Environment Canada Environnement Canada

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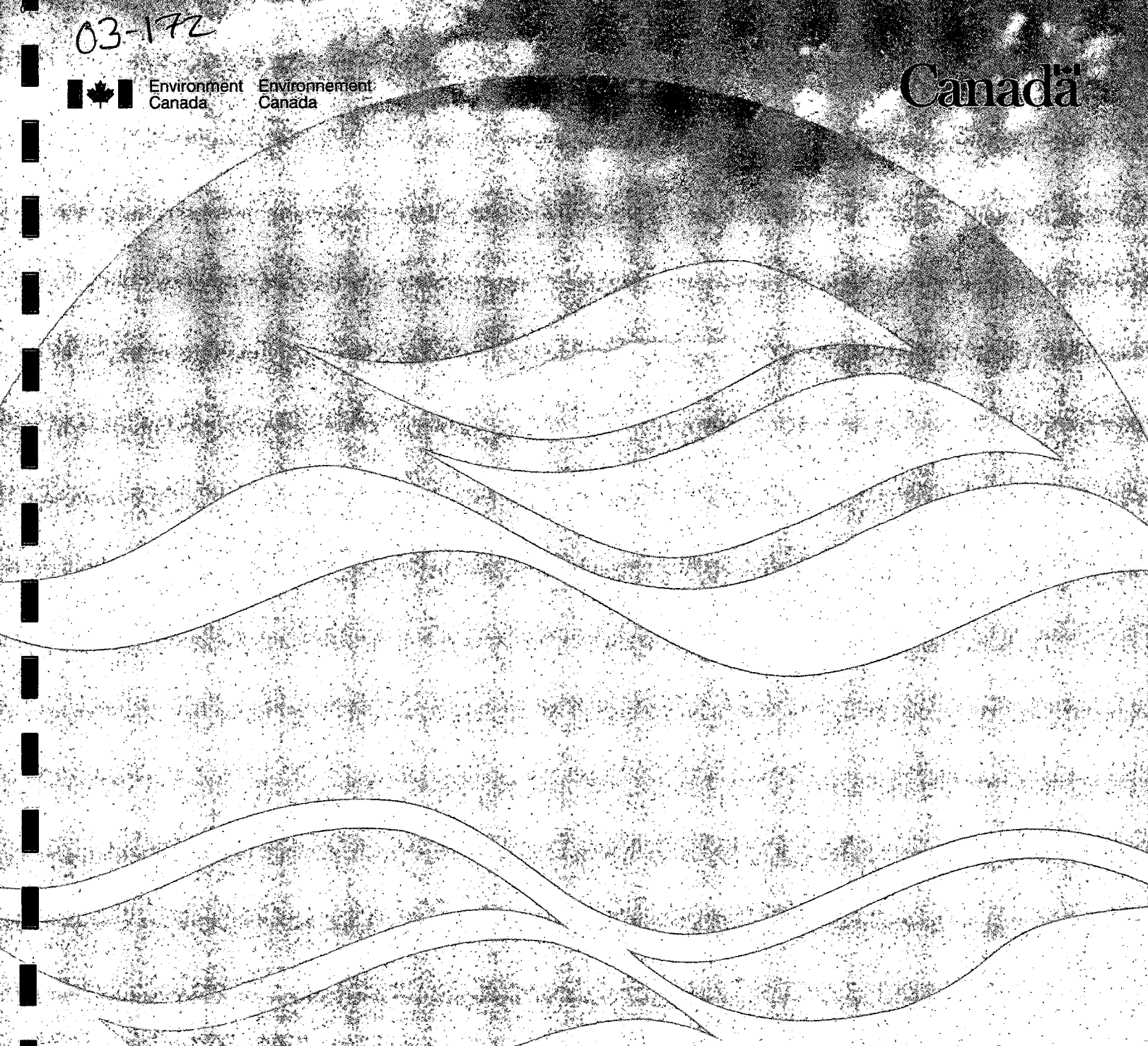

Sediment Sampling at Randle Reef, Hamilton Harbour.

BY:

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NWRI Contribution No. 03-172

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Abstract

Randle Reef is a nearshore area located in the southern portion of Hamilton Harbour and contains the most contaminated sediment within the harbour. Sediment contamination at Randle Reef, particularly with polycyclic aromatic hydrocarbons (PAHs), has been a concern for decades. Historical industrial discharges created the contaminated sediment site which contains a high concentration of coal tar. There have been at least 6 sediment sampling events at Randle Reef, spanning over 25 years. This has included grab sampling, gravity coring, and borehole coring. The sampling events and the concentrations of PAHs measured are described. The precise extent of sediment contamination at Randle Reef is not fully known. Enough information has been obtained, however, to define the most severely contaminated sediment in the vicinity of Randle Reef, within an area of about 10 ha.

Échantillonnage de sédiments au récif Randle dans le port de Hamilton

A.J. Zeman et T.S. Patterson

Résumé

Situé près du rivage dans la partie sud du port de Hamilton, le récif Randle contient les sédiments les plus contaminés de la zone portuaire. Depuis des décennies, on se préoccupe de la contamination de ces sédiments, en particulier par des hydrocarbures aromatiques polycycliques (HAP). Des rejets industriels historiques sont responsables de la forte contamination des sédiments par le goudron de houille. Depuis plus de 25 ans, des échantillons ont été prélevés à au moins six reprises au récif Randle au moyen des méthodes suivantes : échantillonnage ponctuel, carottage par gravité et carottage par forage. Les concentrations d'HAP et les prélèvements d'échantillons sont décrits dans ce rapport. L'étendue précise de la contamination des sédiments du récif Randle n'est pas connue. Cependant, on possède suffisamment de renseignements pour établir quels sont les sédiments les plus contaminés à proximité du récif, à l'intérieur d'une zone d'environ dix hectares.

NWRI RESEARCH SUMMARY

Plain language title
Sediment Sampling at Randle Reef, Hamilton Harbour

What is the problem and what do sicentists already know about it?
Hamilton Harbour is one of the most polluted bodies of water in the Great Lakes. The most contaminated area of Hamilton Harbour is at a location close to the south shore, known as Randle Reef. Randle Reef sediment has for decades been highly contaminated with polycyclic aromatic hydrocarbons (PAHs). This is a result of historical industrial discharges. PAHs are toxic to benthic invertebrates, fish, and other aquatic life. PAHs are also toxic to humans.

Why did NWRI do this study?
Randle Reef is the most sampled area of Hamilton Harbour, with sampling events for sediment contamination dating back to the mid-1970s. There have been at least 6 sets of sediment samples retrieved from Randle Reef from the mid-1970s to 1999. The nature of sampling during this time frame has varied (e.g. grab sampling, gravity coring, and borehole coring). This report details the sediment sampling events by date, quantity of samples, PAH concentrations, etc., so that a comprehensive summary of sampling studies and results exists.

What were the results?
The results show that Randle Reef continues to remain highly contaminated with PAHs. The contamination is very heterogeneous (variable) both in horizontal and vertical dimensions. Contamination extends below the sediment-water interface as much as 3 metres or more in some areas. An area of approximately 10 ha is considered to be significantly contaminated.

How will these results be used?
These results may be used by other Hamilton Harbour researchers who require specific data on sampling locations, dates, and PAH concentrations. This information may be used to plan any potential clean-up initiatives of Randle Reef, which are expected to commence at a future date.

Who were our main partners in the study?
The Great Lakes Sustainability Fund

Sommaire des recherches de l'INRE

Titre en langage clair
Échantillonnage de sédiments au récif Randle dans le port de Hamilton

Quel est le problème et que savent les chercheurs à ce sujet?
Le port de Hamilton constitue un des plans d'eau les plus pollués dans les Grands Lacs. Situé près de la rive sud, le récif Randle est la zone la plus fortement contaminée du port. Depuis des décennies, les sédiments du récif sont fortement contaminés par des hydrocarbures aromatiques polycycliques (HAP) en raison de rejets industriels. Les HAP sont toxiques pour les invertébrés benthiques, les poissons et d'autres organismes aquatiques. De plus, ils sont toxiques pour les humains.

Pourquoi l'INRE a-t-il effectué cette étude?
Le récif Randle est la zone du port de Hamilton qui a été la plus échantillonnée; du milieu des années 1970 jusqu'en 1999, on y a prélevé des échantillons de sédiments contaminés à au moins six reprises. Durant cette période, les méthodes d'échantillonnage ont varié (échantillonnage ponctuel, carottage par gravité, carottage par forage, etc.). Ce rapport contient la date des prélèvements, le nombre d'échantillons et les concentrations d'HAP, et constitue une synthèse globale des études sur les sédiments et des résultats d'échantillonnage.

Quels sont les résultats?
Les résultats montrent que le récif Randle est encore fortement contaminé par des HAP. La contamination est très hétérogène (variable), sur le plan tant horizontal que vertical. Dans certaines zones, la contamination s'étend à au moins trois mètres sous l'interface sédiments-eau. Une zone d'environ dix hectares est fortement contaminée.

Comment ces résultats seront-ils utilisés?
Ces résultats peuvent être utilisés par d'autres chercheurs qui étudient le port de Hamilton et qui ont besoin de renseignements précis sur les stations et les dates d'échantillonnage, et sur les concentrations d'HAP. Ils peuvent servir aussi à planifier de futures initiatives d'assainissement du récif Randle.

Quels étaient nos principaux partenaires dans cette étude?
Le Fonds de durabilité des Grands Lacs

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1.0 INTRODUCTION

Randle Reef is a nearshore area located in the southern portion of Hamilton Harbour. Sediment contamination at Randle Reef, particularly with polycyclic aromatic hydrocarbons (PAHs) has been a concern for decades. Historical industrial discharges created the contaminated sediment site which contains a high concentration of coal tar. Sediment containing coal tar can be a source for long term contamination to the water column, due to the slow release of organic solutes (Environment Canada, 1999). In the late 1990s, a geographic area containing the most highly contaminated sediment in the vicinity was mapped out, and is known as the "hot spot" or "fish tail" (Fig. 1). Mapping of the hot spot was completed with reference to a polygon map of sediment PAH concentrations which was produced using linear interpolation between adjacent points. The hot spot was delineated on the map based on sediment PAH concentrations of 800 µg/g and higher. Although the hot spot is generally referred to as "Randle Reef", it should be noted that the actual geomorphic feature is located to the north-west of the hot spot. The hot spot is generally considered to contain the most contaminated sediments in Hamilton Harbour.

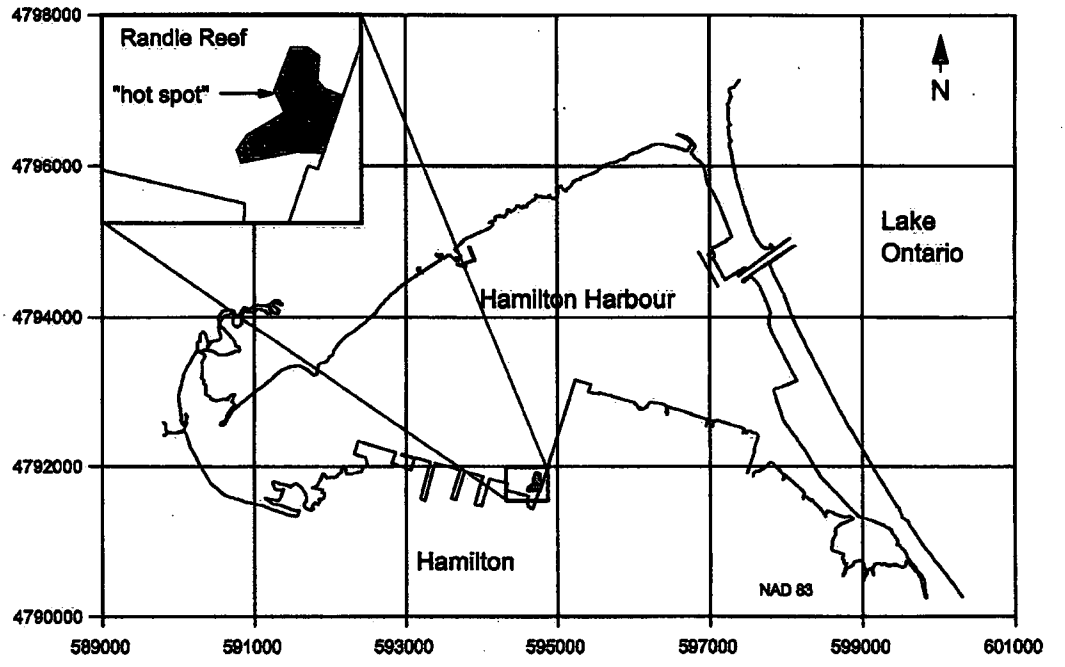

Figure 1: Randle Reef Site Map

The stratigraphy of Randle Reef is very mixed and complex. Sediment cores retrieved just metres apart from each other have often been found to be significantly different in composition, texture and layering. This suggests a man-made origin of the deposit and combination of sediment deposition, mixing and disturbance that will not likely ever be

fully understood. The widely differing geotechnical and chemical data extracted from the first few sets of cores retrieved resulted in the continuation of sediment sampling in more closely spaced core and grab sample sets. The varying sets of sediments samples collected over the years has led to Randle Reef being the most sampled area of the harbour to date.

All of the known sets of sediment samples conducted at Randle Reef are herein described. This includes the type of sediment sampling, the geotechnical properties of sediment measured from cores, and the concentrations of PAHs found in the sample sets. The historical sequence of sampling along with the varying methodologies used is also described.

2.0 HISTORICAL CONTEXT

The pre-industrial shoreline near Randle Reef was comprised of marshes. This marshland was filled in to make room for industrial properties during the period between 1862 and 1926 (RAP, 1992). An additional 1,000 acres of landfill for commercial use was created in 1957. The present day shoreline both to the south and east of Randle Reef is now used for industrial purposes and is comprised of landfill.

Steel mills on the south shore began operating in 1910. Industrial discharges into the harbour from these and other industries increased over the decades until the late 1970s. Environmental awareness, more stringent legislation, and an improvement in effluent controls resulted in a marked decrease of industrial wastes being discharged into the harbour. The sediment at Randle Reef contains the most heavily contaminated accumulation of these historical discharges, particularly for PAH contamination, and in some areas is deeper than 3 metres.

The joint Canada-US body known as the International Joint Commission (IJC) ratified a water quality agreement in 1987 which recognized 43 highly contaminated areas within the Great Lakes, called Areas of Concern (AOCs). Hamilton Harbour is among the AOCs with a high priority for sediment remediation. With this distinction, funding for cleanup has been directed towards the harbour from both the federal and provincial governments. More funding has been directed towards Randle Reef than any other area of the harbour.

Each AOC was provided with committees of representatives from government, businesses and private citizens that have some concern for the environmental health of the AOC. The committees involved are known as Remedial Action Plan (RAP) committees, and were commissioned with creating reports describing problem definitions and recommended solutions. The Hamilton Harbour RAP produced two reports in 1992 concerning these issues.

