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Porirua Harbour

Sediment Plate Monitoring 2014/15

Prepared for Greater Wellington Regional Council

February 2015

Cover Photo: Pauatahanui Inlet - measuring shallow subtidal sediment plates, Jan. 2015.

Porirua Harbour, Onepoto Arm - shallow subtidal flats in the south of the harbour. Note the high water clarity in the absence of wind generated waves disturbing bottom sediments.

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Prepared for
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by

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1. INTRODUCTION AND METHODS

Soil erosion is a major issue in New Zealand and the resulting suspended sediment impacts are of particular concern in estuaries which act as a sink for fine sediments or muds. Where fine sediment inputs exceed the assimilative capacity of an estuary, high value habitat (e.g. seagrass, saltmarsh, shellfish beds) can be displaced, and the estuary can infill (often rapidly). Excess mud will also commonly result in adverse conditions including reduced sediment oxygenation, production of toxic sulphides, increased nuisance macroalgal growth, increased turbidity (from re-suspension), and a shift towards a degraded invertebrate and plant community. Such changes greatly reduce its value for fish, birdlife, and its amenity value for humans.

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 (e.g. 2-10% mud). However, baseline intertidal monitoring of Porirua Harbour (Robertson and Stevens 2008, 2009, 2010) found that while the intertidal sediments of the estuary remained the sand-dominated, they had elevated mud contents (7-15%), showed a general trend of increasing muddiness, and comprised sediments that were not very well oxygenated. In addition, because 65% of Porirua Harbour is subtidal (remains covered in water at low tide), it is particularly at risk from sedimentation within its subtidal settling basins.

Based on the above results, Greater Wellington Regional Council (GWRC) initiated annual monitoring of sedimentation rates, grain size, and RPD depth (sediment oxygenation) at four existing intertidal sites in the estuary in 2011 (e.g. Stevens and Robertson 2011). Then, following 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, four additional intertidal sites were established in February 2012 (3 in Pauatahanui Arm and 1 in the Onepoto Arm - Figure 1), and an additional nine sites established in Jan 2013 (1 intertidal and 5 subtidal sites in the Pauatahanui Arm and 3 subtidal sites in the Onepoto Arm - Figure 1) - see Stevens and Robertson (2014a). Sites were positioned to assess the dominant sediment sources to the estuary - identified as discharges of both bed-load and suspended load from the various streams entering the estuary (most notably Pauatahanui, Horokiri and Porirua Streams - see Green et al. 2015). 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 2013, Robertson and Stevens 2008, 2009, 2010).

A second technical workshop on sediment issues in the estuary in March 2013 recommended broad scale subtidal habitat mapping of the estuary, and assessment of key indicators of sediment condition (e.g. grain size, organic carbon, total sulphur, sediment oxygenation). This work, reported on in Stevens and Robertson (2014b), highlighted the very muddy nature of the subtidal basins with 59% of the subtidal area dominated by very soft muds (mud content >25%), and deeper subtidal basin mud content averaging >60% mud (and often >80%). Such very high mud contents reflected very poor sediment conditions.

In addition, comprehensive bathymetric surveys of the Harbour have been undertaken by Gibb and Cox (2009) and Cox (2014) to characterise major seabed changes over the entire estuary. Gibb and Cox (2009) reported high annual average sedimentation rates for the 1974-2009 period of 9.1mm/yr in the Pauatahanui Arm, and 5.7mm/yr in the Onepoto Arm, the rates attributed primarily to sediment entering the harbour system during the 1970-1980's, a busy urbanisation period with a resultant elevated inputs of sediment from the surrounding catchment. Based on these results, Gibb and Cox (2009) predicted the main subtidal basins to rapidly infill and change from tidal estuaries to brackish swamps within 145-195 years if rates of deposition over the last ~30 years continued.

The most recent results of Cox (2014) indicate that the mean annual average rate of accretion for all harbour areas over the past 5 years to be less than 2mm per year, indicating recent accumulation in the estuary has been relatively low compared to the 1974-2009 period.

