



Contaminant Accumulation in the Open Coastal Zone

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Contaminant Accumulation in the Open Coastal Zone

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1 Executive Summary

This study provides an overview of sediment settling characteristics from urban stormwater discharging to an open coastal environment and provides recommendations for monitoring the effects of stormwater discharging to that environment. It has focused on East Coast Bays because this area receives stormwater from a large urban area and has the best database of all the open coastal regions in Auckland.

The sediment textural pattern off East Coast Bays is predominantly sand at water depths <10m and predominantly mud at water depth > 10 m. This 10 m water depth contour occurs approximately 1 km offshore near Rangitoto Island and near Okura. While the mud/sand transition seems to occur at approximately 1 km offshore at the north and south ends of East Coast Bays, it is about 2 km off the coast in the middle of the Bays. This difference is probably due to differences in the relative exposure throughout the length of the East Coast Bays.

Stormwater discharges directly to the coast and via the freshwater drainage system. The streams discharge via small estuaries. Most of the contaminants would be carried beyond these estuaries to the open coast, especially during floods. It is expected that the contaminants would be carried offshore to settle in deeper waters. Contaminants may deposit near shore during calm conditions, but it is expected that, over time, these will be remobilised and moved further offshore. Any contaminant accumulation would only occur in the muddy sediment offshore, i.e., 1-2 km offshore.

Surveys of sediment quality have found that the small estuary sites are highly contaminated.

Sites in the surf zone are largely uncontaminated, but occasional elevated concentrations are found at Cheltenham (Zn, Pb, PAH), Browns Bay (Zn) and Milford (PAH), and these levels can sometimes exceed 'amber' Environmental Response Criteria (ERC). Therefore there is the possibility that the mud fraction of near shore sediments could occasionally contain elevated concentrations of contaminants.

Further offshore, concentrations reflect a slight contamination, although this may be partly due to higher concentrations in the background material (P. Kennedy, pers. comm.) Overall, the data suggests that the offshore sediments are generally not contaminated to levels of concern for aquatic life and that concentrations in the mud fraction are generally low.

Simple modelling has predicted only small increases in Zn concentrations (the main contaminant) and this is what is observed to date from sediment surveys. The predicted concentrations into the future for 2050 and 2150 are also relatively small compared with the ERC. Because the predicted and observed concentrations are relatively low, there is no need for an extensive monitoring programme in the muddy sediments 1-2 km off the coast.

Apart from the very high concentrations that can be found in the estuaries, there is the concern about open coastal discharges of particulate Zn, Cu, Pb and PAH can sometimes elevate concentrations in the near shore zone. These concerns can be addressed by monitoring the near shore situation. A site offshore from Wairau Creek could usefully augment the existing ARC LTB monitoring sites at Long Bay, Browns Bay and Cheltenham. Note that the small fraction of mud found in the sediments on most occasions at Long Bay and Browns Bay is compromising this programme at the present time and this argues for a revised sampling strategy there.

2 Scope

The discharge of urban-derived stormwater contaminants to the open coast, such as East Coast Bays, has been assumed to lead to widespread dispersal of contaminants rather than accumulation which, over time, could result in sediment quality guidelines being exceeded. This assumption was based on the high energy nature of the open coast and low proportion of mud in near-shore sediments.

However, there has not been a critical scientific evaluation of this paradigm and some concerns were expressed when the sediment dynamics of Auckland harbours was reviewed (Green et al. 2001). These concerns were:

- That fine sediments containing contaminants will accumulate over long periods of time in deeper off-shore areas where wave orbital velocities have decreased below the critical level required for resuspension.
- That the fine sediments when discharged to the open coast would sometimes settle on the near-shore sandy bottom and be gradually transported further off-shore. These fine sediments would contain relatively high levels of contaminants. Although they would not accumulate in the near shore "transition" zone, their continual input and passage through the transition zone, could threaten the aquatic ecosystem there.

This report reviews the current information and estimates concentrations based on some simple assumptions and the Urban Stormwater Contaminant Model. It carries this out for the East Coast Bays catchments and receiving waters as a test case.

3 Project Brief

The project objectives and tasks were:

Objective: To provide an overview of sediment settling characteristics from urban stormwater discharging to an open coastal environment and provide recommendations for monitoring the effects of stormwater discharging to that environment.

Services to be performed:

1. Estimate catchment loads.
2. Locate and summarise all sediment quality data.
3. Construct a conceptual model of sediment dynamics and contaminant dispersal and accumulation.
4. Estimate contaminant concentrations in sediments under likely scenarios.

4 Current Sediment Quality Information

Sediment quality information on the sediments off East Coast Bays is available from the following publications.

1. Port of Auckland studies on the old Rangitoto Dump ground (Ports of Auckland 1989, 1990).
2. Environmental impact assessments of the old and proposed North Shore City sewage outfalls (Rosedale Outfalls) (NIWA 1999, Kingett Mitchell 1999).
3. Surveys of urban marine receiving water sediments conducted around the Regional Discharges Project (URS 2002) and the ARC Long Term Baseline Sediment Monitoring programme (ARC 2003).
4. Ultra-sound mapping of sediment texture (ARC 2000).
5. Recent sediment surveys (Kingett Mitchell pers. comm.)

4.1 Ports of Auckland

The Port of Auckland studies on the Rangitoto dredge spoil dumpsite are somewhat remote from the influence of the East Coast Bays urban catchments, but do provide some background information.

