Porirua Harbour targeted intertidal sediment quality assessment

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Executive summary

Various investigations have reported elevated concentrations of persistent contaminants in the surface sediments of Porirua Harbour. This report presents the results of a targeted assessment of sediment quality at selected intertidal locations in Porirua Harbour in February 2009. The primary focus of the assessment was the southern end of the Onepoto Arm where sediment contamination is believed to be greatest. However, intertidal sediment sampling was also undertaken at a few other potential contaminant "hotspots", including the mouths of 'Onepoto' and Browns streams, and Duck Creek. In addition, sediment samples were collected from the lower reaches of several streams discharging into the harbour that receive urban stormwater inputs, including the Porirua Stream.

The results of this targeted assessment confirm that there is clear evidence of stormwater-derived contamination at intertidal sites in Porirua Harbour. Zinc is present above sediment quality guidelines at all 10 sites sampled between the Semple Street stormwater outfall and the Porirua Stream channel at the southern end of the Onepoto Arm. Copper, lead and total high molecular weight polycyclic aromatic hydrocarbon (HMW PAH) concentrations are also present above guideline values at some sites in this area, and total DDT is present above guidelines at all sites. Although only two sediment core samples were taken, zinc was present in one at a concentration equal to the ANZECC (2000) 'high' guideline value. This suggests that contamination may exist to some depth, at least in the vicinity of the Semple Street stormwater outfall.

Sediments at the mouth of the 'Onepoto' Stream beside the Porirua Rowing Club contain concentrations of lead, zinc, total DDT and various PAH compounds above sediment quality guidelines. Sediments adjacent to the mouths of Browns Stream and Duck Creek have total DDT concentrations above guideline values, with lead and total HMW PAH concentrations also above guidelines in the sediments adjacent to the mouth of Browns Stream.

Stormwater-derived contaminants are also present in the sediments from the beds of streams that discharge into the Porirua Harbour. Concentrations of total DDT, and to a lesser extent zinc, exceed sediment quality guidelines in Porirua, Kenepuru and 'Onepoto' streams. Sediments in the 'Onepoto' Stream also contain concentrations of several HMW PAH compounds and dieldrin above guideline values.

In most cases, existing sediment contaminant concentrations only exceed 'alert level' or 'early warning' guidelines. This indicates that there is an opportunity for management intervention to limit the extent of degradation and prevent adverse environmental effects from occurring.

Contents

1. Introduction

Various investigations have reported elevated concentrations of persistent contaminants in the surface sediments of Porirua Harbour, in particular the heavy metals copper, lead and zinc (e.g., Glasby et al. 1990, Botherway & Gardner 2002, Hooper 2002, Williamson et al. 2005, Stephenson & Mills 2006, Robertson & Stevens 2008). The highest contaminant concentrations have generally been recorded in sediments at the southern end of the Onepoto Arm, with urban stormwater outfalls and the Porirua Stream identified as the primary contaminant sources (e.g., Glasby 1990, Robertson & Stevens 2008) (Figure 1.1). However, as most of the recent sediment sampling has been focused on long-term monitoring at representative intertidal and subtidal sites in both arms of the harbour, the full magnitude and spatial extent of sediment contamination at the southern end of the Onepoto Arm is relatively unknown. With future development possible in the southern-most area adjacent to Porirua City, it was considered necessary to obtain further information on the degree of contamination present in this area.

This report summarises a targeted investigation of contaminants in surface sediments at selected intertidal locations in Porirua Harbour in February 2009. The investigation was carried out by Greater Wellington Regional Council (Greater Wellington) in association with Porirua City Council. While the southern end of the Onepoto Arm was the primary focus of the study, some intertidal sediment sampling was also undertaken at a few other potential contaminant "hotspots": the mouth of a stream entering the Onepoto Arm adjacent to the Porirua Rowing Club, and adjacent to the mouths of Browns Stream and Duck Creek in the Pauatahanui Arm. In addition, sediment samples were collected from the lower reaches of several streams discharging into the harbour that receive urban stormwater inputs, including the Porirua Stream. The investigation was designed primarily as a screening exercise, with spatial coverage favoured over sample replication.

Figure 1.1: Outflow from the Semple Street stormwater outfall at the southern end of the Onepoto Arm of Porirua Harbour

2. Sites and methods

2.1 Sampling sites

A total of 17 intertidal sites in Porirua Harbour were selected for sediment sampling (Table 2.1, Figure 2.1). Ten of these sites (POR-A to POR-J) were located at the southern-most end of the Onepoto Arm, in the area between several large stormwater outfalls and the outflow from the Porirua Stream. The other seven sites were located near the mouths of several urban streams that discharge into the harbour, including an unnamed stream that runs through Onepoto Park (for the purposes of this report referred to as Onepoto Stream), and Browns Stream and Duck Creek in the Pauatahanui Arm. Where possible, sampling sites were the same as the one-off intertidal locations sampled in February 2004 as part of a joint sediment and shellfish investigation between GNS Science and Greater Wellington (Figure 2.1, Appendix 1)[1].

Table 2.1: Site position and collection details for the Porirua Harbour targeted intertidal sediment quality assessment undertaken in February 2009

Site	Location	Date	Position (NZMG coordinates)	
			Easting	Northing
POR-A	Onepoto Arm, adjacent to Porirua Stream, True Right Bank	02/02/09	2664714	6006981
POR-B	Onepoto Arm, adjacent to Porirua Stream, True Right Bank	02/02/09	2664722	6006885
POR-C	Onepoto Arm, adjacent to Porirua Stream, True Left Bank	02/02/09	2664684	6006846
POR-D	Onepoto Arm, adjacent to Porirua Stream, True Left Bank	02/02/09	2664682	6006927
POR-E	Onepoto Arm, midway Porirua Stream & stormwater outfall	02/02/09	2664649	6006897
POR-F	Onepoto Arm, 100 m NE from a stormwater outfall	02/02/09	2664617	6006865
POR-G	Onepoto Arm, adjacent to Porirua Stream, True Left Bank	02/02/09	2664672	6007011
POR-H	Onepoto Arm, 100 m NE of Semple St stormwater outfall	02/02/09	2664615	6006965
POR-I	Onepoto Arm, 50 m N of Semple St stormwater outfall	02/02/09	2664560	6006967
POR-J	Onepoto Arm, 50 m SE of Semple St stormwater outfall	02/02/09	2664589	6006925
OP-A	Onepoto Stream mouth, adjacent to jetty	03/02/09	2664950	6008665
OP-B	Onepoto Stream mouth	03/02/09	2664985	6008665
BB-A	Browns Bay, 50 m W of stream outflow	03/02/09	2668003	6009539
BB-B	Browns Bay, 100 m W stream outflow	03/02/09	2667966	6009593
BB-C	Browns Bay, stream channel banks	03/02/09	2668003	6009516
DC-A	Duck Creek, 50 m N from creek outflow	03/02/09	2669646	6009491
DC-B	Duck Creek, 20 m W of creek outflow	03/02/09	2669614	6009506
SMS043	Porirua Stream, upstream of Kenepuru Stream	02/02/09	2664697	6005900
SMS011	Kenepuru Stream upstream of Porirua S confluence	02/02/09	2664762	6006321
SMS044	Porirua Stream, downstream of Kenepuru Stream	02/02/09	2664711	6006398
SMS045	Onepoto stream, upstream of Onepoto Road	03/02/09	2664954	6008734

Four streambed sites were also selected for sampling: the Porirua Stream upstream and downstream of the Kenepuru Stream confluence, the lower reaches of the Kenepuru Stream, and the lower reaches of the Onepoto Stream (Table 2.1, Figure 2.1).

[1] This investigation was limited to single composite 'grab' samples from 19 sites around the margins of the harbour.

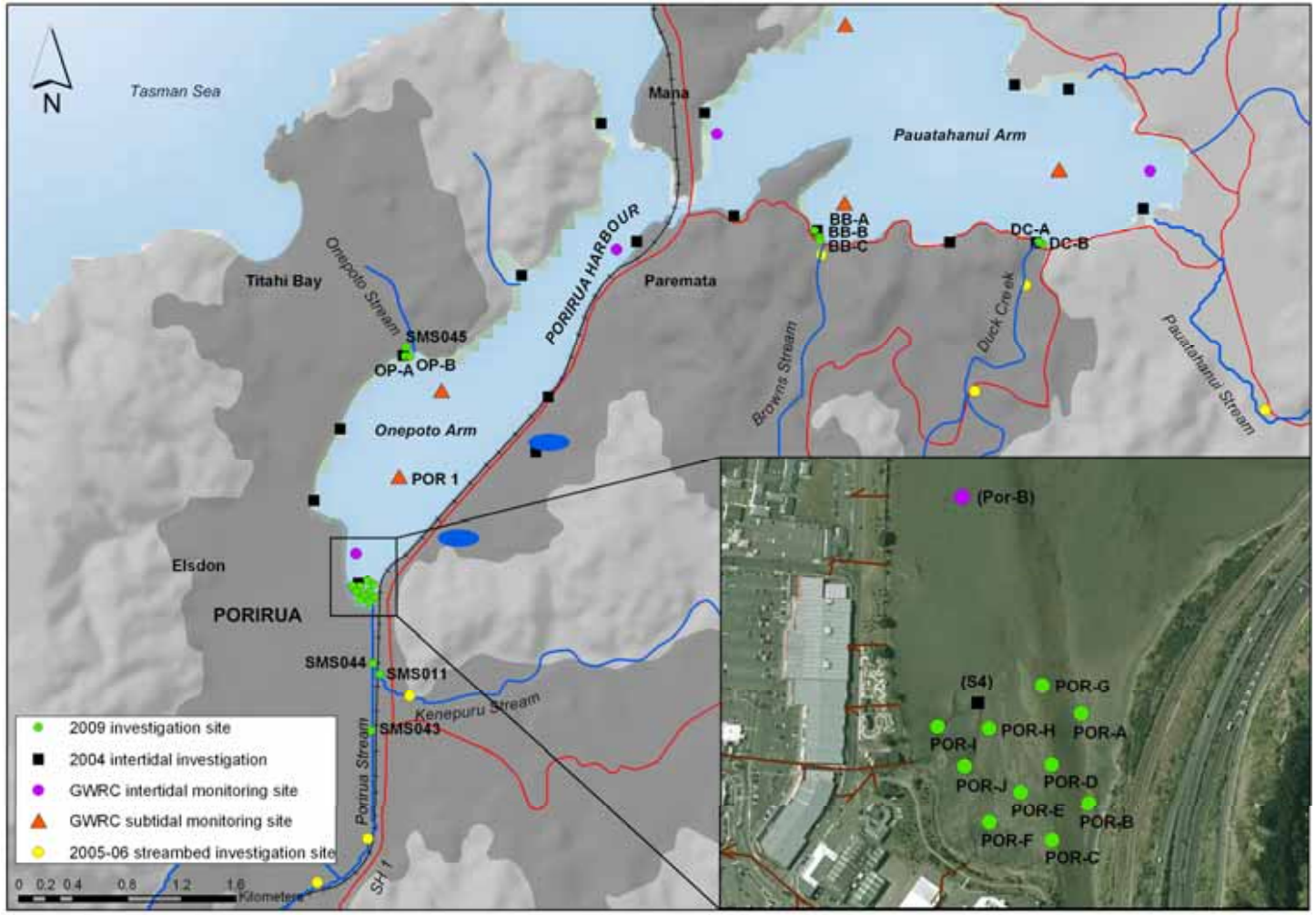

Figure 2.1: Map of Porirua Harbour showing the 2009 sediment sampling locations, and the sediment sampling locations in other relevant monitoring programmes and investigations. The red lines in the inset map denote stormwater inputs.

While streambed sediment sampling had been conducted previously in the Porirua Harbour catchment in 2005 and 2006 (Milne & Watts 2008), this sampling had not included the lower reaches of the Porirua and Onepoto streams. Coordinates of all sampling locations were recorded in the field using a Global Positioning System (GPS).

2.2 Sample collection

At each of the sites, approximately 10 surface (top 20 mm) sediment samples were collected into a bucket using a plastic scoop, and then mixed to create a single bulk composite sample. The bulk sample was mixed thoroughly and representative sub-samples taken and transferred into two glass sample jars, one for chemical analysis and the other for particle size analysis. At two of the sites (POR-H and POR-I), a sediment core sample was collected using a 100 mm diameter by 500 mm deep plastic pipe. The pipe was manually inserted 200 mm into the sediment. The core sample was then released from the pipe onto a plastic tray (Figure 2.2) and the top 20 mm discarded. The remaining sediment was then thoroughly mixed and transferred into glass sample jars. The sediment samples were stored in a refrigerator at 4°C overnight before being transported to Hill Laboratories in Hamilton for analysis.

Figure 2.2: A sediment core sample taken from site POR-J, prior to removal of the top 20 mm

Streambed sediment samples were collected as outlined in Milne & Watts (2008); one composite sample comprising multiple grabs of surface sediment was collected at each site using a plastic scoop to remove the top 10-20 mm of streambed sediment, with sampling targeting the finer sediments present at each site.

2.3 Sample analysis

Details of the laboratory analytical methods are provided in Appendix 2. Each intertidal sediment sample (sub-2 mm fraction[2]) was analysed for the following:

- Particle size distribution;
- Total organic carbon (TOC);
- Total nitrogen and total recoverable phosphorus;
- Total recoverable arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc;
- 16 USEPA priority polycyclic aromatic hydrocarbons (PAHs); and
- Organochlorine pesticides (OCPs), including DDT and dieldrin.

Particle size was included in the analyses to assist with characterisation of the sediments and interpretation of the contaminant data. As noted in subsection 2.4, the TOC content is needed when comparing organic contaminant concentrations against sediment quality guidelines.

The streambed samples were analysed for the same suite of variables, with the exception of total nitrogen and total recoverable phosphorus. In addition, sediment particle size analysis was restricted to five broad size classes (Appendix 2).

Quality Control (QC) reports were requested at the time of the sediment sample analyses. These reports provided data from standard analytical QC checks, including analysis of procedural blanks, duplicates, spiked duplicates and certified reference materials. Surrogate recovery data for PAH and OCP analyses were also included in the reports.

2.4 Data analysis

2.4.1 Sediment quality guidelines

Both the Australian and New Zealand Environment and Conservation Council (ANZECC 2000) and the Auckland Regional Council's (2004) "Environmental Response Criteria" (ERC)[3] sediment quality guidelines were used to assess the potential ecological effects of contaminants in the Porirua Harbour intertidal sediments (Table 2.2). These guidelines are generally considered to be reasonably robust, and conservative (i.e., they err on the side of environmental protection). They are not "pass or fail" numbers, and the developers of the guidelines emphasise that they are best used as one part of a "weight of evidence" approach to evaluating potential effects of contaminants on benthic biota (Stephenson et al. 2008).

[2] The exceptions were particle size and PAHs, where the laboratory analysed the samples on an "as received" basis.

[3] Note that these guidelines are currently under appeal.

Table 2.2: Sediment quality guidelines used in this report. Guideline values are taken from ANZECC (2000) and ARC (2004).

Contaminant	ANZECC trigger values		ARC ERC thresholds	
	ISQG-Low	ISQG-High	amber	red
Metals (mg/kg dry wt):				
Arsenic[1]	20	70		
Cadmium	1.5	10		
Chromium	80	370		
Copper	65	270	19	34
Lead	50	220	30	50
Mercury	0.15	1		
Nickel	21	52		
Zinc	200	410	124	150
Polycyclic Aromatic Hydrocarbons (µg/kg dry wt):[2]				
Naphthalene	160	2,100		
Acenaphthalene	44	640		
Acenaphthene	16	500		
Fluorene	19	540		
Phenanthrene	240	1500		
Anthracene	85	1,100		
Low Molecular Weight PAHs[3]	552	3,160		
Fluoranthene	600	5,100		
Pyrene	665	2,600		
Benzo[a]anthracene	261	1,600		
Chrysene	384	2,800		
Benzo[a]pyrene	430	1,600		
Dibenzo[a,h]anthracene	63	260		
High Molecular Weight PAHs[4]	1,700	9,600	660	1,700
Total PAHs	4,000	45,000		
Organochlorines (µg/kg dry wt):[2]				
Dieldrin	0.02	8		0.72
Endrin	0.02	8		
4,4'-DDE	2.2	27		
2,4'-DDD + 4,4'-DDD	2	20		
Total DDT[5]	1.6	46		3.9

[1] Arsenic is, strictly speaking, a metalloid (ANZECC 2000).

[2] Normalised to 1% total organic carbon.

[3] Low Molecular Weight PAHs are the sum of the concentrations of naphthalene, 2-methyl-naphthalene, acenaphthalene, acenaphthene, fluorene, phenanthrene and anthracene.

[4] High Molecular Weight PAHs are the sum of the concentrations of fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[a]pyrene and dibenzo[a,h]anthracene.

[5] Total DDT is the sum of the concentrations of 2,4'-DDE, 2,4'-DDD, 2,4'-DDT, 4,4'-DDE, 4,4'-DDD and 4,4'-DDT.

The ANZECC (2000) sediment quality guidelines provide low and high values:

1. ANZECC ISQG-Low trigger values – nominally indicative of the contaminant concentrations where the onset of biological effects could possibly occur. These values provide an early warning, enabling management intervention to prevent or minimise adverse environmental effects.

2. ANZECC ISQG-High trigger values – nominally indicative of the contaminant concentrations where significant biological effects are expected. Exceedance of these values therefore indicates that adverse environmental effects are probably already occurring, and management intervention may be required to remediate the problem.

The Auckland Regional Council's amber and red ERC were derived from the Threshold Effect Levels and Effects Range Low values (with rounding) of MacDonald et al. 1994 and Long & Morgan (1990) respectively (Kelly 2007). These guidelines provide a conservative, yet practical[4] early warning of environmental degradation which allows time for investigations into the causes of contamination to be carried out and the options for limiting the extent of degradation to be developed (Kelly 2007, ARC 2004). Note that as these guidelines were developed for estuarine sediments, they have not been applied to the streambed sample results.

Condition ratings described by Robertson & Stevens (2008) were used to interpret nitrogen and phosphorus results, and also sediment organic carbon content. The ratings are primarily based on a review of monitoring data and expert opinion, and are designed to be used in combination with a range of assessments (e.g., benthic fauna, toxicity) when evaluating overall estuary condition and deciding on appropriate management responses (Robertson & Stevens 2008).

2.4.2 Data adjustment

For the purpose of calculating Total PAHs, Total Low Molecular Weight (LWM) PAHs, Total High Molecular Weight (HMW) PAHs and Total DDT, any individual compounds reported at a concentration less than the laboratory detection limit were replaced by a value one half of the detection limit (e.g., a value of <0.01 became 0.005). The exception was where all individual compounds were below the level of detection; in these instances the total concentration has been reported as being below detection.

For comparison of the sediment concentrations of organic contaminants against the ANZECC (2000) and ARC (2004) guidelines, the concentrations were normalised to a TOC content of 1%. The exception was where any organic contaminant was below the level of detection; in these instances no comparison with the guidelines was deemed necessary as the results were reported as being below detection.

[4] Some of the ANZECC guideline values are not practical. For example, the organochlorine pesticide dieldrin has an ANZECC ISQG-Low value of 0.02 µg/kg (parts per billion), which is below the analytical detection limits of almost all laboratories, and probably represents a level that would be present at most rural and urban estuaries in New Zealand. Some other examples of differences between the ANZECC and ARC ERC guidelines are discussed in ARC (2004).

3. Results

This section summarises the results from the Porirua Harbour targeted intertidal sediment quality investigation and streambed sediment sampling. The full analytical results are presented in Appendices 3–5, and their associated quality assurance results in Appendix 6.

3.1 Harbour sediments

For ease of reporting, the sites located at the southern end of Porirua Harbour (POR-A to POR-J) are referred to as "Area A".

3.1.1 Sediment particle size distribution

Mean particle size and the percentage of particles <63 µm (i.e., mud fraction) in the sediments of all the sites are shown in Table 3.1. The mean particle size for the sediments of sites in Area A ranged from 54.8 µm at site POR-B to 251.1 µm at site POR-J. The mean particle size range for sediments at the other sites was greater, from 171.4 µm at site BB-C (Browns Stream channel margins) to 309.6 µm at site DC-A (Duck Creek).

The sediments at the majority of the sites had a percentage of particles <63 µm of less than 20%, with ranges of 3.3–55.4% in Area A, and 8.3–22.7% across the other sites. The sediments at several sites contained less than 10% of particles <63 µm, with most sites classed as very sandy. Site POR-B (adjacent to the true right bank of the Porirua Stream channel) in Area A was the only site with sediment containing a significant percentage (55%) of particles <63 µm (very sandy mud).

3.1.2 Total recoverable metals

In Area A the total recoverable concentrations of copper, lead, zinc and mercury were generally higher in the sediments of sites located closest to the main Semple Street stormwater outfall (POR-I and POR-J) and Porirua Stream channel (POR-B, POR-C and POR-D) (Table 3.1, Figures 3.1 & 3.2). Elsewhere in the harbour, the concentrations were highest in the sediments of sites OP-B (Onepoto Stream mouth) and BB-C (Browns Stream channel margins).

Total recoverable copper concentrations ranged from 8.5–30 mg/kg in the sediments from Area A and from 2.7–15 mg/kg in sediments from the other intertidal sites. The ARC ERC amber threshold for total recoverable copper was exceeded at three sites in Area A (POR-B, POR-I core and POR-J), but was not exceeded at any other site.

Total recoverable lead concentrations ranged from 14–34 mg/kg in Area A sediments, and exceeded the ARC ERC amber threshold at three sites (POR-B, POR-D and POR-I core). Concentrations in the sediments at the other sites were slightly lower, ranging from 7–31 mg/kg, with just one site exceeding the amber threshold (OP-B).

Table 3.1: Mean particle size, percentage of particles <63 µm, and concentrations of nutrients and total recoverable metals in sediments of 17 intertidal sites sampled in the Porirua Harbour during February 2009. Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ARC ERC amber threshold and values in red exceed the ARC ERC red threshold and/or the ANZECC ISQG-Low trigger value. The value in bold red font exceeds the ANZECC ISQG-High trigger value.

Analyte	Fraction	ANZECC		ARC ERC		POR-A	POR-B	POR-C	POR-D	POR-E	POR-F	POR-G	POR-H	POR-H	POR-I	POR-I	POR-J
	analysed	ISQG-Low	ISQG-High	amber	red									core		core	
Mean particle size (µm)	<2 mm	-	-	-	-	106.1	54.8	115.3	112.2	155.2	213.9	210.0	136.5	178.2	128.4	192.8	251.1
% particles <63 µm	<2 mm	-	-	-	-	18.6	55.4	27.5	27.2	11.6	3.29	5.43	9.08	14.5	17.4	13.6	7.29
Total nitrogen (mg/kg)	<2 mm	-	-	-	-	520	1,800	1,400	880	810	<500	<500	<500	<1,300	2,500	690	<510
Carbon:Nitrogen ratio	<2 mm	-	-	-	-	8.5	12.0	8.2	13.0	6.5	6.4	6.1	8.3	12.0	3.9	14.0	7.3
Total phosphorus (mg/kg)	<2 mm	-	-	-	-	330	560	410	410	290	190	300	350	240	450	630	290
Metals (mg/kg, total digest):																	
Arsenic	<2 mm	20	70	-	-	4.8	8.7	5.4	5.1	3.5	2.4	4.0	3.1	3.8	4.8	5.3	3.7
Cadmium	<2 mm	1.5	10	-	-	0.08	0.15	0.16	0.11	0.17	0.13	0.06	0.13	0.17	0.16	0.19	0.11
Chromium	<2 mm	80	370	-	-	11	17	13	15	12	7.7	12	11	9.3	16	15	13
Copper	<2 mm	65	270	19	34	8.8	19	15	16	11	8.8	9.7	14	8.5	18	30	19
Mercury	<2 mm	0.15	1	-	-	0.05	0.10	0.07	0.15	0.04	0.03	0.05	0.03	0.04	0.06	0.06	0.05
Nickel	<2 mm	21	52	-	-	7.9	9.8	8.0	9.3	7.4	4.9	8.6	6.5	6.9	9.7	10	7.6
Lead	<2 mm	50	220	30	50	21	34	27	33	22	14	21	20	15	28	33	20
Zinc	<2 mm	200	410	124	150	140	220	220	200	180	220	150	210	130	270	**410**	200

Table 3.1 *cont.*: Mean particle size, percentage of particles <63 µm, and concentrations of nutrients and total recoverable metals in sediments of 17 intertidal sites sampled in the Porirua Harbour during February 2009. Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ARC ERC amber threshold.

