However, there is no clear definition of when a sediment becomes a soil. Therefore, the terms sediment and soil are used interchangably throughout this report when referring to disposed sediments in an upland state.

Vegetation and soil samples were collected from eleven dredge disposal sites at eight locations, plus a control site, between August 4 and September 17, 1987. The sites sampled were:

- cells 1 and 3 of the Mission Bay Disposal Facility (MBDF), Thunder Bay;
- the South-East Bend Cut-Off Channel (SEBCOC) CDF on Seaway Island;
- Chenal Ecarte;
- the Dust and Pulley properties at Wheatley;
- Port Stanley;
- the Bayside Disposal Facility (BDF), Hamilton Harbour;
- Whitby Harbour;
- the CDF and an upland site at Oshawa Harbour;
- and Mercer's Glen (Royal Botanical Gardens, Hamilton), the control site (Fig. 1).

The vegetation sampled included species of grass, sedge, white sweet clover and nodding smartweed, depending on which were present at each site. Leaf litter associated with the grass and soil associated with each plant sample were also collected. Earthworms were collected from sites where they were found.

A minimum of 60 g (fresh weight) of vegetation was sampled for each plant type at each site, being a composite of five plants randomly sampled from the site. Plants were cropped at ground level. The seeds of sedges were removed from sedge plants for separate analysis. Leaf litter was collected by hand, down to the soil level. Soil samples were obtained using a hand held corer-type soil sampler and were taken to a depth of 25 cm. Soil samples were also a composite of five cores randomly selected from each site. Earthworms were obtained by digging at five random locations at the sites. A summary of what samples were collected from each site appears in Table 4.

At the Thunder Bay cell 3 location, 10 replicates of each sample were collected and left unpooled to determine the variability of the contamination.

All samples were immediately frozen in the field with dry ice and then freeze-dried prior to chemical analysis. Vegetation samples were ground using a mill with a size 20 mesh screen. Sediment samples were homogenized by hand using a mortar and pestel. The particle size distributions of the sediment samples were determined using a sedigraph following seiving through a 63 μm mesh-size seive to separate the sand from silt and clay particles (Duncan and LaHaie 1979). Organic matter content was determined by loss on ignition, and calculated using the following formula:

$$\%\ \text{Loss on Ignition} = \frac{[\text{wt of sed sample before ignition} - \text{wt of sed sample after ignition}]}{[\text{wt of sed sample before ignition}]} \times 100$$

Both the <63 μm (fine) and the >63 μm (coarse) size fractions of the soil samples were analysed separately for all parameters.

3.1.2 Chemical Analyses

3.1.2.1 Major Elements

The fine and coarse fractions of the sediments from all of the sites were analysed for the oxides of the following major elements: silicon, aluminum, iron, magnesium, calcium, sodium, potassium, titanium, manganese, and phosphorus, using x-ray fluorescence spectrometry (Mudroch 1985).

3.1.2.2 Metals

The sediment samples were analysed for the following metals: arsenic, cobalt, chromium, copper, nickel, lead, vanadium, zinc, cadmium and mercury. The fine and coarse fractions were analysed separately. Arsenic, cobalt, chromium, copper, nickel, lead, vanadium and zinc concentrations were determined using x-ray fluorescence spectrometry. Mercury and cadmium concentrations were determined using cold vapour atomic adsorption spectrometry.

Vegetation and earthworm samples were analysed for cadmium, chromium, copper, lead, nickel and zinc according to the Water Quality Branch Analytical Methods Manual (1979). They were analysed for mercury using cold vapour atomic adsorption spectrometry. Iron and manganese concentrations were also analysed in leaf litter, sedge seeds, earthworms and smartweed (from Hamilton Harbour) samples according to the Water Quality Branch Analytical Methods Manual (1979).

3.1.2.3 Organics

The fine fractions of one sediment sample from all of the sites (except Wheatley-Pulley), coarse fractions of sediments from Thunder Bay cells 1 and 3 and Hamilton Harbour, and all the earthworm samples, were analysed for the presence of a range of organics using gas chromatography/mass spectrometry (GC/MS) scans. The specific compounds were analysed quantitatively using GC/MS techniques with selected ion monitoring. Based on the results of the sediment scans, all of the vegetation (grass, sedge, clover and smartweed), leaf litter and earthworm samples were analysed for polyaromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorobenzenes (CBs) and organochlorines (OCs). Samples from Whitby Harbour (sediment, grass, leaf litter and earthworms) were also analysed for chlorinated diphenyl ethers (DPEs). All sediment and earthworm samples were analysed for phthalate esters (PEs) as well.

The detection limits for the GC/MS determination of aliphatic hydrocarbons, PAHs, phthalates and chlorophenols were 5, 1, 5 and 0.05 µg/kg, respectively. Detection limits for GC/ECD analysis of PCBs and chlorobenzenes were 0.05 µg/kg.

3.1.3 **Data Analyses**

The concentrations of contaminants in samples were expressed on a dry weight basis in µg/g (equivalent to parts per million [ppm]) for metals and µg/kg (equivalent to parts per billion [ppb]) for organics.

Concentrations for the total sediment samples were calculated using the following formula:

[contam. concentr. x % fine] + [contam. concentr. x % coarse]
[in fine fraction fraction] [in coarse fraction fraction]

Mean contaminant concentrations in sediments were determined for each site from the different samples associated with each vegetation type. The contaminant concentrations in our sediments from the uncapped sites were compared to the concentrations reported in sediment samples collected before dredging by Public Works Canada (DPW) (see Tables 2-11). Concentrations were considered different if the 1987 concentrations were at least 20% higher or lower than the DPW samples. This figure was used based on the average variance observed in contaminants in the sample replicates from Thunder Bay cell 3 (see Results, section 3.2.1.2). Metal concentrations in sediment samples from each site were compared to OMOE's soil guidelines for proposed land use (Table 5, Rinne 1988), dredged material classification criteria (Table 1, OMOE 1987) and normal upper limits of metals in urban and rural soils (Table 6, OMOE 1986). The capped and uncapped sediments were compared to each other as were the coarse and fine fractions of

each sample. The concentrations of organics were compared to literature values.

The concentrations of metals in vegetation were compared to guidelines for maximum tolerable concentrations in forages for livestock (Table 7, Chaney 1982, in EPS 1984), and to normal upper limits in urban and rural foliage and grass (Table 6, OMOE 1986). Concentrations in vegetation were compared to the sediment concentrations on which they grew. Bioaccumulation factors (the ratio between the concentration in the vegetation and the concentration in the surrounding sediment) were calculated as well. The types of vegetation were compared to each other to determine which accumulated contaminants the most. Concentrations in leaf litter were expressed on an ash weight basis and were compared to concentrations in grass and sediment associated with it. Concentrations in sedge seeds were compared to those in sedge leaves. Vegetation concentrations were also compared between capped and uncapped sites.

Contaminant concentrations in earthworms were compared to literature values to determine their significance. Bioaccumulation factors were determined between the earthworms and the sediments from which they were collected.

3.2 RESULTS

3.2.1 Sediments

3.2.1.1 Physical Parameters and Major Elements

3.2.1.1.a Particle Size Distribution The mean particle size distributions of the sediment samples from the twelve sites are summarized in Table 8. The overall mean particle size of all the sediment samples was 87.6% gravel and sand (coarse fraction, >63 μm) and 12.4% silt and clay (fine fraction, <63 μm). Thunder Bay cell 3 had the smallest quantity of coarse fraction with 57.6%. Oshawa-Upland had the next smallest quantity of coarse fraction with 74.5%, while all the other sediments contained more than 83% of coarse fraction.

3.2.1.1.b Percent Loss on Ignition The overall mean percent loss on ignition of all the sediment samples was 3.7% with a range of 1.7 to 10.8% (Table 8).

3.2.1.1.c Major Elements The percent composition of the major elements in the fine, coarse and total fractions of sediment samples are summarized in Table 9.

3.2.1.2 Metals

The mean sediment metal concentrations for the fine and coarse fractions and bulk sediments for the 12 sites are summarized in Table 10.

The mean arsenic and zinc concentrations in nine replicate sediment samples from Thunder Bay cell 3 were 14.0 µg/g (standard deviation (SD) = 2.4) and 149.7 µg/g (SD = 4.3), respectively (Table 11). The percent variance of the standard deviations from the means were 17% for arsenic and 3% for zinc. A conservative difference of 20% was selected to determine difference of sediment metal concentrations in comparisons between samples.

3.2.1.2.a Guidelines Comparison The highest arsenic concentration in bulk sediments was found at Mercer's Glen (14 µg/g), the control site. This concentration was within the restricted land use classification criteria for dredged material (Table 1). Four other sites had arsenic concentrations within the unrestricted land use criteria: Thunder Bay cell 3 (10 µg/g), Chenal Ecarte (9 µg/g), Port Stanley (8 µg/g) and Hamilton Harbour (13 µg/g). The Mercer's Glen, Thunder Bay cell 3 and Hamilton Harbour concentrations were higher than the normal upper level of arsenic found in rural soils (10 µg/g, Table 6), while all sites were below the normal upper level in urban soils (20 µg/g, Table 6).

The highest cobalt concentration was found at Thunder Bay cell 1 (15 µg/g). Thunder Bay cell 3 (15 µg/g), Hamilton Harbour (15 µg/g) and Mercer's Glen (14 µg/g) also had high concentrations of cobalt, however, none of these were over the guideline for open water disposal (Table 1). All sites had concentrations below the normal upper level for urban and rural soils (25 µg/g, Table 6).

Chromium was observed to be highest at the Hamilton Harbour CDF (407 µg/g). This concentration was well above the criteria for restricted land use which is 120 µg/g (Table 1). All of the sites had concentrations exceeding the open water disposal guideline of 25 µg/g (Table 1), and the normal upper level for urban and rural soils of 50 µg/g (Table 6), except Whitby Harbour (47 µg/g, Table 10).

The copper concentration at Hamilton Harbour (201 µg/g) was well above the restricted land use criteria of 100 µg/g (Table 1). Soil of this copper concentration is suitable for commercial or industrial uses only (Table 5). The only other site higher than the open water disposal guideline of 25 µg/g (Table 1) was Thunder Bay cell 3 (65 µg/g). The Hamilton Harbour concentration exceeded the normal upper limit for urban soils (100 µg/g) while the Thunder Bay cell 3 concentration was higher than the normal upper limit for rural soils (60 µg/g, Table 6).

The highest nickel concentration (100 µg/g) was found at the Oshawa-Upland site. This and the Hamilton Harbour concentration

of 69 µg/g were the only ones above the restricted land use guideline of 60 µg/g (Table 1), and they also exceeded the normal upper limit for urban and rural soils (60 µg/g, Table 6). The Thunder Bay cell 1 (44 µg/g) and cell 3 (52 µg/g), Wheatley-Dust (35 µg/g), Oshawa CDF (43 µg/g) and Mercer's Glen (34 µg/g) concentrations were all over the unrestricted land use criteria of 32 µg/g (Table 1).

The Hamilton Harbour CDF had the highest lead concentration (436 µg/g), which was well over the restricted land use criteria of 60 µg/g (Table 1). The concentration at the Oshawa-Upland site (77 µg/g) also exceeded this criteria. Soil with a concentration of lead such as that found at Hamilton Harbour was suitable for commercial or industrial uses only (Table 5). It was also above the normal upper limit for rural soils (150 µg/g, Table 6).

The highest concentrations of vanadium were found at Thunder Bay cell 1 (129 µg/g) and cell 3 (124 µg/g). Guidelines for the suitability of open water disposal for vanadium have not been established (Table 1). All of the vanadium concentrations were below the tentative criteria for proposed land use of 200 µg/g (Table 5). Concentrations at Thunder Bay cells 1 and 3, Wheatley-Dust (84 µg/g), Hamilton Harbour (82 µg/g) and Mercer's Glen (84 µg/g) were all higher than the normal upper limit for urban and rural soils (70 µg/g, Table 6).

Zinc was found to be highest at Hamilton Harbour (2482 µg/g). This concentration was well over the restricted land use criteria of 500 µg/g (Table 1), was above the concentration that is suitable for industrial or commercial uses (Table 5) and exceeded the normal upper limit for urban and rural soils (500 µg/g, Table 6). Zinc concentrations at Thunder Bay cell 1 (113 µg/g) and cell 3 (167 µg/g), Chenal Ecarte (146 µg/g), Oshawa-Upland (194 µg/g) and Mercer's Glen (130 µg/g) exceeded the open water disposal guideline of 100.0 µg/g (Table 1).

The greatest mercury concentration was found at Chenal Ecarte (1.10 µg/g). This concentration and those at Thunder Bay cell 3 (0.99 µg/g) and Hamilton Harbour (0.69 µg/g) all exceeded the restricted land use guideline of 0.5 µg/g (Table 1), which is also the normal upper limit for urban soils (Table 6). The mercury concentration found at Chenal Ecarte would be suitable for commercial or industrial uses only (Table 5). Thunder Bay cell 1 mercury concentration of 0.22 µg/g was higher than the normal upper limit for rural soils (0.15 µg/g, Table 6).

The highest cadmium concentration was found at Hamilton Harbour (5.70 µg/g). This exceeded the restricted land use guideline of 4.0 µg/g (Table 1), which is also the normal upper limit for urban and rural soils (Table 6). This concentration was also just below the permissible level for commercial or industrial land use (6 µg/g, Table 5). The cadmium concentration in cell 3

at Thunder Bay (1.14 μg/g) exceeded the open water disposal guideline of 1 μg/g (Table 1).

3.2.1.2.b DPW Sampling Comparison The comparison between metal concentrations in sediments from the uncapped sites and the initial DPW sampling (using a 20% difference between the two values) revealed that at Thunder Bay cell 3, concentrations of arsenic, copper, nickel, zinc, and mercury were all higher in the 1987 samples than in the DPW samples, although arsenic was the only element which was more than 100% higher. At Chenal Ecarte there was no difference in mercury concentrations between the two samples. At Wheatley-Dust, chromium, lead, and nickel concentrations were higher in 1987, all by approximately 100%. At Port Stanley, only arsenic was higher in 1987, by a factor of greater than 10. At Hamilton Harbour arsenic, cadmium, copper, nickel, lead, and zinc were all much higher in the 1987 samples, by as much as 100%. At the Whitby Harbour and Oshawa CDF sites all of the metal concentrations were lower in the 1987 samples than in the DPW samples.

3.2.1.2.c Capped versus Uncapped Comparison of the metal concentrations in sediments from the capped cell 1 and uncapped cell 3 at Thunder Bay (using a 20% variance to determine difference) revealed that arsenic, copper, lead, and mercury concentrations were higher at the uncapped site. Cobalt, chromium, nickel, vanadium, zinc, and cadmium concentrations were not different between the two sites.

The same comparison between the Wheatley-Pulley (capped) and Wheatley-Dust (uncapped) sites revealed that concentrations of cobalt, copper, nickel, vanadium, and zinc were higher at the uncapped site. Arsenic, chromium, lead, mercury, and cadmium concentrations were no different between the two sites.

3.2.1.2.d Fine versus Coarse Fractions Using a 20% variance to determine difference, the fine grained sediment fraction (<63 μm) at Thunder Bay cell 1 contained greater concentrations of arsenic, copper and mercury, and lower concentrations of cadmium than the coarse fraction. Concentrations of cobalt, chromium, nickel, lead, vanadium, and zinc were similar.

At Thunder Bay cell 3, only the cadmium concentration was lower in the fine sediment fraction while the rest of the metals were similar in both fractions.

At Seaway Island, the fine sediment fraction contained greater concentrations of cobalt, copper, nickel, lead, vanadium and mercury, while arsenic, chromium, zinc and cadmium concentrations were similar in the coarse and fine sediment fractions.

At Chenal Ecarte, the fine sediment fraction contained greater concentrations of copper, nickel, vanadium, mercury, and cadmium,

a lower zinc concentration, and the same concentrations of arsenic, cobalt, chromium, and lead as the coarse sediment fraction.

The fine sediment fraction of Wheatley-Pulley sediments had higher concentrations of all metals except arsenic which was similar in the fine and coarse fractions.

The concentration of all metals at Wheatley-Dust were similar in the fine and coarse sediment fractions, except zinc, which was higher in the fine sediment fraction, and cadmium, which was higher in the coarse sediment fraction.

At Port Stanley, concentrations of cobalt, copper, nickel, lead, vanadium, and mercury were higher in the fine sediment fraction, while arsenic, cadmium and chromium concentrations were similar in the fine and coarse sediment fractions.

The concentrations of all metals at Hamilton Harbour were lower in the fine sediment fraction, except for cobalt and vanadium, which were similar in the fine and coarse sediment fractions.

The fine sediment fraction at Whitby Harbour had higher concentrations of all metals, except chromium and cadmium, which had similar concentrations in the fine and coarse sediment fractions.

At Oshawa CDF, concentrations of arsenic, cobalt, nickel, vanadium, and mercury were higher in the fine sediment fraction, while the cadmium concentration was lower in the fine sediment fraction, and chromium, copper, lead, and zinc concentrations were similar in the two sediment fractions.

The concentrations of cobalt, chromium, nickel, lead, zinc, and mercury at Oshawa-Upland were lower in the fine sediment fraction than in the coarse, and arsenic, copper, vanadium, and cadmium concentrations were similar in the fine and coarse sediment fractions.

Mercer's Glen fine sediment fraction had a higher copper concentration and lower arsenic, cobalt, and cadmium concentrations than the coarse sediment fraction, while the chromium, nickel, lead, vanadium, zinc, and mercury concentrations were no different in the two sediment fractions.

3.2.1.3 Organics

3.2.1.3.a PCBs The concentrations of total PCBs in bulk sediments are summarized for 12 sites in Fig. 12. PCB concentrations for the Whitby Harbour fine fraction sediment sample could not be

determined due to interference from diphenylethers (DPEs), therefore only the coarse fraction PCBs are represented.

The greatest concentration of total PCBs in sediments was found in Hamilton Harbour bulk sediments (4579 µg/kg, Fig. 12). This concentration exceeds the restricted land use guideline for dredged sediments (2000 µg/kg, Table 1). Concentrations of total PCBs in the sediment also exceeded OMOE guidelines for open water disposal (50 µg/kg, Table 1) at Thunder Bay cell 1 (101 µg/kg), Thunder Bay cell 3 (201 µg/kg), Chenal Ecarte (145 µg/kg), Oshawa CDF (110 µg/kg) and Oshawa-Upland (144 µg/kg).

The Canadian Council of Resource and Environment Ministers has recommended interim guidelines for total PCBs in soil, which are as follows: agricultural soil, including home gardens, 0.5 µg/g; non-agricultural soil (e.g. residential or general public access), 5 µg/g; and industrial/commercial, 50 µg/g (DPH 1988). The only sediment sample which exceeded the agricultural soil guideline was at Hamilton Harbour (4579 µg/kg, Fig. 12).

Specific PCB congeners in the sediment samples were summarized into groups (i.e., monochlorobiphenyls, dichlorobiphenyls, trichlorobiphenyls...decachlorobiphenyls) and plotted for each site to illustrate the PCB congener pattern in each sample (see Appendix 1 for chemical structures of specific congeners).

The bulk sediments from Thunder Bay cell 1 had a higher amount of tetrachlorobiphenyls, lower concentrations of tri-, penta- and hexachlorobiphenyls and very low concentrations of di-, hepta-, octa-, and nonachlorobiphenyls (Fig. 13).

The Thunder Bay cell 3 sediment had a similar congener pattern to that of cell 1. The predominate group was tetrachlorobiphenyls, while tri-, penta- and hexachlorobiphenyls had lower concentrations, and mono- and octachlorobiphenyls had very low concentrations (Fig. 14).

The sediments from Seaway Island, which had a very low total PCB concentration (3.6 µg/kg, Fig. 12), had a PCB congener pattern with higher amounts of tetra- and heptachlorobiphenyls with lower proportions of tri-, penta-, hexa- and octachlorobiphenyls (Fig. 15).

The PCB congener pattern in Chenal Ecarte sediments revealed high proportions of di-, penta- and hexachlorobiphenyls, lower amounts of tri-, tetra- and nonachlorobiphenyls and low levels of hepta-, octa- and decachlorobiphenyls (Fig. 16).

The Wheatley-Pulley sediments had a rather even pattern, although the total PCB concentration was very low (3.9 µg/kg), with higher amounts of hexa- and heptachlorobiphenyls and very low amounts of octa-and nonachlorobiphenyls (Fig. 17).

The Wheatley-Dust sediments had a PCB congener pattern which had a high hexachlorobiphenyl concentration with successively decreasing concentrations of penta-, tetra-, hepta- and octachlorobiphenyls (Fig. 18).

The Port Stanley sediments, which had a very low total PCB concentration (2.0 µg/kg, Fig. 12), had a PCB congener pattern with high tetrachlorobiphenyls and successively decreasing proportions of penta-and hexachlorobiphenyls (Fig. 19).

The extremely high PCB concentrations in the bulk sediments from Hamilton Harbour revealed a congener pattern which had high hexa-and heptachlorobiphenyl concentrations, lower octa-, penta-, tetra-, and trichlorobiphenyls, and much lower di- and nonachlorobiphenyls (Fig. 20). Eighteen specific congeners were in excess of 100 µg/kg, including PCB-153+132+105 (411 µg/kg), PCB-138+158 (529 µg/kg), PCB-180 (628 µg/kg), PCB-170+190 (369 µg/kg), and PCB-203+196 (281 µg/kg).

The very low PCB concentration in the Whitby Harbour coarse sediment fraction (1.5 µg/kg) was largely composed of tetrachlorobiphenyls with some penta- and octachlorobiphenyls (Fig. 21).

The Oshawa CDF bulk sediments had a PCB congener pattern which had high tetrachlorobiphenyls, lower di-, penta- and hexachlorobiphenyls, and much lower mono-, tri-, hepta- and octachlorobiphenyl concentrations (Fig. 22).

The Oshawa-Upland sediments had a PCB congener pattern which had high tetrachlorobiphenyls, with low proportions of penta- and hexachlorobiphenyls, and lower di-, tri-, hepta-, octa-, nona- and decachlorobiphenyls (Fig. 23).

The Mercer's Glen sediments had a PCB congener pattern that had high tetrachlorobiphenyls, lower penta- and hexachlorobiphenyls, and much lower tri- and heptachlorobiphenyls (Fig. 24).

A general pattern for the occurrence of PCB congeners in sediments among most of the sites can be seen (Figs. 25a, 25b). At the majority of the sites, the PCB concentrations were largely comprised of tri-, tetra-, penta-, hexa- and heptachlorobiphenyls, while mono-, di-, octa-, nona-, and decachlorobiphenyls were at very low concentrations. At eight of the twelve sites, the tetrachlorobiphenyls had the highest concentrations. The Wheatley-Dust and Hamilton Harbour sediments had PCB congener patterns obviously different from the other sites, with greater proportions of the higher molecular weight chlorinated biphenyls.

3.2.1.3.b PAHs The concentration of total priority PAHs was highest in Hamilton Harbour coarse sediment fraction (13800 µg/kg)

(Fig. 26). High concentrations were also found in fine sediment fractions at Chenal Ecarte (1148 µg/kg), Oshawa Upland (808 µg/kg) and Mercer's Glen (652 µg/kg), and at Thunder Bay cell 3 bulk sediment (1628 µg/kg).

The concentrations of specific priority PAHs in the Hamilton Harbour coarse sediment fraction are plotted in Fig. 27. The greatest concentrations were found for benzo(b)+benzo(k)-fluoranthene (BbF+BkF) (2400 µg/kg), fluoranthene (F) (1800 µg/kg), benzo(a)pyrene (BaP) (1700 µg/kg) and pyrene (PY) (1600 µg/kg). The Thunder Bay cell 3 bulk sediments had lower concentrations of several PAHs, including phenanthrene (PH) (283 µg/kg), fluoranthene (277 µg/kg) and pyrene (303 µg/kg) (Table 12). Chenal Ecarte fine sediment fraction also had similar concentrations of phenanthrene (220 µg/kg), fluoranthene (180 µg/kg), pyrene (140 µg/kg) and benzo(a)pyrene (240 µg/kg) (Table 12). The concentrations of most specific PAHs at the other sites were lower.

3.2.1.3.c CBs, OCs and DPEs The concentrations of several chlorobenzenes (1,3,5-TCB, 1,2,4-TCB, 1,2,3-TCB, 1,2,3,5+1,2,4,5-TeCB, 1,2,3,4-TeCB, QCB and HCB) and several organochlorines (HCBD, OCS, α-BHC, Lindane, heptachlor, τ-chlordane, p,p'-DDE, p,p'-DDD, p,p'-DDT and Mirex) in the sediments from the disposal sites are summarized in Table 13.

The Thunder Bay cell 1 coarse sediment fraction had a low chlorobenzene concentration and organochlorine concentrations below the detection limits (0.05 µg/kg).

Thunder Bay cell 3 bulk sediments had the highest concentrations of heptachlor (2.1 µg/kg) and p,p'-DDD (1.6 µg/kg), and relatively high concentrations of 1,3,5-TCB (3.6 µg/kg), 1,2,4-TCB (4.1 µg/kg), 1,2,3,5+1,2,4,5-TeCB (3.3 µg/kg), HCB (2.0 µg/kg), τ-chlordane (1.5 µg/kg) and DDE (3.8 µg/kg).

Seaway Island had relatively high concentrations of HCB (1.4 µg/kg).

Chenal Ecarte had the highest levels of 1,2,3,5-TeCB (6.08 µg/kg), HCB (425 µg/kg), and OCS (95.2 µg/kg). Relatively high concentrations of 1,3,5-TCB (2.0 µg/kg), 1,2,4-TCB (1.6 µg/kg), τ-chlordane (1.7 µg/kg), p,p'-DDD (1.4 µg/kg) and p,p'-DDT (1.1 µg/kg) were also found at Chenal Ecarte.

The highest p,p'-DDT concentration was found at Wheatley-Dust (11.0 µg/kg), which also had relatively high concentrations of τ-chlordane (1.0 µg/kg) and p,p'-DDE (1.5 µg/kg).

Port Stanley had relatively low concentrations of all CBs and OCs.

Hamilton Harbour had the highest concentrations of 1,3,5-TCB (3.9 μg/kg) 1,2,4-TCB (15.0 μg/kg), QCB (1.5 μg/kg) and Lindane (3.2 μg/kg), and relatively high concentrations of HCB (2.8 μg/kg) and OCS (1.3 μg/kg).

Whitby Harbour sediments had the highest p,p'-DDE concentration (20.0 μg/kg) and a relatively high p,p'-DDT concentration (2.8 μg/kg) as well.

The Oshawa CDF site had relatively high concentrations of HCB (2.5 μg/kg), p,p'-DDE (4.6 μg/kg) and p,p'-DDT (1.5 μg/kg).

The Oshawa-Upland site had relatively high concentrations of 1,2,4-TCB (3.9 μg/kg), τ-chlordane (2.1 μg/kg) and p,p'-DDE (1.1 μg/kg).

At the control site, Mercer's Glen, there were relatively high concentrations of HCB (20.4 μg/kg), OCS (1.5 μg/kg), τ-chlordane (1.3 μg/kg) and p,p'-DDE (1.6 μg/kg).

Mirex and HCBD were below the detection limit (0.05 μg/kg) in all of the sediment samples.

Diphenyl ethers (DPEs) were found only in the Whitby Harbour sediments at a concentration of 100.0 μg/kg (Table 13).

3.2.1.3.d Phthalate Esters and Hydrocarbons The highest concentration of total phthalate esters in sediments was found at the control site, Mercer's Glen (3579 μg/kg). High concentrations were also found at Chenal Ecarte (3210 μg/kg) and at the Oshawa CDF (2697 μg/kg). The specific compounds which had the highest concentrations at all of the sites were generally butyl benzyl phthalate, dibutyl phthalate and bis(2-hexyl ethyl)phthalate (Table 14).

Port Stanley sediments had the highest concentration of total aliphatic hydrocarbons (C12-C26) (40 μg/g). The next highest concentrations were found at Mercer's Glen (9.5 μg/g), Wheatley-Dust (9.4 μg/g) and Chenal Ecarte (8.8 μg/g).

3.2.2 Vegetation

3.2.2.1 Metals

The concentrations of cadmium, chromium, copper, nickel, lead, zinc, and mercury in grass, clover, sedge leaves and smartweed are summarized for all the sites in Table 15. Iron and manganese concentrations were also reported for Hamilton Harbour smartweed.

The mean concentrations of lead and zinc in grass, leaf litter, sedge leaves and seeds, and clover, and cadmium in sedge

leaves and clover for the replicate samples from the Thunder Bay cell 3 are summarized in Table 11. The average variance of the standard deviations from the means for these analyses was approximately 20%, and this value was used to determine difference of vegetation metal levels in comparisons between samples.

3.2.2.1.a Guidelines Comparison Cadmium concentrations were within normal ranges for plant foliage (0.01-1.00 µg/g, Table 7) for all samples except sedge leaves at Wheatley-Dust (2.16 µg/g) and Oshawa CDF (1.04 µg/g). These two levels are not phytotoxic, but are above the maximum tolerable concentration chronically exposed to domestic livestock (0.5 µg/g dry diet, Table 7). They are both below the upper normal limit for cadmium in urban plant foliage (3 µg/g, Table 6).

Chromium concentrations exceeded normal plant foliage levels (0.1-1.0 µg/g, Table 7) in grass from Seaway Island (1.02 µg/g), sedge leaves from Thunder Bay cell 3 (2.77 µg/g), Chenal Ecarte (4.32 µg/g) and Oshawa CDF (2.01 µg/g), and in smartweed from Hamilton Harbour (3.42 µg/g) and Oshawa CDF (2.26 µg/g). None of the chromium concentrations were phytotoxic, or above the upper normal limit in urban plant foliage (8 µg/g, Table 6).

All of the copper concentrations were within the normal ranges for plant foliage (3-20 µg/g, Table 7), and below the upper normal level in urban plant foliage (20 µg/g, Table 6).

Nickel concentrations exceeded normal plant foliage levels (0.1-5.0 µg/g, Table 7) in grass from Oshawa-Upland (10.88 µg/g) and sedge leaves (6.55 µg/g) and smartweed (5.01 µg/g) from Oshawa CDF. The Oshawa-Upland grass concentration exceeded the normal upper limit for urban plant foliage (7 µg/g, Table 6).

All concentrations of lead were within the normal range for plant foliage (2-5 µg/g, Table 7) and well below the upper normal limit for urban plant foliage (60 µg/g, Table 6).

Zinc concentrations were within the normal plant foliage range (15-150 µg/g, Table 7) for all samples except smartweed from Hamilton Harbour (279 µg/g), which also exceeded the upper normal limit for urban plant foliage (250 µg/g, Table 6).

Mercury concentrations were very low in most of the plant samples, except for sedge leaves from Chenal Ecarte (0.125 µg/g), however this was below the upper normal limit for urban plant foliage (0.3 µg/g, Table 6).

Smartweed from Hamilton Harbour had concentrations of iron (377 µg/g) and manganese (171 µg/g) which exceeded the normal levels in plant foliage (Fe: 300 µg/g; Mg: 150 µg/g, Table 7).

3.2.2.1.b Bioaccumulation Factors Bioaccumulation factors (BFs) for the metals from the sediments to the plants are summarized in Table 16. The highest mean BF was for cadmium in sedge leaves (BF=2.77, Fig. 28). All other mean BFs were below 1.00. Mean BFs for cadmium, copper and zinc were generally the highest in all vegetation types. Mean BFs in clover were generally lower than in other vegetation types. The only individual samples which had a BF greater than 1.0 were sedge leaves at Wheatley-Dust (BF=12.00) and Oshawa CDF (BF=2.04) for cadmium.

3.2.2.1.c Comparison of Vegetation Types The concentrations of metals in vegetation were compared among the different vegetation types for cadmium, chromium, copper, nickel, lead, zinc and mercury (Table 15). Generally, sedge leaves had the highest concentrations of cadmium, chromium, copper, lead and mercury, while grass had the highest nickel concentration, and smartweed had the highest zinc concentration, although only two smartweed samples were collected, one being from a site highly contaminated with zinc (Hamilton Harbour). The cadmium and zinc vegetation levels were plotted for visual comparison (Figs. 29 and 30, respectively).

3.2.2.1.d Leaf Litter Concentrations of metals in leaf litter associated with grass samples are expressed on a dry weight and ash weight basis in Table 17. The ash weight concentrations were compared between the two samples at all the sites for each metal using a 20% level of difference.

Leaf litter cadmium concentrations were significantly higher than grass concentrations at most of the sites. At Oshawa-Upland the cadmium concentration in leaf litter (2.0 µg/g dry wt) exceeded the normal level for plant foliage (1.0 µg/g, Table 7).

Chromium concentrations were significantly higher in leaf litter than in grass at most sites, with levels (dry wt) in the litter exceeding normal foliage levels (1.0 µg/g, Table 7) at all sites.

Concentrations of copper were significantly higher in grass than in leaf litter. Levels (dry wt) at Thunder Bay cell 1 (20.8 µg/g) exceeded normal foliage levels (20 µg/g, Table 7).

No significant difference was observed between concentrations of nickel in grass and leaf litter. Nickel concentrations (dry wt) in leaf litter at Thunder Bay cell 1 (18.0 µg/g) and cell 3 (13.7 µg/g), Seaway Island (5.72 µg/g), Wheatley-Dust (6.33 µg/g), Port Stanley (5.42 µg/g), Oshawa-Upland (14.8 µg/g) and Mercer's Glen (5.6 µg/g) all exceeded normal foliage levels (5 µg/g, Table 7). The Thunder Bay cell 1 and 3 and Oshawa-Upland leaf litter concentrations are above the critical levels in animal diet which may cause toxicity (>10 µg/g, Allaway 1968).

Lead concentrations were significantly higher in leaf litter at several sites, but were significantly higher in grass at other sites. No consistent pattern was observed. Lead concentrations exceeded normal foliage levels (5 µg/g, Table 7) at Port Stanley (5.38 µg/g), Whitby Harbour (16.84 µg/g), Oshawa-Upland (8.37 µg/g) and Mercer's Glen (6.68 µg/g). The Whitby Harbour concentration was above the critical level in animal diet which may cause toxicity (>10 µg/g, Allaway 1968).

Zinc concentrations were significantly higher in grass than in leaf litter. Concentrations (dry wt) in leaf litter from Whitby Harbour (151 µg/g) and Oshawa-Upland (177 µg/g) exceeded normal levels in foliage (150 µg/g, Table 7), and were above critical levels in animal diet which may cause toxicity (>100 µg/g, Allaway 1968).

Concentrations of mercury were significantly higher in leaf litter than in grass. At Chenal Ecarte, mercury was at least five times higher in the leaf litter than at the other sites.

Concentrations of iron ranged up to 5390 µg/g at Thunder Bay cell 1. Manganese concentrations in leaf litter exceeded the critical level in animal diet (100 µg/g, Allaway 1968) at Thunder Bay cell 1 (582 µg/g), cell 3 (492 µg/g), Seaway Island (118 µg/g), Wheatley-Pulley (439 µg/g), Wheatley-Dust (255 µg/g), Port Stanley (229 µg/g), Whitby Harbour (203 µg/g) and Mercer's Glen (332 µg/g).

3.2.2.1.e Sedge Seeds versus Leaves The metal concentrations in sedge seeds are summarized in Table 18. The concentrations were compared to those in sedge leaves and significant difference was determined using a 20% difference between samples.

Overall, cadmium was significantly higher in the sedge leaves than in the seeds. The concentration in seeds at Wheatley-Dust (1.31 µg/g) was above the normal foliage level (1 µg/g, Table 7).

Chromium concentrations were significantly higher in sedge seeds than in leaves at most sites. The concentrations exceeded normal foliage levels (1 µg/g, Table 7) at Thunder Bay cell 1 (2.42 µg/g) and cell 3 (2.1 µg/g), Chenal Ecarte (9.55 µg/g) and Oshawa CDF (7.61 µg/g).

Copper concentrations were higher in the seeds at both Thunder Bay cells, Chenal Ecarte and Oshawa CDF, but much lower in seeds at Wheatley-Dust, thus no consistent pattern was observed.

Nickel concentrations were significantly higher in the sedge seeds than in leaves at most sites. Concentrations in seeds exceeded normal foliage levels (5 µg/g, Table 7) at Thunder Bay cell 1 (9.19 µg/g) and cell 3 (8.69 µg/g), Chenal Ecarte (7.48 µg/g) and Oshawa CDF (15.6 µg/g). The Oshawa CDF concentration was

above the critical level in animal diet which may cause toxicity (10 µg/g, Allaway 1968).

Lead concentrations were significantly higher in the leaves at most of the sites except both Thunder Bay cells. The Thunder Bay cell 1 concentration (6.0 µg/g) exceeded normal foliage levels (5 µg/g, Table 7).

No consistent pattern was observed regarding the significant difference of zinc concentrations between sedge seeds and leaves. However, the concentration at Oshawa CDF was higher in the leaves than in seeds, while at both Thunder Bay sites, seeds had higher zinc concentrations.

There was no consistent pattern observed regarding the significant difference for mercury concentrations between sedge leaves and seeds. The concentrations at Chenal Ecarte, Oshawa CDF and Mercer's Glen were higher in the leaves, while concentrations at Thunder Bay cell 1, Seaway Island and Wheatley-Dust were higher in seeds.

Concentrations of manganese in sedge seeds at Thunder Bay cell 1 (137 µg/g) and Mercer's Glen (126 µg/g) were above the critical level in animal diet which may cause toxicity (100 µg/g, Allaway 1968).