The results and data from other studies reviewed in the Ports of Auckland reports suggest that off the East Coast Bays, there is a sediment textural pattern of predominantly sand at water depths <10m and predominantly mud at water depth > 10 m. (However, coarse sediments are found in the deeper channels of the Rangitoto Channel). This 10 m water depth contour occurs approximately 1 km off shore near Takapuna.

The analyses in the Ports Of Auckland study were done using 0.5 M HCl. Most data was from total sediment samples, but there is some data on the sediment mud (< 63 µm) fraction. Samples were collected in deeper water and were well beyond the inner 10 m water depth contour line.

Analyses on the mud fraction show Zn concentrations of 45-50 µg/g at the control sites (about 800-1100m from the dumpsite). This is a somewhat higher than what is typically assumed for background with weak acid extraction for Auckland (<35 mg/kg). It may mean that the natural background of these offshore sediments is high because of geochemical reasons, or it may mean that samples this far off shore have been affected by past industrial, dredge dumping and/or urban stormwater disposal.

4.2 Other sediment textural surveys

An acoustic and video survey of the soft sediments habitats of the Okura/Long Bay area was carried out by NIWA for the ARC (ARC 2000). The results show that silty sediment lie about 1 km off-shore at about 10 m depth in agreement with Ports of Auckland surveys near the Rangitoto channel.

4.3 Project Rosedale

The Rosedale outfall is located 0.62 km offshore from Campbells Bay. Data from the Rosedale outfall investigations (Table 1) shows slightly elevated concentrations of Zn against expected background, but the effect may be geochemical (i.e., due to the presence of more metalliferous background rocks) rather than due to Stormwater and/or Wastewater disposal.

Sediment texture measurements confirm sandy inshore sediments and muddy offshore sediments, although the transition may occur at greater distances (2 km) at this location. Indeed, the mud/sand transition seems to occur at approximately 1 km off shore at the north and south ends of East Coast Bays and about 2 km in the middle of the bays. This is probably due to differences in the relative exposure throughout the length of the East Coast Bays.

Table 1. Earlier data from Project Rosedale investigations.

Site	Site No.	Offshore	Longshore	% mud	Total Cu	Total Pb	Total Zn
		(m)	(m)		mk/kg	mg/kg	mg/kg
Rosedale	X1	620	43		4.7	15.7	54.1
	X2	620	636		9.9	10	48.3
	X3	620	1228		4.9	15.2	50.9
	X4	620	2000		3.4	9.9	41.2
	C1	2500			6	20.5	56.7
Mairangi Bay	M1/1	2850			8.8	25.1	65
At proposed Northern Long Outfall	M1/2	2850			7.9	25.4	62.2
50-100m offshore CSO	M2	50			4.4	8.1	33.4
Rosedale Northern transect	N50	620	50	12.5			
	N100	620	100	23.5			
	N200	620	200	25.6			
	N1000	620	1000	17.2			
	N2000	620	2000	39			
Southern transect	S50	620	50	18.4			
	S100	620	100	12.1			
	S200	620	200	22.4			
	S1000	620	1000	10.7			
	S2000	620	2000	7.9			
Western transect	W50	570	0	23.4			
	W100	520	0	9.5			
Eastern Transect	E50	670	0	22.7			
	E100	720	0	23.8			
From proposed outfall	MLA	2350	500	90.1			
(Northern Long - NL)	MLA	2350	0	83.4			
	MLA	2350	-500	72.5			
	MLB	2850	500	92.5			
	MLB	2850	0	85.7			
	MLB	2850	-500	77.3			
	MLC	3350	500	92.2			
	MLC	3350	0	86.2			
	MLC	3350	-500	79.6			

4.4 Regional Discharges Project

The RDP project has collated data for sediments in the inshore area of East Coast Bays (Table 3) from the ARC Long Term Baseline monitoring programme and sediment surveys carried out by North Shore City. In addition to this data, historical information on sediments in the Wairau (Milford) estuary shows that this estuary is highly contaminated.

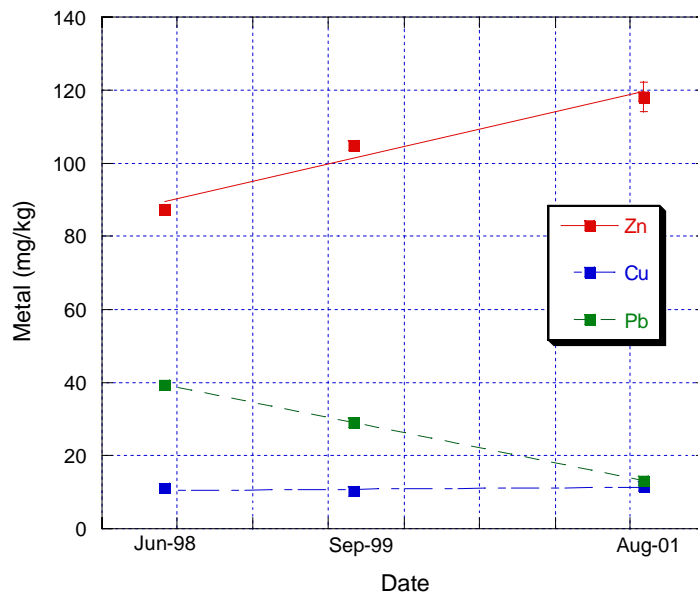
Table 2. Regional Discharges Project data for East Coast Bays.