Analyte	Fraction analysed	ANZECC		ARC ERC		OP-A	OP-B	BB-A	BB-B[1]	BB-C	DC-A	DC-B[1]
		ISQG-Low	ISQG-High	amber	red	Onepoto Stream mouth			Browns Bay		Duck Creek mouth	
Mean particle size (µm)	<2 mm	-	-	-	-	240.0	237.2	227.6	-	171.4	309.6	-
% particles <63 µm	<2 mm	-	-	-	-	11.5	22.7	8.28	-	18.1	8.78	-
Total nitrogen (mg/kg)	<2 mm	-	-	-	-	910	770	<500	<500	1,300	<500	<510
Carbon:Nitrogen ratio	<2 mm	-	-	-	-	3.7	7.2	7.6	6.7	15.0	6.3	7.3
Total phosphorus (mg/kg)	<2 mm	-	-	-	-	380	440	230	140	340	260	240
Metals (mg/kg, total digest):												
Arsenic	<2 mm	20	70	-	-	9.0	9.2	4.8	2.9	6.6	3.0	2.6
Cadmium	<2 mm	1.5	10	-	-	0.05	0.06	0.03	0.03	0.06	0.03	0.03
Chromium	<2 mm	80	370	-	-	9.5	12	7.1	4.9	9.8	9.6	8.9
Copper	<2 mm	65	270	19	34	7.4	15	4.1	2.7	11	5.6	4.8
Mercury	<2 mm	0.15	1	-	-	0.03	0.04	<0.01	0.01	0.05	0.06	0.04
Nickel	<2 mm	21	52	-	-	7.0	9.5	5.4	3.5	6.7	8.3	7.1
Lead	<2 mm	50	220	30	50	15	31	11	7.2	23	9.1	8.2
Zinc	<2 mm	200	410	124	150	82	140	63	44	140	59	54

[1] Samples from these sites were not analysed for sediment particle size but particle sizes can be inferred from neighbouring sites BB-A and DC-A.

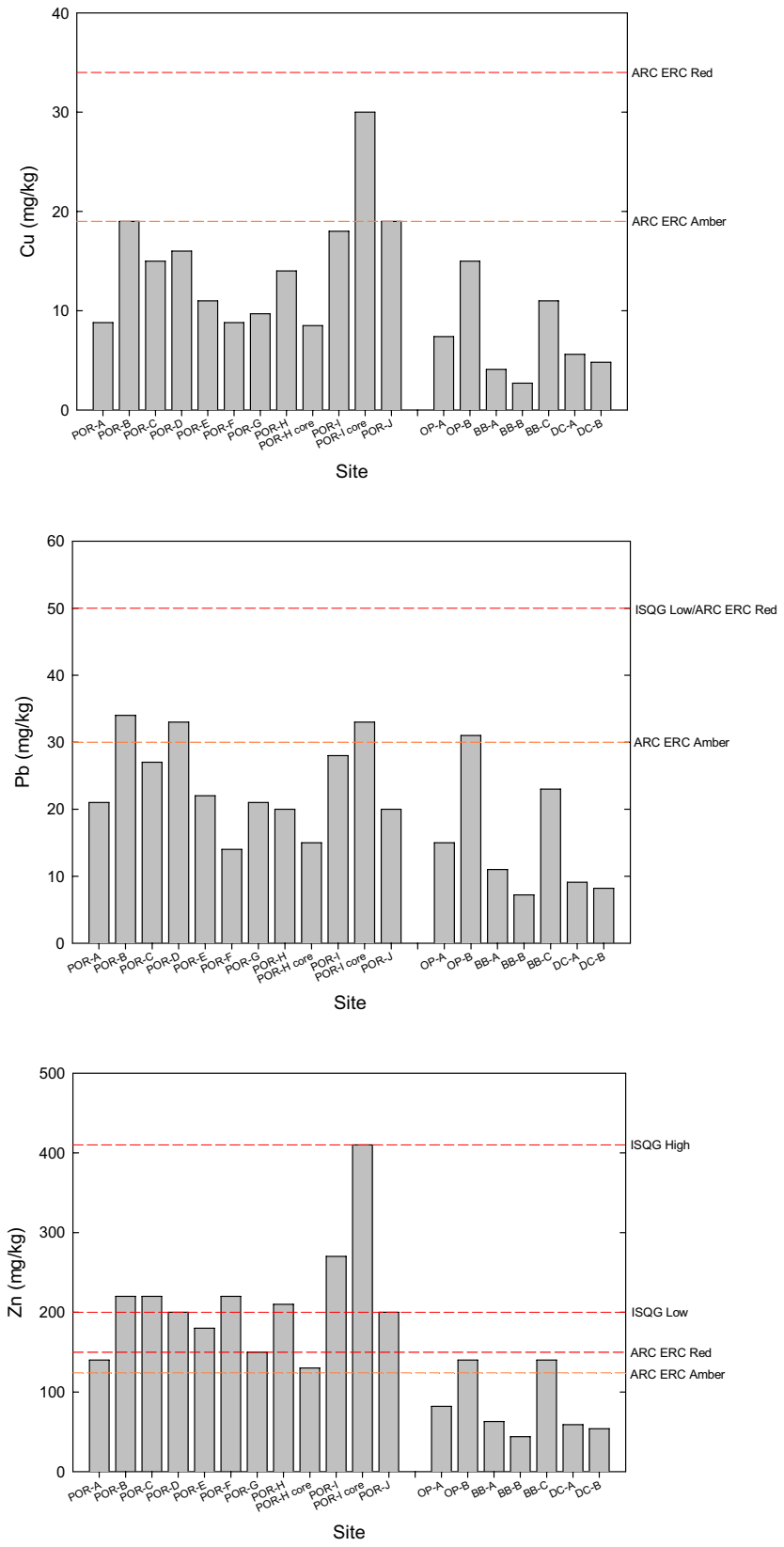

Figure 3.1: Concentrations of total recoverable copper (Cu), lead (Pb) and zinc (Zn) in sediments of 17 intertidal sites sampled in the Porirua Harbour in February 2009, based on the <2 mm fraction of a single composite sample from each site

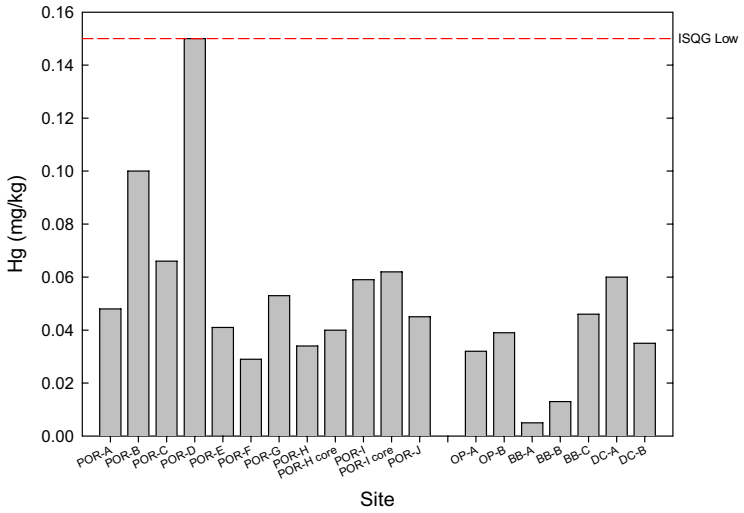

Figure 3.2: Concentration of total recoverable mercury (Hg) in sediments of 17 intertidal sites sampled in the Porirua Harbour in February 2009, based on the <2 mm fraction of a single composite sample from each site

Total recoverable zinc concentrations ranged from 130–410 mg/kg and exceeded the ARC ERC amber threshold in the sediments of all sites located in Area A. Sediments at seven sites in this area also exceeded the ANZECC ISQG-Low trigger value, while the concentration in the core sample from POR-I (adjacent to the Semple Street stormwater outfall) also exceeded the ANZECC ISQG-High trigger value. Total recoverable zinc concentrations were lower at the other intertidal harbour sites, ranging from 44–140 mg/kg, although the ARC ERC amber threshold was exceeded in sediments from site OP-B (Onepoto Stream mouth) and site BB-C (Browns Stream channel margins).

Total recoverable mercury concentrations were generally low with the exception of site POR-D (Area A), which recorded a concentration equal to the ANZECC ISQG-Low trigger value of 0.15 mg/kg.

Total recoverable arsenic, cadmium, chromium and nickel concentrations were below their respective ANZECC ISQG-Low trigger values in the sediment of all sites.

3.1.3 Nutrients

Sediment nutrient concentrations (total nitrogen and total recoverable phosphorus) varied across both Area A and the other sites sampled (Table 3.2, Figure 3.3). Total nitrogen was recorded above the laboratory detection limit in the sediments of seven of the 12 samples from Area A, with concentrations ranging from <500–2,500 mg/kg. Site POR-I adjacent to the Semple Street stormwater outfall was found to exceed the ‘enriched’ condition rating, while several other sites had ‘low-moderate’ condition ratings. Of the other seven sites sampled, sediments at only three (OP-A and OP-B at Onepoto Stream mouth, and BB-C on the channel margins of Browns Stream) recorded total nitrogen concentrations above the detection limit, with concentrations ranging from <500–1,300 mg/kg.

Total recoverable phosphorus was detected in the sediments of all 17 sites sampled and ranged from 190–630 mg/kg in Area A, and from 140–440 mg/kg for the other sites. The sites with the highest concentrations were POR-I and POR-B, which both exceeded the 'enrichment' condition rating. The highest concentrations in the other areas sampled were found at sites OP-A and OP-B at the Onepoto Stream mouth, which resulted in a 'low-moderate' enrichment condition rating.

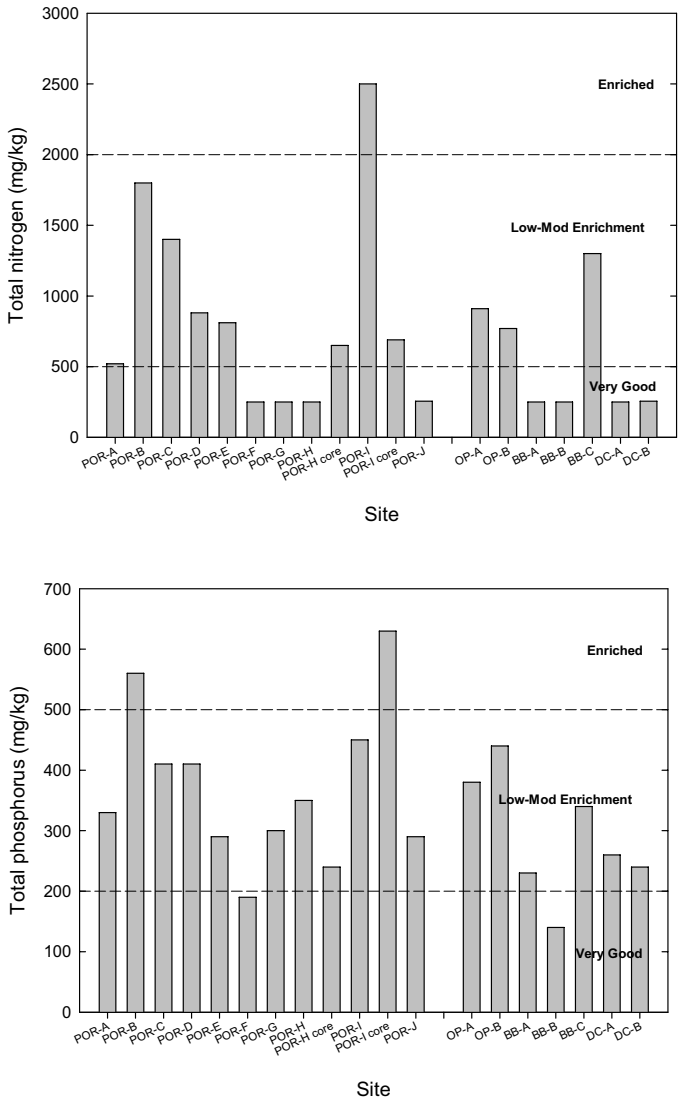

Figure 3.3: Concentrations of total nitrogen and total recoverable phosphorus in sediments of 17 intertidal sites sampled in the Porirua Harbour in February 2009, based on the <2 mm fraction of a single composite sample from each site

3.1.4 Total organic carbon

The total organic carbon (TOC) contents in the <2 mm fraction of the intertidal sediment samples are listed in Table 3.2, along with the concentrations of selected organic contaminants.

The TOC contents of the sediments ranged from 0.24–2.2% at sites in Area A, and 0.24–1.9% at the other sites sampled. Overall, TOC contents were

generally low, with over half of the sites having a TOC content of less than 0.5%. All of the sites were found to have a TOC content with either a 'good' or 'very good' condition rating, apart from site POR-B in Area A which had a 'fair' rating (Figure 3.4).

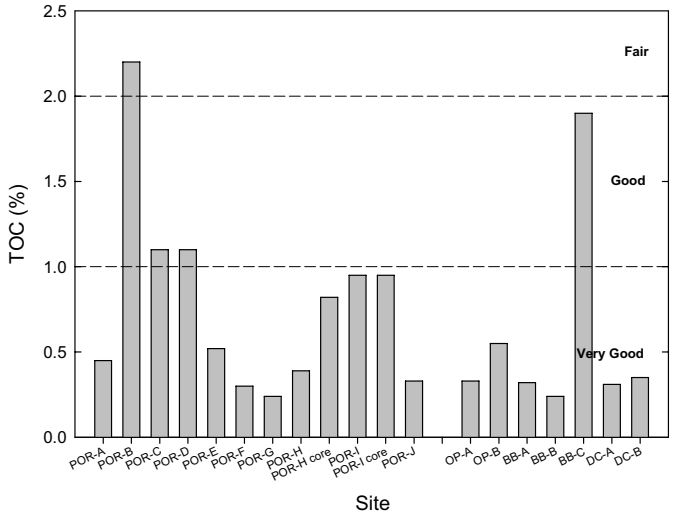

Figure 3.4: Total organic carbon (TOC) contents in sediments of 17 intertidal sites sampled in the Porirua Harbour in February 2009, based on the <2 mm fraction of a single composite sample from each site

3.1.5 Polycyclic aromatic hydrocarbons

Total polycyclic aromatic hydrocarbons (PAH), Total low molecular weight (LMW) PAH and Total high molecular weight (HMW) PAH concentrations were highest in the sediments of sites POR-I and POR-I core (adjacent to the Semple Street stormwater outfall) in Area A and site OP-B at the Onepoto Stream mouth (Table 3.2; Figure 3.5).

Total LMW PAH concentrations ranged from 32–402 µg/kg in sediment samples from Area A, and from 34–381 µg/kg in samples from the other sites. Concentrations at all of the sites were below the ANZECC ISQG-Low trigger value however, samples from sites POR-I and OP-B exceeded ISQG-Low trigger values for the individual concentrations of phenanthrene and anthracene respectively.

Total HMW PAH concentrations ranged from 191–1,738 µg/kg in sediment samples from Area A, and from 36–4,273 µg/kg in sediments from the other sites. Two sites (POR-I and OP-B) exceeded the ANZECC ISQG-Low trigger value; site OP-B at the Onepoto Stream mouth also exceeded ANZECC ISQG-Low trigger values for all six of the individual HMW PAH compounds.

Total PAH concentrations in the sediments ranged from 505–2,761 µg/kg in Area A, and from 91–5,945 µg/kg in sediments from the other sites. Site OP-B was the only site to exceed the ANZECC ISQG-Low trigger value of 4,000 µg/kg.

Table 3.2: Percentage of total organic carbon (TOC) and concentrations of selected organic contaminants in sediments of 17 intertidal sites sampled in the Porirua Harbour during February 2009. Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ARC ERC amber threshold and values in red exceed the ARC ERC red threshold and/or the ANZECC ISQG-Low trigger value. ND=not detected.

Analyte	Fraction	ANZECC		ARC ERC		POR-A	POR-B	POR-C	POR-D	POR-E	POR-F	POR-G	POR-H	POR-H	POR-I	POR-I	POR-J
	analysed	ISQG-Low	ISQG-High	amber	red									core		core	
Total organic carbon (%)	<2 mm	-	-	-	-	0.45	2.2	1.1	1.1	0.52	0.30	0.24	0.39	0.82	0.95	0.95	0.33
Organics (µg/kg)[1]:																	
Anthracene	Raw sample	85	1,100	-	-	6.4	5.9	20	26	6.5	ND	14	9.5	3.5	52	35	7.9
Phenanthrene	Raw sample	240	1,500	-	-	42	33	65	145	29	19	63	56	18	305	189	23
Total LMW PAH[2,3]	Raw sample	552	3,160	-	-	55	46	99	199	51	49	110	86	32	402	263	55
Benzo(a)anthracene	Raw sample	261	1,600	-	-	47	38	155	127	60	28	113	67	44	221	211	91
Benzo(a)pyrene	Raw sample	430	1,600	-	-	62	45	191	145	77	32	133	87	50	232	242	127
Dibenzo(a,h)anthracene	Raw sample	63	260	-	-	8.4	11	42	30	17	ND	18	ND	7.8	54	52	26
Chrysene	Raw sample	384	2,800	-	-	56	40	155	118	60	32	117	69	44	211	179	94
Fluoranthene	Raw sample	600	5,100	-	-	104	100	364	300	123	47	233	177	87	568	453	197
Pyrene	Raw sample	665	2,600	-	-	107	82	300	264	112	50	221	154	87	453	400	182
Total HMW PAH[2,3]	Raw sample	1,700	9,600	660	1,700	384	315	1,205	985	448	191	835	556	319	1,738	1,536	717
Total PAH[2,3]	Raw sample	4,000	45,000	-	-	642	505	1,809	1576	710	366	1,332	871	510	2,761	2,440	1,135
4,4'-DDE	<2 mm	2.2	27	-	-	ND	2.5	3.4	3.7	3.5	ND	8.3	3.6	2.7	3.7	2.9	5.5
2,4'-DDD + 4,4'-DDD	<2 mm	2	20	-	-	ND	1.1	1.6	2.4	ND	ND	ND	ND	3.3	ND	ND	ND
Total DDT[4]	<2 mm	1.6	46	-	3.9	ND	7.4	8.7	10.4	8.8	ND	18.8	9.9	8.4	8.8	5.6	23.0
Dieldrin	<2 mm	0.02	8	-	0.72	ND	0.6	0.9	1.1	ND	ND	ND	ND	ND	1.2	ND	ND
Endrin aldehyde	<2 mm	-	-	-	-	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[1] Concentrations expressed for a sediment containing 1% TOC. This TOC "normalisation" is used in the ANZECC sediment quality guidelines and ARC Environmental Response Criteria for comparing sediments with different TOC content.

[2] Polycyclic aromatic hydrocarbons have been summarised as "Total PAH" (all the PAH compounds analysed), "Total Low Molecular Weight PAH", which is the sum of the concentrations of naphthalene, 2-methyl-naphthalene, acenaphthalene, acenaphthene, fluorine, phenanthrene and anthracene, and as "Total High Molecular Weight PAH", which is the sum of the concentrations of chrysene, fluoranthene, pyrene, benz[a]anthracene, benzo[a]pyrene, and dibenz[a,h]anthracene.

[3] Total LMW PAH, Total HMW PAH, Total PAH and Total DDT values have been calculated using "less than detection limit" values as "0.5 times the detection limit" except where all compounds contributing to the total were below detection (refer subsection 2.3.2).

[4] DDT and related compounds have been summarised as "Total DDT", which is the sum of the concentrations of 2,4'-DDE, 2,4'-DDD, 2,4'-DDT, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT.

Table 3.2 *cont.*: Percentage of total organic carbon (TOC) and concentrations of selected organic contaminants in sediments of 17 intertidal sites sampled in the Porirua Harbour during February 2009. Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ARC ERC amber threshold and values in red exceed the ARC ERC red threshold and/or the ANZECC ISQG-Low trigger value. ND=not detected.

Analyte	Fraction	ANZECC		ARC ERC		OP-A	OP-B	BB-A	BB-B	BB-C	DC-A	DC-B
	analysed	ISQG-Low	ISQG-High	amber	red	Onepoto Stream mouth			Browns Bay		Duck Creek mouth	
Total organic carbon (%)	<2 mm	-	-	-	-	0.33	0.55	0.32	0.24	1.9	0.31	0.35
Organics (µg/kg)[1]:												
Anthracene	Raw sample	85	1,100	-	-	9.1	102	10	ND	26	17	ND
Phenanthrene	Raw sample	240	1,500	-	-	45	236	47	31	126	58	8.3
Total LMW PAH[2,3]	Raw sample	552	3,160	-	-	79	381	85	68	175	101	34
Benzo(a)anthracene	Raw sample	261	1,600	-	-	61	564	75	32	174	55	ND
Benzo(a)pyrene	Raw sample	430	1,600	-	-	85	582	119	46	205	58	6.3
Dibenzo(a,h)anthracene	Raw sample	63	260	-	-	ND	73	ND	ND	46	8.1	ND
Chrysene	Raw sample	384	2,800	-	-	73	509	78	42	158	61	ND
Fluoranthene	Raw sample	600	5,100	-	-	167	1,418	178	79	405	174	10
Pyrene	Raw sample	665	2,600	-	-	155	1,127	147	79	337	135	11
Total HMW PAH[2,3]	Raw sample	1,700	9,600	660	1,700	542	4,273	600	282	1,325	492	36
Total PAH[2,3]	Raw sample	4,000	45,000	-	-	864	5,945	1,001	498	2,068	771	91
4,4'-DDE	<2 mm	2.2	27	-	-	ND	1.8	ND	4.2	2.2	5.2	4.6
2,4'-DDD + 4,4'-DDD	<2 mm	2	20	-	-	ND	ND	ND	5.8	ND	11.9	11.1
Total DDT[4]	<2 mm	1.6	46	-	3.9	ND	6.8	ND	32.9	5.3	25.8	23.9
Dieldrin	<2 mm	0.02	8	-	0.72	ND	ND	ND	ND	ND	ND	ND
Endrin aldehyde	<2 mm	-	-	-	-	5.8	10.7	ND	ND	ND	ND	ND

[1] Concentrations expressed for a sediment containing 1% TOC. This TOC "normalisation" is used in the ANZECC sediment quality guidelines and ARC Environmental Response Criteria for comparing sediments with different TOC content.

[2] Polycyclic aromatic hydrocarbons have been summarised as "Total PAH" (all the PAH compounds analysed), "Total Low Molecular Weight PAH", which is the sum of the concentrations of naphthalene, 2-methyl-naphthalene, acenaphthalene, acenaphthene, fluorine, phenanthrene and anthracene, and as "Total High Molecular Weight PAH", which is the sum of the concentrations of chrysene, fluoranthene, pyrene, benz[a]anthracene, benzo[a]pyrene, and dibenz[a,h]anthracene.

[3] Total LMW PAH, Total HMW PAH, Total PAH and Total DDT values have been calculated using "less than detection limit" values as "0.5 times the detection limit" except where all compounds contributing to the total were below detection (refer subsection 2.3.2).