3.2.2.1.f Capped versus Uncapped In a comparison between the capped Thunder Bay cell 1 and uncapped Thunder Bay cell 3 sites, the metal concentrations in grass were no different (within 20% of each other), except for chromium, which was higher at the capped cell, and copper, which was higher at the uncapped cell (Table 15). In clover, most concentrations levels were no different, except for chromium, nickel and mercury, which were all higher at the capped cell (Table 15). In sedge leaves, chromium, nickel and mercury were all higher at the uncapped cell, the rest being no different (Table 15).

In a comparison between the Wheatley-Pulley (capped) and Wheatley-Dust (uncapped) sites, metal concentrations in grass were higher for cadmium, copper, nickel and zinc at the uncapped site, higher for chromium at the capped site, and no different for lead and mercury (Table 15).

3.2.2.2 Organics

3.2.2.2.a PCBs At Thunder Bay cell 1, grass had a higher concentration of total PCBs (10.0 µg/kg) than did sedge (4.4 µg/kg), clover (5.3 µg/kg) or leaf litter (6.8 µg/kg) (Table 19). In a comparison of the PCB congener patterns of the vegetation types, grass reflected the pattern in the bulk sediments (Fig. 13), while clover had greater concentrations of pentachlorobiphenyls

than tetrachlorobiphenyls. Sedge had only tetra- and pentachlorobiphenyls, while leaf litter had only tetrachlorobiphenyls.

The concentration of total PCBs in grass (10.3 µg/kg) at Thunder Bay cell 3 was similar to that at cell 1, while sedge (1.5 µg/kg) and clover (0.4 µg/kg) concentrations at cell 3 were lower than at cell 1. The total PCB concentrations in vegetation at cell 3 were much lower than the bulk sediment concentration (Table 19). However, the PCB congener group pattern in grass was similar to that in bulk sediment, but without any monochlorobiphenyls (Fig. 14).

Relatively low levels of total PCBs were found in Seaway Island grass (7.1 µg/kg), sedge (6.7 µg/kg) and clover (0.6 µg/kg), while none were found in the leaf litter (Table 19). None of the PCB congener patterns in sedge, grass or clover reflected the bulk sediment congener pattern (Fig. 15).

Relatively high concentrations of total PCBs were found in grass (30.4 µg/kg), sedge (17.9 µg/kg) and leaf litter (90.8 µg/kg) at Chenal Ecarte (Table 19). The PCB congener group patterns in these samples did not resemble that in the bulk sediment very closely (Fig. 16).

Wheatley-Pulley grass and leaf litter had relatively low concentrations of total PCBs (12.7 and 6.1 µg/kg, respectively) (Table 19). The congener patterns in these samples were not similar to that in sediments (Fig. 17).

Low concentrations of total PCBs were found in grass (4.5 µg/kg), sedge (8.1 µg/kg) and clover (8.2 µg/kg) at Wheatley-Dust, while none were found in leaf litter (Table 19). The PCB congener patterns in all of the vegetation samples were similar to each other, however the sediment congener pattern reflected concentrations of higher molecular weight PCBs (Fig. 18).

At Port Stanley, the concentrations of total PCBs were 12.4 µg/kg in grass and 17.2 µg/kg in leaf litter (Table 19). The grass had a similar PCB congener pattern as the sediment (Fig. 19). The leaf litter PCB congener pattern was not similar to that of either the grass or sediment (Fig. 19).

Hamilton Harbour smartweed had a total PCB concentration (9.0 µg/kg) which was approximately 0.2% of that found in the bulk sediments (Table 19). The PCB congener pattern found in smartweed was not similar to that in the sediment. The smartweed had relatively higher proportions of the lower molecular weight PCBs than the sediment (Fig. 20).

The Whitby Harbour grass had a total PCB concentration of 14.5 µg/kg (Table 19). The PCB congener pattern in grass was not similar to that in sediments (Fig. 21).

Relatively low concentrations of total PCBs were found in Oshawa CDF grass (7.6 µg/kg), sedge (17.7 µg/kg) and smartweed (1.8 µg/kg) (Table 19). The PCB congener patterns in the vegetation were generally similar to that in the sediment, although the sediment had a high proportion of dichlorobiphenyls which were not present in the vegetation (Fig. 22).

At Oshawa-Upland, relatively high concentrations of total PCBs were found in grass (21.9 µg/kg) and leaf litter (24.7 µg/kg) (Table 19). The PCB congener pattern in the grass was similar to that in the sediment, however the leaf litter had a higher proportion of pentachlorobiphenyls than both the sediment and grass (Fig. 23).

Low concentrations of total PCBs were found in grass (10.3 µg/kg), sedge (4.6 µg/kg), clover (3.1 µg/kg) and leaf litter (6.2 µg/kg) at Mercer's Glen (Table 19). The PCB congener patterns for the vegetation were somewhat similar to that in sediment, although the leaf litter had higher proportions of trichlorobiphenyls than the other congener groups (Fig. 24).

Overall, the grass samples had the same PCB congener pattern at all the sites except Seaway Island, which had a higher proportion of trichlorobiphenyls than of tetrachlorobiphenyls (Figs. 31a, 31b). The PCB congener patterns in the sedge samples were also similar at most of the sites, except Mercer's Glen, which had roughly equal proportions of tetra-, penta- and hexachlorobiphenyls, and Thunder Bay cell 3 which had higher proportion of trichlorobiphenyls and a lower proportion of pentachlorobiphenyls (Fig. 32). The two smartweed samples from Hamilton Harbour and Oshawa CDF did have similar PCB congener patterns (Fig. 33). The Thunder Bay cell 1 clover sample differed from the other clovers in that it had a high proportion of pentachlorobiphenyls (Fig. 33). The leaf litter samples did not show a consistent PCB congener pattern among all the sites (Fig. 34).

3.2.2.2.b PAHs The highest concentration of total priority PAHs was found in leaf litter at Wheatley-Pulley (4878 µg/kg, Fig. 26). Port Stanley leaf litter also had a high total PAH concentration (2116 µg/kg, Fig. 26). The concentration of total PAHs in Hamilton Harbour smartweed was 1866 µg/kg. The highest specific PAH concentrations in Hamilton Harbour smartweed occurred for fluoranthrene (460 µg/kg), phenanthrene (410 µg/kg), pyrene (270 µg/kg) and naphthalene (260 µg/kg) (Fig. 27). The concentrations of specific PAHs in all the samples are summarized in Table 12.

3.2.2.2.c Chlorobenzenes Relatively low concentrations of all chlorobenzenes were found in all grass, clover, sedge, smartweed and leaf litter samples with a few exceptions (Table 13). Sedge leaves from Chenal Ecarte had relatively high concentrations of 1,3,5-trichlorobenzene (3.1 µg/kg), 1,2,4-trichlorobenzene (1.9

μg/kg), 1,2,3,5+1,2,4,5-tetrachlorobenzene (1.4 μg/kg), pentachlorobenzene (2.0 μg/kg) and hexachlorobenzene (28.0 μg/kg). Chenal Ecarte leaf litter also had a relatively high hexachlorobenzene concentration (14.0 μg/kg). Oshawa-Upland leaf litter had a concentration of 1.1 μg/kg of 1,2,3,4-tetrachlorobenzene, while Mercer's Glen leaf litter had a concentration of 1.5 μg/kg of pentachlorobenzene.

3.2.2.2.d Organochlorines The majority of organochlorine concentrations in vegetation samples were relatively low (Table 13). Some of the exceptions are as follows: p,p'-DDT (2.1 μg/kg) and α-chlordane (1.7 μg/kg) in Seaway Island grass; hexachlorobutadiene (5.7 μg/kg), octachlorostyrene (5.1 μg/kg) and p,p'-DDE (3.1 μg/kg) in Chenal Ecarte sedge leaves; p,p'-DDE (8.6 μg/kg) and p,p'-DDT (3.0 μg/kg) in Chenal Ecarte leaf litter; p,p'-DDD (5.9 μg/kg) in Wheatley-Pulley leaf litter; and p,p'-DDE (3.0 μg/kg) and p,p'-DDT (3.4 μg/kg) in Whitby Harbour leaf litter.

3.2.2.2.e Diphenyl Ethers Diphenyl ethers were found in Whitby Harbour grass (40.0 μg/kg) and leaf litter (39.0 μg/kg) (Table 13).

3.2.3 Earthworms

3.2.3.1 Metals

3.2.3.1.a Site Comparison Earthworms were collected at Seaway Island, Chenal Ecarte, Whitby Harbour, Oshawa-Upland, and Mercer's Glen. The concentrations of cadmium (6.59 μg/g), chromium (57.31 μg/g), nickel (42.9 μg/g), lead (24.48 μg/g), zinc (670 μg/g) and iron (5670 μg/g) were highest in earthworms from the Oshawa-Upland site (Table 20). Copper (24.1 μg/g) and mercury (>1.0 μg/g, upper detection limit) concentrations were greatest at Chenal Ecarte, while the manganese concentration was highest at Mercer's Glen (364 μg/g) (Table 20).

3.2.3.1.b Bioaccumulation Factors The mean BFs, from the five sites from which earthworms were collected, for cadmium (BF=6.67), copper (BF=2.56), zinc (BF=5.74) and mercury (BF=7.00) were all greater than one (Table 20). The highest single BF was for mercury in Seaway Island earthworms (BF=22.50), while BFs for zinc (BF=17.99) and cadmium (BF=12.20) at Whitby Harbour were also relatively high.

3.2.3.2 Organics

3.2.3.2.a PCBs The total PCB concentrations in earthworms at each site, and their BFs, were: Seaway Island (0 μg/kg, BF=0), Chenal Ecarte (30.0 μg/kg, BF=0.3), Oshawa-Upland (182.5 μg/kg, BF=1.5) and Mercer's Glen (64.1 μg/kg, BF=0.9) (Table 19). PCB levels could not be determined in earthworms from Whitby Harbour due to

interference from diphenyl ethers. The PCB congener patterns in the earthworms from these sites were similar, having higher proportions of penta-and hexachlorobiphenyls (Fig. 35).

3.2.3.2.b PAHs The total priority PAH concentrations in earthworms at each site were: Seaway Island (196 µg/kg), Chenal Ecarte (1360 µg/kg), Whitby Harbour (279 µg/kg), Oshawa-Upland (1259 µg/kg) and Mercer's Glen (762 µg/kg) (Fig. 26). The specific PAHs with the highest levels in earthworms were benzo(b)+benzo(k)-fluoranthene, fluoranthene, naphthalene and phenanthrene (Table 12).

3.2.3.2.c Chlorobenzenes Chlorobenzenes were found in earthworms in varying amounts. The highest concentration measured was for hexachlorobenzene at Chenal Ecarte (57.0 µg/kg) (Table 13). The remaining chlorobenzenes were found at concentrations one-to-two orders of magnitude lower in the remaining samples.

3.2.3.2.d Organochlorines Very few organochlorines were detected in earthworms. Relatively high concentrations of p,p'-DDE were found at Seaway Island (6.6 µg/kg), Whitby Harbour (4.4 µg/kg), Oshawa-Upland (15.0 µg/kg) and Mercer's Glen (13.0 µg/kg) (Table 13). At Chenal Ecarte, hexachlorobutadiene (3.7 µg/kg) and octachlorostyrene (8.7 µg/kg) were also found. At Seaway Island, α-hexachlorocyclohexane (1.8 µg/kg) was detected.

3.2.3.2.e Diphenyl Ethers Earthworms at Whitby Harbour were found to have a concentration of 310 µg/kg of diphenyl ethers (Table 13).

3.2.3.2.f Phthalate Esters Earthworms at Seaway Island had the highest concentration of total phthalate esters (380 µg/kg) (Table 14). This concentration was 82% of that found in sediments at Seaway Island. At the remaining sites, concentrations of phthalate esters in earthworm samples ranged from 4 to 29% of those found in the sediments at each site.

3.2.4 Overview

The contaminant data for all samples are summarized for each dredge disposal site, along with DPW sediment parameter data and applicable OMOE soil clean-up guidelines and normal foliage metal ranges, in order to facilitate comparisons within sites. A summary for each site is found in Appendix 2.

3.3 DISCUSSION

3.3.1 **Sediments**

3.3.1.1 Significance of Metal Concentrations

The classification of bulk sediments from the twelve sample sites for metal concentrations based on the OMOE dredge disposal guidelines (OMOE 1987) are summarized in Table 21. The classification of the sediments for metals based on the OMOE clean-up guidelines (Rinne 1988) are summarized in Table 22. The metal concentrations in sediments are discussed for each site below.

3.3.1.1.a Thunder Bay Based on the open water dredging disposal guidelines (Table 1), the surficial cap material of Thunder Bay cell 1, which was composed of 0.5 m of "clean" fill placed there in 1985, was contaminated with nickel, chromium and zinc. The high nickel concentration in this sediment restricts the placement of this material onto an area zoned for non-residential uses only. In comparison with the original DPW pre-dredging sampling, concentrations of zinc, chromium and arsenic were higher in the capping material than in the sediments they were covering, while cadmium and nickel concentrations were not different. Therefore the capping material served to reduce the concentrations of only copper, lead and mercury in material exposed to the surface.

Thunder Bay cell 3 sediments can be classified as "waste" material by the OMOE dredged material classification criteria due to its high mercury concentration. This would require the application of the OMOE acid leach test for determination of hazardous waste (OMOE 1987). The OMOE soil criteria for proposed land use (Table 5) would permit commercial or industrial uses on this material. These sediments were also contaminated with arsenic, chromium, copper, nickel, zinc, and cadmium. The concentrations of five of these metals were found to be higher (>20%) in our 1987 samples than in the DPW pre-dredging samples. This indicates that the sediments are not homogenous with respect to metal contamination. This could pose a problem if small sample sizes are used to determine sediment quality.

When comparing the metal concentrations in sediment samples collected from the two cells at Thunder Bay in 1987, arsenic, copper, lead, and mercury concentrations were higher in the uncapped cell 3, while the remaining metals were not different. When comparing the DPW pre-dredging samples of the original dredged materials which were placed in cells 1 and 3, concentrations of arsenic, mercury and chromium were higher in the cell 3 material, while lead, zinc, copper, cadmium, and nickel concentrations were not different. Since the cell 3 material was at least 20% more contaminated with these metals originally, and that situation has not changed after the capping of cell 1, it cannot be shown that the capping of cell 1 has actually reduced the availability of

these metals at the surface by comparing the present surface sediment concentrations from the capped and uncapped sites.

3.3.1.1.b Seaway Island Chromium was the only metal which exceeded the open water disposal guidelines in Seaway Island sediments, and this concentration was only 5% higher than the upper normal limit for urban soils. The mercury concentration in the 1987 sample was much lower than that reported in pre-dredging samples (Table 3).

These sediments were originally disposed of in a CDF due to their high mercury concentration and were capped with clean fill to isolate this contamination (McLaren Ltd., 1984). Based on our sampling, the present surface sediment does not have a high concentration of mercury. The surface sediment does have a slightly higher than normal concentration of chromium (OMOE 1986), however this concentration does not restrict the land use of the site.

3.3.1.1.c Chenal Ecarte Sediment at Chenal Ecarte had the highest mercury concentration of our sites. This concentration classified it as waste material, subject to the acid leach test for determination of hazardous waste (OMOE 1987). The sediment was also contaminated with arsenic, chromium and zinc. The material is presently in place spread out over an upland site adjacent to the Chenal Ecarte waterway. However, its mercury concentration indicates that it should be disposed of at a certified waste disposal site (OMOE 1987). Conversely, this site could be used for commercial or industrial land purposes based on OMOE soil clean-up guidelines (Rinne 1988).

3.3.1.1.d Wheatley Harbour In comparison with all of the CDFs studied here, the two Wheatley Harbour disposal sites had relatively low concentrations of most metals in the sediments. The exceptions are chromium, which exceeded open water disposal guidelines at both sites, and nickel at the Dust property, which classified the material as suitable for placement on areas zoned for restricted (commercial, industrial or recreational) uses only (OMOE 1987). The Dust property site is immediately adjacent to an agricultural field under cultivation, and plans are to plow the material into the field. However, the nickel levels in the sediment at this site would not allow it to be used for agricultural purposes, even if it were to be capped with "clean" fill material.

3.3.1.1.e Port Stanley The sediments at Port Stanley had relatively low metal concentrations with only arsenic and chromium being above the open water dredge disposal guideline. This level of metal contamination does not preclude the present use of the site as a park.

3.3.1.1.f Hamilton Harbour The Hamilton Harbour sediments were contaminated with high concentrations of metals. Chromium, copper, lead, zinc, mercury, and cadmium concentrations result in the classification of these sediments as waste material (OMOE 1987). The zinc concentrations were much higher than the allowable level for commercial or industrial uses, thereby they alone would exclude this site from any land uses in its present state.

3.3.1.1.g Whitby Harbour The concentrations of all metals in Whitby Harbour sediments were relatively low. Chromium was the only metal whose concentration exceeded the open water disposal guideline, however this was within the upper normal level found in urban soils. This site would be open to any land use based on metal contamination.

3.3.1.1.h Oshawa Harbour The Oshawa CDF sediments had a nickel concentration which classified the material as being suitable for placement on areas restricted to commercial or industrial uses only. The 1987 metal concentrations were lower than the DPW pre-dredging concentrations here and at Whitby Harbour which indicates the problems with sampling large volumes of sediments and the heterogeniety of metal concentrations in the sediments.

The Oshawa-Upland site had the highest concentration of nickel, which, along with the high lead concentration, classified the sediments as waste material (OMOE 1987), however they do not preclude the use of the site for residential, agricultural or recreational uses based on the clean-up guidelines for soils (Rinne 1988).

3.3.1.1.i Mercer's Glen Concentrations of chromium and zinc in sediments from the control site, Mercer's Glen, exceeded the open water disposal guideline. The nickel concentration in these sediments restrict their placement to areas zoned for commercial or industrial uses only, however, this concentration is within the normal upper limit for urban soils (OMOE 1986).

The extent of the metal concentrations at this "natural" control site is comparable to the average concentrations in sediments disposed of at sites we sampled. It actually contained the highest arsenic concentration. Concentrations of cobalt, chromium, copper, nickel, lead, vanadium, zinc, mercury, and cadmium were at least 20% higher at Mercer's Glen than at many of the disposal sites. However, all of the metal concentrations were within normal ranges for urban soils. If this can be considered a typical natural environment in urbanized southern Ontario, then most of the soils at the disposal sites sampled are no more contaminated with metals than a typical natural site in southern Ontario.

3.3.1.2 Fine versus Coarse Fractions

Overall, the fine sediment fractions had higher concentrations of cobalt, copper, nickel and mercury than the coarse fractions at most of the sites, while cadmium concentratins were higher in the coarse fractions. Arsenic, chromium, lead, vanadium and zinc concentrations were not different between the two fractions at most of the sites.

Due to the high percentage of the coarse fraction in all of the bulk sediment samples, a significant amount of the contaminants are associated with the coarse fractions. Mudroch (1984) found the greatest concentration of metals in the 63-250 μm and <4 μm size fractions of sediments from Lake Erie. Mudroch and Duncan (1986) reported that fine sediment particles (<13 μm) from the Niagara River contained higher concentrations of metals than other size fractions except for some larger sized man-made particles. The high percentage of coarse material in our samples may be due to a large amount of flocculation of finer particles due to a high organic material content, which the majority of contaminants are associated with (Mudroch, 1984), resulting in a high amount of larger sized particles and a significant amount of contaminants associated with them.

It has been suggested that the use of hydrocycloning techniques may be beneficial in reducing the volume of dredged material that would require confined disposal (Marquenie and Bowmer 1988). This would involve separating the fine more contaminated material from coarse relatively uncontaminated particles, followed by confining the fine sediment fraction, and reusing or disposing of the coarser material in open water areas. This process separates the size fractions based on density of the particles. Since the coarse sediment fraction of our samples may largely be flocculated fine particles, their density would not be as great as coarse mineral particles (i.e., sand). Therefore these flocculated particles would largely be separated out with the finer particles. This hydrocycloning technique may be useful for reducing volumes of sediments requiring confined disposal.

3.3.1.3 Significance of Organic Contaminant Concentrations

3.3.1.3.a PCBs The total PCB concentration in Hamilton Harbour bulk sediments were above the level for the classification of waste material (OMOE 1987). However, the Canadian Council of Resource and Environment Ministers' guideline would allow non-agricultural uses on sediment with this concentration of total PCBs (DPH 1988). The total PCB concentrations at Thunder Bay cell 3, Chenal Ecarte, Wheatley-Dust, Oshawa CDF, Oshawa-Upland, and Mercer's Glen were not high enough to restrict the land use of these sites although the PCB concentrations in these sediments would not allow for open water disposal.

The similarity of the PCB congener group patterns in the sediments from most of the sites (except Hamilton Harbour and Wheatley-Dust) suggest that the PCB source may be similar for these sites, but not necessarily the same point source. The likely source of PCBs to all these sites is from atmospheric fallout.

The different PCB congener pattern in Hamilton Harbour bulk sediments suggests that there is a different source of PCBs to the Harbour which masks the contribution from atmospheric sources. The pattern in the Hamilton Harbour sediments is similar to that in Windermere Basin sediments (Environment Canada, unpubl. data), which receives effluents from the Hamilton-Wentworth Sewage Treatment Plant (HWSTP). The HWSTP has been identified as the major contributor of PCB loadings to Hamilton Harbour (COA 1988).

The PCB congener pattern in Wheatley-Dust bulk sediments also suggests a different source of PCBs to these sediments. PCBs have been detected in effluents discharged by at least one local industry on Wheatley Harbour, and may also enter the watershed through agricultural runoff into Muddy Creek (COA 1987).

3.3.1.3.b PAHs A concentration of 1.0 µg/g of the specific priority PAH BaP in sediments has been recommended as the upper allowable limit for the protection of aquatic life (AEOC 1983). The concentration of BaP in Hamilton Harbour sediments did exceed this level. None of the other sites had BaP concentrations close to this level. BaP has been documented to have carcinogenic effects on mammals (Christiansen 1976).

The concentrations of certain priority PAHs (PH, F, PY and BaP) were much higher (3 to 8 times) in Thunder Bay cell 3 sediments than the concentrations reported in surficial sediments from Lake Superior (Gschwend and Hites 1981). The Thunder Bay cell 1 sediment concentrations of these compounds were the same as or up to twice as high as the Lake Superior sediment concentrations. Therefore, the capping material had PAH concentrations similar to those in Lake Superior, which receives large amounts of PAHs from airborne sources (Eisenreich et al. 1981). The PAH concentrations in the cell 3 sediments were 2 to 3 times higher than in cell 1, indicating that a local point source of PAHs may be present at Thunder Bay Harbour.

The Chenal Ecarte and Seaway Island concentrations of PAH compounds (PH, F, PY, BaP) in sediments were lower than those reported for Lake Huron surface sediments (Eadie 1984). These sites are down river from Lake Huron, and higher concentrations would be expected at these sites because of possible point sources of PAHs from the many chemical and petroleum industries along the St. Clair River.

Concentrations of the PAH compounds in Wheatley-Dust and Port Stanley sediments were lower than those reported in Lake Erie

surface sediments (Eadie et al. 1982). The concentrations at the Whitby Harbour, Oshawa CDF and Oshawa-Upland sites were also lower than those reported in Lake Ontario surface sediments (IJC 1977).

3.3.1.3.c CBs, OCs and DPEs Greater concentrations of CBs and OCs in the uncapped Thunder Bay cell 3 sediments than in the capped cell 1 sediments indicate that the capping layer has served to isolate these organics from the surface sediment at cell 1.

The concentrations of HCB and OCS in Chenal Ecarte sediments are similar to mean concentrations found in sediment samples by NWRI (HCB 99.5 µg/kg, OCS 96.1 µg/kg [B. Oliver, Environment Canada, unpubl. data]). These and other organics found in the sediments probably originate from the heavily industrialized area upriver on the St. Clair River (B. Oliver, Environment Canada, unpubl. data). Low levels of OCs and CBs in Seaway Island sediment, which is also down river from the St. Clair River, indicate that the capping material may be effectively isolating sediments, that are potentially contaminated with OCs and CBs, from the surface at the CDF.

The OC and CB concentrations in the sediments from all of the Lake Ontario sites were generally lower than those found in mean sediment samples from Lake Ontario (B. Oliver, Environment Canada, unpubl. data). The relatively high concentration of HCB at Mercer's Glen indicates a contribution from atmospheric sources, and this concentration is still substantially lower than the concentration in the central basin of Lake Ontario sediments (100 µg/kg [B. Oliver, Environment Canada, unpubl. data]), which may also be the result of atmospheric transport of these contaminants.

The absence of mirex from our sediment samples is not suprising since this contaminant is largely confined to the sediments along the south shore and eastern basin of Lake Ontario between the Niagara and Oshwego Rivers (Holdrinet et al. 1978).

The presence of diphenylethers in only the Whitby Harbour sediments indicates a local source of these compounds.

3.3.1.3.d Phthalate Esters and Hydrocarbons The concentrations of phthalate esters in sediment samples were considered to be relatively high, but these compounds are ubiquitous (B. Oliver, pers. comm.).

The presence of the aliphatic hydrocarbons indicates that high concentrations of oil and grease were present in the sediments (B. Oliver, pers. comm.). The concentration of hydrocarbons in Wheatley-Dust sediments was high, as was the concentration of oil and grease in the pre-dredging analyses of Wheatley Harbour sediments (9.5 mg/g, Table 6). This exceeded the open water dredge disposal guideline of 1.5 mg/g (OMOE 1987). However, this hydrocarbon concentration was no higher than that found at the

control site, Mercer's Glen. The highest hydrocarbon concentrations were reported at Port Stanley, but oil and grease concentrations were not reported with the pre-dredging analyses. The pre-dredging sediment analyses from Chenal Ecarte reported a low concentration of oil and grease (0.29 mg/g, Table 5) although the sediments had a rather high concentration of hydrocarbons.

3.3.2 Vegetation

3.3.2.1 Metals

The classification of vegetation samples from the twelve sites based on the OMOE upper limits of normal metal concentrations in foliage from rural and urban Ontario (OMOE 1986) are summarized in Table 23.

3.3.2.1.a Significance of Metal Concentrations Several metals were found in vegetation samples at concentrations which were higher than normally found in foliage from urban areas. These include cadmium, mercury, nickel and zinc. Cadmium in sedge leaves from Wheatley-Dust and Oshawa CDF were at concentrations which may be hazardous to livestock if chronically exposed to them. Iron and manganese in Hamilton Harbour smartweed were also above normal foliage concentrations. Copper, lead and chromium in vegetation samples from all sites were within normal ranges. The concentrations of zinc and manganese in Hamilton Harbour smartweed and zinc in Oshawa CDF sedge leaves are above critical toxic levels in animal diet (>100 μg/g, Allaway 1968). All of the other vegetation metal concentrations were below critical toxic levels in animal diet.

3.3.2.1.b Bioaccumulation from Sediments The determination of bioaccumulation factors for metals from sediments to vegetation with our data uses the assumption that the metal concentrations determined for the vegetation are due totally to uptake by the plants from the sediments, and that contributions from atmospheric fallout are minimal. This assumption may or may not be accurate, however, in terms of relating the significance of metal concentrations in vegetation at the CDFs to effects on wildlife, one has to look at what the concentrations are which the wildlife would be exposed to. This would include any metal contributions from atmospheric sources. For this reason our vegetation samples were not washed before analyses. This approach also allows the comparison of metal concentrations in vegetation from non-dredge disposal site areas which would be subject to the same atmospheric contributions.

The only metals which appeared to be bioaccumulating in the vegetation were cadmium, copper and zinc. Although chromium concentrations in many of the vegetation samples were above normal levels, the sediment concentrations were also higher than normal

and thus a bioaccumulation effect was not observed. The same applies to nickel concentrations in some vegetation samples.

These results compare with those from similar studies at other dredge disposal sites on the Great Lakes. At Times Beach, Buffalo Harbour, New York, the transport of zinc, cadmium and copper from the sediment into vegetation was documented (Stafford 1987). Agricultural plants grown on dredged material also accumulated copper, cadmium and zinc with BFs similar to our own (Mudroch 1973). Emergent macrophytes (Cyperus, Typha, Phragmites) grown on upland sediments from the disposal sites at Times Beach, Buffalo, New York, and Hamilton Harbour also had similar BFs for all metals except cadmium, which had a higher BF in our study (Mudroch and Painter 1986).

3.3.2.1.c Comparison of Vegetation Types Our data indicate that different plant types will take up different amounts of metals. Sedges appear to accumulate higher levels of most metals, including cadmium, chromium, copper, lead and mercury. Clover generally accumulated the lowest metal levels.

The study of uptake of metals by plants by the U.S. Army Corps of Engineers at Times Beach, Buffalo, New York, also found differences in metal levels in different plant types due to inter-species differences in metal uptake (Stafford 1987). Similar findings were made by Mudroch and Painter (1986) using different emergent macrophytes grown on Hamilton Harbour and Times Beach sediments.

This observation has management implications for CDFs. Plant species growing on CDFs after dewatering or capping can be selectively managed to include only those types which do not accumulate metals to any extent, such as clover.

3.3.2.1.d Leaf Litter Concentrations of cadmium, chromium and mercury in leaf litter associated with grass were higher than in grass, while copper and zinc concentrations were higher in grass than in leaf litter, and nickel and lead concentrations were similar in these samples. A higher metal concentration per unit weight would be expected in leaf litter, since the total amount of a metal in the original plant tissue would be concentrated into the decreasing volume of solid material during decomposition (Lindberg and Harriss, 1974). Other studies have shown that leaf litter contains higher levels of metals than associated vegetation and soils (Nilsson 1972, Lindberg and Harriss 1974, Martin et al. 1976, Coughtrey et al. 1979, Larsen and Schierup 1981, Martin et al. 1982).

By normalizing our data to an ash weight basis, the concentrations of metals present in the sample, irrespective of the amount of remaining organic material in the decomposed leaves, can be compared to the leaf litter associated with the grass. If metal

concentrations in the litter are related solely to the concentrations in the vegetation, the ash weight concentrations for litter and vegetation should not be significantly different. Our data indicates this for nickel and lead only. Higher concentrations of cadmium, chromium and mercury in the litter may be due to contributions from atmospheric sources. It has been shown that at aerially contaminated sites the uptake of metals from soil by plants contributes only a minor proportion to the total metal content (Martin et al. 1982).

The leaf litter at all of the sites, except Chenal Ecarte, had potentially toxic concentrations, of at least one metal, to domestic animals which would ingest it. Leaf litter with these concentrations may also pose a threat to wildlife which eats invertebrates that decompose the litter and bioaccumulate the metals to concentrations which could be toxic to the predators. In this study, data was not collected to document this process.

3.3.2.1.e Sedge Seeds versus Leaves Our data indicate that different plant tissues accumulate metals to different degrees. Sedge seeds had higher concentrations of chromium and nickel than the leaves. Sedge leaves had higher cadmium and lead concentrations than the seeds. This difference may have an effect on uptake by herbivores which may selectively feed on certain plant parts (e.g., seeds of sedges by certain waterfowl species [Bellrose 1976]). Other similar studies have also reported that different parts of plants accumulate metals to different degrees (Mudroch 1973, Stafford 1987).

The presence of metals in the sedge seeds at concentrations which may be toxic to domestic animals at Thunder Bay cell 1, Oshawa CDF and Mercer's Glen indicated that these sites may pose a health threat to wildlife utilizing them.

3.3.2.1.f Capped versus Uncapped The metal concentrations in vegetation at Thunder Bay cells 1 and 3 reflect the levels in the sediment for cadmium and zinc only, which were similar in all vegetation types and the sediments. Chromium concentrations were similar in the sediments but were higher in grass and clover at the capped cell and higher in sedge at the uncapped cell. Copper concentrations were higher in the sediment at the uncapped cell, yet were similar in all vegetation types at both cells. Mercury concentrations were higher in the sediments and sedge at the uncapped cell, but were higher in the capped cell clover and similar in grass from the two cells. Nickel concentrations were similar in sediments at the two sites, but were higher at the capped cell in clover, higher at the uncapped cell in sedge, and similar in grass. Lead concentrations were higher in the uncapped cell sediments but were similar in all plant types. This great deal of inconsistency leads to difficulty in predicting relative uptake of metals by vegetation on sediments with a certain level of contamination. Ideally, one would predict that a site with a

higher concentration of a metal than a similar site would also have a higher concentration of that metal in grass, for instance, growing on that site. However, our data does not support this idea.

3.3.2.2 Organics

3.3.2.2.a PCBs Our results indicate that higher concentrations of the lower chlorinated biphenyl congeners (tetra- to hexachlorobiphenyls) are taken up by vegetation. This finding is consistent with other studies (Iwata et al. 1974, Suzuki et al. 1977, Mrozek and Leidy 1981). This does not imply a selective uptake process by the vegetation, but may be a result of the different mobilities of congeners due to differences in water solubilities (Suzuki et al. 1977).

None of the concentrations of total PCBs in the vegetation samples were high enough to have adverse effects on birds. A minimum concentration of 100 µg/kg total PCBs in feed has been reported to cause alteration of enzyme levels in domestic birds (Strachan 1988).

Of the different vegetation types, grasses apparently accumulated higher concentrations of total PCBs than sedges, clover or smartweed. This may have implications as to the type of vegetative cover which should be allowed to grow on contaminated dredge disposal sites.

3.3.2.2.b PAHs Typical concentrations of total PAHs found in other industrial areas range up to 1000 µg/kg (Edwards 1983). The total PAH concentrations in leaf litter from Wheatley-Pulley and Port Stanley and smartweed from Hamilton Harbour were well above these typical concentrations. Typical concentrations of endrogenous PAHs in vegetation (plants synthesize certain amounts of PAHs) range from 10 to 20 µg/kg (Edwards 1983). The concentration of BaP in Wheatley-Pulley leaf litter (4878 µg/kg) was also higher than reported concentrations in vegetation (up to 150 µg/kg [Edwards 1983]).

Concentrations of PAHs in vegetation reported in the literature are generally lower than in sediments (Edwards 1983). This was true for our samples except for leaf litter at Seaway Island and Port Stanley which were higher than the sediment concentrations. The main source of PAHs in soils and vegetation is by deposition from air (Suess 1976), although uptake of PAHs by plants from soils has been demonstrated (Edwards 1983). The higher PAH concentrations in the leaf litter samples from Seaway Island and Port Stanley are likely a result of higher atmospheric contributions.

The high PAH concentrations in vegetation at three of the sites may be of some concern. These compounds may bioaccumulate

in lower trophic levels in the food chain (invertebrate decomposers), but are usually metabolized by higher organisms with mixed-function oxidase systems (AEOC 1983). The resulting metabolites of PAHs, dihydrodiol epoxides, are in fact highly carcinogenic and may accumulate in these organisms (Hallett and Brecher 1984). Therefore, a relatively low concentration of PAHs in tissues of higher organisms which are exposed to high PAH concentrations in sediments or food organisms does not necessarily indicate that those high PAH concentrations do not pose a hazard to the higher trophic organisms, since the PAHs may have been broken down into the more highly toxic metabolites in their tissues.

3.3.2.2.c Chlorobenzenes Chlorobenzenes appeared to be taken up by vegetation to a small degree. When they appeared in the sediment at high concentrations, the concentrations in vegetation were elevated as well. For example, a very high concentration of hexachlorobenzene at Chenal Ecarte (425 µg/kg) occurred in the sediments, while the sedge (28 µg/kg) and leaf litter (14 µg/kg) samples also had elevated concentrations. No information about the significance of chlorobenzene concentrations in vegetation could be found.

3.3.2.2.d Organochlorines Most of the organochlorines were found in very low concentrations in the vegetation, even when the concentrations were relatively high in the sediments. There appeared to be little uptake of these compounds by plants.

3.3.2.2.e Diphenyl Ethers The concentrations of DPEs in grass and leaf litter at Whitby Harbour reflect the concentrations in the sediment, indicating uptake of DPEs by the grass. Very little is known about the biological significance of these compounds, however they will likely bioaccumulate in fish as well (B. Oliver, pers. comm.)

3.3.3 Earthworms

3.3.3.1 Metals

The concentrations of metals found in earthworm samples at CDFs were within the ranges reported in the literature for Cd, Pb, Zn, Cu and Hg (Gish and Christensen 1973, Ireland 1979, and Simmers et al. 1986). The Ni concentration found in worms from Oshawa-Upland (42.9 µg/g) was higher than those reported in other studies. Manganese concentrations at all of the sites sampled were much higher than those reported in worms from contaminated soils in Wales (Ireland 1979).

The biomagnification of cadmium and zinc was reported in other earthworm studies (Gish and Christensen 1973, Ireland 1979, and Simmers et al. 1986), however copper and mercury were not reported to biomagnify in earthworms. Our samples were not corrected for

gut sediment content, and therefore high BFs for mercury and copper may not truly represent high tissue concentrations relative to sediments.

The concentrations of zinc found in earthworms at Whitby Harbour and Oshawa-Upland are above the range reported to cause mortality in dietary studies with domestic animals (Gish and Christensen 1973). Therefore they may also be a threat to wildlife which may be feeding on worms for an extended period at these sites.

3.3.3.2 Organics

3.3.3.2.a PCBs The total PCB concentrations found in earthworms from CDFs were much lower than those reported in earthworm tissues from agricultural and control areas in Europe, however the PCB concentrations in the soils in the European study were also much higher (Diercxsens et al. 1985). The European study also found higher bioaccumulation factors for PCBs in earthworms. Since our study did not involve a correction factor for gut soil content, our BFs may not be totally representative of actual bioaccumulation in tissues, and may be lower due to a dilution effect by the gut sediments. The total PCB concentrations observed in the earthworms were much lower than concentrations which caused reproductive problems in dietary studies with domestic birds (20 µg/g [Lillie et al. 1974]). However, the total PCB concentration at Oshawa-Upland (183 µg/kg) is above the level reported to cause alteration of enzyme levels in domestic birds (100 µg/kg, Strachan 1988). Therefore this site may pose a threat to wildlife which are feeding on earthworms there.