Site	Source	Offshore (m)	% mud	<500 um				<63 um		
				Cu mg/kg	Pb mg/kg	Zn mg/kg	PAH µg/kg	Cu mg/kg	Pb mg/kg	Zn mg/kg
Wairau Creek	NSC	Estuary		119	136	397		135	167	508
Wairau Surf zone	NSC	5		4	39	9	163	6	34	9
Milford Beach	NSC	0	8	3.4	11.7	49.6	877	4	6.7	31.6
Wairau-subtidal	NSC	30	36	4.1	8.8	39.1	601	5.9	9.1	34.3
Torbay Deep Creek Estuary	NSC	Estuary		4	42	7		46	83	311
Torbay Deep Creek Mouth	NSC	0	13	3.5	6.8	42.2		3.5	3.8	17.9
Browns Bay 1999	1999	0		1.3	3.9	22		10	*	130
Browns Bay 1998	1998	0		2.3	4.6	43.9		*	*	*
Browns Bay 2001	2001	0		2.0	*	43.2	49	*	*	*
Mairangi Stream	2000	Estuary						43	66	259
Cheltenham Beach	1999	0		1.7	7.2	27.3		10	29	105
Cheltenham Beach	1998	0		3	11	47		11	39	87
Cheltenham Beach	2001	0		2.2	5.1	48.7	339	11.6	13.1	118
Long Bay Awaruku	1999	0		2.5	0.9	13.6		8	*	87
Long Bay Awaruku	1998	0		1.7	1.3	24		9	12	62
Long Bay Awaruku	2001	0		1.5	*	26.4	15	*	*	*
Long Bay Vaughn	1999	0		4.2	1.4	18		9	*	80
Long Bay Vaughn	1998	0		1.4	*	22.5		*	*	*
Long Bay Vaughn	2001	0		1.2	*	24.7	12	*	*	*

Only one of these sites, Cheltenham, has sufficient data to determine time trends. The trends (Figure 1) show Zn increasing and approaching the 'amber' Environmental Response Criteria (ERC). Pb is decreasing, as at all LTB monitoring sites in Auckland.

The other LTB sites have insufficient data to determine trends. This is because sometimes the proportion of mud in the sediment sample is insufficient to get a representative mud sample to analyse.

Figure 1. Trends in concentration at the ARC LTB Cheltenham site.



4.5 Recent offshore sediment surveys

Recent surveys of the sediment quality have been conducted offshore from East Coast Bays. The variation of the concentration of Cu, Pb and Zn has been examined along the coast and with distance offshore for North Shore City (Kingett Michell, pers. comm.). There is detailed information from the around Wairau Creek, as well as a broader survey along the East Coast. This data is summarised in Table 3, along with summarised data from Table 2 and recent data collected at a possible future outfall site (Kingett Michell, pers. comm.)

Sites and Zn concentrations are shown in Figures 2 and 3.

Table 3 yields 3 interesting points in respect to the project aim.

- Estuary sites are highly contaminated even though most of the contaminants would be carried beyond them to the open coast because of their small size, especially during floods.
- Sites in the surf zone are usually below ERC. However:
 - Data from Browns Bay suggests that Zn levels could reach 'amber' status. However this is a high-energy site which makes it difficult to get enough mud-sized sediment to analyse, and the result may be an artefact of this difficulty. On the other hand, it may also mean that the fine fraction of sediments can indeed be contaminated from time to time.
 - Sediments on the open coast adjacent to the mouth of the Wairau estuary were slightly contaminated with Pb, Cu and Zn on two occasions, and concentrations are approximately twice expected background concentrations. The relatively low Zn, Cu and Pb concentrations are found despite the size of the Wairau catchment (11.4 km²) and the relatively large load of Zn, Cu and Pb that will be discharged from the Wairau Stream. However, a relatively high PAH concentration was found of 877 µg/kg (not

shown in Table 4. This value has been obtained by adjusting concentrations to 1% TOC). This concentration exceeds the amber ERC.

- data from Cheltenham suggest the mud fraction is becoming increasingly contaminated, although the level on contamination is still below ERC "amber" levels. There is an overall increase in Zn and decrease in Pb between 1998 and 2001 (Figure 1). This trend is typically observed at many other urban coastal sites in the ARC LTB programme (ARC 2003). This would be of concern if the source of this contamination were solely the Cheltenham catchment. However, the contamination may also be due to exports from the Middle Waitemata Harbour.
- Further offshore, concentrations reflect a slight contamination, although this may be partly due to higher concentrations in the background material (P. Kennedy, Kingett Mitchell, pers. comm.).

Table 3. Concentrations in the mud fraction of sediments collected along East Coast Bays.