In 1995, the Hamilton RAP Strategy for Contaminated Sediment identified a portion of Randle Reef as a "high priority zone". As a result of this designation, the RAP recommended removal of the sediment. In 1997, a plan was proposed to incinerate the sediment removed from Randle Reef in a sinter plant blast furnace (Hamilton Harbour RAP Implementation Office, 1997). This plan was abandoned due to health and environmental concerns. The most recent plan to date, introduced in 2002, is to build a containment facility/land form around the most contaminated sediment at the site, with the capacity to store additional sediment to be dredged up from areas close to the containment facility. The newly created land is to be either an island, or an attached land form to the adjacent industrial land.

3.0 SEDIMENT SAMPLING

3.1 Early Sampling

The Ontario Ministry of the Environment (MOE) conducted sediment sampling in Hamilton Harbour for trace organics as early as the mid-1970s. A study from 1975 showed that out of 6 samples taken from throughout Hamilton Harbour, a sample taken close to Randle Reef contained the highest PAH concentrations (MOE, 1985). A 1976 sediment study showed that "severe pollution" of sediments existed at Randle Reef (MOE, 1977).

Murphy et al. (1990), collected 12 Ekman dredge grab samples throughout 1988, and 81 sediment cores during April and July, 1989, in the Randle Reef area. PAH and bioassay measurements were conducted on some of these samples. They found that tarry/oily sediment at the hot spot existed deeper than 40 cm below the sediment/water interface. One grab sample collected in the hot spot contained PAH concentrations of greater than 1,400 μg/g.

A set of 31 sediment cores was collected at Randle Reef during October and November, 1994. These cores were also analysed for PAH concentrations and were reported to "confirm" the data obtained from the cores retrieved in 1989 (Murphy et al., 1995).

3.2 Gravity Cores, May 1996

In May 1996, 41 benthos gravity cores were taken at 50 m grid intervals using a 100 kg weight on the corer. The cores were taken by Technical Operations, NWRI, in cooperation with Environment Canada, Ontario Region (EC-OR). The grid interval was based on an extended area in and around Randle Reef (about 12 ha). This area was in turn based on a mapped area of PAH toxicity taken from Murphy et al. (1990).

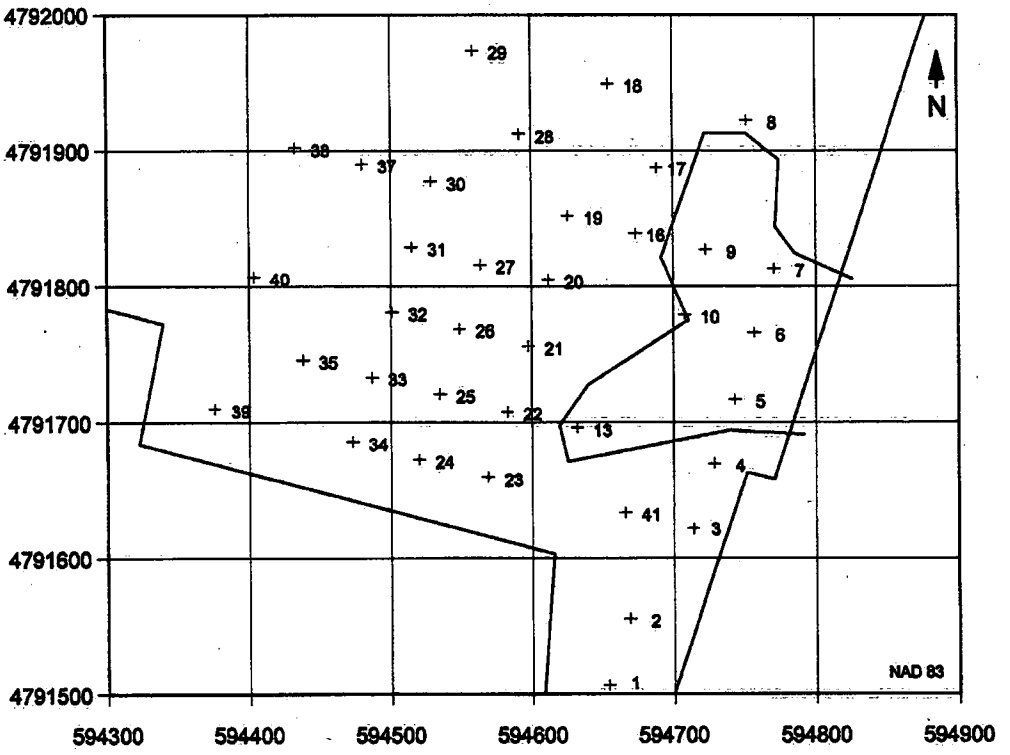

Figure 2: May 1996 Core Locations

The core tubes used for sampling were made of acrylic and had a 3 in. diameter. The lengths and coordinates for all cores were carefully noted to the nearest metre using a Differential Global Positioning System (DGPS). EC-OR inspected, logged and sub-sampled the cores. These cores were later analysed for polycyclic aromatic hydrocarbon (PAH) content.

The May 1996 cores were sub-sampled for PAHs at varying intervals. This was based on two things: First, it was assumed that Murphy et al. (1990) had already analysed the top 40 cm of area sediment for PAH concentrations, so sampling was generally done at 40 cm and below (although there are some cores from this set with the upper 40 cm sampled). Second, varying horizons of sediment were examined in each core. Initially, one horizon per core was sampled before it was determined whether another horizon should also be sampled, based on how contaminated it appeared to be. The majority of cores had only one continuous section sampled (i.e. A "strip" of sediment was subsampled vertically along the core sample by scooping out a shallow groove which was usually between 10 and 40 cm long). The remaining cores had two sections sampled, with the exception of Core 6 which had three. The sampled sections vary in both length and core depth. There were 23 cores sampled from sections that include the top of the core. Intervals taken at 40-50 cm are also common.

3.3 Gravity Cores, December 1996

The May 1996 map of PAH toxicity was determined to be improperly geo-referenced, thus another core grid was mapped and sampled in December 1996. This newer grid had 25 m sampling station intervals, as opposed to 50 m, for greater mapping resolution than the sampling grid used in May. There were 75 cores taken by Technical Operations, NWRI, and EC-OR using an 80-kg weight on the same corer as the May set. Positioning, sub-sampling and logging of the cores were completed using the same methodology as for the May set. A notable exception was the fact that only the top 20 or 25 cm of each core was sampled and analysed for PAH levels. This was to make up for the lack of sampling of the upper sections of cores in the May set, where sampling of the upper core sections was deemed not to be necessary at the time.

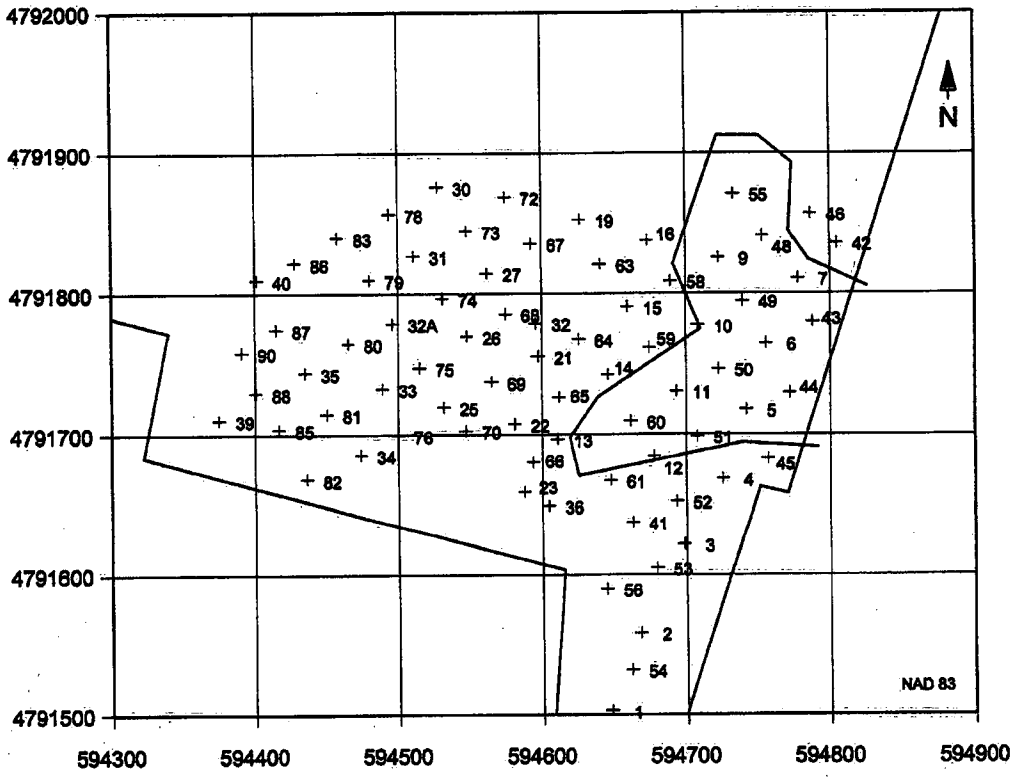

Figure 3: December 1996 Core Locations

Physical data from both the May and December 1996 cores were plotted in a graphics software program (Freelance). A template was drawn up, showing a scale of 10 cm intervals, totalling 2.4 m, with 32 core station numbers per page (Appendix A). The May and December cores were plotted under the same station numbers, showing a maximum of 4 cores per station (several pairs of Dec. 1999 cores were taken at the same station). An outline of the length of each core taken was drawn on the template, then coloured

according to appearance and general sediment type observed in logging notes taken by EC-OR. Homogeneous layers of sediment were given a colour according to their descriptions. Where a sediment type was mentioned, such as clay or sand, it was given a pattern in addition to the colour. A graph highlighting the interface between clean and contaminated sediment was also created, using a connecting red line from core to core (Appendix C).

Both the May and December 1996 core sets were sampled for PAH concentrations. After sampling, the data were plotted, showing total PAH concentrations, excluding naphthalene, from 15 different PAH compounds (Appendix D). Three different colours were used to show the differences in PAH concentrations for various sub-sections of each core. Green was used for concentrations below 700 μg/g, yellow for 700 - 1000 μg/g, and red for concentrations greater than 1000 μg/g. Boundaries between sub-samples within the same core, and classified with the same colour were marked with a dark line.

3.4 Borehole Samples, April 1999

Nine geotechnical boreholes (Fig. 4) were put down at Randle Reef in April, 1999 by Trow Consulting Engineers Ltd. (Stoney Creek), referenced by a differential global positioning system (DGPS). A report by Trow described the logged boreholes, the results of in-situ tests, and borehole samples taken (Trow, 1999). Descriptions in the report included sediment appearance, texture, results of the Standard Penetration Tests, and the shear strength measured using a field vane and pocket penetrometer. The borehole samples ranged in length from 2.4 to 4.9 m and were taken from a drill rig adapted for soil sampling, which was mounted on the front of a spud barge.

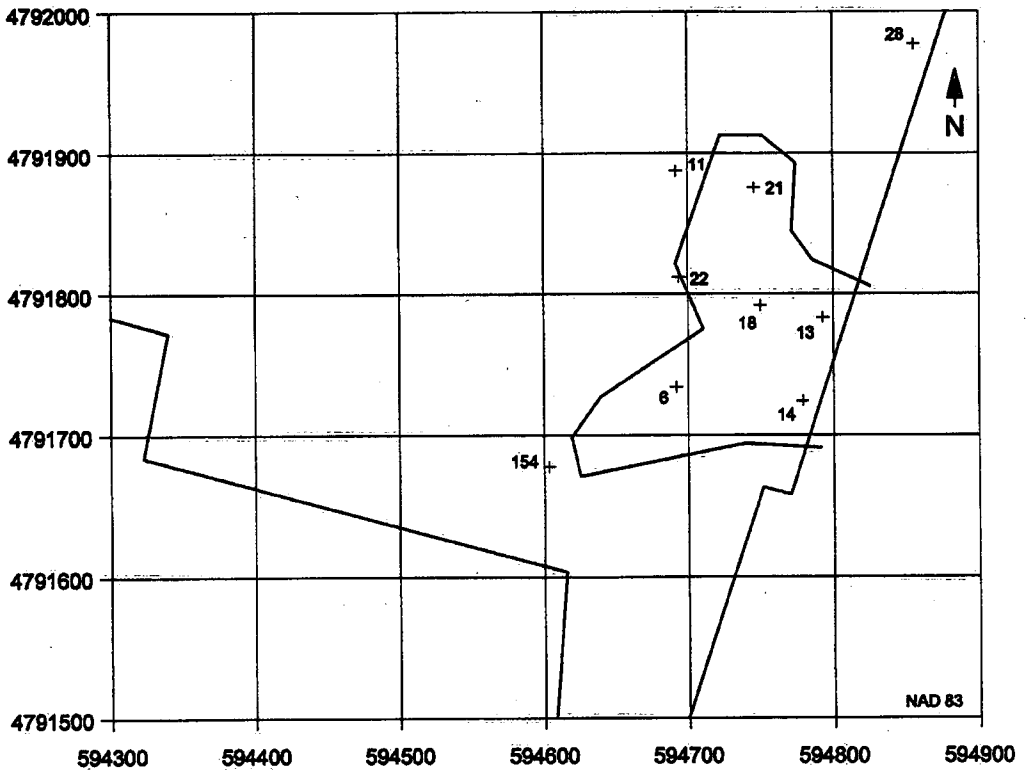

Figure 4: April 1999 Borehole Sample Locations

3.5 Gravity Cores, December 1999

In December 1999 27 benthos cores were taken from 21 sites at Randle Reef by Technical Operations, NWRI, in co-operation with EC-OR. A 60 kg weight was used for the first two cores taken (T22, and 10). The remaining cores were taken with an 80 kg weight for greater penetration. These cores were taken at some of the same sites as the 1996 core series, but were based in and around the "hot spot". In most cases, the coordinates for these cores were within 5 m of the original 1996 core coordinates.