The PCB congener patterns in the earthworms were different from those in the sediments. The earthworms accumulated penta- and hexachlorobiphenyls while the sediments contained higher concentrations of tetra-and pentachlorobiphenyls. Thus, the lower chlorinated biphenyls are either not taken up as readily by earthworms as the higher chlorinated biphenyls, or they are metabolized faster than the higher chlorinated biphenyls once they are accumulated. A similar pattern was found with PCB congeners in earthworms from the European study (Diercxsens et al. 1985). They hypothesized that the difference in congener patterns between soils and earthworms was due to diffusion selectivity of different PCBs through cellular membranes.

3.3.3.2.b PAHs The concentrations of several individual PAHs (anthracene, pyrene, benzo(a)anthracene and benzo(a)pyrene) were within or below the range of values reported in earthworms from a bioassay study using contaminated dredged sediments from Times Beach, Buffalo, New York (Simmers et al. 1986). The concentration of BaP in all of our samples was well below the level recommended to be acceptable for the protection of aquatic life (1.0 µg/g [AEOC 1983]).

The PAH concentrations were generally higher in the earthworms than in the sediments at all of the five sites they were sampled from, except at Whitby Harbour. Bioaccumulation of PAHs by earthworms was also reported by Simmers et al. (1986), although to a higher degree than in our samples. Since our earthworm samples were not corrected for gut sediment content, the BFs may not be truly representative of bioaccumulation into earthworm tissues, and may be lower due to a dilution effect by the gut sediments.

3.3.3.2.c Chlorobenzenes Chlorobenzenes were generally found at concentrations in the earthworms that were higher than in sediments. In several cases, the CBs in the earthworms were undetected in the sediments. HCB, which was found at high concentrations in sediments at Chenal Ecarte (425 µg/kg) and Mercer's Glen (20.4 µg/kg), was found at lower concentrations in earthworms from these two sites (57.0 µg/kg and 1.0 µg/kg, respectively). This may imply that the higher chlorinated CBs, such as HCB, are not taken up as readily as the lower chlorinated CBs.

3.3.3.2.d Organochlorines The concentrations of DDE found in earthworms were higher than the concentrations found in sediments at all sites except Whitby Harbour. At Seaway Island, no DDE was found in the sediments. The DDE concentrations in the earthworms were much lower than the concentration reported for waterfowl foods which would cause eggshell thinning (0.6 µg/g wet wt [Longcore and Stendell 1982]). The concentration of OCS in earthworms at Chenal Ecarte was much lower than that in sediments, suggesting limited uptake of this compound by earthworms.

3.3.3.2.e Diphenyl Ethers The diphenyl ether concentration in earthworms at Whitby Harbour was three times higher than in the sediments, indicating a significant bioaccumulation. The effects of these compounds are not well known.

3.3.3.2.f Phthalate Esters The phthalate ester concentrations in earthworms were substanially lower than in the sediments, therefore little bioaccumulation of these compounds was occurring. The effects of these compounds on biota are not well known.

3.4 SUMMARY

3.4.1 Health of CDFs to Biota

Based on comparisons of our sediment samples from the CDFs and our control site, and to concentrations reported to be the upper normal limits for urban soils, sediments at most of the CDFs (except at Hamilton Harbour) are no more contaminated than soils at typical urban natural areas. In theory, the threat of exposure of contaminants to wildlife using these CDFs is about the same as at any other natural area in our urbanized part of the world.

Our samples indicate that cadmium, copper and zinc bioaccumulate in vegetation. Different plant types take up different metals to different degrees, as do different parts of plants. Sedges appeared to have the highest concentrations of most metals, while clover had the lowest, and sedge seeds had higher concentrations of cadmium than did sedge leaves. These findings have relevence to the types of wildlife which may be exposed to these contaminants. For example, a seed-eater would likely be exposed to higher concentrations of cadmium than a leaf-eater. Also, an area which has been colonized largely by sedges may be a greater threat than an area colonized mostly by clover, since sedges were shown to accumulate metals more so than clovers.

Several CDFs have vegetation with metal concentrations which may be hazardous to the health of wildlife which would consume them, including Hamilton Harbour, the Thunder Bay capped cell, the Wheatley Harbour uncapped site, Oshawa CDF and Mercer's Glen. Leaf litter metal concentrations at all sites, except Chenal Ecarte, were also at a level which would be hazardous to wildlife health if consumed. Concentrations of cadmium, chromium and mercury were shown to be higher in leaf litter than in grass samples. Invertebrates which decompose leaf litter are exposed to elevated concentrations of metals which may bioaccumulate in their tissues, and then be transported to wildlife which consume them.

Our results indicate that vegetation accumulates the lower chlorinated biphenyls, to concentrations lower than those found in the sediments. Grasses had the highest PCB concentrations of the plant types we sampled. None of the PCB concentrations found in vegetation were of a level which was reported to be hazardous to wildlife according to the literature reviewed. PAHs were found at higher than typical concentrations (>1000 $\mu g/kg$) in leaf litter from the Wheatley Harbour capped site and Port Stanley, and in smartweed from Hamilton Harbour. These concentrations may be hazardous to wildlife. The concentration of the PAH benzo(a)pyrene in the Hamilton Harbour sediments is above that considered safe for aquatic life.

Earthworms were found to accumulate metals and organics from disposed sediments. Concentrations of zinc in earthworms from Whitby Harbour and Oshawa-Upland and PCBs from Oshawa-Upland were

at levels which may be hazardous to wildlife which consume them. The PCB congener patterns in earthworms were different than those in sediments, having a larger proportion of the higher chlorinated biphenyls.

3.4.2 Management Considerations for CDFs

Although only four actual CDFs were sampled in this study, the other sites being upland disposal sites, the results from the upland areas are totally relevant for evaluating the management of CDFs.

The sediments at four CDFs, Thunder Bay cell 3, Chenal Ecarte, Hamilton Harbour and Oshawa-Upland, have metal concentrations which classify them as waste material. CDFs are engineered sediment disposal facilities and are considered to be suitable waste material disposal sites, with industrial or commercial land uses allowable on these sites after consolidation and capping. However, the Chenal Ecarte and Oshawa-Upland sites are upland disposal areas which are not engineered disposal facilities. They have no provisions for the prevention of leaching. The placement of waste material in these types of sites should be carefully considered.

The Thunder Bay cell 3 site is planned to be used as recreational property after filling and capping, however the concentration of mercury in its sediments would not allow for this use, even after capping (OMOE 1987).

The Wheatley-Dust site is a presently uncapped, upland disposal facility in an agricultural field. The sediments contain levels of nickel which restrict the land use to non-agricultural purposes, therefore this site should be excluded from the adjacent farming practices, even after capping of the site.

The high concentration of zinc in Hamilton Harbour sediments exceeds the allowable level for industrial or commercial land uses, which is the planned use of the site after filling and capping. This material should be further analysed to determine the extent of zinc contamination before any uses be considered.

Our sediment analyses have identified the presence of organic compounds at concentrations which may be considered hazardous to biota, and for which there are no dredge disposal guidelines in place at present. Some of these organics have been shown to have originated from local point sources, rather than atmospheric deposition, such as PCBs at Hamilton Harbour and Wheatley Harbour, PAHs at Thunder Bay and diphenylethers at Whitby Harbour. Future dredging projects should include analyses of sediments for a wide range of organics to identify possible local problems.

A major proportion of the contaminants are associated with the coarse fraction of the sediments considering the large component of the coarse fraction to the bulk sediment. However, this caorse

sediment fraction may largely be flcculated fine particles at most of the sites sampled. The use of hydrocycloning techniques to decrease the volume of dredged material which would require confined disposal relies on the density of particles for separation, and would likely result in the removal of most of the contaminated sediments.

The types of vegetation which are allowed to grow on CDFs will largely determine if contaminants will re-enter the ecosystem. Sedges will uptake metals to a larger degree than will clovers and grasses. Therefore a plant community having a high component of clovers would be an appropriate ground cover for a filled and capped CDF. The depth of the capping material is another important factor. If the vegetation roots extend below the cap, then contaminant uptake is more likely. This study did not measure root depth of vegetation types or cap thickness.

3.4.3 Aspects for Further Study

In order to determine an appropriate clean fill capping layer thickness for CDFs, the depth of roots of different plant types should be measured. A bioassay using different thicknesses of clean fill over contaminated sediments with vegetation grown on them, and subsequent contaminant analyses of plant tissues, would determine the optimum depth of cap required to prevent bioaccumulation of contaminants into this type of ground cover.

Little data exists on the uptake of organics such as PAHs, CBs and OCs in plants. Vegetation samples of a variety of different plant species from CDFs with high concentrations of these contaminants in sediments should be collected and analysed for these contaminants.

The potential bioaccumulation of contaminants by higher trophic levels present at CDFs should be evaluated. Wildlife such as small mammals, waterfowl and predator species could be sampled for contaminant analyses. The extent of usage of CDFs by wildlife should also be documented.

The use of earthworms as indicators of the bioavailabliity of contaminants in sediments at CDFs has been used by the US Fish and Wildlife Service (USFWS 1987), and should be assessed to determine its feasibility for use on Canadian sites.

4. ACKNOWLEDGEMENTS

We would like to thank the following colleagues for their assistance with this study. Ansar Khan and Erle Douglas of Public Works Canada, Laurie Sarazin and Ian Orchard of Environmental Protection Service, Environment Canada, and Tam Beaulieu of Small Craft Harbours, Fisheries and Oceans Canada, all provided valuable information regarding CDFs. Adelle Leaney-East conducted a literature search for information on CDFs. Laurie Montour of the Walpole Island Indian Band provided logistical and field assistance with the sampling on Seaway Island. Tom Peart and Camilla Teixeira of Lakes Research Branch performed chemical analyses of the samples, while Tom also assisted with field sampling. George Duncan and Keith Salisbury of the Hydraulics Division, Environment Canada, assisted with sediment size distribution analyses. Special thanks go to Diane Crabtree of Lakes Research Branch, Environment Canada, who provided valuable editoral advice and guidance.

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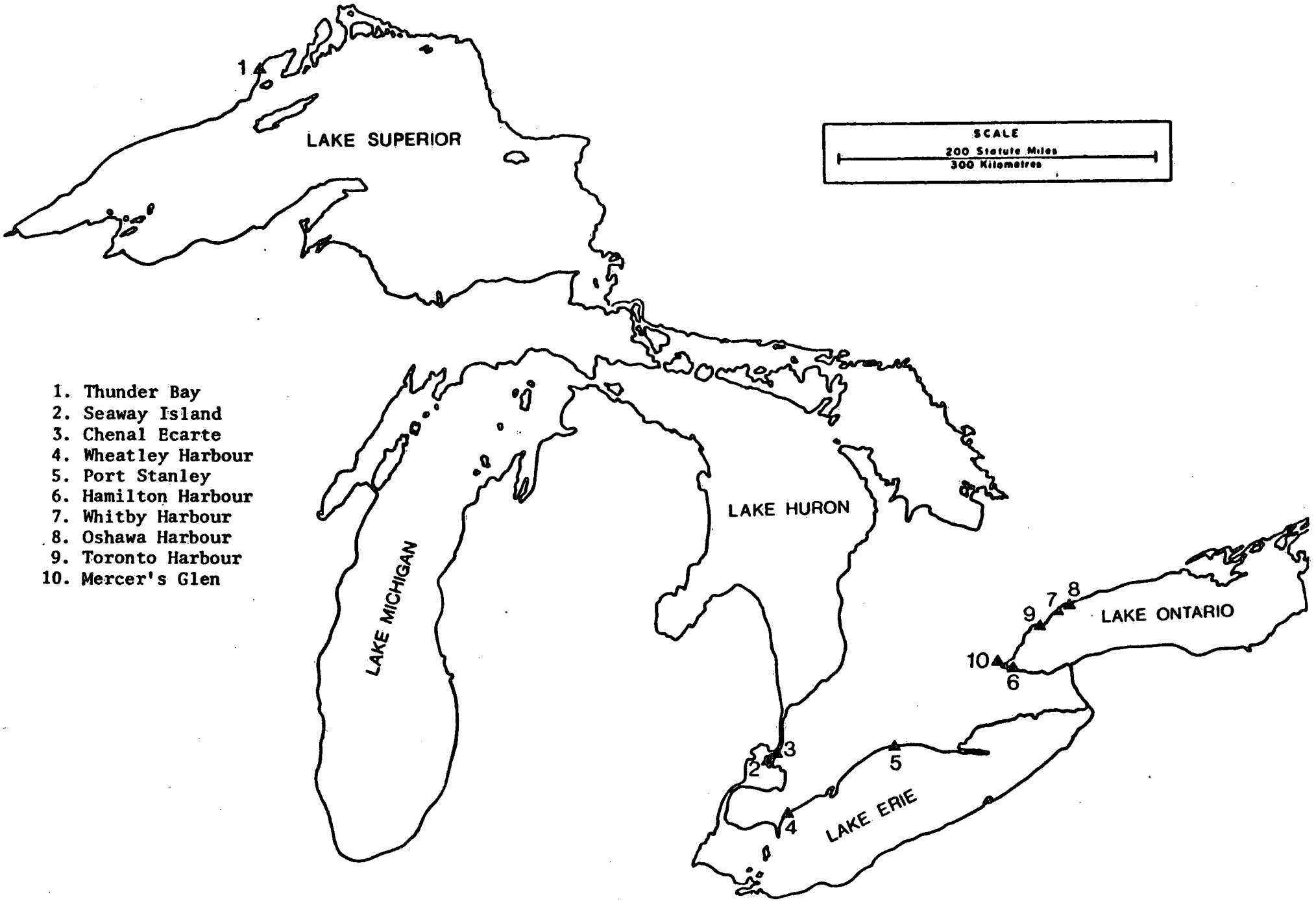


Fig. 1. Locations of confined disposal sites on the Canadian Great Lakes.

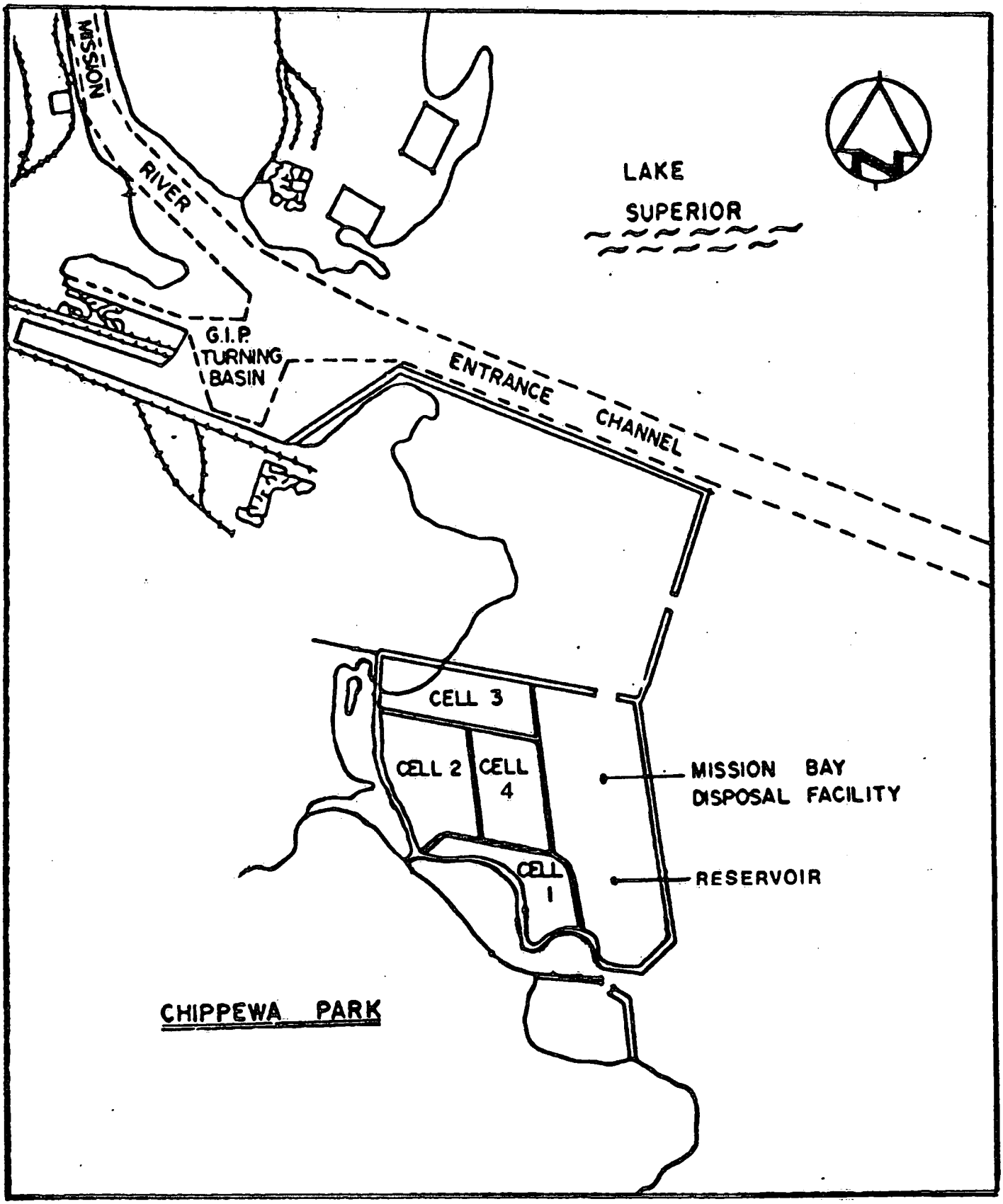


Fig. 2. The Mission Bay Disposal Facility at Thunder Bay, Lake Superior.

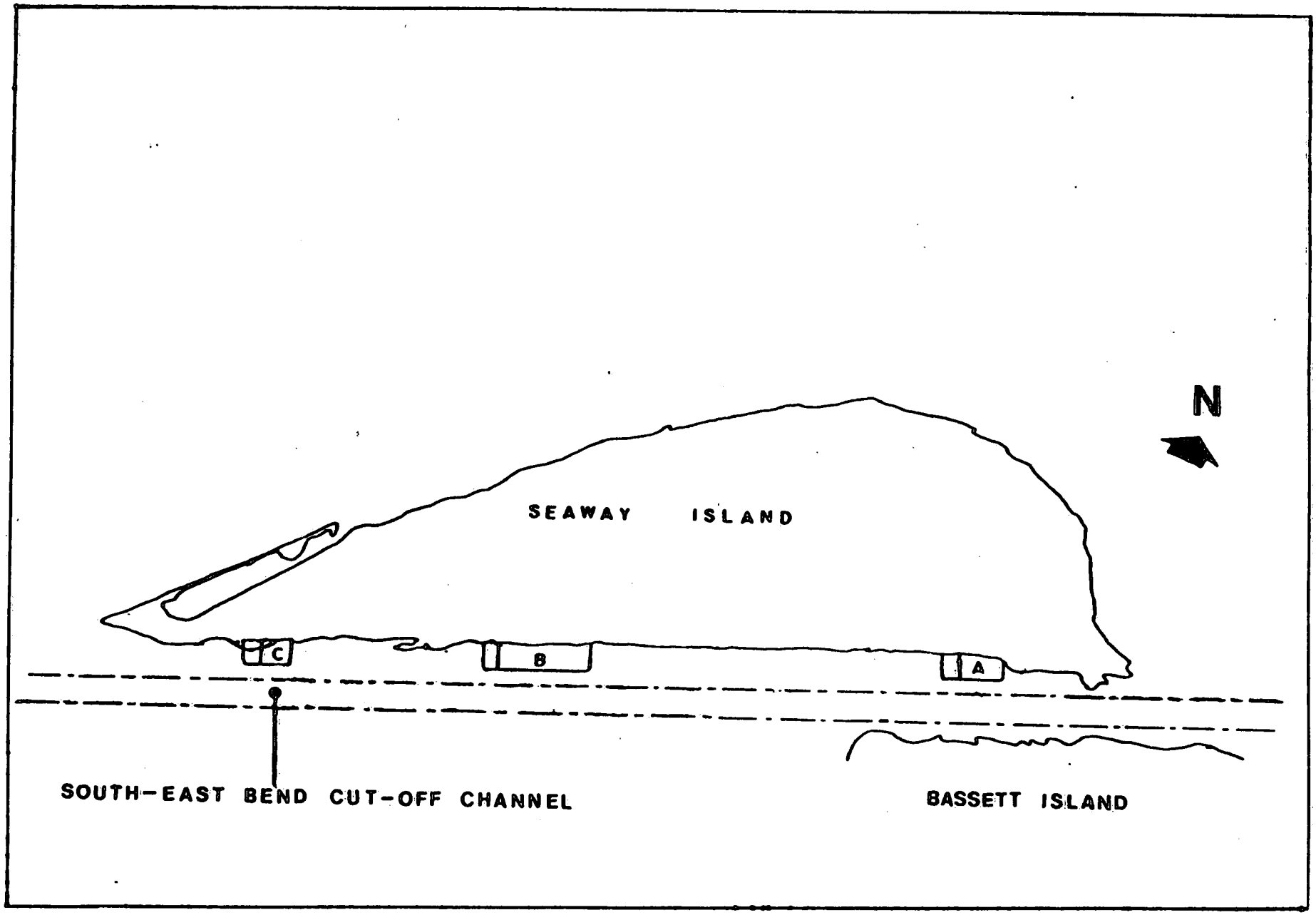


Fig. 3. The South-East Bend Cut- Off Channel confined disposal facility on Seaway Island, Walpole Island Indian Reserve.

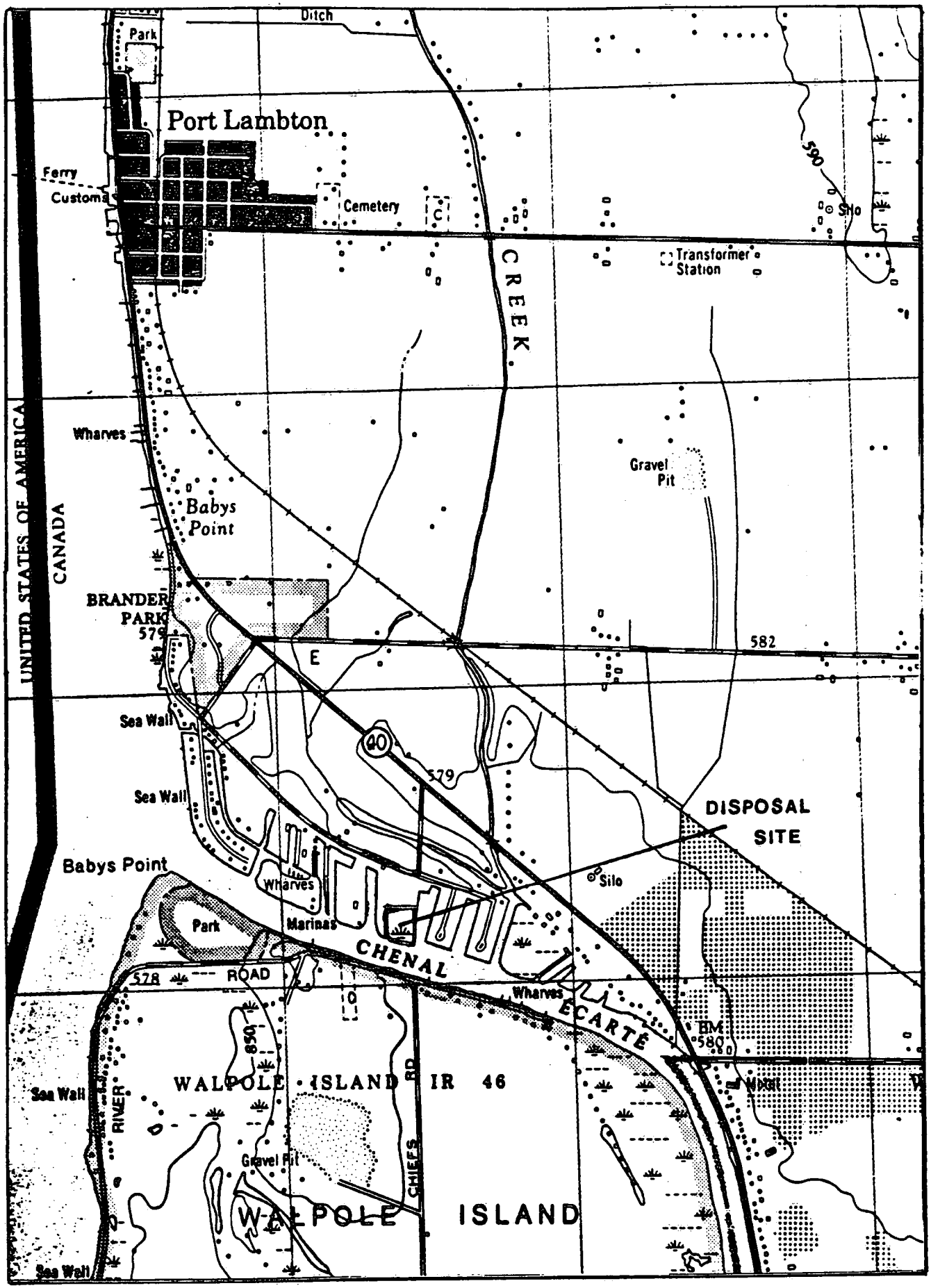
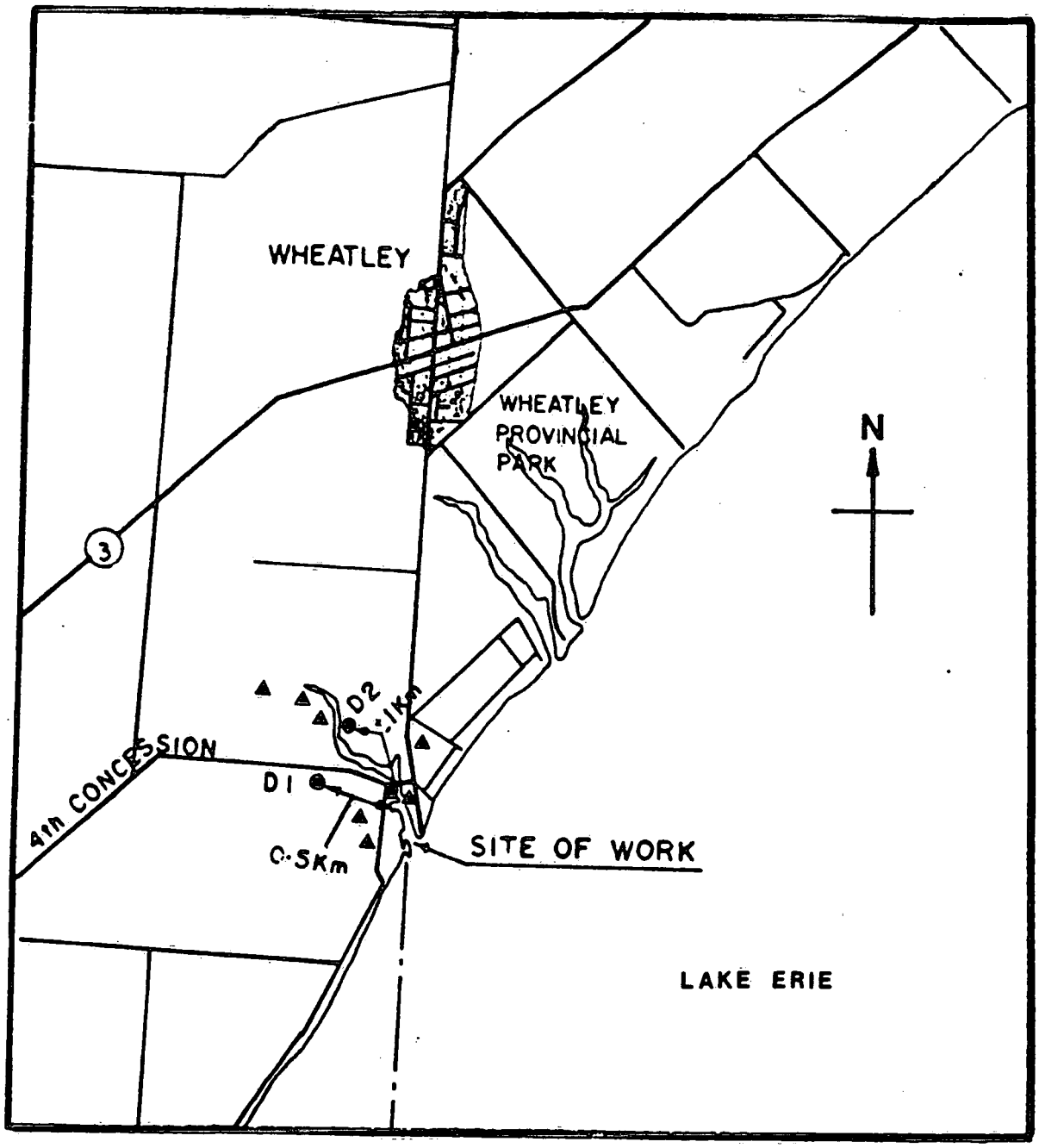


Fig. 4 Location of the dredge dispoal site on Chenal Ecarte on the St. Clair River.



DISPOSAL SITE LEGEND

- ● D1 - PULLEY PROPERTY SITE
- ● D2 - DUST PROPERTY SITE
- ▲ 1976 DISPOSAL SITES

Fig. 5. Locations of dredged disposal sites at Wheatley Harbour, Lake Erie.

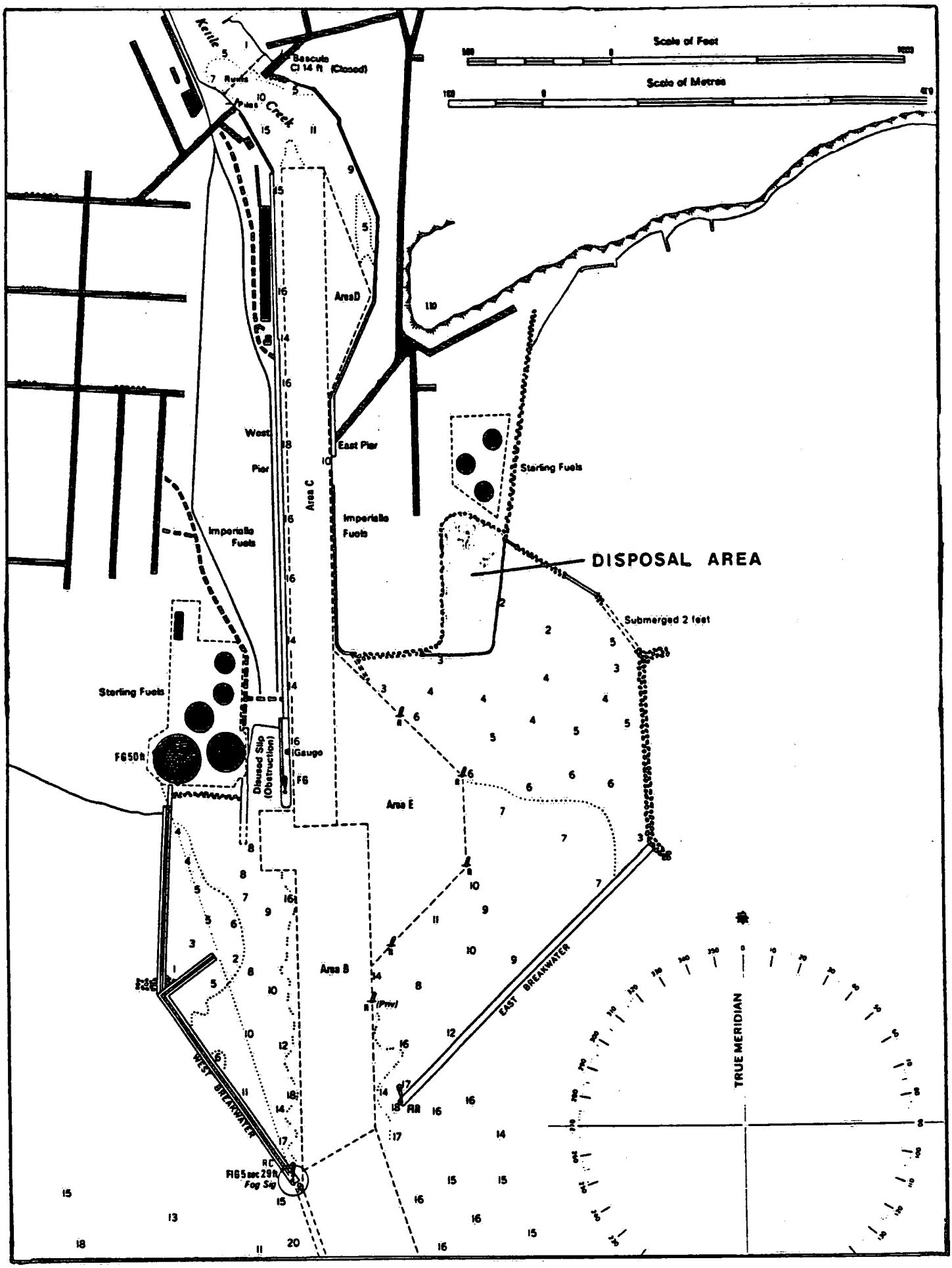


Fig. 6 Location of the dredge disposal site at Port Stanley, Lake Erie.

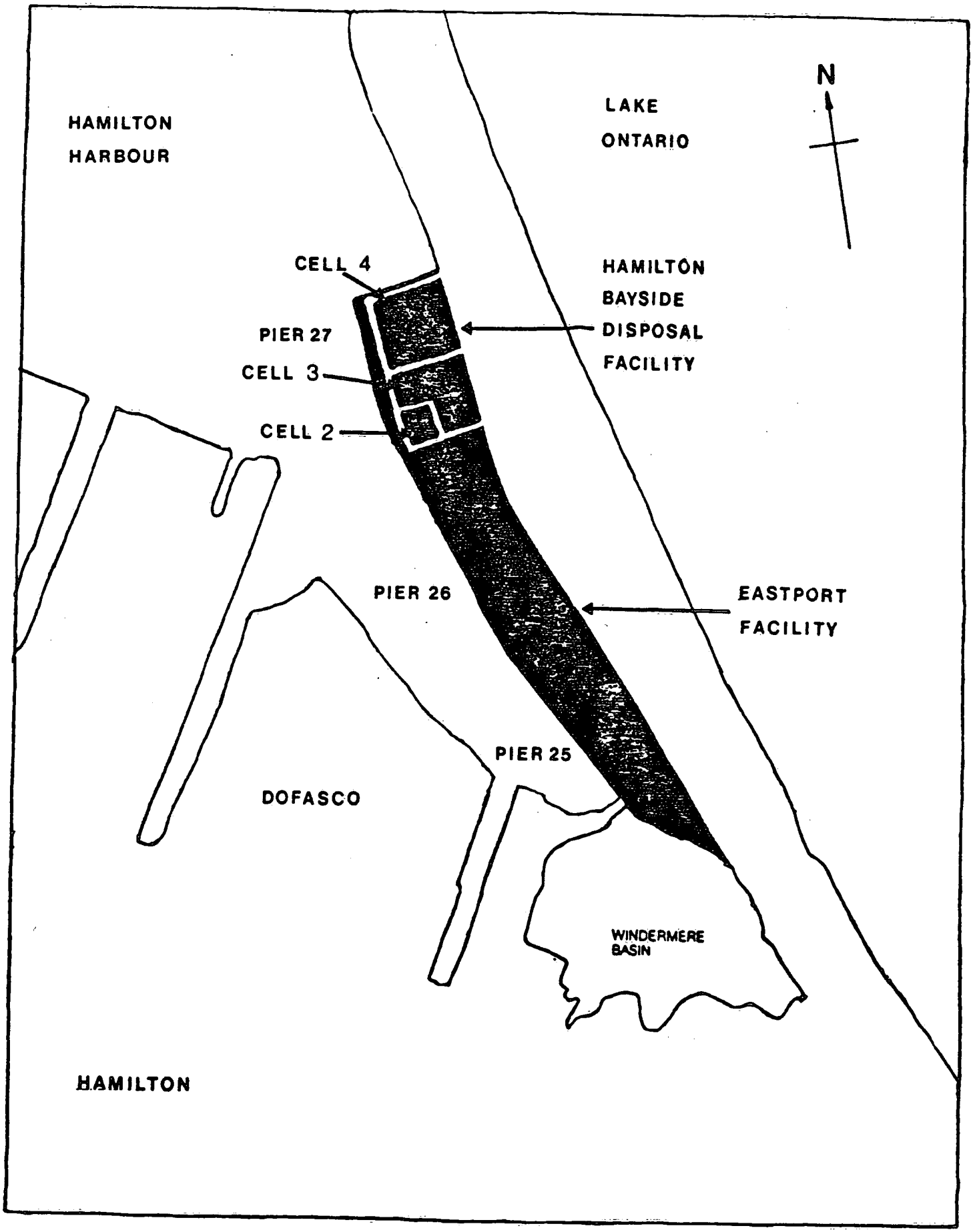


Fig. 7. The Bayside Confined Disposal Facility in Hamilton Harbour, Lake Ontario.