[4] DDT and related compounds have been summarised as "Total DDT", which is the sum of the concentrations of 2,4'-DDE, 2,4'-DDD, 2,4'-DDT, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT.

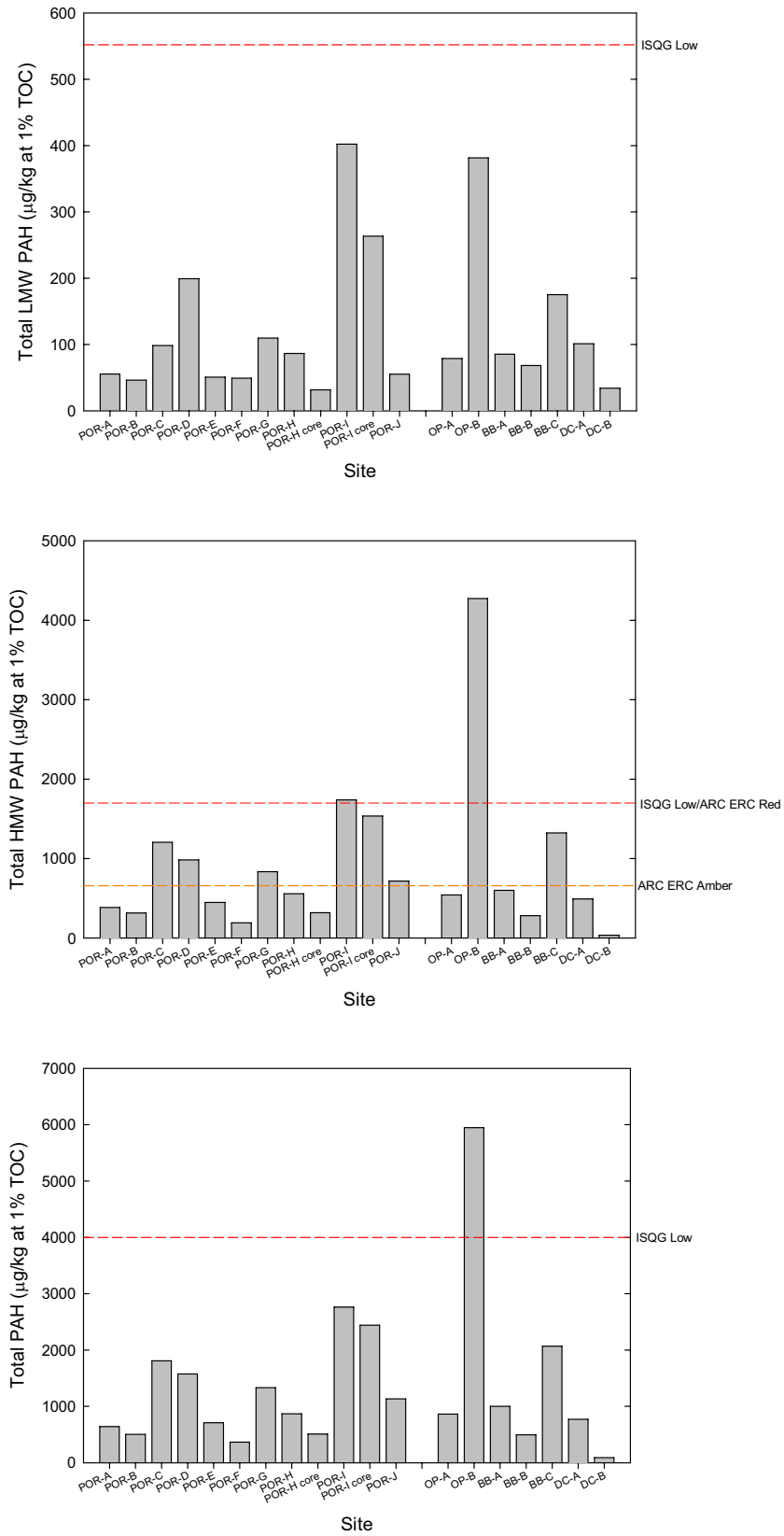

Figure 3.5: Concentrations of TOC-normalised Total Low Molecular Weight PAH, Total High Molecular Weight PAH and Total PAH in sediments of 17 intertidal sites sampled in the Porirua Harbour in February 2009, based a single composite sample from each site

3.1.6 Organochlorine pesticides

Of the 25 organochlorine pesticide compounds analysed, only DDT, DDE and DDD were consistently found above detection limits in the sediments of all sites. Total DDT concentrations ranged from <0.99–23.0 µg/kg in Area A, and from 5.3–32.9 µg/kg at the other sites (Table 3.2, Figure 3.6). All of the sites that recorded a concentration greater than the laboratory detection limit exceeded the ANZECC ISQG-Low trigger value and the ARC ERC red threshold level. Sediments from sites POR-G and POR-J in Area A, site BB-B in Browns Bay and DC-A and DC-B near Duck Creek recorded the highest concentrations of Total DDT.

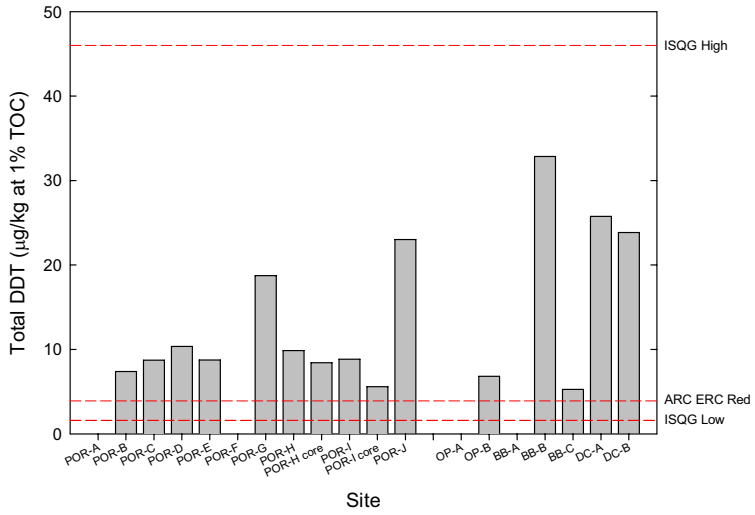

Figure 3.6: Concentrations of TOC-normalised Total DDT in sediments of 17 intertidal sites sampled in the Porirua Harbour in February 2009, based on the <2 mm fraction of a single composite sample from each site

Dieldrin was found at concentrations above the laboratory detection limit in the sediments from sites POR-B, POR-C and POR-D along the Porirua Stream channel margins and from site POR-J near the Semple Street stormwater outfall in Area A. Endrin aldehyde was detected in the sediments from both sites adjacent to the Onepoto Stream mouth (sites OP-A and OP-B).

3.2 Streambed sediments

3.2.1 Sediment particle size distribution

The size distribution of sediment particles in each streambed sample is presented in Table 3.3. The percentage of mud particles (<63 µm) in the sediments at all the sites was generally low, ranging from 4.9–19.1%. All of the sites had a large percentage of particles greater than 2 mm (21.7–61.9%).

3.2.2 Total recoverable metals

The concentrations of total recoverable copper, lead and particularly zinc were higher in the sediments of the Onepoto Stream sampling site compared to those in the sediments from the Porirua and Kenepuru streams (Table 3.3; Figure 3.7). Zinc was the only metal present above ANZECC (2000) guidelines.

Table 3.3: Particle size distribution and concentrations of total recoverable metals in sediments from four streambed sites sampled as part of the Porirua Harbour intertidal sediment quality assessment. Sediment quality guidelines for comparison are ANZECC (2000) – values in amber and red exceed the ANZECC ISQG-Low and ISQG-High trigger values respectively.

Analyte	ANZECC trigger values		SMS043	SMS011	SMS044	SMS045
	ISQG-Low	ISQG-High	Porirua u/s	Kenepuru S	Porirua d/s	Onepoto S
Particles >2mm (%)	-	-	35.7	21.7	49.1	61.9
Particles <2 mm, ≥500 µm (%)	-	-	2.1	25.4	7.1	21.5
Particles <500 µm, ≥250 µm (%)	-	-	12.7	23.1	16.0	4.6
Particles <250 µm, ≥63 µm (%)	-	-	30.4	21.1	22.9	4.5
Particles <63 µm (%)	-	-	19.1	8.6	4.9	7.5
Metals (mg/kg):						
Arsenic	20	70	6.8	5.0	5.5	6.3
Cadmium	1.5	10	0.14	0.08	0.08	0.15
Chromium	80	370	15	14	13	14
Copper	65	270	20	12	14	24
Mercury	0.15	1	0.07	0.04	0.08	0.03
Nickel	21	52	12	9.8	11	13
Lead	50	220	40	30	34	37
Zinc	200	410	250	130	170	430

Total recoverable copper concentrations ranged from 12–24 mg/kg, with the highest concentration recorded at site SMS043 in the Onepoto Stream. Total recoverable lead concentrations were similar at each site, ranging from 30–40 mg/kg. Total recoverable zinc concentrations were more variable, ranging from 130–430 mg/kg. Sites SMS043 (Porirua Stream above the Kenepuru Stream confluence) and SMS045 (Onepoto Stream) recorded concentrations that exceeded ANZECC ISQG-Low and High trigger values respectively.

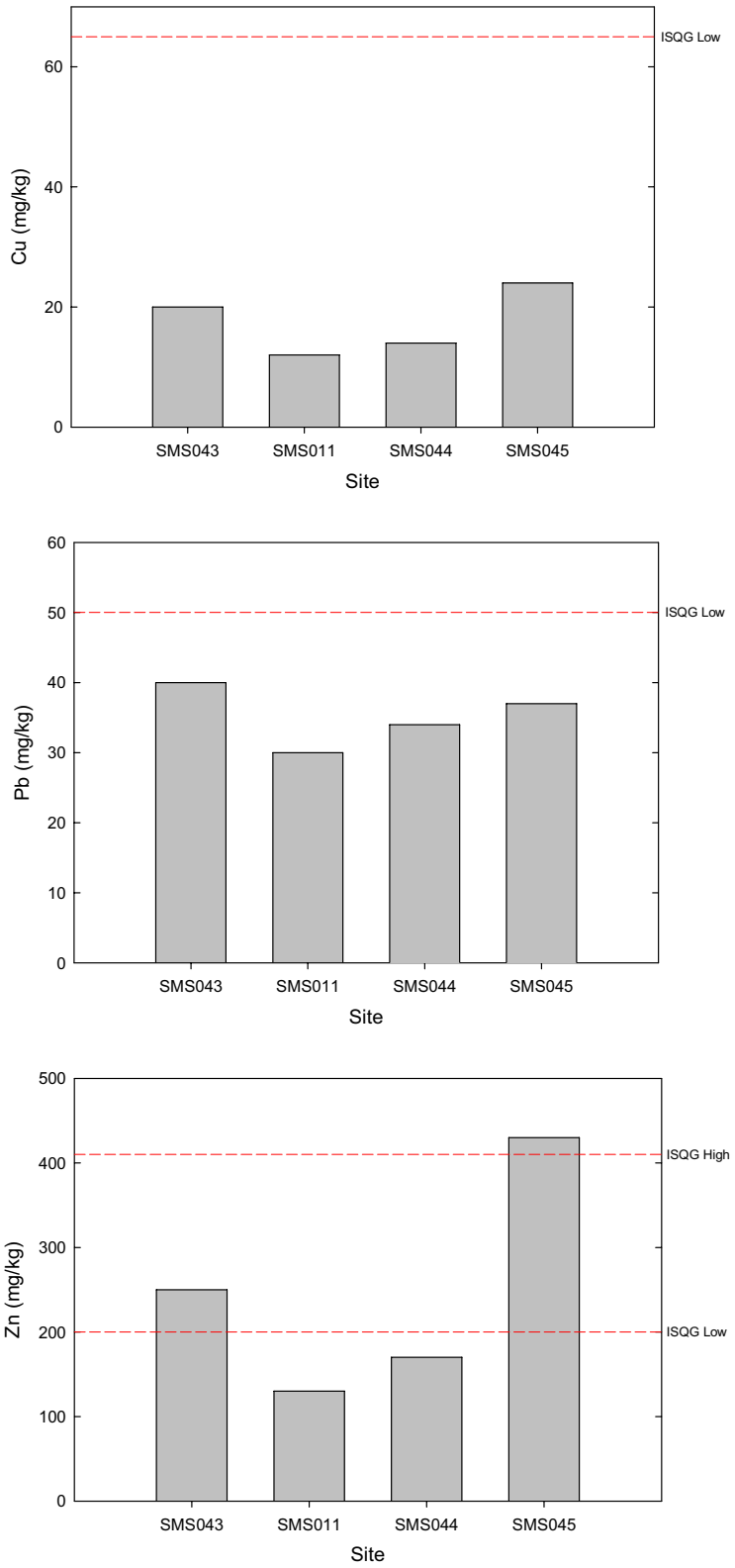

Figure 3.7: Concentrations of total recoverable copper (Cu), lead (Pb), and zinc (Zn) in sediments of four streambed sites sampled in February 2009, based on the <2 mm fraction of a single composite sample from each site

3.2.3 Total organic carbon

The total organic carbon (TOC) contents of the <2 mm fraction of the streambed sediments were generally low, ranging from 0.70–1.90% (Table 3.4; Figure 3.8). Site SMS043 (Porirua Stream above the Kenepuru Stream confluence) was the only site with a TOC content greater than 1%.

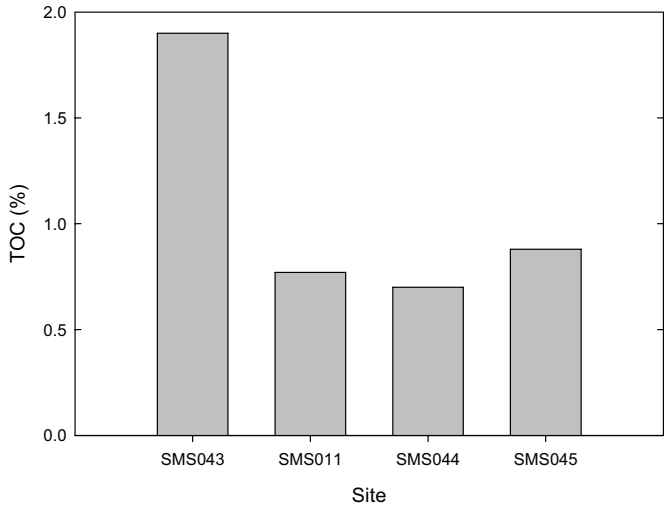

Figure 3.8: Total organic carbon (TOC) contents in sediments of four streambed sampled in February 2009, based on the <2 mm fraction of a single composite sample from each site

3.2.4 Polycyclic aromatic hydrocarbons

Total LMW PAH, Total HMW PAH and Total PAH concentrations were highest in the sediments of site SMS045 in the lower reaches of the Onepoto Stream (Table 3.4, Figure 3.9).

Total LMW PAH concentrations in the sediments ranged from 52–211 µg/kg and were below the ANZECC sediment quality guidelines at all sites. Total HMW PAH concentrations exceeded the ISQG-Low trigger value at all sites except the Kenepuru Stream, with concentrations ranging from 639–1,566 µg/kg. The sediments from site SMS045 in the Onepoto Stream also exceeded ISQG-Low trigger values for the individual PAH compounds of benzo(a)anthracene and dibenzo(a,h)anthracene. Total PAH concentrations were below the ISQG-Low trigger value, ranging from 993 µg/kg at site SMS011 in the Kenepuru Stream to 2,516 µg/kg at site SMS045 in the Onepoto Stream.

Table 3.4: Percentage of total organic carbon (TOC) and concentrations of selected organic contaminants in sediments from four streambed sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment. Sediment quality guidelines for comparison are ANZECC (2000) – values in amber exceed the ANZECC ISQG-Low trigger value. ND = not detected.

Analyte	Fraction analysed	ANZECC ISQG-Low	ANZECC ISQG-High	SMS043 Porirua u/s Kenepuru S	SMS011 Kenepuru Stream	SMS044 Porirua d/s Kenepuru S	SMS045 Onepoto Stream
Total organic carbon (%)	<2 mm	-	-	1.90	0.77	0.70	0.88
Organics (µg/kg):							
Anthracene	Raw sample	85	1,100	8.9	11	40	36
Phenanthrene	Raw sample	240	1,500	31	55	134	148
Total LMW PAH[1,2]	Raw sample	552	3,160	52	79	204	211
Benzo(a)anthracene	Raw sample	261	1,600	105	79	171	284
Benzo(a)pyrene	Raw sample	430	1,600	137	92	171	307
Dibenzo(a,h)anthracene	Raw sample	63	260	18	ND	34	66
Chrysene	Raw sample	384	2,800	95	90	143	227
Fluoranthene	Raw sample	600	5,100	195	208	414	352
Pyrene	Raw sample	665	2,600	168	169	329	330
Total HMW PAH[1,2]	Raw sample	1,700	9,600	718	639	1,263	1,566
Total PAH[1,2]	Raw sample	4,000	45,000	1,149	993	1,911	2,516
4,4'-DDE	<2 mm	2.2	27	2.2	1.9	5.1	1.8
2,4'-DDD + 4,4'-DDD	<2 mm	2	20	5.8	3.5	7.7	5.0
Total DDT[4]	<2 mm	1.6	46	12.6	9.2	22.6	10.5
Dieldrin	<2 mm	0.02	8	ND	ND	1.6	1.5
Endrin aldehyde	<2 mm	-	-	ND	ND	ND	ND

[1] Concentrations expressed for a sediment containing 1% TOC. This TOC "normalisation" is used in the ANZECC sediment quality guidelines and ARC Environmental Response Criteria for comparing sediments with different TOC content.

[2] Polycyclic aromatic hydrocarbons have been summarised as "Total PAH" (all the PAH compounds analysed), "Total Low Molecular Weight PAH", which is the sum of the concentrations of naphthalene, 2-methyl-naphthalene, acenaphthalene, acenaphthene, fluorine, phenanthrene and anthracene, and as "Total High Molecular Weight PAH", which is the sum of the concentrations of chrysene, fluoranthene, pyrene, benz[a]anthracene, benzo[a]pyrene, and dibenz[a,h]anthracene.

[3] Total LMW PAH, Total HMW PAH, Total PAH and Total DDT values have been calculated using "less than detection limit" values as "0.5 times the detection limit".

[4] DDT and related compounds have been summarised as "Total DDT", which is the sum of the concentrations of 2,4'-DDE, 2,4'-DDD, 2,4'-DDT, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT.

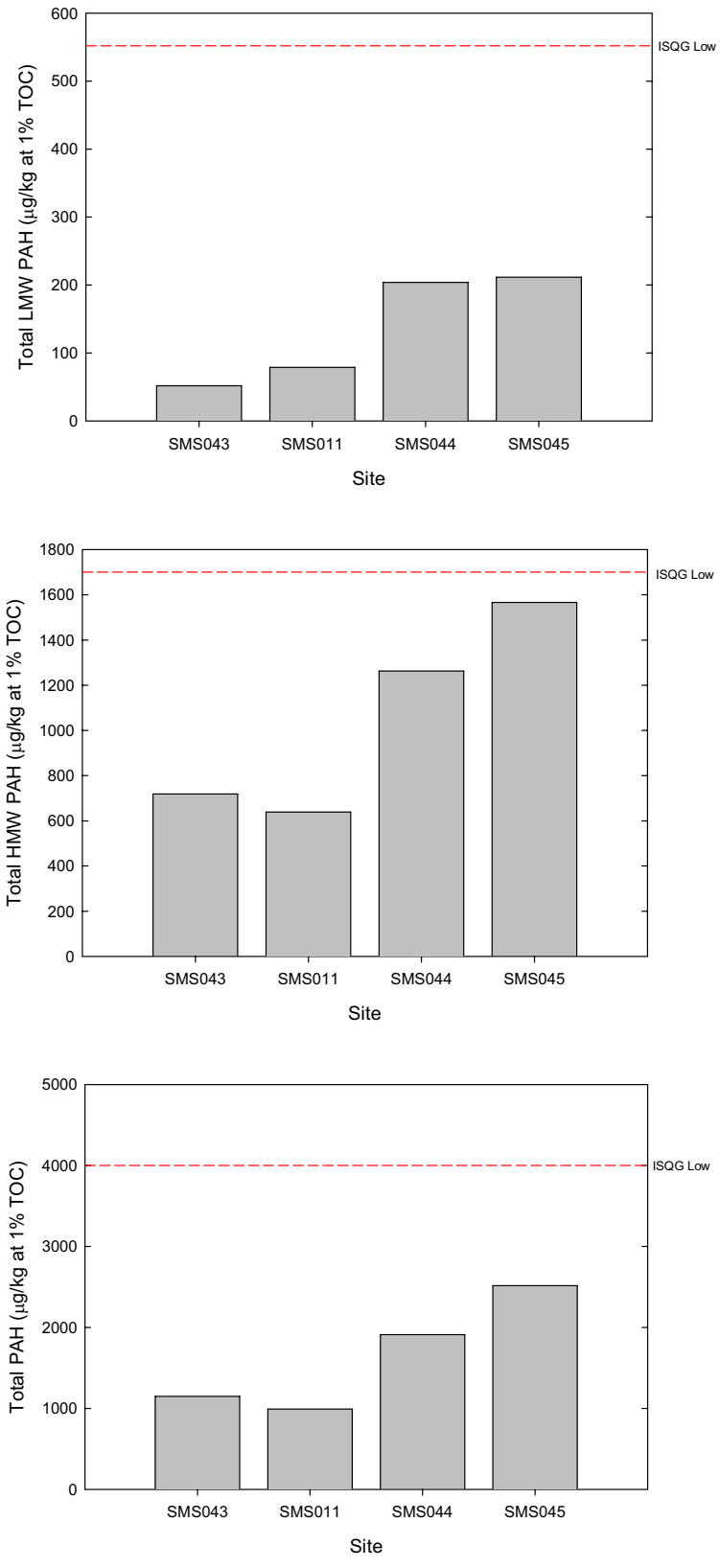

Figure 3.9: Concentrations of TOC-normalised Total Low Molecular Weight PAH, Total High Molecular Weight PAH and Total PAH in sediments of four streambed sites sampled in February 2009, based on a single composite sample from each site

3.2.5 Organochlorine pesticides

Of the 25 organochlorine pesticide compounds analysed, only DDT, DDE and DDD were consistently found above analytical detection limits in the sediments of all four streambed sites. Total DDT concentrations ranged from 9.2–22.6 µg/kg and exceeded the ANZECC ISQG-Low trigger value at all four sites (Table 3.4, Figure 3.10). The ISQG-Low trigger value was also exceeded at all the sites for concentrations of the individual DDT compound 2,4'-DDD + 4,4'-DDD, and at both sites on the Porirua Stream (SMS043 and SMS044) for concentrations of 4,4'-DDE. Dieldrin was detected at concentrations greater than the ISQG-Low trigger value at two sites (Porirua Stream downstream of Kenepuru Stream confluence and Onepoto Stream); the detection limit was too high to determine whether the trigger value was exceeded at the other two sites.