Date	Easting	Northing	Location	Distance offshore	Cu mg/kg	Pb mg/kg	Zn mg/kg
Estuaries							
01-30-02	2666900	6498500	Deep Creek	Estuary	27	53	251
09-26-00	2667000	6494250	Mairangi Bay		43	66	259
09-26-00	2668000	6491000	Wairau Creek, Castor Bay	Estuary	135	167	509
01-31-02	2668100	6491550	Wairau Creek	Estuary	32	33	171
Surf Zone							
01-31-02	2668300	6491500	Wairau Creek Beach (Milford)	0	4.0	6.7	32
01-30-02	2668700	6491600	Wairau Surf Zone	0	6.0	9.0	34
01-30-02	2667070	6498400	Deep Creek Mouth	0	3.5	3.8	18
1/08/1999	2666812	6500800	Long Bay off Vaughn Stream	0	9.2	0.0	80
1/08/1999	2666850	6496845	Browns Bay	0	10.2	1.4	131
1/08/1999	2667046	6500078	Long Bay off Awaruku Stream	0	8.5	0.0	87
1/08/1999	2671826	6485010	Cheltenham Beach	0	10.1	29	105
Near Shore							
30/01/2003	2668446	6491515	Wairau Creek Beach (Milford)	200	11	19	78
30/01/2003	2668646	6491315	Wairau Creek Beach (Milford)	400	8	19	74
30/01/2003	2668646	6491515	Wairau Creek Beach (Milford)	400	9	26	72
30/01/2003	2668646	6491715	Wairau Creek Beach (Milford)	400	9	23	73
30/01/2003	2668846	6491115	Wairau Creek Beach (Milford)	600	7	20	65
30/01/2003	2668846	6491315	Wairau Creek Beach (Milford)	600	8	21	71
30/01/2003	2668846	6491515	Wairau Creek Beach (Milford)	600	9	23	77
30/01/2003	2668846	6491715	Wairau Creek Beach (Milford)	600	8	25	73
30/01/2003	2668846	6491915	Wairau Creek Beach (Milford)	600	8	24	75
Off Shore							
13/01/2003	2669285	6491521	Wairau Creek Beach (Milford)	1150	9	32	73
13/01/2003	2667868	6496610	Rothesay Bay	1300	7	24	63
13/01/2003	2668560	6499251	Toroa Pt, Torbay	750	7	23	63
13/01/2003	2667675	6503019	Piripiri Pt, Okura	1000	7	20	58
Far Off Shore							
1/01/2000	2670072	6495482	Tatarata Pt, Murray Bay	2600	8.7	20	56
1/01/2000	2670038	6495476	Tatarata Pt, Murray Bay	2600	8.8	21	58
1/01/2000	2670022	6495432	Tatarata Pt, Murray Bay	2600	9.2	21	59
1/01/2000	2670022	6495334	Tatarata Pt, Murray Bay	2600	8.6	20	55
13/01/2003	2671395	6504485	Piripiri Pt, Okura	5000	7	23	69
13/01/2003	2672280	6500717	Toroa Pt, Torbay	4500	6	22	65
13/01/2003	2671588	6498108	Browns Bay	4500	6	24	62
13/01/2003	2673005	6492987	Campbells Bay	5000	7	23	56

Overall, the data suggests that, beyond the estuaries, the nearshore sediments are generally not contaminated to levels of concern. Concentrations in the mud fraction are generally lower than ERC, and there is sometimes very little mud present. However, some elevated concentrations have been recorded at some sites from time to time (Wairau, Browns Bay and Cheltenham). One is left with the conclusion that sediments just offshore can become contaminated from time to time, but no high ("red") concentrations have been encountered so far.

4.6 Likely processes and resulting concentrations

The results and data from these studies confirm that off the East Coast Bays, there is a sediment textural pattern of predominantly sand at water depths <10m and predominantly mud at water depth > 10 m. This 10 m water depth contour occurs approximately 1 km off shore at the northern and southern ends of the East Coast Bays, but may be further out in the middle of East Coast Bays, which is less sheltered.

In calm conditions, the fine sediments discharged to the open coast may settle on the near-shore sandy bottom and be gradually transported further offshore. The fine sediments would contain relatively high levels of contaminants as confirmed by the high levels found in estuaries. Off-shore, some dilution by uncontaminated mud particles will occur. The data reviewed above suggest that contaminants do not accumulate in the near shore "transition" zone, and that their continual input and passage through the transition zone does not seem to result in a threat to the near shore aquatic ecosystem. Concentration appear to be higher than natural background, but are still well below 'red' ERC, although the limited data suggest that they might reach 'amber' ERC from time to time.

Deeper offshore, below depths at which the wave orbital velocities have decreased below a critical level, fine sediment containing contaminants will accumulate over long periods of time as suggested by the sediment textural data. The data summarized above suggest that, to date, there could be some small increase in concentrations above natural background. It is difficult to be certain about the magnitude of the increase because of the uncertainty in the background concentration.

Figure 2. Sampling sites and Zn concentrations in the mud fraction of sediments in coastal areas off East Coast Bays. (Data courtesy of North Shore City Council (Kingett Mitchel, pers.comm.)).

