ISDN 1039-3218

Study of Sedimentation Rates in Port Phillip Bay using Lead - 210

J.D. Smith
Marine Chemistry Laboratory
School of Chemistry
University of Melbourne
Parkville Victoria 3052

Technical Report No.41

Port Phillip Bay Environmental Study
CSIRO Environmental Projects Office
Canberra, ACT, Australia

GPO Box 1666, Canberra, ACT 2601, Australia

October 1996

EXECUTIVE SUMMARY

Measurements were made of beryllium-7, lead-210, caesium-137 and radium-226 in box and vibrocores from a site in northern Port Phillip Bay and a site in the deep central basin.

Interpretation of results was made difficult by suspected loss of the uppermost few centimetres of the vibrocores and the unknown extent of bioturbation. These aspects are set out and discussed.

Insufficient levels of beryllium-7 were found to draw any conclusions on sedimentation or mixing rates.

Concentrations of caesium-137 were also low. No signal from historical atmospheric bomb testing could be detected.

Profiles of lead-210 were satisfactorily matched between box and vibro cores. The mid-Bay site consists of finer material than the northern site which seems to contain detritus. Sedimentation rates for the two sites are of the order of 3 mm / year if mixing is ignored, but much lower (1 mm / year or less) if bioturbation is taken into account.

TABLE OF CONTENTS

Page No.

LIST OF FIGURES

1. INTRODUCTION

The main objective of this project was to elucidate information on rates of sediment accumulation, rates and depth of sediment mixing, and any other sediment behaviour, from measurements of radionuclides in the sediments of Port Phillip Bay.

The time of interest is the last 100 years. The radionuclides that could yield information on this time-scale must have an appropriate half-life. The most likely to be of value is lead-210 with a half-life of 22.3 years and a useful range of up to 120 years. The short-lived beryllium-7 with a half life of 53 days persists in sediments at measurable levels for about six months. Both isotopes are naturally occurring.lead-210 being formed by decay of radon-222 in the atmosphere whilst beryllium-7 is produced by the impact of cosmic rays on nitrogen and oxygen atoms in the atmosphere. The fraction of lead-210 introduced to the sediment by fallout from the atmosphere is referred to as unsupported.

Lead-210 is also produced in the sediment by radioactive decay of the long- lived parent radium-226 and this fraction of the total is the supported lead-210. Only the unsupported lead-210 is used in calculations of chronology.

The artificial radionuclide caesium-137 with a half-life of 30 years was introduced into the environment in atmospheric nuclear bomb testing in the period 1945-1974. It remains as a persistent marker in the sediments. This makes it potentially useful in confirming sediment chronology derived from lead-210 measurements.

In this study these three radionuclides were measured in sediment cores collected from two locations in Port Phillip Bay. The locations were nominated by the Port Phillip Bay study management team. One location was near the centre of Port Phillip Bay and this is called the Mid-Bay site. It is located in the deep central basin which is the final collecting area for catchment input of fine sediment and also endocthonous organic production. The second site was in the northern part of the Bay and is called here the North-Bay site. The sediments in this area tend to show the influence of inputs from the Yarra River.

2. SAMPLING

Samples were collected at two sites in Port Phillip Bay in March 1995 (Figure 1). The first site was in the northern part of the Bay (37°54.13’ S, 144°54.30’ E, depth 12m), the second was towards the middle of the Bay (38°09.00’ S, 144°54.02’ E, depth 19m).

Divers collected box-cores (25cm deep) at both sites. The box corers were designed and built in the School of Chemistry, University of Melbourne. Part of the system includes a jig permitting division of the box core sediments into precise 1cm sections.

Vibracores were collected under contract by Arrowsmith and Associates, Melbourne. The corer was operated from a barge that carried the A-frame and air-compressor. Three

cores were collected at the North-Bay site. Each contained about 50 cm of sediment above a layer of clay. Three cores were collected at the Mid-Bay site. Each contained about 170cm of sediment. The vibracores were returned to the laboratory in a vertical position and frozen with dry ice or liquid nitrogen within 24 hours of collection. The frozen cores were cut into 50cm lengths for storage. The cores were allowed to partially thaw and then extruded.

The sediment horizons obtained from each of the cores were dried to constant weight at 75oC and the water content obtained by weighing.

Figure 1: Location of sample sites with geographic coordinates

3. METHODS

3.1. Reagents

Acid was of analytical grade and water was purified using a Milli-Q (Millipore, Bedford, MA, USA) system. The standard Polonium-208 solution of 2.31 +/- 0.11 kBq mL in 1 M HCl (25 June 1989) was supplied by the UK Atomic Energy Authority. This was diluted by weight to give a working standard of about 0.2 Bq^{-1} (30 September 1993). Barium-133 solution of 150 kBq mL (May 1992) in 1M HCl was diluted by weight to give a working standard of about 750 Bq mL.

3.2. Lead 210 and radium-226 determinations

Sediment samples (2 g) were digested by gentle boiling in 20 mL of 2 M HCl for 2 hours with continual shaking. Polonium-208 and barium-133 were added to each sample as yield tracers for polonium-210 and radium-226 respectively. The digests were centrifuged and the acid solutions decanted into pre-weighed 50mL beakers. The residues were rinsed with 10 mL 2 M HCl and centrifuged again, then the rinse solutions combined with their corresponding digests. The digest was made up to 50 mL and polonium was spontaneously plated from the digest solution on a pure silver disc (Hamilton and Smith, 1986). The disc was presented for alpha-spectrometry using a Canberra (Meriden, CT, USA) 7404 Quad Alpha-spectrometer with passively implanted planar silicon (PIPS) detectors connected to a PC-based multi-channel analyser. The activity of polonium-210 was corrected using the recovery of polonium-208 determined by alpha-spectrometry. Lead-210 was determined by inference from the polonium-210 activity in the sediment samples, assuming that polonium-210 was in secular equilibrium with lead-210. The radium-226 in the residual solution was measured by liquid scintillation counting with alpha-beta discrimination (Packard, Model 1905

AB/LA) after precipitation with $PbSO_4$, collection by centrifugation and re-solution in EDTA. A toluene-naphthalene scintillant was used.

In this report the radium-226 activities correspond to the fraction that is dissolved in the acid digestion of the sediment. The same solution was used for determination of lead-210 and radium-226. Gamma-spectrometry measures total radium-226 and can give higher specific activities.

Details of the methods used are given in the relevant papers in the list of references.

3.3. Beryllium-7 and caesium-137 determinations

Beryllium-7 was measured in 100g samples of ground sediment sent to Dr M Matthews, National Radiation Laboratory, Christchurch, New Zealand. Beryllium-7 and Caesium-137 were also measured in Melbourne at the Australian Radiation Laboratory (ARL), Yallambie, Victoria. These radionuclides were measured in the sediment by high-resolution gamma spectrometry using high-purity germanium detectors. With counting times of 2-4 days the limits of detection were about 4 mBq/g for beryllium-7 and about 0.3 mBq/g for caesium-137. The energy peak at 477.59 keV was used for beryllium-7 and the peak at 661.66 keV was used for caesium-137.

4. RESULTS

4.1. Beryllium-7

Measurable concentrations of beryllium-7 were found only in the top 1 cm of the North-Bay sediment (Figure 2). The beryllium-7 in the Mid-Bay sediment was below the limit of detection. Even when using 100 g of sediment and counting times of up to 4 days the limit of detection was insufficient to allow observation of the distribution of beryllium-7 in the sediment profiles. Calculation of sedimentation or mixing rates based on beryllium-7 could therefore not be undertaken.

Figure 2: Table of results for beryllium-7

4.2. Lead-210

Total lead-210 was measured in the box cores and the vibracores from both sites. The box corer used is diver operated and gives cores with minimum disturbance of the sediment. The surface layer is intact and there is no compression or shortening of the core. The limitation is the short length of penetration. Adequate sample is obtained only to a depth of 25 cm. To obtain deeper sediment material a vibracorer was used. This is known to be likely to lose the top few cm of the sediment and cause some compaction of unconsolidated sediments. Overlaying the vertical profiles of results from the two cores was expected to allow matching and provide complete sedimentary records down to 2 m. The vibracorer was used particularly to allow measurement of the concentration of lead-210 deep in the sediment as this represents the supported lead-210 to be used in modelling.