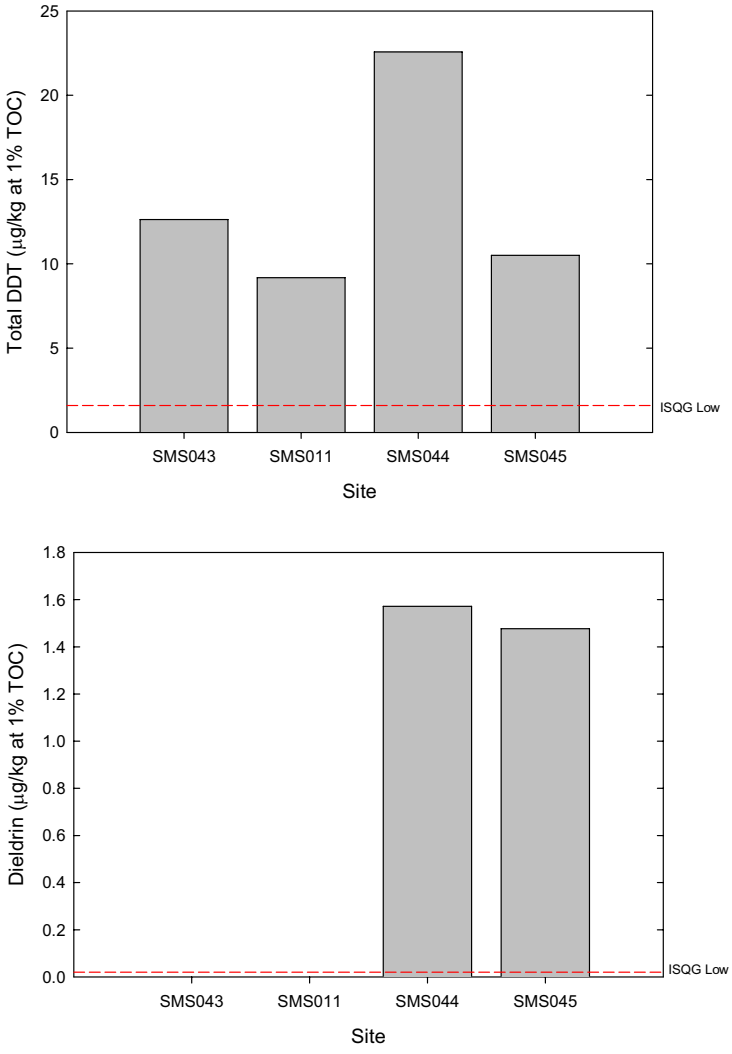

Figure 3.10: Concentrations of TOC-normalised Total DDT and dieldrin in sediments of four streambed sites sampled in February 2009, based on the <2 mm fraction of a single composite sample from each site

4. Discussion

Concentrations of one or more contaminants are present above sediment quality guidelines in the surface sediments of all 10 intertidal sites sampled at the southern-most end of the Onepoto Arm of the Porirua Harbour. Of the heavy metals, zinc exceeds the ARC ERC amber threshold at all sites and the ANZECC ISQG-Low trigger value at seven sites (Figure 4.1). Sediments from several sites also exceed ARC ERC amber thresholds for copper and lead (Figures 4.2 and 4.3), and one site exceeds the ANZECC ISQG-Low trigger value for mercury. Five sites have Total HMW PAH concentrations above the ARC ERC amber threshold, with one site close to the Semple Street stormwater outfall recording a concentration above the ANZECC ISQG-Low trigger value (Figure 4.4). Samples from all 10 sites exceed ARC ERC amber and ANZECC ISQG-Low trigger values for Total DDT, including the two sites where core samples were taken (Figure 4.6). There is good agreement between the present results and those obtained at site S4 in the 2004 investigation (Table 4.1).

Contaminant concentrations are generally highest in the sediments at sites in close proximity to the Semple Street stormwater outfall (POR-I and POR-J) and the Porirua Stream channel (e.g., POR-B, POR-C and POR-D). These findings confirm earlier conclusions (e.g., Glasby et al. 1990, Botherway & Gardener 2002, Robertson & Stevens 2008) that stormwater outfalls and the Porirua Stream are the primary source of contaminants entering the southern end of the harbour. Although only two sediment core samples were taken, the presence of zinc at a concentration equal to the ANZECC ISQG-High trigger value in one suggests that contamination may be present to some depth, at least in the vicinity of the Semple Street stormwater outfall. Thick black anoxic sediments are common at most of the sites sampled between the outfall and the Porirua Stream, with only a very thin oxygenated layer of surface sediment present (refer Figure 2.2).

Elevated concentrations of one or more contaminants are also present in the surface sediments of intertidal sites in or adjacent to the mouths of the Onepoto Stream, Browns Stream and Duck Creek. Sediments from the Onepoto Stream mouth (especially site OP-B) contain concentrations of lead and zinc, Total DDT and various PAH compounds above ARC ERC amber and (in the case of PAHs) ANZECC ISQG-Low sediment quality guidelines (Figures 4.1–4.6). Total DDT concentrations in sediment samples taken adjacent to the mouths of Browns Stream and Duck Creek also exceed ARC ERC amber and ISQG-Low guideline values, with lead and Total HMW PAH concentrations above ARC ERC amber thresholds at site BB-C adjacent to the Browns Stream channel. There is good agreement between the present results and those obtained at these three locations in the 2004 investigation with two exceptions: lead concentrations are lower in the intertidal sediments adjacent to the mouths of Onepoto and Browns Bay streams in 2009 than in 2004, while zinc is higher in 2009 than in 2004 in the intertidal sediments at the mouth of Duck Creek (Table 4.2).

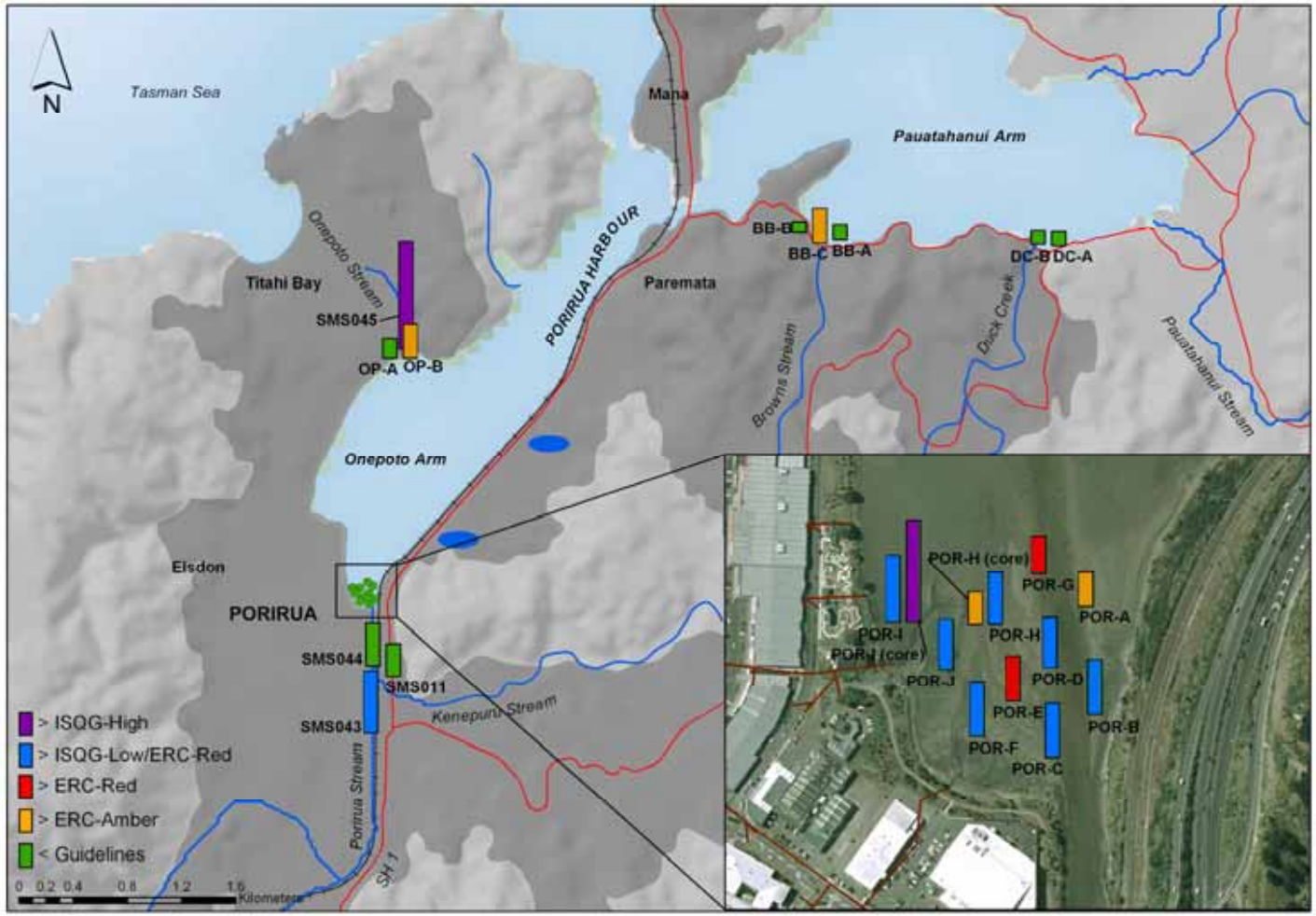

Figure 4.1: Concentration of total recoverable zinc in sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on the <2 mm fraction of a single composite sample from each site. Note that the scale used for the bars is unique to each map.

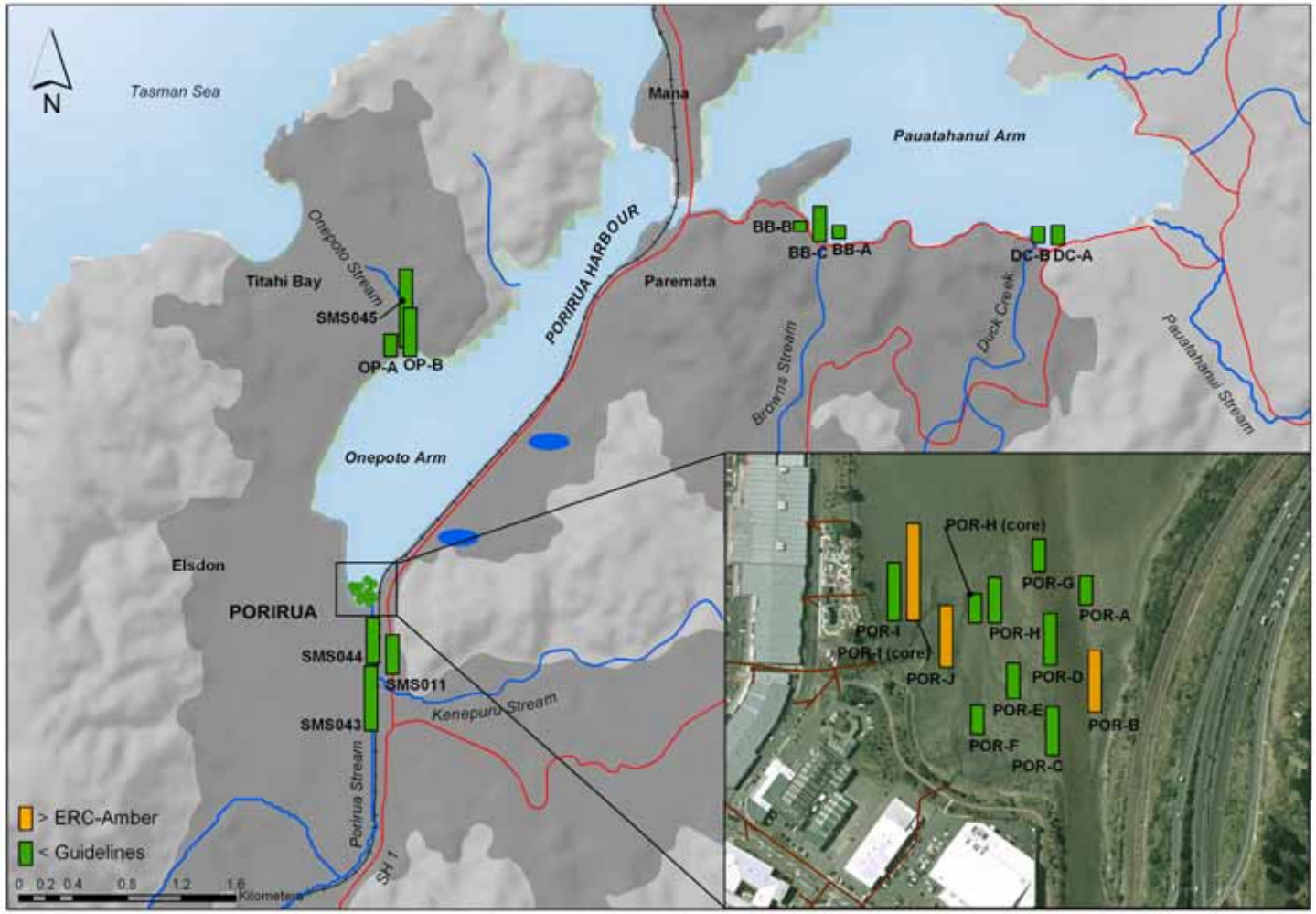

Figure 4.2: Concentration of total recoverable copper in sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on the <2 mm fraction of a single composite sample from each site. Note that the scale used for the bars is unique to each map.

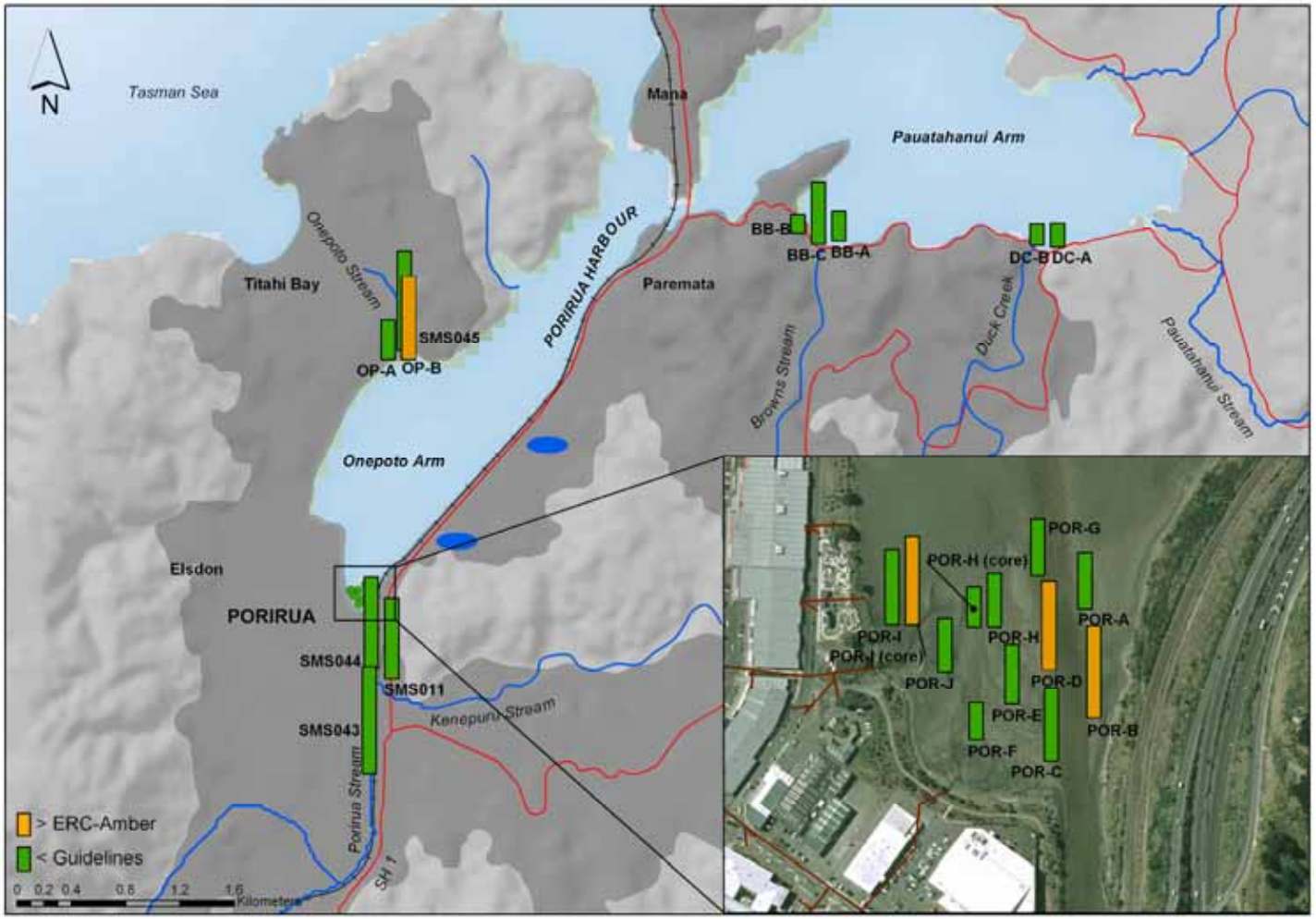

Figure 4.3: Concentration of total recoverable lead in sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on the <2 mm fraction of a single composite sample from each site. Note that the scale used for the bars is unique to each map.

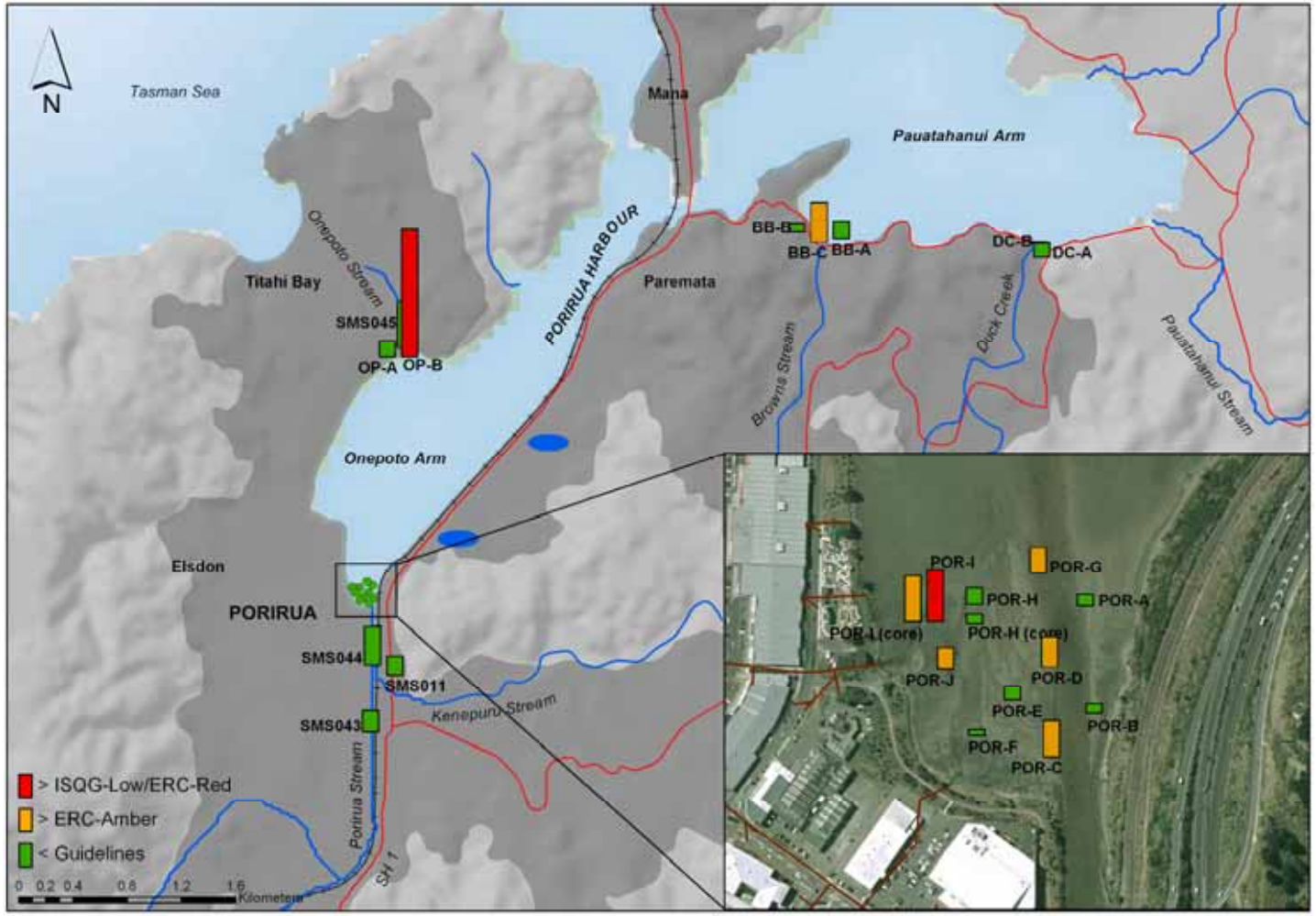

Figure 4.4: Concentration of Total HMW PAH in sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on a single composite sample from each site. Note that the scale used for the bars is unique to each map.

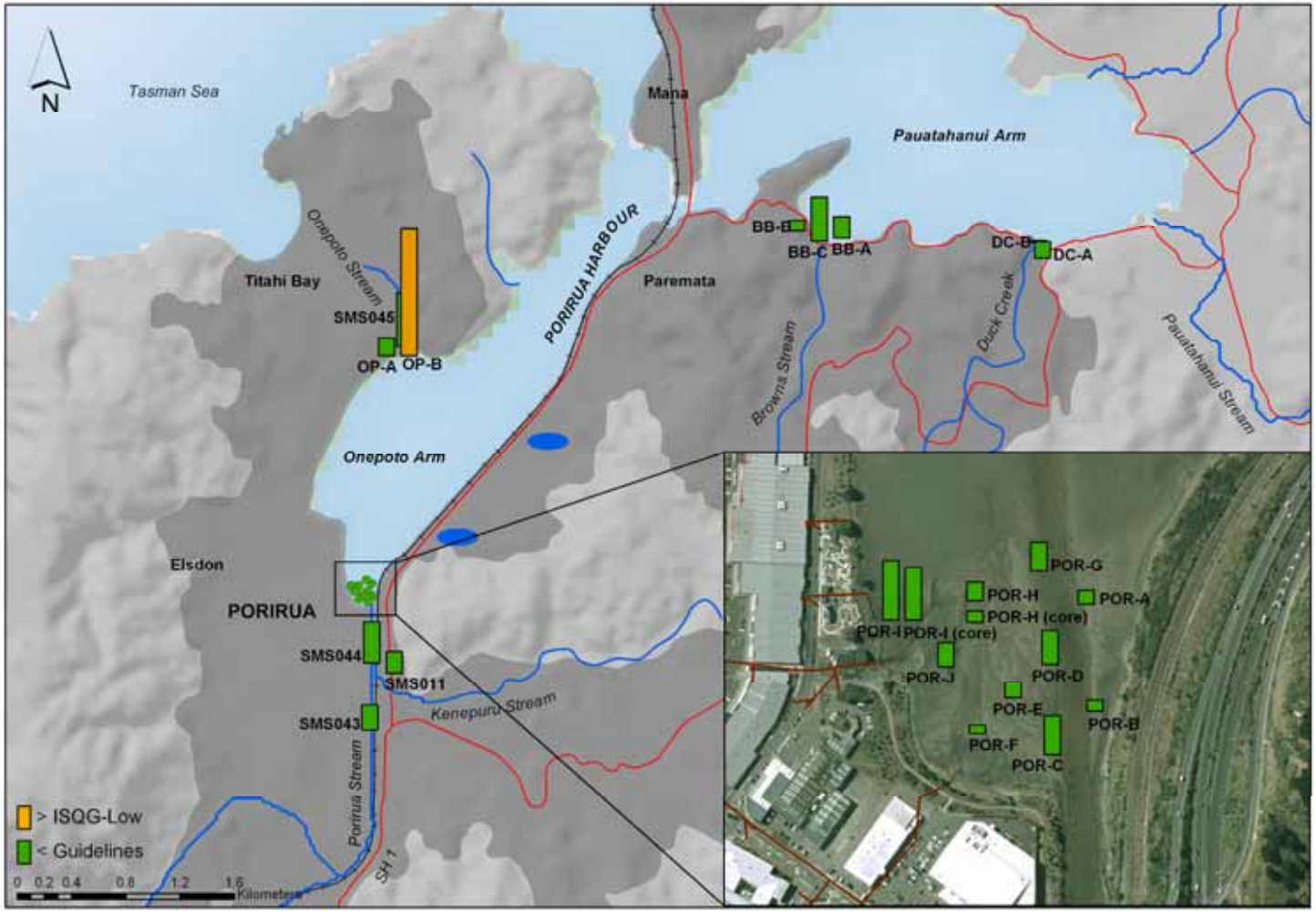

Figure 4.5: Concentration of Total PAH in sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on a single composite sample from each site. Note that the scale used for the bars is unique to each map.