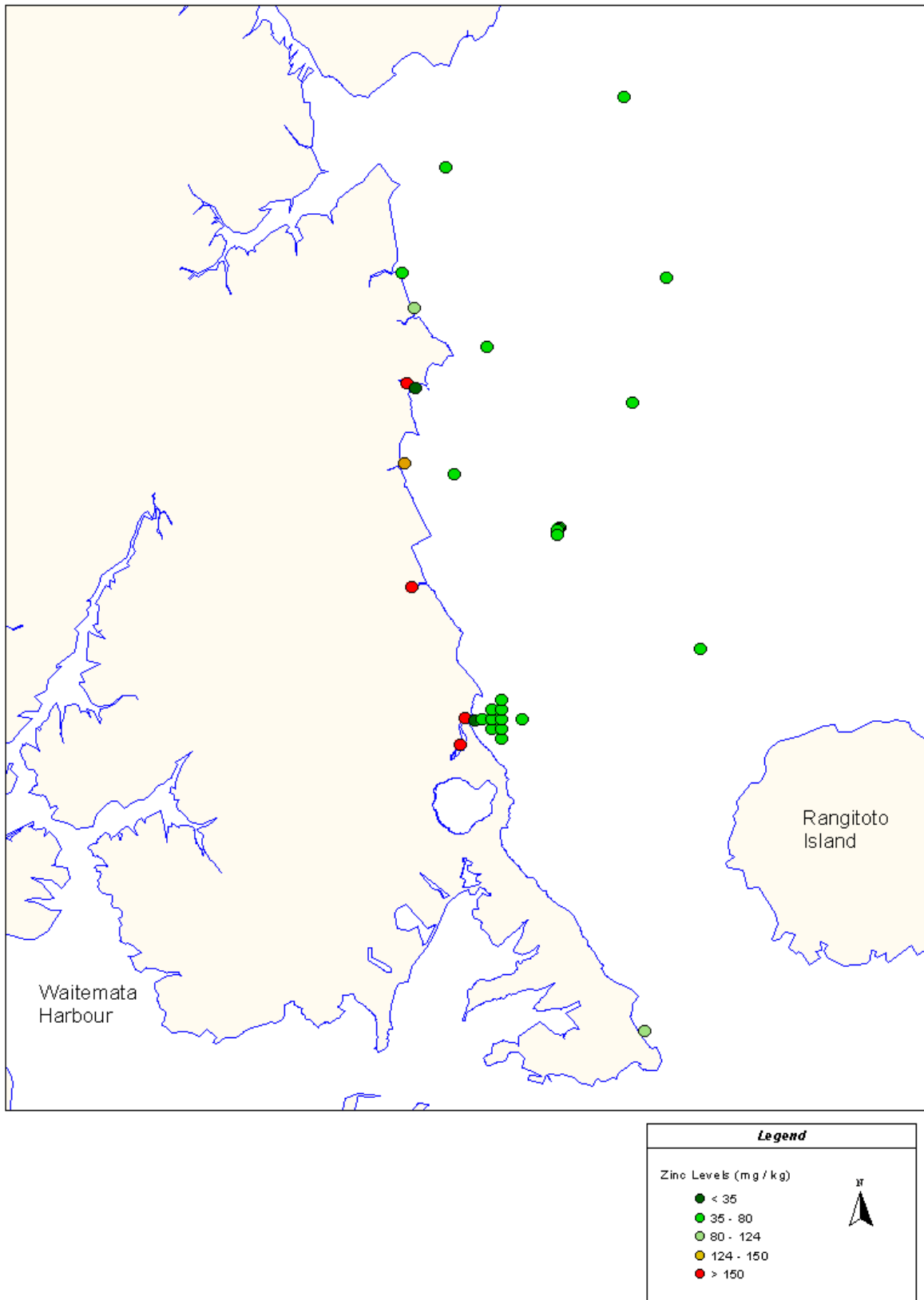
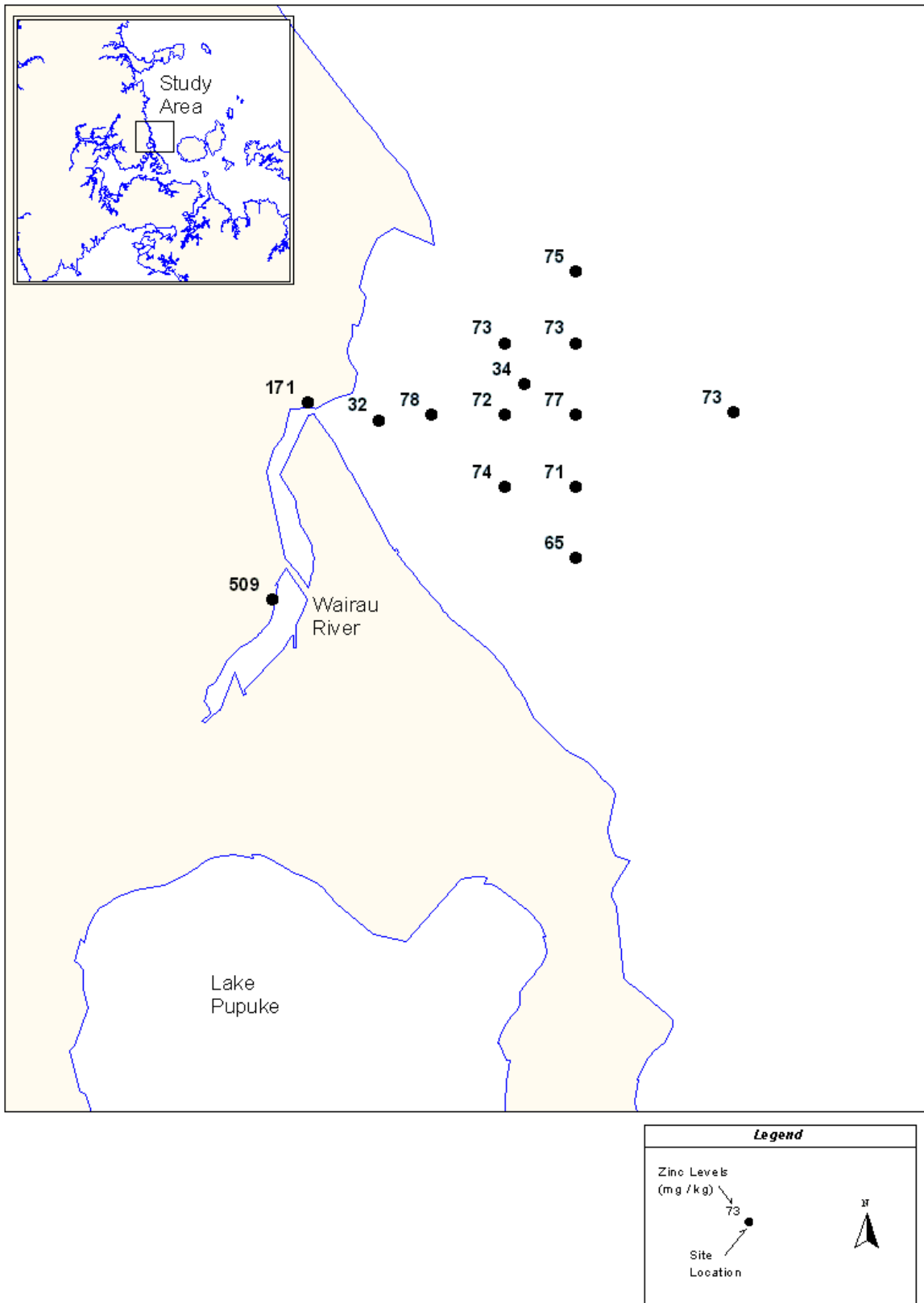