This strategy worked at the North-Bay site (Figure 3). The vibracorer struck consolidated clay at 50 cm below the sediment surface and this is believed to be the base of the recent sediment. The total lead-210 was 34 mBq/g in the top 1 cm of the sediment and the supported lead-210 below 30 cm was about 6 mBq/g.

At the Mid-Bay site (Figure 4) the box-core sediment had a uniform lead-210 level of 22 mBq/g below a depth of 10 cm. Above this was a layer of about 8 cm with an essentially uniform lead-210 concentration of about 35 mBq/g. The top 1 cm of sediment contained lead-210 at 48 mBq/g.

The results from the vibracore are ambiguous. The uniformity of the lead-210 concentration throughout the 160 cm of the core could be taken as indicating that the top 10 cm was lost and the material analysed represents the supported lead-210. The results for radium-226 have an average concentration of 24 mBq/g that is consistent with this. Another possibility is suggested by the results for biomarkers measured by Dr J Volkman (CSIRO, Hobart). The biomarkers in a duplicate vibracore, collected at the same time, show remarkable uniformity down the entire core. This is explicable if the sediment is completely mixed over a short time scale. Two possibilities are; a) that the sediment in this part of the Bay is mixed to a depth of at least 160cm or b) that the sediment was mixed in the vibracorer at the time of collection. The high water content indicates an unconsolidated sediment. The North-Bay core had a lower water content and was much more consolidated.

A triplicate vibracore has been archived frozen and is available for further study to resolve this question.

Figure 3: Tables and graphs of results for lead-210 in North Bay

Figure 4: Tables and graphs of results for lead-210 in Mid-Bay

4.3. Water content

The water content of the core material was measured to provide information on the nature of the sediments and for use on modelling the rates of sedimentation. Results from the Mid-Bay cores (Figures 5 & 6) show water contents of 1.5-1.9 g water per g dry sediment. This is considerably higher than the water content of the North-Bay cores (Figures 7 & 8) which contained 0.2-0.9 g water per g dry sediment.

Comparison of the box core and vibracore results showed that the upper layers of sediment in the vibracores had been fluidised and the water content increased. Graphical manipulation of the vibracore results for the North-Bay cores (Figure 8) showed that shifting the vibracore data down 7 cm gave coincidence for parts of the data sets. This suggests that the top 7 cm of sediment was lost in the North-Bay vibracore. The top 10 cm of the Mid-Bay vibracore was apparently fluidised and the water content increased (Figure 6). Graphical manipulation of the data did not give satisfactory coincidence of the Mid-Bay vibracore and box core data.

Figure 5: Tables of water content for Mid-Bay box and vibro core sediments

Figure 6: Graphs of Mid-Bay sediment water content

Figure 7: Tables of water content for North-Bay box and vibro core sediments

Figure 8: Graphs of North-Bay sediment water content

4.4. Radium-226

The radium-226 (acid soluble) in the sediment from the North-Bay site (Figure 9) was uniform with an average of 4.5 mBq/g. This was similar to the activity of lead-210 which was about 6.5 mBq/g deep in the sediment. This agreement within the limits of accuracy of the two radiochemical methods provides confirmation of the supported lead-210 activity for use in modelling.

The radium-226 in the sediment from the Mid-Bay site (Figure 9) was also uniform with an average of 24 mBq/g. This was similar to the activity of lead-210 which was about 24 mBq/g in the vibracore and about 22mBq/g at the bottom of the box core (10-25 cm).

The difference between the two sites is probably a result of the presence of a high proportion of detrital material at the North-bay site and the relatively higher

concentrations of radium-rich clay minerals at the Mid-Bay site. It does show that care is needed when choosing values for the supported lead-210 for use in modelling studies.

Figure 9: Tables and graphs of results for radium-226 in Mid-Bay and North Bay vibrocores

4.5. Caesium-137

The concentrations of caesium-137 in these sediments is low and any peak representing the years of maximum fallout (1964) would be difficult to recognise. A depth in the sediment at which caesium-137 was detectable would give a chronological marker (1953/1956).

The caesium-137 was present from the surface of the sediment down to at least 25 cm at the Mid-Bay site (Figure 10). The high water content of this sediment makes it likely that caesium-137 will be mobile. The questions raised about the reliability of the vibracore inhibited the work on this sample. A recent measurement of caesium-137 shows that it is below the limit of detection (<0.3 mBq/g) at 35-40cm depth in the core. This would be about 50 cm real depth assuming the top 10 cm was lost. We will continue to measure caesium-137 in this core.

At the North-Bay site the caesium-137 was present from the surface to the bottom of the box core (Figure 10). Caesium-137 is below the limit of detection (<0.3 mBq/g) at 35-40cm depth in the vibracore.

Figure 10: Tables of results for caesium-137 in Mid-Bay and North Bay box cores

5. DISCUSSION

5.1. Mid-Bay site

The distribution of lead-210 in the Mid-Bay cores collected in 1994 and 1995 (Figure 11) shows similarities in the surface concentration and the down core asymptote. The surface concentrations were 53 and 48 mBq/g and the asymptotes were both about 22 mBq/g. This asymptote is similar to the mean radium-226 activity of 24 mBq/g for the vibracore material (Figure 9). This indicates that the supported lead-210 in the Mid-Bay sediment is about 22 mBq/g and this value was used in recalculation of sedimentation

rates using the 1994 data (Figure 12).

If the distribution of excess lead-210 in the 1994 Mid-Bay core was due to sedimentation the constant rate of supply model (CRS) yields an average rate of 0.3 cm/y. The same data is consistent with mixing of the sediment to 30 cm depth and a much slower rate of sedimentation.

The 1995 core shows a classical profile with three layers (Figures 11 & 12). The layer below 10 cm depth contains only supported lead-210 at 22 mBq/g. The layer of about 8 cm above this had essentially uniform lead-210 concentration of about 35 mBq/g. This uniformity is characteristic of mixing through bioturbation. The top 1 cm of sediment with a higher lead-210 concentration of 48 mBq/g is possibly due to accumulation of very fine grain material in this layer caused by physical or biological reworking of the sediment. This profile is characteristic of a mixed sediment and calculation of sedimentation rate was not undertaken.

At the Mid-Bay site the sediment may mix rapidly so that beryllium-7 does not accumulate to a measurable concentration in the surface layer. It may be that it does not reach the sediment within a few weeks of formation because of a slow rate of particle settling. There is not enough information to resolve the process controlling beryllium-7 concentrations in the middle of Port Phillip Bay. This work will continue.

The occurrence of low but measurable concentrations of caesium-137 from the surface to 25 cm depth in the 1995 core indicates that the 1953/1956 boundary, corresponding to the years of atmospheric nuclear weapons testing, lies below this depth. The depth of recent mixing in the 1995 core is about 10 cm. The vibracore results for caesium-137 show this radionuclide being detected above 30 cm but not below 40 cm (allowing for about 10 cm being lost on collection).

The presence of excess unsupported lead-210 shows this to be a site of sedimentation but uniform mixing to 10 cm depth masks the rate of sedimentation. The absence of supported lead-210 below 10 cm in the box core indicates an age of at least 100 years. This would give a sedimentation rate of less than 0.1 cm/y. The 1994 results showed unsupported lead-210 to at least 40 cm depth with a maximum sedimentation rate of 0.6 cm/y but that lead-210 profile was probably altered by mixing, and the true rate of sediment accumulation would be considerably less. The 1994 and 1995 sample sites were nominally the same, but the imprecision of position fixing and the effects of drift due to wind and tide mean they could be up to 200 m apart.