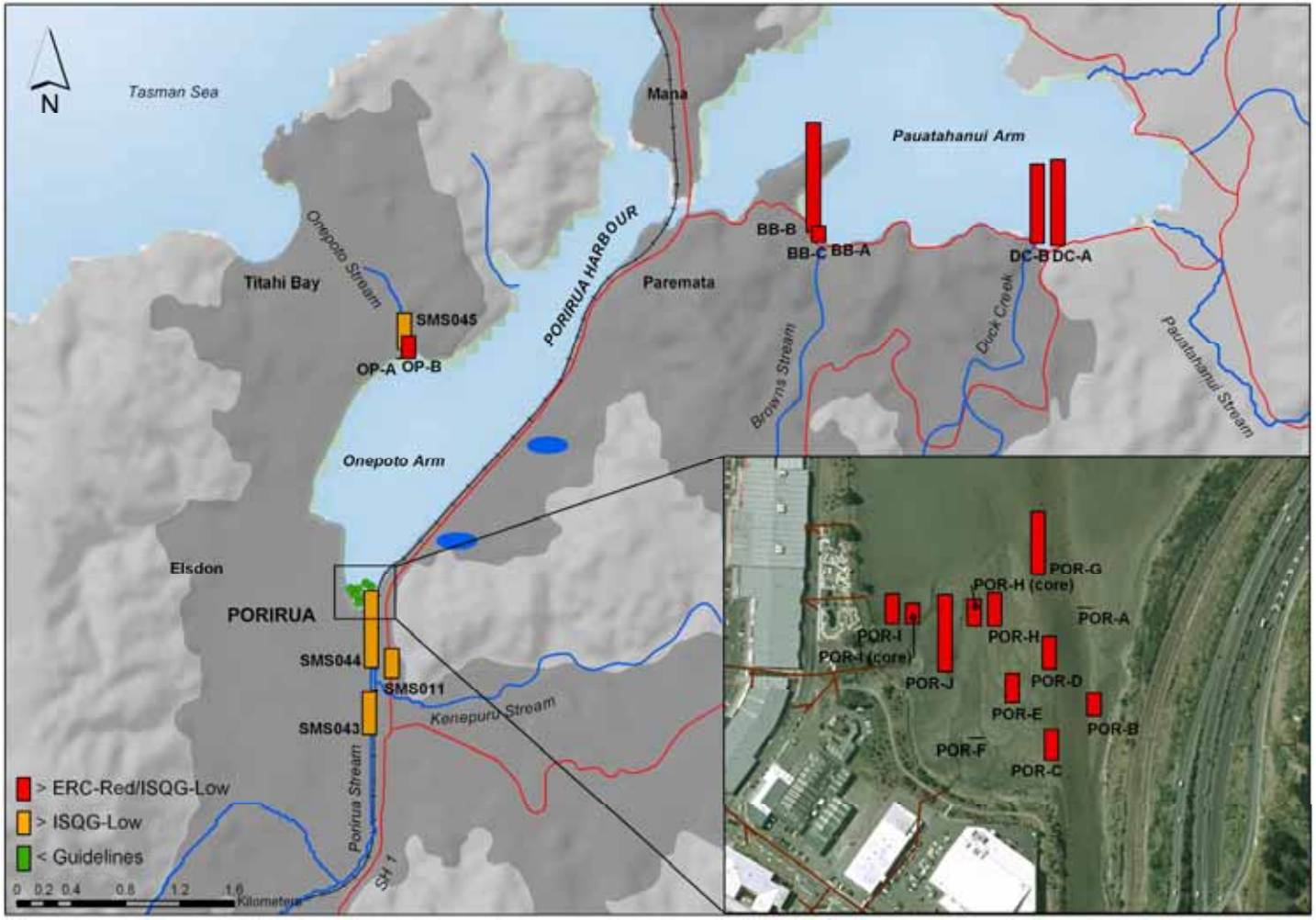

Figure 4.6: Concentration of Total DDT in sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on the <2 mm fraction of a single composite sample from each site. Note that the scale used for the bars is unique to each map.

Table 4.1: Summary of particle size, TOC, and selected contaminant concentrations in sediments at sites sampled in Area A of the Porirua Harbour targeted intertidal sediment quality assessment, and comparison with sediment quality data from nearby Greater Wellington intertidal and subtidal monitoring sites. Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ARC ERC amber threshold and values in red exceed the ARC ERC red threshold and/or the ANZECC ISQG-Low trigger value. The value in bold red font exceeds the ANZECC ISQG-High trigger value.

	Guidelines				2009 investigation	2004 investigation site[1]	Long-term monitoring site[2]	Long-term monitoring site[3]
	ANZECC		ARC ERC		Intertidal	Intertidal	Intertidal	Subtidal
	ISQG-Low	ISQG-High	amber	red	(Area A)	(S4)	(POR-B)	(POR-1)
Fraction analysed					<2 mm [4]	<500 µm	<2 mm	<500 µm
Mean particle size (µm)	-	-	-	-	54.8 – 251.1	154.6	-	39.1 – 47.5
% particles <63 µm	-	-	-	-	3.29 – 55.4	3.44	4.03 – 5.73	73.8 – 85.8
Metals (mg/kg, total digest):								
Arsenic	20	70	-	-	2.4 – 8.7	2.1	-	10.5 – 12.0
Cadmium	1.5	10	-	-	0.06 – 0.19	0.09	0.04 – 0.05	0.14 – 0.17
Chromium	80	370	-	-	7.7 – 17	6.5	5.1 – 5.6	16.3 – 24.0
Copper	65	270	19	34	8.5 – 30	9.7	3.6 – 3.9	21.0 – 26.9
Mercury	0.15	1	-	-	0.03 – 0.15	0.04	-	0.11 – 0.13
Nickel	21	52	-	-	4.9 – 10	3.9	3.7 – 9.5	10.4 – 14.0
Lead	50	220	30	50	14 – 34	15	3.6 – 8.9	40.2 – 42.0
Zinc	200	410	124	150	130 – **410**	134	58 – 60	169 – 203
TOC (%)	-	-	-	-	0.24 – 2.2	0.37	0.21 – 0.60	1.94 – 2.22
Organics (µg/kg)[5]:								
Total HMW PAH	1,700	9,600	660	1,700	191 – 1,738	1,241	-	202 – 211
Total PAH	4,000	45,000	-	-	366 – 2,761	2,159	-	367 – 368
Total DDT	1.6	46	-	3.9	5.6 – 23.0	-	-	4.4 – 5.8

[1] See Appendix 1 for the results of the full list of compounds analysed (results previously unpublished).

[2] Results are shown as a range from data presented in Robertson & Stevens (2008) and Robertson & Stevens (2009).

[3] Results are shown as a range from data presented in Stephenson & Mills (2006) and Milne et al. (2009).

[4] The exception is PAHs for which the laboratory analysed the samples on an "as received" basis.

[5] Concentrations expressed for a sediment containing 1% TOC.

Table 4.2: Summary of particle size, TOC and selected contaminant concentrations in sediments near stream outlets sampled in the Porirua Harbour targeted intertidal sediment quality assessment, and comparison with sediment quality data from previous Greater Wellington intertidal and streambed investigations. Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ARC ERC amber threshold and values in red exceed both the ARC ERC red threshold and the ANZECC ISQG-Low trigger value. The values in bold red font exceed the ANZECC ISQG-High trigger value. ND=not detected.

	Guidelines				Onepoto Stream mouth			Brown's Bay			Duck Creek mouth		
	ANZECC		ARC ERC		2009	2004	2009	2009	2004	2005-06	2009	2004	2005-06
	ISQG-Low	ISQG-High	amber	red	Intertidal (OP-A, OP-B)	Intertidal (S7)[1]	Streambed (SMS045)	Intertidal (BB-A – BB-C)	Intertidal (P7)[1]	Streambed (SMS013)[2]	Intertidal (DC-A, DC-B)	Intertidal (P9)[1]	Streambed (SMS015)[2]
Fraction analysed					<2 mm[3]	<500 µm	<2 mm	<2 mm[3]	<500 µm	<2 mm	<2 mm[3]	<500 µm	<2 mm
Mean particle size (µm)	-	-	-	-	237.2 – 240.0	281.6	-	171.4 – 227.6	135.9	-	309.6	192.2	-
% particles <63 µm	-	-	-	-	11.5 – 22.7	11.0	7.5	8.3 – 18.1	19.2	0 – 3.4	8.78	4.05	3.5 – 10.2
Metals (mg/kg, total digest):													
Arsenic	20	70	-	-	9.0 – 9.2	10.7	6.3	2.9 – 6.6	4.9	5.9 – 12.1	2.6 – 3.0	2.9	2.6 – 3.2
Cadmium	1.5	10	-	-	0.05 – 0.06	0.02	0.15	0.03 – 0.06	0.04	0.05	0.03	ND	0.04
Chromium	80	370	-	-	9.5 – 12	13.1	14	4.9 – 9.8	10.6	14.3 – 14.9	8.9 – 9.6	7.0	11.9 – 14.3
Copper	65	270	19	34	7.4 – 15	11.4	24	2.7 – 11	14.9	16.0 – 66.2	4.8 – 5.6	3.8	6.5
Mercury	0.15	1	-	-	0.03 – 0.04	0.03	0.03	ND – 0.05	0.12	0.04 – 0.06	0.04 – 0.06	0.12	0.08 – 0.09
Nickel	21	52	-	-	7.0 – 9.5	8.0	13.0	3.5 – 6.7	6.9	11.6 – 13.9	7.1 – 8.3	3.1	9.1 – 10.9
Lead	50	220	30	50	15 – 31	51.3	37	7.2 – 23	37.7	25.6 – 39.7	8.2 – 9.1	5.42	10.8 – 12.3
Zinc	200	410	124	150	82 – 140	91.9	**430**	44 – 140	74.8	215 – 217	54 – 59	26.5	72.2 – 82.7
TOC (%)	-	-	-	-	0.33 – 0.55	0.22	0.88	0.24 – 1.90	0.87	0.74 – 1.03	0.31 – 0.35	0.16	0.60 – 0.88
Organics (µg/kg)[4]:													
Total HMW PAH	1,700	9,600	660	1,700	542 – 4,273	1,618	1,566	282 – 1,325	546	34	36 – 492	356	ND – 9
Total PAH	4,000	45,000	-	-	864 – 5,945	2,841	2,516	498 – 2,068	1,011	70 – 80	91 – 771	556	ND – 30
Total DDT	1.6	46	-	3.9	ND – 6.8	-	10.5	ND – 32.9	-	3 – 16	23.9 – 25.8	-	12 – **66**

[1] See Appendix 1 for the results from the full list of compounds analysed for (results previously unpublished by Greater Wellington).

[2] Results are shown as a range from data presented in Milne & Watts (2008).

[3] The exception is PAHs for which the laboratory analysed the samples on an "as received" basis.

[4] Concentrations expressed for a sediment containing 1% TOC.

Table 4.3: Summary of % mud, % TOC and selected contaminant concentrations in streambed sediments at sites upstream of Area A in the Onepoto Arm of the Porirua Harbour sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment, and concentrations reported by Milne & Watts (2008)[1] for other streambed sediments sampled in the Porirua Stream catchment in 2005 and 2006. ANZECC (2000) sediment quality guidelines are provided for comparison – values in amber and red exceed the ISQG-Low and ISQG-High trigger values respectively. ND=not detected.

	ANZECC Guidelines		SMS007	SMS008	SMS010	SMS009	SMS043 (2009)	SMS011	SMS011 (2009)	SMS044 (2009)
	ISQG-Low	ISQG-High	Porirua S at Redwood Station	Porirua S at Glenside O/Cables	Mitchell S d/s Kenepuru Drive	Porirua S at Kenepuru fields	Porirua S u/s of Kenepuru S	Kenepuru S u/s SH 1	Kenepuru S u/s Porirua S	Porirua S d/s Kenepuru S
Fraction analysed			<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm	<2 mm
% particles <63 µm	-	-	0.62 – 4.1	1.7 – 7.0	2.2 – 5.7	1.7 – 2.1	19.1	0 – 12.9	8.6	4.9
Metals (mg/kg):										
Arsenic	20	70	4.7 – 5.1	4.7 – 5.7	4.9 – 5.1	5.5 – 5.7	6.8	5.4 – 5.7	5.0	5.5
Cadmium	1.5	10	0.06	0.07 – 0.08	0.05 – 0.09	0.06	0.14	0.06 – 0.08	0.08	0.08
Chromium	80	370	14.3 – 15.4	16.0 – 19.1	13.7 – 15.1	15.3 – 16.7	15	14.1 – 14.9	14	13
Copper	65	270	13.5 – 13.9	16.2 – 17.7	13.2 – 17.2	14.3 – 14.6	20	12.6 – 17.9	12	14
Mercury	0.15	1	0.05 – 0.06	0.06	0.10 – 0.11	0.06 – 0.09	0.07	0.06 – 0.07	0.04	0.08
Nickel	21	52	12.3 – 13.0	13.9 – 15.6	13.3 – 15.4	12.3 – 12.7	12.0	11.0 – 12.6	9.8	11.0
Lead	50	220	23.7 – 26.3	26.6 – 41.4	20.9 – 32.6	25.2 – 26.7	40	28.2 – 42.5	30	34
Zinc	200	410	135 – 160	154 – 158	148 – 227	140 – 180	250	131 – 140	130	170
TOC (%)	-	-	0.32 – 0.33	0.40 – 0.41	0.22 – 0.86	0.34 – 0.46	1.90	0.42 – 0.57	0.77	0.70
Organics (µg/kg)[2]:										
Total HMW PAH	1,700	9,600	72 – 142	49 – 58	322 – 345	135 – 178	718	5,850 – 11,900	639	1,263
Total PAH	4,000	45,000	180 – 270	110 – 140	590 – 710	270 – 330	1,149	9,530 – 18,400	993	1,911
Total DDT	1.6	46	ND – 7	29 – 54	ND – 39	5 – 34	12.6	6 – 54	9.2	22.6

[1] Results are shown as a range from data presented in Milne & Watts (2008).

[2] Concentrations expressed for a sediment containing 1% TOC.

Contaminant concentrations found in sediment samples from the Porirua and Kenepuru streambeds are generally within the range of the concentrations determined from sampling at other streambed locations in 2005 and 2006 (Milne & Watts 2008)[5], with zinc and Total DDT concentrations present above ANZECC ISQG-Low trigger values (Table 4.3). This was the first time sediments from the Onepoto Stream had been sampled and the results suggest a localised contaminant source is affecting both the streambed and intertidal sediments at the stream mouth. As well as exceeding ANZECC ISQG-Low trigger values for several HWM PAH compounds and dieldrin, the sediment sample from the Onepoto Stream also exceeded the ANZECC ISQG-High trigger value for zinc.

The small proportion of fine sediments present at the four streambed sites is consistent with the findings of previous streambed sampling reported by Milne & Watts (2008) and suggests that suspended particulates (fine sediments) in stormwater – and the contaminants attached to them – are not retained in streams for long, but instead are rapidly flushed through the system and into the Porirua Harbour, mainly during storms. This is confirmed by the presence of elevated contaminant concentrations in the surface sediments adjacent to the mouths of the Porirua, Onepoto and Browns streams and Duck Creek, as well as in the subtidal basins where the finer (muddier) sediments tend to accumulate (e.g., Stephenson & Mills 2006, Milne et al. 2009). In addition to contamination through the deposition of fine sediment particulates from stormwater, some of the harbour sediment contamination will also be arising through dissolved elements[6] that are taken out of solution through sorption and removal processes when stream storm flows enter saline water.

Although stormwater-derived contamination is clearly evident in the surface layers of the intertidal (and subtidal) sediments of Porirua Harbour, in most cases the contaminant concentrations only exceed 'alert level' or 'early warning' guidelines (e.g., ARC ERC amber thresholds). This indicates that there is an opportunity for management intervention to limit the extent of degradation and prevent adverse environmental effects from occurring. Of the metals, zinc is possibly the greatest concern because, based on this study alone, its concentration is above the ANZECC ISQG-Low trigger value in sediments covering an area of at least 20,000 m^2 at the southern-most end of the Onepoto Arm. Moreover, zinc is a persistent contaminant and stormwater quality and stream investigations to date confirm inputs of this metal are ongoing (e.g., Cameron 2001, KML 2005, Milne & Watts 2008), suggesting that sediment concentrations may increase over time. Managing zinc inputs is not likely to be easy; work undertaken in Auckland and overseas has identified the key sources of zinc in urban stormwater as being unpainted galvanized roofs and vehicle tyre wear (Timperley[7], pers. comm. 2008).

The other contaminant of concern is Total DDT (i.e., DDT+DDE+DDD) because it is widespread throughout the harbour in both the intertidal (this

[5] The main exception is PAH concentrations in the Kenepuru Stream; significantly higher concentrations were recorded in streambed sediments collected in 2005 (see Table 4.3 and Milne & Watts 2008).

[6] Some contaminants, in particular heavy metals, are present at biologically significant concentrations in both piped stormwater and wet weather stream flows – *see* KML (2005) and Milne & Watts (2008).

[7] Dr Mike Timperley, Timperley Associates (former Stormwater Action Team Leader, Auckland Regional Council).

study) and subtidal sediments (*see* Stephenson & Mills 2006). The consistent detection of DDT and its derivatives reflects the widespread application of this pesticide to rural and urban land last century. Although the use of DDT in agriculture effectively ceased in the 1970s, and its use in urban areas has been banned since the late 1980s, the streambed sediment results in this study, together with the results of previous stormwater quality and streambed sediment investigations (e.g., Cameron 2001, KML 2005, Milne & Watts 2008) confirm inputs to the harbour are ongoing. DDT, DDE and DDD tend to bind strongly to sediment particles and this – together with the organic carbon content[8] of the sediments – is probably limiting their bioavailability and therefore their impact on the benthic biota.

[8] ANZECC (2000) suggests guidelines for organic contaminants should be 'relaxed' if the sediment organic carbon content is *"markedly higher than 1%"* due to the role organic carbon plays in binding with organic contaminants to reduce their bioavailability. This suggests that exceedance of guidelines in areas with elevated TOC levels may not necessarily be associated with adverse effects on benthic biota.

5 Conclusion

The results of this targeted assessment confirm that there is clear evidence of stormwater-derived contamination at intertidal sites in Porirua Harbour located in close proximity to urban stormwater outfalls and stream mouths. Concentrations of one or more contaminants are present above sediment quality guidelines in the surface sediments of all 17 intertidal sites sampled. Stormwater-derived contaminants are also present in the sediments from the beds of streams that discharge into the Porirua Harbour.

In most cases, existing sediment contaminant concentrations only exceed 'alert level' or 'early warning' guidelines indicating that there is an opportunity for management intervention to limit the extent of degradation and prevent adverse environmental effects from occurring. Zinc and DDT are the contaminants of greatest concern because concentrations are present above their respective ANZECC ISQG-Low trigger values in both intertidal and subtidal sediments (zinc over much of the southern end of the Onepoto Arm and DDT throughout the harbour). Zinc and DDT are persistent contaminants and stormwater and stream investigations to date confirm inputs of both are ongoing.

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Appendix 1: 2004 Intertidal sediment sampling locations & results

Table A1.1: 2004 intertidal sediment sampling locations and details

Site	Location	Date	Position (NZMG coordinates)	
			Easting	Northing
S1	Paremata Railway	27/01/2004	2666653	6009511
S2	Papakowhai	3/02/2004	2666004	6008365
S3	Aotea Lagoon	3/02/2004	2665913	6007962
S4	Porirua Stream	27/01/2004	2664603	6006992
S5	Takapuwahia	27/01/2004	2664275	6007600
S6	Whanga Avenue	26/01/2004	2664470	6008132
S7	Onepoto Park	26/01/2004	2664933	6008673
S8	Te Onepoto Bay	29/01/2004	2665806	6009261
S9	"Whitireia Creek"	29/01/2004	2666392	6010384
P1	Horokiri Stream	14/01/2004	2669837	6010642
P2	Motukaraka Point	14/01/2004	2669438	6010675
P3	Kakaho Stream	14/01/2004	2669040	6011345
P4	"Camborne Creek"	14/01/2004	2668097	6011302
P5	Pascoe Avenue	16/01/2004	2667155	6010466
P6	Ivey Bay	16/01/2004	2667370	6009705
P7	Browns Bay	16/01/2004	2667986	6009597
P8	Bradeys Bay	16/01/2004	2668961	6009506
P9	Duck Creek	16/01/2004	2669597	6009501
P10	Pauatahanui Stream	14/01/2004	2670387	6009757

Table A1.2: 2004 intertidal sediment quality results (<500 µm fraction)

Site	S1	S2	S3	S4	S5	S6	S7	S8	S9	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
TOC (%)	0.28	0.69	-	0.37	0.52	0.39	0.22	0.32	0.17	0.52	1.46	1.32	2.8	0.27	0.29	0.87	0.36	0.16	0.35
Metals (mg/kg):																			
Arsenic	5.3	6.2	-	2.1	4	5.6	10.7	5.6	7.2	2.9	6	3.1	7.8	1.2	4.9	4.9	4.4	2.9	2.8
Cadmium	0.01	0.03	-	0.09	0.03	0.01	0.02	0.04	< 0.01	0.03	0.05	0.04	0.05	0.01	0.02	0.04	0.02	< 0.01	0.03
Chromium	10.1	11.4	-	6.5	7.9	9	13.1	9.6	9.5	9.5	12.4	9.5	13.3	3.2	10.5	10.6	6.8	7	8.3
Copper	4.4	9.3	-	9.7	8.1	7.8	11.4	8.5	4	8	10.4	9.4	11.2	2.2	7.6	14.9	5.9	3.8	6
Lead	6.49	16.4	-	15	22.4	20.7	51.3	16.4	5.13	11.1	16.3	11.5	14.4	3.71	9.71	37.7	10.9	5.42	9.71
Mercury	0.02	0.04	-	0.04	0.02	0.03	0.03	0.04	0.01	0.03	0.06	0.05	0.08	0.01	0.04	0.12	0.04	0.12	0.06
Nickel	6.7	7.9	-	3.9	6	5.4	8	8.2	6.8	8	9	8.4	9.1	2.2	7.2	6.9	4	3.1	5.4
Silver	0.02	0.04	-	0.04	0.03	0.04	<0.02	0.03	<0.02	0.04	0.07	0.06	0.07	<0.02	0.02	0.04	<0.02	<0.02	0.02
Zinc	33.1	67	-	134	80.7	62.5	91.9	66	30.6	51.2	59.6	49	57.1	14.7	55	74.8	53	26.5	48.8
PAHs (µg/kg):																			
Naphthalene	< 30	< 30	-	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 30	< 20	< 30	< 30	< 30	< 30	< 30	< 30
Acenaphthylene	2.5	2.5	-	13	2.5	9	13	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Acenaphthene	2.5	2.5	-	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Fluorene	2.5	2.5	-	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Phenanthrene	2.5	2.5	-	137	6	2.5	14	21	2.5	2.5	2.5	2.5	47	2.5	2.5	23	9	6	2.5
Anthracene	2.5	2.5	-	2.5	2.5	7	11	2.5	2.5	2.5	2.5	2.5	13	2.5	2.5	7	2.5	2.5	2.5
Fluoranthene	2.5	2.5	-	157	13	22	78	120	2.5	2.5	10	2.5	239	19	12	104	29	14	22
Pyrene	2.5	2.5	-	148	13	20	72	107	2.5	2.5	11	2.5	209	13	12	95	26	13	20
Benz[a]anthracene	2.5	2.5	-	27	7	18	53	56	2.5	2.5	2.5	2.5	119	6	2.5	63	13	2.5	8
Chrysene	2.5	2.5	-	70	22	37	73	86	2.5	2.5	17	2.5	157	23	20	107	33	17	24

Table A1.2 *cont.*: 2004 intertidal sediment quality results (<500 µm fraction)

Site	S1	S2	S3	S4	S5	S6	S7	S8	S9	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Benzo[b]fluoranthene	6	5	-	72	16	47	95	84	2.5	2.5	9	2.5	239	15	11	159	31	11	18
Benzo[k]fluoranthene	2.5	2.5	-	38	7	23	50	48	2.5	2.5	2.5	2.5	113	8	6	81	18	6	11
Benzo[a]pyrene	2.5	2.5	-	50	8	25	69	54	2.5	2.5	2.5	2.5	153	2.5	7	88	19	8	12
Indeno[1,2,3-c,d]pyrene	2.5	2.5	-	32	5	17	38	25	2.5	2.5	2.5	2.5	73	8	2.5	57	12	5	8
Dibenz[a,h]anthracene	2.5	2.5	-	7	2.5	2.5	11	9	2.5	2.5	2.5	2.5	26	2.5	2.5	18	2.5	2.5	2.5
Benzo[g,h,i]perylene	2.5	2.5	-	48	9	20	48	30	2.5	2.5	8	2.5	105	2.5	9	78	19	9	12

Appendix 2: Analytical methods

Table A2.1: Intertidal sediment analytical methods

Variable	Method	Detection Limit
Particle Size Analysis	Malvern Laser Sizer particle size analysis. Subcontracted to Earth Sciences Department, Waikato University, Hamilton	N/A
Total Organic Carbon (TOC) and Total Nitrogen	Catalytic Combustion (900°C, O^2), separation, Thermal Conductivity Detector [Elementar Analyser]	N/A
Total Recoverable Phosphorus	Total Recoverable digest Nitric / hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt
Total Recoverable Metals	Total Recoverable digest Nitric / hydrochloric acid digestion. US EPA 200.2.	N/A
Polycyclic Aromatic Hydrocarbons (PAHs)	Sonication Extraction, SPE cleanup, GC-MS selected ion monitoring quantitation. US EPA 8270C.	N/A
Organochlorine pesticides (OCPs)	Sonication extraction, SPE cleanup, GPC cleanup, dual column GC-ECD analysis.	N/A

Table A2.2: Streambed sediment analytical methods

Variable	Method	Detection Limit
Sediment Texture (2 mm, 500 µm, 250 µm, 63 µm sieves)	Wet sieving, 2mm, 500 µm, 250 µm and 63 µm sieves, gravimetry.	0.1 g/100 g dry wt
Total Organic Carbon (TOC)	Acid pretreatment to remove carbonates if present, Elementar Combustion Analyser.	0.05 g/100g dry wt
Total Recoverable Metals	Total Recoverable digest Nitric / hydrochloric acid digestion. US EPA 200.2.	N/A
Polycyclic Aromatic Hydrocarbons (PAHs)	Sonication Extraction, SPE cleanup, GC-MS selected ion monitoring quantitation. US EPA 8270C.	N/A
Organochlorine pesticides (OCPs)	Sonication extraction, SPE cleanup, GPC cleanup, dual column GC-ECD analysis	N/A

Appendix 3: Intertidal sediment chemistry results

See Appendix 4 for sediment particle size results.