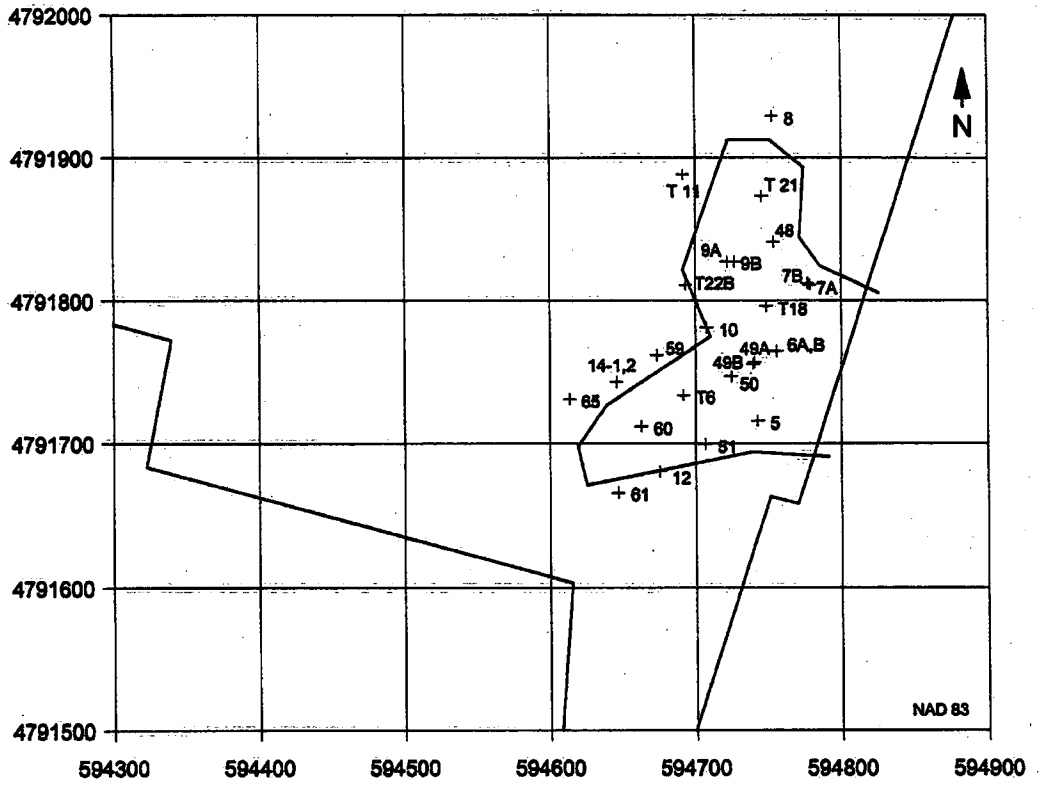

Figure 5: December 1999 Core Locations

The December 1999 cores were sub-sampled in a different manner than the 1996 cores. Sampling was mainly conducted on core sections where the upper 5 cm of the clay base were perceived to be. These sections were used for the analyses of all 27 cores analysed. Two cores (6B and 7A) were also sampled at the lower 5 cm of the clay base, since very high PAH values (>5,000 μg/g) were found in the upper 5 cm of the clay base. Core 7A also had a third sample taken where a black streak was obvious on the core tube, but the clay at this depth (9 cm) contained a very low PAH concentration (2 μg/g).

All of the December 1999 gravity cores were X-radiographed to reveal layering and density of sediment. The X-ray prints were reviewed and logged. The notes were recorded in a Lotus file, and a black and white diagram of each core was electronically drawn up (Appendix B).

4.0 RESULTS

4.1 Gravity Cores, May and December 1996

Sediment texture and appearance (including colour) were somewhat mixed from both the May and December sets of cores, although most cores had black fine sediment in the upper portions, with clay or sand underlying (sometimes referred to as a "plug"). Thin black bands of sediment mixed with lighter shades were also common. Some cores had shells. One core (well outside of the hot spot) was noted to contain zebra mussels on the surficial sediment. Cores with the deepest clay or sand layers were mainly found in two areas, namely, the central part of the hot spot and the off-shore area south-west and just outside of the hot spot.

The cores containing the highest PAH concentrations were mainly found within the hot spot boundaries next to the Stelco dock. Only two cores with PAH concentrations above 1,000 μg/g were found outside these boundaries. There were three cores with concentrations between 700 to 1,000 μg/g also outside the boundaries.

The recorded PAH levels for the set of 41 cores taken in May 1996 were generally below 700 μg/g (32 cores), comprising 78% of the set. There were 5 cores between 700 and 1,000 μg/g (12%) and 4 cores had levels over 1,000 μg/g PAHs (10%).

Of these 75 cores from the December set, 64 had maximum PAH concentrations below 700 μg/g (85%), 6 cores had concentrations between 700 and 1,000 μg/g (8%), and 5 cores had greater than 1,000 μg/g (7%).

4.2 Borehole Samples, April 1999

Samples from four of the Trow boreholes (154, 6,18, and 22) were submitted for PAH analysis to NWRI. Samples from Borehole 6 were not analysed since it appeared obvious that the core was heavily contaminated by coal tar. Borehole 18, sub-sampled in three sections, was found to be heavily contaminated with PAH concentrations over 4,000 μg/g in the mid section. Both Borehole 6 and Borehole 18 were well within the hot spot. Boreholes 22 and 154 were either at or just outside the hot spot boundaries and were each sub-sampled in two sections. Both boreholes had PAH concentrations of under 700 μg/g.

4.3 Gravity Cores, December 1999

For the December 1999 set of cores, the upper sediment at the top of the cores was not sampled, since sampling of the surficial sediment was considered to have been adequately conducted with the May and December 1996 core sets. The mid and lower core sections were sampled, where deemed appropriate. Most sampling was conducted on the lower, denser sediment which often existed towards the bottom of most cores. The lower sections of the cores were generally comprised of natural pre-industrial sediment, thus PAH concentrations tended to be much lower than values from the 1996 core sets where

the upper, softer sediment was sampled. Almost all of the cores (24) were found to contain less than 700 μg/g PAH concentrations (89%). There were no cores with values between 700 and 1,000 μg/g, and 3 cores (11%) above 1,000 μg/g (all 3 were in fact above 5,000 μg/g).

The X-radiographs taken of the cores revealed a very complex layering of sediment (see Appendix B). Cores that were within metres of each other were often found to have significantly different denser, natural sediment depths. The sediment was usually mainly clay material, although sand or sandy clay was common. Shells were sometimes present. Cores with the deepest natural clay or sand layers were generally found in the south central portion of the hot spot.

CONCLUSIONS

It is obvious that sediments at Randle Reef are highly contaminated by PAHs. The contaminant trends are highly irregular, as layers of sediment within core samples only metres apart were sometimes significantly different in PAH concentrations. Sediment appearance descriptions and radiographs also show many variations in colour, layering, density and consistency (see Appendices A,B,C and E).

The heterogeneous layering and irregular occurrence of high concentrations of PAHs in layers of sediment several metres deep suggest contamination from industrial sources over a time span of several decades. More specifically, the PAH concentrations found suggest coal tar contamination which is a common byproduct of steel manufacturing.

Despite the numerous sediment sampling events at Randle Reef, spanning about 25 years, the precise extent of sediment contamination is not fully known. Enough information has been obtained, however, to define the most severely contaminated sediment in the vicinity of Randle Reef, within an area of about 10 ha.

ACKNOWLEDGEMENTS

This report was funded by Environment Canada's Great Lakes Sustainability Fund. NWRI's Technical Operations Section under the direction of Roger Santiago of the Environmental Protection Service collected the Benthos cores. Mr. Santiago was also responsible for the core descriptions and the subsampling for PAH analysis. Trow Consulting Engineers Ltd. collected the borehole samples and associated geotechnical data. PAHs in the Benthos cores were analyzed by the Wastewater Technology Centre; Dr. Chris Marvin of NWRI did the PAH analysis for the borehole samples.

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APPENDICES

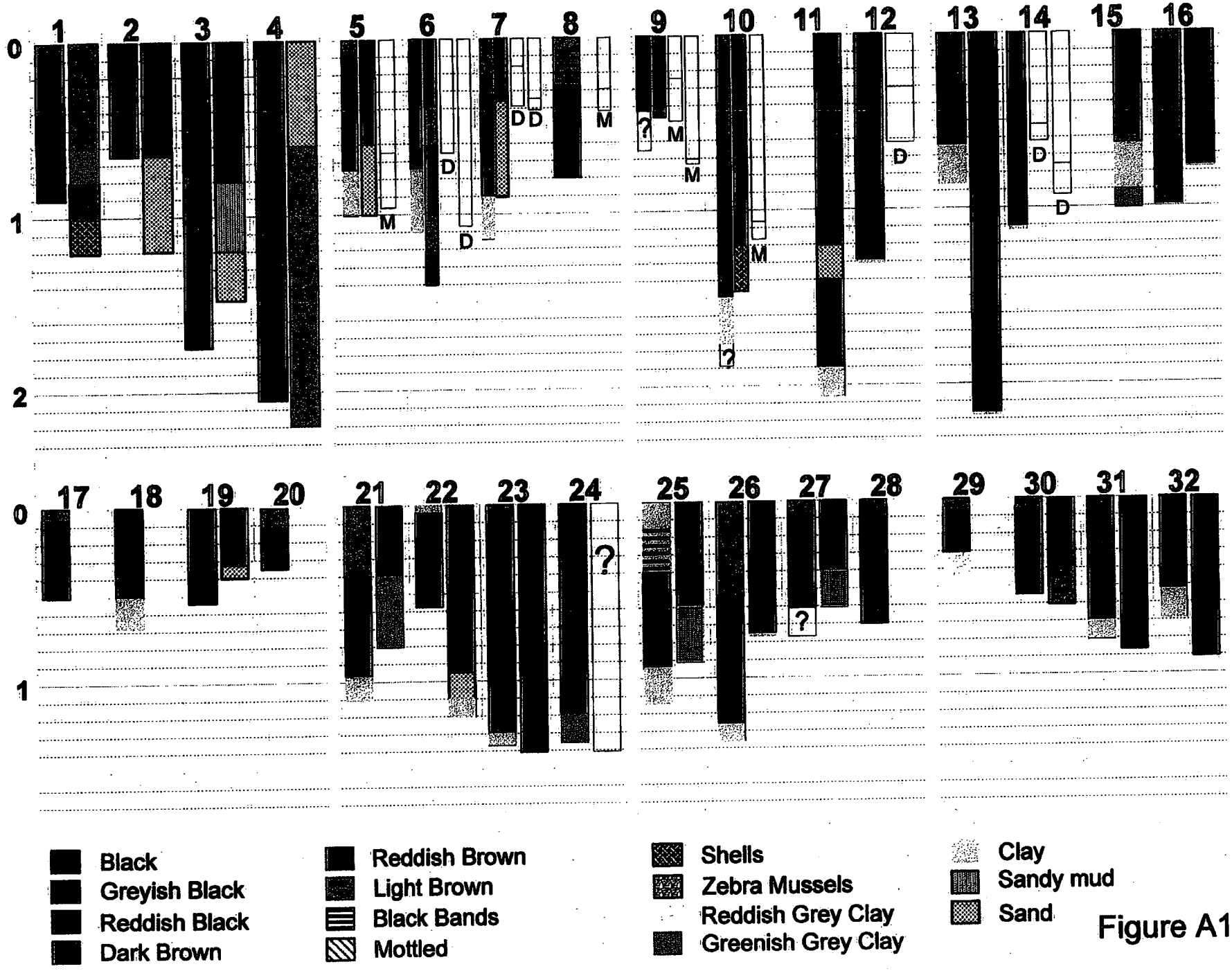
APPENDIX A

Sediment Characteristics of Gravity Cores Taken in May and December 1996

A1	Cores 1 - 32
A2	Cores 33 - 64
A3	Cores 65 - 90

Notes:

Station numbers appear at the top of each column and apply to both sets of 1996 cores.
Where only one core for each of the two months (May and December) exist under the same station number, the May 1996 core is depicted in the first vertical half of the column, and the December 1996 core is depicted in the second half the column.
Where two or three cores were taken in either month, core depictions appear narrower, and the December core (if taken) may appear in the first half of the column to the right of the May core. The additional core(s) appears to the right of these first two cores and is identified by the first letter of the month the core was taken. (i.e. Cores taken in May 1996 are labelled with an "M" at the base of the depicted core. Cores taken in December 1996 are labelled with a "D").
Where documentation exists stating that a core was taken, but no data were found, an uncoloured outline of the core is depicted.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18
19
20
21
22
23
24
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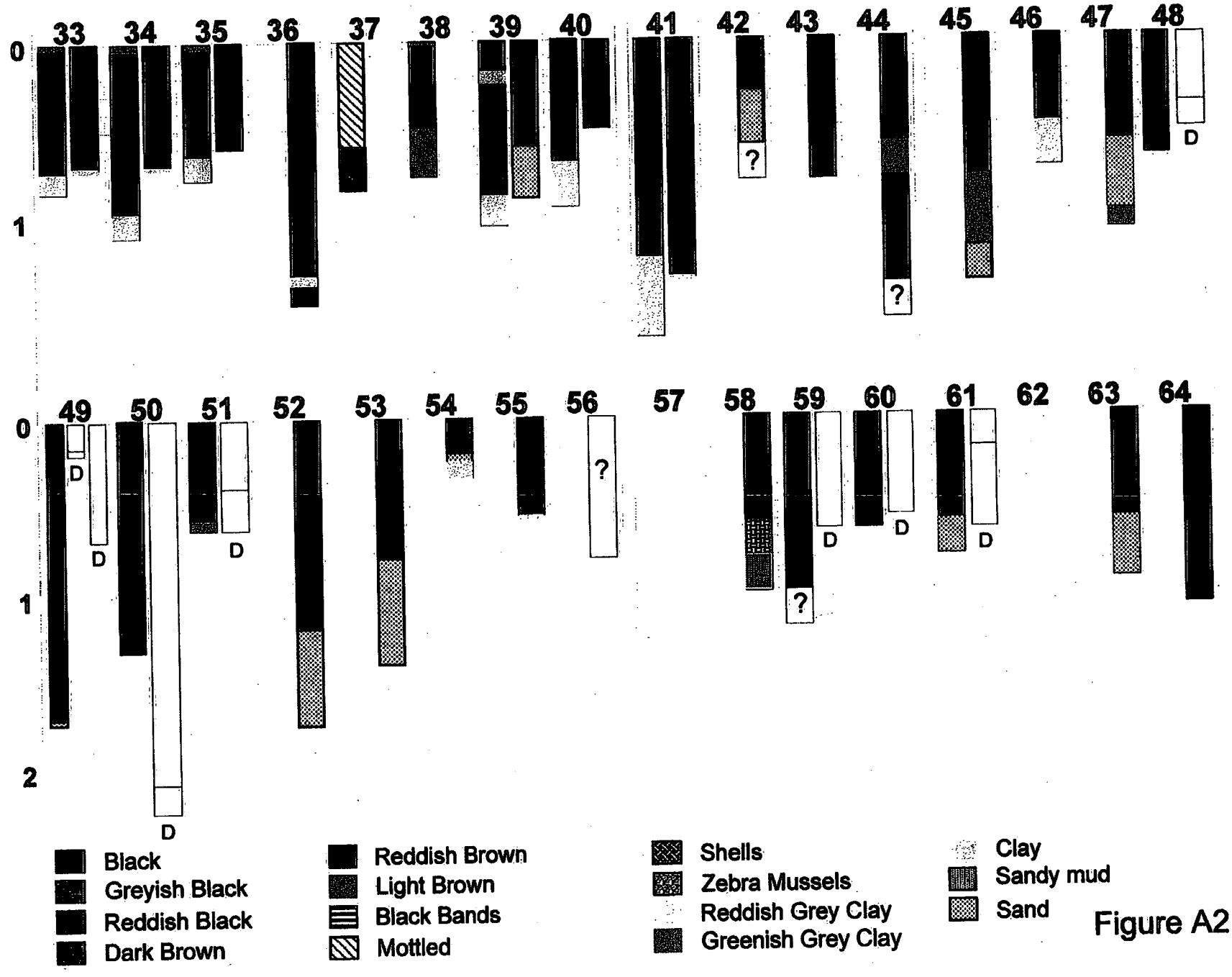
26
27
28
29
30
31
32
?
?
Black
Greyish Black
Reddish Black
Dark Brown
Reddish Brown
Light Brown
Black Bands
Mottled
Shells
Zebra Mussels
Reddish Grey Clay
Greenish Grey Clay
Clay
Sandy mud
Sand