Figure 3. Sampling sites and Zn levels in the mud fraction of sediments near Wairau Creek, Milford. (Data courtesy of North Shore City Council (Kingett Mitchel, pers.comm.)).



5 Modelling Zn Concentrations Off East Coast Bays

The East Coast Bays catchments are shown in Figure 4. The catchments included in the load estimation are listed in Table 4 and catchment details are found in Appendix 1.

Modelling was carried out using the USC model using the following assumptions.

Average Zinc Load	0.75	kg/ha/yr
Length of accumulation zone	16	km
Maximum width of accumulation zone	1	km
Mass of sediment in 16 km x 1 km	19200000	tonnes

To calculate the present day concentrations, the following calculation spreadsheet was used.

Table 4. Zn load estimates from East Coast Bays.

Catchment	m ²	ha	Age (yrs)	To 2002	To 2050	To 2150
4) East Coast Bays Catchment 1	1026707	102.7	52	4004	7854.3	15555
5) Deep Creek Catchment	2538797	253.9	20	3808	13329	32370
8) Taiaotea Catchment	3866312	386.6	20	5799	20298	49295
10) Rothesay Bay Catchment	648714.7	64.9	30	1460	3892.3	8757.6
13) Tairahi Catchment	1386409	138.6	30	3119	8318.5	18717
15) East Coast Bays Catchment 2	369495.2	36.9	52	1441	2826.6	5597.9
16) Mairangi Bay Catchment	1730546	173.1	42	5451	11941	24920
17) Campbells Bay Catchment	1668482	166.8	42	5256	11513	24026
18) Wairau Valley Catchment	13009899	1301.0	30	29272	78059	175634
20) Castor Bay Catchment	720261.8	72.0	30	1621	4321.6	9723.5
22) Seaview Catchment	628749.7	62.9	40	1886	4244.1	8959.7
25) Milford Beach Catchment	922810.1	92.3	52	3599	7059.5	13981
37) Takapuna Beach Catchment	1296477	129.6	52	5056	9918	19642
54) North Head Catchment	1149485	114.9	52	4483	8793.6	17415
Total		3096	Total (kg)	76256	192368	424592
4% of Total		124				

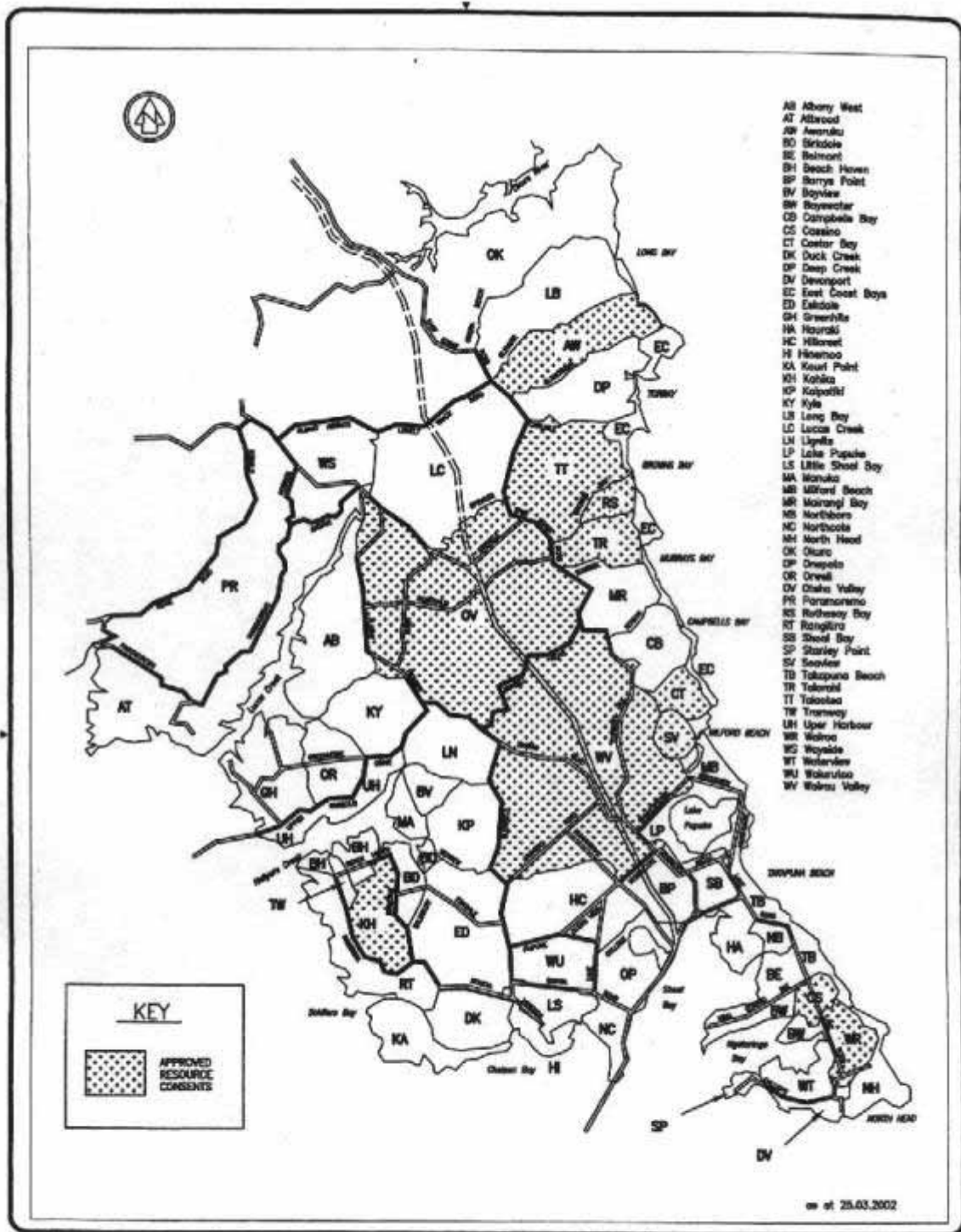
To calculate the concentrations, the following assumptions were made

