Wriggle

coastalmanagement

Porirua Harbour

Intertidal Sediment Monitoring 2011/12

Prepared for
Greater Wellington Regional Council
July 2012

Cover Photo: Pauatahanui Inlet - Fine surface sediment deposits near the Horokiri Stream mouth.

Porirua Harbour Estuary, Onepoto Arm - lower estuary.

Porirua Harbour Estuary

Intertidal Sediment Monitoring 2011/12

Prepared for
Greater Wellington Regional Council

By

Leigh Stevens and Barry Robertson

Wriggle Limited, PO Box 1622, Nelson 7040, NZ. Ph 03 545 6315, 021 417 936; 0275 417 935, www.wriggle.co.nz

Contents

List of Figures

List of Tables

1. INTRODUCTION AND METHODS

Porirua Harbour Estuary

↓

Vulnerability Assessment
Identifies issues and recommends monitoring and management. Completed in 2007 (Robertson and Stevens 2007)

↓

Porirua Estuary Issues
Moderate eutrophication
Excessive sedimentation
Habitat Loss (saltmarsh, dune and terrestrial margin)

↓

Monitoring

Broad Scale Mapping
Sediment type
Saltmarsh
Seagrass
Macroalgae
Land margin

5 -10 yearly
First undertaken in 2008.
Next survey 2013.

Fine Scale Monitoring
Grain size, RPD, Organic Content
Nutrients, Metals, Invertebrates, Macroalgae, Sedimentation,

4yr Baseline then 5 yearly
3 year baseline completed 2009/10.
Next survey 2015.
Sedimetation, 2013.

↓

Condition Ratings
Area soft mud, Area saltmarsh, Area seagrass, Area terrestrial margin, RPD depth, Benthic Community, Organic content, N and P, Toxicity, Sedimentation rate.

Other Information
Previous reports, Observations, Expert opinion

↓

ESTUARY CONDITION
Moderate Eutrophication
Excessive Sedimentation
Low Toxicity
Habitat Degraded (saltmarsh, terrestrial margin)

↓

Recommended Management

- Limit intensive landuse.
- Set nutrient, sediment guidelines.
- Margin vegetation enhancement.
- Manage for sea level rise.
- Enhance saltmarsh.
- Manage weeds and pests.

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in estuaries because they act as a sink for fine sediments or muds. The main intertidal flats of developed estuaries (e.g. Porirua Harbour) are usually characterised by sandy sediments reflecting their exposure to wind-wave disturbance, and are hence relatively low in mud content (2-10% mud).

Recent monitoring (Robertson and Stevens 2008, 2009, 2010) showed Porirua Harbour Estuary had low-moderate intertidal sedimentation rates and a benthic invertebrate community dominated by species that prefer sand or a little mud. However, the sand dominated sediments had an elevated mud content, showed a general trend of increasing muddiness, and sediments were not very well oxygenated. Based on these findings, in 2011 Greater Wellington Regional Council (GWRC) decided to continue annual monitoring of sedimentation rates, grain size, and RPD depth at existing intertidal sites in the estuary (e.g. Stevens and Robertson 2011).

In addition to intertidal areas, Porirua Harbour has also been identified as being particularly at risk from subtidal sedimentation because the main subtidal basins are rapidly infilling (Gibb and Cox 2009). Gibb and Cox predict that both estuary arms are highly likely to rapidly infill and change from tidal estuaries to brackish swamps within 145-195 years. The dominant sources contributing to increasing sedimentation rates in the estuary were identified as discharges of both bedload and suspended load from the various input streams (most notably Pauatahanui, Horokiri and Porirua Streams). Elevated inputs of nutrients from the same streams are also causing symptoms of moderate eutrophication (i.e. poor sediment oxygenation and moderate nuisance macroalgal cover) in the estuary (Stevens and Robertson 2009, 2010, 2011, Robertson and Stevens 2009, 2010, 2011).