Figure A1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64
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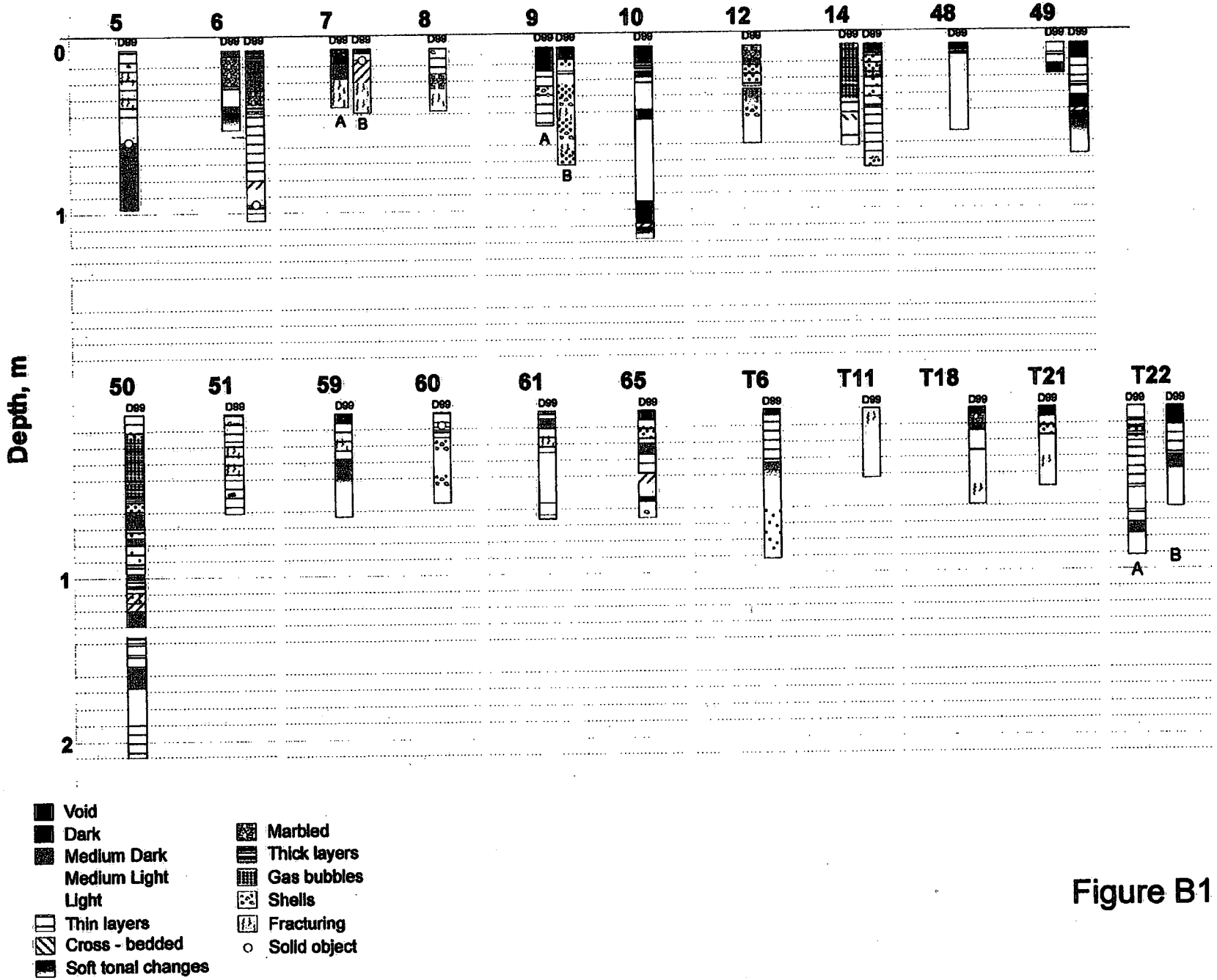
Black
Greyish Black
Reddish Black
Dark Brown
Reddish Brown
Light Brown
Black Bands
Mottled
Shells
Zebra Mussels
Reddish Grey Clay
Greenish Grey Clay
Clay
Sandy mud
Sand

Figure A2

APPENDIX B

B1 Radiographs of December 1999 Gravity Cores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14
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50
51
59
60
61
65
T6
T11
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T21
T22
A
B
Depth, m
0
1
2
Void
Dark
Medium Dark
Medium Light
Light
Thin layers
Cross - bedded
Soft tonal changes
Marbled
Thick layers
Gas bubbles
Shells
Fracturing
Solid object

Figure B1

APPENDIX C

C1 December 1999 Gravity Cores, Depth to Denser Sediment

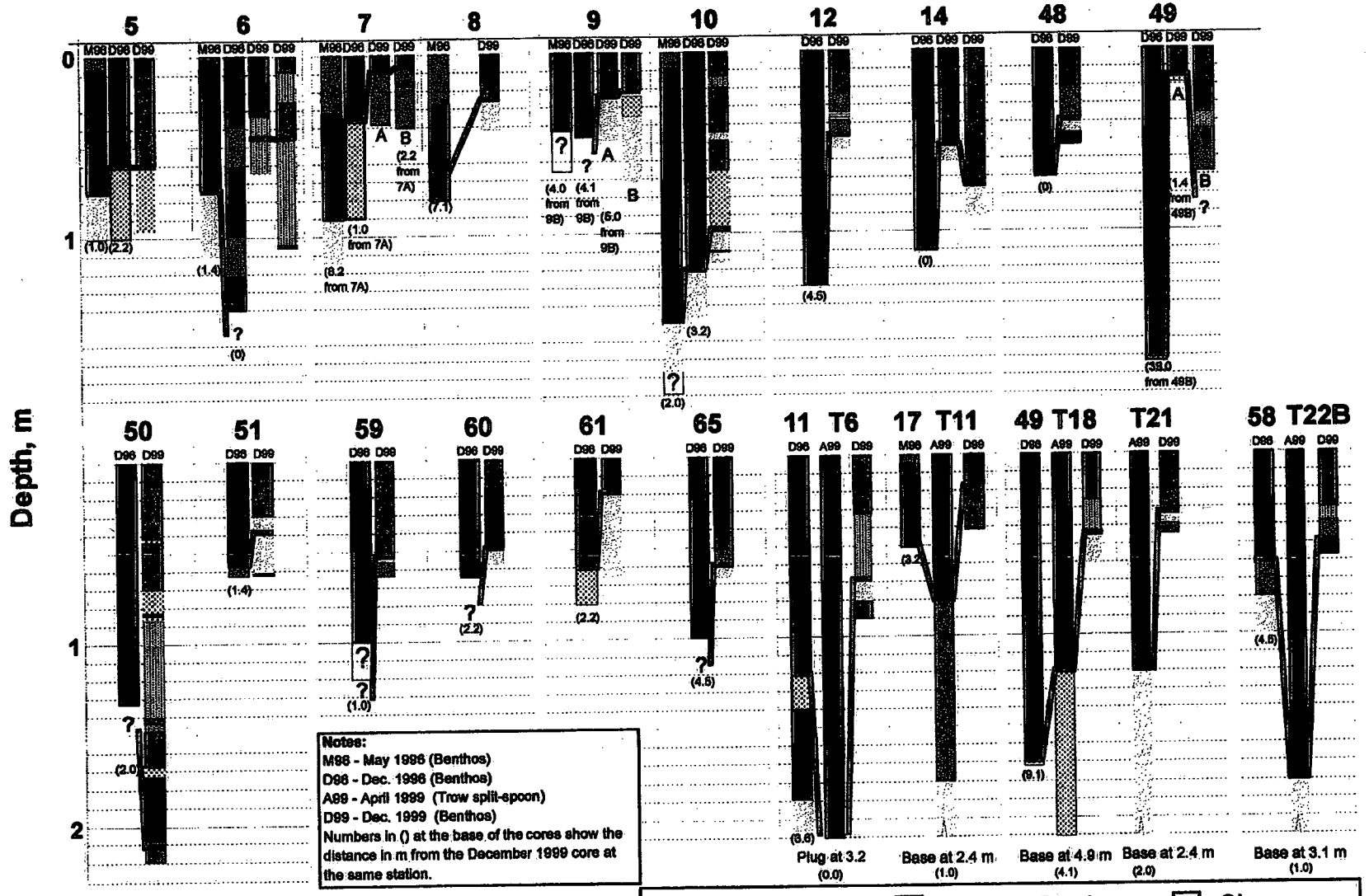

5
6
7
8
9
10
12
14
48
49
50
51
59
60
61
65
11 T6
17 T11
49 T18
T21
58 T22B
Depth, m
0
1
2
M96 D96 D99
D96 D99
M96
A99
Notes:
M96 - May 1996 (Benthos)
D96 - Dec. 1996 (Benthos)
A99 - April 1999 (Trow split-spoon)
D99 - Dec. 1999 (Benthos)
Numbers in () at the base of the cores show the distance in m from the December 1999 core at the same station.
Plug at 3.2
(0.0)
Base at 2.4 m
(1.0)
Base at 4.9 m
(4.1)
Base at 2.4 m
(2.0)
Base at 3.1 m
(1.0)
Black or undefined (presumed to be contaminated)
Base of contaminated sediment
Basal sediment (non-contaminated?)
Reddish Black
Greenish Grey Clay
Reddish Brown
Light Brown
Medium Brown
Dark Brown
Clay
Sandy mud
Sand

Figure C1

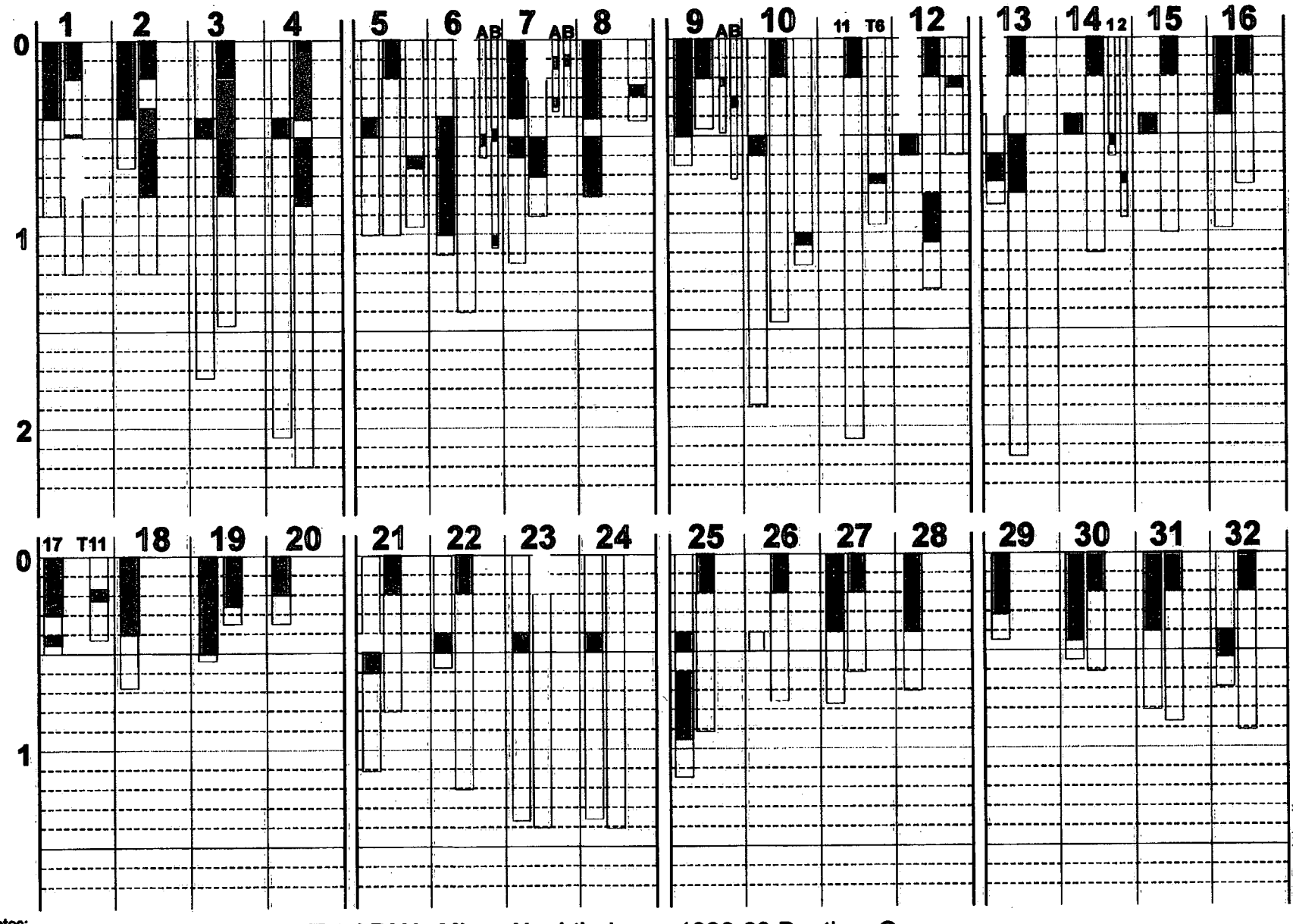
APPENDIX D

December 1999 Gravity Cores, PAH Concentrations

D1 Cores 1 - 32
D2 Cores 33 - 64
D3 Cores 65 - 90 (additional cores included)

Note:

The grey areas in cores 1 - 4 are program errors.



Notes:
First core in each set taken in May 1996
Second is Dec. 1996
Third core is Dec.1999 (two narrow cores where applicable).
A gap is left where no core in the allotted space was sampled.

