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THE GREAT LAKES SEDIMENT BANK - I
(including catalogs of Lakes Huron
and Ontario samples)

by

R.A. Bourbonniere, B.L. VanSickle
and T. Mayer

Aquatic Ecology Division
National Water Research Institute
Environment Canada
Burlington, Ont.

MANAGEMENT PERSPECTIVE

A bank of Great Lakes sediment samples has been established by the National Water Research Institute. The Great Lakes Sediment Bank contains sediment from four of the Great Lakes - Ontario, Erie, Huron and Superior. The Sediment Bank serves as a source of baseline material from which to reference future contamination problems, and as an aid to understanding trends in contaminant loadings.

This first report contains the results of sediment preservation studies, protocols for obtaining samples from the bank, brief literature reviews of past work related to Lake Huron and Lake Ontario sediments, catalogs of samples collected from these two lakes in 1980 and 1981, and bulk data obtained from those samples.

PERSPECTIVE-GESTION

Une banque d'échantillons de sédiments provenant des Grands Lacs a été mise sur pied par l'Institut national de recherche sur les eaux. Cette banque renferme des sédiments provenant de quatre des Grands Lacs : Ontario, Erié, Huron et Supérieur. La banque de sédiments sert de source de matériaux de référence à partir desquels les problèmes futurs de contamination pourront être évalués et permet également de mieux comprendre les tendances d'apport de contaminants.

Ce premier rapport renferme les résultats des études de conservation de sédiments, la marche à suivre pour l'obtention d'échantillons de la banque, de brefs examens des comptes-rendus de travaux passés se rapportant aux sédiments des lacs Hurons et Ontario, des catalogues d'échantillons prélevés dans ces deux lacs en 1980 et 1981 et des données brutes obtenues à partir de ces échantillons.

ABSTRACT

Sediments act as the ultimate sink of many persistent toxic substances and therefore may serve to record contamination events. A bank of Great Lakes sediment samples has been established by the National Water Research Institute (NWRI) of Environment Canada. The Great Lakes Sediment Bank (Sediment Bank) contains relatively large quantities of sediment (1-2 kilograms dry weight) from each of 39-53 sampling locations in four of the Great Lakes - Ontario, Erie, Huron and Superior. It is stored at the Canada Centre for Inland Waters (CCIW) and maintained by NWRI. The Sediment Bank serves as a source of baseline material from which to reference future contamination problems, and as an aid to understanding trends in contaminant loadings.

As part of the initial Sediment Bank investigations a preservation study was undertaken. Comparison of frozen (-20° C) and freeze-dried (20° C) storage for five organochlorine components showed that the latter method gave values within $\pm 20\%$ of the former. A time series for both frozen and freeze-dried storage was carried out for up to six years. In practical terms, results from analysis of stored samples by either method are comparable to analysis of "fresh" samples to within about 10% if the component is "high" in concentration and to within a factor of two if the component is "low" in concentration.

This first report contains the details of further wet/dry comparisons in Appendix I. Appendices II and III are catalogs of samples in the Sediment Bank from Lakes Huron and Ontario respectively. These Appendices also contain the bulk data available from the Sediment Bank samples.

RESUME

Les sédiments, parce qu'ils sont le refuge ultime de nombreuses substances toxiques persistantes, peuvent être de bons indicateurs des phénomènes de contamination. Une banque d'échantillons de sédiments provenant des Grands Lacs a été mise sur pied par l'Institut national de recherche sur les eaux (INRE) d'Environnement Canada. Cette banque de sédiments contient des quantités relativement importantes de sédiments (1 à 2 kilogrammes en poids sec) provenant de chacun des 39 à 53 sites d'échantillonnage dans quatre des Grands Lacs : Ontario, Erié, Huron et Supérieur. Ces sédiments sont conservés au Centre canadien des eaux intérieures (CCEI); l'INRE alimente cette banque. La banque de sédiments sert de source de matériaux de référence à partir desquels pourront être évalués les problèmes futurs de contamination et permet également de mieux comprendre les tendances d'apport de contaminants.

Dans le cadre des études préliminaires de la banque de sédiments, une étude de conservation a été entreprise. La congélation (-20°C) et le séchage à froid (20°C) ont été comparés pour la conservation de cinq composés organochlorés; on a montré que le séchage à froid donnait des résultats qui s'écartaient de $\pm 20\%$ des valeurs obtenues par la congélation. Une étude chronologique de la conservation sous congélation et sous séchage à froid a été réalisée pour des périodes atteignant six ans. En termes pratiques, les résultats provenant de l'analyse des échantillons conservés par l'une ou l'autre des deux méthodes sont comparables à ceux de l'analyse des échantillons "frais" avec une marge

d'environ 10 % si la composante recherchée a une teneur élevée et une variation pouvant aller du simple au double si la teneur de la composante recherchée est faible.

L'annexe I du présent rapport comprend les détails d'autres comparaisons des méthodes de conservation (humide/sec). Les annexes II et III sont des catalogues des échantillons de la banque de sédiments provenant des lacs Huron et Ontario respectivement. Ces annexes présentent également les données brutes tirées des échantillons.

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DISCLAIMER

Throughout this document references are made to name brand products for the purpose of identification only. Such references in no way constitute an endorsement of such products by the authors or by Environment Canada.

INTRODUCTION

A bank of Great Lakes sediment samples has been established by the National Water Research Institute (NWRI) of Environment Canada. The Great Lakes Sediment Bank contains relatively large quantities of sediment (1-2 kilograms dry weight) from each of 39-53 sampling locations in four of the Great Lakes - Ontario, Erie, Huron and Superior. It is stored at the Canada Centre for Inland Waters (CCIW) and maintained by NWRI.

Sediments act as the ultimate sink of many persistent toxic substances and therefore may serve to record contamination events. The Great Lakes Sediment Bank (Sediment Bank) serves as a source of baseline material from which to reference future contamination problems, and as an aid to understanding trends in contaminant loadings.

Canada and the United States of America signed the "Great Lakes Water Quality Agreement of 1978" (GLWQA) on November 22, 1978. Among the purposes and objectives of this agreement were policies concerning persistent toxic substances. Article II paragraph (a) states: "...the discharge of any or all persistent toxic substances [should] be virtually eliminated;..." Annex 12 of the GLWQA outlines specific principles and programs concerning persistent toxic substances. The Annex requires the establishment of an "Early Warning System," the purpose of which is "...to anticipate future environmental contaminants...and to set priorities for environmental research, monitoring and regulatory action..." Among the elements of this early warning system, Annex 12, section 5(e) specifies: "Maintenance of a biological tissue bank and sediment bank to permit retroactive analysis to establish trends over time." The Sediment Bank was established to fulfil, in part, this requirement. It was funded by special appropriation to Environment Canada through the office of the Regional Director General (Ontario).

Initial sampling for the Sediment Bank occurred over a four year period, concentrating on a different one of the Great Lakes each year. Samples were processed for long-term storage and made available for distribution to those interested in analyzing them. Availability of samples is announced via reports, of which this is the first. Catalogs of samples in the Sediment Bank will include sample collection information and bulk properties of samples determined by NWRI personnel during and subsequent to sampling. In addition, all analytical results obtained by users of the Sediment Bank will be stored in a computer-based data bank which will be available to the scientific and regulatory communities of the Great Lakes Region.

This first report is primarily intended to inform the Great Lakes scientific and regulatory community of the existence of the Sediment Bank. Included are details of our sampling strategy and methodology. The report also describes our methods for sample preservation and processing for long-term storage and our sample distribution policies and guidelines. Appended to this report are catalogs of samples available from the Lake Huron sampling of June, 1980 and the Lake Ontario sampling which occurred in May, 1981.

SAMPLING

This section includes the long-term sampling strategy, policies on sample size and type, and criteria for site selection adopted for the Sediment Bank. Also included here are details concerning sampling equipment and methodology and onboard sample characterization.

Long-Term Schedule

The initial sampling phase for the Sediment Bank is began in April 1980 and continued for four years. This allowed the practical timetable for sampling a different one of the Great Lakes in each of the four years. Sampling occurred in Lake Huron (June, 1980), Lake Ontario (May, 1981), Lakes Erie and St. Clair (May, 1982), and Lake Superior (July, 1983). Long-term trend analysis is a desirable feature that should be built into the program. Resampling of the lakes should occur at a frequency which takes into account their respective hydraulic residence times and average sediment accumulation rates.

Site Selection, Sample Size and Type

Most persistent toxic substances tend to be associated with fine-grained sediments and therefore accumulate in the deeper sedimentary basins. The majority of sampling sites are located in basins where the sediment is predominantly silt and/or clay. With respect to sedimentary basins, sampling sites are chosen to give as broad a spatial distribution as possible. Sites are also chosen so that they will coincide, wherever possible, with those sites at which previous workers from NWRI and other organizations have studied the sediments. In this way most of the Sediment Bank stations will have been studied for various physical and chemical parameters prior to Sediment Bank sampling. The results of previous researchers may therefore be utilized for trend analysis.

In some cases small amounts of sediment have been incorporated into the Sediment Bank from the collections of those previous workers.

The total quantity of surficial sediment stored in the Sediment Bank from each site is generally 1-2 kilograms dry weight. This quantity assures a reasonable longevity for the Sediment Bank, and should minimize restrictions on the use of Sediment Bank samples, at least at the outset. Core samples representing about the last 100 years of sedimentation are collected from 3-7 sites in each lake in addition to the surficial sediment samples. Locations for these historical samples are chosen on the basis of the best available geochronological information from the various basins in each lake. In addition to surficial and historical samples, 2-4 sites in each lake were chosen as quality control stations.

Sampling Methodology

An important sampling requirement is the ability to collect a large quantity of undisturbed surficial sediment at each location. A large volume box corer is ideally suited for this purpose. The corer used is an adaptation of the U.S. Navy spade corer (Bouma, 1969) with modifications made for the Bedford Institute of Oceanography. It has a stainless steel box which is 0.25 m² in cross section (Figure 1). Between one and two kilograms (dry weight) of high quality surficial sediment can be obtained by subsampling the upper three centimeters of a single core.

For historical (core) samples the box core is sub-cored by carefully inserting plastic tubes by hand. The sub-cores are then extruded vertically, saving sections which represent integrations of approximately 20-25 years of sediment accumulation. Corresponding sections extruded from all sub-cores at each station are combined.

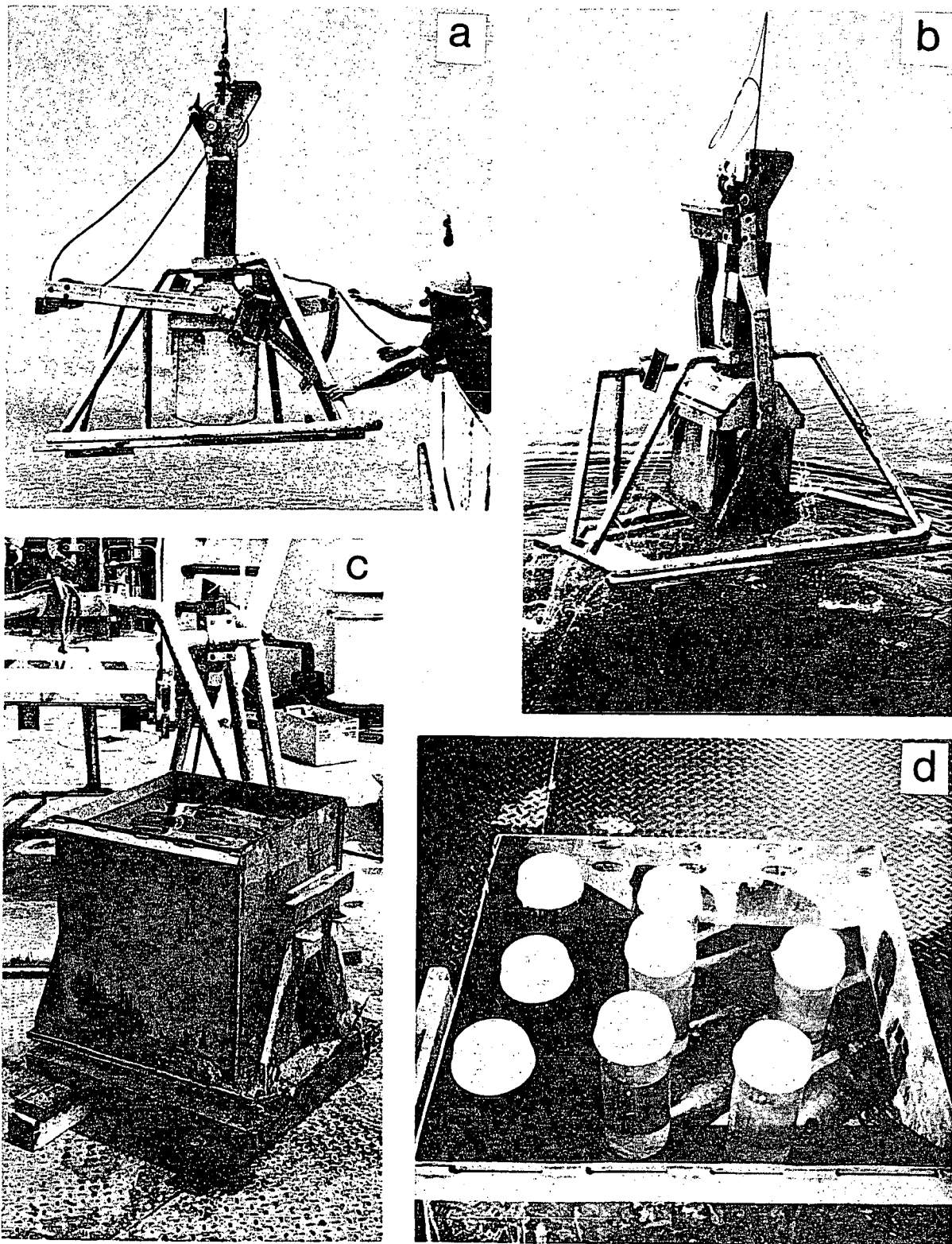


Figure 1. Large volume box corer used for Sediment Bank sampling. a.) Lowering the corer with retaining shovel in cocked position. The gimballed frame allows it to act on the bottom as a level gravity corer. b.) As the corer is hauled out of the bottom the shovel swings under to hold in the sample. c.) The frame is lifted off the core to provide access for subsampling the surficial sediment with 5 x 5 x 3 cm "cookie cutter" samplers. d.) Butyrate tubes, carefully inserted by hand, provide subcores from which historical samples are extruded.