Figure 11: Graphical comparisons of lead-210 results for 1994 and 1995 cores from the Mid-Bay sites

Figure 12: Unsupported lead-210 results for 1994 and 1995 cores from the Mid-Bay sites

5.2. North-Bay site

The distribution of lead-210 in the North-Bay cores collected in 1994 and 1995 (Figure 13) shows similarities. The surface concentrations were 37 and 34 mBq/g and both profiles showed a steady decrease to 9 and 15 mBq/g at the bottom of the box cores (25 cm). The asymptote in the vibracore was about 6 mBq/g and this is similar to the mean radium-226 activity of 5 mBq/g for the vibracore material (Figure 9). This strongly indicates that the supported lead-210 in the North-Bay sediment is about 6 mBq/g and this value was used in calculation of sedimentation rates using the 1995 data and recalculation using the 1994 data (Figure 14).

The 1994 profile of unsupported lead-210 was represented by two straight-line portions (0-10 and 10-25 cm) corresponding to average sedimentation rates of 0.3 and 0.2 cm/y. The 1995 data fell in one straight line corresponding to an average sedimentation rate of 0.7 cm/y.

Beryllium-7 was detectable only in the top 1 cm of sediment (about 13 mBq/g) and this suggests that mixing in the top few cm is not rapid on the time scale of a few weeks.

The occurrence of a uniform caesium-137 concentration (about 1.5 mBq/g) to the bottom of the 1995 box core indicates that the 1953/1956 boundary, corresponding to the years of atmospheric nuclear weapons testing, lies below 25 cm depth. The vibracore results for caesium-137 show this radionuclide being below the limit of detection at 40 cm (allowing for about 10 cm being lost on collection).

The presence of excess unsupported lead-210 shows this to be a site of sedimentation with a maximum rate of sedimentation of 0.3 cm/y near the surface. Mixing of the sediment to a depth of about 30cm has altered the profile and the rate of sedimentation will be considerably less than the maximum.

Figure 13: Graphical comparisons of lead-210 results for 1994 and 1995 cores from the North-Bay sites

Figure 14: Unsupported lead-210 results for 1994 and 1995 cores from the North-Bay sites

6. ACKNOWLEDGMENTS

This work was funded by the Melbourne Water Corporation.

My thanks are due to the following: In my group in the University of Melbourne Rick Tinker and Philip Towler for their major efforts in all aspects of the work including

sampling, analyses and interpretation. Dr Malcolm Cooper (ARL) for help and advice with the gamma-spectrometry.

7. REFERENCES

Smith, J.D. and Hamilton, T.F., 1985. Modelling of Pb behaviour in the catchment and sediment of Lake Tali Karng, Victoria, and estimation of recent sedimentation rates. Australian Journal of Marine and Freshwater Research, 36: 15-22.

Hamilton, T.F. and Smith, J.D., 1986. Improved alpha energy resolution for the determination of polonium isotopes by alpha-spectrometry. Applied Radiation and Isotopes, 37: 628-630.

Smith, J.D. and Hamilton, T.F., 1992. Trace metal fluxes to lake sediments in south-eastern Australia. The Science of the Total Environment, 125: 227-233.

Tinker, R.A., Smith, J.D. and Cooper, M.B., 1995. An assessment of the selection criteria for an analytical method for radium-226 in environmental samples. Journal of Radioanalytical and Nuclear Chemistry, Articles 193, 329-336.

8. FIGURES - on the following pages...

Port Phillip Bay

Sample Sites March 1995

	Latitude	Longitude	Water Depth
North Bay	37° 54.13' S	144° 54.30' E	12 m
Mid Bay	38° 09.00' S	144° 54.02' E	19 m

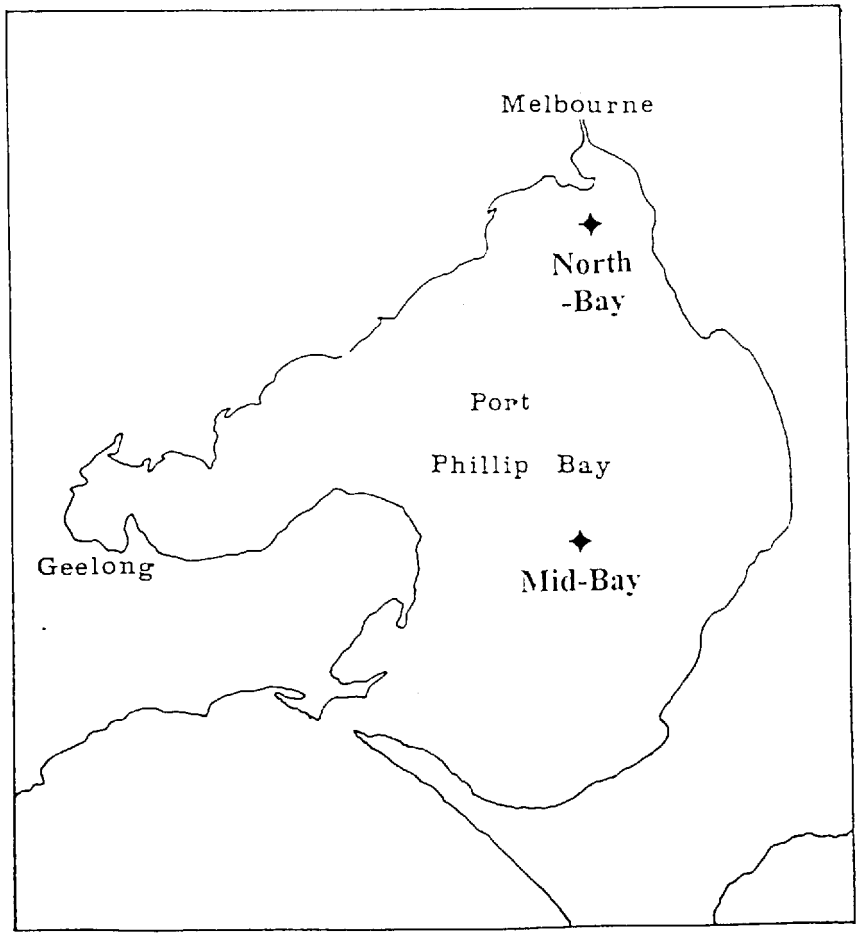


Figure 1: Location of sample sites with geographic coordinates

North-Bay Box Core

Depth (cm)	Mid-depth (cm)	Be-7 (mBq/g)	
		Total	SD
0-1	0.5	14.4	3.6
1-2	1.5	<7	-
2-3	2.5	<7	-
4-5	4.5	<7	-
6-7	6.5	<7	-

Results from M. Matthews, New Zealand

Depth (cm)	Mid-depth (cm)	Be-7 (mBq/g)	
		Total	SD
0-1	0.5	11.3	1.9
1-2	1.5	<5	-
2-3	2.5	<5	-
4-5	4.5	<5	-

Results from M. Cooper, ARL, Melbourne

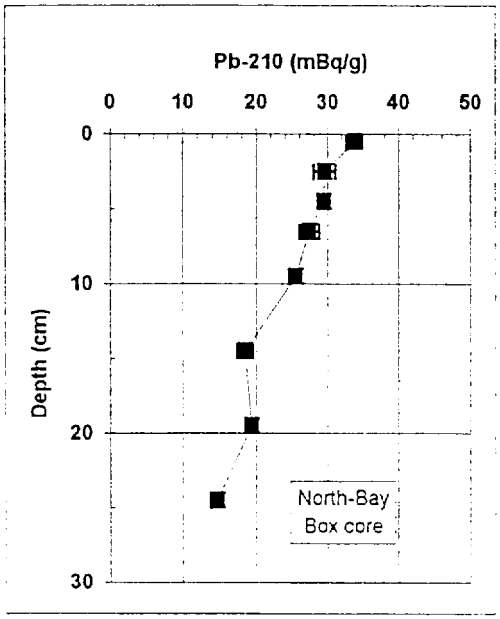
Mid-Bay Box Core

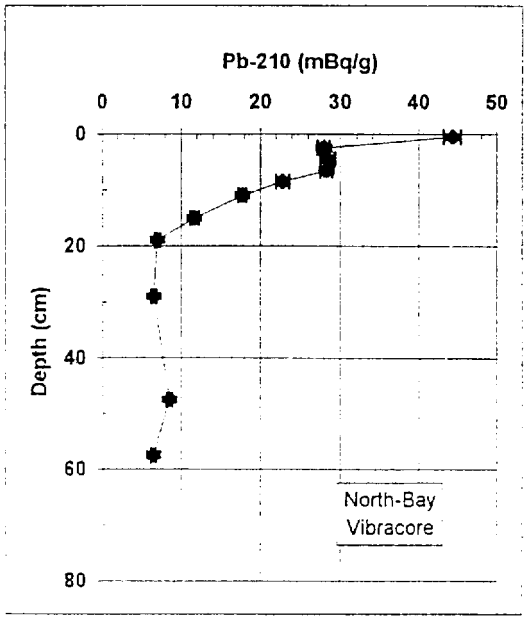
All results were below the limit of detection (<4.5 mBq/g)