Site	POR-A	POR-B	POR-C	POR-D	POR-E	POR-F	POR-G	POR-H	POR-H (core)	POR-I	POR-I (core)	POR-J
Dry Matter (g/100 g)	74	54	65	68	75	80	76	76	76	78	79	78
Total organic carbon (%)	0.45	2.2	1.1	1.1	0.52	0.3	0.24	0.39	0.82	0.95	0.95	0.33
Total nitrogen (g/100 g)	0.052	0.18	0.14	0.088	0.081	< 0.050	< 0.050	< 0.050	< 0.13	0.25	0.069	< 0.051
Carbon:Nitrogen ratio	8.5	12	8.2	13	6.5	6.4	6.1	8.3	12	3.9	14	7.3
Total recoverable phosphorus (mg/kg)	330	560	410	410	290	190	300	350	240	450	630	290
Metals (mg/kg, strong acid, <2 mm):												
Arsenic	4.8	8.7	5.4	5.1	3.5	2.4	4	3.1	3.8	4.8	5.3	3.7
Cadmium	0.076	0.15	0.16	0.11	0.17	0.13	0.059	0.13	0.17	0.16	0.19	0.11
Chromium	11	17	13	15	12	7.7	12	11	9.3	16	15	13
Copper	8.8	19	15	16	11	8.8	9.7	14	8.5	18	30	19
Lead	21	34	27	33	22	14	21	20	15	28	33	20
Mercury	0.048	0.1	0.066	0.15	0.041	0.029	0.053	0.034	0.04	0.059	0.062	0.045
Nickel	7.9	9.8	8	9.3	7.4	4.9	8.6	6.5	6.9	9.7	10	7.6
Zinc	140	220	220	200	180	220	150	210	130	270	410	200
Polycyclic Aromatic Hydrocarbons (µg/kg):												
Acenaphthene	< 2.0	2.9	3.2	5.1	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	13	6.2	< 2.0
Acenaphthylene	< 2.0	3.9	4.6	8.3	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	6	7.1	< 2.0
Anthracene	2.9	13	22	29	3.4	< 2.0	3.3	3.7	2.9	49	33	2.6
Benzo[a]anthracene	21	83	170	140	31	8.3	27	26	36	210	200	30
Benzo[a]pyrene (BAP)	28	100	210	160	40	9.5	32	34	41	220	230	42

Site	POR-A	POR-B	POR-C	POR-D	POR-E	POR-F	POR-G	POR-H	POR-H (core)	POR-I	POR-I (core)	POR-J
Benzo[b]fluoranthene + Benzo[j]fluoranthene	34	110	200	160	41	15	39	32	55	220	220	40
Benzo[g,h,i]perylene	20	86	130	110	27	9.6	20	22	28	130	150	32
Benzo[k]fluoranthene	18	46	87	64	17	7.2	18	15	27	90	89	18
Chrysene	25	87	170	130	31	9.6	28	27	36	200	170	31
Dibenzo[a,h]anthracene	3.8	24	46	33	8.8	< 2.0	4.3	< 2.0	6.4	51	49	8.5
Fluoranthene	47	220	400	330	64	14	56	69	71	540	430	65
Fluorene	< 2.0	3.8	< 2.1	11	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	19	9.8	< 2.0
Indeno[1,2,3-c,d]pyrene	14	71	140	98	25	6	16	20	21	150	150	30
Naphthalene	< 10	< 13	< 11	< 10	< 10	< 10	< 10	< 10	< 10	< 10	14	< 10
Phenanthrene	19	73	71	160	15	5.7	15	22	15	290	180	7.6
Pyrene	48	180	330	290	58	15	53	60	71	430	380	60
Total PAH (< D.L. = 0)	281	1,103	1,984	1,728	361	100	312	331	410	2,618	2,318	367
Total PAH (< D.L. = 0.5 x D.L.)	289	1,110	1,990	1,733	369	110	320	340	418	2,623	2,318	375
<u>Organochlorine Pesticides (µg/kg, <2 mm):</u>												
Aldrin	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
alpha-BHC	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
beta-BHC	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
delta-BHC	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
gamma-BHC (Lindane)	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Cis-chlordane	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Trans-chlordane	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
2,4'-DDE	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
2,4'-DDD	< 1.1	2.3	1.8	2.6	< 1.1	< 0.99	< 1.0	< 0.98	2.7	< 1.1	< 1.0	< 1.1

Site	POR-A	POR-B	POR-C	POR-D	POR-E	POR-F	POR-G	POR-H	POR-H (core)	POR-I	POR-I (core)	POR-J
2,4'-DDT	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
4,4'-DDE	< 1.1	5.4	3.7	4.1	1.8	< 0.99	2.0	1.4	2.2	3.5	2.8	1.8
4,4'-DDD	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
4,4'-DDT	< 1.1	6.9	2.6	3.2	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	2.7	< 1.0	3.6
Dieldrin	< 1.1	1.3	1.0	1.2	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	1.1	< 1.0	< 1.1
Endosulphan I	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Endosulphan II	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Endosulphan sulphate	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Endrin	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Endrin aldehyde	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Endrin ketone	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Heptachlor	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Heptachlor epoxide	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Hexachlorobenzene	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Methoxychlor	< 1.1	< 1.1	< 1.0	< 1.0	< 1.1	< 0.99	< 1.0	< 0.98	< 1.0	< 1.1	< 1.0	< 1.1
Total Chlordane ((cis+trans)*100/42)	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Total DDT (< D.L. = 0)	0	14.6	8.1	9.9	1.8	0	2	1.4	4.9	6.2	2.8	5.4
Total DDT (< D.L. = 0.5 x D.L.)	3.3	16.25	9.6	11.4	4.55	2.97	4.5	3.85	6.9	8.4	5.3	7.6

Site	OP-A	OP-B	BB-A	BB-B	BB-C	DC-A	DC-B
Dry Matter (g/100 g)	75	72	80	78	66	78	75
Total organic carbon (%)	0.33	0.55	0.32	0.24	1.9	0.31	0.35
Total nitrogen (g/100 g)	0.091	0.077	< 0.050	< 0.050	0.13	< 0.050	< 0.051
Carbon:Nitrogen ratio	3.7	7.2	7.6	6.7	15	6.3	7.3
Total recoverable phosphorus (mg/kg)	380	440	230	140	340	260	240
Metals (mg/kg, strong acid, <2 mm):							
Arsenic	9	9.2	4.8	2.9	6.6	3	2.6
Cadmium	0.045	0.056	0.025	0.03	0.061	0.033	0.032
Chromium	9.5	12	7.1	4.9	9.8	9.6	8.9
Copper	7.4	15	4.1	2.7	11	5.6	4.8
Lead	15	31	11	7.2	23	9.1	8.2
Mercury	0.032	0.039	< 0.010	0.013	0.046	0.06	0.035
Nickel	7	9.5	5.4	3.5	6.7	8.3	7.1
Zinc	82	140	63	44	140	59	54
Polycyclic Aromatic Hydrocarbons (µg/kg):							
Acenaphthene	< 2.0	9.1	< 2.0	< 2.0	12	< 2.0	< 2.0
Acenaphthylene	< 2.0	5	2.1	< 2.0	14	< 2.0	< 2.0
Anthracene	3	56	3.2	< 2.0	50	5.3	< 2.0
Benzo[a]anthracene	20	310	24	7.6	330	17	< 2.0
Benzo[a]pyrene (BAP)	28	320	38	11	390	18	2.2
Benzo[b]fluoranthene + Benzo[j]fluoranthene	27	280	36	14	390	25	2.8
Benzo[g,h,i]perylene	22	150	25	8.8	270	11	2.5
Benzo[k]fluoranthene	14	120	15	6.6	160	11	< 2.0

Site	OP-A	OP-B	BB-A	BB-B	BB-C	DC-A	DC-B
Chrysene	24	280	25	10	300	19	< 2.0
Dibenzo[a,h]anthracene	< 2.0	40	< 2.0	< 2.0	87	2.5	< 2.0
Fluoranthene	55	780	57	19	770	54	3.4
Fluorene	< 2.0	4.7	< 2.0	< 2.0	11	< 2.0	< 2.0
Indeno[1,2,3-c,d]pyrene	17	160	25	6	260	8.3	< 2.0
Naphthalene	< 10	< 10	< 10	< 10	< 11	< 10	< 10
Phenanthrene	15	130	15	7.4	240	18	2.9
Pyrene	51	620	47	19	640	42	3.9
Total PAH (< D.L. = 0)	276	3264.8	312.3	109.4	3924	231.1	17.7
Total PAH (< D.L. = 0.5 x D.L.)	285	3269.8	320.3	119.4	3929.5	239.1	31.7
Organochlorine Pesticides (µg/kg, <2 mm):							
Aldrin	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
alpha-BHC	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
beta-BHC	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
delta-BHC	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
gamma-BHC (Lindane)	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Cis-chlordane	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Trans-chlordane	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
2,4'-DDE	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
2,4'-DDD	< 1.1	< 1.1	< 0.99	1.4	< 1.0	3.7	3.9
2,4'-DDT	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
4,4'-DDE	< 1.1	1	< 0.99	1.0	4.2	1.6	1.6
4,4'-DDD	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1

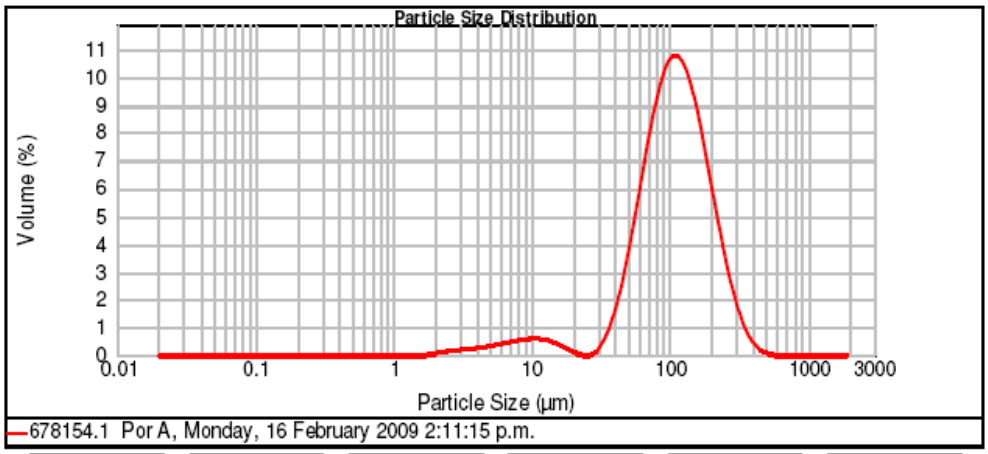
Site	OP-A	OP-B	BB-A	BB-B	BB-C	DC-A	DC-B
4,4'-DDT	< 1.1	< 1.1	< 0.99	4.0	3.8	1.2	1.2
Dieldrin	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Endosulphan I	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Endosulphan II	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Endosulphan sulphate	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Endrin	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Endrin aldehyde	1.9	5.9	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Endrin ketone	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Heptachlor	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Heptachlor epoxide	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Hexachlorobenzene	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Methoxychlor	< 1.1	< 1.1	< 0.99	< 0.99	< 1.0	< 0.99	< 1.1
Total Chlordane ((cis+trans)*100/42)	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0
Total DDT (< D.L. = 0)	0.0	1.0	0.0	6.4	8.0	6.5	6.7
Total DDT (< D.L. = 0.5 x D.L.)	3.3	3.8	3.0	7.4	10.0	8.0	7.8

Appendix 4: Intertidal sediment particle size results

Result Analysis Report

Sample Name: 678154.1 Por A	**SOP Name:** Marine Sediment	**Measured:** Monday, 16 February 2009 2:11:15 p.m.	
Sample Source & type: Hill	**Measured by:** rodgers	**Analysed:** Monday, 16 February 2009 2:11:16 p.m.	
Sample bulk lot ref: 2009011/1	**Result Source:** Measurement		
Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 18.97 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.399 %	**Result Emulation:** Off
Concentration: 0.1538 %Vol	**Span :** 1.545	**Uniformity:** 0.491	**Result units:** Volume
Specific Surface Area: 0.106 m²/g	**Surface Weighted Mean D[3,2]:** 56.420 um	**Vol. Weighted Mean D[4,3]:** 119.617 um	

d(0.1): 48.459 um **d(0.5):** 106.059 um **d(0.9):** 212.325 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.02
2.000	0.69
3.900	1.69
7.800	2.49
15.600	0.53
31.000	0.77
37.000	

Size (µm)	Volume In %
37.000	1.96
44.000	4.16
53.000	6.25
63.000	7.99
74.000	10.60
88.000	12.16
105.000	

Size (µm)	Volume In %
105.000	12.24
125.000	11.43
149.000	9.45
177.000	7.19
210.000	5.04
250.000	3.13
300.000	

Size (µm)	Volume In %
300.000	1.36
350.000	0.66
420.000	0.16
500.000	0.01
590.000	0.00
710.000	0.00
840.000	

Size (µm)	Volume In %
840.000	0.00
1000.000	0.00
2000.000	

Result Analysis Report

Sample Name:
678154.2 Por B

SOP Name:
Marine Sediment

Measured:
Monday, 16 February 2009 2:24:19 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Monday, 16 February 2009 2:24:21 p.m.

Sample bulk lot ref:
2009011/2

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
18.74 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.376 %

Result Emulation:
Off

Concentration:
0.0526 %Vol

Span :
3.532

Uniformity:
1.35

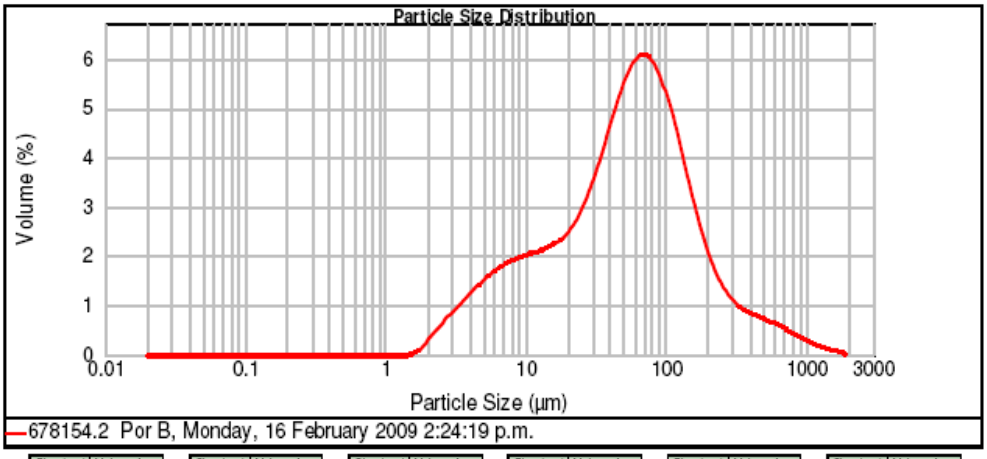
Result units:
Volume

Specific Surface Area:
0.29 m²/g

Surface Weighted Mean D[3,2]:
20.661 um

Vol. Weighted Mean D[4,3]:
97.767 um

d(0.1): 7.355 um **d(0.5):** 54.745 um **d(0.9):** 200.702 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.17
2.000	3.31
3.900	7.24
7.800	9.35
15.600	12.33
31.000	4.58
37.000	

Size (µm)	Volume In %
37.000	5.29
44.000	6.52
53.000	6.65
63.000	6.41
74.000	6.76
88.000	6.34
105.000	

Size (µm)	Volume In %
105.000	5.40
125.000	4.41
149.000	3.34
177.000	2.49
210.000	1.90
250.000	1.51
300.000	

Size (µm)	Volume In %
300.000	1.04
350.000	1.06
420.000	0.89
500.000	0.75
590.000	0.71
710.000	0.52
840.000	

Size (µm)	Volume In %
840.000	0.41
1000.000	0.62
2000.000	

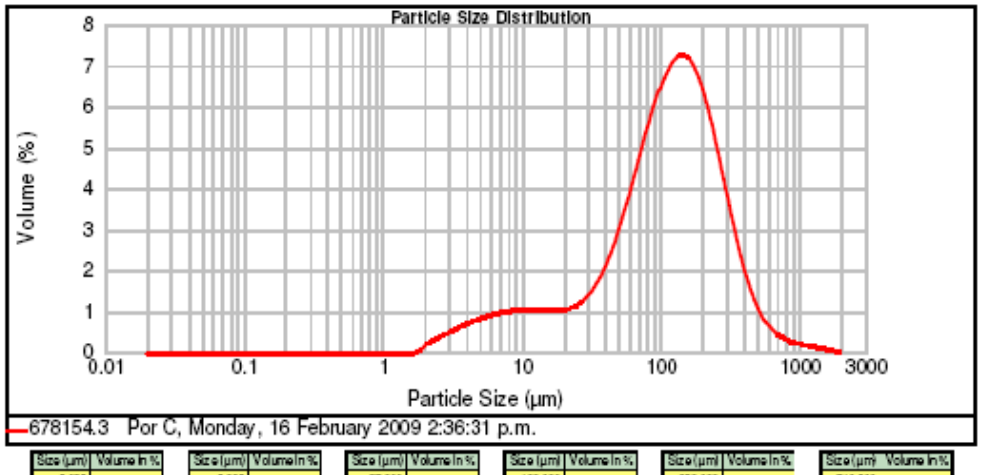
Result Analysis Report

Sample Name: 678154.3 Por C	**SOP Name:** Marine Sediment	**Measured:** Monday, 16 February 2009 2:36:31 p.m.
Sample Source & type: Hill	**Measured by:** rodgers	**Analysed:** Monday, 16 February 2009 2:36:32 p.m.
Sample bulk lot ref: 2009011/3	**Result Source:** Edited	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 16.83 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.262 %	**Result Emulation:** Off

Concentration: 0.0809 %Vol	**Span :** 2.536	**Uniformity:** 0.828	**Result units:** Volume
Specific Surface Area: 0.169 m²/g	**Surface Weighted Mean D[3,2]:** 35.471 um	**Vol. Weighted Mean D[4,3]:** 150.624 um	

d(0.1): 14.502 um **d(0.5):** 115.248 um **d(0.9):** 306.717 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.990	0.00

Size (µm)	Volume In %
0.990	0.05
2.000	1.91
3.900	3.92
7.800	4.60
15.600	5.05
31.000	1.90
37.000	

Size (µm)	Volume In %
37.000	2.43
44.000	3.45
53.000	4.17
63.000	4.82
74.000	5.21
88.000	5.21
100.000	

Size (µm)	Volume In %
100.000	2.11
105.000	7.04
125.000	8.34
149.000	8.05
177.000	7.39
210.000	6.50
250.000	

Size (µm)	Volume In %
250.000	5.40
300.000	3.40
350.000	2.77
420.000	1.66
500.000	0.96
590.000	0.64
710.000	

Size (µm)	Volume In %
710.000	0.37
840.000	0.27
1000.000	0.48
2000.000	

Result Analysis Report

Sample Name:
678154.4 Por D

SOP Name:
Marine Sediment

Measured:
Monday, 16 February 2009 2:49:20 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Monday, 16 February 2009 2:49:21 p.m.