At the quality control sites a second box core was collected and marked off in quadrants. Surficial sediment subsampled from each quadrant are stored separately. Four more surficial samples were collected by a Shipek sampler at these same stations. This sampling device was in common use on Great Lakes sediment surveys done previously out of CCIW. Sampling done at quality control stations allows some testing of sampling reproducibility, sediment patchiness and comparison with previous collection methods.

All positioning for Sediment Bank sampling is done with an Internav^R Model 123 Loran C receiver. Latitude and longitude reported for each station result from conversion of Loran C coordinates and are periodically confirmed by radar. Sites can be re-occupied using the same equipment with a precision of approximately 50 meters. All Sediment Bank coring was performed on board the CSS Limnos, operated by the Department of Fisheries and Oceans out of CCIW.

SAMPLE PROCESSING AND ANALYSIS

Among the important considerations in setting up a bank of sediment samples are the procedures adopted for preserving, processing and storing the sediment. To assist the user in choosing samples for analysis certain bulk characteristics may be useful. In this section the methods used for sample processing and bulk determinations are described.

Preservation and Storage

On shipboard, homogenized samples are frozen in solvent-cleaned glass trays at -20° C immediately after sampling from the box core and maintained at that temperature until freeze-dried. The decision to store the Sediment Bank samples in the dry state was based on the results of a preservation study which compared freeze-dried and frozen (-20°) storage. Detailed results of this study are given in Appendix I. In summary, there were few differences between the two preservation methods. Losses of certain organochlorine compounds occurred after six months' storage, but they were of the same order for both frozen and freeze-dried storage. In addition, standard deviations of replicate analyses were usually lower for the freeze-dried samples. This probably reflects the better degree of homogenization attainable on dry samples, another important consideration. It should be noted that the preservation study was prematurely curtailed because of a freezer failure. The continuing possibility of this occurrence, especially over many years, points to another disadvantage of frozen storage which was taken into consideration when the decision was made to store the Sediment Bank samples in the freeze-dried state.

To be sure, dry storage represents a compromise which is not at all acceptable for volatile components of sediments. Sediment Bank samples will be of little use in studying such components. A number of other environmental specimen banks have been realized in

the USA, Federal Republic of Germany, Canada, Japan, and Sweden (Wise and Zeisler, 1985). Banks such as the U.S. National Environmental Specimen Bank (Wise and Zeisler, 1984; Wise et al., 1984), the environmental specimen bank program of the Federal Republic of Germany (Kayser et al., 1982; Stoeppler et al., 1984), the Canadian Wildlife Service National Specimen Bank (Elliot, 1984, 1985), and the Great Lakes Biological Tissue Archive (Hyatt et al., 1986) at CCIW have utilized frozen storage at -40°C , -80°C and -196°C (liquid nitrogen). Resources for capital equipment necessary for such low temperature storage were not available to the Sediment Bank program. Also, our program was limited to four sampling years; and with due consideration to vessel scheduling, manpower and other operational parameters, we decided to proceed with dry storage.

Frozen aliquots of all Sediment Bank surficial samples were analyzed for chlorobenzenes, chlorotoluenes and other organochlorine compounds within six months of collection. Reports of these analyses (Oliver and Nicol, 1982; Oliver, 1984; Oliver and Charlton, 1984; Oliver and Bourbonniere, 1985) provide information which should be useful to workers in the future who are interested in comparison of contemporary sediment levels of organochlorines with those determined on Sediment Bank samples at the time of our sampling.

Freeze-Drying

Samples collected from Lake Huron in 1980 were freeze-dried under contract to a commercial operator. Glass trays containing frozen sediment were placed upon the shelves of a pilot plant scale freeze-drier. Initially the shelves were heated to 37°C . When the water content had been reduced by approximately one-half, after about two days, shelf heating was turned off and the remainder of the drying occurred at ambient temperature. Total drying time was four to five days per load.

Beginning with Lake Ontario samples collected in 1981, all subsequent Sediment Bank samples were dried at CCIW using a Virtis^R 100-SRC Subliminator. This pilot plant scale freeze-drier was purchased early in 1982 to support the Sediment Bank and other projects. Glass trays containing a total of approximately 30 litres of frozen sediment are dried in four days using a shelf temperature of 20° C for the entire run. A comparison of the effect of different shelf temperatures in freeze-drying is given in Appendix I.

Grinding and Homogenization

Freeze-dried samples are ground by hand with a mortar and pestle. Ground sediment is made to pass through a 60 mesh (250 micrometre) brass sieve. Coarse material which collects on the sieve is re-ground and re-sieved until 90% of the sample passes the sieve. Any coarse particles which cannot be ground are stored separately as the "coarse fraction".

Ground sediment is homogenized in a V-tube mixer. Four hundred grams of ground sediment is stored half in glass (solvent-cleaned) and half in plastic (acid-washed) containers each containing nominally ten grams. The remaining sample is stored similarly in bulk. All containers are of the tight fitting screw-capped type, and are stored at ambient temperature. Caps for the glass containers are lined with solvent-cleaned aluminum foil.

Grain Size Distribution

At the time of sampling a subsample of the wet homogenized sediment is frozen separately for grain size analysis. Samples are submitted to the Particle Size Laboratory of the Hydraulics Division, NWRI. Samples are analyzed by a combination of sieve and Sedigraph methods (Duncan and LaHaie, 1979) which is the standard in that laboratory. Percentages of sand, silt and clay as well as mean grain size (phi units), standard deviation and median are reported in the catalogs for each lake (see Appendices II and III).

Eh and pH Determinations

During sampling cruises shipboard measurements of Eh and pH are made on the sediment immediately after overlying water is siphoned from the box core. Measurements are made by inserting electrodes directly into the sediment to a depth of approximately one centimetre. Meters used are Radiometer^R Model PHM80 and electrodes are of the combination type. The pH meter is calibrated by a two-point procedure using buffers at pH 7 and pH 4. "Zobell solution" (Zobell, 1946) is used to calibrate the Eh meter. Results of these determinations are reported in the catalogs for each lake.

Bulk Carbon Analyses

Total and organic carbon is determined on all Sediment Bank samples. Analyses are performed by staff from the Aquatic Ecology Division, NWRI. The method used involves dry combustion with cupric oxide on a Leco^R Model IR12 Carbon Determinator which utilizes infrared detection of the carbon dioxide produced. Organic carbon is determined on samples which have been treated with sulfurous acid (H_2SO_3) to remove carbonates by volatilization. Calibration is done on a daily basis using a standard (Lake Ontario) sediment of known carbon content. Organic and inorganic carbon (by difference) contents are reported in the catalogs for each lake (see Appendices II and III).

SAMPLE DISTRIBUTION

Our general philosophy concerning distribution of samples is that they will be readily available to the entire Great Lakes scientific community. Limitations will be imposed depending on intended use and will become more severe in cases where sample supply is nearly depleted. Users will be expected to report the results of their analyses within six months from receipt of samples. The Sediment Bank has no interest in publication of the results for its own purposes. Data supplied by all users will be incorporated into a public domain data base so that anyone may make use of them. Once implemented, the details of input and retrieval from this data base will be included in a future report. If requested in writing we will maintain confidentiality of data reported for an additional six months. This we believe will encourage users to publish their results. The Sediment Bank represents a considerable investment by the Government of Canada. Each ten gram sample cost approximately \$20.00 to collect, process and store. In recognition of this investment we require that users acknowledge the Great Lakes Sediment Bank in any publication which results from use of the samples. We also require users to provide the Sediment Bank with two reprints of any publication or copies of any technical or unpublished report.

Procedures for Acquiring Samples

To provide a systematic evaluation of proposals for use of samples from the Sediment Bank, prospective users will be required to provide the following information in addition to institutional and individual identification:

- (i) objectives/goals of the proposal including anticipated completion times;
- (ii) analytical procedures intended to be applied;
- (iii) any other information that the proposer feels will add to an understanding of items (i) and (ii);
- (iv) specification of exactly which samples are being requested;

- (v) a signed agreement to provide analytical results within six months of receipt of samples, with the understanding that these will remain confidential for a further six months if requested in writing.

Proposals will be assessed against the stated objectives of the Sediment Bank which are "to provide retroactive analysis in order to establish spatial and temporal trends..." of contaminants in the Great Lakes. In practical terms, acceptable proposals will address (i) the identification of new contaminants; (ii) the establishment of the extent of distribution of new or previously identified contaminants. Proposals will be particularly favoured if the examination is novel in scope or analytical methodology, but re-examinations of previous work may also be supported. Additionally, proposals will be assessed against the criterion of analytical suitability and inclusion of an acceptable quality assurance regime. The Sediment Bank reserves the right to include quality assurance samples along with samples requested, in either blind or non-blind numbered form. Of major importance in assessing proposals will be whether the sample request is an important part of a well conceived and planned project. Whenever it is deemed appropriate, proposals may be sent to referees for comment.

Samples from the Sediment Bank are available free of charge. The proposer must agree to accept the samples via courier, collect. NWRI retains sole responsibility for and control of the distribution of samples. All requests for samples (with the exception of in-house users) are subject to approval of the Director, NWRI.

The form which appears on the following two pages constitutes the minimum amount of information required for sample requests. Prospective users are encouraged to submit additional information in support their request. The scientist-in-charge of the Sediment Bank and the Director, NWRI reserve the right to require additional information whenever warranted.

GREAT LAKES SEDIMENT BANK - REQUISITION FORM

SEND TWO COPIES BOTH ORIGINALLY SIGNED TO:

Great Lakes Sediment Bank
National Water Research Institute
Environment Canada
P.O. Box 5050, 867 Lakeshore Road
Burlington, Ontario
CANADA L7R 4A6
ATTENTION: Dr. R.A. Bourbonniere

REQUESTER INFORMATION

NAME _____

MAILING ADDRESS _____

TELEPHONE(S) _____

SHIPPING ADDRESS IF DIFFERENT FROM ABOVE

SAMPLES REQUESTED - LIST HERE OR ATTACH SEPARATE LISTING

PROPOSED USE OF SAMPLES - EXPLAIN HERE OR ATTACH SEPARATE PROPOSAL

SPECIAL CONSIDERATIONS - E.G. SAMPLE SIZE, CONTAINER, ETC.

AGREEMENT

I _____ request samples as described above be sent to me from the Great Lakes Sediment Bank. I agree to be bound by these conditions:

- That I will not use samples provided for any purpose other than that stated on this application without first obtaining written authorization approved by the Director, NWRI;
- That I will not transfer samples to any other person, laboratory or organization without first obtaining written authorization approved by the Director, NWRI;
- That I will accept samples shipped to me by courier COLLECT;
- That I will submit results of analyses and data developed from these samples to the Great Lakes Sediment Bank within six months from date samples were received;
- That the Great Lakes Sediment Bank may enter the results of my analyses into a data base in the realm of the Public Domain;
- That in all reports or publications arising from the analyses of these samples I will acknowledge their source with this statement: "Sediment samples were obtained from the Great Lakes Sediment Bank held by Environment Canada, courtesy of the Director, National Water Research Institute."

SIGNATURE: _____ DATE: _____

APPROVED: _____ DATE: _____

Director, National Water Research Institute

LAKE HURONBackground to the Lake and its Sediments

Lake Huron is the third largest of the Great Lakes, receiving waters from Lakes Michigan and Superior and discharging into Lake St. Clair. The main basin of Lake Huron is physically separated from Georgian Bay and the North Channel with respect to sedimentation, but receives sediment input from Saginaw Bay. The two largest sub-basins in the northern part of the main basin, the Manitoulin and Mackinac Basins, are characterized by undulating topography with glaciolacustrine clay outcrops. However, more than half of the area of these two basins are covered by postglacial sediments. The southern sub-basins, Goderich, Port Huron, and Saginaw, contain predominantly postglacial mud deposits over their entire area. The Alpena sub-basin is also covered mostly with postglacial mud deposits but contains significant glaciolacustrine clay outcrops (Thomas et al., 1973).

Saginaw Bay is a shallow, high energy extension of the southern basin of Lake Huron. Sediments in this bay are predominantly postglacial and are winnowed somewhat by local current action (Wood, 1964). Georgian Bay contains six smaller depositional sub-basins, the Flowerpot, French River, Cabot and Nottawasaga Basins and the Owen Sound and Lion's Troughs, which are covered with postglacial deposits. The remainder of Georgian Bay is a non-depositional area as is the North Channel (Kemp and Harper, 1977).

Mean grain size for surficial (0-3 cm) samples from all basins in the main part of Lake Huron is 7.4 ± 1.3 (phi units), mean basin organic carbon content is $2.61 \pm 1.17\%$ and mean inorganic carbon content is $0.54 \pm 0.86\%$ (Thomas et al., 1973). Saginaw Bay surficial sediments are coarser than those of the main basin. content of surficial sediments from the depositional basins of the samples less than 0.09% (Wood, 1964). Mean organic carbon between

0.062-0.25 mm and half between 0.25-0.50 mm. For a suite of 61 sampling sites covering the entire bay, 44 contain less than 0.062-0.25 mm and half between 0.25-0.50 mm. For a suite About 90% of the area shows median grain diameters between 0.062 of the samples less than 0.09% (Wood, 1964). Mean organic carbon content of surficial sediments from the depositional basins of Georgian Bay was reported as 2.97% (range: 1.0-4.77%) by Kemp et al. (1977a).