Results from M. Cooper, ARL, Melbourne
and M. Matthews, New Zealand

Figure 2: Table of results for beryllium-7

Pb-210 in Sediment from North-Bay



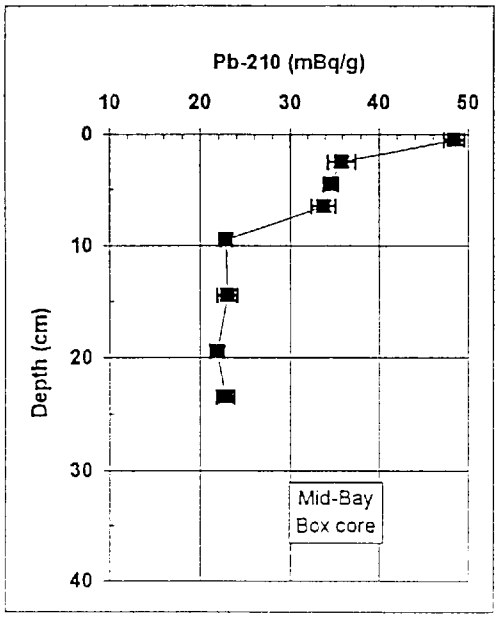


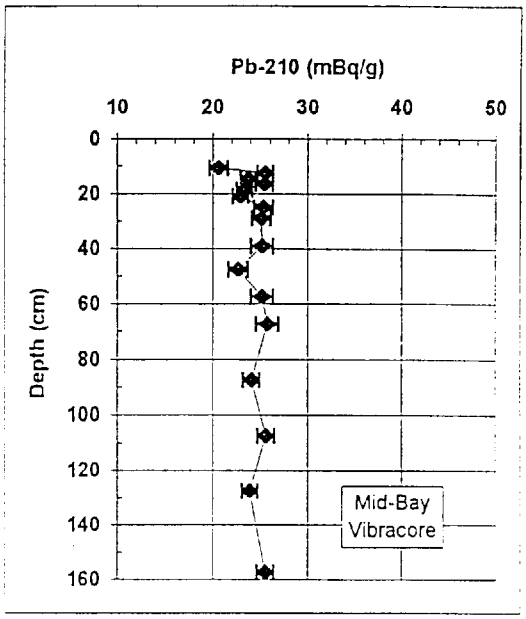
Box Core			
Depth (cm)	Mid-depth (cm)	Pb-210 (mBq/g)	
		Total	SD
0-1	0.5	**33.8**	1.3
2-3	2.5	**29.5**	1.3
4-5	4.5	**29.4**	1.2
6-7	6.5	**27.4**	1.1
10-11	9.5	**25.4**	1.0
14-15	14.5	**18.5**	0.8
19-20	19.5	**19.3**	0.9
24-25	24.5	**14.7**	0.8

Vibracore			
Depth (cm)	Mid-depth (cm)	Pb-210 (mBq/g)	
		Total	SD
0-1	0.5	**44.3**	1.1
2-3	2.5	**27.9**	0.8
4-5	4.5	**28.4**	0.9
6-7	6.5	**28.2**	0.7
8-9	8.5	**22.8**	0.8
10-12	11	**17.7**	0.5
14-16	15	**11.7**	0.5
18-20	19	**7.0**	0.4
28-30	29	**6.6**	0.3
45-50	47.5	**8.6**	0.4
55-60	57.5	**6.5**	0.3

Figure 3: Tables and graphs of results for lead-210 in North Bay

Pb-210 in Sediment from Mid-Bay





Box Core			
Depth (cm)	Mid-depth (cm)	Pb-210 (mBq/g)	
		Total	SD
0-1	0.5	48.4	1.2
2-3	2.5	35.9	1.5
4-5	4.5	34.6	0.8
6-7	6.5	33.8	1.4
9-10	9.5	22.8	0.6
14-15	14.5	23.0	1.1
19-20	19.5	21.8	0.7
23-24	23.5	22.8	1.0

Vibracore			
Depth (cm)	Mid-depth (cm)	Pb-210 (mBq/g)	
		Total	SD
0-1	0.5	20.6	1.0
2-3	2.5	25.5	0.8
4-5	4.5	23.8	0.8
6-7	6.5	25.5	0.9
8-9	8.5	23.3	0.8
10-12	11	22.9	0.8
14-16	15	25.4	1.0
18-20	19	25.1	1.0
28-30	29	25.2	1.2
35-40	37.5	22.7	1.0
45-50	47.5	25.2	1.2
55-60	57.5	25.8	1.2
75-80	77.5	24.1	0.9
95-100	97.5	25.6	0.9
115-12	117.5	23.9	0.8
145-15	147.5	25.5	0.9

Figure 4: Tables and graphs of results for lead-210 in Mid-Bay

Water Content - Mid-Bay Cores

Box Core		
Depth (cm)	Mid-depth (cm)	Water (g/g dry)
0-1	0.5	1.94
1-2	1.5	1.86
2-3	2.5	1.87
3-4	3.5	1.78
4-5	4.5	1.83
5-6	5.5	1.78
6-7	6.5	1.78
7-8	7.5	1.73
8-9	8.5	1.77
9-10	9.5	1.71
10-11	10.5	1.75
11-12	11.5	1.74
12-13	12.5	1.75
13-14	13.5	1.80
14-15	14.5	1.78
15-16	15.5	1.76
16-17	16.5	1.77
17-18	17.5	1.72
18-19	18.5	1.78
19-20	19.5	1.68
20-21	20.5	1.72
21-22	21.5	1.71
22-23	22.5	1.73
23-24	23.5	1.73
24-25	24.5	1.64

Vibracore		
Depth (cm)	Mid-depth (cm)	Water (g/g dry)
0-1	0.5	8.82
1-2	1.5	2.84
2-3	2.5	1.92
3-4	3.5	1.76
4-5	4.5	1.73
5-6	5.5	1.70
6-7	6.5	1.66
7-8	7.5	1.61
8-9	8.5	1.54
9-10	9.5	1.59
10-12	11	1.45
12-14	13	1.59
14-16	15	1.58
16-18	17	1.58
18-20	19	1.54
22-23	22.5	1.57
25-26	25.5	1.69
26-28	27.0	1.72
28-30	29.0	1.76
30-35	32.5	1.63
35-40	37.5	1.51
40-45	42.5	1.46
45-50	47.5	1.55
50-55	52.5	1.60
55-60	57.5	1.60
60-65	62.5	1.56
65-70	67.5	1.48
70-75	72.5	1.34
75-80	77.5	1.50
80-85	82.5	1.58
85-90	87.5	1.55
90-95	92.5	1.54
95-100	97.5	1.56
100-105	102.5	1.67
105-110	107.5	1.63
110-115	112.5	1.60
115-120	117.5	1.61
120-125	122.5	1.48
125-130	127.5	1.57
130-135	132.5	1.67
135-140	137.5	1.58
140-145	142.5	1.57
145-150	147.5	1.58
150-155	152.5	1.56
155-160	157.5	1.56
160-165	162.5	1.56
165-170	167.5	1.45
170-175	172	1.50