The current report presents the results of sedimentation rate measurements in January 2015 at the intertidal and shallow subtidal sites established in Porirua Harbour (Figure 1). Sediment grain size and RPD were also measured at all sites, and risk indicator ratings developed for Wellington's estuaries (Section 2) have been used to rate the condition of the estuary, and recommend monitoring and management actions (Section 3).

Measuring subtidal plates in the Pauatahanui Arm, January 2015.

1. Introduction and Methods (Continued)

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

Sedimentation Rate

To measure sedimentation rates, 42 concrete plates (20cm x 20cm paving stones at intertidal sites and 30cm diameter circular pavers at subtidal sites) have been buried at a variety of locations throughout the intertidal and subtidal reaches of the estuary (Figure 1, Appendix 1). In December 2007, 4 intertidal sites and 1 subtidal site were established. In January 2012, an additional 4 intertidal sites (16 plates) were added, followed by 1 intertidal and 8 subtidal plates in January 2013. Each buried plate was located in stable substrate beneath the sediment surface and its position recorded using a handheld Trimble GeoXH differential GPS (post-processing accuracy 10-50cm).

Subtidal plates have been positioned at least 5m from the edge of soft mud deposition zones located by wading from the shore until firmer sediments transition into soft muds. These conditions were generally encountered ~1-1.5m below low water depth.

The differential GPS and a probe is used to relocate each plate without disturbing the overlying soft mud sediments. For intertidal sites, a 2m straight edge is then laid across the top of the plate to determine the average sediment level, and the depth to the underlying plate measured using the probe and ruler.

For subtidal sites, a measuring frame comprising a tube fixed to an aluminium cross piece (see photos below) is aligned over the relocated plate and allowed to settle. A graduated measuring rod, pushed down through the vertical tube, enables the depth of sediment overlying the buried plate to be measured above the water surface.

To account for irregular sediment surfaces, 3 replicate measures per plate are taken, and averaged in the field to determine the mean annual rate of sedimentation above each plate.


Measuring frame and probe used to measure shallow subtidal plates.

Grain Size

To monitor changes in the mud content of sediments, a single composite sample of the top 20mm of sediment is collected from adjacent to each sediment plate site. Samples are analysed by Hill Laboratories for grain size (% mud, sand, gravel). Triplicate sampling in 2013 found no appreciable within-site variance therefore single therefore composite analyses were considered appropriate for ongoing annual monitoring. It is recommended that triplicate sampling be undertaken again in conjunction with the next 5 yearly fine scale monitoring (scheduled for 2020) to re-check within-site sample variability in the future.

Apparent Redox Potential Discontinuity (aRPD) depth

To assess sediment oxygenation, the mean depth to the visually apparent RPD was determined at each intertidal site by repeatedly digging down from the surface with a hand trowel until the mean RPD transition level was located. The same approach was used at subtidal sites, although representative sediment cores were first collected and brought to the surface where the aRPD depth was determined. Because visual changes in oxygenation can sometimes be difficult to readily discern, it is recommended that a relationship between aRPD and sediment oxygenation measured using a redox probe be established if sediment deterioration appears significant.