Brief Guide to Previous Work

In this section some of the literature which has a bearing on the understanding of the problem of contaminants in Lake Huron sediments are cited. This review is not meant to be exhaustive, but is rather a guide to recent work which form the background upon which the Sediment Bank sampling plans were based. For comprehensive bibliographic information on all aspects of Lake Huron research the reader is referred to Rossmann and Treese (1981) and for Great Lakes research in general to the index published by IAGLR (1983). An extensive literature review of contaminants in sediments was summarized by Mudroch et al. (1985).

Sediments in General

During the summer of 1969 an extensive sampling of surficial sediments was carried out by the Canadian Department of Energy, Mines and Resources. The upper 3 cm of Shipek grab samples was subjected to numerous sedimentological and geochemical analyses. Replicate Shipek samples were processed for enumeration of benthic organisms wherever possible. This work resulted in an overview report, Thomas et al. (1973), which describes the character of sediments in the main basin of the lake. It remains the most comprehensive survey of modern Lake Huron sediments and was the basis for selection of most of the sites chosen for sampling for the Sediment Bank. Further reports related to this sampling of Lake Huron sediments discuss sediment geochronology (Kemp et al. 1974, Kemp and Harper 1977) and organic carbon and nitrogen (Kemp 1971, Kemp et al. 1977a).

During 1974 and 1975 sediment cores were collected by the Great Lakes Research Division of The University of Michigan using a Benthos gravity corer. The sampling included the main basin of the lake and Saginaw Bay; stations occupied numbered 178. The cores were analyzed for major and minor elements and geochronological studies were undertaken. Reports which resulted from this work include; Robbins (1980a,b), Robbins et al. (1977) and Krezoski et al. (1978).

A number of other studies have reported on various sediment properties. Wood (1964) undertook a detailed survey of Saginaw Bay sediments and reported on their sedimentological properties. Schneider et al. (1969) reported on the distribution and abundance of benthic fauna in Saginaw Bay. Kemp (1973), Meyers and Takeuchi (1979) and Meyers et al. (1979, 1980a,b) reported on various organic matter components in Lake Huron and Saginaw Bay surficial sediments and cores.

Contaminants in Sediments

As part of a comprehensive study of heavy metal inputs to all of the Great Lakes, Fitchko and Hutchinson (1975) reported on distributions of Pb, Ag, Cd, Co, Cu, Cr, Ni, Zn, Mn and Hg in sediments collected from the mouths of eleven rivers flowing into Lake Huron. Thomas (1973) reported on the distribution of Hg in the surficial sediments of the main basin of the lake. Heavy metals were included in the studies carried out by Robbins (1980a,b) on sediment cores also taken from the main basin. Mudroch et al. (1985) completed an extensive review of the literature and compiled a summary of concentrations of As, Cd, Cr, Cu, Fe, Hg, N, Ni, P, Pb, Zn, Oil & Grease, Org-C (LOI), and Total PCB's in sediments from all areas of the Great Lakes.

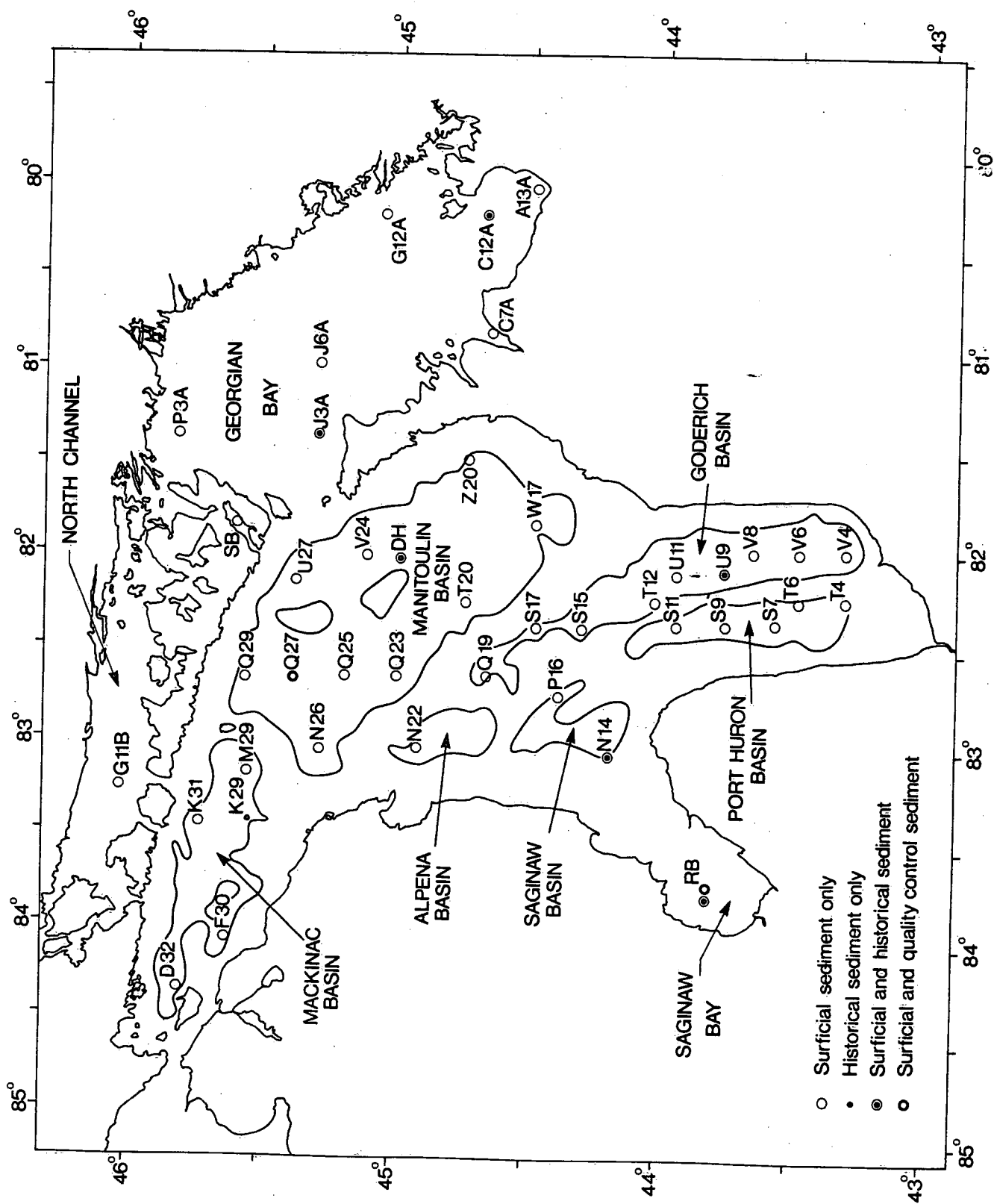
Organic contaminants have also been studied in sediments from Lake Huron. Glooschenko et al. (1976) reported on concentrations of several pesticides and PCB's in 17 surface samples from Lake Huron, Saginaw and Georgian Bays and the North Channel. Oliver and Nicol

(1982) analyzed chlorobenzenes in 42 wet, frozen aliquots of surficial sediment from Sediment Bank collections sampled in 1980 from all basins. A total of 114 chlorinated compounds (chlorobenzenes and toluenes, pesticides, PCB congeners and others) were determined on nine of these same Sediment Bank aliquots from the Goderich and Port Huron basins (Oliver and Bourbonniere, 1985). Petroleum hydrocarbons have been determined in surficial sediments in the Goderich basin and Saginaw Bay (Meyers and Takeuchi, 1979), and in a core from Saginaw Bay (Meyers et al. 1980b). Polychlorinated dioxins and furans were found in surficial and core sediments from Saginaw Bay and southern Lake Huron (Czuczwa and Hites, 1984).

LAKE HURON SAMPLING - SEDIMENT BANK

In June, 1980 the first Sediment Bank sampling cruise took place on Lake Huron aboard the CSS Limnos. Samples are mostly from the depositional basins in the main part of the lake, but were also taken from depositional sites in Georgian Bay, North Channel, Saginaw Bay and South Bay on Manitoulin Island (Figure 2). Surficial sediment is available from 42 sites. These samples are listed in Appendix II along with their locations and various bulk properties. All of the sampling sites except two were chosen to be identical to those occupied on the various cruises of Thomas and co-workers. Names (eg. P16, J3A, G12B, etc.) are the same as used in such publications as Thomas et al. (1973) and Kemp and Harper (1977). Locations of sites are as near as possible to those stated in the referenced publications with the proviso that in 1980 we used Loran C positioning and in 1969 positioning was done by radar. The other two stations were chosen for special interest. Station DH is the "deep hole" of Lake Huron, a relatively small topographic feature with a water depth of 245 m (Kemp and Harper, 1977). Since Thomas and co-workers have not sampled in Saginaw Bay, we chose station RB in the centre part of the Bay. This station is the same as Station 30A reported on by Meyers and Takeuchi (1979) and Meyers et al. (1980b).

Historical samples were collected from seven of the 42 sites. These were chosen to give spatial coverage of the lake, and on the basis of geochronological information reported by previous workers. Core interval samples represent integrations of depositional periods ranging from approximately 11-50 years (Table 1). Locations of these samples are listed in Appendix II.



- Surficial sediment only
- Historical sediment only
- ⊙ Surficial and historical sediment
- ⊗ Surficial and quality control sediment

Figure 2. Sediment Bank sampling sites from the Lake Huron cruise in June, 1980 (LH80). Locations and bulk data from these sites appear in Appendix II.

TABLE 1

AGE CHARACTERISTICS OF HISTORICAL SAMPLES TAKEN DURING
LAKE HURON SAMPLING IN 1980

Core ID	Modern Lin. Sed. Rate (mm/yr)*	Lit. Source	Sampling Intervals (cm)	(yrs)	Maximum Sampled (cm)	(yrs)
LH80-C12A	0.3	1,2	1	33	5	167
LH80-DH	0.4	1,2	2	50	10	250
LH80-J3A	0.6	1,2	1	17	5	83
LH80-K29	2.2	2	5	23	25	114
LH80-N14	1.6	2	3	19	15	94
LH80-RB	4.5	3	5	11	35	78
LH80-U9	1.7	2	3	18	15	88

* Average rate if more than one source.

1 Unpublished data from S.R. Joshi from 1980 cores - Pb-210.

2 Kemp and Harper (1977) - Ambrosia.

3 Meyers et al. (1980b) - Pb-210.

Two sites, RB and Q27, were chosen as quality control sites. Site RB is in Saginaw Bay, a higher energy environment than at site Q27, which is in the Manitoulin Basin. Sampling methodology for the quality control sites was described previously.

Organic carbon results were slightly higher for the box core quadrants (Table 2) probably because of that corer's superior preservation of the sediment-water interface during sampling. The Shipek sampler has a tendency to compress the soft upper layers so that a 0-3 cm subsample may actually represent a deeper sampling interval in the natural state. Maximum organic carbon concentration almost always occurs in the upper cm and decreases with depth (Kemp et al., 1977b). Compression upon sampling would have the effect of dilution with sediment of lower organic carbon content. Mudroch et al. (1985) presents similar results for eight of nine major and minor sediment components.

Inorganic carbon data show a higher degree of variability for both sampling methods (Table 2). Several factors contribute to this variability; (1) drifting of the ship during the Shipek sampling sequence, (2) the derived nature of inorganic C (total - organic), and (3) the vertical variability of inorganic C concentrations in the upper layers of the sediments (Kemp et al., 1977b) sometimes showing subsurface maxima.

TABLE 2

ORGANIC AND INORGANIC CARBON FOR QUALITY CONTROL SAMPLES TAKEN
DURING LAKE HURON SAMPLING IN 1980, N = 4

		ORGANIC C (%)	INORG C (%)
LH80-RB	Box Core Quadrants	3.30 ± 0.21	1.00 ± 0.24
	coef. of var. (%)	6.4	24.0
	Shipek Bucket	3.12 ± 0.41	0.80 ± 0.34
	coef. of var. (%)	13.1	42.5
	* t-test prob. (%)	95	>95
LH80-Q27	Box Core Quadrants	3.28 ± 0.08	0.38 ± 0.15
	coef. of var. (%)	2.4	39.5
	Shipek Bucket	3.09 ± 0.08	0.42 ± 0.13
	coef. of var. (%)	2.6	31.0
	* t-test prob. (%)	>99.9	>90

* Probability that mean values are not equivalent using the two-tailed Student's t distribution.

LAKE ONTARIOBackground to the Lake and its Sediments

Lake Ontario is the last in the chain of five Great Lakes, smallest in area and fourth in volume. It receives much of its water from Lake Erie through the Niagara River and discharges at the St. Lawrence River. The main basin of Lake Ontario can be described as an elongated trough trending east-west. It is separated from a shallow basin in the northeast (the Kingston Basin) by a limestone sill outcrop. The main basin is further subdivided into three sub-basins by two cross lake ridges. Thus the Niagara Basin is the western sub-basin, the Mississauga Basin is the central sub-basin and the Rochester Basin is the eastern sub-basin. All three sub-basins of the main basin contain on average from 4-14 m of postglacial muds. These muds grade from silty clays in the centre of each sub-basin to silts at the edges. The Whitby-Olcott and Scotch Bonnet sills, non-depositional zones which separate the sub-basins, are composed of glaciolacustrine clay, as is a band of sediment in the northern third of the lake which separates the inshore zone from the main basins (Thomas et al., 1972).

Mean grain size for the depositional zones of the lake is 8.1 ± 1.1 (phi units) for surficial (0-3 cm) sediments. Mean basin organic carbon content is $3.01 \pm 0.55\%$ and mean inorganic carbon content of the basins is $0.46 \pm 0.29\%$ (Thomas et al., 1972).