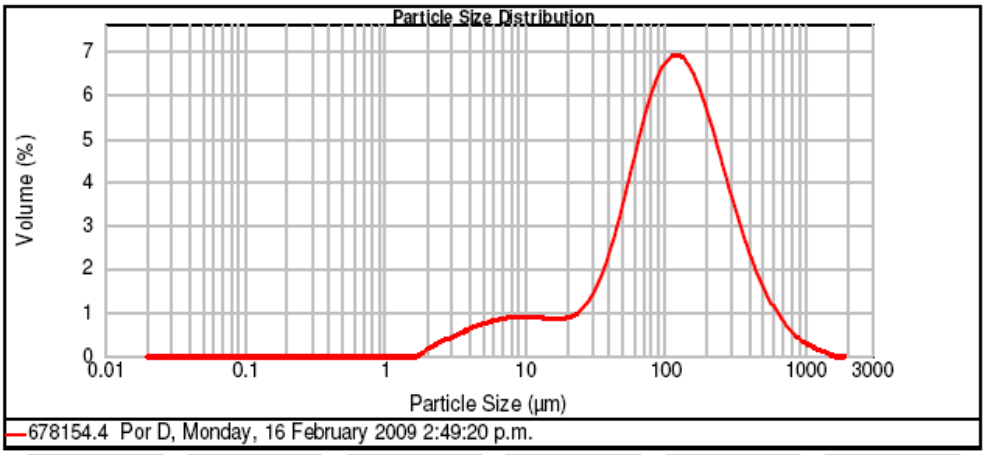
Sample bulk lot ref:
2009011/4

Result Source:
Measurement

Particle Name:	Accessory Name:	Analysis model:	Sensitivity:
Marine Sediment	Hydro 2000G (A)	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	16.55 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	0.206 %	Off

Concentration:	Span :	Uniformity:	Result units:
0.0860 %Vol	2.888	0.912	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.157 m²/g	38.255 um	158.249 um	

d(0.1): 17.902 um **d(0.5): 112.164 um** **d(0.9): 341.784 um**



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.05
2.000	1.69
3.900	3.46
7.800	4.03
15.600	4.50
31.000	1.98
37.000	

Size (µm)	Volume In %
37.000	2.69
44.000	3.95
53.000	4.80
63.000	5.45
74.000	6.80
88.000	7.64
105.000	

Size (µm)	Volume In %
105.000	7.67
125.000	7.64
149.000	7.24
177.000	6.48
210.000	5.71
250.000	4.94
300.000	

Size (µm)	Volume In %
300.000	3.36
350.000	3.10
420.000	2.20
500.000	1.51
590.000	1.16
710.000	0.69
840.000	

Size (µm)	Volume In %
840.000	0.45
1000.000	0.43
2000.000	

Result Analysis Report

Sample Name:
678154.5 Por E

SOP Name:
Marine Sediment

Measured:
Monday, 16 February 2009 3:01:26 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Monday, 16 February 2009 3:01:27 p.m.

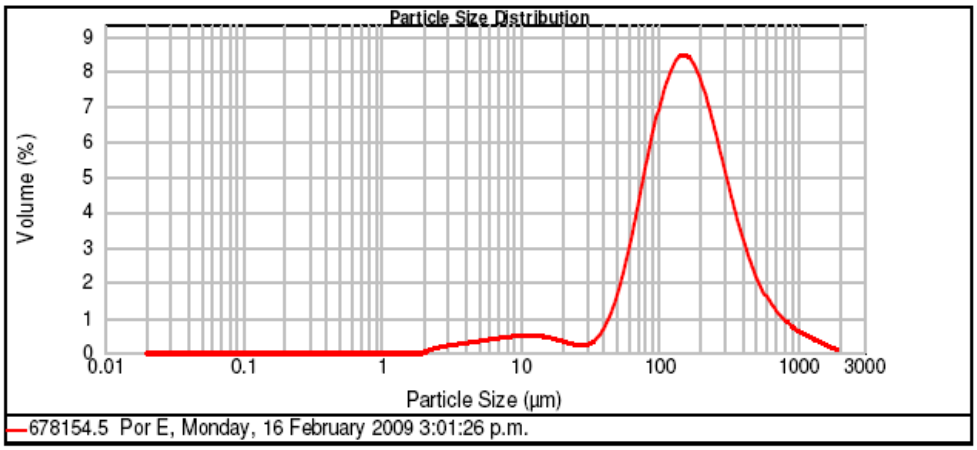
Sample bulk lot ref:
2009011/5

Result Source:
Measurement

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 16.49 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.225 %	**Result Emulation:** Off

Concentration: 0.1606 %Vol	**Span :** 2.348	**Uniformity:** 0.795	**Result units:** Volume
Specific Surface Area: 0.0872 m²/g	**Surface Weighted Mean D[3,2]:** 68.777 um	**Vol. Weighted Mean D[4,3]:** 214.093 um	

d(0.1): 57.947 um **d(0.5):** 155.205 um **d(0.9):** 422.410 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	0.67
3.900	1.59
7.800	2.18
15.600	1.30
31.000	0.39
37.000	

Size (µm)	Volume In %
37.000	0.81
44.000	1.76
53.000	2.88
63.000	4.04
74.000	5.96
88.000	7.70
105.000	

Size (µm)	Volume In %
105.000	8.86
125.000	9.62
149.000	9.46
177.000	8.63
210.000	7.97
250.000	6.93
300.000	

Size (µm)	Volume In %
300.000	4.69
350.000	4.27
420.000	2.98
500.000	2.06
590.000	1.66
710.000	1.09
840.000	

Size (µm)	Volume In %
840.000	0.84
1000.000	1.49
2000.000	

Result Analysis Report

Sample Name:
678154.6 Por F

SOP Name:
Marine Sediment

Measured:
Monday, 16 February 2009 3:50:20 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Monday, 16 February 2009 3:50:21 p.m.

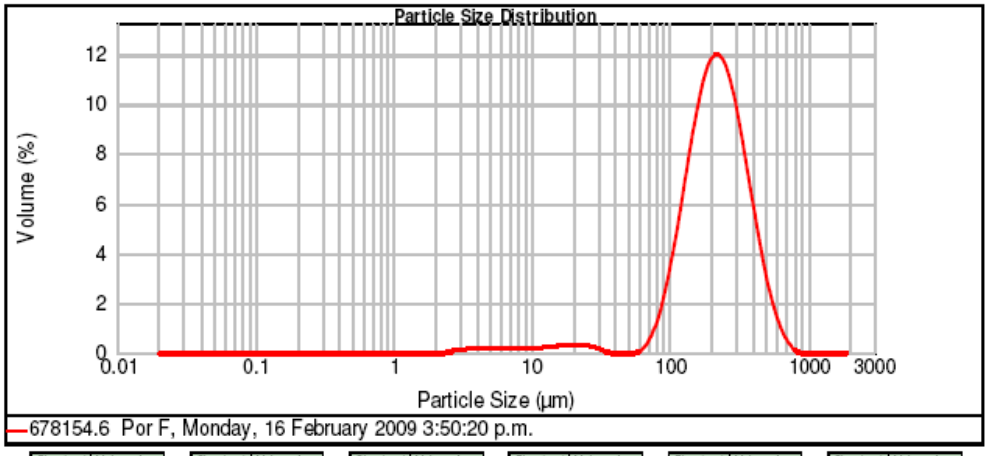
Sample bulk lot ref:
2009011/6

Result Source:
Measurement

Particle Name:	Accessory Name:	Analysis model:	Sensitivity:
Marine Sediment	Hydro 2000G (A)	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	17.30 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	0.302 %	Off

Concentration:	Span :	Uniformity:	Result units:
0.2923 %Vol	1.351	0.43	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.0521 m^2/g	115.222 um	235.989 um	

d(0.1): 109.879 um **d(0.5):** 213.861 um **d(0.9):** 398.836 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	0.34
3.900	0.71
7.800	0.88
15.600	1.28
31.000	0.06
37.000	

Size (µm)	Volume In %
37.000	0.00
44.000	0.00
53.000	0.02
63.000	0.43
74.000	1.51
88.000	3.48
105.000	

Size (µm)	Volume In %
105.000	6.06
125.000	9.12
149.000	11.56
177.000	13.11
210.000	13.64
250.000	12.97
300.000	

Size (µm)	Volume In %
300.000	8.97
350.000	7.72
420.000	4.57
500.000	2.31
590.000	1.06
710.000	0.20
840.000	

Size (µm)	Volume In %
840.000	0.00
1000.000	0.00
2000.000	

Result Analysis Report

Sample Name:
678154.7 Por G

SOP Name:
Marine Sediment

Measured:
Monday, 16 February 2009 4:02:42 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Monday, 16 February 2009 4:02:43 p.m.

Sample bulk lot ref:
2009011/7

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
20.50 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.335 %

Result Emulation:
Off

Concentration:
0.2945 %Vol

Span :
1.617

Uniformity:
0.51

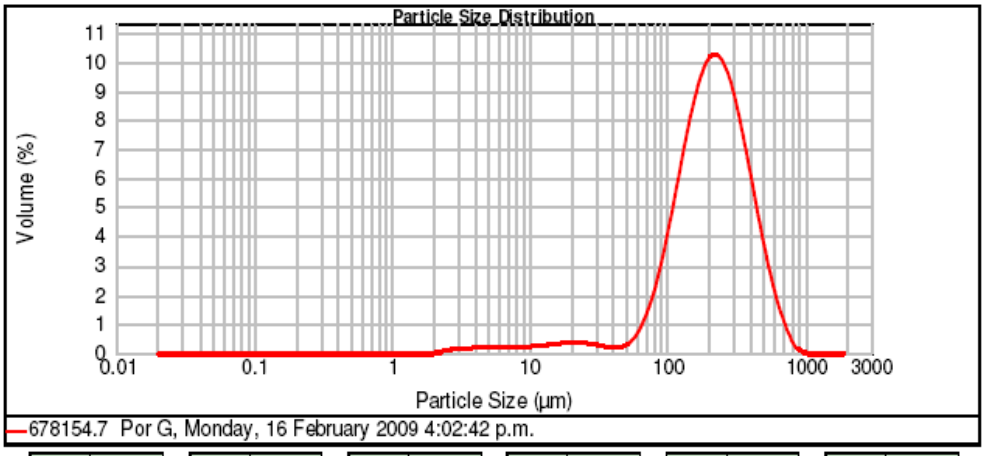
Result units:
Volume

Specific Surface Area:
0.0607 m²/g

Surface Weighted Mean D[3,2]:
98.827 um

Vol. Weighted Mean D[4,3]:
238.339 um

d(0.1): 91.122 um **d(0.5):** 209.997 um **d(0.9):** 430.642 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	0.46
3.900	0.84
7.800	1.13
15.600	1.54
31.000	0.27
37.000	0.21

Size (µm)	Volume In %
37.000	0.21
44.000	0.31
53.000	0.65
63.000	1.28
74.000	2.57
88.000	4.37
105.000	6.39

Size (µm)	Volume In %
105.000	6.39
125.000	8.57
149.000	10.18
177.000	11.20
210.000	11.65
250.000	11.39
300.000	8.31

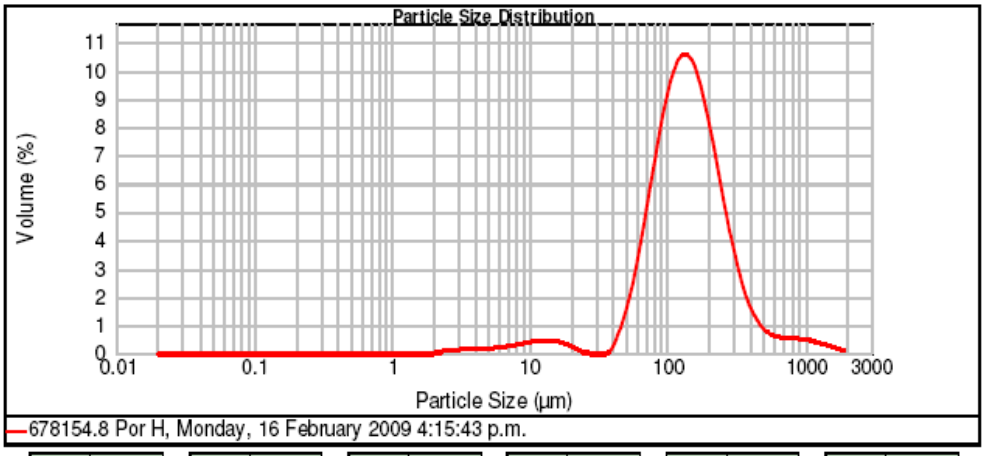
Size (µm)	Volume In %
300.000	8.31
350.000	7.77
420.000	5.22
500.000	3.13
590.000	1.85
710.000	0.59
840.000	0.10

Size (µm)	Volume In %
840.000	0.10
1000.000	0.00
2000.000	

Result Analysis Report

Sample Name: 678154.8 Por H	**SOP Name:** Marine Sediment	**Measured:** Monday, 16 February 2009 4:15:43 p.m.	
Sample Source & type: Hill	**Measured by:** rodgers	**Analysed:** Monday, 16 February 2009 4:15:44 p.m.	
Sample bulk lot ref: 2009011/8	**Result Source:** Measurement		
Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 13.60 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.467 %	**Result Emulation:** Off
Concentration: 0.1542 %Vol	**Span :** 1.758	**Uniformity:** 0.68	**Result units:** Volume
Specific Surface Area: 0.0752 m²/g	**Surface Weighted Mean D[3,2]:** 79.801 um	**Vol. Weighted Mean D[4,3]:** 181.502 um	

d(0.1): 65.219 um **d(0.5):** 136.533 um **d(0.9):** 305.267 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	0.40
3.900	0.86
7.800	1.86
15.600	0.74
31.000	0.00
37.000	0.00

Size (µm)	Volume In %
37.000	0.34
44.000	1.61
53.000	3.27
63.000	5.07
74.000	7.83
88.000	10.26
105.000	11.64

Size (µm)	Volume In %
105.000	11.64
125.000	12.14
149.000	11.17
177.000	9.46
210.000	7.49
250.000	5.46
300.000	3.00

Size (µm)	Volume In %
300.000	3.00
350.000	2.17
420.000	1.22
500.000	0.76
590.000	0.71
710.000	0.60
840.000	0.59

Size (µm)	Volume In %
840.000	0.59
1000.000	1.35
2000.000	

Result Analysis Report

Sample Name:
678154.9 Por H core

SOP Name:
Marine Sediment

Measured:
Monday, 16 February 2009 4:27:46 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Monday, 16 February 2009 4:27:47 p.m.

Sample bulk lot ref:
2009011/9

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
20.52 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.290 %

Result Emulation:
Off

Concentration:
0.1691 %Vol

Span :
3.968

Uniformity:
1.14

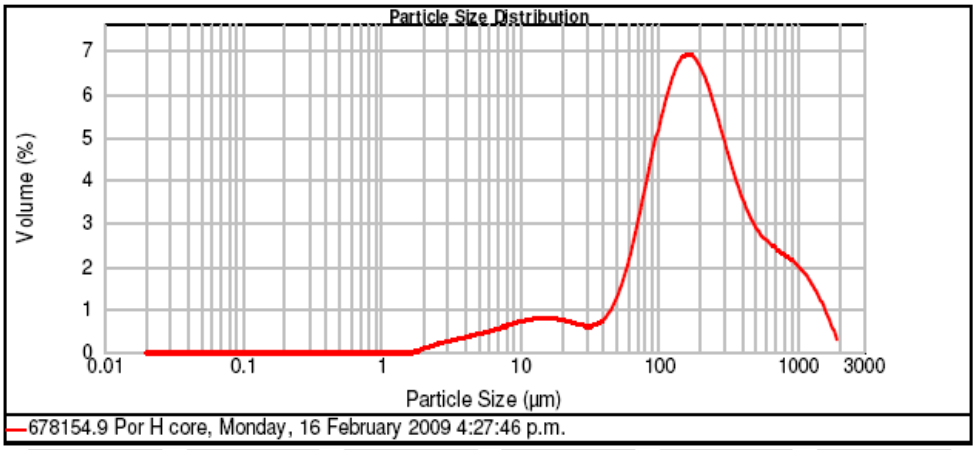
Result units:
Volume

Specific Surface Area:
0.103 m²/g

Surface Weighted Mean D[3,2]:
58.183 um

Vol. Weighted Mean D[4,3]:
296.146 um

d(0.1): 35.665 um **d(0.5):** 178.238 um **d(0.9):** 742.999 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.02
2.000	0.92
3.900	2.09
7.800	3.25
15.600	3.15
31.000	0.72
37.000	

Size (µm)	Volume In %
37.000	0.87
44.000	1.41
53.000	2.07
63.000	2.67
74.000	4.31
88.000	5.73
105.000	

Size (µm)	Volume In %
105.000	6.82
125.000	7.66
149.000	7.79
177.000	7.51
210.000	7.01
250.000	6.37
300.000	

Size (µm)	Volume In %
300.000	4.57
350.000	4.52
420.000	3.62
500.000	2.99
590.000	3.02
710.000	2.54
840.000	

Size (µm)	Volume In %
840.000	2.43
1000.000	5.74
2000.000	

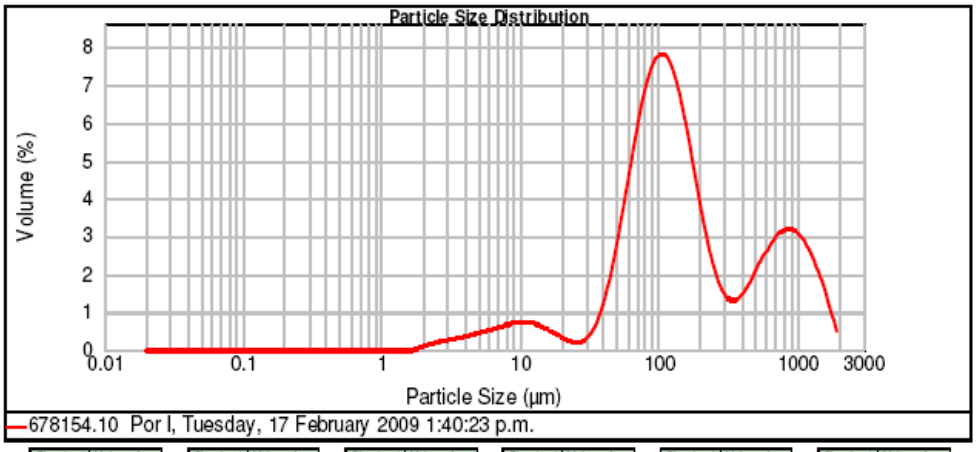
Result Analysis Report

Sample Name: 678154.10 Por I	**SOP Name:** Marine Sediment	**Measured:** Tuesday, 17 February 2009 1:40:23 p.m.
Sample Source & type: Hill	**Measured by:** rodgers	**Analysed:** Tuesday, 17 February 2009 1:40:24 p.m.
Sample bulk lot ref: 2009011/10	**Result Source:** Measurement	

Particle Name: Marine Sediment	**Accessory Name:** Hydro 2000G (A)	**Analysis model:** General purpose	**Sensitivity:** Enhanced
Particle RI: 1.500	**Absorption:** 0	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 18.96 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.484 %	**Result Emulation:** Off

Concentration: 0.1441 %Vol	**Span :** 7.072	**Uniformity:** 1.87	**Result units:** Volume
Specific Surface Area: 0.11 m²/g	**Surface Weighted Mean D[3,2]:** 54.313 um	**Vol. Weighted Mean D[4,3]:** 313.107 um	

d(0.1): 44.572 um **d(0.5): 128.410 um** **d(0.9): 952.694 um**



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	0.03
3.900	0.99
7.800	2.24
15.600	3.11
31.000	1.39
37.000	0.64

Size (µm)	Volume In %
37.000	0.64
44.000	1.45
53.000	3.01
63.000	4.55
74.000	5.85
88.000	7.77
105.000	8.67

Size (µm)	Volume In %
105.000	8.67
125.000	8.60
149.000	8.01
177.000	6.38
210.000	4.64
250.000	3.16
300.000	2.12

Size (µm)	Volume In %
300.000	2.12
350.000	1.35
420.000	1.64
500.000	2.02
590.000	2.50
710.000	3.40
840.000	3.45

Size (µm)	Volume In %
840.000	3.45
1000.000	3.63
2000.000	9.01

Result Analysis Report

Sample Name:
678154.11 Por I core

SOP Name:
Marine Sediment

Measured:
Tuesday, 17 February 2009 1:52:49 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Tuesday, 17 February 2009 1:52:50 p.m.

Sample bulk lot ref:
2009011/11

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
19.40 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.301 %

Result Emulation:
Off

Concentration:
0.1813 %Vol

Span :
5.115

Uniformity:
1.49

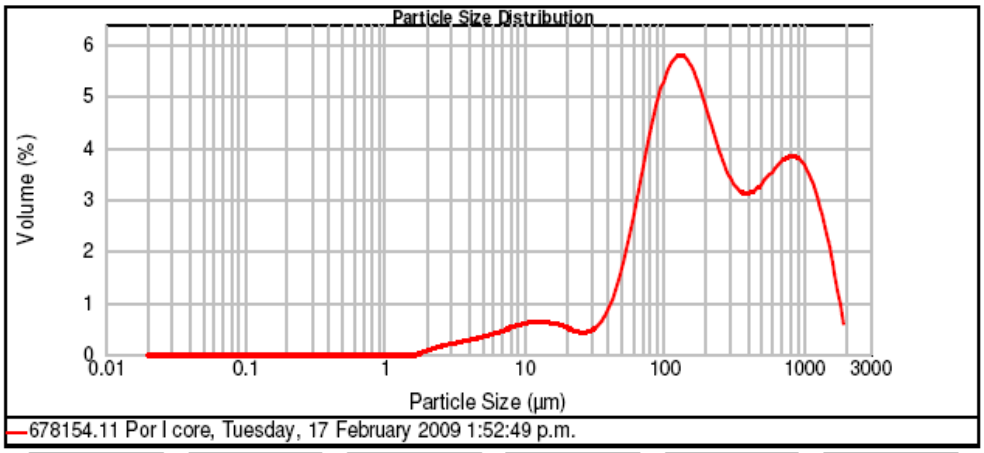
Result units:
Volume

Specific Surface Area:
0.0905 m²/g

Surface Weighted Mean D[3,2]:
66.334 um

Vol. Weighted Mean D[4,3]:
382.669 um

d(0.1): 48.761 um **d(0.5):** 192.746 um **d(0.9):** 1034.739 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.02
2.000	0.76
3.900	1.73
7.800	2.69
15.600	2.24
31.000	0.65
37.000	

Size (µm)	Volume In %
37.000	1.01
44.000	1.82
53.000	2.66
63.000	3.49
74.000	4.86
88.000	5.94
105.000	

Size (µm)	Volume In %
105.000	6.46
125.000	6.63
149.000	6.18
177.000	5.51
210.000	4.87
250.000	4.37
300.000	

Size (µm)	Volume In %
300.000	3.30
350.000	3.72
420.000	3.63
500.000	3.68
590.000	4.42
710.000	4.20
840.000	

Size (µm)	Volume In %
840.000	4.33
1000.000	10.82
2000.000	

Result Analysis Report

Sample Name:
678154.12 Por J

SOP Name:
Marine Sediment

Measured:
Tuesday, 17 February 2009 2:09:19 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Tuesday, 17 February 2009 2:09:21 p.m.

Sample bulk lot ref:
2009011/12

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
14.50 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.251 %

Result Emulation:
Off

Concentration:
0.1915 %Vol

Span :
1.956

Uniformity:
0.612

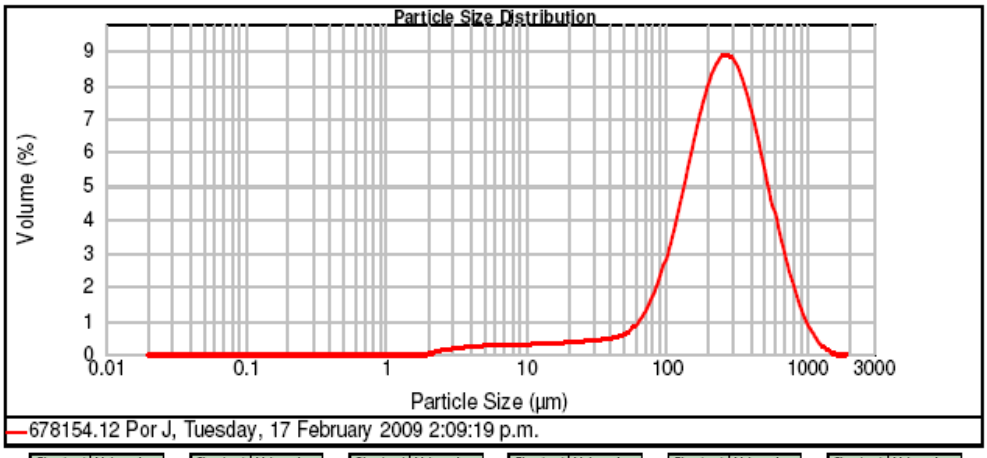
Result units:
Volume

Specific Surface Area:
0.0634 m²/g

Surface Weighted Mean D[3,2]:
94.609 um

Vol. Weighted Mean D[4,3]:
298.897 um

d(0.1): 85.390 um **d(0.5):** 251.126 um **d(0.9):** 576.638 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	0.53
3.900	1.16
7.800	1.34
15.600	1.65
31.000	0.51
37.000	0.54

Size (µm)	Volume In %
37.000	0.54
44.000	0.69
53.000	0.87
63.000	1.18
74.000	1.93
88.000	3.01
105.000	4.34

Size (µm)	Volume In %
105.000	4.34
125.000	5.97
149.000	7.44
177.000	8.74
210.000	9.64
250.000	10.59
300.000	8.60

Size (µm)	Volume In %
300.000	8.60
350.000	9.13
420.000	7.24
500.000	5.34
590.000	4.26
710.000	2.50
840.000	1.52

Size (µm)	Volume In %
840.000	1.52
1000.000	1.08
2000.000	

Result Analysis Report

Sample Name:
678153.1 OP - A

SOP Name:
Marine Sediment

Measured:
Friday, 13 February 2009 2:40:32 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Friday, 13 February 2009 2:40:33 p.m.