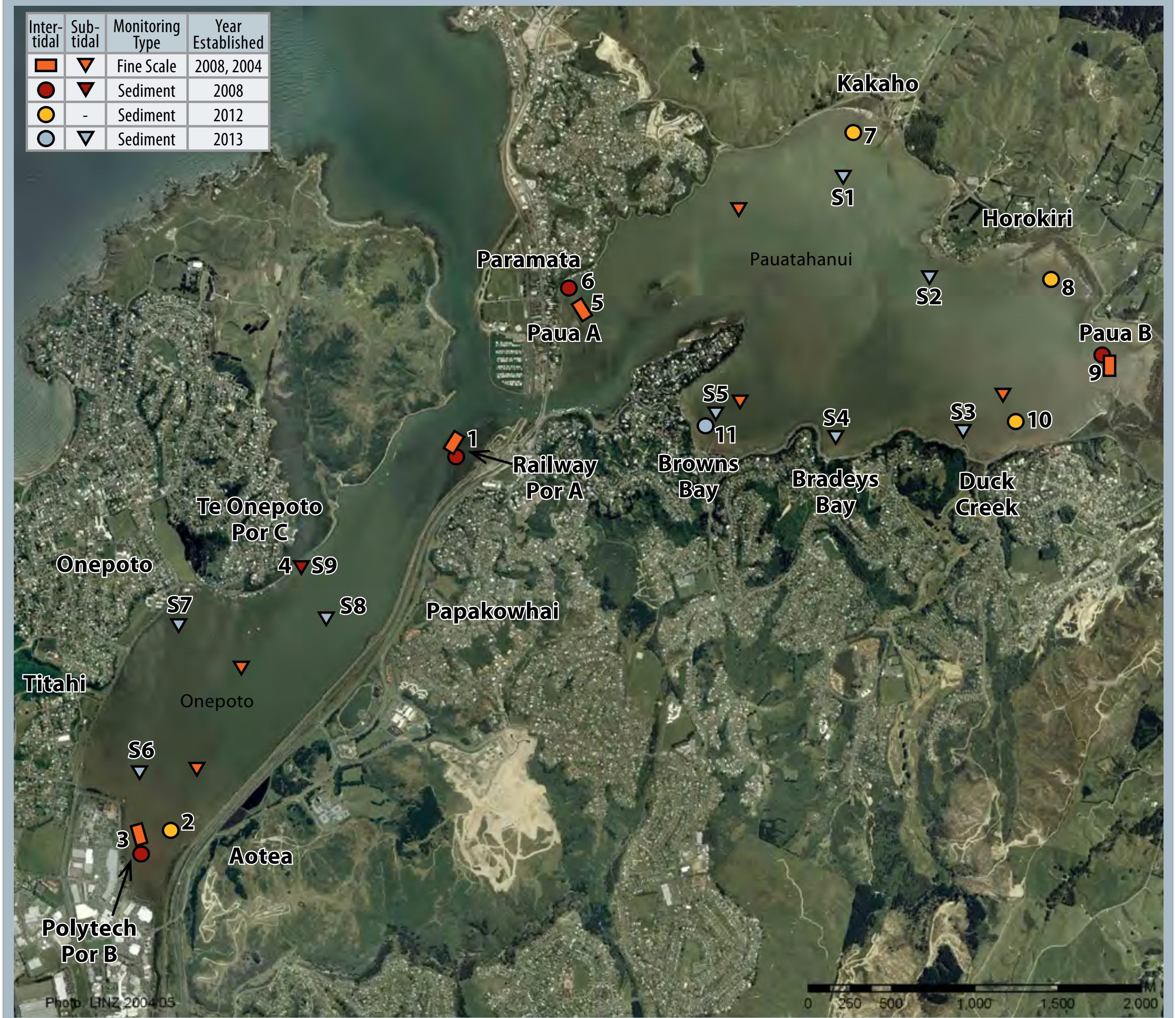


Figure 1. Location of fine scale sites and buried sediment plates established in Porirua Harbour.

Onepoto Arm looking toward Aotea Lagoon

2. RISK INDICATOR RATINGS

The National Estuary Monitoring Protocol (NEMP, Robertson et al. 2002), and subsequent additions (e.g. Robertson and Stevens 2006, 2007, 2012), recommend a defensible, cost-effective monitoring design for assessing the long term condition of shallow, intertidally-dominated, NZ estuarine systems. The design is based on the use of indicators that have a documented strong relationship with water or sediment quality. The approach is intended to help quickly identify the likely presence of the predominant issues affecting NZ estuaries (i.e. eutrophication, sedimentation, disease risk, toxicity and habitat change). In order to facilitate this process, "risk indicator ratings" have been proposed that assign a relative level of risk of adversely affecting estuary conditions (e.g. very low, low, moderate, high, very high) to each indicator (see examples below). Each risk indicator rating is designed to be used in combination with relevant information and other risk indicator ratings, and under expert guidance, to assess overall estuary condition in relation to key issues. When interpreting risk indicator results we emphasise:

- The importance of taking into account other relevant information and/or indicator results before making management decisions regarding the presence or significance of any estuary issue.
- That rating and ranking systems can easily mask or oversimplify results. For instance, large changes can occur within a risk category, but small changes near the edge of one risk category may shift the rating to the next risk level.
- Most issues will have a mix of primary and secondary ratings, primary ratings being given more weight in assessing the significance of indicator results.
- Ratings for many indicators have yet to be established using statistical measures, primarily because of the additional work and cost this requires. In the absence of funding, professional judgment, based on our wide experience from monitoring >300 NZ estuaries, has been used in making initial interpretations. Our hope is that where a high level of risk is identified, the following steps are taken:
    1. Statistical measures be used to refine indicators and guide monitoring and management for priority issues.
    2. Issues identified as having a high likelihood of causing a significant change in ecological condition (either positive or negative) trigger intensive, targeted investigations to appropriately characterise the extent of the issue.
    3. The outputs stimulate discussion regarding what an acceptable level of risk is, and how it should best be managed.

While developed specifically for intertidally dominated estuaries, the indicators and risk ratings presented in Table 1 below, are directly relevant to the Porirua Harbour sediment monitoring programme.

Table 1. Risk indicator ratings for sedimentation rate, sediment mud content, and RPD depth.

RISK INDICATOR RATING	SEDIMENTATION RATE[1]	MUD CONTENT[2]	RPD DEPTH[3]
Very Low	<1mm/yr	<2%	>10cm
Low	>1-2mm/yr	2-5%	3-10cm
Moderate	>2-5mm/yr	>5-15%	1-<3cm
High	>5-10mm/yr	>15-25%	0-<1cm
Very High	>10mm/yr	>25%	Anoxic at surface

NOTES:

[1]**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. Note the very low risk category is based on a typical NZ pre-European average rate of <1mm/year, which may underestimate sedimentation rates in soft rock catchments.

[2]**Sediment Mud Content:** In their natural state, most NZ estuaries would have been dominated by sandy or shelly substrates. Fine sediment is likely to cause detrimental and difficult to reverse changes in community composition (Robertson 2013), can facilitate the establishment of invasive species, increase turbidity (from re-suspension), and reduce amenity values. High or increasing mud content can indicate where changes in land use management may be needed.

[3]**Redox Potential Discontinuity (RPD):** RPD depth, the transition between oxygenated sediments near the surface and deeper anoxic sediments, is a primary estuary condition indicator as it is a direct measure of whether nutrient and organic enrichment exceeds levels causing nuisance (anoxic) conditions. Knowing if the 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 support very little aquatic life.

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. The tendency for sediments to become anoxic is much greater if the sediments are muddy.

3. RESULTS, RATING AND MANAGEMENT

The indicators used to assess sediment condition in 2015 were: sedimentation rate, grain size, and aRPD depth.

Sedimentation Rate. The 42 sedimentation plates buried at 18 sites in Porirua Harbour (Figure 1) were measured in January 2015, with results summarised in Table 2 (full details are presented in Appendix 1).

Because of the variable length of monitoring, and particularly the recent establishment of the subtidal plates which require at least a 5 year annual monitoring period before being used in any trend analyses, it is necessary to interpret the early results of this monitoring programme with caution.

Table 2. Mean sediment plate depths (2007-2015), and 2015 condition rating, Porirua Harbour.

Site		No	Name	Calendar Year Baseline Commenced	Site Mean (mm/yr)								Mean Annual Sedimentation since baseline (mm/yr)	2015 Sed Rate Risk Indicator Rating
					2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015		
Onepoto Arm	Intertidal	1	Por A Railway (FS)	2008	Baseline	0.8	2.3	-4.5	-0.3	14.3	-4.3	1.5	1.4	Low
		2	Aotea	2012					Baseline	12.3	-0.3	2.3	4.8	Moderate
		3	Por B Polytech (FS)	2008	Baseline	7.0	0.5	2.0	0.3	4.3	1.8	2.3	2.3	Moderate
	Subtidal	S6	Titahi	2013						Baseline	0.0	5.0	-1.5	Very Low
		S7	Onepoto	2013						Baseline	-6.0	-92.0	-49.0	Very Low
		S8	Papakowhai	2013						Baseline	-8.0	-93.0	-46.5	Very Low
		S9	Te Onepoto	2008	Baseline	-2.5	-2.5	3.0	-1.0	-14.0	0.0	4.0	-1.7	Very Low
Pauatahanui Arm	Intertidal	6	Boatsheds	2008		Baseline	0.5	-0.8	0.3	3.5	-2.0	-3.0	-0.3	Very Low
		7	Kakaho	2008					Baseline	9.3	-4.0	-2.0	1.1	Low
		8	Horokiri	2009					Baseline	2.0	-2.5	1.3	0.3	Very Low
		9	Paua B (FS)	2008	Baseline	2.3	3.8	0.3	-5.3	-0.8	4.5	-2.5	0.3	Very Low
		10	Duck Creek	2012					Baseline	-3.0	14.8	-5.5	2.1	Moderate
		11	Browns Bay	2013						Baseline	-30.0	4.0	-13.0*	Very Low
	Subtidal	S1	Kakaho	2013						Baseline	6.6	2.0	4.3	Moderate
		S2	Horokiri	2013						Baseline	26.4	18.0	22.2	Very High
		S3	Duck Creek	2013						Baseline	8.0	-12.0	-2.0	Very Low
		S4	Bradeys Bay	2013						Baseline	11.0	-4.0	3.5	Moderate
		S5	Browns Bay	2013						Baseline	9.2	-10.0	-0.4	Very Low