Brief Guide to Previous Work

In this section some of the literature which has a bearing on the understanding of the problem of contaminants in Lake Ontario sediments are cited. This review is not meant to be exhaustive, but is rather a guide to recent work which forms the background upon which the Sediment Bank sampling plans were based. For comprehensive bibliographic information on Great Lakes research in general the reader is referred to the index published by IAGLR

(1983). An extensive literature review of contaminants in sediments was summarized by Mudroch et al. (1985).

Sediments in General

In 1968 the Canadian Department of Energy, Mines and Resources conducted an extensive sampling of surficial sediments on an eight kilometer grid covering the entire lake. Thomas et al. (1972) analyzed the upper 3 cm of Shipek samples and reported many sedimentological and geochemical parameters. This work remains the most comprehensive systematic study of modern Lake Ontario sediments and formed the basis for selection of many of the sites chosen for Sediment Bank sampling.

Kemp and Harper (1976) report on a broad survey of modern sedimentation rates from 39 coring locations on Lake Ontario collected between 1969 and 1971. Sedimentation rates were determined from the depth of the Ambrosia horizon in the cores collected. From these and other data the authors present a sediment budget for Lake Ontario and suggest that river inputs are the major source of fine-grained sediments, about 50% of all incoming sediments are from the Niagara River alone. Most suspended materials are being carried eastward and are either deposited in the Rochester and Kingston Basins, or are carried out via the St. Lawrence River.

Other work on Lake Ontario sediments and its sources include that of Kemp and Dell (1976) which discusses the composition of bluffs and their relationships to that of sediments. Farmer (1978) and Robbins et al. (1978) present geochronological data for several sites and the latter paper includes a comparison of three methods for determining sedimentation rates.

The area of western Lake Ontario near the mouth of the Niagara River was studied intensively. Sly (1983a) reported on the sedimentology and stratigraphy of the Niagara bar and on the geochemistry of recent sediments there (Sly, 1983b). Sedimentation

processes were studied by Charlton (1983), by measuring the downflux of sediment with traps, and Sandilands and Mudroch (1983) reported on the existence of a nepheloid layer which extends over all sedimentary zones in the lake.

Contaminants in Sediments

Lake Ontario sediments have been analyzed for a number of organic contaminants. The most celebrated is the case of Mirex (Kaiser, 1978). Analysis for Mirex of sediment samples archived from the 1968 sampling described above by Thomas et al. (1972), indicated two concentration "anomalies" in the surficial sediments. One of these was a band along the southern part of the lake between the Niagara River and Rochester, NY, the other was in the Rochester Basin off Oswego, NY (Holdrinet et al., 1978). Resampling of these "anomalies" and other samples in 1976 confirmed the earlier work and traced the Mirex to its likely sources (Holdrinet et al., 1978). This case study is a prime example of the value of sediment archives and indeed was an incentive for the establishment of the Sediment Bank.

Frank et al. (1979) reported the distribution of a number of organochlorine insecticides and PCB's in Lake Ontario sediments from the same 1968 surficial samples and from three cores collected in 1976. Oliver and Nicol (1982) reported on chlorobenzene determined on 11 surficial sediment samples. Sediment Bank samples were used by Oliver (1984) to describe how chlorobenzenes may move between environmental compartments in Lake Ontario. Concentrations of chlorobenzenes on settling particulates and Sediment Bank samples from the same area are reported by Oliver and Charlton (1984). Octachlorostyrene was measured in 11 sediment cores from various locations in the lake, some of which correspond to Sediment Bank stations from 1981 (Kaminsky and Hites, 1984). Jaffe and Hites (1985) identified fluorinated biphenyls in a number of sites from the lake and Niagara River.

There is a great deal of recent interest on the impact of pollution from the heavily industrialized Niagara River area on water quality in Lake Ontario. A 1982 symposium on the topic (Allan et al., 1983) resulted in a number of publications related to contaminants in sediments of western Lake Ontario. Mudroch (1983) reported on the distribution of major elements, trace metals, and mineralogy in cores taken from this area. Thomas (1983) shows how the distribution of Hg in surficial sediments of the lake pinpoints the Niagara River as a major source.

A number of organic contaminants were also studied and reported at the symposium. Compounds and compound classes determined by several authors include: aliphatic esters, aldehydes, alkylbenzenes, alkyl benzoates, benzyl ethers, chlorobenzenes, chlorodibenzofurans, chloro-PAH's, chlorostyrenes, chlorotoluenes, cyclic ketones, hexachlorobutadiene, mirex, olefins, PCB's, photomirex, phthalates, polyaromatic hydrocarbons, 2,3,7,8-TCDD, and some unique chloro-fluoro-substituted compounds (Durham and Oliver, 1983; Kaminsky et al., 1983; Onuska et al., 1983; Thomas, 1983). Fox et al. (1983) studied the compartmental distributions (dissolved, suspended sediments, sediments, and benthic fauna) of some of these same contaminants in western Lake Ontario.

Fitchko and Hutchinson (1975) report the distributions of Pb, Ag, Cd, Co, Cu, Cr, Ni, Zn, Mn and Hg in sediments collected from the mouths of 15 rivers flowing into Lake Ontario. Thomas (1972) reported on the distribution of Hg in Lake Ontario surficial sediments. Mudroch et al. (1985) completed an extensive review of the literature and compiled a summary of concentrations of As, Cd, Cr, Cu, Fe, Hg, N, Ni, P, Pb, Zn, Oil & Grease, Org-C (LOI), and Total PCB's in sediments from all areas of the Great Lakes.

LAKE ONTARIO SAMPLING - SEDIMENT BANK

In May, 1981 a cruise of the CSS Limnos served to collect samples for the Sediment Bank. Most of the samples were taken from the the main depositional basins, but several were also sampled which were on the periphery of the lake. The latter were chosen for particular interest such as proximity to the Niagara River (S21, S22 and S93) and the Bay of Quinte (S82). Surficial sediment is available from 39 sites (see Figure 3). These samples are listed in Appendix III along with their locations and various bulk properties. Many of the sites were chosen to be identical to those occupied on the various cruises of Thomas and co-workers. These stations are named in accordance with those used in such publications as Thomas et al. (1972) and Kemp and Harper (1976), (eg. E30, WB, G21, etc.). In addition a number of stations chosen were suggested by NWRI researchers prior to the cruise. These were taken from the usual Lake Ontario surveillance stations, and are named S2, S64, etc. Locations of stations are as near as possible to those of referenced publications considering that in 1981 Loran C positioning was used, while earlier studies used radar.

Four stations were sampled for historical samples. These were chosen to represent each of the main basins (Niagara, Mississauga, Rochester and Kingston) and on the basis of geochronological information reported by previous workers. Core interval samples represent integrations of depositional periods ranging from approximately 9-30 years (Table 3). The oldest intervals from the historical stations range from 38-120 years B.P. Locations of these samples are listed in Appendix III.

Stations S23 and S64 were sampled for quality control studies. Station S64 is in the Rochester Basin near to the deepest part of the lake. Station S23 is located near the Niagara River mouth, but in the deeper water of the Niagara Basin proper. Organic and inorganic carbon results for both sampling methods are given in

Table 4. Differences between the methods are explained in much the same way as was done for the Lake Huron quality control samples previously.

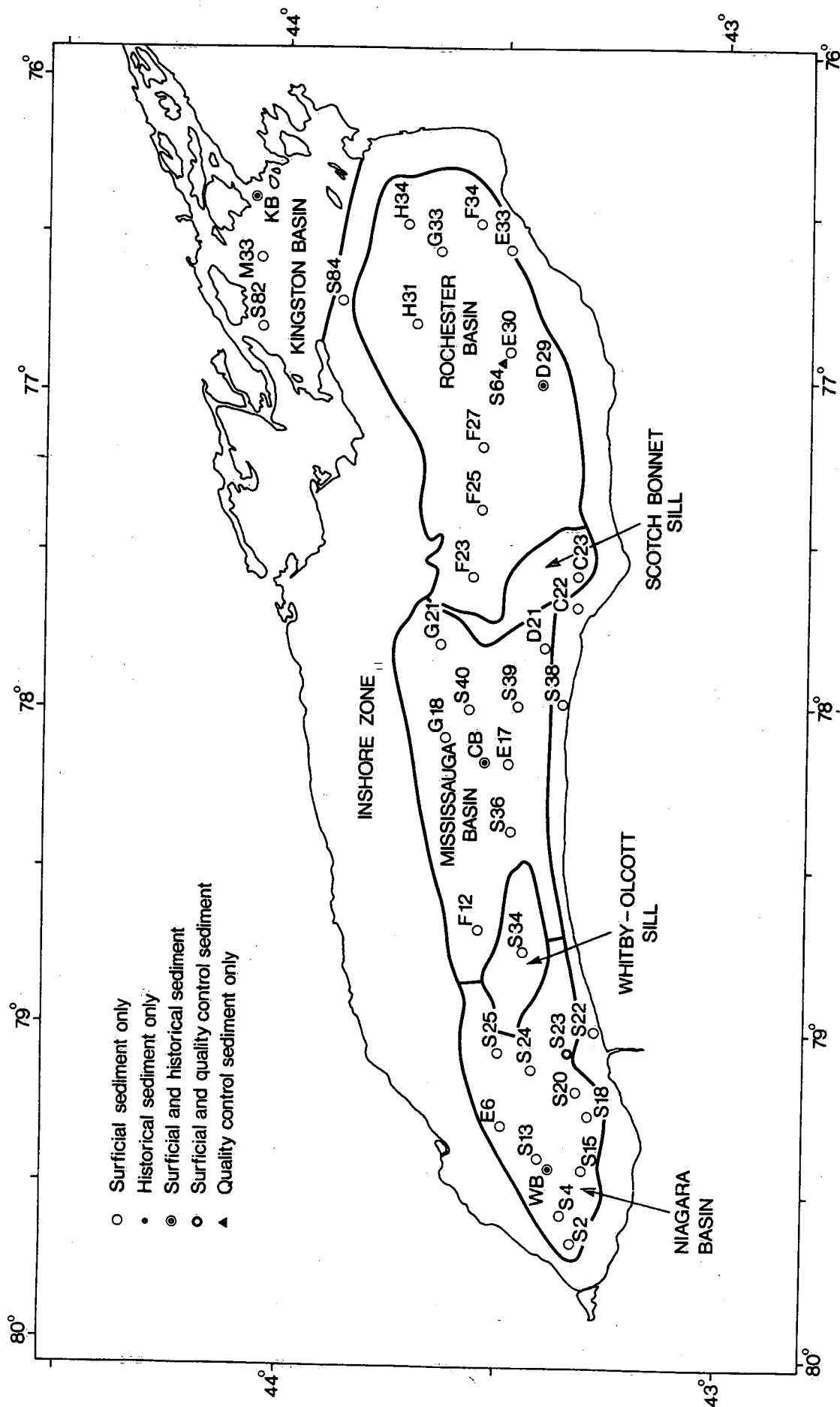


Figure 3. Sediment Bank sampling sites from the Lake Ontario cruise in May, 1981 (LO81). Locations and bulk data from these sites appear in Appendix III.

TABLE 3

AGE CHARACTERISTICS OF HISTORICAL SAMPLES TAKEN DURING
LAKE ONTARIO SAMPLING IN 1981

Core ID	Modern Lin. Sed. Rate (mm/yr)	Lit. Source	Sampling Intervals (cm)	(yrs)	Maximum Sampled (cm)	(yrs)
LO81 - WB	2.9	1	3	9	12	38
LO81 - CB	1.6	2	4	25	16	100
LO81 - D29	1.0	2	3	30	12	120
LO81 - KB	2.9	3	5	17	20	70

1 Robbins et al. (1978) - Average of Pb-210 and Cs-137.

2 Kemp and Harper (1976) - Ambrosia.

3 Robbins et al. (1978) - Average of Pb-210, Cs-137 and Ambrosia.

TABLE 4

ORGANIC AND INORGANIC CARBON FOR QUALITY CONTROL SAMPLES TAKEN
DURING LAKE ONTARIO SAMPLING IN 1981, N = 4

		ORGANIC C (%)	INORG C (%)
LO81-S23	Box Core Quadrants	3.22 ± 0.14	1.53 ± 0.10
	coef. of var. (%)	4.3	6.5
	Shipek Bucket	3.68 ± 0.36	1.27 ± 0.36
	coef. of var. (%)	9.8	28.3
	* t-test prob. (%)	>99.8	>99.8
LO81-S64	Box Core Quadrants	4.31 ± 0.12	2.04 ± 0.11
	coef. of var. (%)	2.1	5.4
	Shipek Bucket	4.24 ± 0.16	1.49 ± 0.67
	coef. of var. (%)	3.8	45.0
	* t-test prob. (%)	>99.8	>98

* Probability that mean values are not equivalent using the two-tailed Student's t distribution.

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APPENDIX I

SEDIMENT PRESERVATION STUDY

The method of preservation and storage used in an archive can have a considerable impact on the future utility of the samples for certain analyses. For example, losses of organic contaminants during sample processing and storage may be significant if they are volatile. As part of the initial work undertaken for the Sediment Bank study we conducted a preservation study.

Collection, Processing, and Storage

On November 29, 1979, surficial sediment (0-2 cm) was pooled from multiple Shipek casts collected at each of two sites in Lake Ontario. Site 1 (43° 22' 02" N., 79° 06' 45" W.) is located near the mouth of the Niagara River and Site 2 (43° 16' 58" N., 79° 41' 59" W.) is located about 10 km east of the Skyway Bridge. Enough sediment (ca. 10 kg wet weight) from each site was collected to study the effects of long-term storage on frozen and freeze-dried samples.