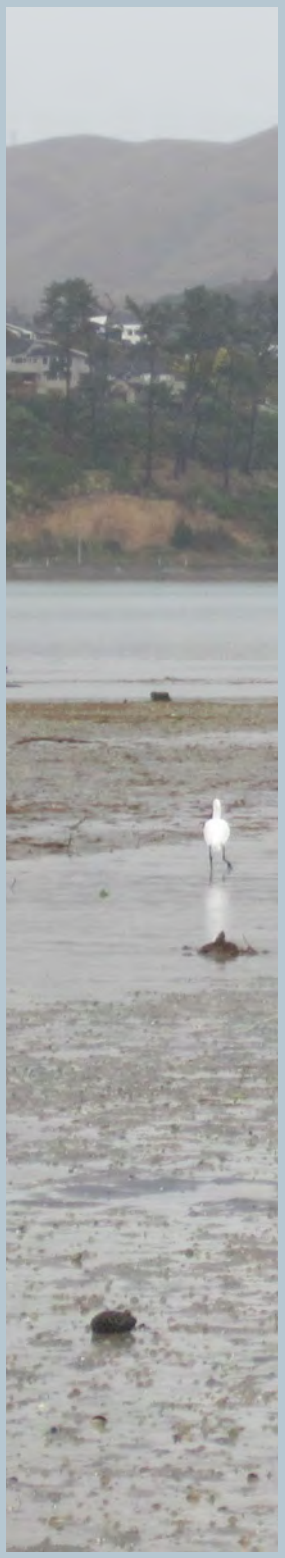
In response to these concerns, GWRC convened a technical workshop in April 2011 which drew on expert scientific advice, combined with existing catchment and estuary models, to highlight the areas of greatest predicted deposition. A key output was the recommendation to increase the number of intertidal plates within areas influenced by priority catchments, and to determine suitable methods and locations for the establishment of subtidal sediment plates which is where the greatest sediment deposition in the estuary is expected to occur. Work into catchment sources and loads is ongoing, particularly in relation to likely increased sedimentation to the estuary as a result of the construction of Transmission Gully motorway.

The current report presents the 2012 monitoring results of intertidal sedimentation rates, grain size, and RPD indicators monitored at established sites in Porirua Harbour Estuary in February 2012. Condition ratings, developed for Wellington's estuaries, are used to rate the condition of the estuary, and recommend monitoring and management actions.

This report also describes the establishment of four additional intertidal sites (3 in Pauatahanui Arm and 1 in the Onepoto Arm - Figure 1), and identifies a series of sites recommended for the establishment of shallow subtidal plates (e.g. photo below).

Pauatahanui Arm - wading into deep soft muds in the shallow subtidal basin near Duck Creek.

1. Introduction and Methods (Continued)



Detailed descriptions of existing sampling sites and methods are provided in Robertson and Stevens (2008, 2009, 2010), Stevens and Robertson (2011a), and are briefly summarised below.

Sedimentation Rate

To measure the sedimentation rate from now and into the future, concrete plates were buried at 4 intertidal sites and 1 subtidal site in the estuary in 2007, with an additional 4 sites (16 plates) added in 2012 (Figure 1, Table 1). Each plate, marked by wooden pegs and GPS referenced, was relocated and the depth of sediment over the plate measured by pushing a probe into the sediment until it hit the plate. A number of measurements on each plate were averaged to account for irregular sediment surfaces and to determine the mean annual rate of sedimentation at each site.

Grain Size

To monitor changes in the mud content of sediments, a single composite sample (10 combined sub-samples) of the top 20mm of sediment was collected from each fine scale site (sites A and B in each arm - see Figure 1), and from all previously and newly established sediment plate sites. All samples were analysed by Hill Laboratories for grain size (% mud, sand, gravel).

In 2012, a single composite sample was collected from each site instead of the replicated triplicate sampling undertaken in previous years. This was to enable a greater spatial spread of samples to be collected from throughout the estuary within the existing budget. The decision was based on the very low within-site sample variability shown during previous monitoring. It is recommended that triplicate sampling be undertaken whenever 5 yearly fine scale monitoring is undertaken to provide a regular check on within-site sample variability.