Total PAHs Minus Naphthalene. 1996-99 Benthos Cores

— Horizon boundary

■ <700 ppm 700 to 1,000 ppm ■ >1,000 ppm

Note: Trow Borehole PAH plots may be viewed in file TrowPAH99.PRZ

Figure D1

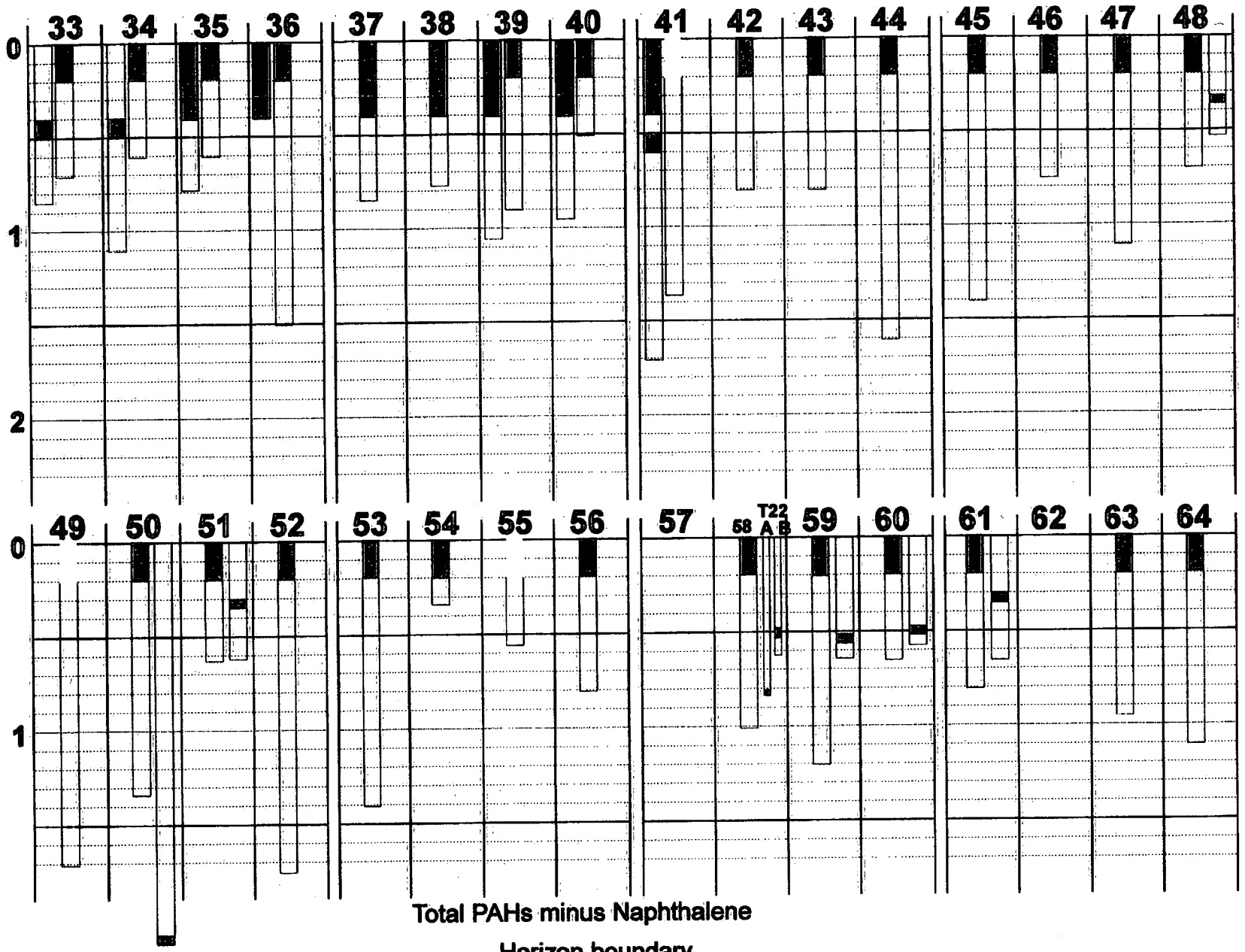
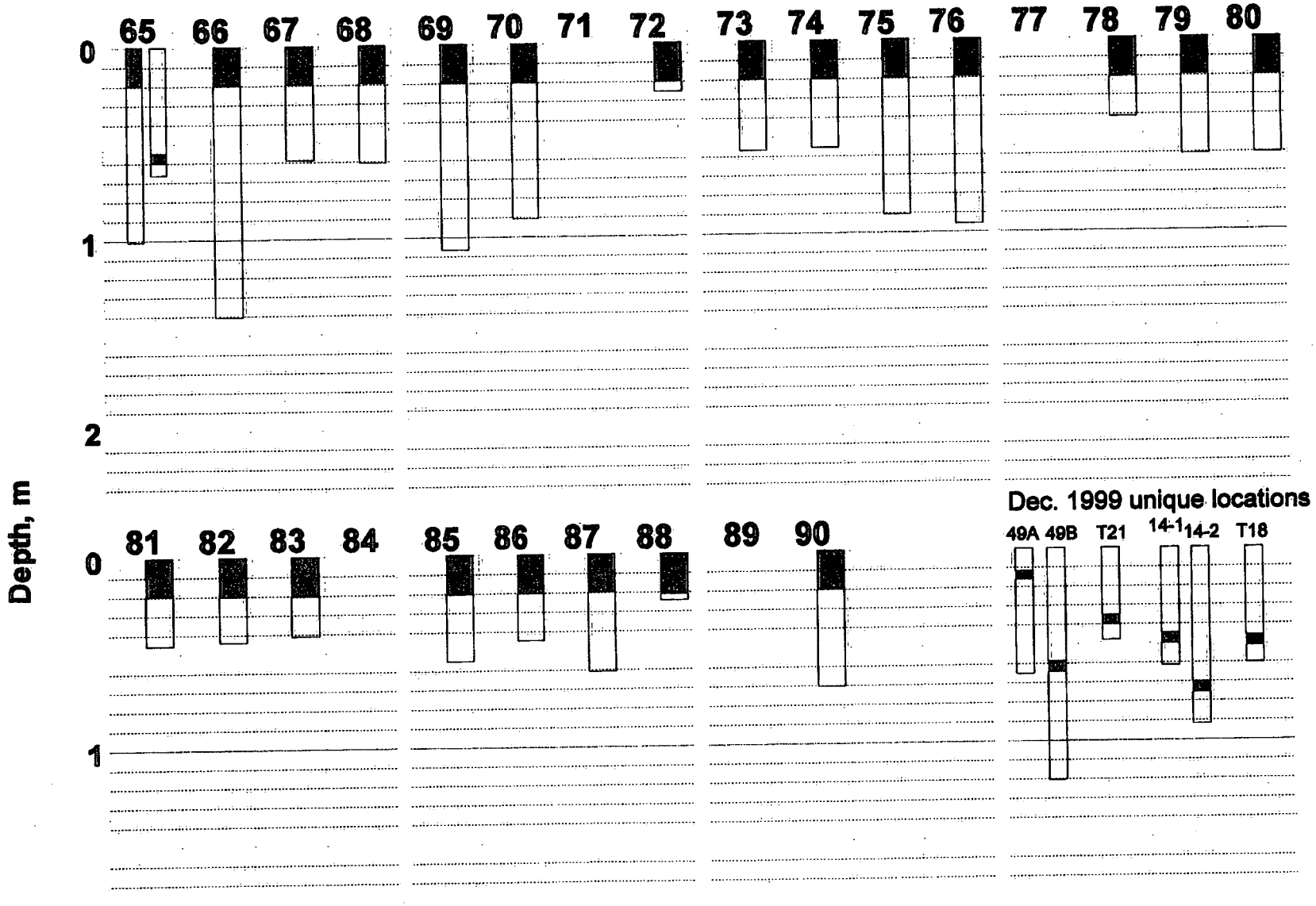

33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
0
1
2
49
50
51
52
53
54
55
56
57
58
T22
A
B
59
60
61
62
63
64
0
1
Total PAHs minus Naphthalene
Horizon boundary
<700 ppm
700 to 1,000 ppm
>1,000 ppm

Figure D2



Note:
Unique locations may bear the same station number as 1996 cores, but have completely different coordinates

Figure D3

APPENDIX E

April 1999 Borehole Samples

E1 Three Dimensional View of Sediment Appearance
E2 PAH Concentrations of Cores 154, 22 and 18
E3 Sediment Characteristics of Cores 154, 22 and 18

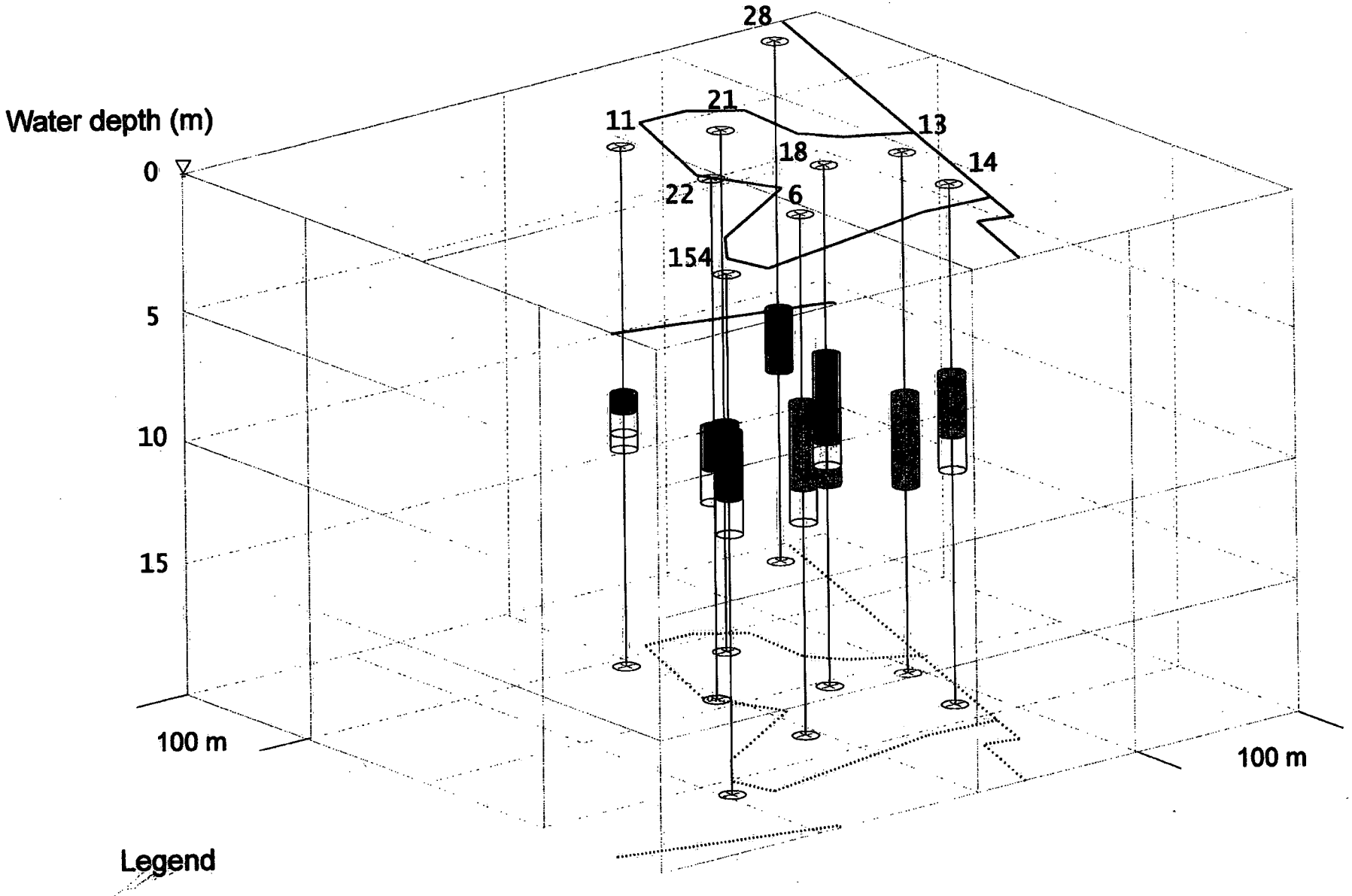

Water depth (m)
0
5
10
15
28
21
11
13
18
14
22
6
154
100 m
100 m
Legend
Sandy silt coal tar mix
Sandy clayey silt coal tar mix
Silty sand
Organic clayey silt
Organic silt
Clay

Figure E1

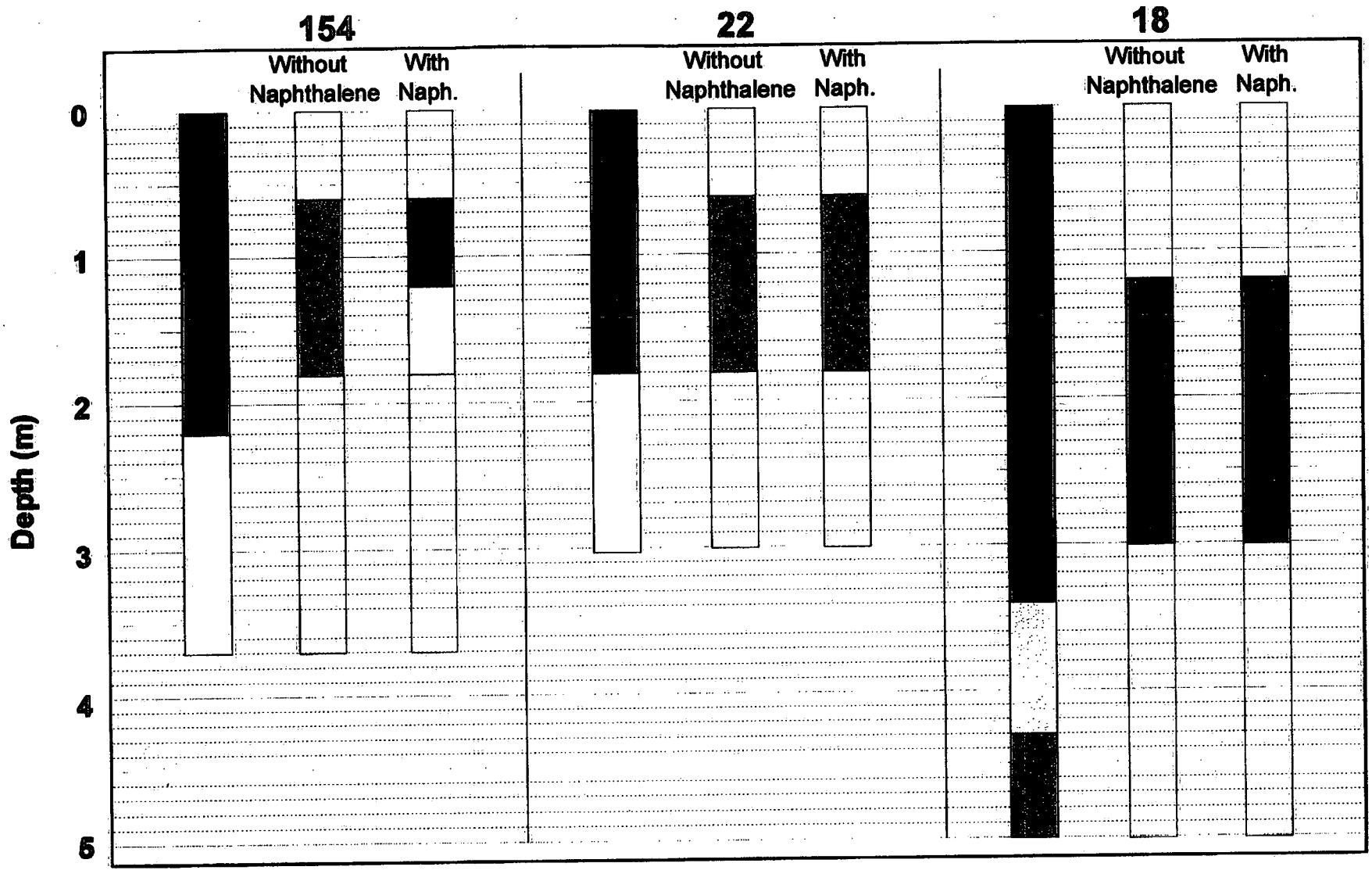

154
Without Naphthalene
With Naph.
22
Without Naphthalene
With Naph.
18
Without Naphthalene
With Naph.
Depth (m)
0
1
2
3
4
5
Legend
Sandy silt coal tar mix
Organic silt
Silty Sand
Clay
PAH Concentrations
< 700 ppm
700-1,000 ppm
> 1,000 ppm

Figure E2

APPENDIX F

Table of Gravity and Borehole Samples: 1996 - 1999

Includes: Station numbers, coordinates, lengths and general description of underlying denser sediment

Benthos Cores: May, 1996, corer weight- 100 kg.