Immediately after collection the fresh sediment was homogenized by stirring on shipboard and a number of wet subsamples (ca 50 g each) were taken. Some of the wet subsamples were stored in solvent-cleaned glass jars and some in acid-washed polypropylene vials. All of these were frozen at -20° C immediately upon return to the laboratory, about 2-3 hours after collection. The remaining bulk sediment from each site was frozen in larger quantities in preparation for freeze-drying.

The following morning three of the frozen glass-jar samples from each site were submitted for organochlorine analyses and were extracted on the same day. Results of these analyses are taken to represent the initial (time zero) concentrations of organochlorines for comparison with subsequent analyses of frozen and freeze-dried samples in the time study. The remaining frozen samples were used in the time study.

Larger bulk samples were placed in a freeze-drier on the next day (November 30th) with the chamber temperature maintained at ambient

(ca. 20° C) for the seven days necessary to dry them. The dry samples were ground by hand with a mortar and pestle until they passed through a 600 micron seive. The homogenized dry sediment was subsampled into a number of glass and polypropylene containers and stored at room temperature. These samples constitute the dry samples for the time study.

Time Series for Organochlorine Analyses

After two months of storage, frozen and dry subsamples (in triplicate) from both sites were submitted for organochlorine analyses. After six months this submission was repeated for Site 1 only since previous results on Site 2 samples revealed that many of the contaminants of interest were below detection limits. Also at six months, three of the Site 1 frozen samples were subjected to test freeze-drying at a commercial establishment. These were dried with the chamber temperature at 37° C until half of the water was removed. The drying was finished at ambient temperature, and the samples subsequently submitted for organochlorine analyses.

When the time study had been conducted for one year, all of the frozen samples were lost because of a major freezer breakdown. Over a four day long weekend a common-user walk-in freezer malfunctioned resulting in the attainment of temperatures of up to 40° C. Unfortunately, we were not able to submit samples for analyses before the disaster, so our frozen time study was limited to six months of data.

Although the dry subsamples remain, they also ran into problems. Our service laboratory underwent a number of administrative, personnel and procedural changes in the early 1980's resulting in a backlog of samples for organochlorine analyses. As a consequence of this, the next time that our dry time series analyses were done was in late 1985, six years after collection. By that time we had already been committed to storage of the Sediment Bank samples in the freeze-dried state.

Results of Preservation Study - Organochlorines

A comparison of frozen and freeze-dried storage is made on both sites (Figure I.1). These data represent the results of triplicate analyses of five organochlorine substances and three different storage treatments. For Site 1 those samples designated as "WET" were stored frozen for six months at -20°C ; those called "FD-20" are samples which were freeze-dried at 20°C during the first week after collection and subsequently stored dry at room temperature for six months. The Site 1 samples designated "FD-37" were stored frozen for six months and freeze-dried just prior to analysis by the commercial procedure described in the previous section. The Site 2 "WET" and "FD-20" samples were treated similar to the corresponding Site 1 samples except that the date of extraction represents only two months of storage.

The results are mixed but some generalizations can be made by careful examination of Figure I.1. For hexachlorobenzene (HCB), total polychlorinated biphenyls (TOT PCB) and 1,1-dichloro-2,2-bis(p-chlorophenyl)ethane (DDE) the ranges of concentration as represented by standard deviations about the mean all overlap regardless of treatment (Figure I.1 A,B,C,F,G,H). Results for the "FD-37" samples indicate the greatest amount of volatility losses. For the three parameters above and for 1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene (TDE) (Figure I.1 E,J) the correspondence for the "WET" and "FD-20" samples is quite good. Furthermore six of the eight comparisons from above show narrower ranges for the "FD-20" samples compared to the "WET" samples. This suggests that homogenization of the dry samples is superior to that of the wet samples. Dry samples consistently showed higher concentrations of Mirex (Figure I.1 D,I) than wet samples. Some possible explanations for this are; contamination upon handling, differential extractability from wet and dry sediments and "production" of Mirex from other organochlorines upon dehydration and heating.

The mean values plotted in Figure I.1 are given in Table I.1 along with calculations of the percentage change of concentrations for the dry samples relative to the corresponding wet values. For the five components studied in Site 1 samples the change upon drying at 20° C ranges from a loss of 19.3% to a gain of 16.4%. For Site 2 samples the range is from no change to a gain of 22.2% if the data from Mirex are eliminated since they are near to or below the accepted detection limit (0.004 mg/kg). It is fair to say therefore that for these components, determinations on samples freeze-dried at 20° C are comparable to those done on frozen samples within an experimental error of 20%. Samples freeze-dried at 37° C are comparable to within about 40%. The average percent changes shown on Table I.1 are encouraging, but represent data from only five components.

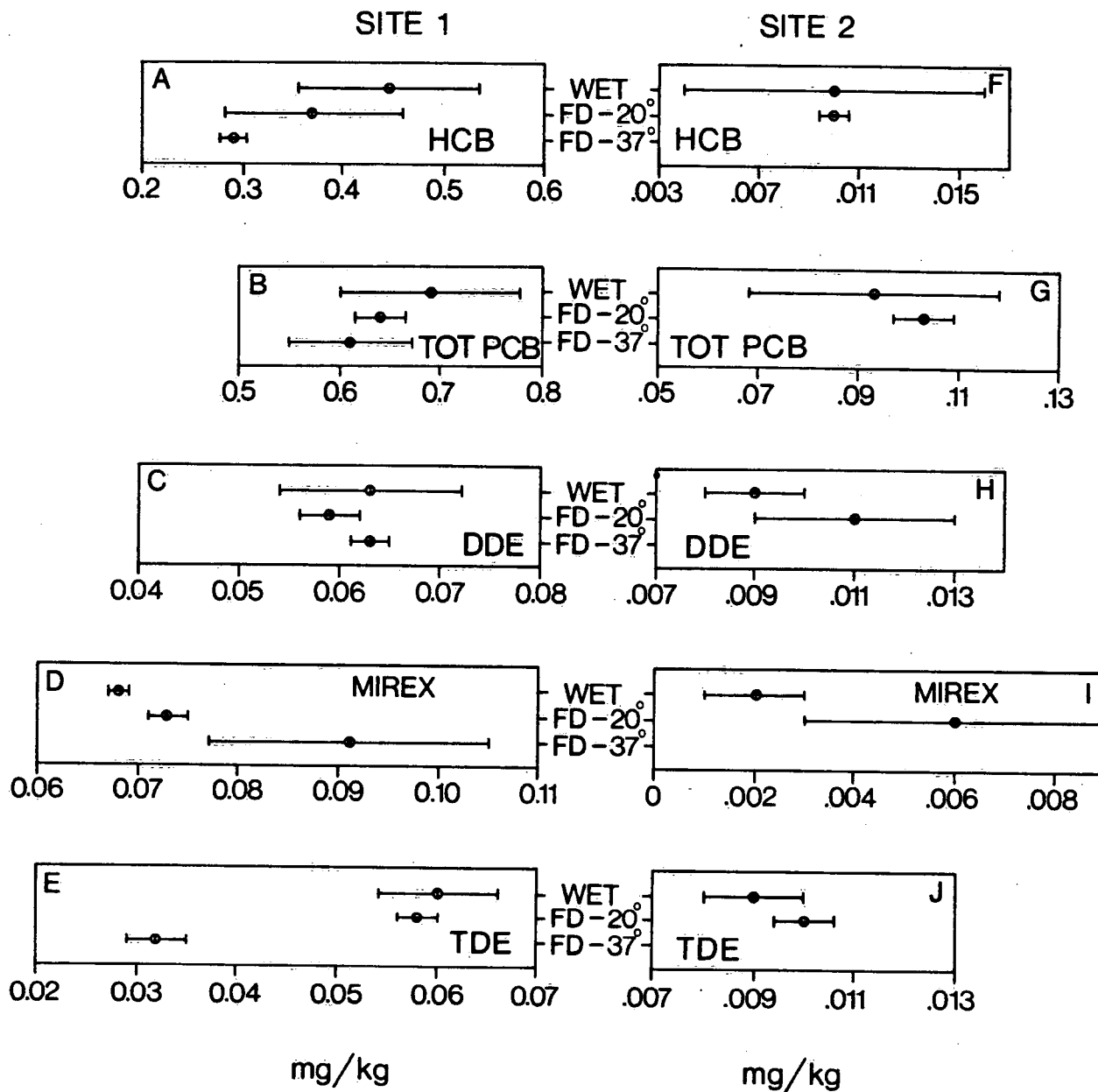


Figure I.1. Comparison of the effect of freeze-drying on the concentrations of five organochlorines. Values plotted are means of triplicate determinations \pm standard deviations.

TABLE I.1

CHANGES UPON FREEZE-DRYING FOR FIVE ORGANOCHLORINES

OC COMPO- NENT	<----- SITE 1 ----->					<----- SITE 2 ----->			
	WET mg/kg	FD-20 mg/kg	% CHG FR WET	FD-37 mg/kg	% CHG FR WET	WET mg/kg	FD-20 mg/kg	% CHG FR WET	AVG % CHG
HCB	0.444	0.362	-18.5	0.289	-34.9	0.010	0.010	0.0	-17.8
TOT PCB	0.690	0.557	-19.3	0.610	-11.6	0.093	0.103	+10.8	-6.7
DDE	0.063	0.066	+4.8	0.063	0.0	0.009	0.011	+22.2	+9.0
MIREX	0.068	0.076	+16.4	0.091	+33.8	0.002	0.006	+200	+25*
TDE	0.060	0.066	+10.0	0.032	-46.7	0.009	0.010	+11.1	-8.5
	AVERAGE		-1.3		-11.8			+11.0*	

* Mirex data for Site 2 eliminated

Results of Preservation Time Series - Organochlorines

Time series data for the same five organochlorine components discussed above are presented in Figures I.2, I.3, and I.4 for Site 1 sediments. Significant losses of concentration over time, compared to the initial wet concentration, are noted for Mirex, DDE and TDE (Figures I.3 and I.4). These losses were approximately parallel for both wet storage (frozen) and dry storage (FD-20). Furthermore for Mirex and DDE most of the losses occurred at the beginning of the study, during the first two months (Figure I.3), whereas the losses for TDE occurred more evenly over the first six months (Figure I.4). TOT PCB and HCB don't appear to experience any significant losses upon storage by either method (Figure I.2).

The mean values plotted in Figures I.2, I.3 and I.4 were used to calculate the percentage change of concentrations for certain periods over the entire time span of the study. For frozen storage (Table I.2) the average losses are somewhat encouraging, but losses (or increases) for individual components can be considerable, and should be taken into account when interpreting results of analyses on samples which were stored this way. For all samples the changes occurring during the 2-month to 6-month period of storage are lower, by an average of about two-thirds, than those which occurred during the first two months.

Losses experienced for the samples which were stored in the dry state are generally comparable to the wet samples for the first six months' storage (Table I.3). On average there was little change between six months and six years of dry storage.

The data in Table I.4 are a comparison of wet and dry storage on a time-for-time basis. After two months of storage the dry samples actually average higher than the wet samples. Considering that on average there was no change simply upon freeze-drying at 20° C (Table I.1); then the relatively higher average value for dry storage suggests that processes which act to decrease organochlorine concentration upon short-term storage are more

effective on wet/frozen samples. Alternatively, it must be considered that processes which act to increase (contaminate) samples would be more likely to affect the dry samples since they have undergone a greater degree of "handling".

The key comparisons of course are those which relate to changes from the initial concentrations. Data in Tables I.2 and I.3 show that differences between wet and dry storage for each of these five components are roughly comparable. For wet storage the range of change after six months, -42.3% to +9.4%, (Table I.2) translates in absolute value to a range of uncertainty factors of 1.1-1.7. Similarly, for dry storage the range of change, -44.2% to -6.3%, (Table I.3) translates in absolute value to a 1.1-1.8 range of uncertainty factors. In practical terms then, results from analysis of stored samples (wet or dry) are comparable to analysis of "fresh" samples to within about 10% if the component is "high" in concentration and to within a factor of two if the component is "low" in concentration.

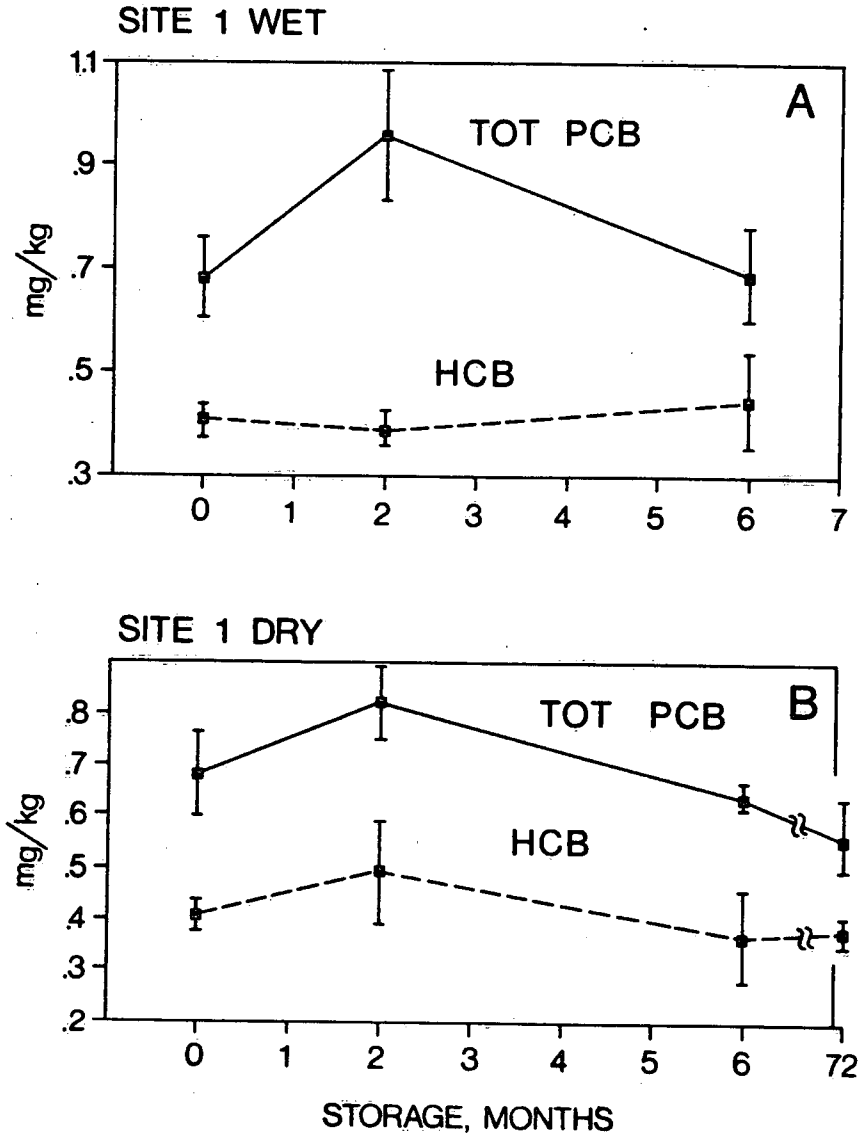


Figure I.2. Change in concentrations of TOT PCB and HCB upon storage for wet (-20°C) and freeze-dried (FD-20) sediment. Values are means of triplicate determinations \pm standard deviations.