*change attributable to localised movement of intertidal sands and does not reflect a significant change in sedimentation. Value excluded from calculation of means.

The 2015 results show a mean annual intertidal sedimentation rate across all sites of +0.7mm/yr in the Pauatahanui Arm, and +2.8mm/yr in the Onepoto Arm, reflecting "very low" and "moderate" risk indicator ratings respectively. The Onepoto rate remains elevated by relatively recent deposition of coarse sands at Site 2 (Aotea), which are expected to dissipate over time.

The subtidal sediment plate monitoring, while still very preliminary, shows overall mean deposition of +5.5mm/yr in the Pauatahanui Arm. Deposition was most obvious in the vicinity of the Kakaho and Horokiri sites where deep soft muds in the shallow subtidal areas had extended 20-30m closer to shore over the previous 12 months at each site, and was evident right up to the MLWS mark at Horokiri (S2). There was no obvious evidence of recent catchment inputs at the time of sampling (e.g. no fresh mud deposits in streamways, or on stream deltas or intertidal flats) and, in the absence of any significant flood events over the past 12 months, the measured increase appears most likely due to the redeposition of subtidal muds by prevailing wind and wave action. These muds are having a significant adverse impact on water clarity and may be becoming exacerbated by ongoing shallowing of the upper estuary.

The 2015 Onepoto Arm subtidal results showed mean erosion of -24.7mm/yr, with a very obvious loss of soft mud from sites S7 and S8 over the previous 12 months. These sites, and the wide area surrounding each, were covered in deep soft mud in 2014, but were noticeably firmer underfoot in 2015. The measured losses (92mm and 93mm respectively from Jan 2014 to Jan 2015) indicate a significant movement in sediment, and likely export of fine muds from this arm of the estuary.

The preliminary subtidal plate data indicate a "high" risk rating in the Pauatahanui Arm, and a "very low" risk rating in the Onepoto Arm.

The sediment plate measurements are generally consistent with the moderate ongoing sediment deposition in settling basin areas recorded by bathymetric surveys characterising major seabed changes over the entire estuary over this same period (see Cox 2014). The recent loss of sediment from the Onepoto Arm is not evident in the comparative plots of sedimentation changes from 2009 to 2014 presented in Cox (2014). This most likely reflects changes that have occurred since the 2014 bathymetric survey was undertaken, but may also reflect the averaging of inter-annual variation in sediment levels over the 5 yearly period between hydrodynamic surveys.

It is also noted that over the past 5 years catchment sediment inputs are likely to have been limited by a low frequency of significant storm events (Megan Oliver, GWRC pers comm.), combined with limited catchment development over this period as a consequence of the Global Financial Crisis. Therefore the relatively low rates of overall sedimentation recorded over the past 5 years may increase again if catchment development increases, and/or if there is in increase in storm frequency or intensity.

Consequently, it is recommended that all plates continue to be monitored annually to assess the impacts of predicted land disturbance from impending forest harvesting, urban development, and road construction (in particular Transmission Gully) in the catchment. Comprehensive reporting of results, including plots of sedimentation trends, is recommended 5 yearly (e.g. next scheduled for 2018), or annually if there is major land disturbance or unexpected results occur.