Redox Potential Discontinuity (RPD) depth

To assess sediment oxygenation, the mean depth to the RPD was calculated in 10 plots at each site by digging down from the surface with a hand trowel until the RPD transition level was located.

Table 1. Location of buried sediment plates, Porirua Harbour Estuary (No. refers to sites shown in Figure 1).

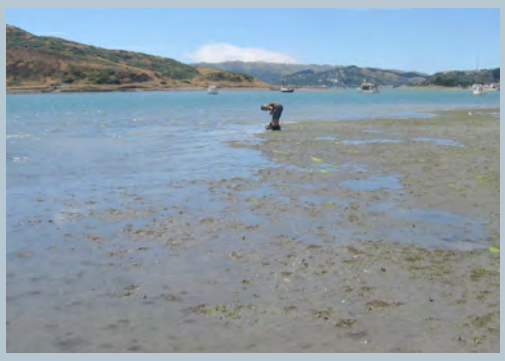
Onepoto Arm					Pauatahanui Arm				
No.	Site	PLATE	NZTM NORTH	NZTM EAST	No.	Site	PLATE	NZTM NORTH	NZTM EAST
1	Por A Railway (fine scale site)	1	5447787	1756508	6	Boatsheds (adjacent to 5. Paua A fine scale site)	1	5448786	1757269
		2	5447783	1756479			2	5448786	1757267
		3	5447761	1756480			3	5448786	1757265
		4	5447754	1756509			4	5448787	1757263
2	Aotea	1	5445521	1754774	7	Kakaho	1	5449750	1758887
		2	5445522	1754773			2	5449748	1758887
		3	5445524	1754771			3	5449746	1758887
		4	5445525	1754770			4	5449744	1758886
3	Por B Polytech (fine scale site)	1	5445431	1754566	8	Horokiri	1	5448830	1760042
		2	5445407	1754580			2	5448828	1760042
		3	5445529	1754561			3	5448826	1760041
		4	5445531	1754562			4	5448824	1760041
4	Por C Western subtidal	1	5447105	1755552	9	Paua B (fine scale site)	1	5448377	1760334
							2	5448356	1760354
							3	5448366	1760376
							4	5448392	1760365
					10	Duck Creek	1	5447947	1759831
							2	5447949	1759831
							3	5447951	1759830
							4	5447953	1759830

1. Introduction and Methods (Continued)

Figure 1. Location of fine scale sites and buried sediment plates established in 2007/8, and 2012 in Porirua Estuary.

1. Introduction and Methods (Continued)

WELLINGTON ESTUARIES: CONDITION RATINGS



A series of interim fine scale estuary "condition ratings" (presented below) have been proposed for Porirua Harbour Estuary (based on the ratings developed for New Zealand estuaries - e.g. Robertson & Stevens 2006, 2007, 2008, 2009). The ratings are based on a review of monitoring data, guideline criteria, and expert opinion. They are designed to be used in combination with each other, and with other fine and broad scale indicators (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an "early warning trigger" to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases initial management is to further assess an issue and consider what response actions may be appropriate (e.g. develop an Evaluation and Response Plan - ERP).

Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	0-1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-2mm/yr	Monitor at 5 year intervals after baseline established
Moderate	2-5mm/yr	Monitor at 5 year intervals after baseline established
High	5-10mm/yr	Monitor yearly. Initiate ERP
Very High	>10mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. The depth of the RPD layer is a critical estuary condition indicator in that it provides a measure of whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments. The majority of the other indicators (e.g. macroalgal blooms, soft muds, sediment organic carbon, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life. Knowing if the surface sediments are moving towards anoxia (i.e. RPD close to the surface) is important for two main reasons:

1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and very little aquatic life.