Core Site	Easting UTM NAD83, m	Northing	Length, m	Depth to "clay plug"	"Clay-plug" description
1	594654	4791507	0.90		reddish brown, clay?
2	594669	4791556	0.66	0.66	
3	594714	4791622	1.73		
4	594729	4791670	2.05		red brown, clay?
5	594743	4791717	1.00	0.77	grey
6	594757	4791766	1.10		
7	594771	4791813	1.13		reddish or light grey
8	594752	4791922	0.80	0.64	red brown
9	594723	4791827	0.64		red brown or light brown
10	594708	4791779	1.88	1.88	
13	594632	4791696	0.86	0.63	light grey
16	594674	4791839	0.99	0.87	red brown
17	594689	4791887	0.50		
18	594655	4791949	0.69	0.5	grey sandy
19	594626	4791852	0.52	0.34	red brown
20	594612	4791805	0.35	0.26	red brown
21	594598	4791756	1.10	0.98	
22	594583	4791708	0.58		
23	594569	4791660	1.37	1.3	
24	594520	4791673	1.35	1.2	grey brown
25	594535	4791721	1.13	0.94	grey
26	594549	4791769	1.37	1.28	grey
27	594564	4791816	0.77	0.6	brown and grey
28	594592	4791912	0.70	0.59	red-brown
29	594559	4791973	0.43	0.31	red grey
30	594529	4791877	0.54	0.47	red brown
31	594515	4791829	0.80	0.7	grey
32	594501	4791781	0.69	0.52	grey
33	594487	4791733	0.84	0.72	grey
34	594473	4791686	1.10	0.98	grey
35	594438	4791746	0.79	0.63	grey
37	594480	4791890	0.84	0.6	red grey
38	594433	4791902	0.78	0.5	brown
39	594376	4791710	1.05	0.89	grey
40	594404	4791807	0.94	0.7	grey
41	594666	4791634	1.70	1.26	grey

Benthos Cores: Dec, 1996, corer weight- 80 kg.

Core Site	Easting UTM NAD83, m	Northing	Length, m	Depth to "clay plug"	"Clay-plug" description
1	594648	4791503	1.20		grey-green organic
2	594668	4791558	1.20	0.7	sand
3	594699	4791622	1.48		hard sand
4	594726	4791669	2.20		
5	594742	4791718	1.00		red-brown sand
6	594756	4791765	1.40		
7	594778	4791811	0.90	0.35	sand
9	594723	4791826	0.45	0.45	
10	594709	4791778	1.45		
11	594694	4791731	2.05	1.9	
12	594678	4791685	1.29	1.3	
13	594611	4791697	2.15	2.15	
14	594646	4791743	1.10		
15	594660	4791791	1.00		brown grit/sandy clay/green organic
16	594674	4791838	0.75	0.75	
19	594627	4791853	0.40	0.32	sand
21	594598	4791756	1.06	0.4	grey-green grit
22	594581	4791708	1.20		sand, clay layer at 1.2 m
23	594588	4791660	1.40		coarse grit
25	594532	4791720	0.90		
26	594548	4791770	0.75	0.75	
27	594562	4791815	0.60		sandy clay
30	594528	4791876	0.60		
31	594511	4791827	0.87		
32	594596	4791779	0.90		
32A	594496	4791779	0.89		
33	594489	4791733	0.70	0.7	
34	594474	4791686	0.60		
35	594435	4791744	0.96		
36	594605	4791650	1.50	1.32	clay plug, 1.32-1.4 m, soft black below
39	594375	4791711	0.90		stiffer, sandy?
40	594402	4791810	0.50		
41	594663	4791638	1.37	1.37	
42	594805	4791836	0.80	0.3	sand
43	594788	4791780	0.80		
44	594772	4791730	1.60		base of record sheet missing
45	594757	4791683	1.40		sandy
46	594787	4791857	0.74	0.5	
48	594754	4791841	0.70	0.7	hard clay
49	594740	4791795	1.70	1.7	hard sand
50	594723	4791747	1.32	1.32	stiff black
51	594708	4791699	0.72		
52	594694	4791653	1.75	1	hard sand (how penetrated?)
53	594680	4791605	1.40		
54	594662	4791532	0.32		
55	594734	4791871	0.55	0.55	
56	594645	4791590	0.80		base of record sheet missing
58	594690	4791809	1.20		grey-green clay, shells, sandy clay at 80?
59	594675	4791762	1.20		base of record sheet missing
60	594662	4791710	0.65	0.65	
61	594648	4791668	0.80		sandy
63	594641	4791821	0.95		
64	594626	4791768	1.10		
65	594612	4791727	1.00	1	
66	594594	4791681	1.40	1.4	grey-green clay
67	594593	4791836	0.59		

Benthos Cores: Dec, 1996. (continued)

Core Site	Easting UTM NAD83, m	Northing	Length, m	Depth to "clay plug"	"Clay-plug" description
68	594575	4791786	0.60		
69	594565	4791738	1.20	1	
70	594547	4791703	0.90		
72	594575	4791869	0.20		
73	594548	4791845	0.58	0.4	
74	594531	4791797	0.55	0.55	
75	594515	4791748	0.90	0.8	
76	594500	4791700	0.95	0.95	grey
78	594494	4791857	0.59		
79	594480	4791810	0.60		
80	594465	4791765	0.77		
81	594450	4791715	0.90	0.45	
82	594436	4791669	0.42		
83	594458	4791840	0.67		
85	594417	4791704	1.07	0.5	
86	594428	4791822	0.42		
87	594415	4791775	0.89		
88	594401	4791730	0.40	0.2	
90	594391	4791759	0.50	0.7	

Benthos Cores: Dec, 1999, corer weight- 80 kg. (except Cores T22B and 10 which had a 60 kg weight)

Core Site	Easting UTM NAD83, m	Northing	Length, m	Depth to "clay plug"
December 17, 1999				
T22B	594694	4791811	0.62	0.49
10	594708	4791781	1.17	1.06
49A	594741	4791757	0.19	0.12
49B	594740	4791756	0.70	0.59
9A	594722	4791827	0.49	0.23
9B	594727	4791827	0.72	0.72
7A	594779	4791811	0.38	0.17
7B	594777	4791812	0.41	0.34
60	594663	4791712	0.58	0.49
12	594676	4791681	0.61	0.3
51	594707	4791700	0.62	0.39
5	594743	4791716	0.97	0.65
61	594647	4791666	0.66	0.19
14-1	594646	4791743	0.61	0.52
14-2	594646	4791743	0.92	0.75
T 21	594746	4791873	0.49	0.35
48	594754	4791841	0.53	0.39
8	594753	4791929	0.41	0.29
T 11	594692	4791888	0.43	0.24
59	594674	4791762	0.64	0.52
December 20, 1999				
6A	594756	4791765	0.61	None
6B	594756	4791765	1.07	1.04
50	594725	4791747	2.23	2.08
T6	594692	4791734	0.97	0.7
T18	594749	4791796	0.60	0.44
65	594614	4791731	0.67	0.59

Borehole Samples: Apr, 1999

Coring Site	Easting UTM NAD83, m	Northing	Length, m	Depth to "clay plug"
6	594692	4791734	4.60	3.2
11	594692	4791887	2.40	0.8
13	594793	4791783	3.70	Complex
14	594779	4791724	4.00	2.5
18	594750	4791792	5.00	3.4
21	594746	4791875	2.40	1.2
22	594694	4791812	3.10	1.8
28	594856	4791977	2.50	None
154	594604	4791678	3.70	2.2

See the following report for more details:

Geotechnical Sampling of Sediment Dredging
of Hamilton Harbour, Pier 16,
Hamilton, Ontario
Trow Consulting Engineers Ltd.
August 10, 1999
Report # HAGE-0053319-A
428 Millen Road
Stoney Creek, Ontario. L8E 3N9
(905) 664-3300

APPENDIX G

PAH Data for Benthos Cores (1996 - 1999) and Borehole Samples (1999)

Note:

"1977 Samples" refers to the December 1996 core set

1996 Sample Data

Sample Name	Depth of Sample Section	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(e)pyrene	Indeno(1,2,3-c,d)pyrene	Dibenzo(a,h)anthracene	Benzo(g,h,i)perylene	Total PAHs	PAH - Naphthalene	TOC (% by weight)	Northing	Easting	Depth to Refusal
		ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g				
SEL		NA	NA	NA	160	950	370	1020	850	1480	460	NA	1340	1440	320	130	320	10000					
S1-1	0-40cm	52.2	3.27	7.98	85.2	52.9	15.5	41.3	31	17.1	14.7	15.7	4	11.8	10.7	2.75	7.75	374	322	10.80	507	654	0.9
S2-1	0-40cm	83.1	2.88	8.77	88.5	48	17.7	47	35.5	24.8	22.4	22.7	6.75	18.3	13.4	2.93	10.8	454	371	13.10	558	669	0.7
S3-2	40-50cm	197	1.51	0.51	22.6	7.59	0.93	4.65	3.92	3.61	2.14	4.23	0.68	1.34	1.45	0.5	1.39	254	57	8.20	622	714	1.7
S4-2	40-50cm	1420	11.7	4.43	125	77.4	14.6	65.2	44.9	29.9	21	27.4	4.27	15.9	9.76	5.46	8.32	1865	465	9.80	670	729	2.1
S5-2	40-50cm	653	2.27	0.97	20.5	10.4	1.57	7.59	6.45	3.95	4.55	3.57	0.76	2.07	1.35	0.4	1.25	721	68	8.04	717	743	1
S6-2	40-50cm	31800	204	62.3	247	625	198	269	190	95.6	77.8	90.9	26.7	74.8	50.6	11.2	42.1	34085	2285	30.90	768	757	*
S6-3	50-60cm	39400	186	47.7	175	534	173	337	225	142	123	136	44	112	74.2	13.5	61	41783	2383				*
S6-4	60-100cm	46200	159	38.7	156	462	146	127	217	143	332	141	39.6	113	72.5	15.2	62.1	48444	2244				1.1
S7-1	0-40cm	55300	15.3	15.6	87.8	122	30.8	98.2	73.3	35.5	29.6	38	13.3	33.2	23.6	4.62	21.3	55940	640	9.94	813	771	*
S7-2	50-60cm	1260	20.2	4.73	42.5	67.2	19.2	43.2	30.8	15	13.1	12.2	3.95	8.97	5.89	1.42	4.73	1553	293				1.1
S8-1	0-40cm	61.7	6.52	14.6	54.8	113	34	121	90.2	42.1	39	49.5	15.9	43	34.6	7.31	32.6	760	698	9.83	922	752	0.6
S9-1	0-40cm	8880	74.7	478	683	3200	519	2490	1800	494	483	563	207	493	315	82.4	309	21091	12211	10.20	827	723	
S9-2	40-50cm	9920	159	569	949	4540	755	3300	2340	653	794	948	237	790	511	90.2	469	27224	17304				0.6
S10-3	50-60cm	2690	22.9	4.1	110	105	21	79	53.9	33	23.5	25.7	4.9	15.9	8.6	6.14	10.1	3214	524	9.20	779	708	1.9
S11-2	40-50cm	3570	5.39	25	41	132	28	145	105	69	51.8	78.9	16.5	55.6	43.1	13.8	44.2	4422	852	18.30	731	695	
S12-1	0-40cm	7790	31.1	13.6	199	148	31.2	123	85	64.7	50.2	68.6	10.4	42.7	31.7	10.6	24.7	8721	4931	13.40	683	680	
S12-2	50-60cm	1340	13.2	4.02	75.2	47.9	16.2	40.4	29.8	16.8	15.1	12.3	4.22	9.44	5.1	1.75	5.38	1637	297				
S13-1	0-40cm	9200	34	1.08	247	160	53.7	88	63.1	33.6	27.1	30.5	9.2	25	16.1	4.37	12.2	10003	803	11.60	696	632	*
S13-2	60-63cm	555	6.19	1.97	23.8	18.4	6.02	14.7	11	7.97	7.51	6.48	2.18	4.88	3.32	0.86	2.95	673	118				0.9
S14-2	40-50cm	13600	8.26	48.9	59.7	190	41.2	164	114	76.2	57.6	85.4	15	55.8	46.9	13.8	38.2	14615	1015	14.80	743	646	
S15-2	40-50cm	16500	28.9	6.99	178	36	5.01	30	20.6	17	9.55	16	2.42	7.61	5.16	2.2	4.69	16868	368	9.28	791	660	
S16-1	0-40cm	9410	6.11	28.6	75.8	67.5	26.2	71.2	51.1	27.9	24.4	30.9	8.45	25.1	20.4	4.89	17.4	9896	486	11.60	839	674	
S17-1	0-40cm	3820	3.88	11.1	67.9	53.2	8.3	60.2	44.5	29	21.8	32.1	4.53	19.8	13.8	6.66	15.1	4212	392	10.10	887	689	1
S17-2	40-45cm	400	1.03	3.15	17.2	6.84	3.25	8.34	5.8	4.39	3.62	3.62	1.43	2.83	1.72	0.42	1.4	465	65				0.5
S18-1	0-40cm	52.3	3.8	5.52	19.7	50.2	14.7	57.2	43.7	22.5	20.1	27.5	6.8	22.3	19.8	4.42	17.5	390	338	9.13	949	655	0.7
S19-1	0-40cm	1230	2.61	4.88	56.2	19	5.88	18.3	13.7	8.78	7.79	9.38	3.31	7.23	7.72	1.7	5.51	1402	172	4.81	852	628	*
S19-2	40-50cm	2.37	<.4	<.4	1.76	1.34	0.68	1.96	1.82	1.2	0.97	1.1	0.44	0.86	0.49	<.4	<.4	<16.57	<14.2				0.5
S20	0-25cm	2320	3.97	18.1	53.8	66.5	15.2	54.4	39.6	24.5	20.2	22.7	6.21	19	14.7	2.83	12.5	2694	374	8.71	805	612	0.4
S21-2	40-50cm	14100	8.18	47.4	103	155	49.5	94.8	69.2	38.4	30.8	39.6	11.5	30.9	21	5.24	17.1	14822	722	17.40	756	598	*
S21-3	50-60cm	56700	56	32	86.6	81.9	35.6	80.2	56.5	39.3	33.5	34.2	9.96	26.2	17.3	4.26	13.5	57309	609				1.1
S22-2	40-50cm	22	1.78	0.83	1.8	9.07	3.03	10.3	8.05	6.34	7.09	6.95	2.28	4.92	4	0.97	2.83	94	72	5.38	708	583	0.6
S23-2	40-50cm	799	4.76	17.2	33.1	108	26.8	98.6	72.2	46.6	39.6	45.2	11.3	35.9	25.3	5.65	21.9	1389	590	14.60	660	569	1.4
S24-2	40-50cm	249	1.84	1.56	2.8	10.8	3.44	7.79	6.11	5.6	5.21	3.42	1.17	2.95	2.14	0.51	1.72	306	57	7.31	673	520	1.4