Finally, because both the amount of fine sediment exported from the estuary to the sea, and the relative extent and importance of both fine sediment remobilisation and relocation within the estuary, remain unquantified, Oliver et al. (2015) have recommended that these aspects be further assessed through the use of hydrodynamic modelling. Results of this work will directly aid understanding of the overall estuary sediment budget, and help in the establishment of defensible catchment load limits for the estuary.

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 (Table 3, Figure 2) shows that sandy sediments dominate the intertidal sites. At intertidal sites, mud content ranged from 2-11%, with a mean of 7.2% in the Pauatahanui Arm and 5.5% in the Onepoto Arm, a risk indicator rating of “moderate”. The highest intertidal mud contents were generally recorded from the lower estuary sites (e.g. fine scale ‘A’ sites, Boatsheds, Kakaho). Previous replicate sample analyses have show within-site variability is relatively low, and for the intertidal sites monitored annually for the past 8 years, the mean mud content has remained relatively stable with no clear trend of increase. However, inter-annual variability is evident and most likely reflects localised sorting of sediments by wave action. Field observations over the past 8 years suggest intertidal mud deposits are predominantly event related (e.g. pulsed deposits from stream inputs), with fine sediments relatively quickly re-mobilised by wind generated waves and tidal streams. It is recommended that Council rainfall and flood records be used to investigate the relationship between such events and measured sediment rate results as part of recommended 5 yearly reporting.

For subtidal sites, significantly more mud was present than at intertidal sites (Table 3, Figure 3). Mud content ranged from 8-42% in the Onepoto Arm (mean of 18%), and 17-78% in the Pauatahanui Arm (mean of 59%), risk indicator ratings of “high” and “very high” respectively. The most significant change evident is a large increase in mud contents of the Pauatahanui Arm subtidal basin sites (mean mud content 40% in 2013, 49% in 2014 and 59% in 2015). The changes coincide with the increase in mud extent noted on page 5. In contrast, there have been no large changes in grain size in the Onepoto Arm over the same period, consistent with the noted reduction in mud extent. Such changes suggest that sediment dynamics within each of the estuary arms operate largely independently of each other and that the recommended hydrodynamic modelling of the estuary will greatly assist understanding of sediment movement and fate within both arms.

Table 3. Sediment grain size and RPD depth results, Porirua Harbour (January 2015).

Site		No	Name	Site Mean				2015 RPD Risk Indicator Rating
				% Mud (g/100g dry wt)	% Sand (g/100g dry wt)	% Gravel (g/100g dry wt)	RPD depth (cm)	
Onepoto Arm	Intertidal	1	Por A Railway (FS)	8.3	90.4	1.3	1	Moderate
		2	Aotea	4.3	94.6	1.1	2	Moderate
		3	Por B Polytech (FS)	3.8	95.1	1.1	1	Moderate
	Subtidal	S6	Titahi	42.2	57.1	0.7	2	Moderate
		S7	Onepoto	8.0	90.4	1.6	2	Moderate
		S8	Papakowhai	11.7	88.3	<0.1	2	Moderate
		S9	Te Onepoto	8.4	91.3	0.4	3	Low
Pauatahanui Arm	Intertidal	5	Paua A (FS)	9.2	82.4	8.3	1	Moderate
		6	Boatsheds	10.0	84.6	5.4	1	Moderate
		7	Kakaho	11.1	85.3	3.5	1	Moderate
		8	Horokiri	7.6	88.1	4.3	1	Moderate
		9	Paua B (FS)	3.7	93.0	3.3	1	Moderate
		10	Duck Creek	1.7	97.6	0.7	3	Low
		11	Browns Bay	7.2	86.9	5.9	3	Low
	Subtidal	S1	Kakaho	77.8	22.1	<0.1	1	Moderate
		S2	Horokiri	60.8	39.2	<0.1	1	Moderate
		S3	Duck Creek	63.4	35.8	0.7	1	Moderate
		S4	Bradeys Bay	16.8	82.2	0.9	1	Moderate
		S5	Browns Bay	74.4	25.3	0.3	1	Moderate