Figure 5: Tables of water content for Mid-Bay box and vibro core sediments

Water Content

Mid-Bay Cores

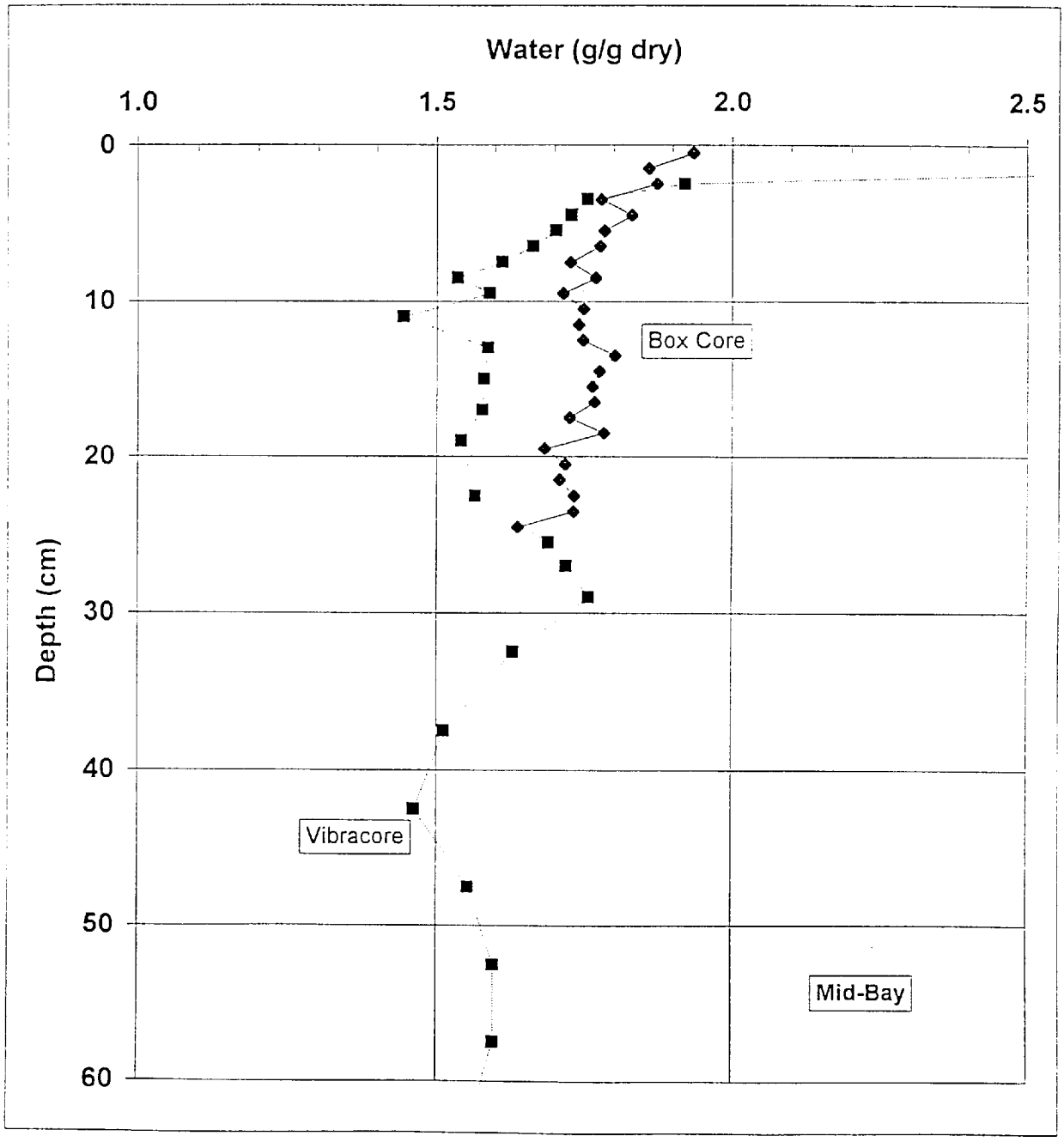


Figure 6: Graphs of Mid-Bay sediment water content

Water Content - North-Bay Cores

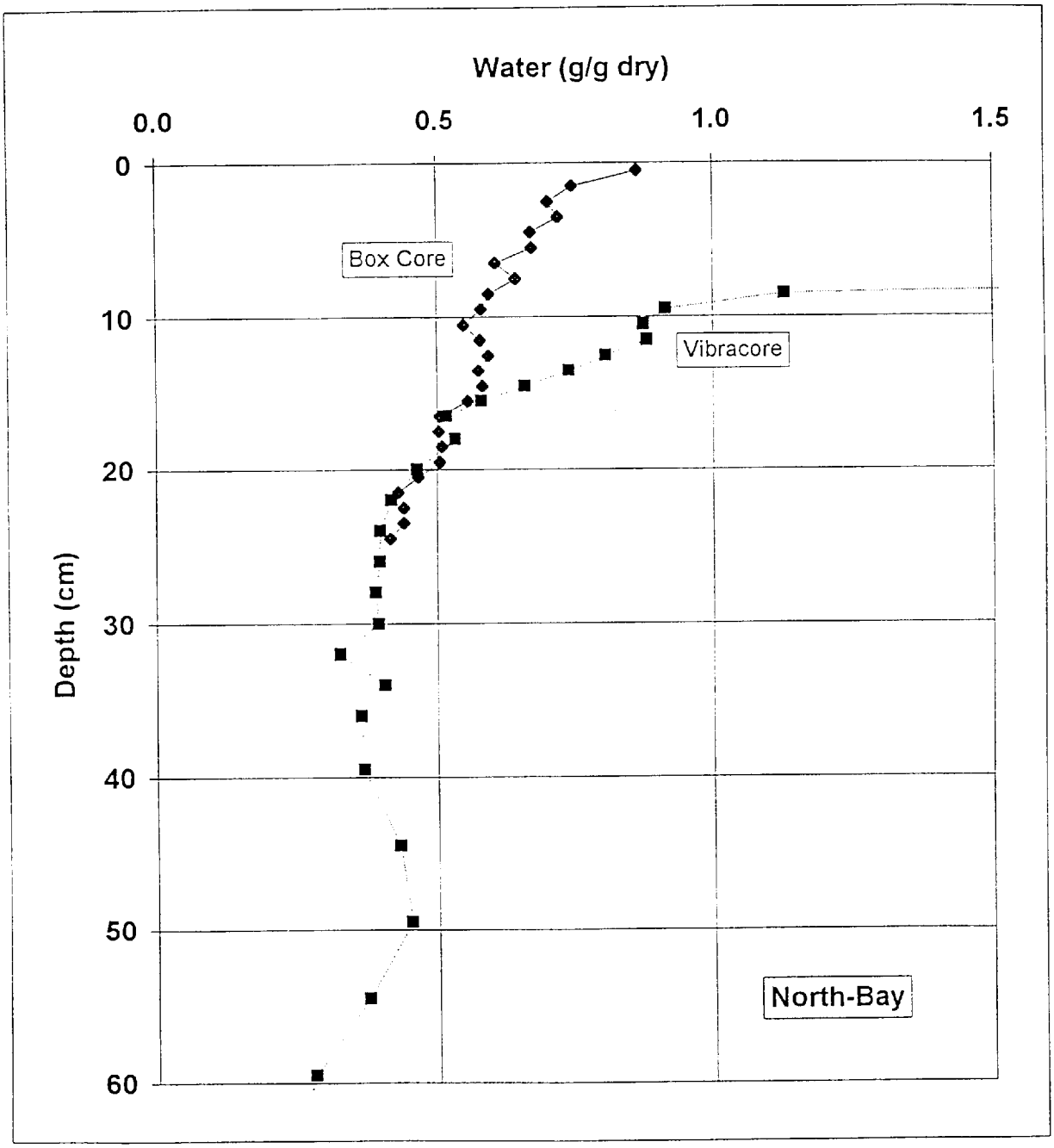
Box Core		
Depth (cm)	Mid-depth (cm)	Water (g/g dry)
0-1	0.5	0.86
1-2	1.5	0.75
2-3	2.5	0.70
3-4	3.5	0.72
4-5	4.5	0.67
5-6	5.5	0.67
6-7	6.5	0.61
7-8	7.5	0.64
8-9	8.5	0.60
9-10	9.5	0.58
10-11	10.5	0.55
11-12	11.5	0.58
12-13	12.5	0.59
13-14	13.5	0.58
14-15	14.5	0.58
15-16	15.5	0.56
16-17	16.5	0.51
17-18	17.5	0.50
18-19	18.5	0.51
19-20	19.5	0.50
20-21	20.5	0.47
21-22	21.5	0.43
22-23	22.5	0.44
23-24	23.5	0.44
24-25	24.5	0.42