1996 Sample Data

Sample Name	Depth of Sample Section	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Indeno(1,2,3-c,d)pyrene	Dibenzo(a,h)anthracene	Benzo(g,h,i)perylene	Total PAHs	PAH - Naphthalene	TOC (% by weight)	Northing	Easting	Depth to Refusal
		ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g	ug/g				
S25-2	40-50cm	48400	36.7	37	376	172	32.5	93.2	66.1	43.9	35.5	44.2	11.5	33.1	20.4	4.87	15.3	49424	>1024	17.40	721	535	*
S25-3	60-95cm	1470	19.7	5.73	113	87.8	26.7	66.1	48.4	31.1	27.3	21.3	8.2	17.9	9.22	2.69	7.5	1965	495				1.1
S26-2	40-60cm	21500	17.7	60	309	167	53.7	75	56.2	30.9	24.4	28.8	10	22.8	13.7	3.9	9.52	22382	882	11.90	769	549	1.4
S27-1	0-40cm	3830	5.7	10.3	69.4	40.5	8.81	41.5	31.3	21.7	18	22.3	6.29	18.2	13.9	3.02	11.3	4152	322	9.50	816	564	0.8
S28-1	0-40cm	78.4	3.05	5.68	19.9	44.6	10.7	53.1	40.7	24.5	21.1	26.8	7.07	21.3	15.8	2.77	13.8	389	311	9.87	912	592	0.7
S29	0-31cm	6.88	0.65	2	26.5	13.4	3.09	13.4	10.3	7.09	5.88	6.21	2	4.52	2.91	0.77	2.31	108	101	6.88	973	559	0.4
S30-1	0-40cm	3830	3.89	10.4	122	45.2	8.35	47.6	34	30	18.5	29.7	5.27	14.9	9.8	8.2	11.6	4030	400	12.50	877	529	*
S30-2	40-45cm	3.84	<0.4	<0.6	4.56	2.16	1.03	2.88	2.43	1.83	1.54	1.81	0.53	1.23	0.79	<0.4	0.64	<26.47	<22.63				0.5
S31-1	0-40cm	8.25	1.12	2.04	15.7	7.72	3.29	9.24	7.01	5	4.17	4.83	2.01	3.42	5.55	1.04	3.83	84	76	3.24	829	515	0.8
S32-2	40-52cm	10.4	1.23	4.89	5.1	21.6	7.8	18	13.3	7.04	6.42	6.51	1.72	5.1	3.48	0.85	2.15	116	105	4.76	781	501	0.7
S33-2	40-50cm	91.7	2.4	6.13	25.7	52.6	12.8	57.3	42.6	25.5	21.9	28.9	9.29	22.6	16.5	3.14	14.5	437	345	11.10	733	487	0.8
S34-2	40-50cm	23.7	0.71	0.58	16.2	5.73	0.98	5.6	5.03	3.92	4.03	4.33	1.03	2.68	1.89	0.52	1.58	78	55	7.12	686	473	1.1
S35-1	0-40cm	89.4	3.35	5.83	29.8	39.2	9.24	49.6	37.8	23.2	19.6	27.4	6.87	21.4	16.4	3.29	14.1	396	307	9.84	746	438	0.8
S36-1	0-40cm	1960	11.8	10.1	178	95.2	18.6	73.3	51.5	36.1	24.6	29.4	5.03	17.5	9.79	6.41	9.7	2555	575	12.00	647	616	
S37-1	0-40cm	55.7	3.47	5.38	20.9	32.9	10.6	41.2	31.1	18.7	17.5	22.9	6.1	17.7	15.8	3.77	12.9	317	261	9.86	890	480	0.8
S38-1	0-40cm	28.1	1.98	1.78	8	15.4	2.92	27.6	21.5	13.5	12.3	16.2	4.76	12.8	10.4	2.14	9.35	187	161	6.98	902	433	0.8
S39-1	0-40cm	167	3.47	6.83	62.4	49.3	15.1	42.5	31.5	18.3	15.8	19.1	4.77	13.7	11.8	2.93	8.56	473	306	9.31	710	376	1.1
S40-1	0-40cm	11.7	0.98	1.76	14.5	11.9	2.34	14.2	10.9	7.09	6.34	6.98	2.16	5.54	4.52	1	3.46	105	94	3.78	807	404	0.9
S41-1	0-40cm	5470	12.6	15.3	156	107	20.7	93.7	64.6	44.3	31.8	44.6	7.27	26.2	20.1	8.09	15.7	6138	668	13.80	634	666	
S41-2	50-60cm	1870	20.9	5.8	119	109	38.4	77.3	57.1	36.5	31.3	23.7	8.7	21.8	10.7	3.17	8.95	2440	570				
mean		8081.1	24.315	33.913	111.02	235.14	49.166	172.02	125.38	54.802	52.104	57.858	16.013	45.975	31.054	7.6751	28.405	9479.9	1082	10.53	765	604	
median		1380	5.905	7.485	65.15	53.05	15.35	55.8	41.75	25.15	21.05	26.25	6.25	18.25	13.55	3.53	11.3	1924.9	382.94	9.865	768	615	

Note: highlighted cell indicate concentration exceeds the MOE (1993) severe effect level (SEL) for sediments

* additional samples at the same location

Tabıe of 1997 Samples - All Available Data

Sample	Naphthalene (ppm)	Acenaphthylene (ppm)	Acenaphthene (ppm)	Fluorene (ppm)	Phenanthrene (ppm)	Anthracene (ppm)	Fluoranthene (ppm)	Pyrene (ppm)	Benzo(a)anthracene (ppm)	Chrysene (ppm)	Benzo(b)fluoranthene (ppm)	Benzo(k)fluoranthene (ppm)	Benzo(e)pyrene (ppm)	Indeno(1,2,3-c,d)pyrene (ppm)	Dibenzo(a,h)anthracene (ppm)	Benzo(g,h,i)perylene (ppm)	Total Organic Carbon (TOC) %	Depth to Refusal (m)	Sum-Naphthalene (ppm)	Northing (479)***	Easting (594***)
1	39.4	0.68	6.84	7.85	29.7	9.59	23.9	16.6	10.8	8.7	9.14	3.27	6.29	4.02	0.9	4.23	9.26	1.2	142.51	503	648
2	144	1.52	14.2	13.9	45.5	19.4	58.3	37.2	29.8	17.4	18.37	8.66	20.3	15.7	3.22	13.8	14.5	1.2	317.27	558	668
3	568	6.65	6.3	9.79	33.3	13.2	38	26.4	20.9	13.1	15.3	7.33	16.3	14	2.42	12.7	11.7	1.48	235.69	622	699
4	482	6.95	5.28	11.9	46.9	18.5	65.5	45.9	28.4	21.3	23.3	9.08	20.1	18.9	2.93	15.2	10.1	2.2	340.14	669	726
5	54500	209	70.5	124	284	87.9	182	124	70.5	57	61.7	14.4	49.8	43.4	7.48	38.6	28.7	1	1424.28	718	742
6	503	1.65	20.3	20.7	97	24.3	105	76.8	36.5	28.5	337.6	12.6	31.5	31.6	3.97	28.9	15.8	1.4	856.92	765	756
7	1070	2.31	55.5	58.2	203	30.4	133	95.2	35.1	23.5	32.7	13.5	23.7	32.2	3.37	26.8	8.95	0.9	768.48	811	778
9	10300	45.1	441	576	4060	424	3240	2370	757	673	839	259	724	538	67.9	524	12.8	0.45	15538	826	723
10	5070	1.39	43	28.4	92.8	27.4	102	69	40.9	29.3	43.5	14.2	35.2	36.9	5.29	32.3	15.7	1.45	601.58	778	709
11	2580	25.5	166	126	516	148	781	567	369	261	348	122	260	358	45.1	313	11.2	2.05	4405.6	731	694
12	2390	14.1	7.4	113	67.6	20.6	59.2	40.2	25.9	16.6	17.5	6.37	12.5	12.9	2.39	11.1	9.66	1.29	427.36	685	678
13	10800	16	19.7	26.8	87.3	26	84.9	56.9	37.9	25.3	31.6	10.3	21.6	30.7	4.38	25.3	15	2.15	504.68	697	611
14	329	1.2	13.6	12.1	51.6	14.4	54.5	38.8	27.3	18.6	23.7	8.6	17.9	27.7	3.29	23.9	10.8	1.1	337.19	743	646
15	3530	1.86	22.3	21	76.8	21.6	91.2	64	37.6	31.89	39.2	12.6	32.4	24.5	4.3	22.9	12.6	1	504.15	791	660
16	18700	3.16	39.5	26.6	82.7	26.4	85.1	59.6	35.3	30.5	42	11.3	33.2	22.7	4.42	21.2	14.5	0.75	523.68	838	674
19	5170	1.61	15.8	12.3	54.2	16.9	68.3	49.4	30.1	24.2	32.2	9.47	26.4	18.8	3.34	18.1	11.3	0.4	381.12	853	627
21	364	2.1	16.5	16.5	80.5	23.2	95.6	70.8	37.7	31.8	44.5	13.9	36.1	27.4	4.41	24.7	10.6	1.06	525.71	756	598
22	19200	47.9	16.2	39.4	103	36.5	81.3	56.8	36.2	29.1	29.1	8.37	24.6	13.6	3.57	13.1	16.7	1.2	538.74	708	581
23	2170	3.31	27.7	25.9	38.2	36.3	141	101	53.1	48.7	69	22.6	55.7	45.1	6.93	39.2	12.7	1.4	713.74	660	588
25	5430	4.87	12.7	13.9	45.4	16	59	41.3	28.7	24.1	27.7	6.63	22.1	14.4	3.66	14.2	12.4	0.9	334.66	720	532
26	268	1.221	9.23	8.76	38.6	12.5	51	37	23.1	19.5	26.2	6.94	20.3	15.1	2.87	15.3	10.3	0.75	287.621	770	548
27	21	1.12	2.37	3.12	14.7	4.97	24.4	18.5	13.4	11.2	15.7	5.86	11.6	7.97	1.67	9.01	6.8	0.6	145.59	815	562
30	1280	1.63	12.9	78.2	38.3	14.2	47.3	34.2	26.1	21.5	23.2	9.47	18.4	12.2	3.04	12.7	13.8	0.6	353.34	876	528
31	941	1.23	5.97	5.29	25.4	8.56	42.9	31.7	21	17.8	23.2	5.35	18.5	14.3	2.7	13.6	7.92	0.87	237.5	827	511
32	169	1.4	8.68	8.23	35.5	10.4	48.2	36.1	22.5	18.5	26.8	7.96	20.3	17.1	3.07	17	8.51	0.9	281.74	779	596
32-a	43	1.68	4.08	4.36	20.5	6.72	33.9	25.7	18.4	15	20.2	6.72	15.4	12.4	2.25	12.6	8.06	0.89		779	496
33	73	1.24	6.03	5.94	34	6.35	55.8	42.6	28.6	21.6	31.1	9.04	23.8	24.5	2.72	17.6	9.81	0.7	310.92	733	489
34	102	1.35	5.76	5.79	32.2	8.06	48.7	36.4	26.8	19.5	30.1	8.36	21.9	23.3	2.75	16.3	14.6	0.6	287.27	686	474

Table of 1997 Samples - All Available Data

Sample	Naphthalene (ppm)	Acenaphthylene (ppm)	Acenaphthene (ppm)	Fluorene (ppm)	Phenanthrene (ppm)	Anthracene (ppm)	Fluoranthene (ppm)	Pyrene (ppm)	Benzo(a)anthracene (ppm)	Chrysene (ppm)	Benzo(b)fluoranthene (ppm)	Benzo(k)fluoranthene (ppm)	Benzo(e)pyrene (ppm)	Indeno(1,2,3-c,d)pyrene (ppm)	Dibenzo(a,h)anthracene (ppm)	Benzo(g,h,i)perylene (ppm)	Total Organic Carbon (TOC) %	Depth to Refusal (m)	Sum-Naphthalene (ppm)	Northing (4791***)	Easting (504***)
35	93	1.32	6.3	6.4	35.6	8.29	47.9	35.8	24.9	16.4	26.7	9.35	18.1	22.4	2.47	15.2	9.68	0.96	277.13	744	435
36	1080	13.5	5.67	16	60.5	19	54.9	38.4	28.4	19.1	22.5	6.42	16	17.4	2.41	10.6	9.12	1.5	330.8	650	605
39	58.1	1.22	5.88	5.28	31.7	7.46	48.7	36.7	25.9	17.8	28.9	7.31	19.9	22.8	2.71	15.5	14.3	0.9	277.76	711	375
40	4.72	0.24	2.69	2.49	10.9	3.02	8.46	5.41	5.89	4.11	4.82	1.16	2.99	2.52	0.42	1.78	1.8	0.5	56.9	810	402
41	2970	2.57	39.6	34	128	65.1	135	94.8	60.6	49.3	60.2	16.4	45.9	42	5.64	30.8	16.6	1.37	809.91	638	663
42	1810	22.9	15.7	31.5	29.7	25.1	84.9	61.4	30.5	22.4	25	7.15	18.6	17.3	2.49	10.8	8.39	0.8	405.44	836	805
43	725	3.98	30.3	40.5	219	43.5	257	192	96.6	80.8	96.6	27	79.6	66.9	8.21	51.7	10.7	0.8	1293.69	780	788
44	412	3.69	28.8	30	134	28.5	142	106	62.3	50.4	66.5	16.9	52.6	48.5	6.43	38.5	13.4	1.6	815.12	730	772
45	3050	1.84	32.9	27	98.2	22.8	121	87.6	53.4	46.5	55.2	12.7	42.2	39.1	4.67	29.8	21.2	1.4	674.91	683	757
46	193	2.02	13.9	13.1	74.4	17.6	88.7	67	40.8	31.5	43.4	10.7	31.7	30.5	4.03	22.4	8.15	0.74	491.75	857	787
47	209	1.73	9.8	9.4	39.2	10.7	41.2	31.2	23.1	15.8	18	5.29	12	15.4	1.94	8.87	9.98	1.1	243.63	556	695
48	108	1.89	15.5	15.3	69.1	10.2	68	51.4	28.2	21.3	31.7	9.33	22.8	26	2.94	18.6	8.2	0.7	392.26	841	754
49	1230	2.18	22.6	20.2	126	25	138	104	47.7	39.4	57.2	19.2	45.5	33.8	4.37	29.4	12.3	1.7	714.55	795	740
50	2030	2.14	10.6	10.4	56.2	10.5	71	51.2	36	28.7	34.5	9.86	26.2	22.6	3.68	18.6	15.8	1.32	392.18	747	723
51	384	4.2	9.83	9.75	64.7	11.9	108	83.1	56.2	46.6	58.1	19	47.6	39.6	6.04	32.9	12.9	0.72	597.52	699	708
52	2830	1.81	19.7	17.7	70.7	19.8	100	71.8	50.7	38.6	50.2	9.69	38.1	34	4.45	25.1	17.5	1.75	552.35	653	694
53	690	6.92	10.2	11.8	63.5	14.8	65	47.2	29.4	23.9	22.9	8.27	17.3	12.1	2.31	9	10.1	1.4	344.6	605	680
54	25.9	0.57	1.64	2.03	8.71	3.53	17.4	13.3	10	8.44	9.84	3.63	6.02	6.55	1	5.05	5.45	0.32	97.71	532	662
55	71.4	1.98	17.2	16.7	134	34	196	145	69.5	62.5	93.9	29.9	76.7	59.6	7.56	50.5	9	0.55	995.04	871	734
56	79.6	0.96	5.05	6.18	33.4	8.4	36	27.2	17.3	13.4	14.9	5.21	9.46	8.21	1.38	5.8	9.09	0.8	192.85	590	645
58	51.6	1.19	2.87	3.09	17.5	4.08	32.5	24.7	15.8	13.3	22.1	5.62	14.8	13.8	1.85	11.6	7.64	1.2	184.8	809	690
59	267	1.42	6.224	5.58	34.4	6.51	45.7	34.7	20.9	16.6	24.9	9.08	16	16	2.16	13.4	7.99	1.2	253.574	762	675
60	12400	25.6	23.6	32.2	174	41.9	189	137	74.1	64.9	76	27	63	46.7	6.93	38.1	12.5	0.65	1020.03	710	662
61	6760	9.26	2.93	0.74	46.3	8.7	40.1	28.8	18.1	14.8	15.8	6.15	8.29	8.77	1.56	6.44	8.35	0.8	216.74	668	648
63	161	1.44	7.67	6.63	44.8	8.74	65.9	50	27.2	22.9	32.7	9.25	23.7	20.7	2.75	18.1	10.6	0.95	342.48	821	641
64	7970	3.5	25.1	19.1	86.3	19.3	112	80.9	53.2	40.2	55.1	9.11	41.2	32	6.92	27.3	11.5	1.1	611.23	768	626
65	148	2.02	7.58	6.83	36.2	9.01	54	41.6	30	23.1	30.2	8.07	22.5	18.7	3.65	16.9	10.3	1	310.36	727	612
66	2330	2.03	11.1	8.42	47.7	11.4	70.9	52	38	28.9	33.1	6.9	22.8	19.2	4.06	16.9	16	1.4	373.41	681	594