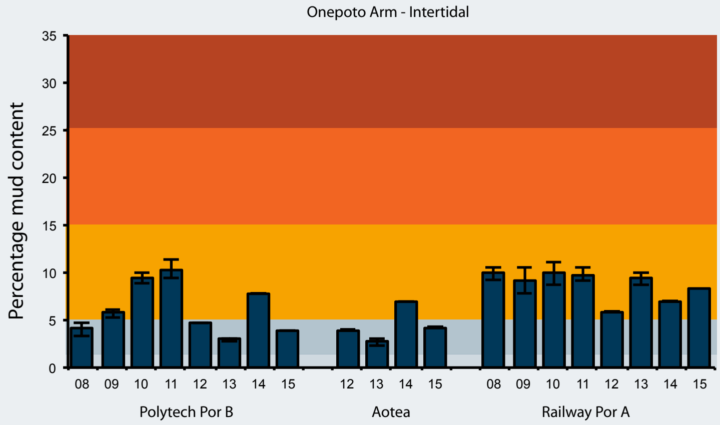
Note grain size results are based on a single composite sample comprising 5 sub-samples collected from each site. RPD depth is based on 10 replicate measures at each site.

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 5-10cm of sediment. However, when fine muds fill the interstitial pore spaces, less re-oxygenation occurs and the RPD moves closer to the surface.

In 2015, the visually assessed aRPD depths (Table 3) were relatively shallow (1-3cm) across all sites, a "low" or "moderate" risk indicator rating.

3. Results, Rating and Management (Continued)



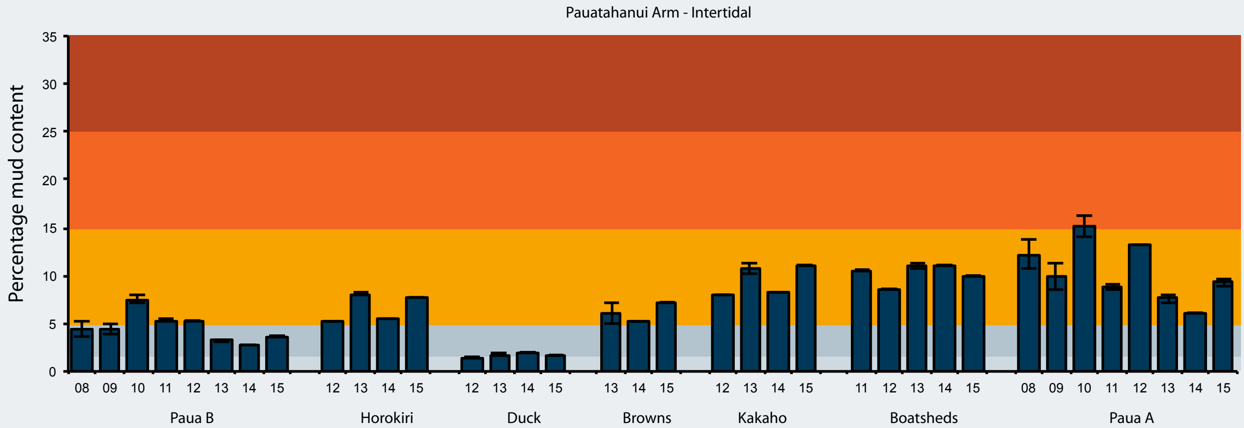
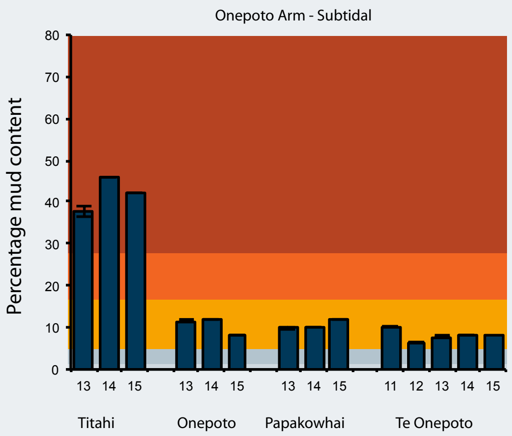


Figure 2. Mean sediment mud content (+/-SE) at Porirua Harbour intertidal sites, (2008-2015).