The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

RPD CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate ERP
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate ERP
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

2. RESULTS, RATING AND MANAGEMENT

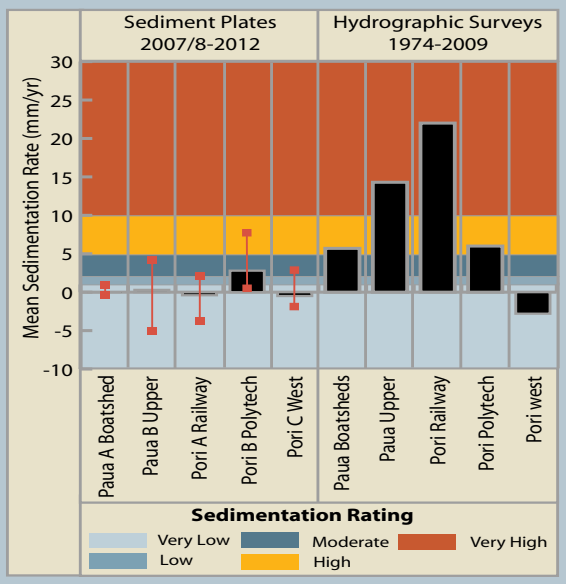


Figure 2. Sedimentation rate (mean and range) from plate data, Porirua Harbour Estuary (2007/8-2012).

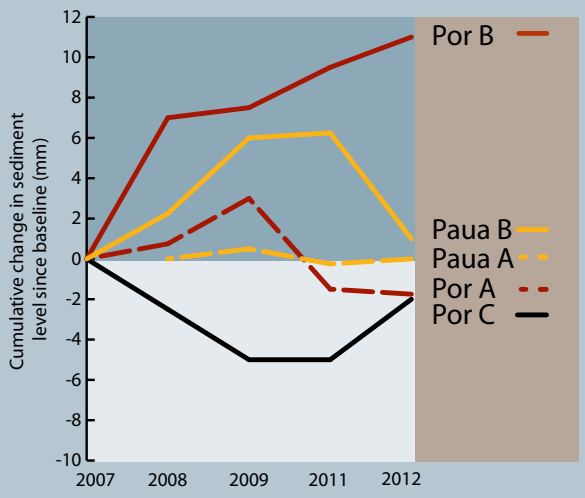


Figure 3. Mean change in sediment showing trends over buried plates from 2007/8-2012.

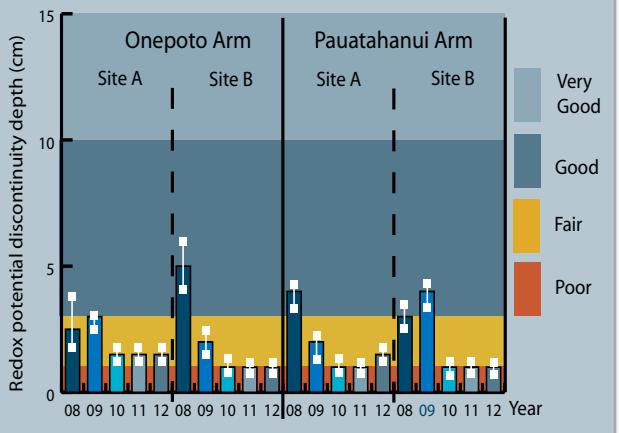


Figure 4. RPD depth (mean and range), Porirua Harbour Estuary fine scale sites, (2008-2012).

Three indicators were used to assess sedimentation at the fine scale monitoring sites in 2012: sedimentation rate, RPD depth, and grain size.

Rate of Sedimentation. The depths to 17 sedimentation plates buried at 5 sites in Porirua Harbour in 2007 (see Robertson and Stevens 2008) were measured in February 2012 as part of annual long term sedimentation rate monitoring in the estuary (Table 2, Figure 2).

Mean annual sedimentation rates for the estuary since 2007/8 range from -0.5 to +2.8mm/yr. Such rates fit within the "very low" to "moderate" categories (Table 2). The upper estuary sites in each arm were the only ones showing an increase in sedimentation, the greatest intertidal deposition currently occurring in the Onepoto Arm (Site Por B - Figures 2 and 3). Additional plates installed at 4 sites in February 2012 to monitor intertidal sedimentation rates over a wider spatial area in both arms will be reported on following establishment of a baseline (see Table 4 for inaugural data).