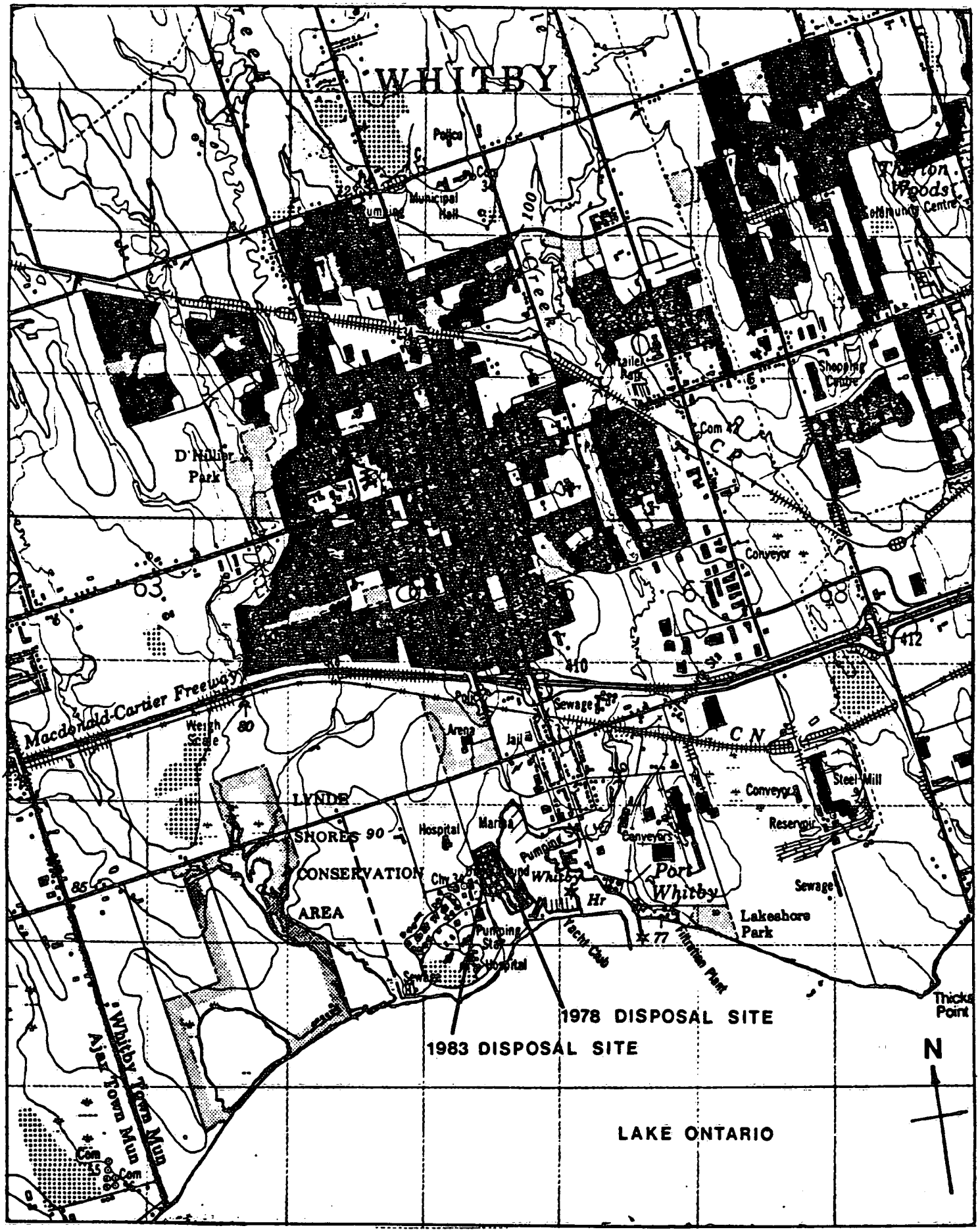


Fig. 8. Locations of dredged disposal sites at Whitby Harbour, Lake Ontario.

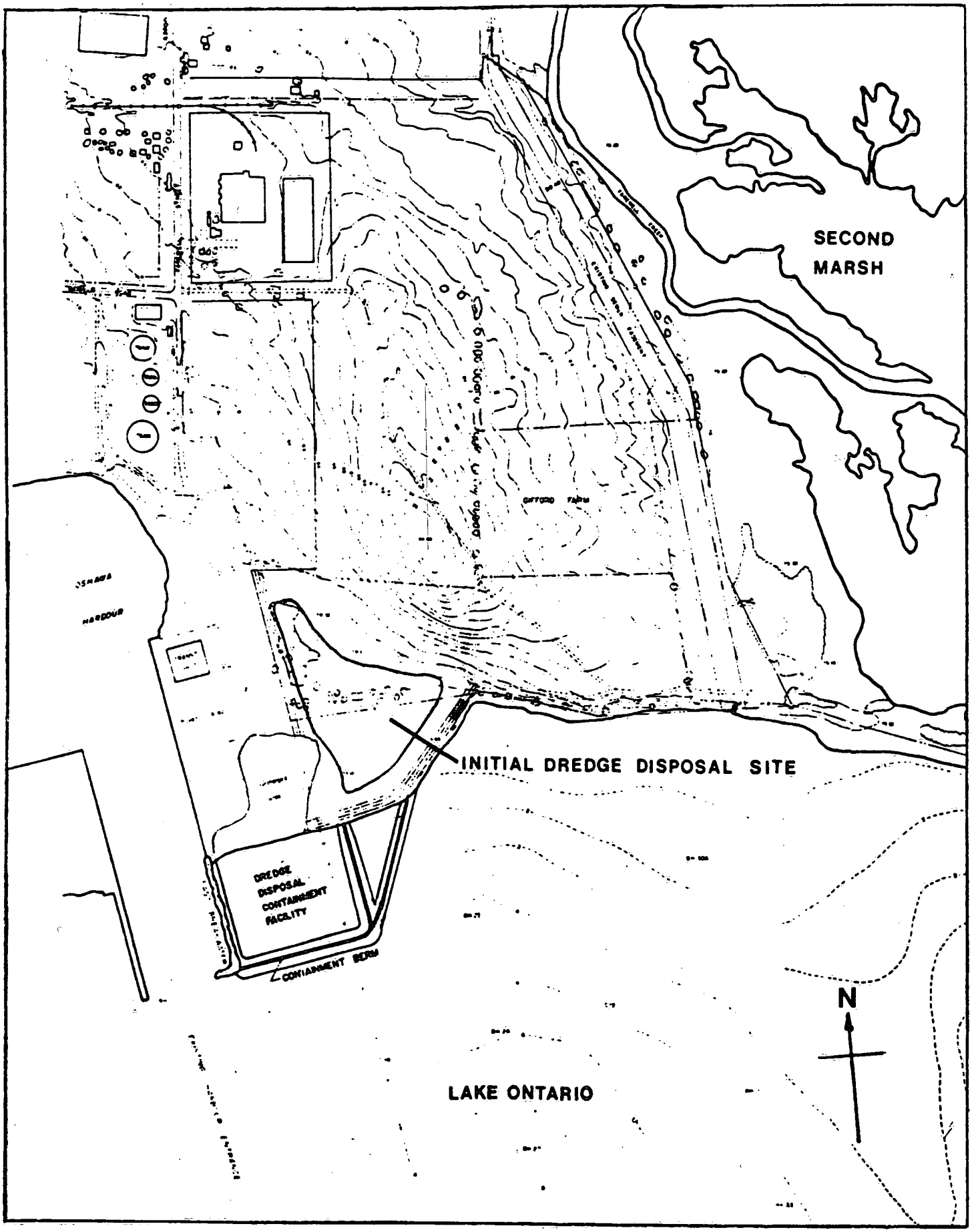


Fig. 9. Locations of Oshawa Harbour Confined Disposal Facility and upland disposal site.

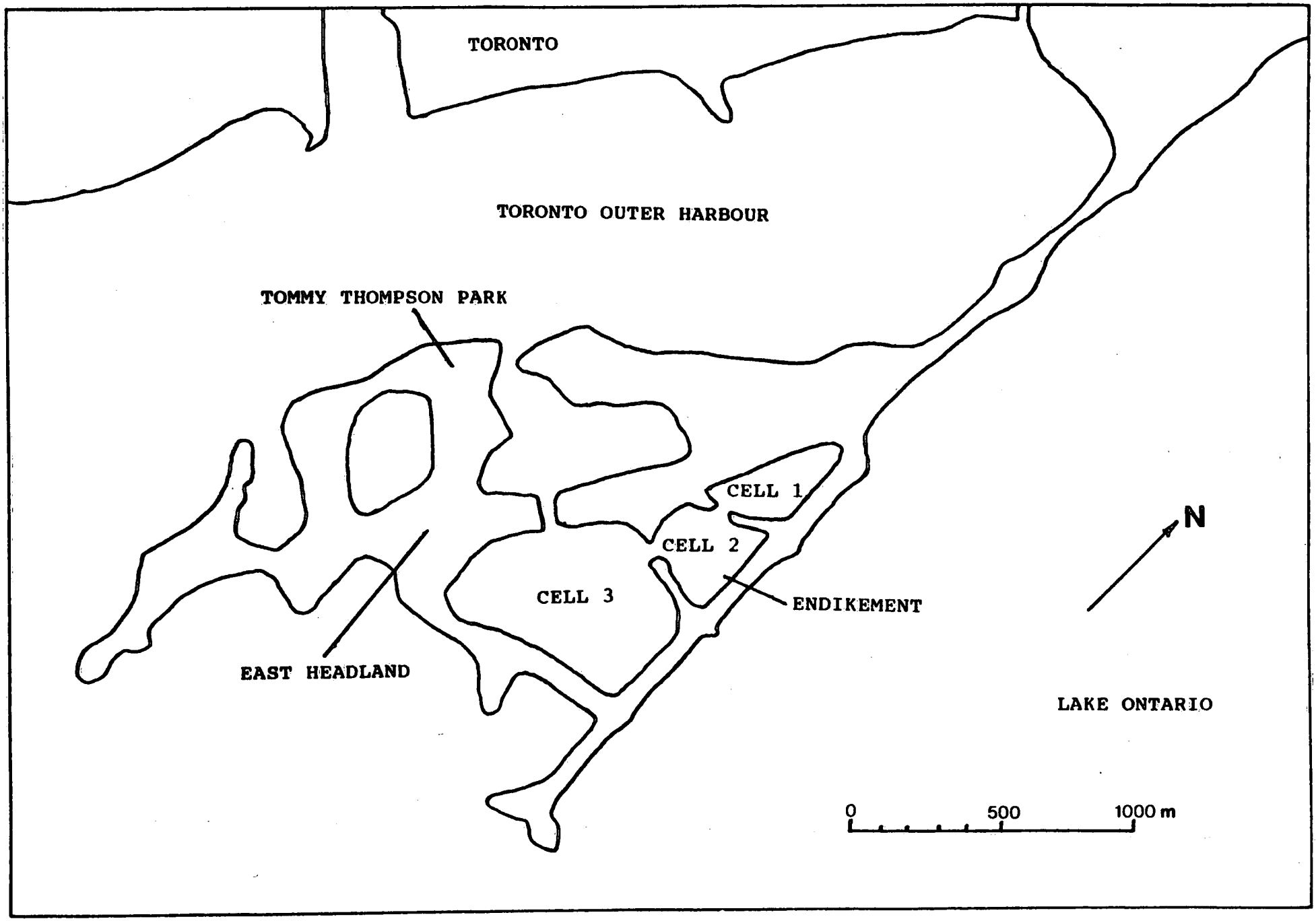


Fig. 10 Location of the confined disposal facility, the Endikement, at the East Headland, Toronto Harbour.

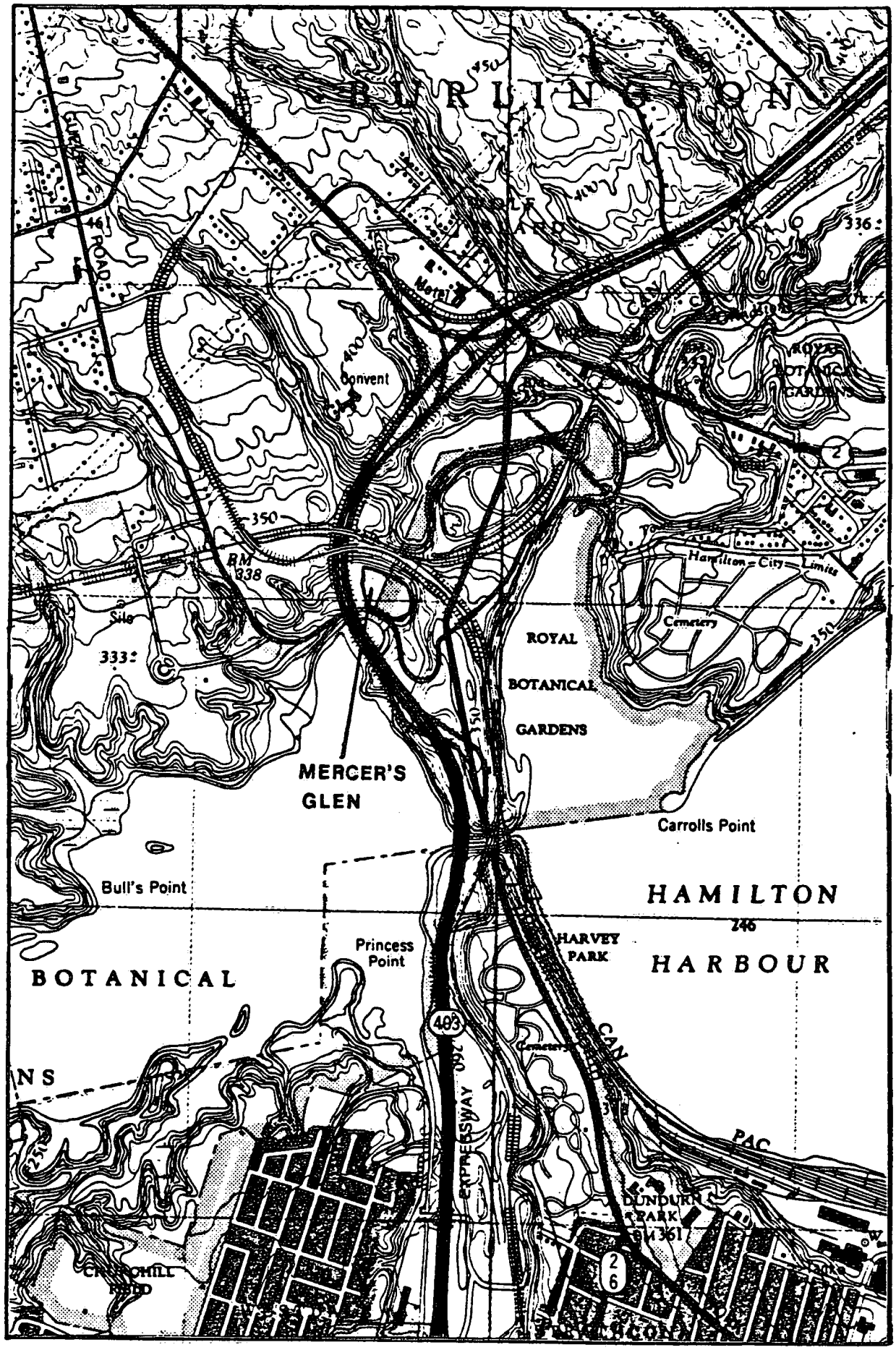
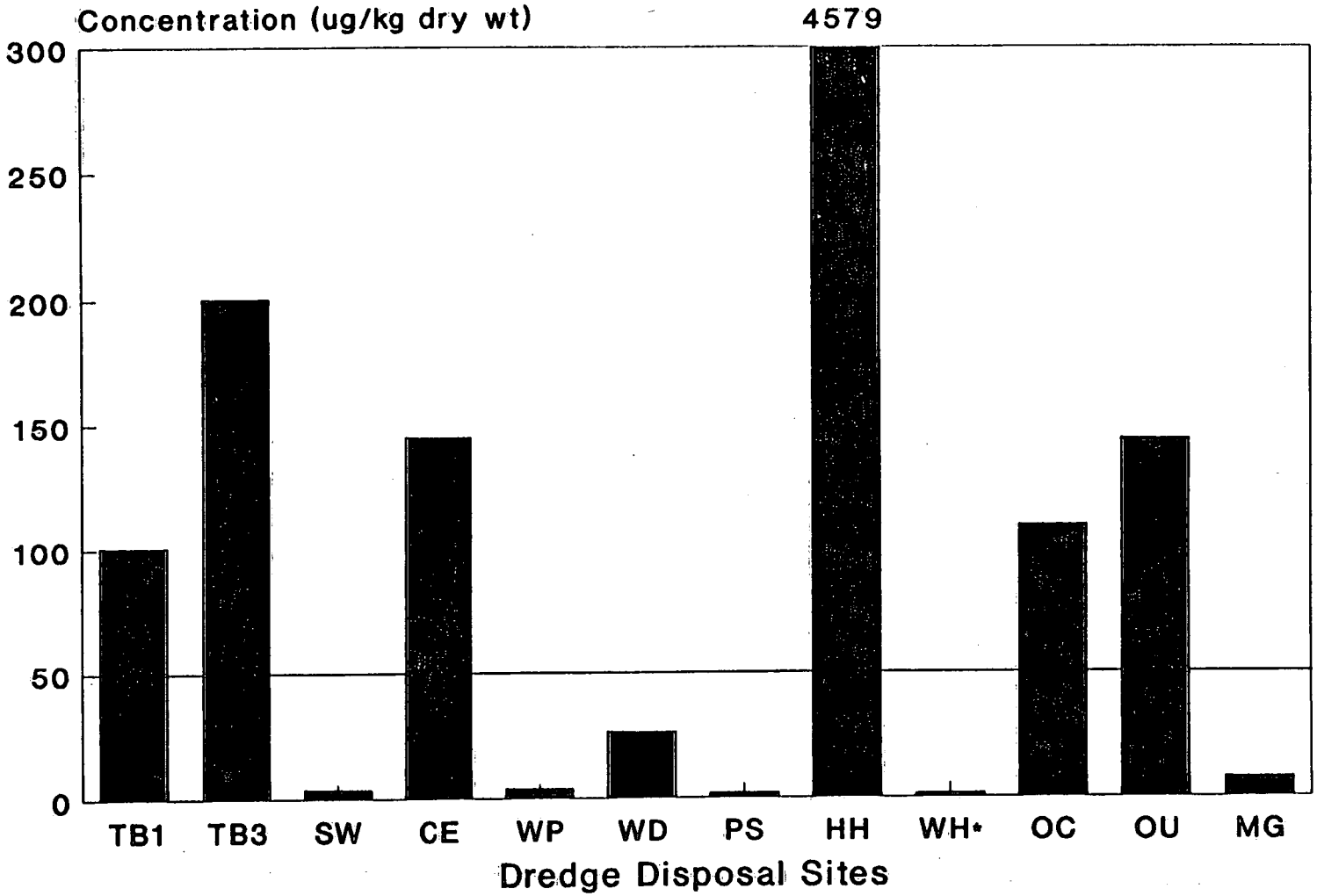


Fig. 11. Location of the control site at Mercer's Glen, Royal Botanical Gardens, Hamilton.

Fig 12. Total PCBs in bulk sediments.



* Coarse Fraction
Line = OMOE Dredge Disposal Guideline

Fig 13. PCB congener patterns in samples at Thunder Bay Cell 1.

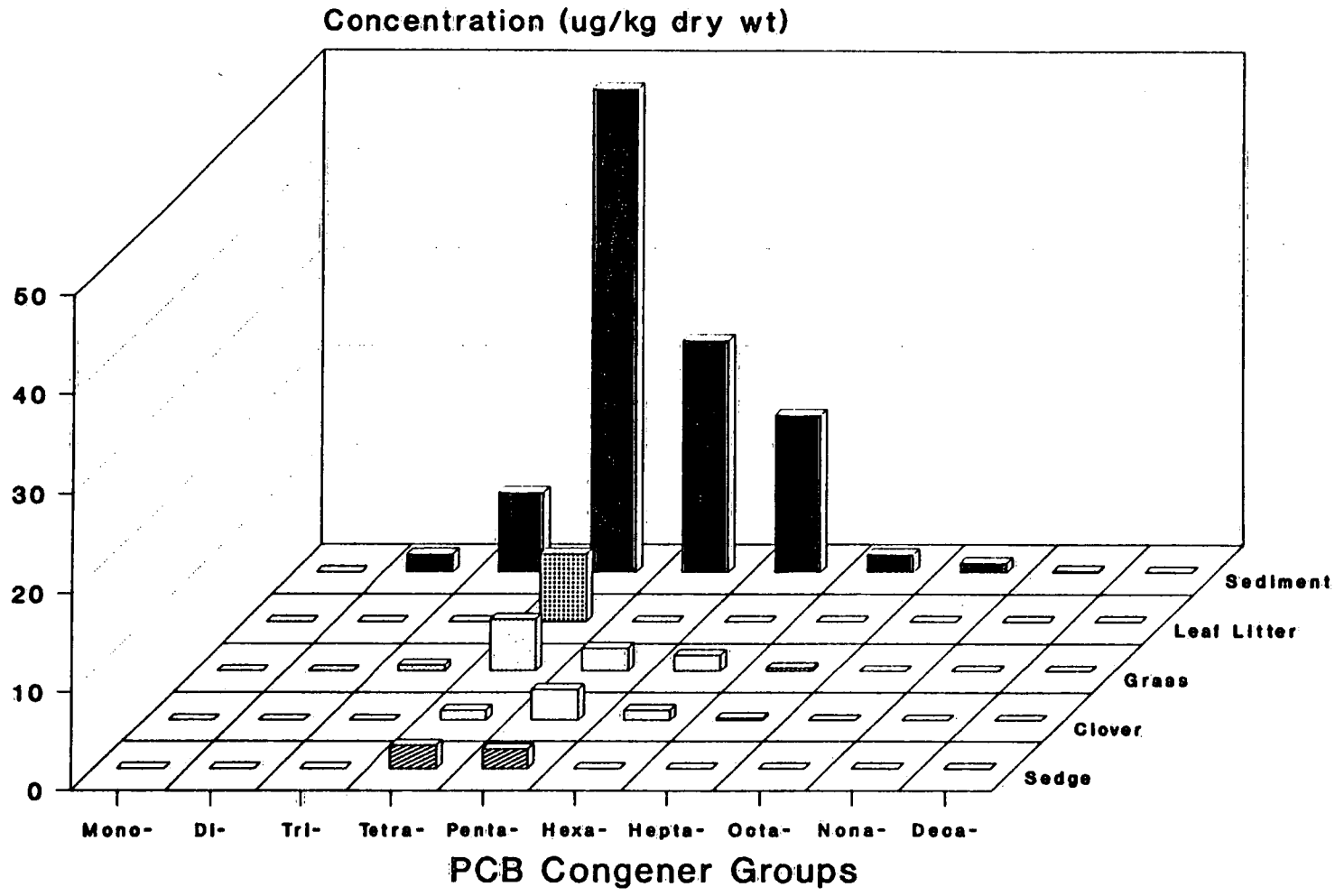


Fig 14. PCB congener patterns in samples at Thunder Bay Cell 3.

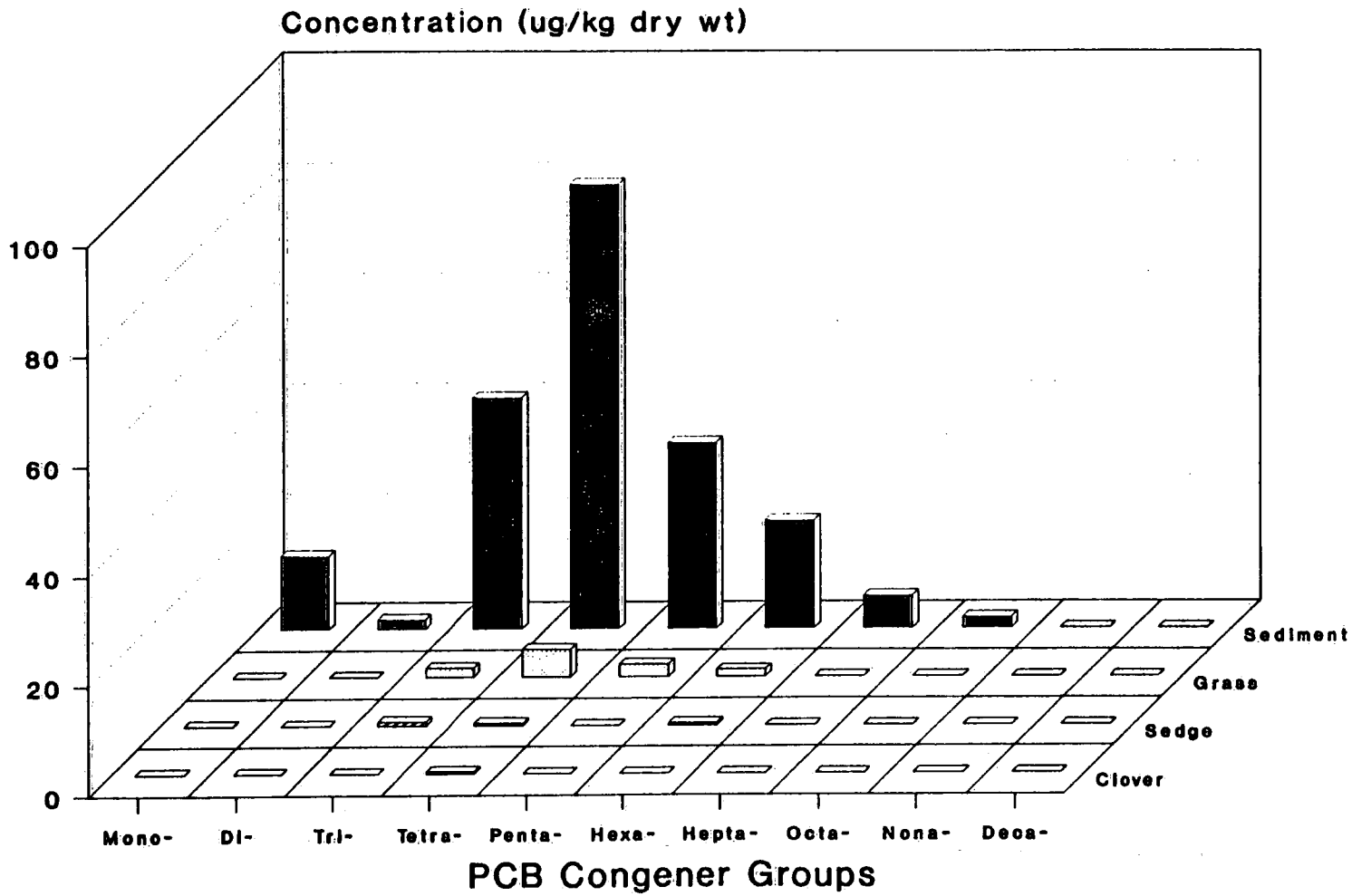


Fig 15. PCB congener patterns in samples at Seaway Island.

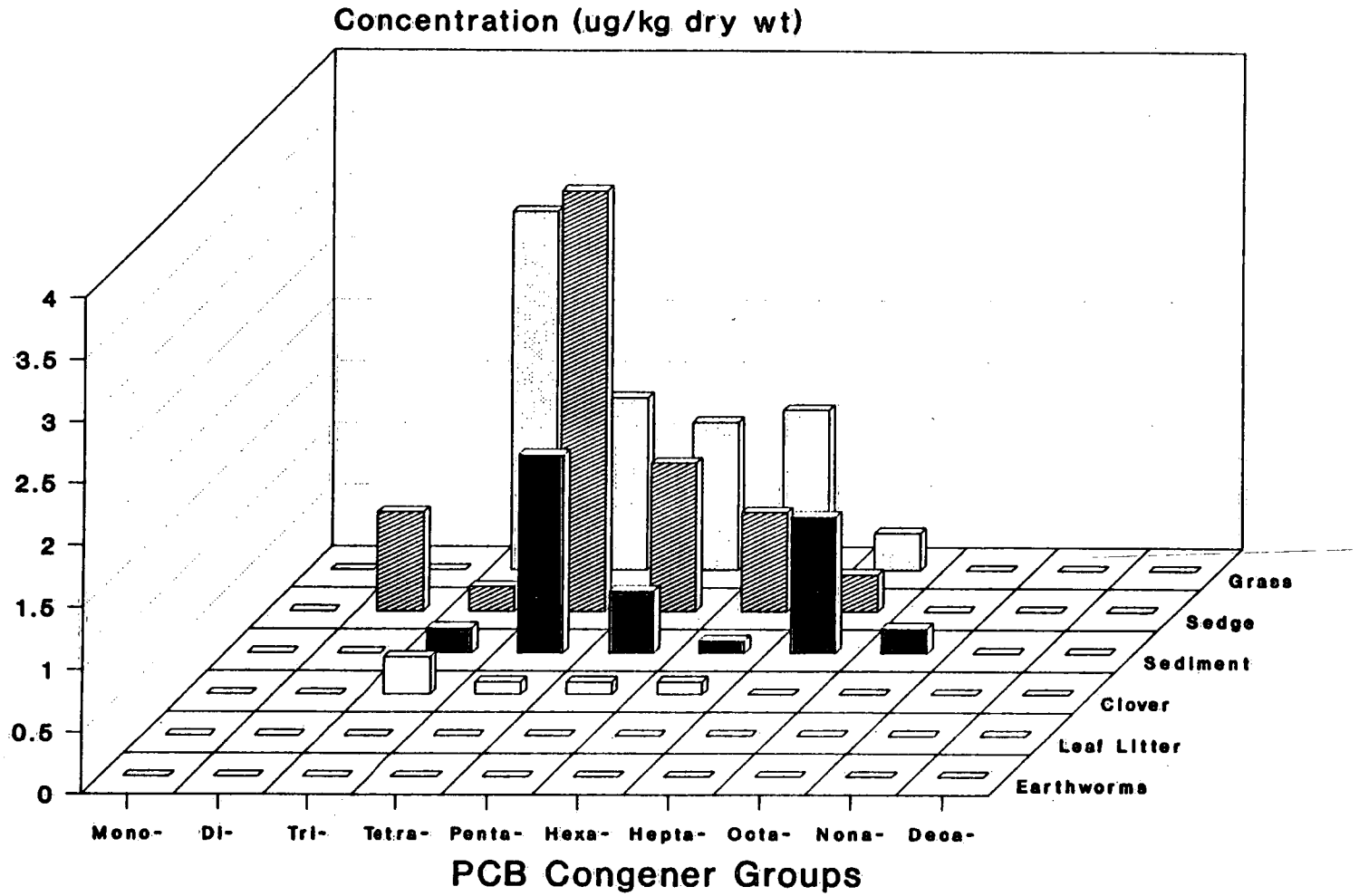


Fig 16. PCB congener patterns in samples at Chenal Ecarte.

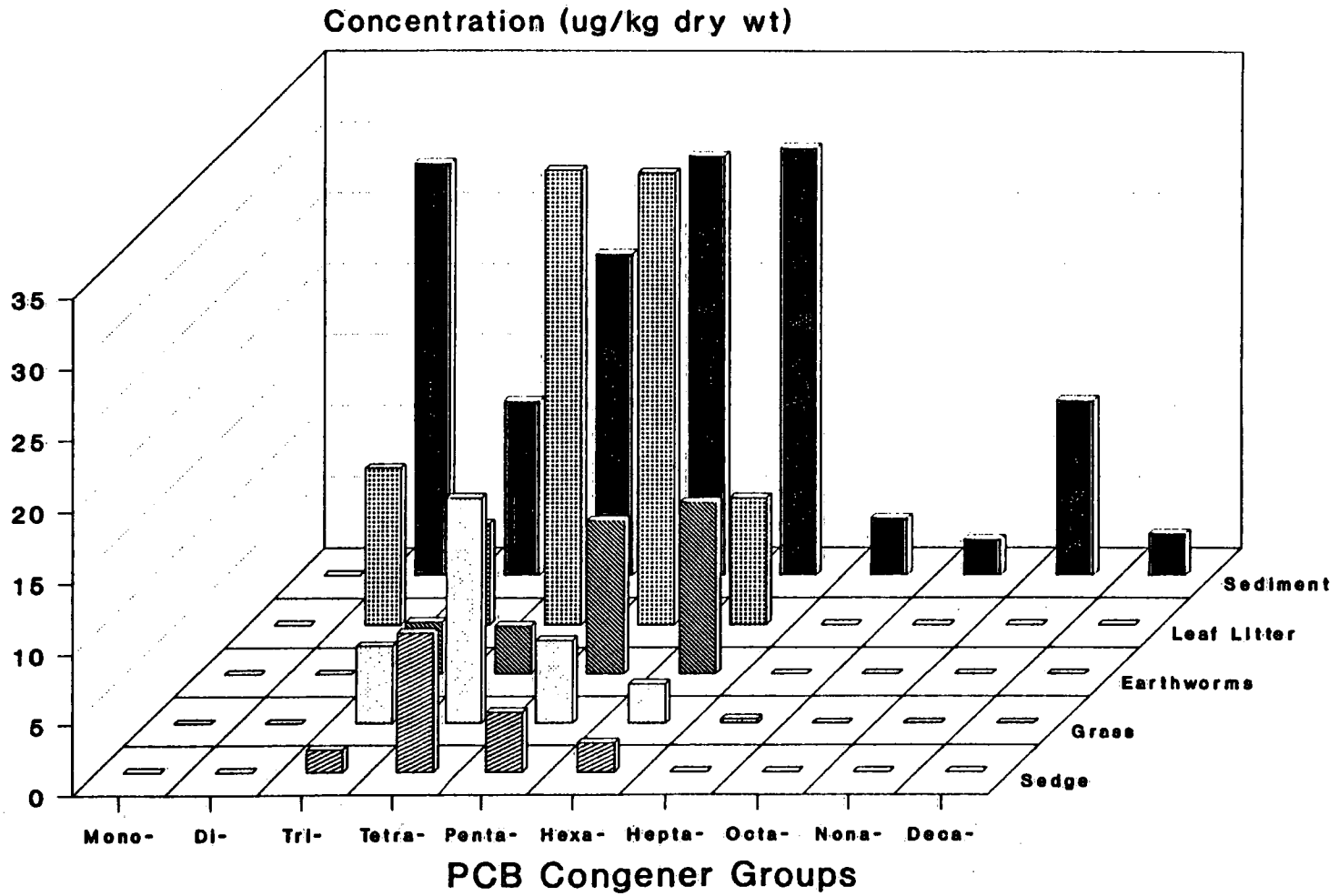


Fig 17. PCB congener patterns in samples at Wheatley-Pulley.

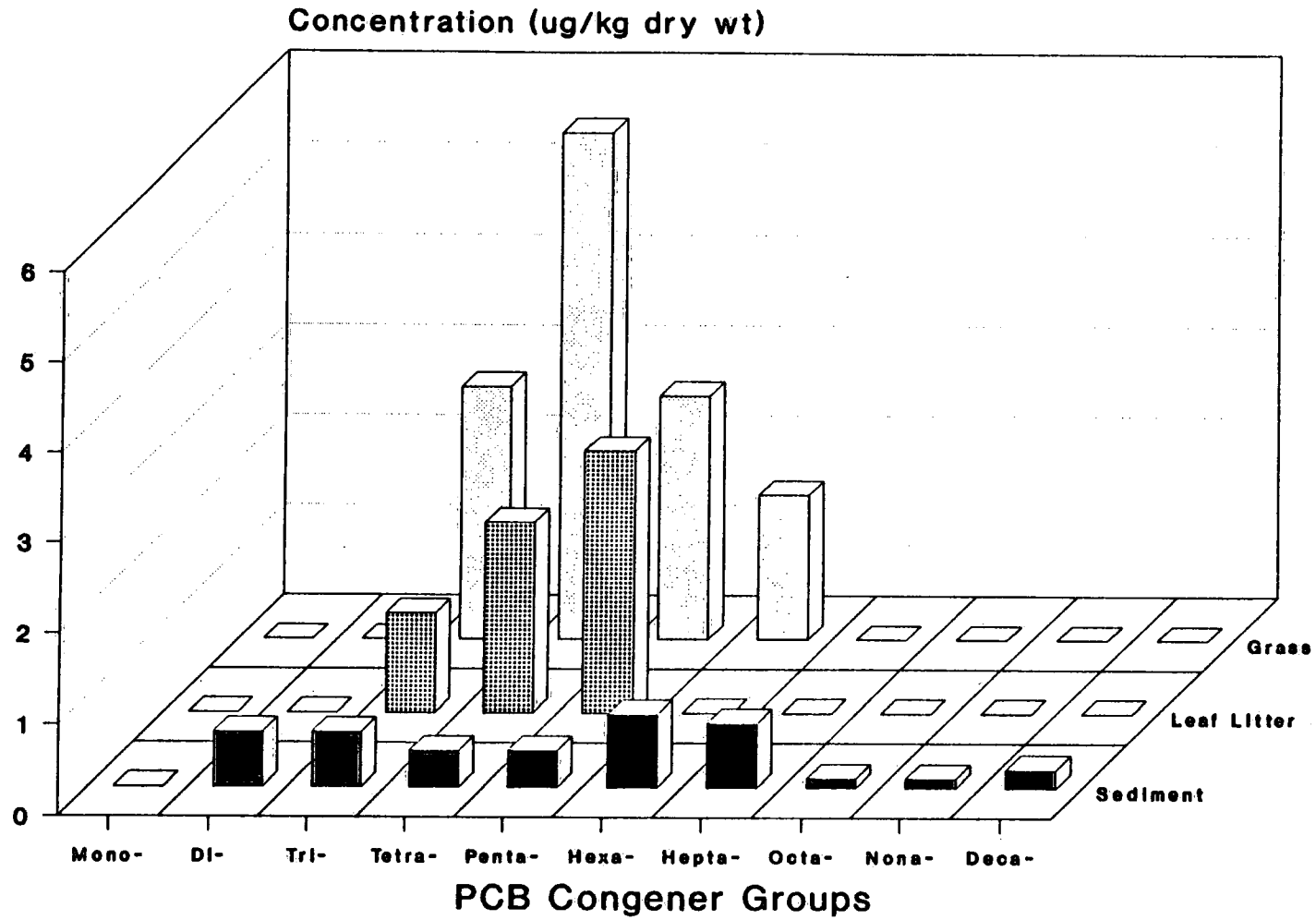


Fig 18. PCB congener patterns in samples at Wheatley-Dust.