Vibracore		
Depth (cm)	Mid-depth (cm)	Water (g/g dry)
0-1	0.5	3.07
1-2	1.5	1.13
2-3	2.5	0.92
3-4	3.5	0.88
4-5	4.5	0.88
5-6	5.5	0.81
6-7	6.5	0.74
7-8	7.5	0.66
8-9	8.5	0.58
9-10	9.5	0.52
10-12	11	0.53
12-14	13	0.46
14-16	15	0.42
16-18	17	0.40
18-20	19	0.40
20-22	22.5	0.39
22-24	25.5	0.40
24-26	27.0	0.33
26-28	29.0	0.41
28-30	32.5	0.36
30-35	37.5	0.37
35-40	42.5	0.43
40-45	47.5	0.45
45-50	52.5	0.38
50-55	57.5	0.28
55-60	62.5	0.23
60-65	67.5	0.21
65-70	72.5	0.21
70-75	77.5	0.20
75-80	82.5	0.18

Figure 7: Tables of water content for North-Bay box and vibro core sediments

Water Content

North-Bay Cores



NOTE: In this graph the results for the vibracore are presented displaced downwards by 7.0 cm

Figure 8: Graphs of North-Bay sediment water content

Radium-226

North-Bay

Vibracore

Depth (cm)	Ra-226 (mBq/g)	SD
0.5	6.2	0.4
2.5	4.1	0.4
4.5	3.4	0.4
6.5	4.9	0.4
8.5	3.3	0.3
11.0	4.4	0.3
15.0	5.5	0.4
19.0	3.9	0.3
29.0	4.2	0.4
47.5	5.0	0.4
Mean	4.5	

Mid-Bay

Vibracore

Depth (cm)	Ra-226 (mBq/g)	SD
0.5	28.2	3.5
8.5	21.2	0.8
11.0	22.7	0.7
15.0	25.7	1.8
19.0	26.4	0.7
29.0	24.1	0.7
37.5	25.2	0.7
47.5	23.2	0.7
57.5	21.7	0.6
77.5	23.4	0.7
97.5	23.4	0.7
117.5	23.7	0.7
147.5	20.9	0.6
Mean	24	

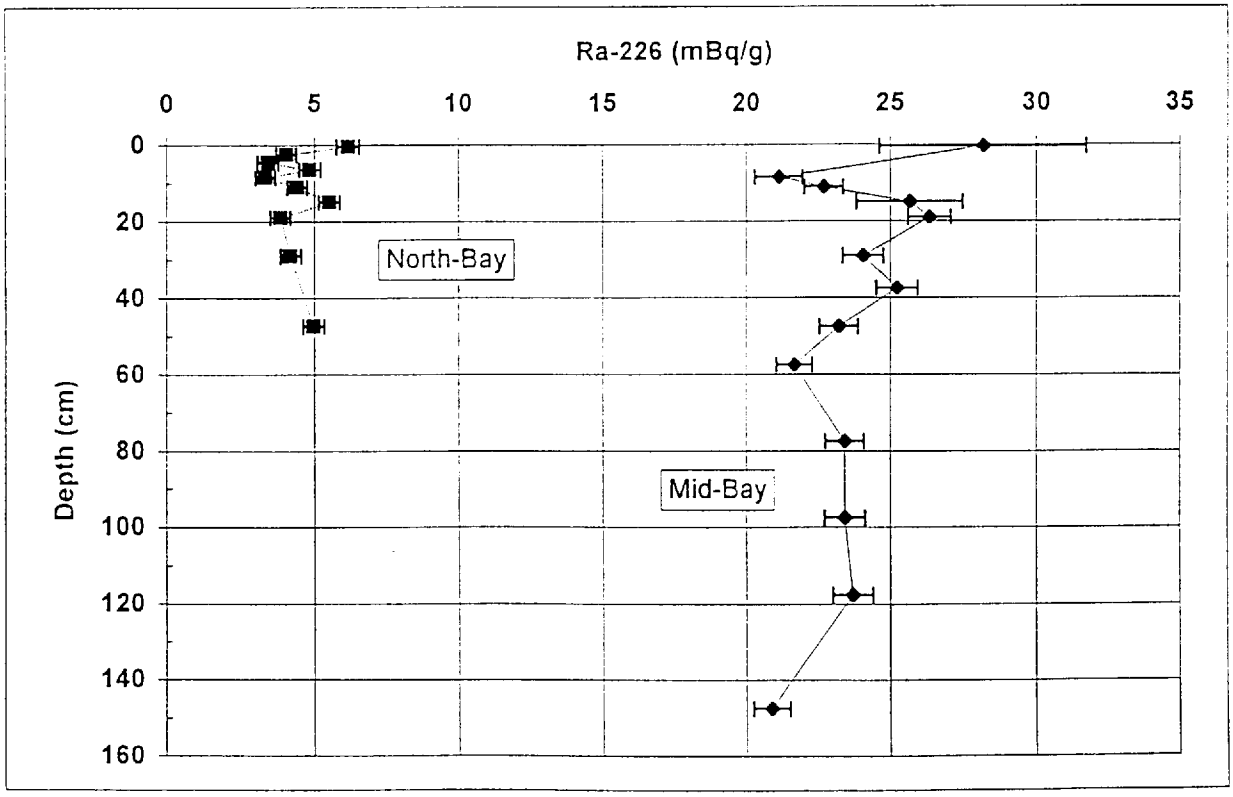


Figure 9: Tables and graphs of results for radium-226 in Mid-Bay and North Bay vibrocores

Caesium-137

Mid-Bay

Box Core

Depth (cm)	Cs-137 (mBq/g)	SD
0.5	1.8	0.2
1.5	2.7	0.3
4.5	2.7	0.3
6.5	2.8	0.3
9.5	3.1	0.3
11.5	2.2	0.5
14.5	2.8	0.4
16.5	2.7	0.2
19.5	2.9	0.4
24.5	3.2	0.2
	Vibracore*	
20	1.0	0.2
28	<0.9	-
37.5	<0.3	-

North-Bay

Box Core

Depth (cm)	Cs-137 (mBq/g)	SD
0.5	1.6	0.3
1.5	1.4	0.2
2.5	1.5	0.3
3.5	1.9	0.3
4.5	1.5	0.3
5.5	1.4	0.3
6.5	1.5	0.3
8.5	1.6	0.3
13.5	1.5	0.1
14.5	1.4	0.2
15.5	1.6	0.4
16.5	1.5	0.2
18.5	1.1	0.3
20.5	1.5	0.2
	Vibracore*	
37.5	<0.3	-