Although the average measured intertidal rates remain below those predicted by Gibb and Cox (2009) (Figure 2), the ranges indicate short-term variability can be high and large inputs over short time intervals following catchment disturbance could account for the higher averages reported by Gibb and Cox (2009). Ongoing monitoring of intertidal plates, and the establishment of plates within the main subtidal basins in both arms of the estuary is recommended.

Redox Potential Discontinuity (RPD). The depth to the RPD boundary is a critical estuary condition indicator in that it provides a direct measure of sediment oxygenation. This commonly shows whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments, and also reflects the capacity of tidal flows to maintain and replenish sediment oxygen levels. In well flushed sandy intertidal sediments, tidal flows typically oxygenate the top 10cm of sediment. However, when fine muds fill the interstitial pore spaces, less re-oxygenation occurs and the RPD moves closer to the surface.

In response to the presence of both fine muds and nutrient enrichment, the RPD depth has decreased at all fine scale sites in Porirua Harbour since 2008 (Figure 4, Table 3). In 2012, the measured RPD remained relatively shallow (1-1.5cm) indicating relatively poorly oxygenated sediments that fall within the "fair-poor" condition rating.

Grain Size. Grain size (% mud, sand, gravel) is a key indicator of both eutrophication and sediment changes. Increasing mud content signals a deterioration in estuary condition and can exacerbate eutrophication symptoms.

Grain size monitoring at fine scale sites (Figure 5, Table 3) shows that although sandy sediments dominate the sites, mud was also a significant component (7-15% mud). The highest mud contents were in the lower estuary ('A' sites). While the mud content has been relatively consistent at Por A and Paua B, it is more variable at Por B and Paua A.

Baseline grain size measures were made at sediment plate sites PorC and Boatsheds for the first time in 2011. Four additional sediment plate sites (three in Pauatahanui and one in Onepoto) were established in 2012. Site locations are presented in Figure 1, and results in Table 3 show the new sites generally have a mud content similar to the upper fine scale 'B" sites (1.5-8%).

2. Results, Rating and Management (Continued)

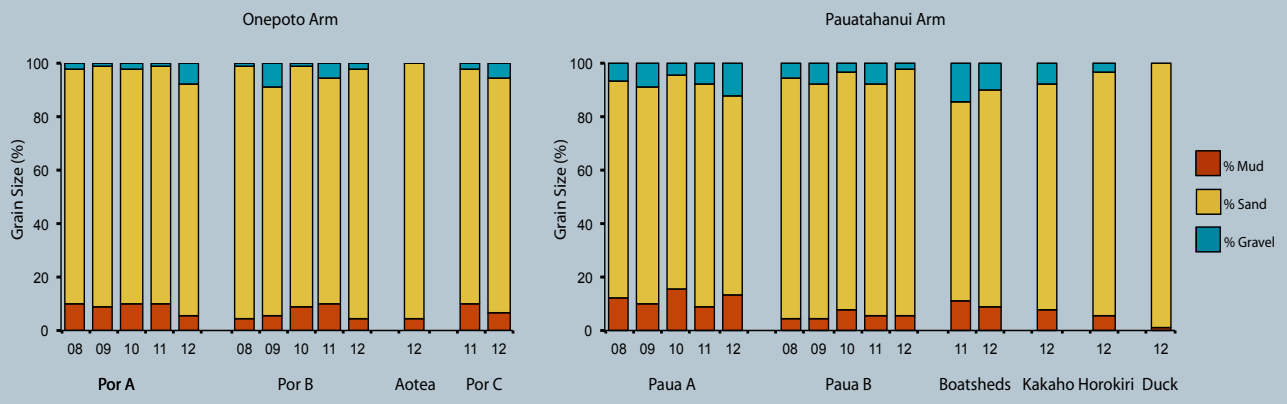


Figure 5. Grain size, Porirua Harbour Estuary fine scale and sediment plate monitoring sites (2008-2012).

Table 2. Intertidal sediment plate data, Porirua Harbour Estuary (2007-2012).