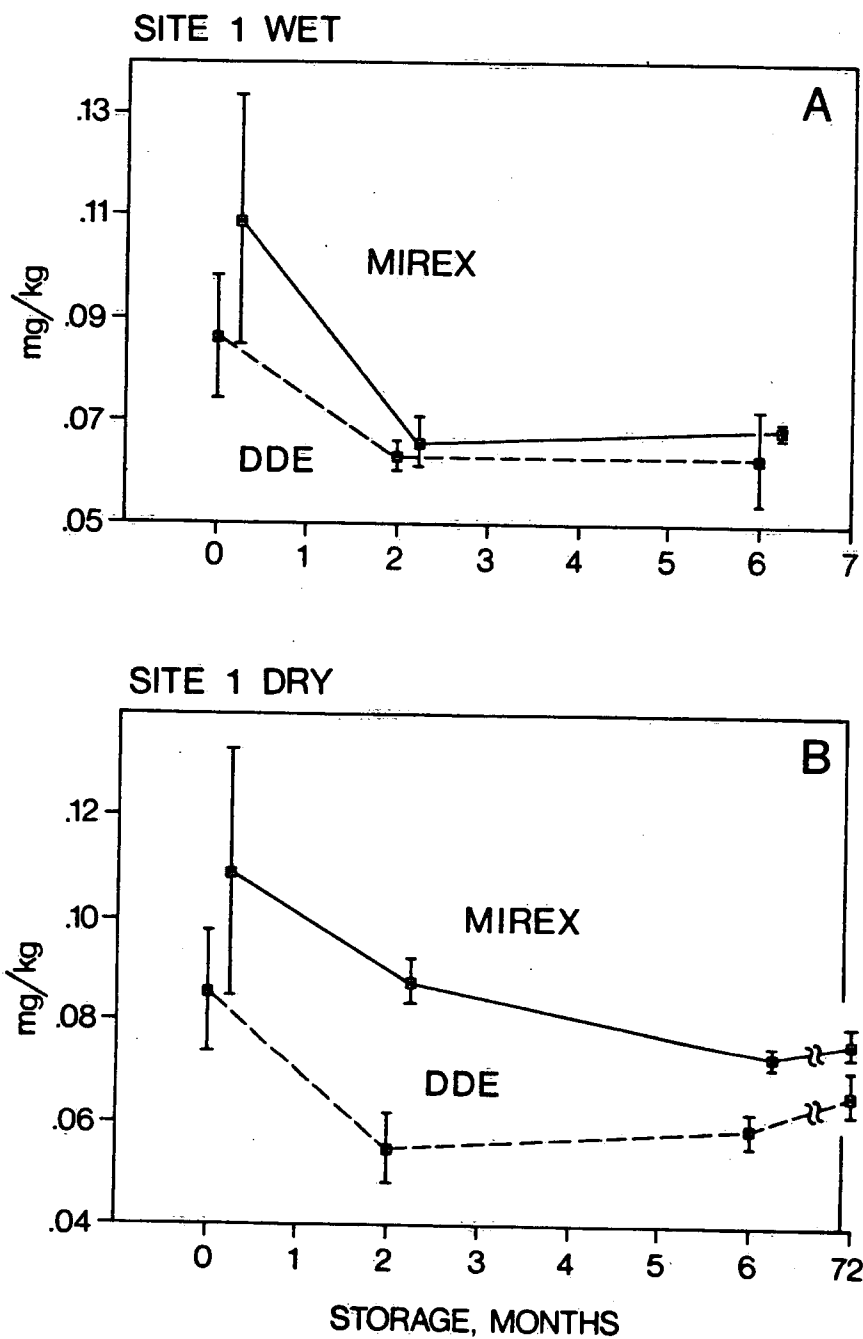


Figure I.3. Change in concentrations of MIREX and DDE upon storage for wet (-20° C) and freeze-dried (FD-20) sediment. Values are means of triplicate determinations \pm standard deviations.

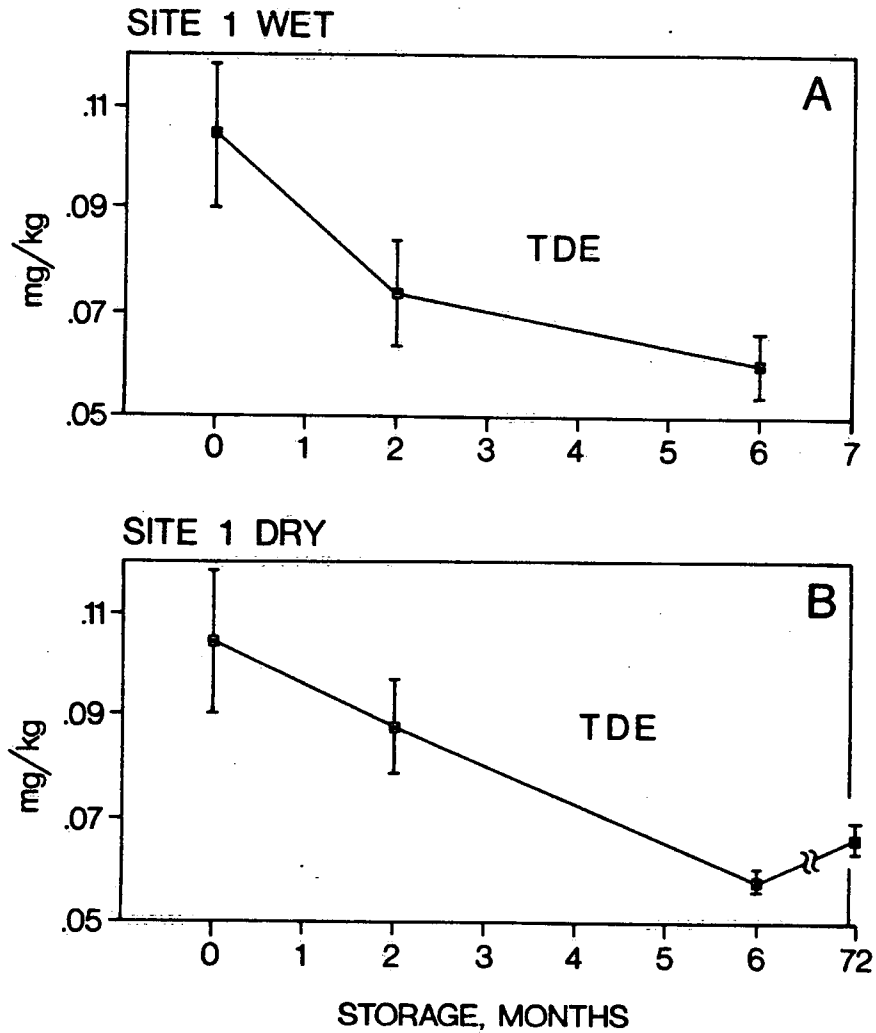


Figure I.4. Change in concentration of TDE upon storage for wet (-20°C) and freeze-dried (FD-20) sediment. Values are means of triplicate determinations \pm standard deviations.

TABLE I.2

CHANGES UPON WET (FROZEN) STORAGE FOR FIVE ORGANOCHLORINES (SITE 1)

ORGANO- CHLORINE	INITIAL mg/kg	2 MOS mg/kg	% CHG FR INIT	6 MOS mg/kg	% CHG FR INIT	% CHG FR 2 MO
TOT PCB	0.683	0.957	+40.1	0.690	+1.0	-27.9
HCB	0.406	0.391	-3.7	0.444	+9.4	+13.6
MIREX	0.109	0.066	-39.4	0.068	-37.6	+3.0
DDE	0.086	0.063	-26.7	0.063	-26.7	0.0
TDE	0.104	0.074	-28.8	0.060	-42.3	-18.9
		AVERAGE	-11.7		-19.2	-6.0

TABLE I.3

CHANGES UPON DRY (FD-20) STORAGE FOR FIVE ORGANOCHLORINES (SITE 1)

ORGANO- CHLORINE	INITIAL mg/kg	2 MOS mg/kg	% CHG FR INIT	6 MOS mg/kg	% CHG FR INIT	% CHG FR 2 MO
TOT PCB	0.683	0.817	+19.6	0.640	-6.3	-21.7
HCB	0.406	0.488	+20.2	0.370	-8.9	-24.2
MIREX	0.109	0.089	-18.3	0.073	-33.0	-18.0
DDE	0.086	0.055	-36.0	0.059	-31.4	+7.3
TDE	0.104	0.088	-15.4	0.058	-44.2	-34.1
		AVERAGE	-6.0		-24.8	-18.1

ORGANO- CHLORINE	6 YRS mg/kg	% CHG FR INIT	% CHG FR 2 MO	% CHG FR 6 MO
TOT PCB	0.557	-18.4	-31.8	-13.0
HCB	0.362	-10.8	-25.8	-2.2
MIREX	0.076	-30.2	-14.6	+4.1
DDE	0.066	-23.2	+20.0	+11.9
TDE	0.066	-36.5	-25.0	+13.8
	AVERAGE	-23.8	-15.4	+2.9

TABLE I.4

COMPARISON OF WET AND DRY STORAGE FOR FIVE ORGANOCHLORINES (SITE 1)

ORGANO- CHLORINE	WET 2 MOS mg/kg	DRY 2 MOS mg/kg	% CHG FROM WET	WET 6 MOS mg/kg	DRY 6 MOS mg/kg	% CHG FROM WET
TOT PCB	0.957	0.817	-14.6	0.690	0.640	-7.4
HCB	0.391	0.488	+24.1	0.444	0.370	-16.7
MIREX	0.066	0.089	+34.8	0.068	0.073	+7.4
DDE	0.063	0.055	-12.7	0.063	0.059	-6.3
TDE	0.074	0.088	+18.9	0.060	0.058	-3.3
		AVERAGE	+10.2		AVERAGE	-5.3

Further Wet/Dry Comparison

The laboratory of Dr. B.G. Oliver (NWRI, Environmental Contaminants Division) has received fresh subsamples from all Sediment Bank sites. These subsamples resulted from wet homogenization of the original sediment at the time of collection, followed by freezing of the subsample at -20° C. These subsamples were kept frozen until the time of analysis and were analyzed for a number of chlorobenzenes and other organochlorines within six months after collection, according to the methodology of Oliver and Bothen (1982). Thus analyses of wet samples described below were completed by the end of the calendar year in which they were collected. For example, Lake Huron (LH80) samples were analyzed by the end of 1980. Results from some of these analyses are published (Oliver and Bourbonniere, 1985; Oliver and Nicol, 1982).

As a test of the effect of freeze-drying on the analyses for chlorobenzenes and other organochlorines, 23 dry Sediment Bank samples were analyzed by Dr. Oliver's laboratory in 1984. These samples ranged in age from one (LS83) to four (LH80) years at the time of analysis. Determinations of up to 114 chlorinated compounds were carried out on some of the samples (Oliver and Bourbonniere, 1985), but a set of eleven organochlorines are used here for comparison. These were chosen because of their abundance and frequency of occurrence in both wet and dry samples used in this comparison. They included six chlorobenzenes; 1,4-dichlorobenzene (2CB), 1,2,4-trichlorobenzene (3CB), 1,2,4,5-tetrachlorobenzene (4CBa), 1,2,3,4-tetrachlorobenzene (4CBb), pentachlorobenzene (5CB), and hexachlorobenzene (6CB); one pesticide residue (DDE); and four other organochlorine contaminants; octachlorostyrene (OCS), hexachlorobutadiene (HCBD), mirex (MIR) and total polychlorinated biphenyls (PCB).

The concentration data for wet and dry analyses for all of the samples and contaminants in this test are given in Table I.5. The individual details of the different results are left for the reader

to observe but a discussion of the ranges, averages and concentration dependent trends follows.

Concentrations of the organochlorines determined vary tremendously, by 2-3 orders of magnitude, over the collection of sediment samples chosen from all of the Great Lakes represented in the Sediment Bank. The comparison of ranges between wet and dry samples is pretty good (Table I.5a,b,c) with the worst comparisons (indicating losses upon drying/storage) occurring for the lighter chlorobenzenes (Table I.5a). For the remainder of the comparisons the ranges are nearly identical or show increases for the dry samples (Table I.5a,b,c). Average data indicates losses upon drying/storage for all chlorobenzenes except 6CB (Table I.5a,b) and for HCBD (Table I.5b). The remaining compounds show on average nearly the same concentration or some increase for the dry samples (Table I.5b,c). These results are generally in line with what would be expected if volatility was the most important factor contributing to the differences observed.