Table of 1997 Samples - All Available Data

Sample	Naphthalene (ppm)	Acenaphthylene (ppm)	Acenaphthene (ppm)	Fluorene (ppm)	Phenanthrene (ppm)	Anthracene (ppm)	Fluoranthene (ppm)	Pyrene (ppm)	Benzo(a)anthracene (ppm)	Chrysene (ppm)	Benzo(b)fluoranthene (ppm)	Benzo(k)fluoranthene (ppm)	Benzo(e)pyrene (ppm)	Indeno(1,2,3-c,d)pyrene (ppm)	Dibenzo(a,h)anthracene (ppm)	Benzo(g,h,I)perylene (ppm)	Total Organic Carbon (TOC) %	Depth to Refusal (m)	Sum-Naphthalene (ppm)	Northing (4791***)	Easting (594***)
67	32.8	1.17	1.34	1.65	11.6	3.28	18.4	14.2	17.1	12.2	16.3	3.32	10.4	9.16	1.95	9.16	7.46	0.59	131.23	836	593
68	37.6	1.31	1.78	2.23	12.5	3.78	24.4	18.7	18.2	12.7	20.2	4.18	11.1	11	2.43	10.9	7.56	0.6	155.41	786	575
69	357	1.85	10.2	8.94	46.3	10.6	58.1	42.8	33.8	24	27.8	7.2	19.1	16.1	3.76	14.7	13.8	1.2	325.25	738	565
70	3920	10.1	10.6	15.1	65.9	16.8	73.2	53.5	38.5	28.6	30.2	6.29	19.9	14.8	4.01	13.1	15.3	0.9	400.6	703	547
72	661	1.48	6.11	5.97	30.2	8.22	34.8	26.3	21.9	15.2	20.5	4.18	12.6	10.8	2.59	10.7	8.88	0.2	211.55	869	575
73	12	0.35	0.52	0.67	4	1.16	6.35	5.31	6.36	3.91	5.75	1.26	3.04	2.66	0.59	2.59	1.35	0.58	44.52	845	548
74	74.7	1.16	4.3	4.11	20	6.04	29.3	22.3	20.2	13.9	17.6	4.33	10.1	9.84	2.18	9.83	11.1	0.55	175.19	797	531
75	82	1.46	7.62	6.99	39.6	8.05	55.1	42.4	29.5	22.2	31.7	6.59	21.1	17.7	3.46	16	10.2	0.9	309.47	748	515
76	780	4.77	8.38	10.2	57.6	14.8	64.4	48.5	38	27.9	27	5.83	18.4	14.6	4	12.8	11.8	0.95	357.18	700	500
78	24.6	0.89	0.96	1.14	7.46	2.14	11.4	8.81	11.9	8.32	11	2.37	6.83	6.26	1.38	6.19	6.53	0.59	87.05	857	494
79	29	1.48	2.59	2.7	18.2	4.92	28.3	22.5	18.3	13.3	17.7	3.61	10.5	9.98	2.11	9.56	7.98	0.6	165.75	810	480
80	58.3	1.76	4.09	5.33	24	7.15	38.1	29.6	20.4	16.2	25.9	6.23	18	15.2	2.56	13.5	9.63	0.77	228.02	765	465
81	46.4	1.17	3.08	2.94	19.2	5.17	29.4	23	17.8	13.7	24.4	4.95	15.7	13.3	2.21	11.9	6.33	0.9	187.92	715	450
82	0.09		0.01	0.03	0.04	0.01	0.1	0.12	0.08	0.05	0.08	0.01	0.01	0.03		0.02	0.828	0.42	0.59	669	436
83	91.1	1.58	5.73	5.75	28.5	8.74	34.2	27	22.7	17.9	24.4	4.55	15.2	14.2	2.59	12.6	12	0.67	225.64	840	458
85	290	3.85	18.5	15.4	63.4	20.5	50.2	37.3	30	22.5	26.2	5.72	16.7	13	2.83	10.7	11.3	1.07	336.8	704	417
86	18.1	1.13	1.08	1.34	10.4	2.44	16.6	13.5	14	10.5	15.5	2.94	9.4	9.39	1.44	7.71	7.31	0.42	117.37	822	428
87	52.5	1.35	2.67	2.6	16.1	4.52	23.8	18.8	17.4	13.4	19.5	3.88	12.1	11.6	1.76	10.1	7.16	0.89	159.58	775	415
88	43.3	0.59	2.48	2.43	12	3.71	12.5	9.71	9.52	6.92	8.73	1.66	5.23	4.34	0.88	3.67	1.81	0.4	84.37	730	401
90	28	1.79	2.12	2.62	16.3	4.73	28.6	22.9	18.5	15.3	22.6	5.26	15.6	14.1	2.16	12.4	7.68	0.5	184.98	759	391

PAH Values of Three Borehole Samples Taken in April 1999

Borehole Number	Depth (m)	Total PAH (µg/g) With Naphthalene	Total PAH (µg/g) Without Naphthalene
18	1.2 - 1.8	2,570	1,470
18	1.8 - 2.4	5,110	4,020
18	2.4 - 3.0	2,250	1,580
22	0.6 - 1.2	590	450
22	1.2 - 1.8	530	440
154	0.6 - 1.2	2,130	650
154	1.2 - 1.8	875	610

Source: Chris Marvin, NWRI

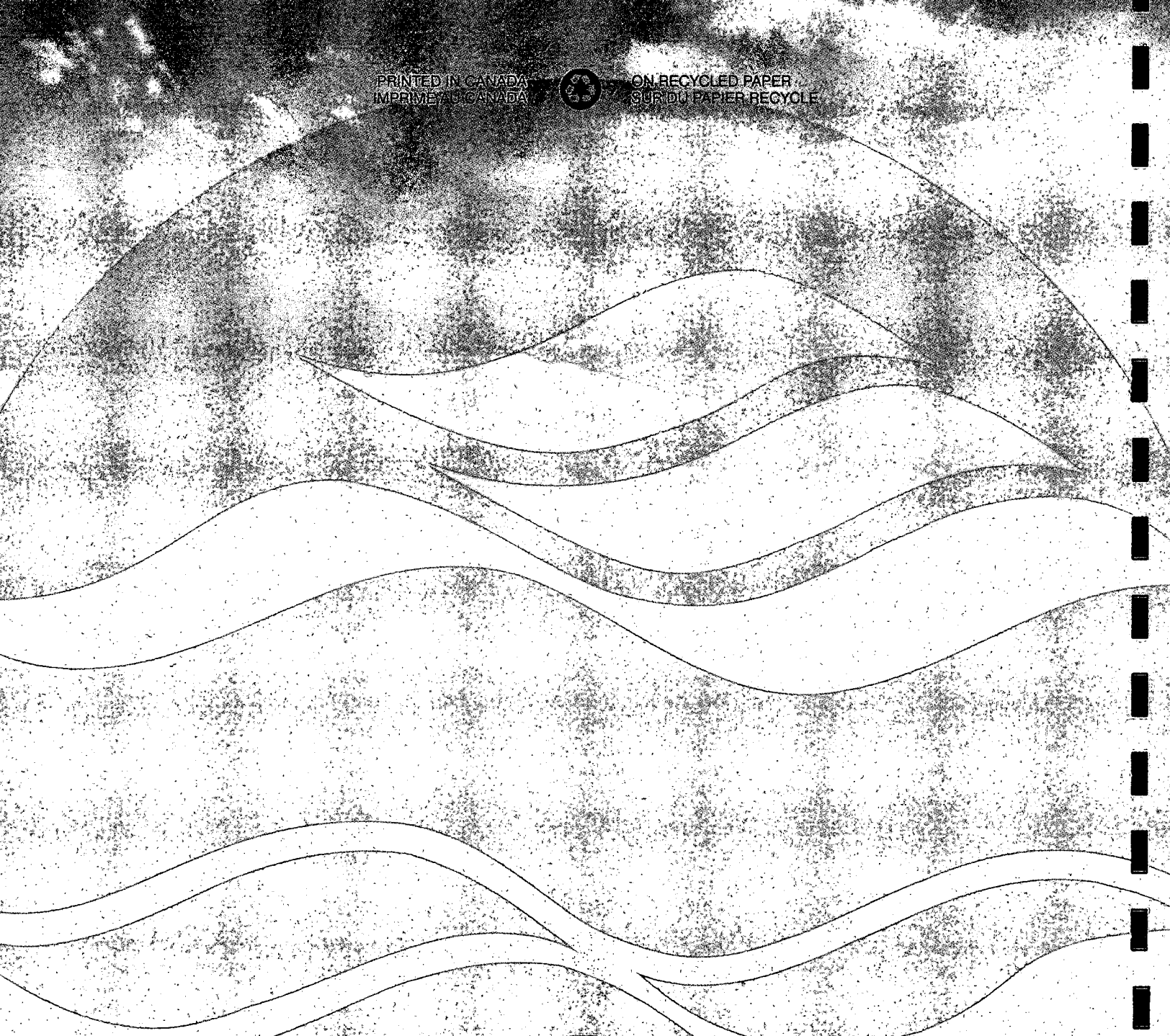
PAH Concentrations for December 1999 Cores

BETO Group #:10080 Reported: 3/30/2000

CCIW
867 Lakeshore Road
Burlington ON L7R 4A6

Hamilton Harbour-Randles Reef

		R6A-A 49-54	R7A-A 9-14	R7B-A Mar-00 17-22 8-13	R8-A 24-29	R9A-A 15-20 20-25	RT11-A 17-22	R12-A 47-52 25-30	RT18-A 42-47 46-51	R48-A 24-29 32-37	R51-A 30-35	R59-A 45-50 51-56	R60-A 47-52	RT22A-A 82-85	R49B-A 59-64
		R6A-A	R7A-A	R7B-A	R8-A	R9A-A	RT11-A	R12-A	RT18-A	R48-A	R51-A	R59-A	R60-A	RT22A-A	R49B-A
Parameter	Units	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result	Result
Naphthalene	ug/g	38100	2290	68.5	1.69	131	2.73	1.33	15.2	21.3	2.37	9.06	32.5	36.1	3040
Acenaphthylene	ug/g	1740	107	3.81	0.03t	1.53	0.11t	0.01t	0.18	0.12	0.09t	0.10t	0.10t	0.18	67.2
Acenaphthene	ug/g	68.8	154	7.79	0.34	3.74	0.36	0.01t	0.02t	0.57	0.06t	1.34	0.38	0.13	5.17
Fluorene	ug/g	1250	330	3.24	0.33	6.01	0.68	0.04t	0.27	0.15	0.15	1.09	0.65	0.28	63.1
Phenanthrene	ug/g	2130	1250	55.3	1.06	29.4	0.64	0.14t	0.61	0.94	0.7	1.12	1.07	1.16	175
Anthracene	ug/g	1000	301	14.3	0.31	4.41	0.71	0.05t	0.17	0.33	0.21	0.27	0.26	0.42	45.7
Fluoranthene	ug/g	1260	1160	38.3	0.34	21	1.78	0.1	0.14	0.43	0.74	0.43	0.28	0.78	63.4
Pyrene	ug/g	855	855	27.3	0.22	15.2	1.25	0.08t	0.09t	0.31	0.59	0.31	0.17	0.53	48.1
Benzo(a)anthracene	ug/g	449	292	9.49	0.08t	4.86	0.83	0.07t	0.04t	0.16t	0.36	0.21t	0.02t	0.3	22.5
Chrysene	ug/g	385	287	8.55	0.09t	4.75	0.77	0.06t	0.02t	0.2	0.47	0.22	0.11	0.25	19.6
Benzo(b)fluoranthene	ug/g	317	303	10.7	0.09t	6.2	0.8	0.06t	0.02t	0.19t	0.5	0.19t	0.03t	0.19t	15.6
Benzo(k)fluoranthene	ug/g	168	88	2.49	0.05t	2.58	0.42	0.04t	0.01t	0.19	0.24	0.08t	0.01t	0.14t	8.15
Benzo(a)pyrene	ug/g	297	264	8.25	0.06t	3.67	0.58	0.04t	0.01t	0.08t	0.37	0.09t	0.01t	0.14	14.5
Indeno(1,2,3-c,d)pyre	ug/g	155	178	5.67	0.03t	3.36	0.43	0.02t	0.01t	0.07t	0.36	0.06t	0.01t	0.09t	7.61
Dibenzo(a,h)anthrace	ug/g	39.8	29.3	1.08	0.01t	0.57	0.08t	0.01t	0.01t	0.02t	0.06t	0.01t	0.01t	0.04t	1.91
Benzo(g,h,i)perylene	ug/g	124	182	6.71	0.04t	4.05	0.38	0.29	0.01t	0.09t	0.5	0.09t	0.01t	0.11t	7.16
Total - Napthalene		10238.6	5780.3	202.98	2.6	111.33	9.63	0.39	1.37	3.24	5.19	4.78	2.92	4.17	564.7
Total PAHs		48338.6	8070.3	271.48	4.29	242.33	12.36	1.72	16.57	24.54	7.56	13.84	35.42	40.27	3604.7



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