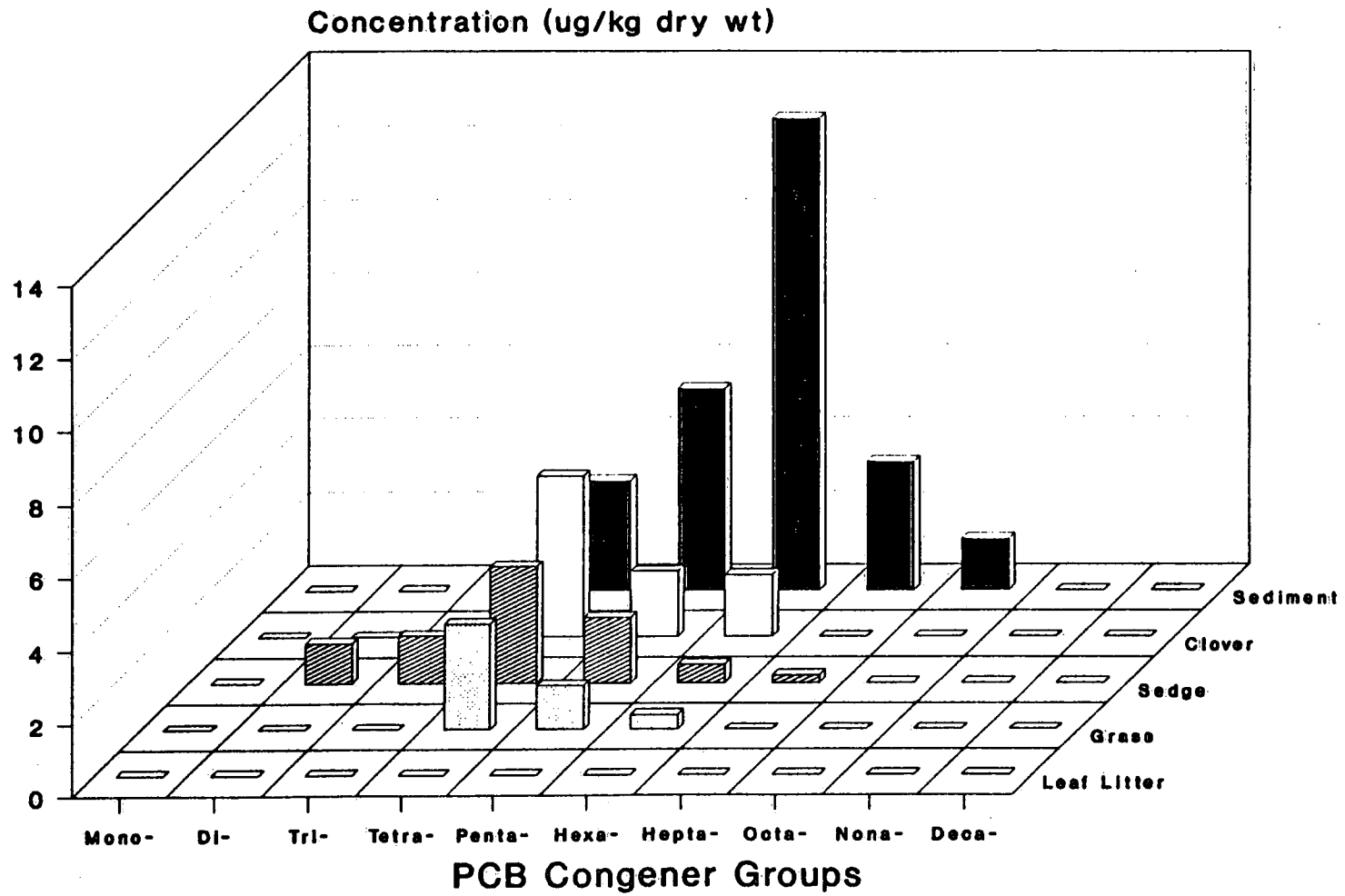


Fig 22. PCB congener patterns in samples at Oshawa-CDF.

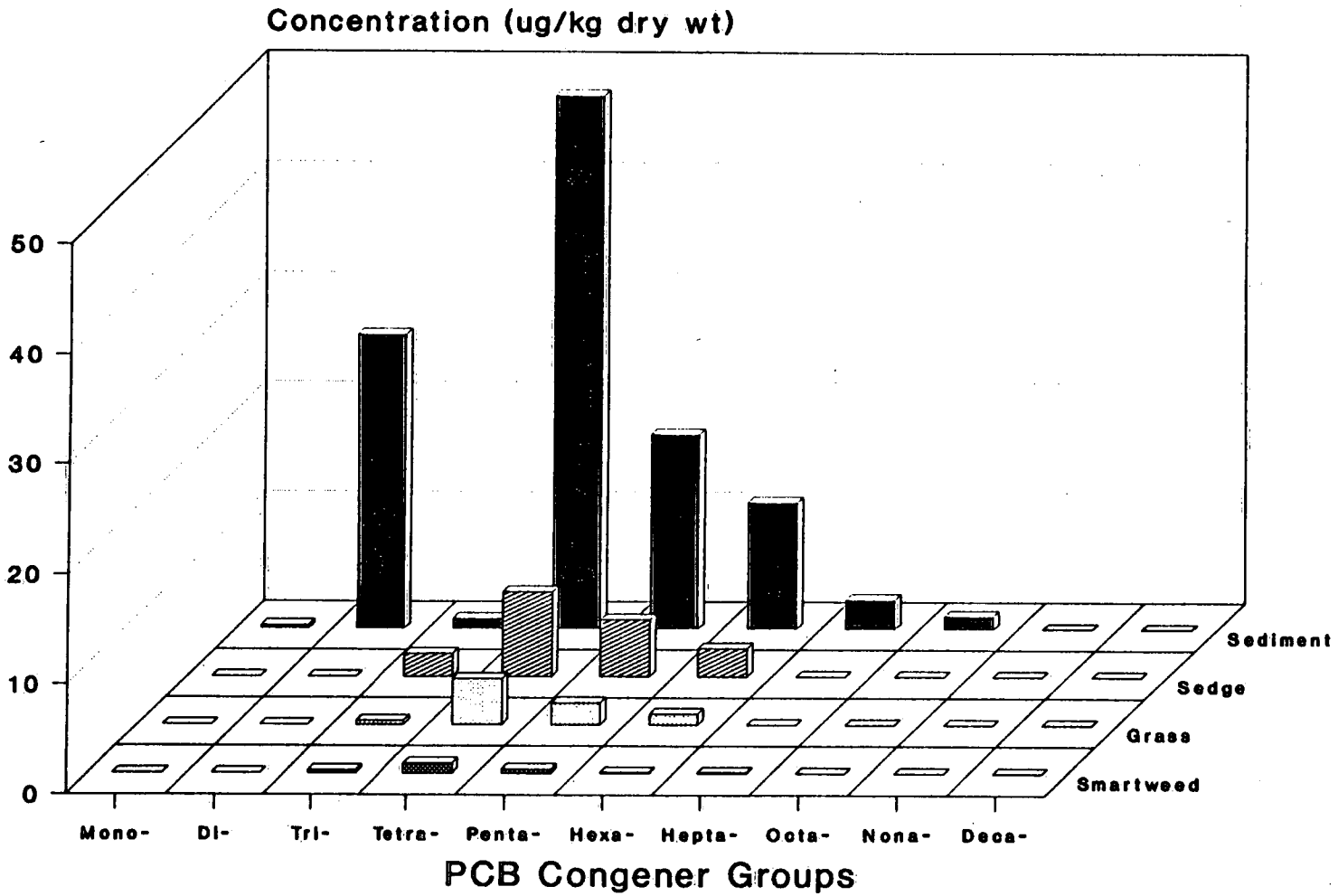


Fig 23. PCB congener patterns in samples at Oshawa-Upland.

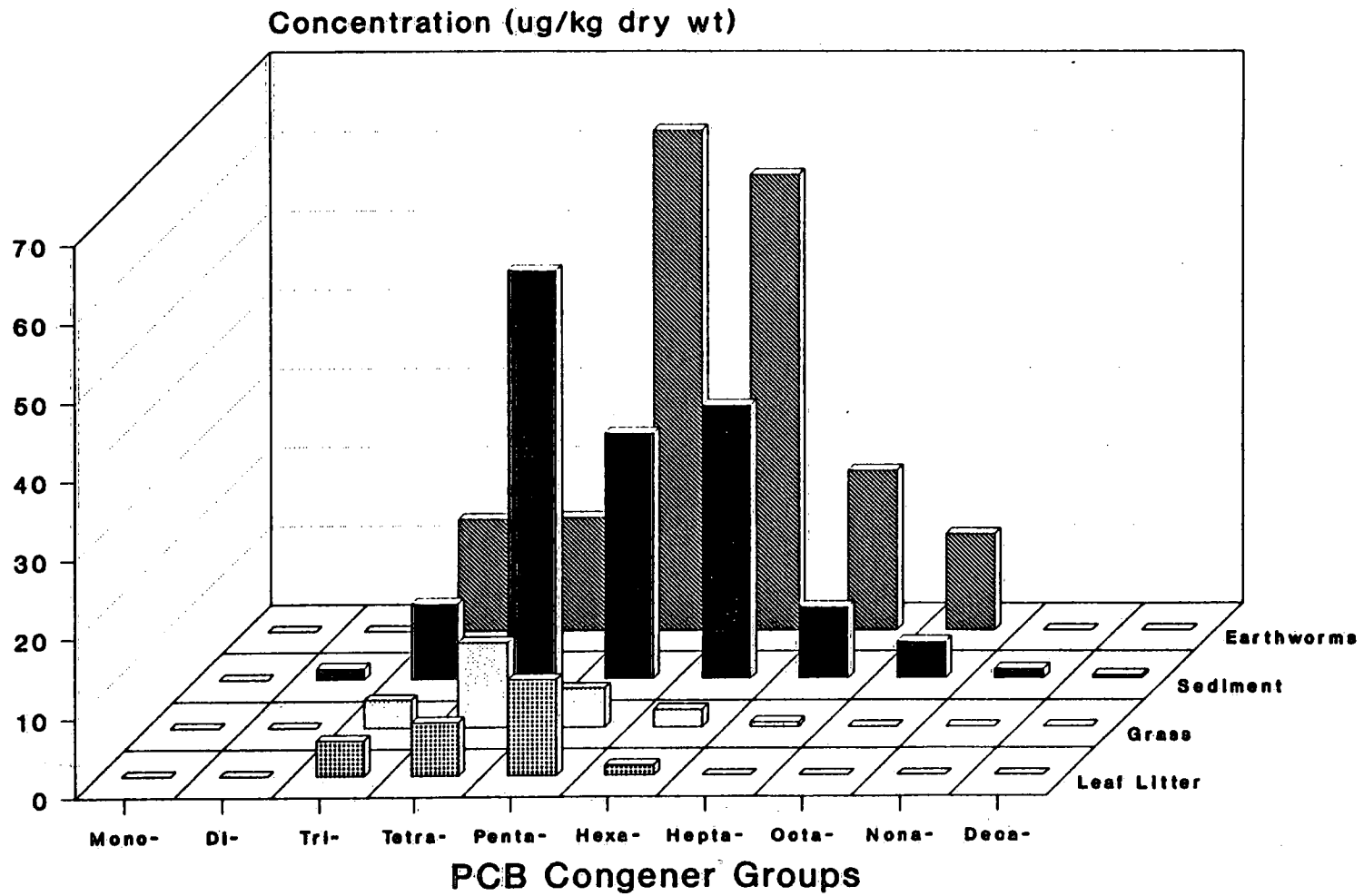


Fig 24. PCB congener patterns in samples at Mercers Glen.

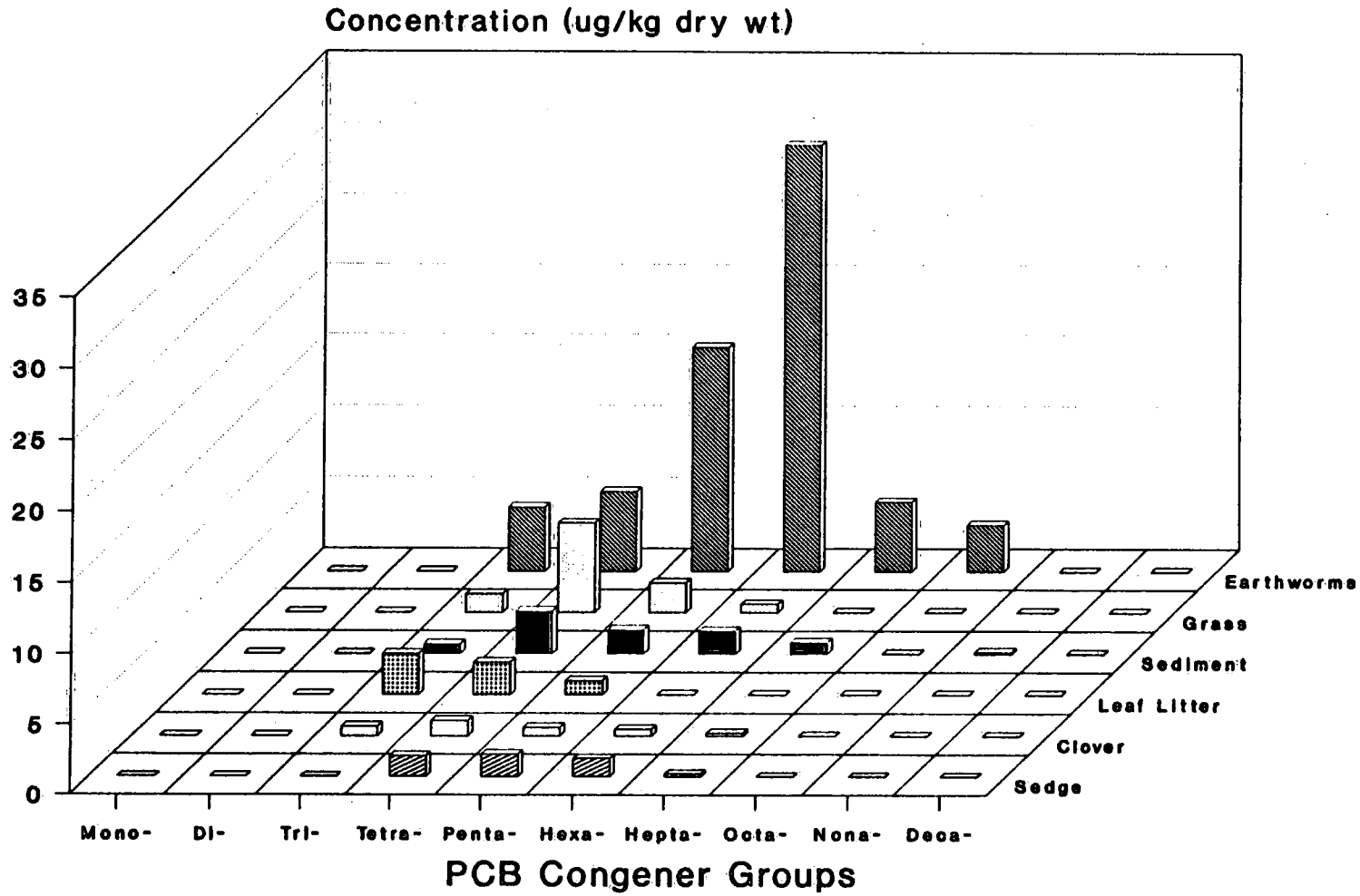


Fig 25a. PCB congener patterns in bulk sediments at 6 sites.

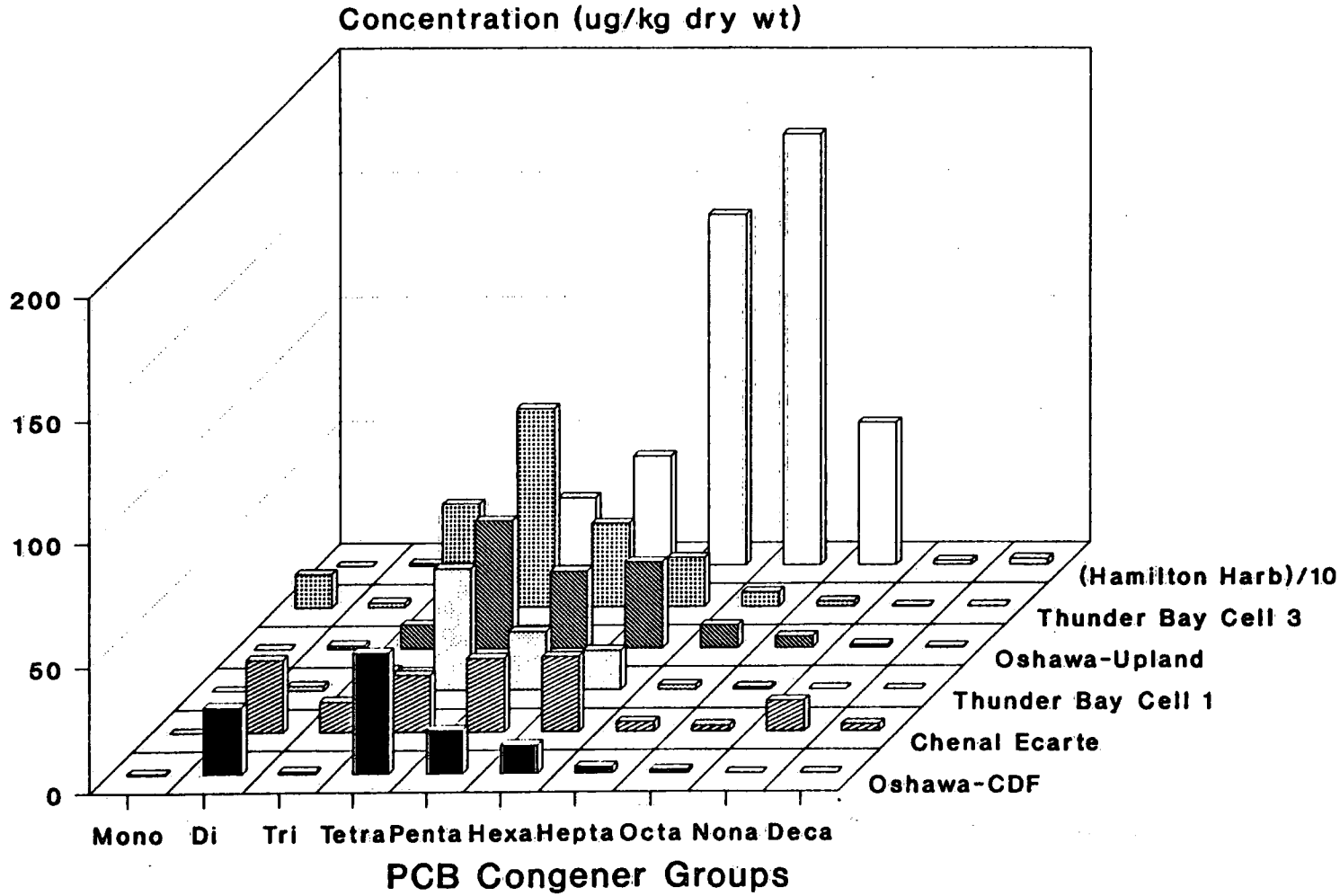
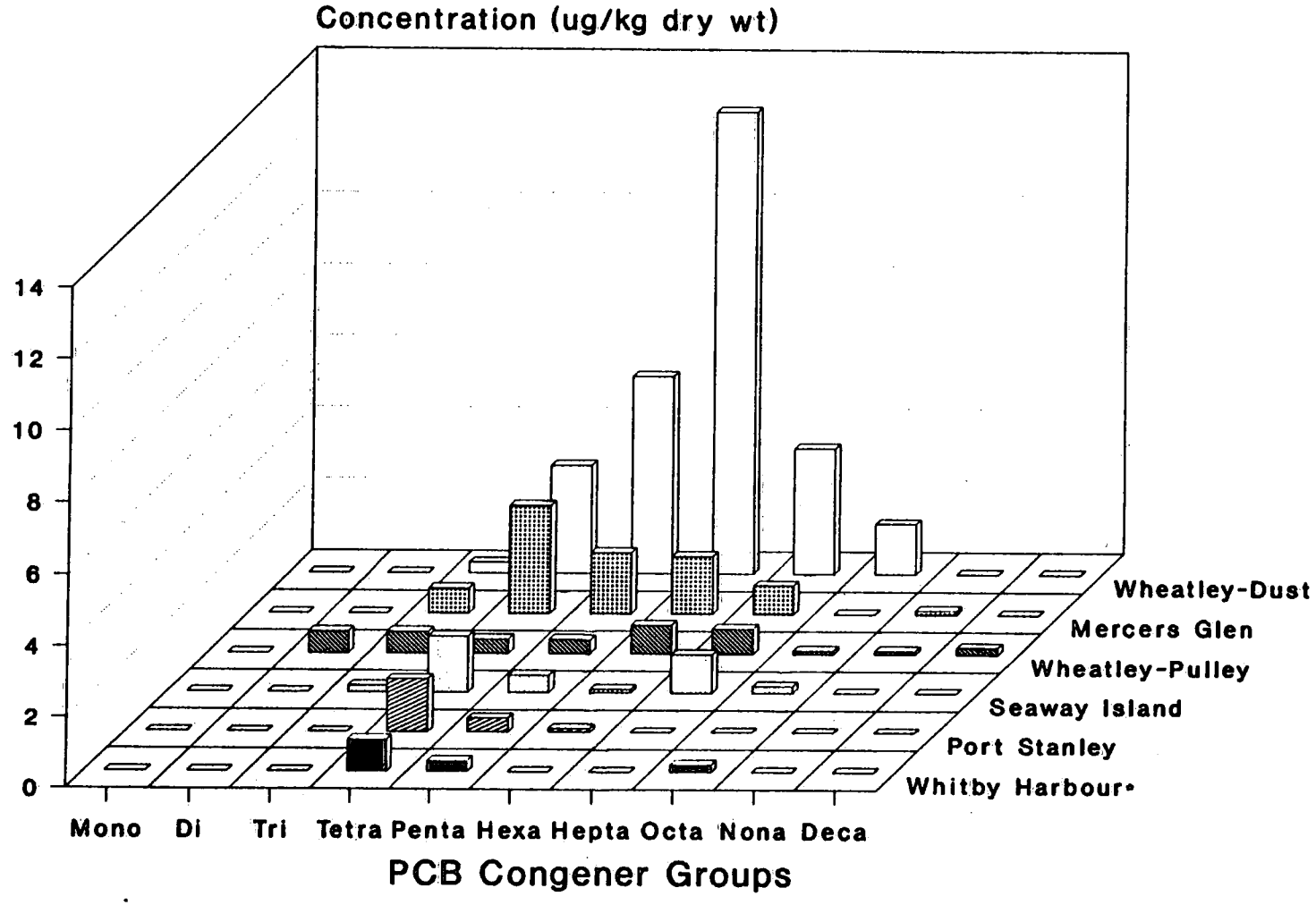


Fig 25b. PCB congener patterns in bulk sediments at 6 sites.



* Coarse Fraction

Fig. 26. Total PAHs at CDFs.

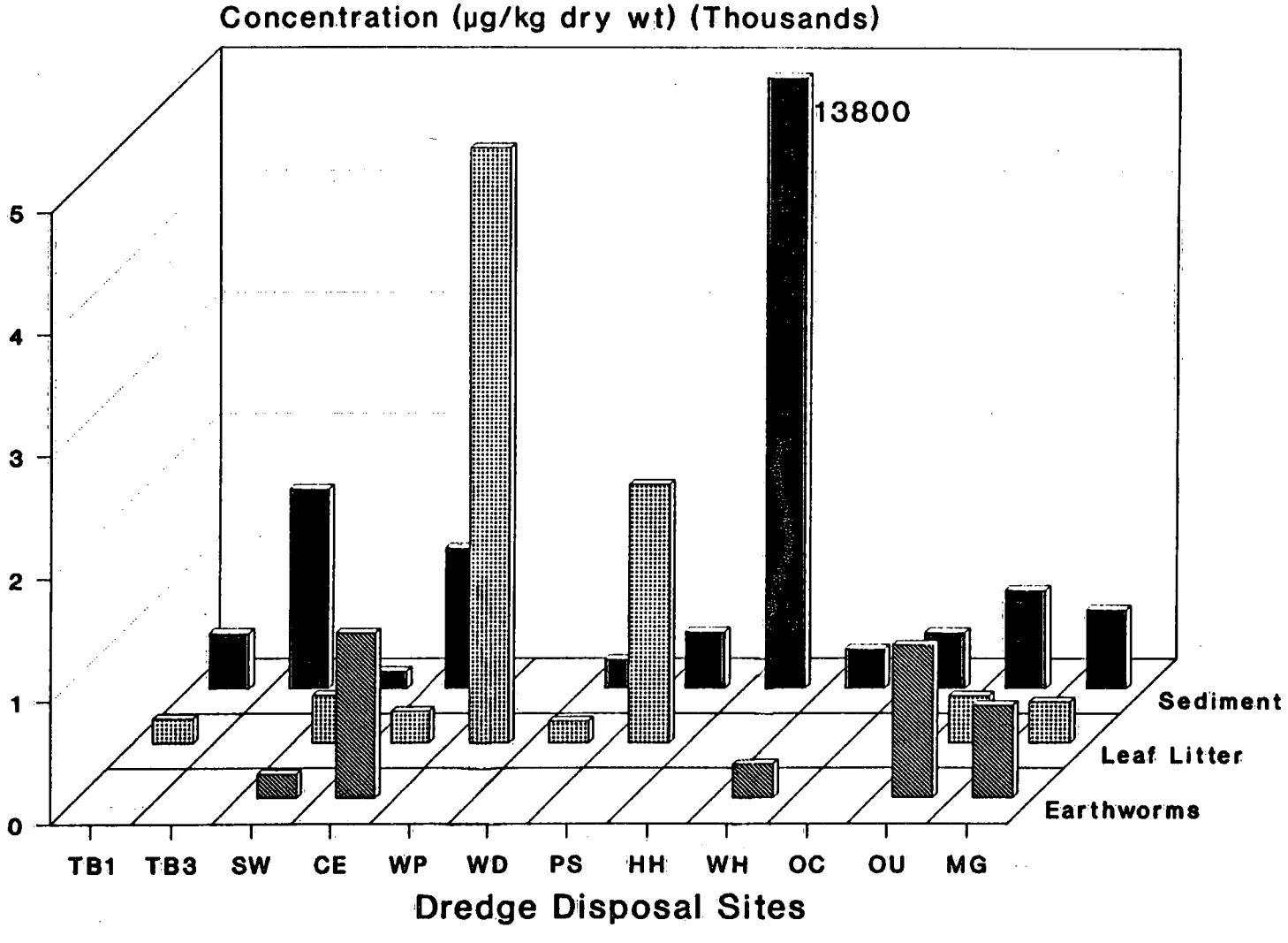


Fig. 27. PAHs at Hamilton Harbour.

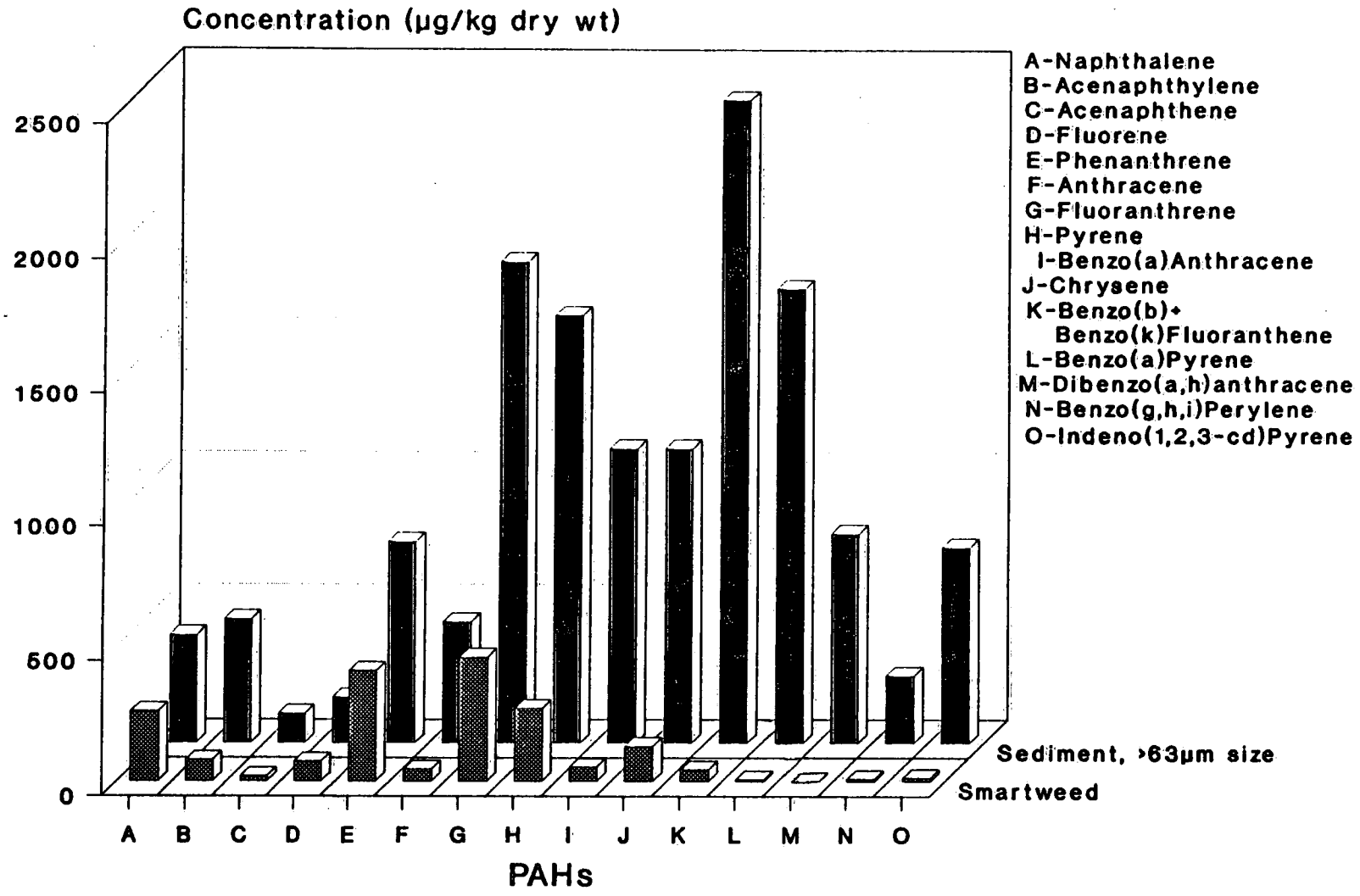


Fig 28. Mean bioaccumulation factors for metals from sediments to vegetation.

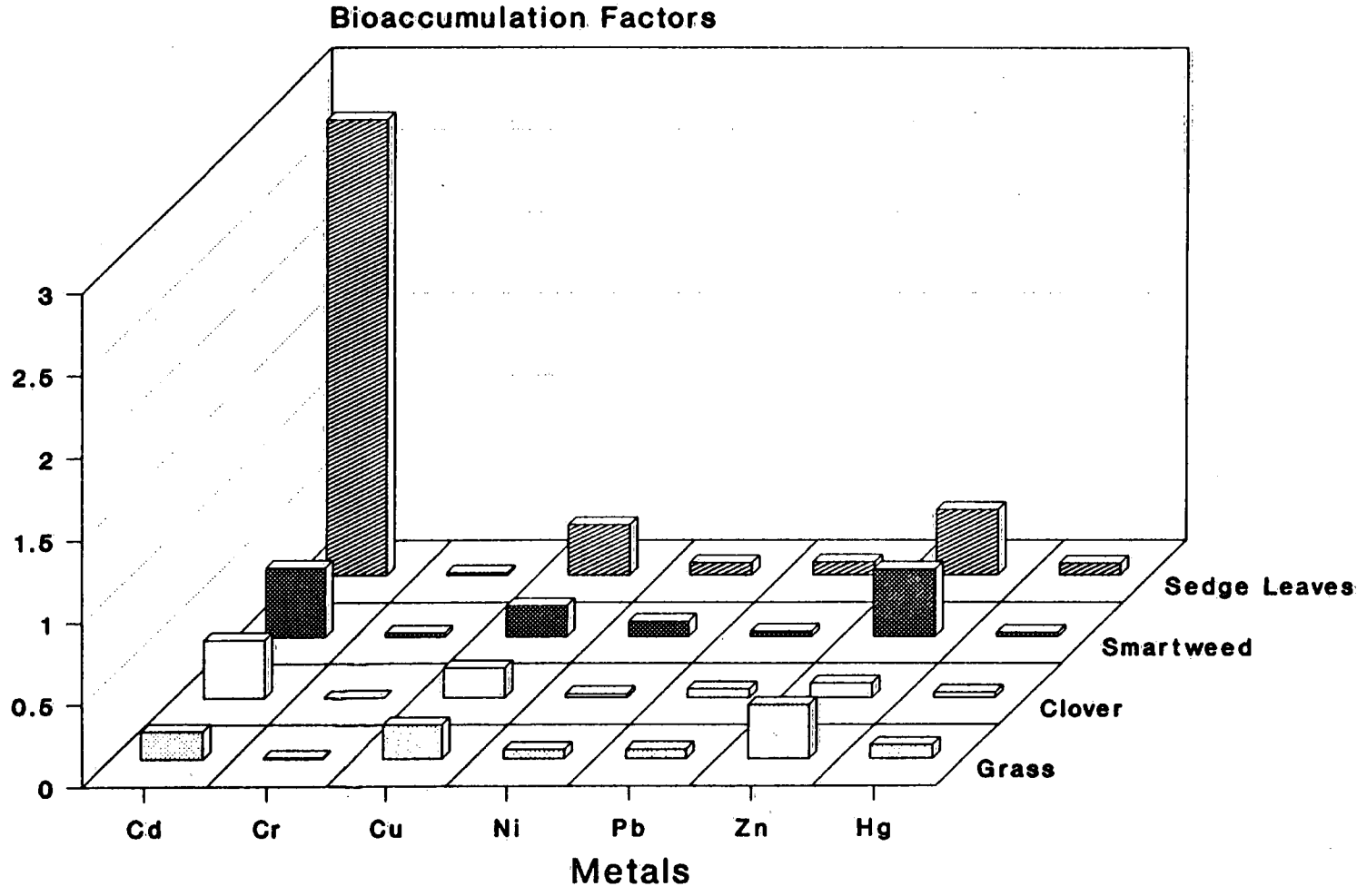
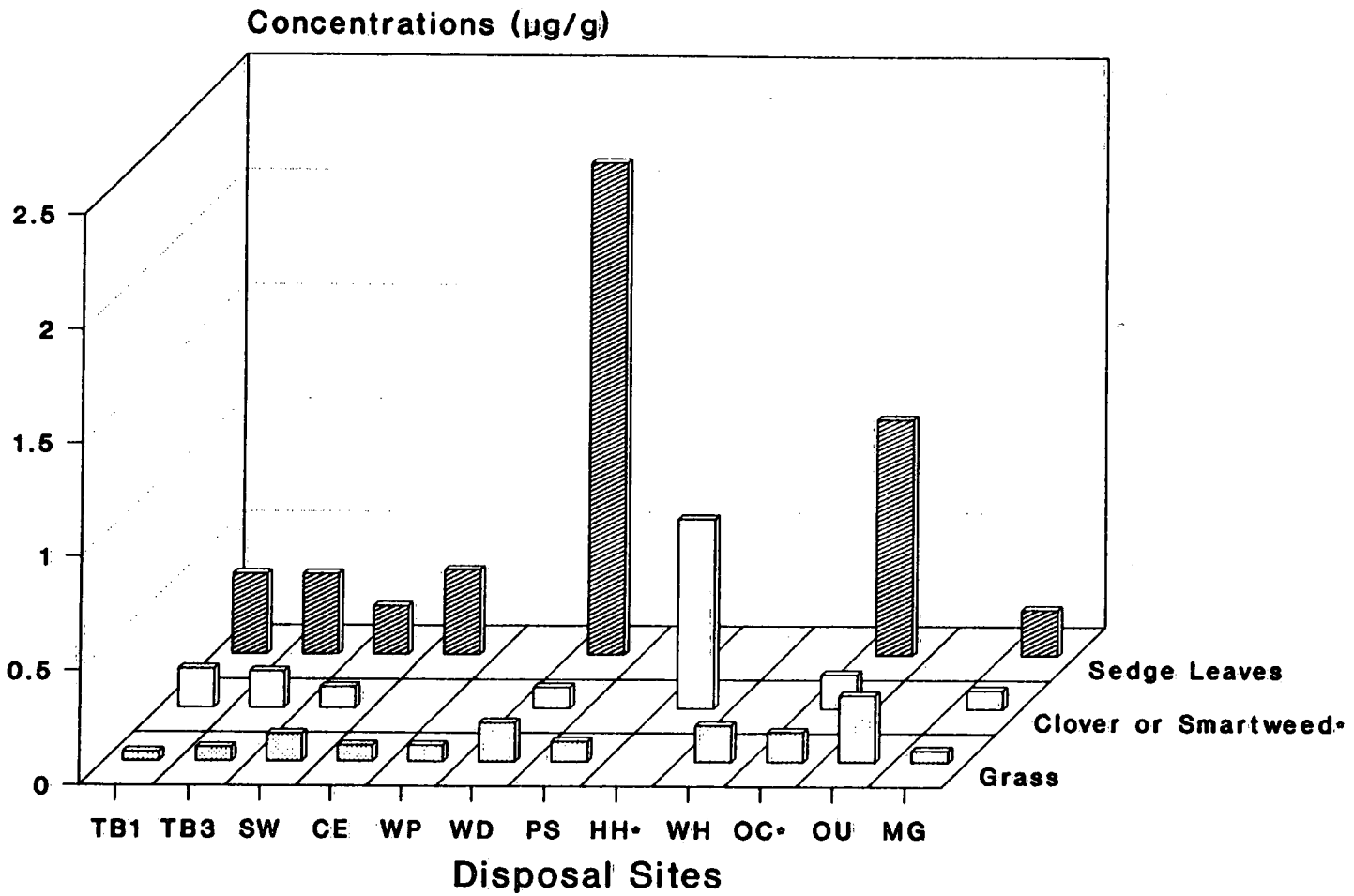
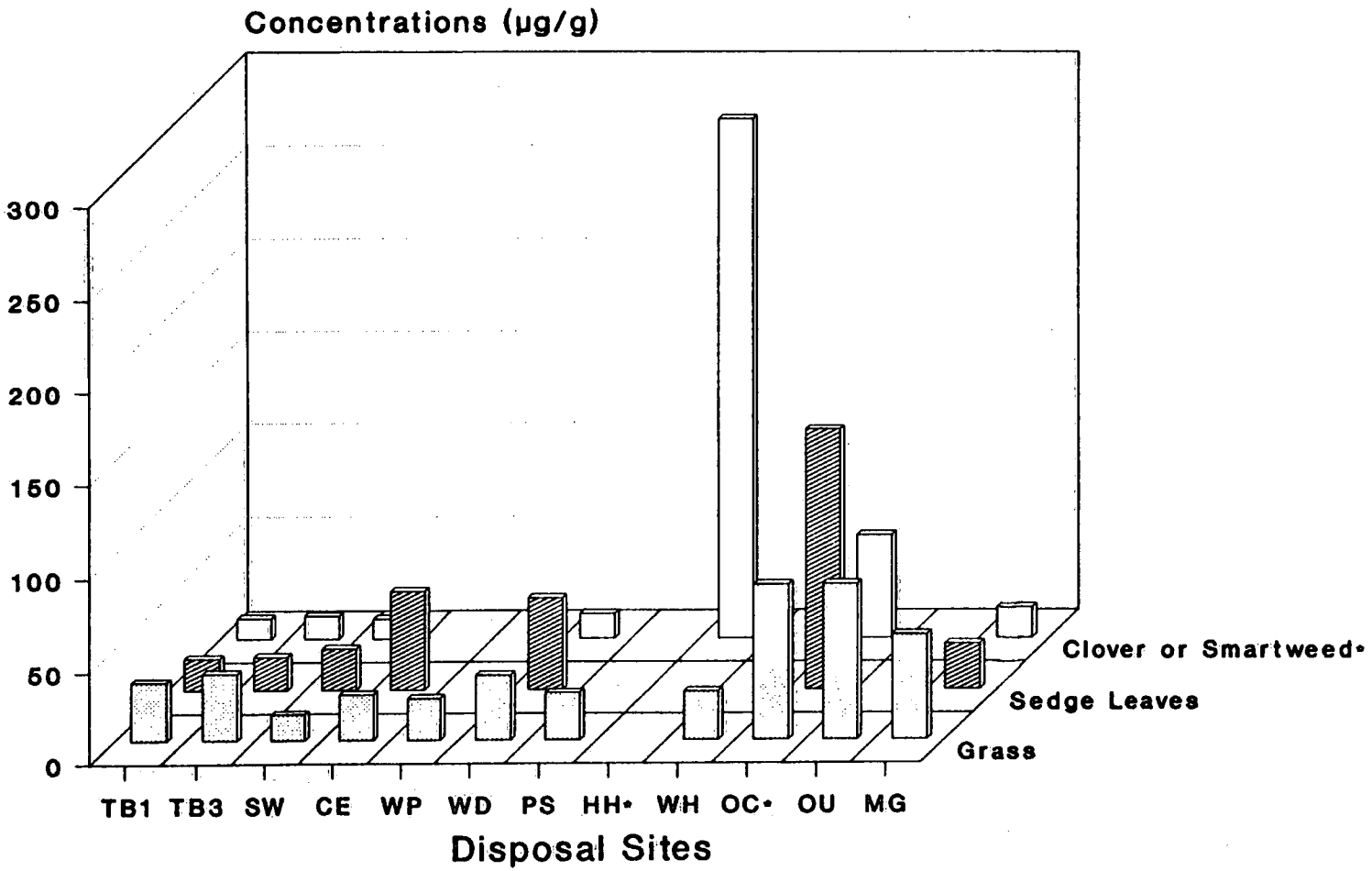


Fig 29. Cadmium concentrations in vegetation.