Another way to look at the concentration data in Table I.5 is to compare the underlined values. These are equal to the minimum and maximum values for each combination of component and treatment. The approach is to ask the question: "Would the same samples be considered the lowest and the highest in concentration by either treatment?". The answer to such a question would more likely be "yes" for the heavier chlorobenzenes and other components than it would be for the lighter chlorobenzenes. Of the 22 possible instances that this question could be posed here, 73% of the answers would be "yes". Although this analysis is perhaps not quite as quantitative as a proper ranking might be, it does indicate that our degree of certainty improves as the volatility of the component decreases. Also it seems we have the ability to use dry samples for comparative trend analysis even in those cases where we cannot be very certain about the absolute concentrations determined.

TABLE I.5a
CONCENTRATIONS OF SELECTED ORGANOCHLORINES (ng/g)

STATION	2CB	2CB	3CB	3CB	4CBa	4CBa	4CBb	4CBb
	WET	DRY	WET	DRY	WET	DRY	WET	DRY
LH80-DH	6.5	10.0	3.1	3.8	.7	1.0	.6	1.0
LH80-N14	13.0	14.0	6.2	4.4	1.3	1.0	1.3	.8
LH80-RB	46.0	44.0	13.0	11.0	4.8	5.0	3.6	3.9
LH80-U11	12.0	19.0	6.1	5.9	1.7	1.4	1.5	1.2
LH80-V8	7.0	10.0	4.1	5.0	1.2	1.5	1.3	1.6
LO81-D21	470.0	<u>376.7</u>	130.0	128.9	77.0	77.3	56.0	<u>53.5</u>
LO81-E30	280.0	200.0	140.0	110.0	59.0	57.0	55.0	50.0
LO81-F34	390.0	310.0	100.0	84.0	67.0	55.0	45.0	37.0
LO81-S20	<u>580.0</u>	370.0	130.0	110.0	99.0	100.0	52.0	53.0
LO81-S23	340.0	169.0	140.0	109.4	<u>120.0</u>	<u>119.3</u>	54.0	41.8
LO81-S24	300.0	250.0	<u>170.0</u>	<u>130.0</u>	110.0	73.0	<u>68.0</u>	52.0
LE82-A8	5.7	5.4	<u>1.2</u>	1.9	<u>.2</u>	.7	<u>.1</u>	.2
LE82-F15	9.6	18.8	2.5	3.4	.7	1.0	.5	.6
LE82-M33	48.0	20.0	3.1	2.3	.7	.6	.8	.5
LE82-U41	17.0	20.0	5.3	3.8	1.7	1.4	1.4	1.0
LE82-W41	27.0	26.0	11.0	13.0	5.9	5.4	1.8	2.3
LSC82-SL	5.2	8.8	2.5	2.2	7.8	7.2	1.1	3.1
LS83-EV1A	<u>3.5</u>	6.7	2.7	2.6	.3	.3	.2	.2
LS83-EV11A	4.3	<u>3.6</u>	3.5	<u>1.3</u>	.4	.3	.2	<u>.1</u>
LS83-EV13	14.0	13.0	7.0	6.3	.5	.4	.5	.6
LS83-EV15A	6.1	5.3	3.0	3.3	<u>.2</u>	<u>.2</u>	<u>.1</u>	<u>.1</u>
LS83-SV157	-	3.7	4.0	2.8	.3	<u>.2</u>	.2	.2
LS83-25A	5.5	8.1	4.7	4.2	.5	.3	.3	.3
MINIMUM	3.5	3.6	1.2	1.3	.2	.2	.1	.1
MAXIMUM	580.0	376.7	170.0	130.0	120.0	119.3	68.0	53.5
AVERAGE	117.7	83.1	38.8	32.6	24.4	22.2	15.0	13.3

TABLE I.5b

CONCENTRATIONS OF SELECTED ORGANOCHLORINES CONT'D (ng/g)

STATION	5CB	5CB	6CB	6CB	OCS	OCS	HCBd	HCBd
	WET	DRY	WET	DRY	WET	DRY	WET	DRY
LH80-DH	.5	1.0	1.2	2.3	.1	<u>.1</u>	.1	.1
LH80-N14	.8	1.3	1.3	1.7	<u>.07</u>	.1	.07	<u>.05</u>
LH80-RB	1.4	1.8	1.9	2.6	.4	.6	.5	.6
LH80-U11	.9	1.4	1.9	2.2	.1	<u>.1</u>	.3	.3
LH80-V8	.7	1.1	3.3	3.1	.1	.2	.1	.3
LO81-D21	64.0	65.4	220.0	228.0	29.0	37.7	40.0	34.7
LO81-E30	55.0	52.0	150.0	150.0	21.0	32.0	32.0	24.0
LO81-F34	49.0	40.0	210.0	210.0	15.0	16.0	36.0	26.0
LO81-S20	<u>89.0</u>	<u>89.0</u>	<u>320.0</u>	<u>380.0</u>	<u>36.0</u>	<u>40.0</u>	<u>58.0</u>	<u>45.0</u>
LO81-S23	64.0	44.7	260.0	188.9	26.0	14.9	39.0	38.8
LO81-S24	73.0	63.0	210.0	200.0	31.0	33.0	46.0	33.0
LE82-A8	.7	1.9	1.9	2.5	.2	.3	.2	.1
LE82-F15	1.0	2.5	2.5	2.8	.1	.2	.2	.2
LE82-M33	1.3	1.2	3.4	2.7	.8	.2	.4	.5
LE82-U41	3.9	3.2	10.0	10.0	2.5	2.9	2.2	1.1
LE82-W41	4.3	5.4	18.0	20.0	7.0	8.2	3.1	2.4
LSC82-SL	6.7	7.2	99.0	103.2	11.0	19.8	9.3	7.0
LS83-EV1A	.9	1.8	.9	2.2	-	-	-	.1
LS83-EV11A	<u>.4</u>	<u>.3</u>	<u>.8</u>	<u>.7</u>	-	-	-	.1
LS83-EV13	.6	2.6	1.5	4.1	-	<u>.1</u>	-	.1
LS83-EV15A	.5	2.0	.9	3.1	-	-	-	.1
LS83-SV157	.6	1.3	.9	2.2	-	-	.1	.1
LS83-25A	.6	1.9	1.8	2.3	-	-	-	.1
MINIMUM	.4	.3	.8	.7	.07	.1	.07	.05
MAXIMUM	89.0	89.0	320.0	380.0	36.0	40.0	58.0	45.0
AVERAGE	18.3	17.0	66.1	66.3	10.6	10.9	14.9	9.3

TABLE I.5c
 CONCENTRATIONS OF SELECTED ORGANOCHLORINES CONT'D (ng/g)

STATION	DDE	DDE	MIR	MIR	PCB	PCB
	WET	DRY	WET	DRY	WET	DRY
LH80-DH	12.0	28.0	<u>.1</u>	<u>.3</u>	51.0	120.0
LH80-N14	20.0	23.0	-	-	57.0	67.0
LH80-RB	3.4	4.0	.4	<u>.3</u>	320.0	390.0
LH80-U11	15.0	19.0	-	-	51.0	64.0
LH80-V8	10.0	28.9	-	-	42.0	119.8
LO81-D21	77.0	95.2	70.0	98.1	830.0	1041
LO81-E30	90.0	130.0	54.0	93.0	<u>1100</u>	<u>1500</u>
LO81-F34	34.0	32.0	55.0	59.0	520.0	630.0
LO81-S20	63.0	77.0	84.0	<u>110.0</u>	800.0	910.0
LO81-S23	54.0	26.8	<u>110.0</u>	45.7	970.0	874.8
LO81-S24	<u>110.0</u>	<u>130.0</u>	99.0	<u>110.0</u>	<u>1100</u>	1100
LE82-A8	3.2	5.7	-	-	130.0	170.0
LE82-F15	5.6	9.8	-	-	190.0	242.2
LE82-M33	4.6	7.1	-	-	140.0	150.0
LE82-U41	8.4	10.0	-	-	350.0	479.2
LE82-W41	21.0	21.0	-	-	1000	1099
LSC82-SL	<u>1.4</u>	2.6	-	-	29.0	74.4
LS83-EV1A	3.7	4.7	-	-	28.0	25.3
LS83-EV11A	5.8	3.4	-	-	23.0	25.0
LS83-EV13	7.4	6.7	-	-	70.0	53.0
LS83-EV15A	3.6	3.3	-	-	14.0	23.0
LS83-SV157	3.0	<u>2.2</u>	-	-	<u>12.0</u>	<u>14.0</u>
LS83-25A	15.0	7.6	-	-	28.0	23.0
MINIMUM	1.4	2.2	.1	.3	12.0	14.0
MAXIMUM	110.0	130.0	110.0	110.0	1100	1500
AVERAGE	24.8	29.5	59.1	64.6	341.5	399.7

The concentration data from Table I.5 provided the input for the comparison data which appears in Table I.6. Here, where comparisons could be made, there were 92 cases where apparent losses occurred, and 133 cases where there was either no change or an apparent gain. The average data is a bit misleading because of the rather large percentage change which occurs in some cases. These result from relatively small changes in cases where only a small concentration occurs. This is most noticeable for Lake Superior samples and in some samples from Lakes Huron and Erie. The Lake Ontario samples, where concentrations were generally the highest (see Table I.5), tended to show the smallest percentage change.

In Table I.7 comparisons have been deleted for all cases where either or both of the wet and dry concentrations was less than 1 ng/g. This resulted in an increase of the "no comparison" cases to 32% as compared to 11% in Table I.6. Most of the cases where large percentage change occurs in Table I.6 have been eliminated by the deletion of low concentration cases. In Table I.7 there are 78 cases where apparent losses occurred, and 93 cases where there was either no change or an apparent gain; and the average data has improved in many cases.

TABLE I.6
 PERCENTAGE CHANGE FROM WET CONCENTRATIONS FOR SELECTED
 ORGANOCHLORINES

STATION	2CB	3CB	4CBa	4CBb	5CB	6CB	OCS	HCBd	DDE	MIR	PCB
LH80-DH	54	23	43	67	100	92	0	0	133	200	135
LH80-N14	8	-29	-23	-38	62	31	43	-29	15	-	18
LH80-RB	-4	-15	4	8	29	37	50	20	18	-25	22
LH80-U11	58	-3	-18	-20	56	16	0	0	27	-	25
LH80-V8	43	22	25	23	57	-6	100	275	189	-	185
LO81-D21	-20	-1	0	-4	2	4	30	-13	24	40	25
LO81-E30	-29	-21	-3	-9	-5	0	52	-25	44	72	36
LO81-F34	-21	-16	-18	-18	-18	0	7	-28	-6	7	21
LO81-S20	-36	-15	1	2	0	19	11	-22	22	31	14
LO81-S23	-50	-22	-1	-23	-30	-27	-43	-1	-50	-58	-10
LO81-S24	-17	-24	-34	-24	-14	-5	6	-28	18	11	0
LE82-A8	-5	58	250	100	171	32	50	-50	78	-	31
LE82-F15	96	34	43	20	150	12	100	0	75	-	27
LE82-M33	-58	-26	-14	-38	-8	-21	-75	25	54	-	7
LE82-U41	17	-28	-18	-29	-18	0	16	-50	19	-	37
LE82-W41	-4	18	-8	28	26	11	17	-23	0	-	10
LSC82-SL	70	-13	-8	182	7	4	80	-25	86	-	157
LS83-EV1A	92	-3	0	0	100	144	-	-	27	-	-10
LS83-EV11A	-17	-62	-25	-50	-25	-12	-	-	-41	-	9
LS83-EV13	-7	-10	-20	20	333	173	-	-	-9	-	-24
LS83-EV15A	-13	10	0	0	300	244	-	-	-8	-	64
LS83-SV157	-	-30	-33	0	117	144	-	-	-27	-	17
LS83-25A	48	-10	-40	0	217	28	-	-	-49	-	-18
AVERAGE	9	-7	5	9	70	40	26	2	28	35	34

TABLE I.7
 PERCENTAGE CHANGE FROM WET CONCENTRATIONS FOR SELECTED
 ORGANOCHLORINES (CASES < 1 ng/g DELETED)

STATION	2CB	3CB	4CBa	4CBb	5CB	6CB	OCS	HCBD	DDE	MIR	PCB
LH80-DH	54	23	-	-	-	92	-	-	133	-	135
LH80-N14	8	-29	-23	-	-	31	-	-	15	-	18
LH80-RB	-4	-15	4	8	29	37	-	-	18	-	22
LH80-U11	58	-3	-18	-20	-	16	-	-	27	-	25
LH80-V8	43	22	25	23	-	-6	-	-	189	-	185
LO81-D21	-20	-1	0	-4	2	4	30	-13	24	40	25
LO81-E30	-29	-21	-3	-9	-5	0	52	-25	44	72	36
LO81-F34	-21	-16	-18	-18	-18	0	7	-28	-6	7	21
LO81-S20	-36	-15	1	2	0	19	11	-22	22	31	14
LO81-S23	-50	-22	-1	-23	-30	-27	-43	-1	-50	-58	-10
LO81-S24	-17	-24	-34	-24	-14	-5	6	-28	18	11	0
LE82-A8	-5	58	-	-	-	32	-	-	78	-	31
LE82-F15	96	34	-	-	150	12	-	-	75	-	27
LE82-M33	-58	-26	-	-	-8	-21	-	-	54	-	7
LE82-U41	17	-28	-18	-29	-18	0	16	-50	19	-	37
LE82-W41	-4	18	-8	28	26	11	17	-23	0	-	10
LSC82-SL	70	-13	-8	182	7	4	80	-25	86	-	157
LS83-EV1A	92	-3	-	-	-	-	-	-	27	-	-10
LS83-EV11A	-17	-62	-	-	-	-	-	-	-41	-	9
LS83-EV13	-7	-10	-	-	-	173	-	-	-9	-	-24
LS83-EV15A	-13	10	-	-	-	-	-	-	-8	-	64
LS83-SV157	-	-30	-	-	-	-	-	-	-27	-	17
LS83-25A	48	-10	-	-	-	28	-	-	-49	-	-18
AVERAGE	9	-7	-8	10	10	21	20	-24	28	17	34