Figure 10: Tables of results for caesium-137 in Mid-Bay and North Bay box cores

Mid-Bay

Comparison of 1994 and 1995 samples

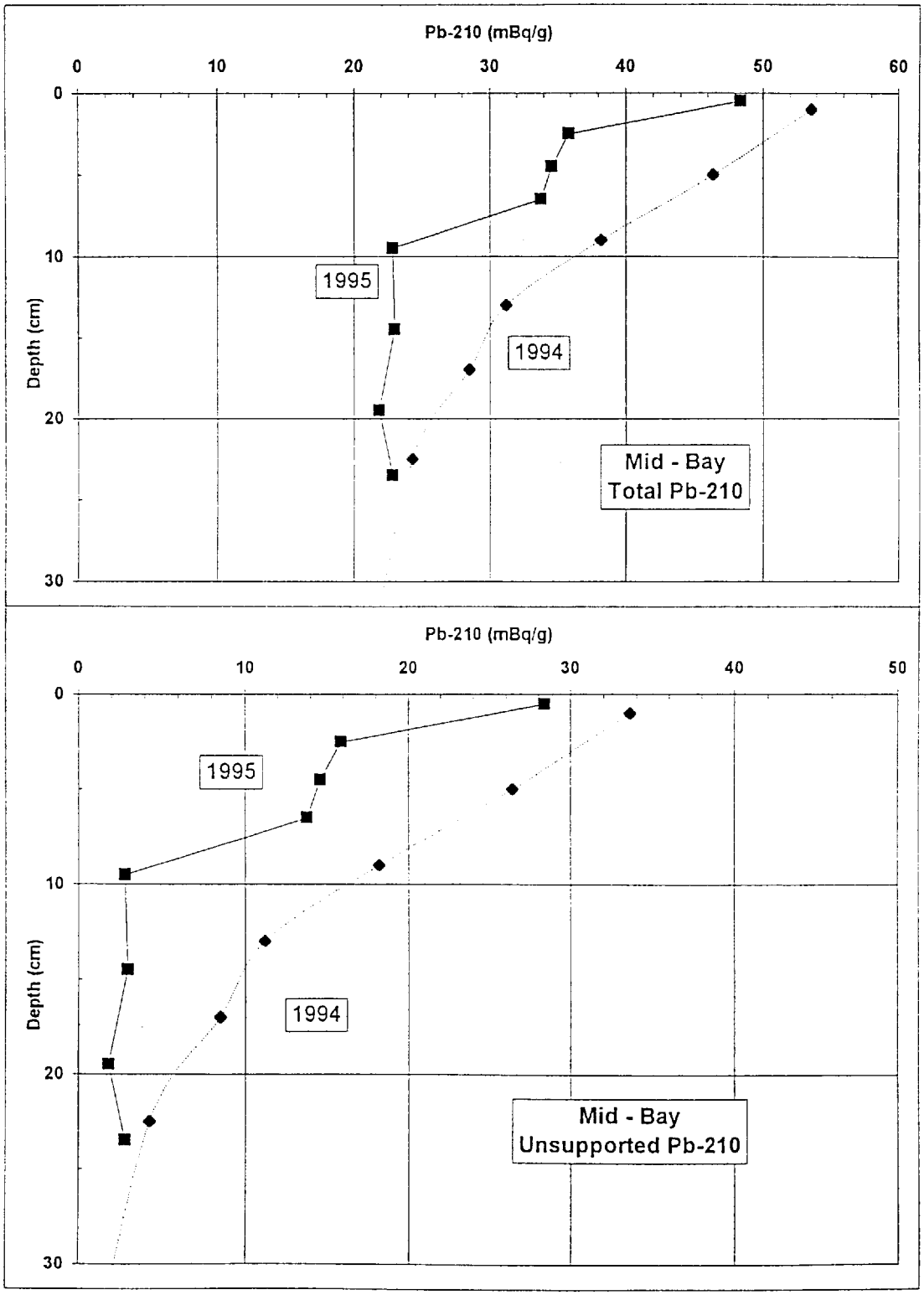
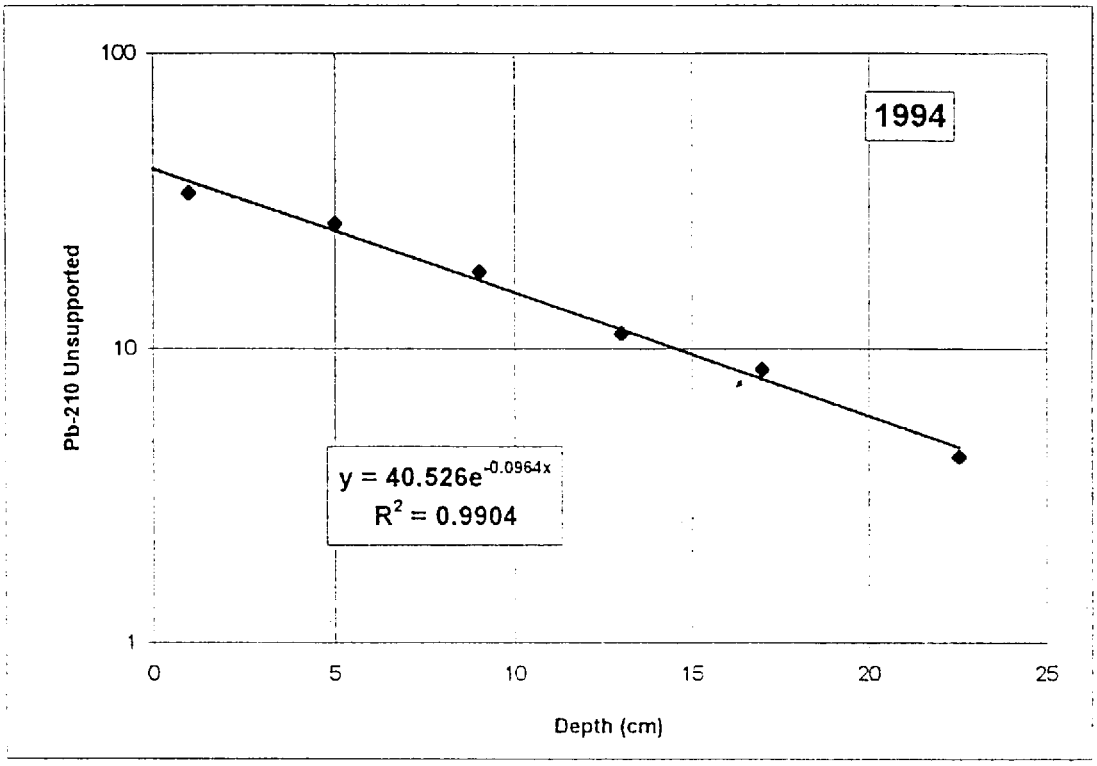


Figure 11: Graphical comparisons of lead-210 results for 1994 and 1995 cores from the Mid-Bay sites

Mid-Bay

Comparison of 1994 and 1995 samples



Year	1994
Surface activity (mBq/g)	41
Correlation (R^2)	0.990
Sedimentation Rate (cm/y)	0.32

1995

The 1995 core shows three layers and dating is not indicated.

1) Surface layer of high Pb-210 concentration
2) Sub-surface layer of 8 cm of mixed sediment
3) Layer below 8 cm of uniform Pb-210 concentration

Figure 12: Unsupported lead-210 results for 1994 and 1995 cores from the Mid-Bay sites