1. The total load was assumed to be evenly distributed in an accumulation zone, approximately 1 km offshore.
2. The length of this zone was maintained at 16 km.
3. The width of the zone was varied within limits that ranged from 100 m to 1000m.
4. All the contaminant was assumed to be in the mud fraction

5. Only half the contaminant load discharged to the coastal zone was incorporated in the accumulation zone.

These calculations are very approximate. The methods here probably overestimate the input of zinc in the short term (i.e., to the present day) because they do not take into account the gradual urbanization process, nor do they allow for dilution by eroded subsoils. These shortcomings are less important for predictions to the year 2050 and 2150, because the errors introduced by the simplifications become smaller. The resulting concentrations for a range of accumulation zone width and mud content are listed in Table 5.

Figure 4. East Coast Bays




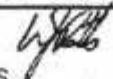
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	WALLY POTTS GROUP OPERATIONS MANAGER Date 16/4/02		Scale: NTS
			Drawing No. 28275
			Sheet 1

Table 5. Calculated Zn concentrations (mg/kg) in a hypothetical accumulation zone in 2002. Concentrations are colour-coded according to the "Traffic Light" Environmental Response Criteria.

2002	Width of Accumulation Zone (m)			
Mud%	100	200	500	1000
5	432	234	114	75
10	234	134	75	55
20	134	85	55	45
50	75	55	43	39
100	55	45	39	37

We know that the mud fraction in the hypothetical accumulation zone is greater than 50% and it is highly unlikely that the width is less than 500m given the distance the contamination has to travel to the accumulation zone (at least 1 km), and the likely dispersion associated with the transport process.

If we then take 50% mud and 500 m width as the worse case, then concentrations of Zn are likely to be of the order of < 43 mg/kg, i.e., there is a very small increase. This is reasonably consistent with measured concentrations. Higher concentrations are observed in the mud fraction of the sediment, but higher background concentrations are suspected.

The other scenarios presented in Table 5 with higher predicted Zn concentrations show under what conditions the model predicts that ERC are exceeded. This would require low mud content in the sediment (which is not observed) and what are deemed to be unrealistically small accumulation areas.

The reason for such a small change for the assumed worse case above is because the accumulation zone is reasonably assumed to be large (in this case 800 ha) compared with the size of the theoretical 4% Settling Zone (124 ha).

Over longer periods these concentrations will increase. The loads generated until 2050 are listed in Table 6. The worse case (50% mud and 500 m width) now has a Zn concentration of 55 mg/kg. The key point here is the predicted magnitude of the increase. The magnitude is too small to be concerned that concentrations of these contaminants will be an issue in the foreseeable future.

Table 6. Calculated Zn concentrations (mg/kg) in a hypothetical accumulation zone in 2050. Concentrations are colour-coded according to the "Traffic Light" Environmental Response Criteria.

2050	Width (m)			
Mud%	100	200	500	1000
5	1037	536	235	135
10	536	285	135	85
20	285	160	85	60
50	135	85	55	45
100	85	60	45	40

For the year 2150, the loads generated are listed in Table 7. The worse case (50% mud and 500 m width) now has a Zn concentration of 79 mg/kg.

Table 7. Calculated Zn concentrations (mg/kg) in a hypothetical accumulation zone in 2150. Concentrations are colour-coded according to the "Traffic Light" Environmental Response Criteria.