Upper normal limit in urban foliage
• 3 µg/g

Fig. 30. Zinc concentrations in vegetation.



Upper normal limit in urban foliage
• 250 µg/g

Fig 31a. PCB congener patterns in grass.

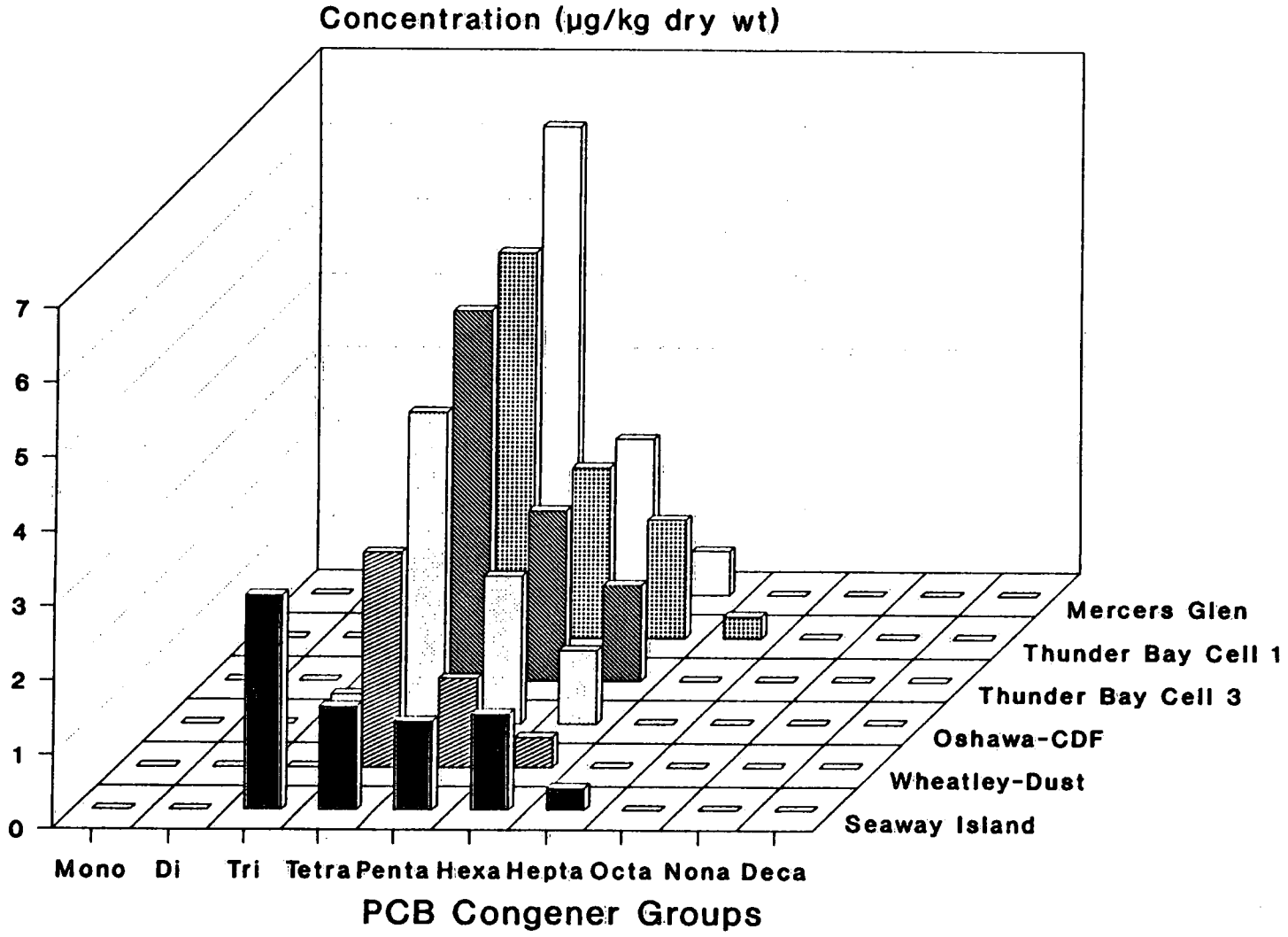


Fig 31b. PCB congener patterns in grass.

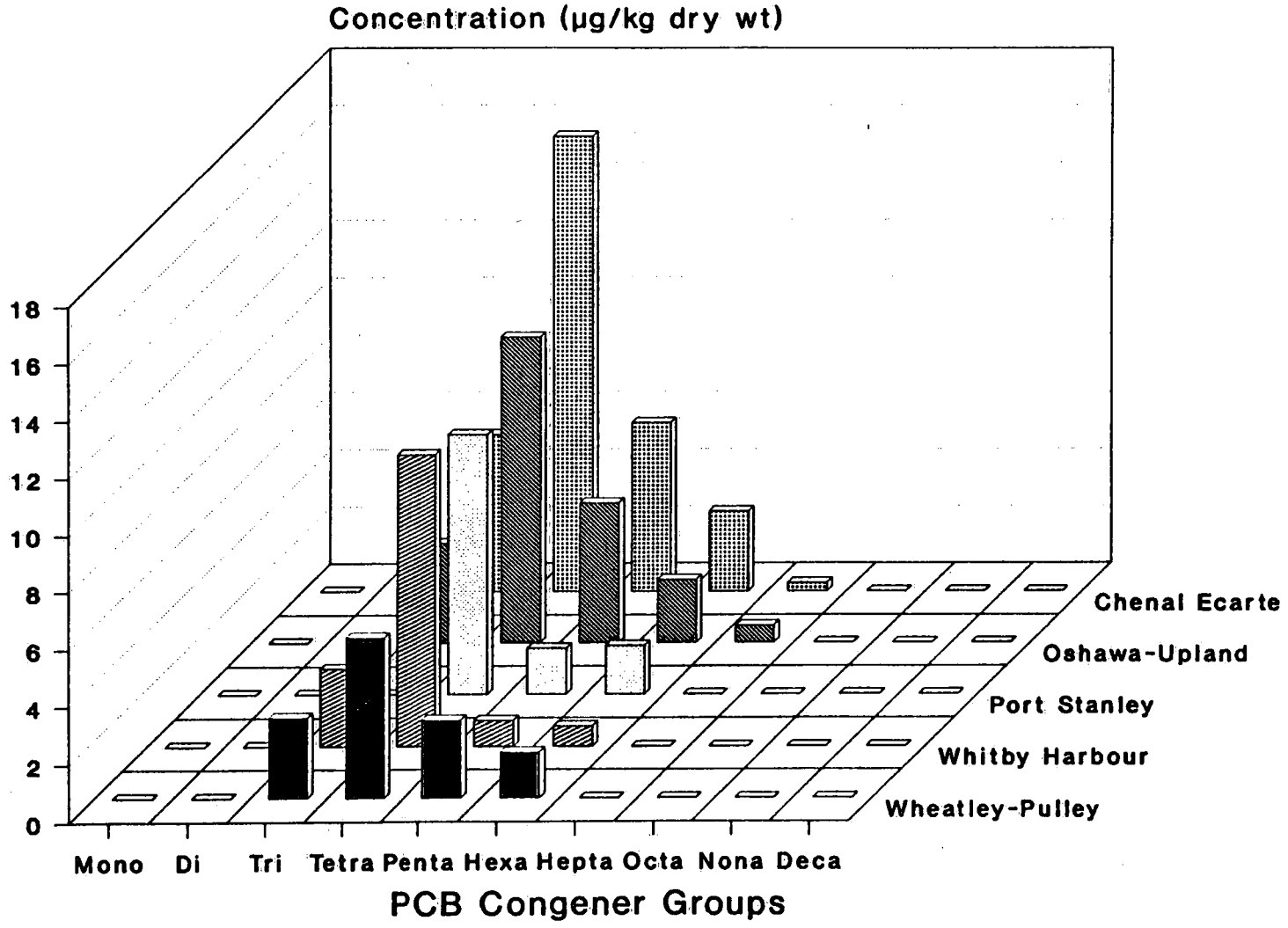


Fig. 32. PCB congener patterns in sedge leaves.

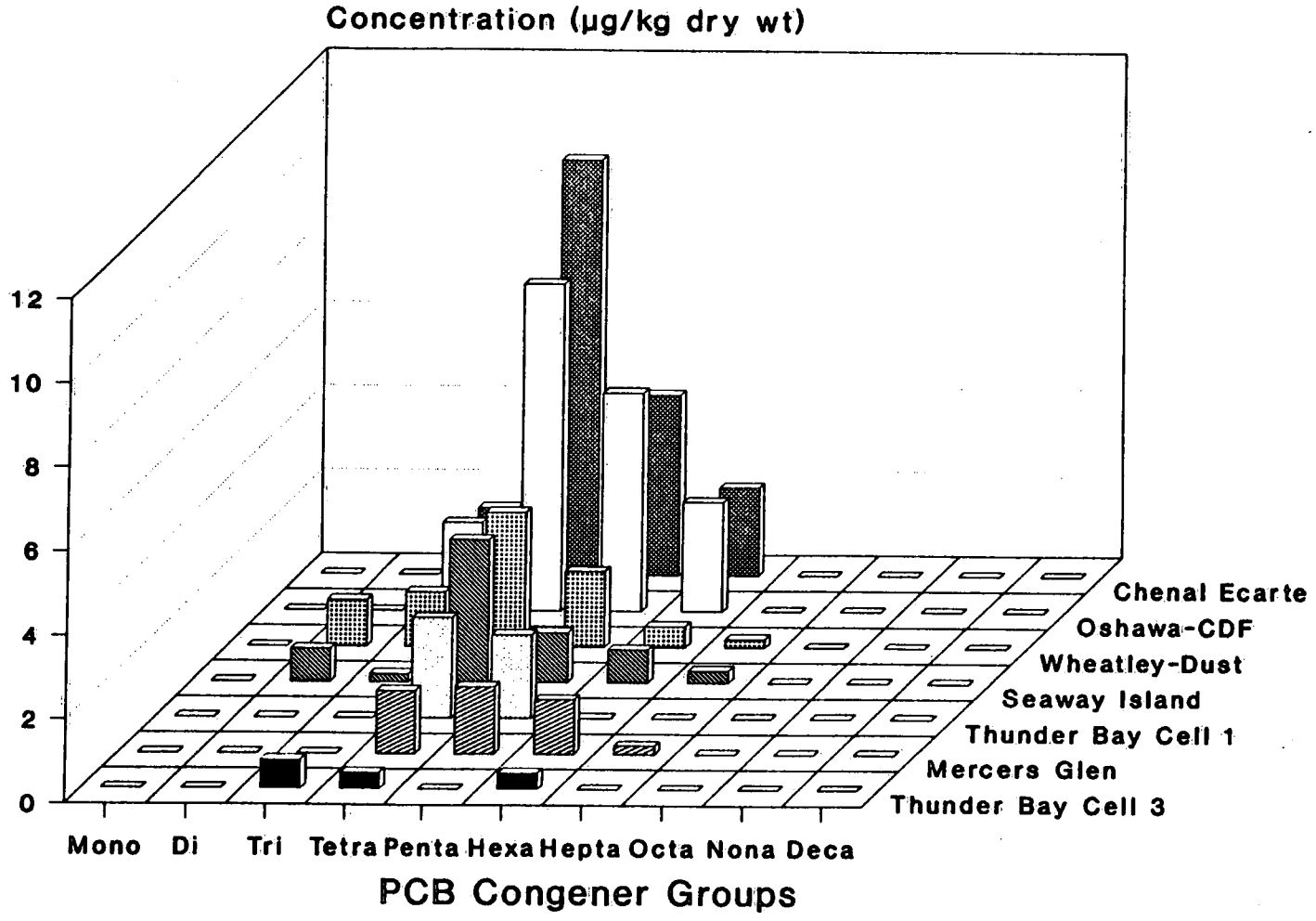
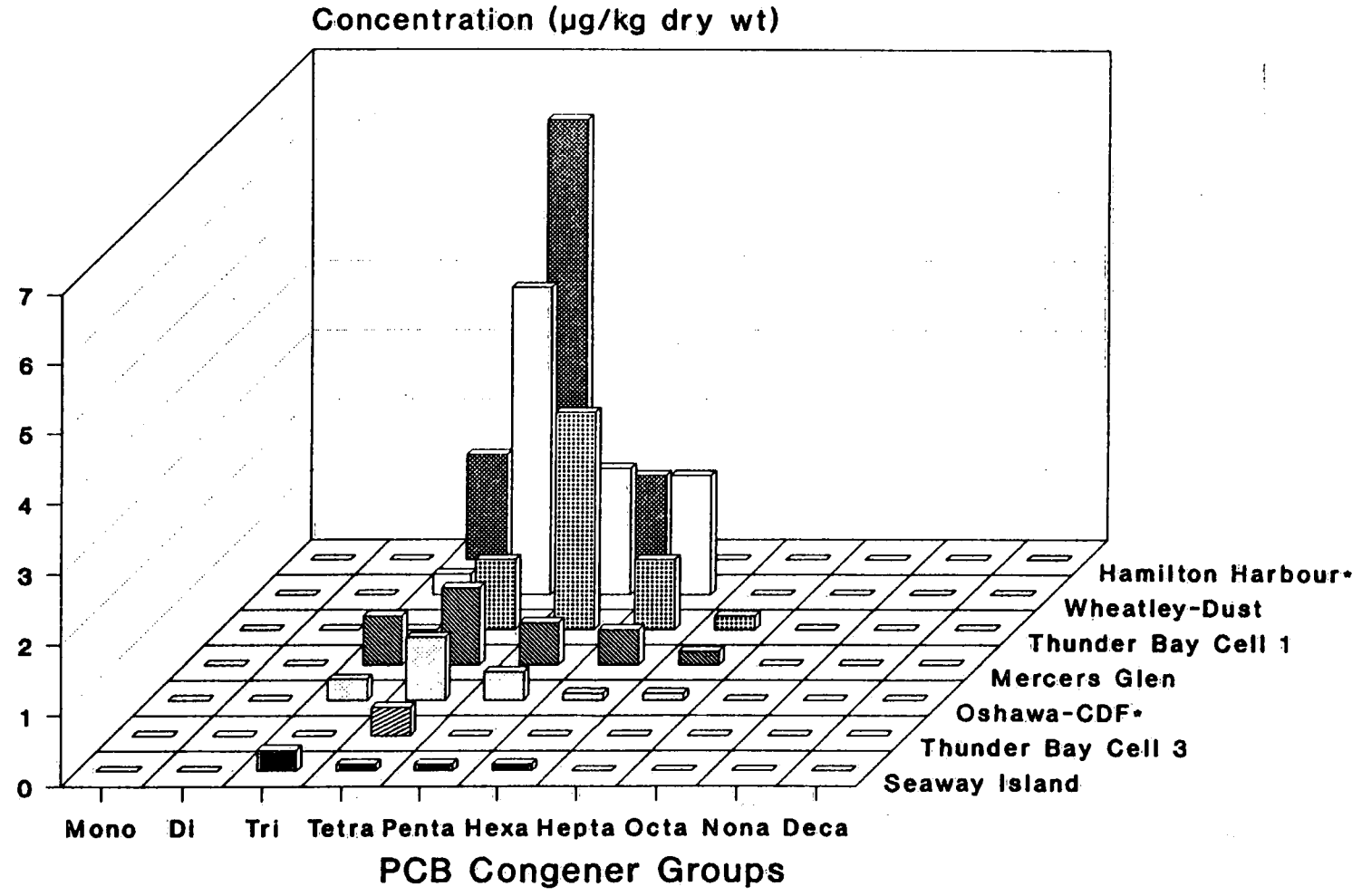


Fig. 33. PCB congener patterns in clover or smartweed.



* -Smartweed

Fig. 34. PCB congener patterns in leaf litter.

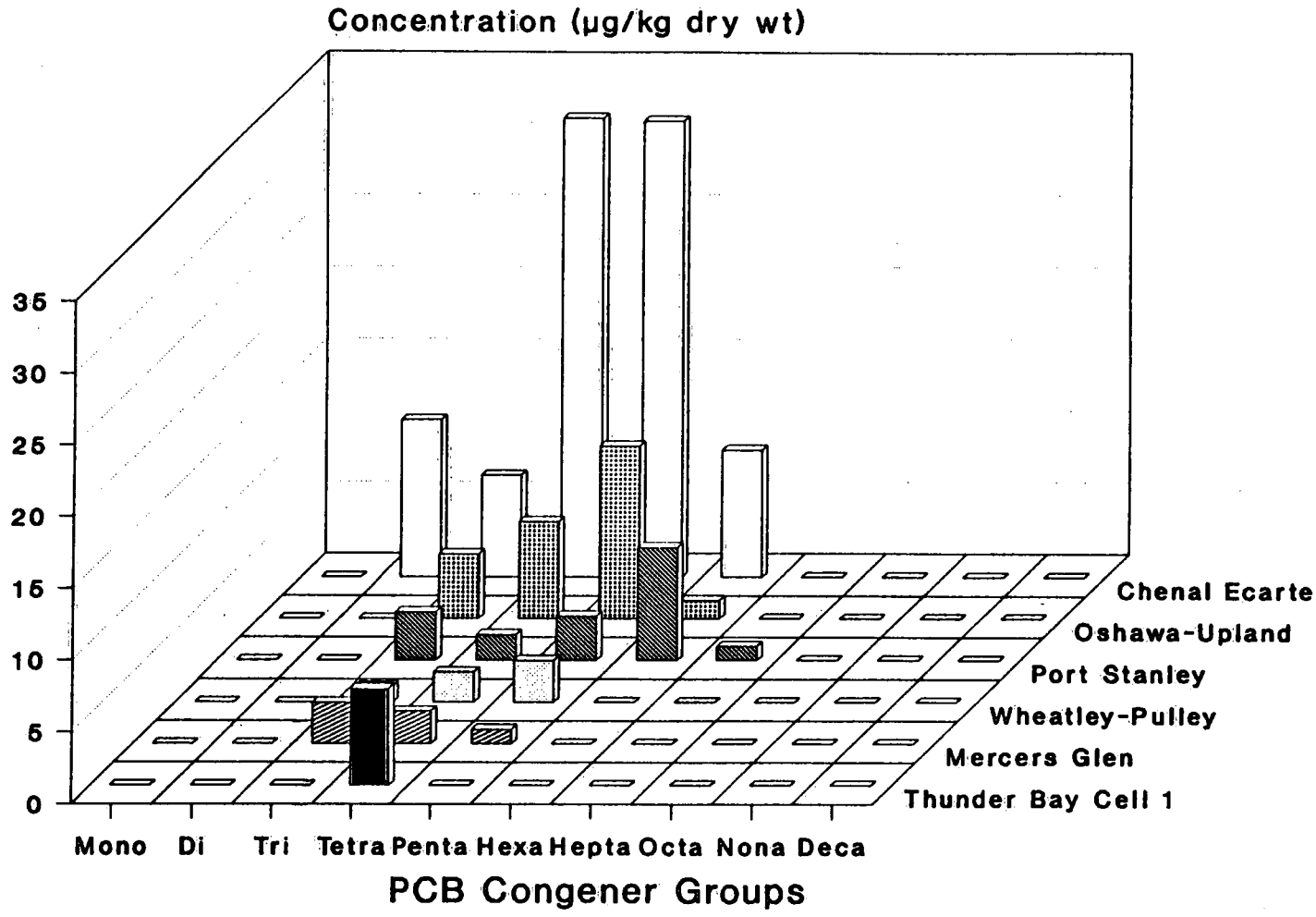


Fig. 35. PCB congener patterns in earthworms.

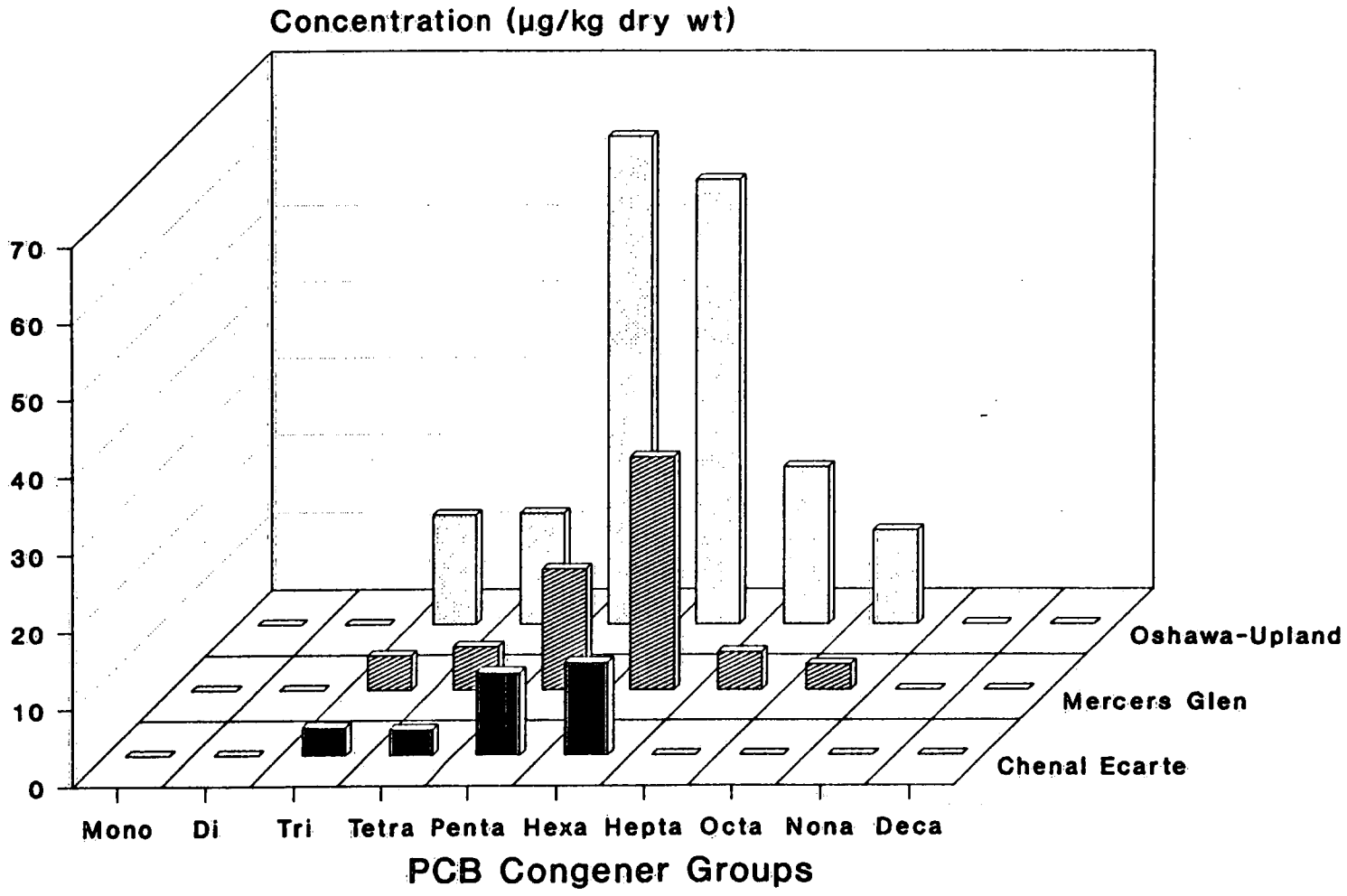


Table 1. Ontario Ministry of the Environment dredged material classification criteria (ug/g dry wt) (OMOE 1987).

Parameter	Open Water Disposal	Unrestricted Land Use	Restricted Land Use
Group 1A			
Cadmium	1	1.6	4
Lead	50	60	500
Mercury	0.3	0.5	0.5
PCBs	0.05	2	2
Group 1B			
Loss on Ignition (%)	6		
Oil & Grease	1500		
Total Phosphorus	1000		
Total Kjeldahl N	2000		
Ammonia	100		
Grain Size	-----Characteristics to be reported------		
Visual Discription	-----Characteristics to be reported------		
Group 2			
Arsenic	8	14	20
Chromium	25	120	120
Cobalt	50	20	25
Copper	25	100	100
Cyanide	0.1		
Iron	10000	35000	35000
Molybdenum		4	4
Nickel	25	32	60
Selenium		1.6	2
Silver	0.5		
Zinc	100	220	500

Table 2. Summary of chemical parameter concentration ranges (ug/g dry weight) in Public Works Canada pre-dredging sediment samples from each study site.

Chemical Parameters	Thunder Bay Cell 1	Thunder Bay Cell 3	Seaway Island	Chenal Ecarte	Wheatley Pulley	Wheatley Dust	Port Stanley	Hamilton Harbour	Whitby Harbour	Oshawa Upland	Toronto Harbour
Cadmium	0.3-0.8	--	--	--	--	--	5.4	2.5-4.1	--	4.7	--
Lead	8.5-23.3	13.7-22.0	--	--	<15	<15	73.0	8.3-244.2	73.0	32.0-55.0	175.0
Mercury	0.110-0.500	0.110-0.610	0.897	1.120	--	--	0.150	0.500-0.630	0.150	0.020-0.130	0.250
Total PCBs	0.07	--	--	0.33	1.80	0.68	--	0.05-7.60	0.18	0.07-1.27	0.23
Arsenic	0.6-1.4	4.0	--	--	9.1	6.5	0.7	2.3-9.8	4.5	2.8	--
Chromium	7.6-31.3	109.0-133.0	--	--	51.0	35.0	--	13.0-387.8	155.0	27.3-129.0	47.0
Copper	25.7-44.8	43.7-44.0	7.2	--	66.0	57.0	34.0	11.7-107.3	83.0	9.7-14.6	45.0
Nickel	9.3-45.7	33.0-39.0	--	--	15.0	14.0	--	22.0-49.0	82.0	27.0-79.0	18.0
Zinc	41.0-80.3	9.7-93.0	26.4	--	210.0	470.0	132.0	99.3-1442.7	207.0	49.2-124.0	230.0
LOI (%)	3.5-5.9	3.4-5.3	1.4	2.5	19.4	15.8	4.4	9.0	18.2	1.3-5.9	7.1
Oil & Grease	123-1499	108-820	--	290	9790	9330	--	7942	1740	997-1560	4200
Total P.	406-814	500-799	--	220	--	--	860	644-3015	860	448-1060	1188
TKN	495-1650	187-600	--	330	--	--	--	274-6413	3500	617-1590	1700

Table 3. Mercury concentrations (ug/g) in biological samples from disposal areas at Seaway Island in 1983.

Sample	Cell A	Cell B	Cell C
Phragmites communis	0.060	<0.010	0.030
Populus deltoides	--	0.010	--
White Clover and Rye	0.070	<0.010	0.050
Potamogeton richardsonii	0.090	0.060	0.080
Potamogeton filiformis	0.030	--	--
Chara sp.	0.100	0.100	0.100
Amphipoda	--	0.032	--
Odonata	--	--	0.026
Muskrat -Liver	0.010	0.120	0.008
Muskrat -Muscle	0.012	0.076	0.005
Voles -Whole	--	0.090	0.040

Table 4. List of samples collected at each dredge disposal site.

Thunder Bay Cell 1 (Capped)	Thunder Bay Cell 3 (Uncapped)	Seaway Island
grass	grass	grass
leaf litter	leaf litter	leaf litter
clover	clover	clover
sedge	sedge	sedge
soil (3)	soil (3)	soil (3)
		worms

Chenal Ecarte	Wheatley Pulley (Capped)	Wheatley Dust (Uncapped)
grass	grass	grass
leaf litter	leaf litter	leaf litter
sedge	soil	clover
soil (3)		sedge
worms		soil (3)

Port Stanley	Hamilton Harbour	Whitby Harbour
grass	smartweed	grass
leaf litter	soil	leaf litter
soil		soil
		worms

Oshawa Upland	Oshawa CDF	Mercers Glen
grass	smartweed	grass
leaf litter	grass	leaf litter
sediment	sedge	clover
worms	soil (3)	sedge
		soil (3)
		worms

Table 5. Ontario Ministry of the Environment clean-up guidelines for soils with criteria for proposed land use (Rinne 1988).

Parameter*	Agricultural/Residential/ Parkland		Commercial/Industrial	
	Soil Texture			
	Medium & Fine	Coarse+	Medium & Fine	Coarse+
pH (recommended range)	6-8	6-8	6-8	6-8
EC (mS/cm)++	2	2	4	4
SAR+++	5	5	12	12
Arsenic	25	25	50	40
Cadmium	4	3	8	6
Chromium (VI)	10	8	10	8
Chromium (total)	1000	750	1000	750
Cobalt	50	40	100	80
Copper	200	150	300	225
Lead	500	375	1000	750
Mercury	1	0.8	2	1.5
Molybdenum	5	5	40	40
Nickel	200	150	200	150
Nitrogen (%)	0.5	0.5	0.6	0.6
Oil & Grease (%)	1	1	1	1
Selenium	2	2	10	10
Silver	25	20	50	40
Zinc	800	600	800	600
Antimony**	25	20	50	40
Barium**	1000	750	2000	750
Beryllium**	5	4	10	8
Vanadium**	250	200	250	200

* All units in ug/g dry weight, unless otherwise stated.

** These guidelines are tentative, with the exception of the agricultural guideline.

\+ Defined as greater than 70 % sand and less than 17 % organic matter.

++ EC -electrical conductivity (saturation extract).

+++ SAR -sodium adsorption ratio

Table 6. Contaminant guidelines representing upper limits of normal concentrations (ug/g dry wt) of selected parameters in soil, foliage and grass in urban and rural Ontario (OMOE 1986).

Parameter	Soil (0-5 cm)		Foliage+		Grass+
	Urban	Rural	Urban	Rural	Rural
Arsenic	20	10	2	0.5, 2*	a, 8*
Cadmium	4	3, 4*	3	1	0.5, 2*
Chromium	50	50	8	8	5
Cobalt	25**	25	2**	2	2, 8*
Copper	100	60	20	20	7, 20*
Lead	500	150	60	30	20
Mercury	0.5	0.15	0.3	0.1	b
Nickel	60**	60	7	5, 30*	5, 25*
Vanadium	70	70	5**	5	6
Zinc	500	500	250**	250	40, 100*

\+ Vegetation unwashed.

* The first value is based on mainly Southern Ontario data while the second is based on NE Region data.

** Rural results higher than urban results -urban guideline based on rural results.

a 50 % or more of results < detection limit -guideline not established.

b Sample size insufficient (< 30) to establish guideline.

Note -These guidelines are approximately equal to the mean of the data plus three standard deviations.

Table 7. Maximum tolerable levels of dietary minerals for domestic livestock in comparison with levels in forages (Chaney 1982).

Metal	Level in Plant Foliage (ug/g dry foliage)		Maximum Level Chronically Tolerated (ug/g dry diet)			
	Normal	Phytotoxic	Cattle	Sheep	Swine	Chicken
As	0.01-1	3-10	50	50	50	50
Cd	0.01-1	5-70	0.5	0.5	0.5	0.5
Cr	0.1-1	20	3000	3000	3000	3000
Co	0.01-0.3	25-100	10	10	10	10
Cu	3-20	25-40	100	25	250	300
Fe	30-300	--	1000	500	3000	1000
Mn	15-150	400-2000	1000	1000	400	2000
Ni	0.1-5	50-100	50	50	100	300
Pb	2-5	--	30	30	30	30
Se	0.1-2	100	2	2	2	--
V	0.1-1	10	50	50	10	10
Zn	15-150	500-1500	500	300	1000	1000

Table 8. Summary of particle size distribution and percent loss on ignition of bulk sediment samples from disposal sites.

Dredge Disposal Site	Particle Size Distribution % Coarse > 63 um (sand & gravel)	% Fine < 63 um (silt & clay)	Percent Loss on Ignition
Thunder Bay Cell 1	84.3	15.7	1.9
Thunder Bay Cell 3	57.6	42.4	10.8
Seaway Island	92.5	7.5	2.9
Chenal Ecarte	94.4	5.6	1.8
Wheatley-Pulley	94.1	5.9	2.7
Wheatley-Dust	96.6	3.4	2.8
Port Stanley	97.8	2.2	1.7
Hamilton Harbour	83.9	16.1	7.8
Whitby Harbour	94.4	5.6	2.2
Oshawa-CDF	87.6	12.4	2.3
Oshawa-Upland	74.5	25.5	4.9
Mercers Glen	93.8	6.2	2.2
Mean	87.6	12.4	3.7

Table 9. Percentage (%) of major elements in bulk sediments, and fine and coarse sediment fractions.