REFERENCES FOR APPENDIX I

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APPENDIX II

CATALOG OF LAKE HURON SAMPLES

TABLE II.1
 GREAT LAKES SEDIMENT BANK - LAKE HURON SURFICIAL SAMPLES
 REFER TO FIGURE 2 FOR LOCATIONS

Sample Identification	Latitude N			Longitude W		
	Deg.	Min.	Sec.	Deg.	Min.	Sec.
LH80 - A13A	44	31	14	80	06	58
C7A	44	42	26	80	52	25
C12A	44	42	12	80	14	36
DH	45	02	06	82	01	23
D32	45	49	37	84	21	00
F30	45	39	08	84	04	37
G12A	45	04	48	80	14	00
G11B	46	04	48	83	15	41
J3A	45	20	13	81	23	21
J6A	45	19	55	81	00	05
K31	45	45	42	83	26	42
M29	45	35	09	83	10	37
N14	44	14	11	83	00	19
N22	44	57	16	83	02	03
N26	45	18	29	83	02	21
P3A	45	52	22	81	23	12
P16	44	25	14	82	45	08
Q19	44	41	25	82	38	31
Q23	45	02	22	82	39	03
Q25	45	13	51	82	39	04
Q27	45	25	33	82	40	02
Q29	45	35	54	82	40	06
RB	43	50	56	83	43	02
SB	45	38	08	81	51	52
S7	43	37	05	82	21	43
S9	43	47	44	82	22	11

TABLE II.1 (CONT.)
 GREAT LAKES SEDIMENT BANK - LAKE HURON SURFICIAL SAMPLES
 REFER TO FIGURE 2 FOR LOCATIONS

Sample Identification	Latitude N			Longitude W		
	Deg.	Min.	Sec.	Deg.	Min.	Sec.
LH80 - S11	43	58	43	82	22	26
S15	44	20	08	82	23	19
S17	44	30	52	82	22	57
T4	43	20	54	82	14	08
T6	43	31	42	82	14	15
T12	44	04	10	82	14	57
T20	44	47	14	82	15	36
U9	43	48	00	82	06	56
U11	43	58	45	82	07	20
U27	45	24	57	82	09	12
V4	43	21	12	81	59	13
V6	43	31	51	81	59	28
V8	43	42	33	81	59	31
V24	45	08	50	82	00	52
W17	44	31	07	81	52	07
Z20	44	47	27	81	30	18

TABLE II.2
 GREAT LAKES SEDIMENT BANK - LAKE HURON HISTORICAL SAMPLES
 REFER TO FIGURE 2 FOR LOCATIONS

Sample Identification	Depth (cm)	Latitude N			Longitude W		
		Deg.	Min.	Sec.	Deg.	Min.	Sec.
LH80 - C12A	0-1	44	42	12	80	14	36
	1-2						
	2-3						
	3-4						
	4-5						
LH80 - DH	0-2	45	02	06	82	01	23
	2-4						
	4-6						
	6-8						
LH80 - J3A	0-1	45	20	13	81	23	21
	1-2						
	2-3						
	3-4						
	4-5						
LH80 - K29	0-5	45	34	53	83	25	49
	5-10						
	10-15						
	15-20						
	20-25						
LH80 - N14	0-3	44	14	11	83	00	19
	3-6						
	6-9						
	9-12						
	12-15						

TABLE II.2 (CONT.)
 GREAT LAKES SEDIMENT BANK - LAKE HURON HISTORICAL SAMPLES
 REFER TO FIG. 2 FOR LOCATIONS

Sample Identification	Depth (cm)	Latitude N			Longitude W		
		Deg.	Min.	Sec.	Deg.	Min.	Sec.
LH80 - RB	0-5	43	50	56	83	43	02
	5-10						
	10-15						
	15-20						
	20-25						
	30-35						
LH80 - U9	0-3	43	48	00	82	06	56
	3-6						
	6-9						
	9-12						
	12-15						

TABLE II.3
 GREAT LAKES SEDIMENT BANK - LAKE HURON SURFICIAL - BULK PROPERTIES
 REFER TO FIG. 2 FOR LOCATIONS

Sample Identification	Grain Size		Size Distribution			Org.	Inorg.
	PHI Units		Percentages			C	C
	Mean	Std Dev	Sand	Silt	Clay	%	%
LH80 - A13A	6.05	1.23	2	75	23	2.9*	0.5*
C7A	**	**	18	55	27	2.8	0.0
C12A	7.12	1.03	0	53	47	2.8	0.0
DH	6.72	1.54	5	45	50	3.8*	0.1*
D32	6.25	1.21	1	64	35	3.7	0.5
F30	6.15	1.25	0	69	31	3.0	0.6
G11B	7.74	1.00	0	23	77	3.7	0.0
G12A	7.13	1.03	0	49	51	5.5	0.0
J3A	7.83	0.98	0	19	81	3.3	0.2
J6A	7.40	1.00	0	42	58	3.5	0.0
K31	7.39	1.04	0	27	73	3.5	0.0
M29	5.04	2.32	67	15	18	1.8*	0.0*
N14	**	**	15	64	21	4.5	0.5
N22	**	**	7	75	18	4.1	0.6
N26	7.86	0.74	0	20	80	3.5	0.1
P3A	6.30	2.63	36	36	28	3.7	0.6
P16	5.96	1.25	0	71	29	3.9	0.0
Q19	**	**	5	56	39	1.6	0.0
Q23	7.74	0.72	0	29	71	3.3	0.1
Q25	7.31	1.14	1	42	57	3.4	0.2
Q27	7.51	0.93	0	36	64	3.4	0.0
Q29	7.41	1.14	2	35	63	3.9	0.0
RB	6.38	1.15	0	67	33	3.7	0.6
SB	6.66	1.10	0	66	34	3.2	0.3
S7	5.56	1.14	3	70	27	2.9	0.0

TABLE II.3 (CONT.)
 GREAT LAKES SEDIMENT BANK - LAKE HURON SURFICIAL - BULK PROPERTIES
 REFER TO FIG. 2 FOR LOCATIONS

Sample Identification	Grain Size		Size Distribution			Org.	Inorg.
	PHI Units		Percentages			C	C
	Mean	Std Dev	Sand	Silt	Clay	%	%
LH80 - S9	6.63	1.20	1	57	42	4.4*	0.2*
S11	7.24	1.02	0	46	54	4.4*	0.0*
S15	7.32	0.96	0	46	54	4.3	0.2
S17	7.05	1.11	0	55	45	4.0	0.1
T6	5.79	1.18	3	72	25	2.9	0.3
T12	7.61	0.82	0	42	58	4.3*	0.2*
T20	7.24	1.04	0	50	50	3.4	0.0
U9	6.84	0.96	0	58	42	4.5	0.2
U11	6.81	1.08	0	60	40	3.6	1.0
U27	7.14	1.47	4	36	60	3.6	0.1
V4	5.11	2.10	49	43	8	2.5	0.7
V6	**	**	11	76	13	1.2	0.0
V8	5.96	1.03	0	83	17	3.9	0.8
V24	7.47	0.88	0	45	55	3.9	0.3
W17	7.16	1.03	0	55	45	3.4	0.4
Z20	5.60	0.98	0	91	9	4.6	0.8

* Mean of duplicate or triplicate determinations

** No calculation of mean because assumed upper size limit > 5%

APPENDIX III

CATALOG OF LAKE ONTARIO SAMPLES

TABLE III.1
 GREAT LAKES SEDIMENT BANK - LAKE ONTARIO SURFICIAL SAMPLES
 REFER TO FIG. 3 FOR LOCATIONS

Sample Identification	Latitude N			Longitude W		
	Deg.	Min.	Sec.	Deg.	Min.	Sec.
LO81 - CB	43	33	00	78	10	28
C22	43	20	57	77	41	54
C23	43	20	59	77	35	55
D21	43	25	52	77	47	55
D29	43	26	09	76	59	59
E6	43	30	02	79	18	00
E17	43	30	04	78	11	02
E30	43	30	14	76	54	04
E33	43	30	01	76	34	58
F12	43	34	04	78	42	00
F23	43	35	12	77	36	03
F25	43	34	02	77	23	02
F27	43	34	07	77	12	00
F34	43	34	16	76	29	59
G18	43	37	57	78	06	02
G21	43	38	57	77	47	59
G33	43	39	07	76	35	13
H31	43	42	57	76	48	10
H34	43	44	09	76	29	59
KB	44	04	41	76	24	35
M33	44	04	08	76	36	05
S2	43	20	27	79	39	45
S4	43	22	01	79	34	32
S13	43	25	01	79	24	00
S15	43	18	58	79	26	38

TABLE III.1 (CONT.)
 GREAT LAKES SEDIMENT BANK - LAKE ONTARIO SURFICIAL SAMPLES
 REFER TO FIG. 3 FOR LOCATIONS

Sample Identification	Latitude N			Longitude W		
	Deg.	Min.	Sec.	Deg.	Min.	Sec.
LO81 - S18	43	18	03	79	16	38
S20	43	20	18	79	11	46
S22	43	17	40	79	00	16
S23	43	22	07	79	04	03
S24	43	26	28	79	07	38
S25	43	31	00	79	04	45
S34	43	27	40	78	45	38
S36	43	29	30	78	23	07
S38	43	22	59	77	59	22
S39	43	29	07	77	59	53
S40	43	35	21	78	00	39
S82	44	04	01	76	48	45
S84	43	53	08	76	44	13
WB	43	23	36	79	26	27

TABLE III.2
 GREAT LAKES SEDIMENT BANK - LAKE ONTARIO HISTORICAL SAMPLES
 REFER TO FIG. 3 FOR LOCATIONS

Sample Identification	Depth (cm)	Latitude N			Longitude W		
		Deg.	Min.	Sec.	Deg.	Min.	Sec.
LO81 - CB	0-4	43	33	00	78	10	28
	4-8						
	8-12						
	12-16						
LO81 - D29	0-3	43	26	09	76	59	59
	3-6						
	6-9						
	9-12						
LO81 - KB	0-5	44	04	08	76	36	05
	5-10						
	10-15						
	15-20						
LO81 - WB	0-3	43	23	36	79	26	27
	3-6						
	6-9						
	9-12						

TABLE III.3
 GREAT LAKES SEDIMENT BANK - LAKE ONTARIO SURFICIAL - BULK PROPERTIES
 REFER TO FIG. 3 FOR LOCATIONS

Sample Identification	Grain Size		Size Distribution			Org.	Inorg.
	PHI Units		Percentages			C	C
	Mean	Std Dev	Sand	Silt	Clay	%	%
LO81 - CB	6.69	1.34	2	58	40	4.6	2.4
C22	**	**	26	58	16	0.6	0.4
C23	**	**	5	77	18	2.8	0.8
D21	7.13	1.04	0	49	51	3.7	1.5
D29	6.68	1.22	0	66	34	4.5	1.7
E6	6.83	1.19	0	61	39	4.5	2.0
E17	6.60	1.22	1	65	34	4.2	2.0
E30	6.25	1.34	5	65	30	4.8	1.4
E33	**	**	39	50	11	0.8	0.3
F12	6.73	1.37	3	55	42	4.3	0.0
F23	NA	NA	NA	NA	NA	3.9	1.1
F25	6.82	1.16	0	68	32	4.8	0.0
F27	**	**	8	68	24	4.3	1.5
F29	6.71	1.24	0	60	40	NA	NA
F34	6.48	1.13	2	71	27	3.6	0.0
G18	7.03	1.15	0	53	47	4.1	1.6
G21	7.04	1.08	0	61	39	4.5	1.6
G33	**	**	13	68	19	4.1	1.0
H31	6.71	1.16	0	68	32	3.8	1.2
H34	6.39	1.04	0	78	22	3.3	0.9
KB	6.27	1.29	0	64	36	5.3	1.8
M33	5.49	1.08	2	84	14	4.5*	0.7*
S2	6.40	1.07	1	77	22	3.6	1.0
S4	**	**	14	69	17	3.6	1.7
S13	6.83	1.08	0	61	39	4.3	2.0

TABLE III.3 (CONT.)

GREAT LAKES SEDIMENT BANK - LAKE ONTARIO SURFICIAL - BULK PROPERTIES
REFER TO FIG. 3 FOR LOCATIONS

Sample Identification	Grain Size		Size Distribution			Org.	Inorg.
	PHI Units		Percentages			C	C
	Mean	Std Dev	Sand	Silt	Clay	%	%
LO81 - S15	6.49	1.44	5	60	35	3.9	1.7
S18	7.10	1.00	0	62	38	3.7	1.3
S20	NA	NA	NA	NA	NA	3.1	1.4
S22	4.53	.71	5	91	4	1.3	0.0
S23	6.49	1.12	2	75	23	3.2	1.6
S24	7.10	1.01	0	57	43	4.2	1.2
S25	6.55	1.20	1	66	33	4.3	1.7
S34	**	**	16	64	20	0.4	0.1
S36	6.54	1.27	3	65	32	4.4	1.5
S38	**	**	37	35	28	0.5*	0.4*
S39	NA	NA	NA	NA	NA	4.2	1.5
S40	6.43	1.35	2	62	36	4.6*	0.1*
S82	**	**	25	68	7	1.0	0.3
S84	**	**	8	63	29	0.6	0.8
WB	6.74	1.21	1	64	35	4.4	1.4

* Mean of duplicate or triplicate determinations

** No calculation of mean because assumed upper size limit > 5%