2150	Width (m)			
Mud%	100	200	500	1000
5	2246	1141	477	256
10	1141	588	256	146
20	588	311	146	90
50	256	146	79	57
100	146	90	57	46

6 Discussion

The sediment textural pattern off East Coast Bays is predominantly sand at water depths <10m and predominantly mud at water depth > 10 m occurs. This 10 m water depth contour occurs approximately 1 km offshore near Rangitoto Island and near Okura. Many sediment texture measurements confirm the sandy inshore sediments and muddy offshore sediments, and although the mud/sand transition seems to occur at approximately 1 km offshore at the north and south ends of East Coast Bays, it is found about 2 km off shore in the middle of the Bays. This is probably due to the relative exposure throughout the length of the East Coast Bays.

Stormwater discharges directly to the coast and via the freshwater drainage system. The streams discharge via small estuaries. Most of the contaminants would be carried beyond these estuaries to the open coast because of their small size, especially during floods. The contaminants would be expected to be carried offshore to settle in deeper waters. Contaminants may deposit near shore during calm conditions, but it is expected that these will be remobilised and moved further offshore. Any contaminant accumulation would only occur in the muddy sediment offshore, i.e., 1-2 km offshore.

Surveys of sediment quality have found that the small estuary sites are highly contaminated, confirming the highly contaminated sediment being transported through these systems.

Sites in the surf zone are largely uncontaminated, but occasional elevated concentrations are found at Cheltenham (Zn, Pb, PAH), Browns Bay (Zn) and Milford (PAH), the latter 2 exceeding 'amber' ERC. Therefore there is the possibility that, during the transport of contaminants from the near shore zone to the offshore zone, the mud fraction of near shore sediments could occasionally contain elevated concentrations of contaminants.

Further offshore, concentrations reflect a slight contamination, although this may be partly due to higher concentrations in the background material (P. Kennedy, Kingett Mitchell, pers. comm.)

Overall, the data suggests that the offshore sediments are generally not contaminated to levels of concern for aquatic life and that concentrations in the mud fraction are generally low.

The modelling carried out in this study is only approximate. The catchment load estimates could be improved through factoring in the gradual urbanisation process and the input of eroded subsoils. Attempts were made in this study to improve these estimates, with the help of North Shore City Council, but the time involved to achieve this was beyond the scope of the study. While this is disappointing, it does not negate the findings in this report. Even if these improvements were made, there would still be large uncertainties about the amount of contaminants accumulating offshore, because of the uncertainties in the delivery to, and the dimensions and concentration gradients of, this accumulation zone.

The important point is that the simple model has predicted only small increases in Zn concentrations (the main contaminant) and this is what is observed to date from sediment surveys. The predicted concentrations into the future for 2050 and 2150 are also relatively small compared with the Environmental Response Criteria (ERC), so more accurate modelling is not required to make conclusions about the projected increases. If the projected increases had approached the 'amber' ERCs, then conclusions from the modelling results would have been uncertain and more accurate modelling would have been required.

Because the predicted and observed concentrations are relatively low, there is no need for an extensive monitoring programme in the muddy sediments 1-2 km off the coast.

Apart from the very high concentrations that can be found in the estuaries, there is the concern that open-coastal discharges of particulate Zn, Cu, Pb and PAH can sometimes elevate concentrations in the near shore zone. Monitoring the near shore situation and re-evaluating the concentration trends after further sampling can address these concerns. A site offshore from Wairau Creek could usefully augment the existing ARC LTB monitoring sites at Long Bay, Browns Bay and Cheltenham. Note that the small fraction of mud found in the sediments on most occasions at Long Bay and Browns Bay is compromising this programme at the present time and this argues for a revised sampling strategy there.

7 References

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Appendix 1: Catchment Data for East Coast Bays

Catchment	Total Area	Prop Area	Imperv Kerb Area	Total Imp Area	Prop Imp Area	Imp Area as a % of Catchment
1) Okura Catchment	6,325,727	6,325,727	2,615	93,951	91,336	1
2) Long Bay Catchment	3,539,398	3,526,102	14,954	75,209	60,255	2
3) Awaruku Catchment	2,998,991	2,848,162	188,882	878,363	689,482	29
4) East Coast Bays Catchment 1	1,026,707	958,368	90,489	420,862	330,373	41
5) Deep Creek Catchment	2,538,797	2,354,019	229,500	1,005,115	775,615	40
8) Taiaotea Catchment	3,866,312	3,604,215	332,700	1,519,058	1,186,358	39
10) Rothesay Bay Catchment	648,715	601,491	61,091	290,083	228,992	45
13) Taiorahi Catchment	1,386,409	1,290,172	121,939	543,730	421,791	39
15) East Coast Bays Catchment 2	369,495	346,870	30,054	160,132	130,078	43
16) Mairangi Bay Catchment	1,730,546	1,593,232	167,276	769,783	602,507	44
17) Campbells Bay Catchment	1,668,482	1,612,739	69,825	389,334	319,508	23
18) Wairau Valley Catchment	13,009,899	12,018,654	1,286,453	6,139,361	4,852,908	47
20) Castor Bay Catchment	720,262	677,424	55,735	282,124	226,388	39
22) Seaview Catchment	628,750	578,676	62,753	300,278	237,525	48
25) Milford Beach Catchment	922,810	846,100	104,676	464,348	359,672	50
37) Takapuna Beach Catchment	1,296,477	1,199,494	127,184	597,543	470,360	46
54) North Head Catchment	1,149,485	1,063,788	98,454	470,980	372,526	41
Totals (confirmed against ArcView totals)	43,827,262	41,445,230	3,044,579	14,400,252	11,355,674	