Sample bulk lot ref:
2009010/4

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
17.28 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.583 %

Result Emulation:
Off

Concentration:
0.1310 %Vol

Span :
1.793

Uniformity:
0.49

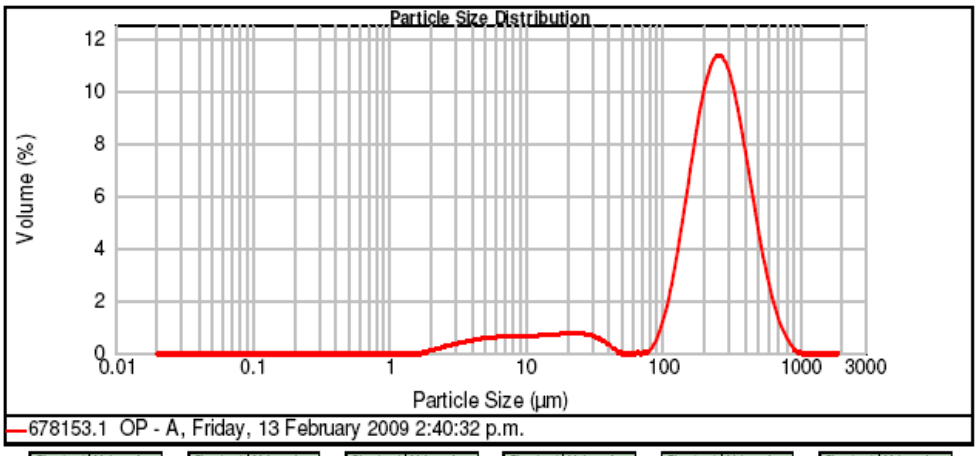
Result units:
Volume

Specific Surface Area:
0.107 m²/g

Surface Weighted Mean D[3,2]:
56.020 um

Vol. Weighted Mean D[4,3]:
257.300 um

d(0.1): 28.030 um **d(0.5):** 240.000 um **d(0.9):** 458.300 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	1.30
3.900	2.67
7.800	3.08
15.600	3.37
31.000	0.64
37.000	0.35

Size (µm)	Volume In %
37.000	0.35
44.000	0.03
53.000	0.00
63.000	-0.00
74.000	0.17
88.000	1.13
105.000	2.92

Size (µm)	Volume In %
105.000	2.92
125.000	5.56
149.000	8.35
177.000	10.82
210.000	12.62
250.000	13.36
300.000	10.22

Size (µm)	Volume In %
300.000	10.22
350.000	9.76
420.000	6.56
500.000	3.88
590.000	2.24
710.000	0.79
840.000	0.15

Size (µm)	Volume In %
840.000	0.15
1000.000	0.00
2000.000	

Result Analysis Report

Sample Name:
678153.2 OP - B

SOP Name:
Marine Sediment

Measured:
Friday, 13 February 2009 2:52:51 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Friday, 13 February 2009 2:52:52 p.m.

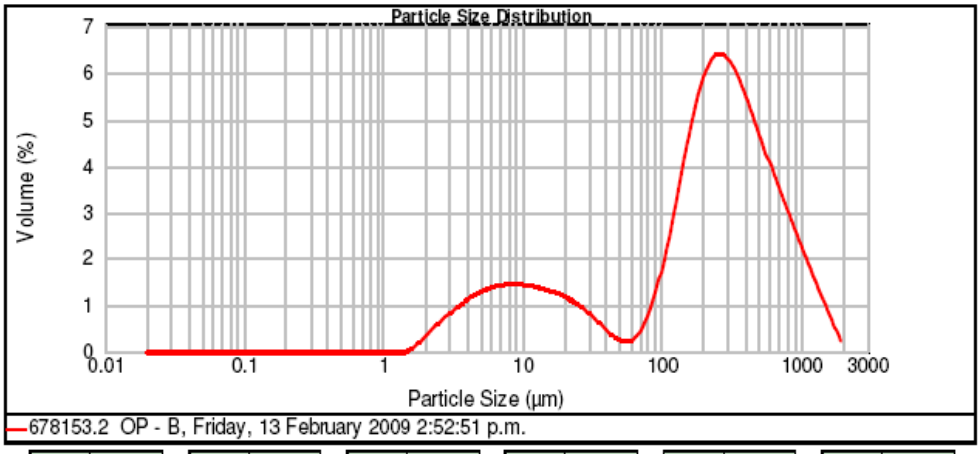
Sample bulk lot ref:
2009010/5

Result Source:
Measurement

Particle Name:	Accessory Name:	Analysis model:	Sensitivity:
Marine Sediment	Hydro 2000G (A)	General purpose	Enhanced
Particle RI:	**Absorption:**	**Size range:**	**Obscuration:**
1.500	0	0.020 to 2000.000 um	19.77 %
Dispersant Name:	**Dispersant RI:**	**Weighted Residual:**	**Result Emulation:**
Water	1.330	0.574 %	Off

Concentration:	Span :	Uniformity:	Result units:
0.0739 %Vol	3.243	0.983	Volume
Specific Surface Area:	**Surface Weighted Mean D[3,2]:**	**Vol. Weighted Mean D[4,3]:**	
0.211 m²/g	28.493 um	328.274 um	

d(0.1): 8.264 um **d(0.5):** 237.208 um **d(0.9):** 777.472 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.26
2.000	3.19
3.900	6.00
7.800	6.43
15.600	4.95
31.000	0.79
37.000	0.53

Size (µm)	Volume In %
37.000	0.53
44.000	0.34
53.000	0.25
63.000	0.39
74.000	0.89
88.000	1.78
105.000	2.94

Size (µm)	Volume In %
105.000	2.94
125.000	4.32
149.000	5.51
177.000	6.45
210.000	7.17
250.000	7.64
300.000	6.23

Size (µm)	Volume In %
300.000	6.23
350.000	6.81
420.000	5.79
500.000	4.79
590.000	4.58
710.000	3.48
840.000	2.96

Size (µm)	Volume In %
840.000	2.96
1000.000	5.52
2000.000	

Result Analysis Report

Sample Name:
678153.3 BB - A

SOP Name:
Marine Sediment

Measured:
Friday, 13 February 2009 1:50:15 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Friday, 13 February 2009 1:50:16 p.m.

Sample bulk lot ref:
2009010/1

Result Source:
Edited

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
13.61 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.467 %

Result Emulation:
Off

Concentration:
0.2079 %Vol

Span :
2.814

Uniformity:
0.898

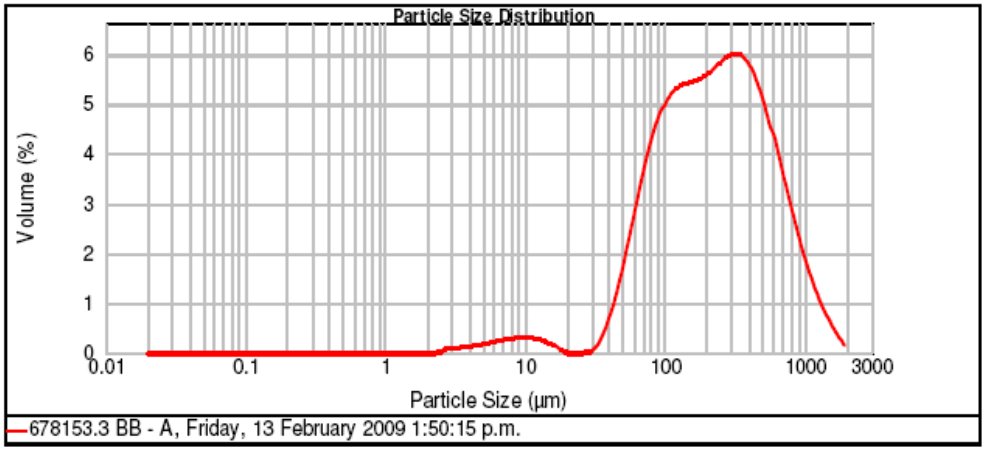
Result units:
Volume

Specific Surface Area:
0.0569 m²/g

Surface Weighted Mean D[3,2]:
105.449 um

Vol. Weighted Mean D[4,3]:
322.504 um

d(0.1): 68.353 um **d(0.5):** 227.553 um **d(0.9):** 708.787 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.00
2.000	0.24
3.900	0.90
7.800	1.27
15.600	0.14
31.000	0.25
37.000	0.82

Size (µm)	Volume In %
37.000	0.82
44.000	1.84
53.000	2.82
63.000	3.62
74.000	4.84
88.000	5.67
105.000	6.00

Size (µm)	Volume In %
105.000	6.00
125.000	6.21
149.000	6.16
177.000	6.23
210.000	6.55
250.000	7.08
300.000	6.07

Size (µm)	Volume In %
300.000	6.07
350.000	7.03
420.000	6.25
500.000	5.22
590.000	4.83
710.000	3.40
840.000	2.61

Size (µm)	Volume In %
840.000	2.61
1000.000	3.95
2000.000	

Result Analysis Report

Sample Name:
678153.5 BB - C

SOP Name:
Marine Sediment

Measured:
Friday, 13 February 2009 2:06:01 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Friday, 13 February 2009 2:06:02 p.m.

Sample bulk lot ref:
2009010/2

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
15.11 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.395 %

Result Emulation:
Off

Concentration:
0.1139 %Vol

Span :
4.253

Uniformity:
1.27

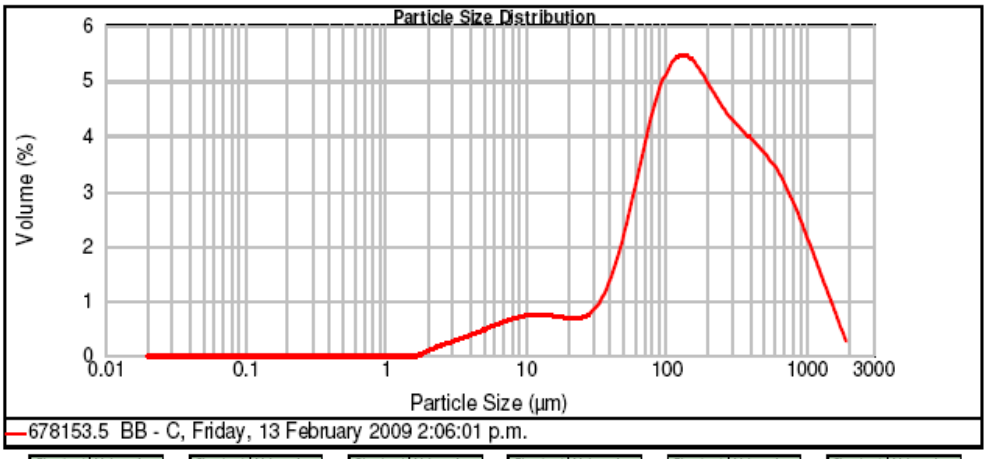
Result units:
Volume

Specific Surface Area:
0.109 m²/g

Surface Weighted Mean D[3,2]:
54.845 um

Vol. Weighted Mean D[4,3]:
300.346 um

d(0.1): 32.424 um **d(0.5):** 171.394 um **d(0.9):** 761.388 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	0.00

Size (µm)	Volume In %
0.980	0.02
2.000	0.97
3.900	2.30
7.800	3.28
15.600	3.18
31.000	1.13
37.000	

Size (µm)	Volume In %
37.000	1.57
44.000	2.45
53.000	3.16
63.000	3.82
74.000	4.96
88.000	5.80
105.000	

Size (µm)	Volume In %
105.000	6.14
125.000	6.28
149.000	5.99
177.000	5.62
210.000	5.37
250.000	5.26
300.000	

Size (µm)	Volume In %
300.000	4.23
350.000	4.79
420.000	4.37
500.000	3.90
590.000	3.99
710.000	3.19
840.000	

Size (µm)	Volume In %
840.000	2.79
1000.000	5.40
2000.000	

Result Analysis Report

Sample Name:
678153.6 DC - A

SOP Name:
Marine Sediment

Measured:
Friday, 13 February 2009 2:18:46 p.m.

Sample Source & type:
Hill

Measured by:
rodgers

Analysed:
Friday, 13 February 2009 2:18:47 p.m.

Sample bulk lot ref:
2009010/3

Result Source:
Measurement

Particle Name:
Marine Sediment

Accessory Name:
Hydro 2000G (A)

Analysis model:
General purpose

Sensitivity:
Enhanced

Particle RI:
1.500

Absorption:
0

Size range:
0.020 to 2000.000 um

Obscuration:
17.67 %

Dispersant Name:
Water

Dispersant RI:
1.330

Weighted Residual:
0.399 %

Result Emulation:
Off

Concentration:
0.2079 %Vol

Span :
2.055

Uniformity:
0.635

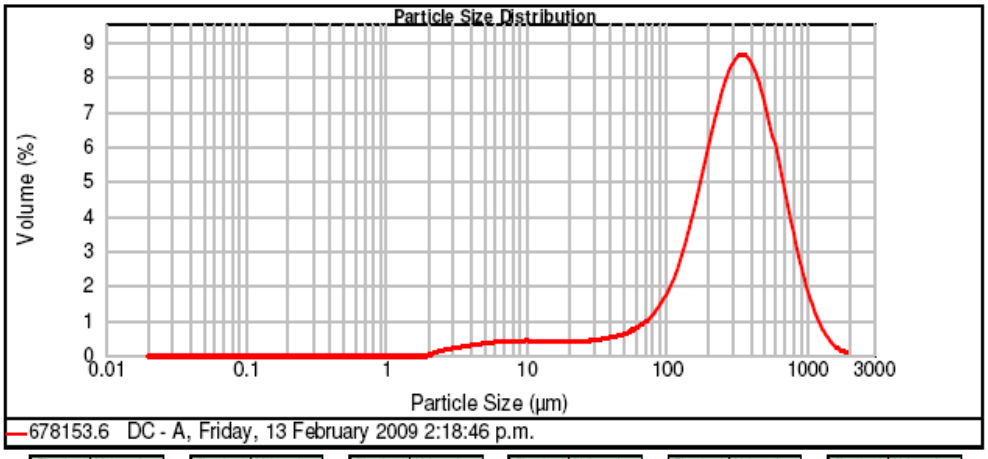
Result units:
Volume

Specific Surface Area:
0.0714 m²/g

Surface Weighted Mean D[3,2]:
84.090 um

Vol. Weighted Mean D[4,3]:
364.949 um

d(0.1): 77.051 um **d(0.5):** 309.640 um **d(0.9):** 713.236 um



Size (µm)	Volume In %
0.050	0.00
0.060	0.00
0.120	0.00
0.240	0.00
0.490	0.00
0.700	0.00
0.980	

Size (µm)	Volume In %
0.980	0.00
2.000	0.70
3.900	1.63
7.800	1.91
15.600	1.84
31.000	0.54
37.000	

Size (µm)	Volume In %
37.000	0.60
44.000	0.74
53.000	0.82
63.000	0.94
74.000	1.32
88.000	1.67
105.000	

Size (µm)	Volume In %
105.000	2.63
125.000	3.74
149.000	4.99
177.000	6.41
210.000	7.97
250.000	9.58
300.000	

Size (µm)	Volume In %
300.000	8.65
350.000	10.19
420.000	9.00
500.000	7.33
590.000	6.46
710.000	4.20
840.000	

Size (µm)	Volume In %
840.000	2.88
1000.000	3.06
2000.000	

Appendix 5: Streambed sediment sample results

Site	SMS043	SMS011	SMS044	SMS045
Dry Matter (g/100 g)	48	62	72	75
Total organic carbon (%)	1.9	0.77	0.7	0.88
Fraction ≥2 mm	35.7	21.7	49.1	61.9
Fraction <2mm, ≥500 µm	2.1	25.4	7.1	21.5
Fraction <500 µm, ≥250 µm	12.7	23.1	16	4.6
Fraction <250 µm, ≥63 µm	30.4	21.1	22.9	4.5
Fraction <63 µm	19.1	8.6	4.9	7.5
Metals (mg/kg, strong acid, <2mm):				
Arsenic	6.8	5.0	5.5	6.3
Cadmium	0.14	0.083	0.078	0.15
Chromium	15	14	13	14
Copper	20	12	14	24
Lead	0.071	0.041	0.076	0.031
Mercury	12	9.8	11	13
Nickel	40	30	34	37
Zinc	250	130	170	430
Polycyclic Aromatic Hydrocarbons (µg/kg):				
Acenaphthene	3.9	< 2.2	4	< 2.0
Acenaphthylene	7.4	2.3	4.2	11
Anthracene	17	8.7	28	32
Benzo[a]anthracene	200	61	120	250
Benzo[a]pyrene (BAP)	260	71	120	270
Benzo[b]fluoranthene + Benzo[j]fluoranthene	260	79	120	260
Benzo[g,h,i]perylene	170	49	70	130
Benzo[k]fluoranthene	110	33	50	110
Chrysene	180	69	100	200
Dibenzo[a,h]anthracene	35	< 2.2	24	58
Fluoranthene	370	160	290	310
Fluorene	4.4	< 2.2	7.5	7
Indeno[1,2,3-c,d]pyrene	180	51	71	150
Naphthalene	< 15	< 11	< 10	< 10
Phenanthrene	58	42	94	130
Pyrene	320	130	230	290
Total PAH (<D.L. = 0)	2,176	756	1,333	2,208
Total PAH (<D.L. = 0.5 x D.L.)	2,183	765	1,338	2,214

Site	SMS043	SMS011	SMS044	SMS045
Organochlorine Pesticides (µg/kg, <2mm):				
Aldrin	< 0.99	< 0.98	< 1.0	< 1.1
alpha-BHC	< 0.99	< 0.98	< 1.0	< 1.1
beta-BHC	< 0.99	< 0.98	< 1.0	< 1.1
delta-BHC	< 0.99	< 0.98	< 1.0	< 1.1
gamma-BHC (Lindane)	< 0.99	< 0.98	< 1.0	< 1.1
Cis-chlordane	< 0.99	< 0.98	< 1.0	< 1.1
Trans-chlordane	< 0.99	< 0.98	< 1.0	< 1.1
2,4'-DDE	< 0.99	< 0.98	< 1.0	< 1.1
2,4'-DDD	11	2.7	5.4	4.4
2,4'-DDT	< 0.99	< 0.98	< 1.0	< 1.1
4,4'-DDE	4.2	1.5	3.6	1.6
4,4'-DDD	< 0.99	< 0.98	< 1.0	< 1.1
4,4'-DDT	7.3	1.4	5.3	1.6
Dieldrin	< 0.99	< 0.98	1.1	1.3
Endosulphan I	< 0.99	< 0.98	< 1.0	< 1.1
Endosulphan II	< 0.99	< 0.98	< 1.0	< 1.1
Endosulphan sulphate	< 0.99	< 0.98	< 1.0	< 1.1
Endrin	< 0.99	< 0.98	< 1.0	< 1.1
Endrin aldehyde	< 0.99	< 0.98	< 1.0	< 1.1
Endrin ketone	< 0.99	< 0.98	< 1.0	< 1.1
Heptachlor	< 0.99	< 0.98	< 1.0	< 1.1

Appendix 6: Analytical quality control results

The quality control (QC) results of the within-batch (duplicate) and certified reference material comparisons carried out are presented in Tables A6.1–A6.3. For Tables A6.1–A6.2, any difference (%) between the QC (new) result (denoted with a "2") and the original result (denoted with a "1") is expressed as:

100 x (new result – original result)/mean of the two results

Note that the QC data presented in Table A6.2 do not relate to Greater Wellington's sediment samples; other sediment samples were analysed by the laboratory in the same batch as Greater Wellington's samples and two of these samples were randomly selected for duplicate total phosphorus analysis.

In summary, the analytical QC results indicate:

- Very good precision for TOC in the within-batch comparisons (Table A6.1).
- Varying levels of precision for total recoverable phosphorus in the within-batch comparisons, with a very good result in the first comparison and a poor result in the second (Table A6.2).
- A very good level of agreement with the laboratory's in-house limits for total recoverable metal concentrations in certified reference material AGAL 10, but varying levels of agreement with the "certified" range (Table A6.3) – in most cases because the digestion method used to obtain the certified values also releases interstitially bound metals.

No comment on precision or accuracy is made for the organochlorine pesticides or polycyclic aromatic hydrocarbons; QC checks for these compounds were limited to procedural blanks and analysis of surrogate recovery data.

Table A6.1: Within-batch comparisons for total organic carbon, <2 mm fraction

Site	POR-J			SMS045		
Result Number	1	2	Diff (%)	1	2	Diff (%)
Total Organic Carbon (%)	0.33	0.31	-6.3	0.88	0.88	0.0

Table A6.2: Within-batch comparisons for total recoverable phosphorus, <2 mm fraction. Concentrations in mg/kg.

Site	Non-GWRC sample			Non-GWRC sample		
Result Number	1	2	Diff (%)	1	2	Diff (%)
Phosphorus	2,310	2,385	3.2	59	43	-31.4

Table A6.3: Certified Reference Material (CRM) comparisons for total recoverable metal and total phosphorus concentrations. Concentrations in mg/kg dry weight.

	Result	Certified Range	In House Limits	Result	Certified Range	In House Limits
Arsenic	20.2	17.2 ± 3.0	16.2 – 23.1	20.3	17.2 ± 3.0	16.2 – 23.1
Cadmium	9.82	9.33 ± 0.64	7.82 – 11.03	9.32	9.33 ± 0.64	7.82 – 11.03
Chromium	44.8	82 ± 11	27.2 – 71.9[1]	43.5	82 ± 11	27.2 – 71.9[1]
Copper	23.6	23.2 ± 1.9	19.6 – 26.4	22.2	23.2 ± 1.9	19.6 – 26.4
Nickel	12.1	17.8 ± 2.7	9.5 – 14.0[1]	12.2	17.8 ± 2.7	9.5 – 14.0[1]
Lead	40.8	40.4 ± 2.7	32.5 – 48.4	41.9	40.4 ± 2.7	32.5 – 48.4
Zinc	55.9	57 ± 4.2	46.1 – 62.7	55.5	57 ± 4.2	46.1 – 62.7
Mercury	11.94	11.6 ± 1.1	10.0 – 13.6	12.24	11.6 ± 1.1	10.0 – 13.6
Phosphorus	362	350 ± 46	301 – 384	N/A	N/A	N/A

[1] The In House Limits for chromium and nickel are lower than the values in the Certified Range because the digestion method used to obtain the In House results is not as strong as that used to obtain the certified values.

Water, air, earth and energy – elements in Greater Wellington's logo that combine to create and sustain life. Greater Wellington promotes **Quality for Life** by ensuring our environment is protected while meeting the economic, cultural and social needs of the community

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Photo Credit
Southern end of Porirua Harbour (Onepoto Arm), Juliet Milne

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