Site			Sediment Depth (mm)					Change (mm)				Site Mean (mm/yr)				2007-2012 Overall Rate (mm/yr)	2007-2012 Rating
			13/12/07	15/1/09	20/1/10	18/1/11	21-24/2/12	2007-2009	2009-2010	2010-2011	2011-2012	2007-2009	2009-2010	2010-2011	2011-2012		
Onepoto Arm	A. Lower (Railway)	1	168	164	159	155	160	-4	-5	-4	5	0.8	2.3	-4.5	-0.3	-0.4	VERY LOW
		2	150	152	158	156	151	2	6	-2	-5						
		3	152	155	163	150	145	3	8	-13	-5						
		4	93	95	95	96	100	2	0	1	4						
	B. Upper (Polytech)	1	237	237	240	242	245	0	3	2	3	7	0.5	2	1.5	2.8	MODERATE
		2	230	244	242	244	244	14	-2	2	0						
		3				110	110	-	-	-	0				-1.0	-	VERY LOW
		4				75	73	-	-	-	-2						
	C. Western Subtidal	1	120	-	115	115	118	-5		0	3	-5		0	3.0	-0.5	VERY LOW
Pauatahanui Arm	A. Lower (Boatsheds)	1	Baseline	171	172	165	166	-	1	-7	1	-	0.5	-0.8	0.3	0.0	VERY LOW
		2		213	213	215	216	-	0	2	1						
		3		232	232	233	234	-	0	1	1						
		4		234	235	236	234	-	1	1	-2						
	B. Upper (East Arm)	1	181	182	186	186	181	1	4	0	-5	2.3	3.8	0.3	-5.3	0.3	VERY LOW
		2	215	218	228	233	228	3	10	5	-5						
		3	182	186	183	183	181	4	-3	0	-2						
		4	176	177	181	177	168	1	4	-4	-9						

Table 3. RPD depth and grain size results, Porirua Harbour Estuary (21-24 Feb. 2012).

Estuary Arm	Site	RPD	Mud	Sand	Gravel
		cm	%		
Onepoto	Por A. Lower (Railway)	1.5	5.9	86.6	7.5
	Por B. Upper (Polytech)	1	4.7	93.2	2.1
	Por C. Western Subtidal	5	6.5	88.4	5.1
	Aotea (24/3/12)	3	4.0	95.8	0.3
Pauatahanui	Paua A. Lower (Boatsheds)	1.5	13.2	74.1	12.8
	Boatsheds (Sed Plates)	1	8.6	81.3	10.1
	Kakaho	3	8.0	84.1	7.8
	Horokiri	2	5.1	91.4	3.5
	Paua B. Upper (East Arm)	1	5.3	92.4	2.3
	Duck Creek	2	1.5	98.5	0.0

Table 4. Inaugural baseline depths of sedimentation plates established in early 2012, Porirua Harbour Estuary.

Estuary Arm	Site	Date established	Plate	Sediment Depth (mm)
Onepoto	Aotea	24/3/2012	1	138
			2	108
			3	103
			4	100
Pauatahanui	Kakaho	22/2/2012	1	73
			2	100
			3	90
			4	92
	Horokiri	22/2/2012	1	106
			2	108
			3	118
			4	98
	Duck Creek	22/2/2012	1	134
			2	108
			3	122
			4	88