Element	Thunder Bay Cell 1	Thunder Bay Cell 3	Seaway Island	Chenal Ecarte	Wheatley Pulley	Wheatley Dust	Port Stanley	Hamilton Harbour	Whitby Harbour	Oshawa CDF	Oshawa Upland	Mercers Glen
Fine Fraction												
SiO2	64.7	64.4	67.2	61.0	69.5	62.0	58.7	63.0	56.6	56.8	59.3	62.4
Al2O3	12.0	12.1	10.6	10.7	15.1	12.6	10.2	10.1	9.0	9.8	8.3	13.6
Fe2O3	7.5	7.3	3.3	3.3	5.2	4.5	3.2	6.1	3.2	2.7	2.4	4.8
MgO	4.8	5.4	3.9	5.8	1.4	4.0	4.4	2.9	2.9	2.5	2.6	3.6
CaO	5.7	5.6	10.9	14.8	3.8	11.6	18.7	12.2	23.5	23.8	22.6	10.0
Na2O	2.0	1.8	0.8	0.7	0.9	0.8	1.0	1.1	1.2	1.5	1.8	0.6
K2O	2.1	2.3	2.4	2.9	2.4	3.4	2.9	2.6	2.5	2.1	2.2	4.0
TiO2	0.9	0.7	0.6	0.5	0.9	0.6	0.5	0.6	0.6	0.4	0.4	0.7
MnO	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2
P2O5	0.2	0.2	0.3	0.2	0.7	0.5	0.3	1.3	0.5	0.4	0.4	0.2
Coarse Fraction												
SiO2	62.2	52.8	81.1	74.0	70.7	36.0	59.8	43.7	49.4	55.2	36.7	53.8
Al2O3	11.4	10.6	6.6	6.7	5.4	8.2	8.4	9.2	5.7	7.2	5.4	11.8
Fe2O3	6.1	7.2	1.5	1.6	1.5	3.9	2.1	6.5	1.1	1.9	2.3	4.5
MgO	2.6	3.8	2.1	2.6	0.5	2.8	2.2	2.0	1.0	1.3	1.5	2.5
CaO	4.2	4.5	4.9	7.2	1.2	10.1	10.4	8.5	9.9	12.5	12.7	8.1
Na2O	2.5	1.7	1.1	1.1	1.5	0.7	1.5	0.8	2.3	2.1	1.5	0.7
K2O	1.6	2.0	1.7	1.9	1.4	3.1	2.2	2.5	1.8	1.9	1.8	3.5
TiO2	0.6	0.7	0.2	0.2	0.2	0.5	0.2	0.5	0.1	0.2	0.3	0.6
MnO	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1
P2O5	0.2	0.2	0.1	0.1	0.1	0.2	0.2	1.4	0.2	0.2	0.3	0.2
Bulk Sediment												
SiO2	62.6	57.7	80.0	73.3	70.6	36.9	59.8	46.8	49.8	55.4	42.5	54.4
Al2O3	11.5	11.2	6.9	6.9	6.0	8.4	8.5	9.4	5.9	7.5	6.1	11.9
Fe2O3	6.3	7.3	1.6	1.7	1.8	3.9	2.1	6.4	1.2	2.0	2.4	4.5
MgO	2.9	4.4	2.3	2.8	0.5	2.8	2.2	2.1	1.1	1.5	1.8	2.6
CaO	4.4	5.0	5.3	7.7	1.4	10.2	10.6	9.1	10.7	13.9	15.2	8.2
Na2O	2.4	1.7	1.1	1.0	1.5	0.7	1.5	0.8	2.3	2.0	1.6	0.7
K2O	1.7	2.1	1.7	2.0	1.5	3.1	2.2	2.5	1.8	1.9	1.9	3.5
TiO2	0.7	0.7	0.2	0.2	0.3	0.5	0.2	0.5	0.1	0.3	0.3	0.6
MnO	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.1
P2O5	0.2	0.2	0.1	0.1	0.1	0.2	0.2	1.4	0.2	0.3	0.3	0.2

Table 10. Mean sediment metal concentrations (ug/g dry wt) for the bulk sediments, and fine and coarse sediment fracti

Metals	Thunder Bay Cell 1	Thunder Bay Cell 3	Seaway Island	Chenal Ecarte	Wheatley Pulley	Wheatley Dust	Port Stanley	Hamilton Harbour	Whitby Harbour	Oshawa CDF	Oshawa Upland	Mercers Glen
Bulk Sediment:												
Arsenic	3.3	10.4	7.9	8.9	6.1	7.1	8.0	12.9	2.1	1.9	3.5	14.5
Cadmium	0.8	1.1	0.6	0.5	0.5	0.5	0.4	5.7	0.5	0.7	0.8	0.5
Cobalt	15.4	15.1	4.0	4.9	2.3	11.1	6.1	15.4	1.6	4.9	6.0	14.5
Chromium	103.7	111.9	52.6	54.1	51.8	76.1	54.3	407.2	47.3	67.4	109.9	76.4
Copper	21.4	65.5	3.4	16.4	1.5	18.4	14.4	201.1	3.3	9.9	19.2	18.8
Nickel	43.8	52.3	11.9	17.1	9.5	35.0	19.4	68.5	8.5	43.2	100.1	34.0
Lead	11.8	19.6	19.8	34.3	15.5	14.9	15.4	435.9	15.7	26.9	76.6	45.7
Vanadium	128.7	123.5	29.1	35.7	30.1	84.1	35.6	82.5	20.7	34.5	38.8	84.0
Zinc	113.4	167.1	60.1	145.6	47.2	90.2	60.3	2481.5	31.8	96.6	193.6	130.2
Mercury	0.220	0.990	0.020	1.100	0.030	0.020	0.010	0.690	0.020	0.040	0.090	0.040
Fine Fraction: (< 63 um)												
Arsenic	4.7	11.0	6.3	8.0	8.0	8.7	8.0	7.0	4.0	8.5	5.0	6.7
Cadmium	0.5	0.8	0.5	0.8	0.8	0.2	0.5	3.1	0.7	0.4	0.8	0.2
Cobalt	17.7	18.0	16.3	4.0	7.0	15.0	10.0	12.0	12.0	11.5	3.0	6.7
Chromium	118.0	110.0	72.7	73.0	80.0	108.3	68.0	220.0	69.0	91.5	95.0	82.3
Copper	39.7	58.0	21.0	40.0	25.0	30.7	30.0	97.0	26.0	23.5	14.0	31.7
Nickel	48.3	47.3	34.7	35.0	33.0	34.7	37.0	40.0	33.0	66.0	71.0	34.0
Lead	11.0	16.3	29.0	40.0	55.0	13.0	31.0	221.0	27.0	33.5	52.0	56.7
Vanadium	159.3	116.0	67.3	65.0	95.0	87.7	60.0	64.0	66.0	52.5	41.0	84.0
Zinc	120.7	152.3	86.0	87.5	145.0	236.7	73.0	1392.0	79.0	122.0	134.0	132.7
Mercury	0.330	0.990	0.080	2.800	0.180	0.030	0.030	0.400	0.060	0.070	0.050	0.040
Coarse Fraction: (> 63 um)												
Arsenic	3.0	10.0	8.0	9.0	6.0	7.0	8.0	14.0	2.0	1.0	3.0	15.0
Cadmium	0.8	1.4	0.6	0.4	0.5	0.5	0.4	6.2	0.5	0.7	0.8	0.5
Cobalt	15.0	13.0	3.0	5.0	2.0	11.0	6.0	16.0	1.0	4.0	7.0	15.0
Chromium	101.0	113.0	51.0	53.0	50.0	75.0	54.0	443.0	46.0	64.0	115.0	76.0
Copper	18.0	71.0	2.0	15.0	<1.0	18.0	14.0	221.0	2.0	8.0	21.0	18.0
Nickel	43.0	56.0	10.0	16.0	8.0	35.0	19.0	74.0	7.0	40.0	110.0	34.0
Lead	12.0	22.0	19.0	34.0	13.0	15.0	15.0	477.0	15.0	26.0	85.0	45.0
Vanadium	123.0	129.0	26.0	34.0	26.0	84.0	35.0	86.0	18.0	32.0	38.0	84.0
Zinc	112.0	178.0	58.0	149.0	41.0	85.0	60.0	2690.0	29.0	93.0	214.0	130.0
Mercury	0.200	1.000	0.017	1.000	0.020	0.018	0.010	0.740	0.014	0.034	0.100	0.042

Table 11. Concentrations of metals (ug/g dry wt) in unpooled replicate sediment and plant samples from Thunder Bay Cell 3, with means, standard deviations and percent variance.

Sample #	Sediment		Grass		Leaf Litter		Sedge Leaves			Sedge Seeds		Clover		
	Arsenic	Zinc	Lead	Zinc	Lead	Zinc	Lead	Zinc	Cadmium	Lead	Zinc	Lead	Zinc	Cadmium
1	13	146	<1	29	4	47	1	39	0.32	2	18	1	23	0.08
2	15	152	1	32	5	50	1	42	0.20	3	21	<1	25	0.20
3	14	147	<1	28	4	51	2	38	0.26	2	20	<1	24	0.22
4	16	144	<1	33	6	50	1	40	0.34	1	22	1	20	0.10
5	17	148	1	30	4	49	2	42	0.42	2	19	2	22	0.08
6	16	148	<1	28	5	52	1	38	0.24	2	20	1	24	0.24
7	13	153	<1	31	5	50	1	40	0.18	3	20	2	23	0.16
8	9	158	1	33	5	54				3	18			
9	13	151			4	49				2	22			
n	9	9	8	8	9	9	7	7	7	9	9	7	7	7
$\bar{X}$	14.0	149.7	0.7	30.5	4.7	50.2	1.3	39.9	0.28	2.2	20.0	1.1	23.0	0.15
S.D.	2.4	4.3	0.3	2.1	0.7	2.0	0.5	1.7	0.08	0.7	1.5	0.6	1.6	0.07
% var.	17.1	2.9	42.9	6.9	14.9	4.0	38.5	4.3	28.6	31.8	7.5	54.5	7.0	46.7

Table 12. PAH concentrations in fine sediment fraction, vegetation, leaf litter and earthworms (ug/kg dry wt).

PAHs	Thunder Bay Cell 1		Thunder Bay Cell 3	Seaway Island			Chenal Ecarte				
	Sediment*	Leaf Litter	Sediment**	Sediment	Leaf Litter	Earth-worms	Sediment	Grass	Sedge	Leaf Litter	Earth-worms
A Naphthalene	20	40	99	4	75	17	37	10	6	73	54
B Acenaphthylene	13	19	65	2	10	8	100	--	--	11	36
C Acenaphthene	2	--	11	1	--	--	5	--	--	--	16
D Fluorene	4	9	39	1	16	--	18	--	--	23	40
E Phenanthrene	80	61	283	3	69	27	220	--	8	100	150
F Anthracene	13	--	57	8	--	--	28	--	1	--	25
G Fluoranthene	89	24	277	25	65	26	180	--	--	23	95
H Pyrene	94	21	303	13	49	23	140	--	--	26	114
I Benzo(a)Anthracene	21	5	75	12	18	30	12	--	--	--	118
J Chrysene	24	10	102	20	35	14	130	--	--	5	100
K Benzo(b)- & Benzo(k)Fluoranthene	51	12	149	23	39	51	--	--	--	--	300
L Benzo(a)Pyrene	22	--	90	10	20	--	240	--	--	--	160
M Dibenzo(a,h)Anthracene	11	--	40	7	--	--	17	--	--	--	58
N Benzo(g,h,i)Perylene	--	--	9	2	--	--	15	--	--	--	0
O Indeno(1,2,3-cd)Pyrene	11	--	30	9	--	--	6	--	--	--	94
Total PAHs	455	201	1628	140	396	196	1148	10	15	261	1360

* Coarse Sediment Fraction

** Bulk Sediments

Table 12(cont). PAH concentrations in fine sediment fraction, vegetation, leaf litter and earthworms (ug/kg dry wt

PAHs	Wheatley Pulley Leaf Litter	Wheatley Dust		Port Stanley		Hamilton Harbour		Whitby Harbour	
		Sediment	Leaf Litter	Sediment	Leaf Litter	Sediment*	Smart-weed	Sediment	Earth-worms
Naphthalene	46	9	49	12	540	400	260	16	45
Acenaphthylene	170	10	8	8	46	460	78	3	12
Acenaphthene	25	3	--	2	68	110	18	1	--
Fluorene	88	1	13	8	150	170	73	4	30
Phenanthrene	600	29	47	120	440	750	410	10	44
Anthracene	49	3	--	7	--	450	44	22	--
Fluoranthene	1000	58	25	84	180	1800	460	56	42
Pyrene	850	37	18	56	150	1600	270	32	33
Benzo(a)Anthracene	350	--	5	--	90	1100	52	38	19
Chrysene	520	17	15	40	170	1100	130	53	19
Benzo(b)- & Benzo(k)Fluoranthene	630	33	--	62	140	2400	43	35	9
Benzo(a)Pyrene	270	35	--	67	64	1700	7	26	5
Dibenzo(a,h)Anthracene	53	--	--	--	22	780	--	12	--
Benzo(g,h,i)Perylene	77	--	--	--	26	250	8	3	8
Indeno(1,2,3-cd)Pyrene	150	--	--	--	30	730	13	16	13
Total PAHs	4878	235	180	465	2116	13800	1866	326	279

Table 12(cont). PAH concentrations in fine sediment fraction, vegetation, leaf litter and earthworms (ug/kg dry wt).

PAHs	Oshawa CDF	Oshawa Upland			Mercers Glen		
	Sediment	Sediment	Leaf Litter	Earth-worms	Sediment	Leaf Litter	Earth-worms
Naphthalene	8	10	74	170	3	46	29
Acenaphthylene	38	40	18	58	18	10	21
Acenaphthene	4	3	8	14	2	--	10
Fluorene	16	10	42	25	9	17	26
Phenanthrene	140	110	95	150	130	61	73
Anthracene	18	15	--	--	11	--	--
Fluoranthene	4	120	43	120	180	55	120
Pyrene	4	93	33	110	110	44	100
Benzo(a)Anthracene	4	10	14	89	--	16	55
Chrysene	61	81	22	83	130	31	70
Benzo(b)- & Benzo(k)Fluoranthene	--	160	27	320	--	31	220
Benzo(a)Pyrene	130	140	14	120	--	8	38
Dibenzo(a,h)Anthracene	17	4	--	--	35	--	--
Benzo(g,h,i)Perylene	17	7	--	--	20	8	--
Indeno(1,2,3-cd)Pyrene	3	5	--	--	3	13	--
Total PAHs	463	808	390	1259	652	339	762

Table 13. Chlorobenzenes and organochlorines (ug/kg dry wt) in fine sediment fraction, vegetation, leaf litter and earthworms.

Compounds	Thunder Bay Cell 1					Thunder Bay Cell 3				Seaway Island					
	Sediment*	Grass	Clover	Sedge	Leaf Litter	Sediment**	Grass	Clover	Sedge	Sediment	Grass	Clover	Sedge	Leaf Litter	Earth-worms
CHLOROBENZENES:															
1,3,5-Trichlorobenzene	--	--	--	--	--	3.6	--	--	--	0.1	--	--	--	--	--
1,2,4-Trichlorobenzene	0.3	--	--	--	--	4.1	--	--	--	0.4	--	--	--	--	3.2
1,2,3-Trichlorobenzene	--	--	--	--	--	0.2	--	--	--	0.1	--	--	--	--	--
1,2,3,5 + 1,2,4,5-Tetrachlorobenzene	--	--	--	--	--	3.3	--	--	--	--	--	--	--	--	6.7
1,2,3,4-Tetrachlorobenzene	--	--	--	--	--	0.3	--	--	--	0.1	--	--	--	--	--
Pentachlorobenzene	0.1	--	--	--	--	0.9	--	--	--	0.3	0.1	--	0.1	--	2.6
Hexachlorobenzene	0.2	0.1	0.1	0.1	--	2.0	--	--	0.2	1.4	0.1	0.1	--	--	1.8
ORGANOCHLORINES:															
Hexachlorobutadiene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
a-Hexachlorocyclohexane	--	--	0.4	0.2	--	--	0.5	0.2	0.4	--	0.6	0.3	0.1	--	1.8
Lindane	--	0.1	0.1	0.1	--	0.7	0.2	0.1	0.1	--	0.2	0.1	0.1	--	--
Heptachlor	--	--	--	--	--	2.1	--	--	--	--	--	--	--	--	--
Heptachlor Epoxide	--	0.1	0.2	0.1	--	--	0.2	0.1	0.3	--	0.9	0.5	0.3	--	--
Octachlorostyrene	--	--	--	--	--	0.2	--	--	--	0.2	--	--	0.1	--	--
g-Chlordane	--	0.2	0.2	--	--	1.5	0.1	--	0.3	0.2	0.8	0.1	0.4	--	--
p,p'-DDE	--	--	--	--	--	3.8	--	--	--	--	--	--	--	--	6.6
p,p'-DDD	--	0.2	--	--	--	1.6	--	--	--	--	0.6	0.1	--	--	--
p,p'-DDT	--	--	0.3	--	--	--	0.2	--	0.2	0.9	2.1	0.5	0.9	--	--
Mirex	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methoxychlor	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexachloroethane	--	--	--	0.2	--	--	--	--	--	--	--	--	--	--	--
Pentachloroanisole	--	0.1	0.1	0.9	--	--	0.1	0.1	0.1	--	0.4	0.2	0.1	--	--
a-Chlordane	--	0.3	0.5	0.5	--	--	0.3	--	--	--	1.7	0.1	0.6	--	--
Dieldrin	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL CHLORINATED DIPHENYL ETHERS:	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

-- below detection limit < 0.1
* Coarse Sediment Fraction
** Bulk Sediment

Table 13 (cont)

Compounds	Hamilton Harbour		Whitby Harbour				Oshawa CDF				Oshawa Upland			
	Sediment*	Smartweed	Sediment	Grass	Leaf Litter	Earth-worms	Sediment	Grass	Sedge	Smart-weed	Sediment	Grass	Leaf Litter	Earth-worms
CHLOROBENZENES:														
1,3,5-Trichlorobenzene	3.9	--	0.2	--	--	--	0.3	--	--	--	--	--	--	--
1,2,4-Trichlorobenzene	15.0	--	0.3	0.5	0.6	--	0.8	--	--	--	3.9	--	--	4.9
1,2,3-Trichlorobenzene	0.6	--	--	--	--	--	--	--	--	--	--	--	--	--
1,2,3,5 + 1,2,4,5-Tetrachlorobenzene	--	--	--	--	0.5	--	1.0	--	--	--	0.1	--	--	--
1,2,3,4-Tetrachlorobenzene	0.7	--	--	0.2	--	1.7	0.5	--	--	--	--	0.2	1.1	3.8
Pentachlorobenzene	1.5	--	0.3	0.3	0.7	2.4	0.7	--	0.3	--	--	0.3	0.0	5.3
Hexachlorobenzene	2.8	--	0.4	0.3	0.6	0.8	2.5	0.2	0.3	0.2	0.3	0.5	0.5	3.1
ORGANOCHLORINES:														
Hexachlorobutadiene	--	--	--	--	--	--	--	--	--	--	--	--	--	--
a-Hexachlorocyclohexane	--	--	--	0.5	--	--	--	0.5	--	0.2	0.3	0.6	--	--
Lindane	3.2	--	--	0.1	--	--	--	--	0.1	--	--	0.8	--	--
Heptachlor	--	--	--	--	--	--	--	--	--	--	--	0.6	--	--
Heptachlor Epoxide	--	--	--	0.1	--	--	--	--	0.2	--	--	0.2	--	--
Octachlorostyrene	1.3	--	--	--	--	--	0.3	--	--	--	0.3	--	--	--
g-Chlordane	--	--	--	0.5	--	--	--	1.3	0.4	0.1	2.1	0.1	--	--
p,p'-DDE	--	--	20.0	--	3.0	4.4	4.6	--	--	--	1.1	--	--	15.0
p,p'-DDD	--	--	0.9	0.2	1.3	--	0.7	--	0.4	--	0.4	--	--	--
p,p'-DDT	--	--	2.8	0.3	3.4	--	1.5	1.0	0.8	0.3	--	1.1	--	--
Mirex	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Methoxychlor	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hexachloroethane	--	--	--	--	--	--	--	0.1	--	--	--	--	--	--
Pentachloroanisole	--	--	--	--	--	--	--	0.1	0.4	0.1	--	0.3	--	--
a-Chlordane	--	--	--	0.6	--	--	--	1.1	0.9	0.2	--	0.2	--	--
Dieldrin	--	--	--	--	--	--	--	--	--	--	--	--	--	--
TOTAL CHLORINATED DIPHENYL ETHERS:	--	--	100.0	40.0	39.0	310.0	--	--	--	--	--	--	--	--

-- below detection limit < 0.1
* Coarse Sediment Fraction
** Bulk Sediment

Table 13 (cont)

Compounds	Chenal Ecarte					Wheatley Pulley		Wheatley Dust					Port Stanley		
	Sediment	Grass	Sedge	Leaf Litter	Earth-worms	Grass	Leaf Litter	Sediment	Grass	Sedge	Clover	Leaf Litter	Sediment	Grass	Leaf Litter
CHLOROBENZENES:															
1,3,5-Trichlorobenzene	2.0	--	3.1	0.6	3.8	--	--	--	--	--	--	0.0	--	--	--
1,2,4-Trichlorobenzene	1.6	--	1.9	0.8	--	--	--	--	--	--	--	0.0	--	--	--
1,2,3-Trichlorobenzene	--	--	--	--	--	--	--	--	--	--	--	0.0	--	--	--
1,2,3,5 + 1,2,4,5-Tetrachlorobenzene	6.8	--	1.4	0.9	6.3	--	--	--	--	--	--	0.0	--	--	--
1,2,3,4-Tetrachlorobenzene	--	0.2	--	--	2.1	0.1	0.4	--	0.1	0.3	0.2	0.0	--	--	0.8
Pentachlorobenzene	--	0.9	2.0	0.6	6.3	0.3	0.9	0.5	--	0.1	0.3	0.0	--	--	--
Hexachlorobenzene	425.0	0.8	28.0	14.0	57.0	--	0.3	--	0.3	--	0.1	0.0	0.1	0.3	0.4
ORGANOCHLORINES:															
Hexachlorobutadiene	--	0.3	5.7	0.7	3.7	--	--	--	--	--	--	0.0	--	--	--
a-Hexachlorocyclohexane	--	0.2	0.4	--	--	--	--	--	0.2	0.2	0.4	0.0	--	0.6	--
Lindane	--	0.6	0.4	--	--	0.6	--	--	--	0.1	0.3	0.0	--	0.4	--
Heptachlor	--	--	--	--	--	0.2	--	--	--	--	--	0.0	--	--	--
Heptachlor Epoxide	--	0.4	0.3	--	--	0.4	--	--	--	0.4	0.3	0.0	--	0.3	--
Octachlorostyrene	95.2	1.0	5.1	1.5	8.7	--	--	--	--	--	--	0.0	0.1	--	--
g-Chlordane	1.7	1.1	0.8	0.5	--	0.9	--	1.0	0.8	0.5	0.8	0.0	0.4	0.1	--
p,p'-DDE	0.7	1.5	3.1	8.6	--	--	1.6	1.5	--	--	--	0.0	0.5	--	6.1
p,p'-DDD	1.4	0.3	0.4	--	--	0.1	5.9	--	--	0.1	0.1	0.0	--	0.5	--
p,p'-DDT	1.1	1.6	--	3.0	--	0.5	--	11.0	0.5	0.9	1.0	0.0	--	1.3	--
Mirex	--	--	--	--	--	--	--	--	--	--	--	0.0	--	--	--
Methoxychlor	--	--	--	--	--	--	--	--	--	--	--	0.0	--	--	--
Hexachloroethane	--	--	0.5	--	--	--	--	--	0.1	--	--	0.0	--	--	--
Pentachloroanisole	--	0.6	0.6	--	--	1.1	--	--	0.5	0.2	0.4	0.0	--	--	--
a-Chlordane	--	1.6	0.4	--	--	1.5	--	--	0.6	0.9	0.7	0.0	--	--	--
Dieldrin	--	--	--	--	--	--	--	--	--	--	--	0.0	--	--	--
TOTAL CHLORINATED DIPHENYL ETHERS:	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

-- below detection limit < 0.1
* Coarse Sediment Fraction
** Bulk Sediment

Table 13 (cont)

Compounds	Mercers Glen					
	Sediment	Grass	Clover	Sedge	Leaf Litter	Earth-worms
CHLOROBENZENES:						
1,3,5-Trichlorobenzene	--	--	--	--	--	--
1,2,4-Trichlorobenzene	--	--	--	--	--	3.5
1,2,3-Trichlorobenzene	--	--	--	--	--	--
1,2,3,5 + 1,2,4,5-Tetrachlorobenzene	0.3	--	--	--	--	--
1,2,3,4-Tetrachlorobenzene	--	0.4	--	--	--	--
Pentachlorobenzene	--	0.1	0.1	--	1.5	3.3
Hexachlorobenzene	20.4	0.2	0.1	0.3	--	1.0
ORGANOCHLORINES:						
Hexachlorobutadiene	--	--	--	--	--	--
a-Hexachlorocyclohexane	--	0.3	0.3	0.3	--	--
Lindane	--	0.1	--	0.1	--	--
Heptachlor	--	--	--	--	--	--
Heptachlor Epoxide	--	0.2	--	0.2	--	--
Octachlorostyrene	1.5	--	--	--	--	--
g-Chlordane	1.3	--	--	0.4	--	--
p,p'-DDE	1.6	--	--	--	--	13.0
p,p'-DDD	--	--	0.1	0.1	--	--
p,p'-DDT	--	0.6	0.4	0.7	--	--
Mirex	--	--	--	--	--	--
Methoxychlor	--	--	--	--	--	--
Hexachloroethane	--	--	--	--	--	--
Pentachloroanisole	--	0.2	0.2	0.1	--	--
a-Chlordane	--	0.9	0.2	0.6	--	--
Dieldrin	--	--	--	--	--	--
TOTAL CHLORINATED DIPHENYL ETHERS:	--	--	--	--	--	--

-- below detection limit < 0.1
* Coarse Sediment Fraction
** Bulk Sediment

Table 14. Phthalate esters in fine sediment fraction and earthworms (ug/kg dry wt).

COMPOUND	Thunder Bay Cell 1 Sediment*	Thunder Bay Cell 3 Sediment**	Seaway Island		Chenal Ecarte		Wheatley Dust Sediment	Port Stanley Sediment	Hamilton Harbour Sediment*
			Sediment	Earthworms	Sediment	Earthworms			
DiMethyl Phthalate	--	25	7	--	120	--	13	6	--
DiEthyl Phthalate	--	22	28	68	--	40	64	35	--
DiButyl Phthalate	4	123	130	230	570	84	190	20	10
Butyl Benzyl Phthalate	--	605	160	--	1900	--	50	1400	--
Bis(2-Ethylhexyl) Phthalate	2	87	140	82	620	18	270	120	8
Di-n-Octyl Phthalate	--	--	--	--	--	--	--	--	2
Total Phthalates	5	863	465	380	3210	142	587	1581	20

* Coarse Sediment Fraction

** Bulk Sediment

Table 14(cont). Phthalate esters in fine sediment fraction and earthworms (ug/kg dry wt).

COMPOUND	Whitby Harbour		Oshawa CDF	Oshawa Upland		Mercers Glen	
	Sediment	Earthworms	Sediment	Sediment	Earthworms	Sediment	Earthworms
DiMethyl Phthalate	8	--	11	14	--	50	--
DiEthyl Phthalate	29	25	820	29	85	99	51
DiButyl Phthalate	180	44	310	60	93	370	93
Butyl Benzyl Phthalate	170	--	1000	890	35	2200	--
Bis(2-Ethylhexyl) Phthalate	420	52	530	90	96	860	74
Di-n-Octyl Phthalate	--	--	26	--	--	--	--
Total Phthalates	807	121	2697	1083	309	3579	218

* Coarse Sediment Fraction

** Bulk Sediment

Table 15. Metal concentrations (ug/g dry wt) in vegetation samples.

Metals	Thunder Bay Cell 1	Thunder Bay Cell 3	Seaway Island	Chenal Ecarte	Wheatley Pulley	Wheatley Dust	Port Stanley	Hamilton Harbour	Whitby Harbour	Oshawa CDF	Oshawa Upland	Mercers Glen
Grass:												
Cadmium	0.0	0.1	0.1	0.1	0.1	0.2	0.1	--	0.2	0.1	0.3	0.1
Chromium	0.5	0.2	1.0	0.7	0.7	0.2	0.5	--	0.7	1.0	0.7	0.2
Copper	3.5	9.4	2.6	6.5	5.7	12.7	4.7	--	4.1	7.5	6.5	5.0
Nickel	1.7	1.6	1.1	2.2	0.9	4.0	1.7	--	0.6	5.5	10.9	1.0
Lead	0.8	0.9	1.3	1.3	1.1	0.8	0.9	--	2.5	1.3	2.5	2.4
Zinc	32.0	36.5	14.4	25.1	23.0	35.7	26.0	--	26.7	83.9	84.2	57.2
Mercury	0.005	0.005	0.005	0.010	<0.005	<0.005	0.005	--	0.005	0.015	0.010	0.010
Clover:												
Cadmium	0.2	0.2	0.1	--	--	0.1	--	--	--	--	--	0.1
Chromium	0.8	<0.20	<0.20	--	--	<0.20	--	--	--	--	--	<0.20
Copper	5.8	5.8	4.9	--	--	7.0	--	--	--	--	--	7.1
Nickel	1.8	1.2	0.8	--	--	0.9	--	--	--	--	--	0.5
Lead	0.7	0.5	1.9	--	--	0.5	--	--	--	--	--	1.4
Zinc	11.0	12.2	10.6	--	--	13.0	--	--	--	--	--	16.1
Mercury	0.010	<0.005	<0.005	--	--	<0.005	--	--	--	--	--	0.005
Sedge Leaves:												
Cadmium	0.4	0.4	0.2	0.4	--	2.2	--	--	--	1.0	--	0.2
Chromium	0.8	2.8	<0.20	4.3	--	<0.20	--	--	--	2.0	--	<0.20
Copper	8.4	9.3	3.9	12.8	--	14.4	--	--	--	12.9	--	6.9
Nickel	2.1	3.9	1.0	4.6	--	4.4	--	--	--	6.6	--	1.0
Lead	1.0	1.2	0.7	3.7	--	0.9	--	--	--	2.4	--	3.1
Zinc	17.1	17.8	22.2	53.0	--	49.2	--	--	--	138.9	--	24.5
Mercury	0.005	0.010	0.005	0.125	--	0.005	--	--	--	0.005	--	0.005
Smartweed:												
Cadmium	--	--	--	--	--	--	--	0.8	--	0.2	--	--
Chromium	--	--	--	--	--	--	--	3.4	--	2.3	--	--
Copper	--	--	--	--	--	--	--	5.6	--	6.8	--	--
Nickel	--	--	--	--	--	--	--	2.9	--	5.0	--	--
Lead	--	--	--	--	--	--	--	1.9	--	1.4	--	--
Zinc	--	--	--	--	--	--	--	279.0	--	54.6	--	--
Mercury	--	--	--	--	--	--	--	0.020	--	<0.005	--	--
Iron	--	--	--	--	--	--	--	377.0	--	--	--	--
Manganese	--	--	--	--	--	--	--	171.0	--	--	--	--

Table 16. Bioaccumulation factors (BFs) for metals from sediments to vegetation.

Metals	Thunder Bay Cell 1	Thunder Bay Cell 3	Seaway Island	Chenal Ecarte	Wheatley Pulley	Wheatley Dust	Port Stanley	Hamilton Harbour	Whitby Harbour	Oshawa CDF	Oshawa Upland	Mercers Glen	Mean BF
Grass:													
Cadmium	0.06	--	--	0.09	0.09	--	0.17	--	0.24	--	0.38	--	0.17
Chromium	0.00	0.00	0.02	0.01	0.01	0.00	0.01	--	0.01	--	0.01	0.00	0.01
Copper	0.08	0.17	0.13	0.18	0.23	0.37	0.16	--	0.16	--	0.46	0.16	0.21
Nickel	0.04	0.03	0.04	0.07	0.03	0.11	0.05	--	0.02	--	0.15	0.03	0.06
Lead	0.06	0.08	0.09	0.03	0.02	0.08	0.03	--	0.09	--	0.05	0.05	0.06
Zinc	0.24	0.24	0.21	0.30	0.16	0.41	0.36	--	0.34	--	0.63	0.45	0.33
Mercury	0.01	0.01	0.11	0.00	0.00	0.00	0.20	--	0.09	--	0.20	0.20	0.08
Clover:													
Cadmium	0.40	0.17	0.22	--	--	0.64	--	--	--	--	--	--	0.36
Chromium	0.01	0.00	0.00	--	--	0.00	--	--	--	--	--	0.00	0.00
Copper	0.13	0.09	0.27	--	--	0.22	--	--	--	--	--	0.20	0.18
Nickel	0.03	0.02	0.02	--	--	0.03	--	--	--	--	--	0.01	0.02
Lead	0.05	0.03	0.10	--	--	0.08	--	--	--	--	--	0.02	0.05
Zinc	0.09	0.08	0.14	--	--	0.02	--	--	--	--	--	0.11	0.09
Mercury	0.04	0.00	0.00	--	--	--	--	--	--	--	--	0.09	0.03
Sedge Leaves:													
Cadmium	0.76	0.57	0.43	--	--	12.00	--	--	--	2.04	--	0.83	2.77
Chromium	0.01	0.03	0.00	0.06	--	0.00	--	--	--	0.02	--	0.00	0.02
Copper	0.26	0.18	0.16	0.29	--	0.53	--	--	--	0.50	--	0.24	0.31
Nickel	0.05	0.09	0.02	0.12	--	0.13	--	--	--	0.08	--	0.03	0.07
Lead	0.19	0.06	0.01	0.09	--	0.04	--	--	--	0.06	--	0.09	0.08
Zinc	0.15	0.13	0.20	0.59	--	0.65	--	--	--	0.89	--	0.19	0.40
Mercury	0.02	0.01	0.05	0.05	--	0.08	--	--	--	0.09	--	0.20	0.07
Smartweed:													
Cadmium	--	--	--	--	--	--	--	0.27	--	0.58	--	--	0.42
Chromium	--	--	--	--	--	--	--	0.02	--	0.03	--	--	0.02
Copper	--	--	--	--	--	--	--	0.06	--	0.32	--	--	0.19
Nickel	--	--	--	--	--	--	--	0.07	--	0.11	--	--	0.09
Lead	--	--	--	--	--	--	--	0.01	--	0.06	--	--	0.03
Zinc	--	--	--	--	--	--	--	0.20	--	0.62	--	--	0.41
Mercury	--	--	--	--	--	--	--	0.05	--	0.00	--	--	0.03

Table 17. Concentrations of metals in leaf litter and associated grass samples on a dry weight and ash weight basis.

Samples	Metals	Thunder Bay Cell 1	Thunder Bay Cell 3	Seaway Island	Chenal Ecarte	Wheatley Pulley	Wheatley Dust	Port Stanley	Hamilton Harbour	Whitby Harbour	Oshawa CDF	Oshawa Upland	Mercers Glen
Grass (ug/g dry wt)	Cadmium	<0.1	0.1	0.1	0.1	0.1	0.2	0.1	--	0.2	0.1	0.3	0.1
	Chromium	0.5	0.2	1.0	0.7	0.7	0.2	0.5	--	0.7	1.0	0.7	0.2
	Copper	3.5	9.4	2.6	6.5	5.7	12.7	4.7	--	4.1	7.5	6.5	5.0
	Nickel	1.7	1.6	1.1	2.2	0.9	4.0	1.7	--	0.6	5.5	10.9	1.0
	Lead	0.8	0.9	1.3	1.3	1.1	0.8	0.9	--	2.5	1.3	2.5	2.4
	Zinc	32.0	36.5	14.4	25.1	23.0	35.7	26.0	--	26.7	83.9	84.2	57.2
	Mercury	0.005	0.005	0.005	0.010	<0.005	<0.005	0.005	--	0.005	0.015	0.010	0.010
Leaf Litter (ug/g dry wt)	Cadmium	0.4	0.8	0.3	0.2	0.1	0.8	0.2	--	0.4	--	2.0	0.2
	Chromium	21.9	20.8	8.5	2.9	7.1	7.2	6.4	--	6.0	--	7.4	7.2
	Copper	20.8	30.2	8.1	10.6	13.2	10.5	12.6	--	12.6	--	11.7	11.8
	Nickel	18.0	13.7	5.7	4.2	3.7	6.3	5.4	--	3.6	--	14.8	5.6
	Lead	0.4	0.2	4.3	3.7	4.2	2.4	5.4	--	16.8	--	8.4	6.7
	Zinc	46.3	64.9	37.6	42.1	57.4	32.5	67.3	--	151.0	--	177.0	74.0
	Mercury	0.050	0.040	0.040	0.090	0.030	0.010	0.030	--	0.040	--	0.020	0.010
	Iron	5390.0	4410.0	3660.0	883.0	4960.0	3370.0	3090.0	--	1600.0	--	809.0	5250.0
	Manganese	582.0	492.0	118.0	60.6	439.0	255.0	229.0	--	203.0	--	58.0	332.0
Grass	% Ash	8.9	6.2	6.5	8.8	11.0	11.0	6.4	--	6.4	--	10.4	7.3
ug metal/g ash	Cadmium	0.0	1.0	1.9	0.8	0.6	1.5	1.4	--	2.5	--	2.8	0.7
	Chromium	5.6	3.2	15.8	7.7	5.9	1.8	7.5	--	10.5	--	7.1	2.7
	Copper	39.2	151.6	40.0	73.5	51.9	115.6	73.1	--	63.2	--	62.6	68.1
	Nickel	18.7	26.5	17.2	25.3	8.4	36.0	26.8	--	10.0	--	104.8	14.2
	Lead	8.8	13.7	20.5	14.8	9.9	7.0	13.2	--	39.2	--	24.5	32.8
	Zinc	358.3	588.7	223.3	285.2	208.3	325.4	405.0	--	416.5	--	811.2	782.5
	Mercury	0.056	0.081	0.078	0.114	0.000	0.000	0.078	--	0.078	--	0.096	0.137
Leaf Litter	% Ash	30.2	32.5	33.9	12.6	40.2	20.3	18.0	--	28.0	--	17.9	32.0
ug metal/g ash	Cadmium	1.4	2.5	0.8	1.4	0.3	4.0	1.0	--	1.4	--	11.2	0.7
	Chromium	72.4	64.2	25.0	23.2	17.6	35.6	35.6	--	21.6	--	41.2	22.5
	Copper	68.8	93.0	23.8	84.0	32.8	51.7	70.1	--	45.0	--	65.4	36.9
	Nickel	59.5	42.2	16.9	32.9	9.2	31.2	30.2	--	12.8	--	82.8	17.5
	Lead	1.4	0.6	12.7	29.2	10.5	11.7	29.9	--	60.2	--	46.8	20.9
	Zinc	153.2	199.9	110.8	333.6	142.8	160.0	374.5	--	539.7	--	989.9	231.1
	Mercury	0.165	0.123	0.118	0.713	0.075	0.049	0.167	--	0.143	--	0.112	0.031

Table 18. Concentrations of metals (ug/g dry weight) in sedge leaves and seeds.