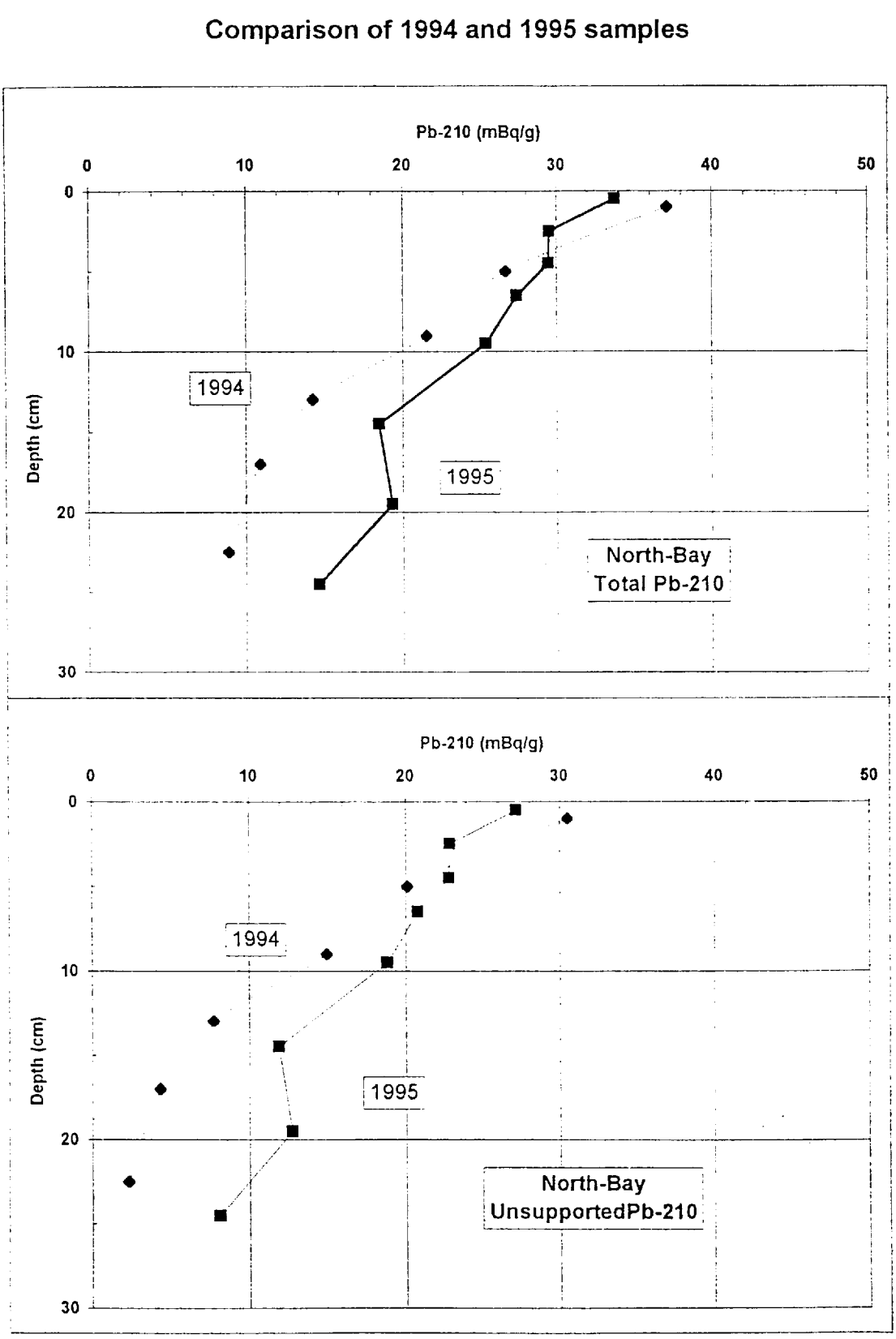
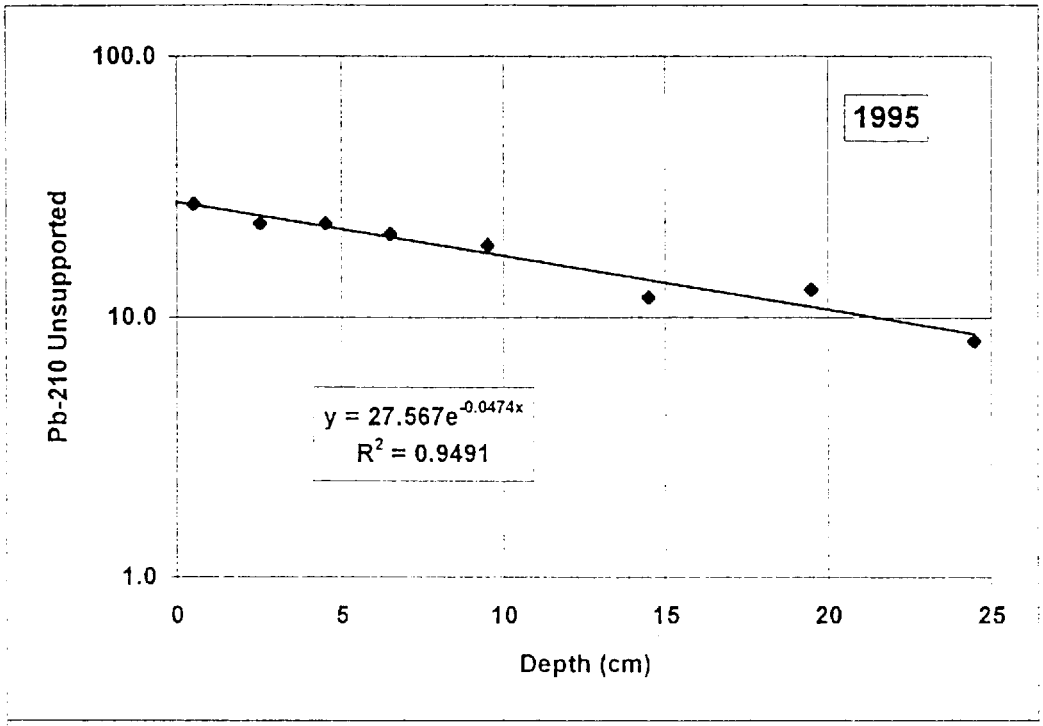
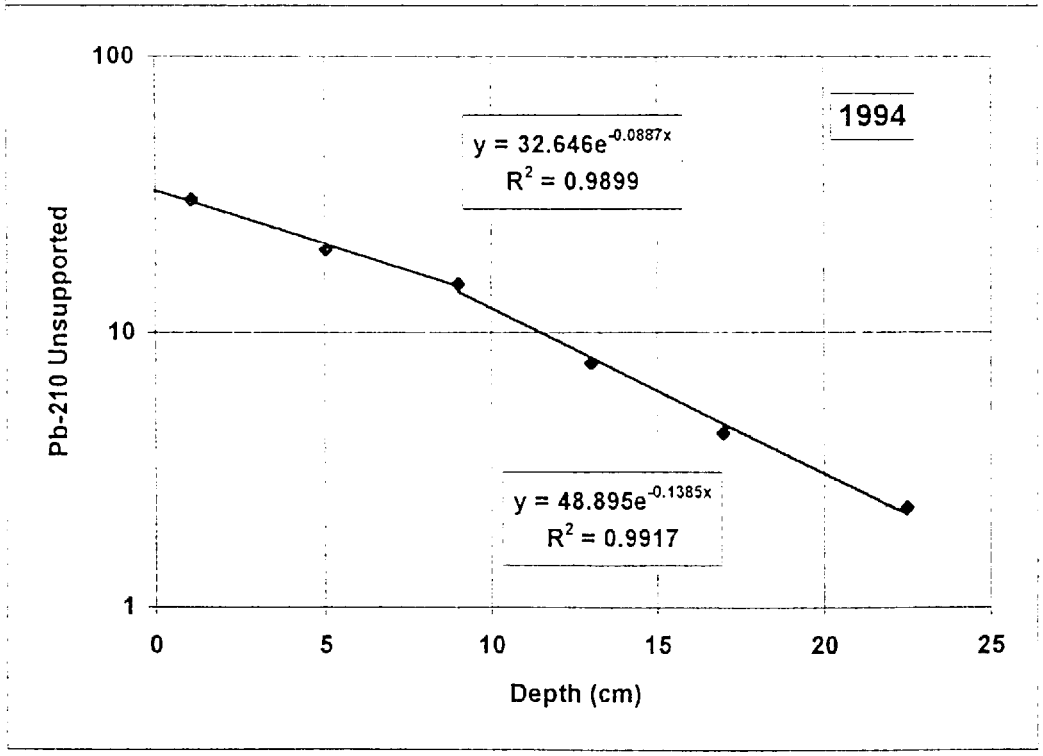


Figure 13: Graphical comparisons of lead-210 results for 1994 and 1995 cores from the North-Bay sites

North-Bay

Comparison of 1994 and 1995 samples





Year	1994	1994(up)	1994(low)	1995
Surface activity (mBq/g)	38	33	49	28
Correlation (R^2)	0.990	0.990	0.992	0.949
Sedimentation Rate (cm/y)	0.25	0.35	0.22	0.66

Figure 14: Unsupported lead-210 results for 1994 and 1995 cores from the North-Bay sites