2. Results, Rating and Management (Continued)

	It was noted that when sampling on the intertidal flats near the Pauatahanui and Horokiri Streams, a thin layer of recently deposited fine mud was evident on the surface (see cover photo). This mud was readily resuspended by wave action and appeared likely to be quickly remobilised and deposited elsewhere. Such sediments are most likely to accumulate in natural settling basins in the shallow subtidal parts of Porirua Harbour Estuary. Exploratory wading into such shallow subtidal areas found they are dominated by deep soft muds. Consequently, to better assess sedimentation in Porirua Harbour Estuary, it is proposed that several subtidal monitoring sites be established within the estuary in such areas. Proposed locations are shown on Figure 1. GWRC and PCC are also undertaking desktop assessments to determine the likely sediment input loads from different landuses, including the Transmission Gully motorway development, and modelling the zones of deposition within the estuary, to determine strategies for best managing sediment within the catchment.
CONCLUSION	Sediment plate monitoring since 2007 at strategic intertidal sites within the Porirua Estuary indicate elevated rates of sedimentation at the upper Onepoto Arm site, but relatively low mean rates at other sites. However, these results are not expected to adequately represent mean sedimentation rates throughout the estuary. This is because the greatest rates of sedimentation are expected to be in certain shallow subtidal areas where accumulation is favoured. It is therefore recommended that future monitoring include these areas of excessive mud deposition. The results also indicated a declining RPD and elevated sediment mud contents at many of the sites, both of which identify mud deposition as a continuing concern within the estuary.
RECOMMENDED MONITORING	It is recommended that monitoring continue as outlined below: **Annual Sediment Monitoring.** To address problems associated with increasing muddiness and a "poor-fair" RPD rating, monitor sedimentation rate, RPD depth and grain size at the existing intertidal sites annually until the situation improves (next monitoring due in Jan-Feb 2013). Establish additional sedimentation rate monitoring sites in subtidal areas in Oct-Dec, 2012. **Fine Scale Monitoring.** It is recommended that a "complete" fine scale monitoring assessment (including sedimentation rate and macroalgal mapping) be undertaken at 5 yearly intervals (next scheduled for Jan-Feb 2015). **Broad Scale Habitat Mapping.** It is recommended that broad scale habitat mapping be repeated in summer 2012/2013.
RECOMMENDED MANAGEMENT	The sediment indicators monitored in 2012 reinforce the 2008 to 2010 fine scale monitoring results about the need to manage fine sediment inputs to the estuary. In particular the following specific management actions are recommended: • Limit catchment suspended sediment inputs to levels that will not cause excessive estuary infilling i.e. limit sedimentation rates to an estuary average of 1mm/yr. It is expected that there will be areas of very high and very low sedimentation throughout the estuary, which together will average 1mm/yr. Such an approach will allow the development of input load guidelines for suspended sediment and targeted management of problem areas. Greater Wellington's ongoing catchment and sediment transport modelling will help determine the catchment suspended sediment load inputs and the target reductions required to reduce in-estuary sedimentation rates.

2. Results, Rating and Management (Continued)

ACKNOWLEDGEMENT

Many thanks to Juliet Milne and Megan Oliver (GWRC) for their support and feedback on the draft report.

REFERENCES

Gibb, J.G. and Cox, G.J. 2009. Patterns & Rates of Sedimentation within Porirua Harbour. Consultancy Report (CR 2009/1) prepared for Porirua City Council. 38p plus appendices.

Jørgensen, N. and Revsbech, N.P. 1985. Diffusive boundary layers and the oxygen uptake of sediments and detritus. Limnology and Oceanography 30:111-122.

Robertson, B.M. and Stevens, L. 2006. Southland Estuaries State of Environment Report 2001-2006. Prepared for Environment Southland. 45p plus appendices.

Robertson, B.M. and Stevens, L. 2008. Porirua Harbour: Fine Scale Monitoring 2007/08. Prepared for Greater Wellington Regional Council. 32p.

Robertson, B.M. and Stevens, L. 2009. Porirua Harbour: Fine Scale Monitoring 2008/09. Prepared for Greater Wellington Regional Council. 26p.

Robertson, B.M. and Stevens, L. 2010. Porirua Harbour: Fine Scale Monitoring 2009/10. Prepared for Greater Wellington Regional Council. 39p.

Stevens, L. and Robertson, B.M. 2009. Porirua Harbour: Intertidal Macroalgal Monitoring 2008/09. Prepared for Greater Wellington Regional Council. 3p.

Stevens, L. and Robertson, B.M. 2010. Porirua Harbour: Intertidal Macroalgal Monitoring 2009/10. Prepared for Greater Wellington Regional Council. 3p.

Stevens, L. and Robertson, B.M. 2011. Porirua Harbour: Intertidal Macroalgal Monitoring 2010/11. Prepared for Greater Wellington Regional Council. 4p.

Stevens, L. and Robertson, B.M. 2011a. Porirua Harbour: Intertidal Sediment Monitoring 2010/11. Prepared for Greater Wellington Regional Council. 6p.