Metals	Thunder Bay Cell 1	Thunder Bay Cell 3	Seaway Island	Chenal Ecarte	Wheatley Pulley	Wheatley Dust	Port Stanley	Hamilton Harbour	Whitby Harbour	Oshawa CDF	Oshawa Upland	Mercers Glen
Sedge Leaves:												
Cadmium	0.4	0.4	0.2	0.4	--	2.2	--	--	--	1.0	--	0.2
Chromium	0.8	2.8	<0.20	4.3	--	<0.20	--	--	--	2.0	--	<0.20
Copper	8.4	9.3	3.9	12.8	--	14.4	--	--	--	12.9	--	6.9
Nickel	2.1	3.9	1.0	4.6	--	4.4	--	--	--	6.6	--	1.0
Lead	1.0	1.2	0.7	3.7	--	0.9	--	--	--	2.4	--	3.1
Zinc	17.1	17.8	22.2	53.0	--	49.2	--	--	--	138.9	--	24.5
Mercury	0.005	0.010	0.005	0.125	--	0.005	--	--	--	0.005	--	0.005
Sedge Seeds:												
Cadmium	0.3	0.2	0.1	0.1	--	1.3	--	--	--	0.4	--	0.1
Chromium	2.4	2.1	<0.20	9.6	--	<0.20	--	--	--	7.6	--	<0.20
Copper	14.1	15.7	3.2	14.9	--	1.3	--	--	--	17.9	--	7.1
Nickel	9.2	8.7	0.9	7.5	--	2.2	--	--	--	15.6	--	0.7
Lead	6.0	3.5	0.2	1.3	--	0.4	--	--	--	0.8	--	2.4
Zinc	26.2	29.2	23.4	42.6	--	55.1	--	--	--	69.5	--	35.7
Mercury	0.014	0.011	0.010	0.037	--	0.015	--	--	--	<0.005	--	<0.005
Iron	660.0	150.0	57.6	552.0	--	118.0	--	--	--	227.0	--	169.0
Manganese	137.0	92.0	49.7	49.2	--	40.2	--	--	--	56.3	--	126.0

Table 19. Summary of total PCBs (ug/kg dry wt) in bulk sediments, vegetation and earthworms from dredge disposal sites.

Sites	Sediment	Grass	Sedge	Clover or Smartweed*	Leaf Litter	Earth-worms
Thunder Bay Cell 1	100.9	10.0	4.4	5.3	6.8	--
Thunder Bay Cell 3	200.6	10.3	1.5	0.4	--	--
Seaway Island	3.6	7.1	6.7	0.6	0.0	0.0
Chenal Ecarte	145.0	30.4	17.9	--	90.8	30.0
Wheatley-Pulley	3.9	12.7	--	--	6.1	--
Wheatley-Dust	26.6	4.5	8.1	8.2	0.0	--
Port Stanley	2.0	12.4	--	--	17.2	--
Hamilton Harbour*	4578.9	--	--	9.0	--	--
Whitby Harbour+	1.5	14.5	--	--	--	--
Oshawa-CDF*	109.5	7.6	17.7	1.8	--	--
Oshawa-Upland	144.1	21.9	--	--	24.7	182.5
Mercers Glen	8.0	10.3	4.6	3.1	6.2	64.1

+ Total Sediment Fraction

* Smartweed sampled

Table 20. Concentrations of metals (ug/g dry weight) and bioaccumulation factors (BFs) from sediments to earthworms.

Metals	Seaway Island	Chenal Ecarte	Whitby Harbour	Oshawa Upland	Mercers Glen	Mean BFs
Earthworms:						
Cadmium	2.3	3.0	5.6	6.6	1.2	
Chromium	16.1	13.7	12.1	57.3	19.3	
Copper	14.2	24.1	17.0	22.2	17.7	
Nickel	11.2	10.3	8.9	42.9	11.1	
Lead	3.7	13.0	15.7	24.5	6.0	
Zinc	178.0	352.0	572.0	670.0	243.0	
Mercury	0.450	>1.000	0.190	0.160	0.049	
Iron	4540.0	4760.0	4690.0	5670.0	2250.0	
Manganese	106.0	131.0	165.0	161.0	364.0	
BFs:						
Cadmium	4.2	6.5	12.2	8.2	2.2	6.7
Chromium	0.3	0.3	0.3	0.5	0.3	0.3
Copper	4.1	1.5	5.1	1.2	0.9	2.6
Nickel	0.9	0.6	1.1	0.4	0.3	0.7
Lead	0.2	0.4	1.0	0.3	0.1	0.4
Zinc	3.0	2.4	18.0	3.5	1.9	5.7
Mercury	22.5	--	9.5	1.8	1.2	7.0
Sediments:						
Cadmium	0.56	0.46	0.46	0.80	0.52	
Chromium	52.63	54.11	47.28	109.90	76.39	
Copper	3.43	16.39	3.34	19.21	18.84	
Nickel	11.86	17.06	8.45	100.05	34.00	
Lead	19.75	34.33	15.67	76.58	45.72	
Zinc	60.11	145.57	31.79	193.59	130.16	
Mercury	0.02	1.10	0.02	0.09	0.04	

Table 21. Classification of CDF sediments for metals based on OMO dredge disposal guidelines (OMOE 1987).

Sites	As	Co	Cr	Cu	Ni	Pb	Zn	Hg	Cd
Thunder Bay Cell 1	b	b	U	b	R	b	U	b	b
Thunder Bay Cell 3	U	b	U	U	R	b	U	W	U
Seaway Island	b	b	U	b	b	b	b	b	b
Chenal Ecarte	U	b	U	b	b	b	U	W	b
Wheatley-Dust	b	b	U	b	R	b	b	b	b
Wheatley-Pulley	b	b	U	b	b	b	b	b	b
Port Stanley	U	b	U	b	b	b	b	b	b
Hamilton Harbour	U	b	W	W	R	W	W	W	W
Whitby Harbour	b	b	U	b	b	b	b	b	b
Oshawa-CDF	b	b	U	b	R	b	b	b	b
Oshawa-Upland	b	b	U	b	W	W	U	b	b
Mercers Glen	R	b	U	b	R	b	U	b	b

b -below open water dredging disposal guideline
U -suitable for unrestricted land use
R -suitable for restricted land use only
W -waste material

Table 22. Classification of CDF sediments for metals based on OMOE clean-up guidelines for coarse textured soils with proposed land uses (Rinne 1988).

Sites	As	Co	Cr	Cu	Ni	Pb	Zn	Hg	Cd
Thunder Bay Cell 1	a	a	a	a	a	a	a	a	a
Thunder Bay Cell 3	a	a	a	a	a	a	a	C	a
Seaway Island	a	a	a	a	a	a	a	a	a
Chenal Ecarte	a	a	a	a	a	a	a	C	a
Wheatley-Dust	a	a	a	a	a	a	a	a	a
Wheatley-Pulley	a	a	a	a	a	a	a	a	a
Port Stanley	a	a	a	a	a	a	a	a	a
Hamilton Harbour	a	a	a	C	a	C	R	a	C
Whitby Harbour	a	a	a	a	a	a	a	a	a
Oshawa-CDF	a	a	a	a	a	a	a	a	a
Oshawa-Upland	a	a	a	a	a	a	a	a	a
Mercers Glen	a	a	a	a	a	a	a	a	a

a -suitable for agricultural, residential and parkland land uses
C -suitable for commercial or industrial land uses only
R -exceeds guidelines for suitability of any land uses

Table 23. Classification of CDF vegetation samples for metals based on OMOE upper limits of normal concentrations in foliage from rural and urban Ontario (OMOE 1986).

Sites	Cr	Cu	Ni	Pb	Zn	Hg	Cd
Thunder Bay Cell 1	a	a	a	a	a	a	a
Thunder Bay Cell 3	a	a	a	a	a	a	a
Seaway Island	a	a	a	a	a	a	a
Chenal Ecarte	a	a	a	a	a	R+	a
Wheatley-Dust	a	a	a	a	a	a	R+
Wheatley-Pulley	a	a	a	a	a	a	a
Port Stanley	a	a	a	a	a	a	a
Hamilton Harbour	a	a	a	a	U++	a	a
Whitby Harbour	a	a	a	a	a	a	a
Oshawa-CDF	a	a	R*	a	a	a	R+
Oshawa-Upland	a	a	U**	a	a	a	a
Mercers Glen	a	a	a	a	a	a	a

a -vegetation level below upper normal limit in rural foliage
R -vegetation level above upper normal limit in rural foliage
U -vegetation level above upper normal limit in urban foliage

Appendix 1. Numbering of PCB isomers (Ballschmiter and Zell 1980).

No.	Structure
	Monochlorobiphenyls
1	2
2	3
3	4
	Dichlorobiphenyls
4	2,2′
5	2,3
6	2,3′
7	2,4
8	2,4′
9	2,5
10	2,6
11	3,3′
12	3,4
13	3,4′
14	3,5
15	4,4′
	Trichlorobiphenyls
16	2,2′,3
17	2,2′,4
18	2,2′,5
19	2,2′,6
20	2,3,3′
21	2,3,4
22	2,3,4′
23	2,3,5
24	2,3,6
25	2,3′,4
26	2,3′,5
27	2,3′,6
28	2,4,4′
29	2,4,5
30	2,4,6
31	2,4′,5
32	2,4′,6
33	2′,3′,4
34	2′,3,5
35	3,3′,4
36	3,3′,5
37	3,4,4′
38	3,4,5
39	3,4′,5

No.	Structure
	Tetrachlorobiphenyls
40	2,2′,3,3′
41	2,2′,3,4
42	2,2′,3,4′
43	2,2′,3,5
44	2,2′,3,5′
45	2,2′,3,6
46	2,2′,3,6′
47	2,2′,4,4′
48	2,2′,4,5
49	2,2′,4,5′
50	2,2′,4,6
51	2,2′,4,6′
52	2,2′,5,5′
53	2,2′,5,6′
54	2,2′,6,6′
55	2,3,3′,4
56	2,3,3′,4′
57	2,3,3′,5
58	2,3,3′,5′
59	2,3,3′,6
60	2,3,4,4′
61	2,3,4,5
62	2,3,4,6
63	2,3,4′,5
64	2,3,4′,6
65	2,3,5,6
66	2,3′,4,4′
67	2,3′,4,5
68	2,3′,4,5′
69	2,3′,4,6
70	2,3′,4′,5
71	2,3′,4′,6
72	2,3′,5,5′
73	2,3′,5′,6
74	2,4,4′,5
75	2,4,4′,6
76	2′,3,4,5
77	3,3′,4,4′
78	3,3′,4,5
79	3,3′,4,5′
80	3,3′,5,5′
81	3,4,4′,5

Appendix 1. Continued.

No.	Structure	No.	Structure
	Pentachlorobiphenyls		Hexachlorobiphenyls
82	2,2′,3,3′,4	128	2,2′,3,3′,4,4′
83	2,2′,3,3′,5	129	2,2′,3,3′,4,5
84	2,2′,3,3′,6	130	2,2′,3,3′,4,5′
85	2,2′,3,4,4′	131	2,2′,3,3′,4,6
86	2,2′,3,4,5	132	2,2′,3,3′,4,6′
87	2,2′,3,4,5′	133	2,2′,3,3′,5,5′
88	2,2′,3,4,6	134	2,2′,3,3′,5,6
89	2,2′,3,4,6′	135	2,2′,3,3′,5,6′
90	2,2′,3,4′,5	136	2,2′,3,3′,6,6′
91	2,2′,3,4′,6	137	2,2′,3,4,4′,5
92	2,2′,3,5,5′	138	2,2′,3,4,4′,5′
93	2,2′,3,5,6	139	2,2′,3,4,4′,6
94	2,2′,3,5,6′	140	2,2′,3,4,4′,6′
95	2,2′,3,5′,6	141	2,2′,3,4,5,5′
96	2,2′,3,6,6′	142	2,2′,3,4,5,6
97	2,2′,3′,4,5	143	2,2′,3,4,5,6′
98	2,2′,3′,4,6	144	2,2′,3,4,5′,6
99	2,2′,4,4′,5	145	2,2′,3,4,6,6′
100	2,2′,4,4′,6	146	2,2′,3,4′,5,5′
101	2,2′,4,5,5′	147	2,2′,3,4′,5,6
102	2,2′,4,5,6′	148	2,2′,3,4′,5,6′
103	2,2′,4,5′,6	149	2,2′,3,4′,5′,6
104	2,2′,4,6,6′	150	2,2′,3,4′,6,6′
105	2,3,3′,4,4′	151	2,2′,3,5,5′,6
106	2,3,3′,4,5	152	2,2′,3,5,6,6′
107	2,3,3′,4′,5	153	2,2′,4,4′,5,5′
108	2,3,3′,4,5′	154	2,2′,4,4′,5,6′
109	2,3,3′,4,6	155	2,2′,4,4′,6,6′
110	2,3,3′,4′,6	156	2,3,3′,4,4′,5
111	2,3,3′,5,5′	157	2,3,3′,4,4′,5′
112	2,3,3′,5,6	158	2,3,3′,4,4′,6
113	2,3,3′,5′,6	159	2,3,3′,4,5,5′
114	2,3,4,4′,5	160	2,3,3′,4,5,6
115	2,3,4,4′,6	161	2,3,3′,4,5′,6
116	2,3,4,5,6	162	2,3,3′,4′,5,5′
117	2,3,4′,5,6	163	2,3,3′,4′,5,6
118	2,3′,4,4′,5	164	2,3,3′,4′,5′,6
119	2,3′,4,4′,6	165	2,3,3′,5,5′,6
120	2,3′,4,5,5′	166	2,3,4,4′,5,6
121	2,3′,4,5′,6	167	2,3′,4,4′,5,5′
122	2,3,3′,4,5	168	2,3′,4,4′,5′,6
123	2′,3,4,4′,5	169	3,3′,4,4′,5,5′
124	2′,3,4,5,5′		
125	2′,3,4,5,6′		
126	3,3′,4,4′,5		
127	3,3′,4,5,5′		

Appendix 1. Continued.

No.	Structure
	Heptachlorobiphenyls
170	2,2′,3,3′,4,4′,5
171	2,2′,3,3′,4,4′,6
172	2,2′,3,3′,4,5,5′
173	2,2′,3,3′,4,5,6
174	2,2′,3,3′,4,5,6′
175	2,2′,3,3′,4,5′,6
176	2,2′,3,3′,4,6,6′
177	2,2′,3,3′,4′,5,6
178	2,2′,3,3′,5,5′,6
179	2,2′,3,3′,5,6,6′
180	2,2′,3,4,4′,5,5′
181	2,2′,3,4,4′,5,6
182	2,2′,3,4,4′,5,6′
183	2,2′,3,4,4′,5′,6
184	2,2′,3,4,4′,6,6′
185	2,2′,3,4,5,5′,6
186	2,2′,3,4,5,6,6′
187	2,2′,3,4′,5,5′,6
188	2,2′,3,4′,5,6,6′
189	2,3,3′,4,4′,5,5′
190	2,3,3′,4,4′,5,6
191	2,3,3′,4,4′,5′,6
192	2,3,3′,4,5,5′,6
193	2,3,3′,4′,5,5′,6
194	2,2′,3,3′,4,4′,5,5′
195	2,2′,3,3′,4,4′,5,6
196	2,2′,3,3′,4,4′,5,6′
197	2,2′,3,3′,4,4′,6,6′
198	2,2′,3,3′,4,5,5′,6
199	2,2′,3,3′,4,5,6,6′
200	2,2′,3,3′,4,5′,6,6′
201	2,2′,3,3′,4,5,5′,6′
202	2,2′,3,3′,5,5′,6,6′
203	2,2′,3,4,4′,5,5′,6
204	2,2′,3,4,4′,5,6,6′
205	2,3,3′,4,4′,5,5′,6
	Nonachlorobiphenyls
206	2,2′,3,3′,4,4′,5,5′,6
207	2,2′,3,3′,4,4′,5,6,6′
208	2,2′,3,3′,4,5,5′,6,6′
	Decachlorobiphenyl
209	2,2′,3,3′,4,4′,5,5′,6,6′

Appendix 2a. Summary of contaminant data for all samples from Thunder Bay cell 1. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1977-81	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Grass	Leaf Litter	Clover	Sedge Leaves	Sedge Seeds	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:										
Cadmium	0.5	0.8	3*/6**	0.0	0.4	0.2	0.4	0.3	1.0	3.0
Lead	15.9	11.8	375/750	0.8	0.4	0.7	1.0	6.0	30.0	60.0
Mercury	0.6	0.220	0.8/1.5	0.005	0.050	0.010	0.005	0.014	0.1	0.3
Total PCBs++	70.0	100.8	--	10.0	6.8	5.3	4.4	--	--	--
Group 2:										
Arsenic	1.0	3.3	25/40	--	--	--	--	--	0.5	2.0
Chromium	22.4	103.7	750/750	0.5	21.9	0.8	0.8	2.4	8.0	8.0
Copper	36.1	21.4	150/225	3.5	20.8	5.8	8.4	14.1	20.0	20.0
Nickel	27.5	43.8	150/150	1.7	18.0	1.8	2.1	9.2	5.0	5.0
Zinc	60.6	113.4	600/600	32.0	46.3	11.0	17.1	26.2	250.0	250.0
Total PAHs++	--	455.0+	--	--	201.0	--	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
+ :coarse sediment fraction (>63 um particle size)
++ :units in ug/kg dry wt

Appendix 2b. Summary of contaminant data for all samples from Thunder Bay cell 3. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1977-83	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Grass	Leaf Litter	Clover	Sedge Leaves	Sedge Seeds	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:										
Cadmium	--	1.1	3*/6**	0.1	0.8	0.2	0.4	0.2	1.0	3.0
Lead	17.9	19.6	375/750	0.9	0.2	0.5	1.2	3.5	30.0	60.0
Mercury	0.386	0.990	0.8/1.5	0.005	0.040	<0.005	0.010	0.011	0.1	0.3
Total PCBs++	--	200.6	--	10.3	--	0.4	1.5	--	--	--
Group 2:										
Arsenic	4.0	10.4	25/40	--	--	--	--	--	0.5	2.0
Chromium	365.1	111.9	750/750	0.2	20.8	<0.2	2.8	2.1	8.0	8.0
Copper	43.9	65.5	150/225	9.4	30.2	5.8	9.3	15.7	20.0	20.0
Nickel	36.7	52.3	150/150	1.6	13.7	1.2	3.9	8.7	5.0	5.0
Zinc	57.2	167.1	600/600	36.5	64.9	12.2	17.8	29.2	250.0	250.0
Total PAHs++	--	1628.0	--	--	--	--	--	--	--	--
Total Phthalate Esters++	--	863.0	--	--	--	--	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses

** :upper allowable limit for commericial or industrial land uses

-- :no data available

++ :units in ug/kg dry wt

Appendix 2c. Summary of contaminant data for all samples from Seaway Island. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1974	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Earthworms	Grass	Leaf Litter	Clover	Sedge Leaves	Sedge Seeds	OMOE Upper Normal Limit in Foliage Rural	OMOE Upper Normal Limit in Foliage Urban
Group 1A:											
Cadmium	--	0.6	3*/6**	2.3	0.1	0.3	0.1	0.2	0.1	1.0	3.0
Lead	--	19.8	375/750	3.7	1.3	4.3	1.9	0.7	0.2	30.0	60.0
Mercury	0.897	0.020	0.8/1.5	0.450	0.005	0.040	<0.005	0.005	0.010	0.1	0.3
Total PCBs++	--	3.6	--	0.0	7.1	0.0	0.6	6.7	--	--	--
Group 2:											
Arsenic	--	7.9	25/40	--	--	--	--	--	--	0.5	2.0
Chromium	--	52.6	750/750	16.1	1.0	8.5	<0.2	<0.2	<0.2	8.0	8.0
Copper	7.2	3.4	150/225	14.2	2.6	8.1	4.9	3.9	3.2	20.0	20.0
Nickel	--	11.9	150/150	11.2	1.1	5.7	0.8	1.0	0.9	5.0	5.0
Zinc	26.4	60.1	600/600	178.0	14.4	37.6	10.6	22.2	23.4	250.0	250.0
Total PAHs++	--	140+	--	196.0	--	396.0	--	--	--	--	--
Total Phthalate Esters++	--	465+	--	308.0	--	--	--	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
+ :fine sediment fraction (<63 um particle size)
++ :units in ug/kg dry wt

Appendix 2d. Summary of contaminant data for all samples from Chenal Ecarte. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1979	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Earthworms	Grass	Leaf Litter	Sedge Leaves	Sedge Seeds	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:										
Cadmium	--	0.5	3*/6**	3.0	0.1	0.2	0.4	0.1	1.0	3.0
Lead	--	34.3	375/750	13.0	1.3	3.7	3.7	1.3	30.0	60.0
Mercury	1.120	0.020	0.8/1.5	>1.000	0.010	0.090	0.125	0.037	0.1	0.3
Total PCBs++	0.3	145.0	--	30.0	30.4	90.8	17.9	--	--	--
Group 2:										
Arsenic	--	8.9	25/40	--	--	--	--	--	0.5	2.0
Chromium	--	54.1	750/750	13.7	0.7	2.9	4.3	9.6	8.0	8.0
Copper	--	16.4	150/225	24.1	6.5	10.6	12.8	14.9	20.0	20.0
Nickel	--	17.1	150/150	10.3	2.2	4.2	4.6	7.5	5.0	5.0
Zinc	--	145.6	600/600	352.0	25.1	42.1	53.0	42.6	250.0	250.0
Total PAHs++	--	1148+	--	1360.0	10.0	261.0	15.0	--	--	--
Total Phthalate Esters++	--	3210+	--	142.0	--	--	--	--	--	--
HCB++	--	425+	--	57.0	0.8	14.0	28.0	--	--	--
OCS++	--	95.2+	--	8.7	1.0	1.5	5.1	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses

** :upper allowable limit for commericial or industrial land uses

-- :no data available

\+ :fine sediment fraction (<63 um particle size)

++ :units in ug/kg dry wt

Appendix 2e. Summary of contaminant data for all samples from Wheatley-Pulley. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1984	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Grass	Leaf Litter	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:							
Cadmium	--	0.5	3*/6**	0.1	0.1	1.0	3.0
Lead	<15	15.5	375/750	1.1	4.2	30.0	60.0
Mercury	--	0.030	0.8/1.5	<0.005	0.030	0.1	0.3
Total PCBs++	1.8	3.9	--	12.7	6.1	--	--
Group 2:							
Arsenic	9.1	6.1	25/40	--	--	0.5	2.0
Chromium	51.0	51.8	750/750	0.7	7.1	8.0	8.0
Copper	66.0	1.5	150/225	5.7	13.2	20.0	20.0
Nickel	15.0	9.5	150/150	0.9	3.7	5.0	5.0
Zinc	210.0	47.2	600/600	23.0	4.2	250.0	250.0
Total PAHs++	--	--	--	--	4878.0	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
++ :units in ug/kg dry wt
<x :below detection limit x

Appendix 2f. Summary of contaminant data for all samples from Wheatley-Dust. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1984	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Grass	Leaf Litter	Clover	Sedge Leaves	Sedge Seeds	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:										
Cadmium	--	0.5	3*/6**	0.2	0.8	0.1	2.2	1.3	1.0	3.0
Lead	<15	14.9	375/750	0.8	2.4	0.5	0.9	0.4	30.0	60.0
Mercury	--	0.020	0.8/1.5	<0.005	0.010	<0.005	0.005	0.015	0.1	0.3
Total PCBs++	0.7	26.6	--	4.5	0.0	8.2	8.1	--	--	--
Group 2:										
Arsenic	6.5	7.1	25/40	--	--	--	--	--	0.5	2.0
Chromium	35.0	76.1	750/750	0.2	7.2	<0.2	<0.2	<0.2	8.0	8.0
Copper	57.0	18.4	150/225	12.7	10.5	7.0	14.4	1.3	20.0	20.0
Nickel	14.0	35.0	150/150	4.0	6.3	0.9	4.4	2.2	5.0	5.0
Zinc	470.0	90.2	600/600	35.7	32.5	13.0	49.2	55.1	250.0	250.0
Total PAHs++	--	235+	--	--	180.0	--	--	--	--	--
Total Phthalate Esters++	--	587+	--	--	--	--	--	--	--	--
p,p'-DDT++	--	11+	--	0.5	0.0	1.0	0.9	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
+ :fine sediment fraction (<63 um particle size)
++ :units in ug/kg dry wt
<x :below detection limit x

Appendix 2g. Summary of contaminant data for all samples from Port Stanley. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1977	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Grass	Leaf Litter	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:							
Cadmium	5.4	0.4	3*/6**	0.1	0.2	1.0	3.0
Lead	73.0	15.4	375/750	0.9	5.4	30.0	60.0
Mercury	0.2	0.010	0.8/1.5	0.005	0.030	0.1	0.3
Total PCBs++	--	2.0	--	12.4	17.2	--	--
Group 2:							
Arsenic	0.7	8.0	25/40	--	--	0.5	2.0
Chromium	--	54.3	750/750	0.5	6.4	8.0	8.0
Copper	34.0	14.4	150/225	4.7	12.6	20.0	20.0
Nickel	--	19.4	150/150	1.7	5.4	5.0	5.0
Zinc	132.0	60.3	600/600	26.0	67.3	250.0	250.0
Total PAHs++	--	465+	--	--	2116.0	--	--
Total Phthalate Esters++	--	1581+	--	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
+ :fine sediment fraction (<63 um particle size)
++ :units in ug/kg dry wt

Appendix 2h. Summary of contaminant data for all samples from Hamilton Harbour. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1983-84	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Smartweed	OMOE Upper Normal Limit in Foliage	
					Rural	Urban
Group 1A:						
Cadmium	3.3	5.7	3*/6**	0.8	1.0	3.0
Lead	140.5	435.9	375/750	1.9	30.0	60.0
Mercury	0.6	0.690	0.8/1.5	0.020	0.1	0.3
Total PCBs++	3.1	4578.9	--	9.0	--	--
Group 2:						
Arsenic	6.4	12.9	25/40	--	0.5	2.0
Chromium	221.6	407.2	750/750	3.4	8.0	8.0
Copper	63.0	201.1	150/225	5.6	20.0	20.0
Nickel	35.0	68.5	150/150	2.9	5.0	5.0
Zinc	704.5	2481.5	600/600	279.0	250.0	250.0
Total PAHs++	--	13800+	--	1866.0	--	--
Total Phthalate Esters++	--	20+	--	--	--	--
124-Trichloro-benzene++	--	15+	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
\+ :coarse sediment fraction (>63 um particle size)
++ :units in ug/kg dry wt

Appendix 2i. Summary of contaminant data for all samples from Whitby Harbour. (All units in ug/g dry wt unless otherwise stated.)

Parameters	DPW Pre-dredging Sediment 1978	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Earthworms	Grass	Leaf Litter	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:								
Cadmium	--	0.5	3*/6**	5.6	0.2	0.4	1.0	3.0
Lead	73.0	15.7	375/750	15.7	2.5	16.8	30.0	60.0
Mercury	0.150	0.020	0.8/1.5	0.190	0.005	0.040	0.1	0.3
Total PCBs++	0.2	1.5+++	--	--	14.5	--	--	--
Group 2:								
Arsenic	4.5	2.1	25/40	--	--	--	0.5	2.0
Chromium	155.0	47.3	750/750	12.1	0.7	6.0	8.0	8.0
Copper	83.0	3.3	150/225	17.0	4.1	12.6	20.0	20.0
Nickel	82.0	15.7	150/150	8.9	0.6	3.6	5.0	5.0
Zinc	207.0	31.8	600/600	572.0	26.7	151.0	250.0	250.0
Total PAHs++	--	326+	--	279.0	10.0	261.0	--	--
Total Phthalate Esters++	--	807+	--	121.0	--	--	--	--
p,p'-DDE++	--	20+	--	4.4	--	3.0	--	--
Diphenyl Ethers++	--	100+	--	310.0	40.0	39.0	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
+ :fine sediment fraction (<63 um particle size)
++ :units in ug/kg dry wt
+++:coarse sediment fraction (>63 um particle size)

Appendix 2j. Summary of contaminant data for all samples from Oshawa-CDF. (All units in ug/g dry wt unless otherwise stated.)

Parameter	DPW Pre-dredging Sediment 1980-81	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Grass	Smartweed	Sedge Leaves	Sedge Seeds	OMOE Upper Normal Limit in Foliage Rural	Urban
Group 1A:									
Cadmium	2.8	0.7	3*/6**	0.1	0.2	1.0	0.4	1.0	3.0
Lead	42.3	26.9	375/750	1.3	1.4	2.4	0.8	30.0	60.0
Mercury	0.079	0.040	0.8/1.5	0.015	<0.005	0.005	<0.005	0.1	0.3
Total PCBs++	0.5	109.5	--	7.6	1.8	17.7	--	--	--
Group 2:									
Arsenic	2.8	1.9	25/40	--	--	--	--	0.5	2.0
Chromium	61.9	67.4	750/750	1.0	2.3	2.0	7.6	8.0	8.0
Copper	12.2	9.9	150/225	7.5	6.8	12.9	17.9	20.0	20.0
Nickel	46.7	43.2	150/150	5.5	5.0	6.6	15.6	5.0	5.0
Zinc	76.1	96.6	600/600	83.9	54.6	138.9	69.5	250.0	250.0
Total PAHs++	--	463+	--	--	--	--	--	--	--
Total Phthalate Esters++	--	2697+	--	--	--	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
\+ :fine sediment fraction (<63 um particle size)
++ :units in ug/kg dry wt

Appendix 2k. Summary of contaminant data for all samples from Oshawa-Upland. (All units in ug/g dry wt unless otherwise stated.)

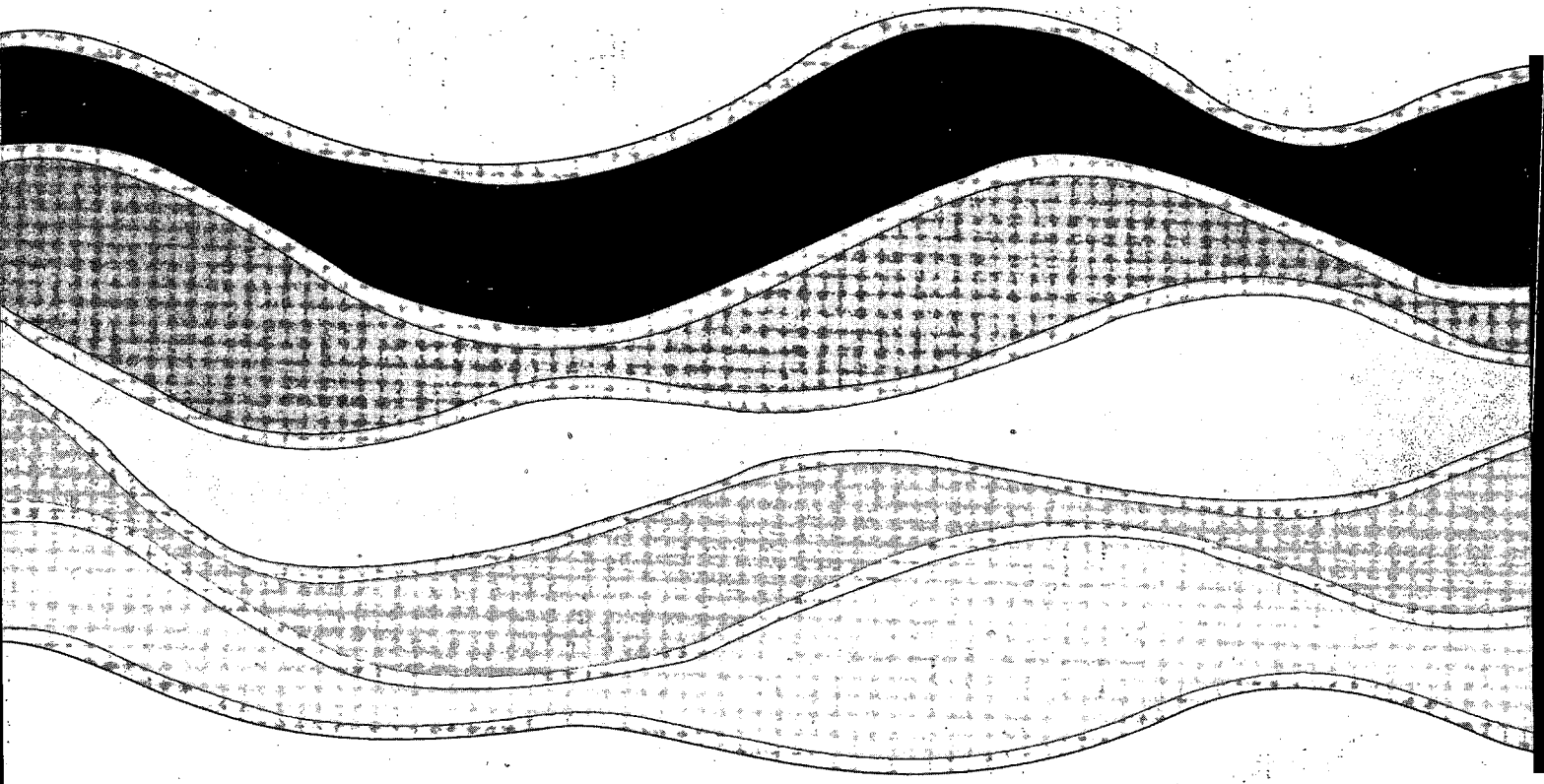
Parameters	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Earthworms	Grass	Leaf Litter	OMOE Upper Normal Limit in Foliage	
						Rural	Urban
Group 1A:							
Cadmium	0.8	3*/6**	6.6	0.3	2.0	1.0	3.0
Lead	76.6	375/750	24.5	2.5	8.4	30.0	60.0
Mercury	0.090	0.8/1.5	0.160	0.010	0.020	0.1	0.3
Total PCBs++	144.1	--	182.5	21.9	24.7	--	--
Group 2:							
Arsenic	3.5	25/40	--	--	--	0.5	2.0
Chromium	109.9	750/750	57.3	0.7	7.4	8.0	8.0
Copper	19.2	150/225	22.2	6.5	11.7	20.0	20.0
Nickel	100.1	150/150	42.9	10.9	14.8	5.0	5.0
Zinc	193.6	600/600	670.0	84.2	177.0	250.0	250.0
Total PAHs++	808+	--	1259.0	--	390.0	--	--
Total Phthalate Esters++	1083+	--	309.0	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
+ :fine sediment fraction (<63 um particle size)
++ :units in ug/kg dry wt

Appendix 21. Summary of contaminant data for all samples from Mercers Glen. (All units in ug/g dry wt unless otherwise stated.)

Parameters	Bulk Sediment 1987	OMOE Soil Clean-up Guidelines	Earthworms	Grass	Leaf Litter	Clover	Sedge Leaves	Sedge Seeds	OMOE Upper Normal Limit in Foliage	
									Rural	Urban
Group 1A:										
Cadmium	0.5	3*/6**	1.2	0.1	0.2	0.1	0.2	0.1	1.0	3.0
Lead	45.7	375/750	6.0	2.4	6.7	1.4	3.1	2.4	30.0	60.0
Mercury	0.040	0.8/1.5	0.050	0.010	0.010	0.005	0.005	<0.005	0.1	0.3
Total PCBs++	8.0	--	64.1	10.3	6.2	3.1	4.6	--	--	--
Group 2:										
Arsenic	14.5	25/40	--	--	--	--	--	--	0.5	2.0
Chromium	76.4	750/750	19.3	0.2	7.2	<0.2	<0.2	<0.2	8.0	8.0
Copper	18.8	150/225	17.7	5.0	11.8	7.1	6.9	7.1	20.0	20.0
Nickel	34.0	150/150	11.1	1.0	5.6	0.5	1.0	0.7	5.0	5.0
Zinc	130.2	600/600	243.0	57.2	74.0	16.1	24.5	35.7	250.0	250.0
Total PAHs++	652+	--	762.0	--	339.0	--	--	--	--	--
Total Phthalate Esters++	3579+	--	218.0	--	--	--	--	--	--	--
HCB	20.4+	--	1.0	0.2	--	0.1	0.3	--	--	--
p,p'-DDE	1.6+	--	13.0	--	--	--	--	--	--	--

* :upper allowable limit for agricultural, residential or recreational land uses
** :upper allowable limit for commericial or industrial land uses
-- :no data available
\+ :fine sediment fraction (<63 um particle size)
++ :units in ug/kg dry wt
<x :below detection limit x



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