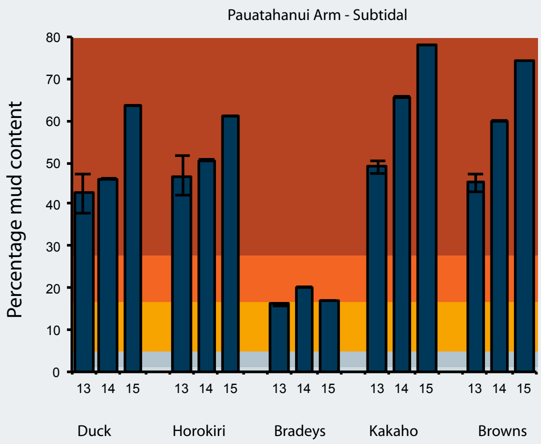


Figure 3. Mean sediment mud content (+/-SE) at Porirua Harbour subtidal sites, (2008-2015).

3. Results, Rating and Management (Continued)

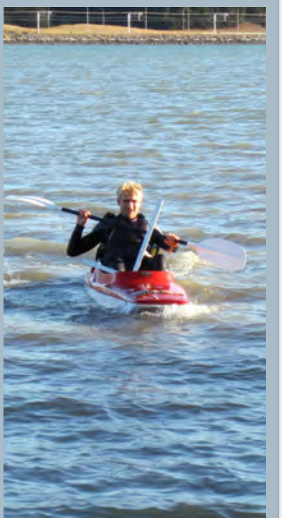
SUMMARY

Sediment plate monitoring, first established in 2007/08 at strategic intertidal sites within the Porirua Harbour, indicates a mean annual intertidal sedimentation rate across all sites of +0.7mm/yr in the Pauatahanui Arm, and +2.8mm/yr in the Onepoto Arm, reflecting "very low" and "moderate" risk indicator ratings respectively.

Sediment plates have been established within the subtidal basins of both estuary arms where the greatest rates of sedimentation are predicted. While these values require at least a 5 year annual monitoring period before being used in any trend analyses, preliminary results after 2 years indicate a high net rate of deposition in the Pauatahanui Arm, and increasing mud content, with net erosion from the Onepoto Arm.

The moderate sediment RPD depth, and elevated sediment mud content results, particularly at the subtidal sites, highlight continuing issues related to mud deposition within the estuary.

RECOMMENDED MONITORING



It is recommended that monitoring continue as outlined below:

Annual Sediment Monitoring (both intertidal and subtidal). To assess sediment derived changes in the estuary, annually monitor sedimentation rate, RPD depth and grain size at the existing intertidal and shallow subtidal sites. Next due in Jan. 2016.

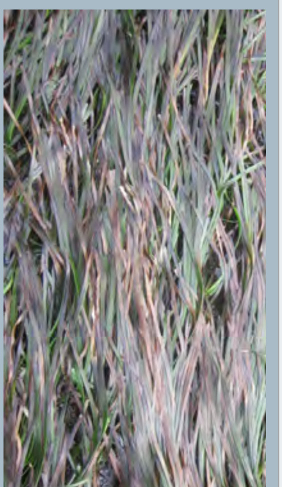
Establish fixed transects extending from intertidal to subtidal areas to annually monitor the boundary between dominant sediment types (e.g. firm muddy sand, soft mud, and very soft mud habitats). Suggested locations are adjacent to existing subtidal sites S1 to S7.

To optimise reporting, it is recommended that results be fully reported every 5 years (first 5 year review due in 2018 after 5 years of annual subtidal monitoring).

Fine Scale Monitoring (both intertidal and subtidal). To assess intertidal estuary condition it is recommended that a "complete" fine scale monitoring assessment be undertaken at 5 yearly intervals (next scheduled for Jan-Feb 2020). To assess subtidal estuary condition it is recommended that subtidal fine scale monitoring be undertaken as part of a "whole of estuary" monitoring approach as recommended in the 2014 broad scale subtidal survey (Stevens and Robertson 2014).

Broad Scale Habitat Mapping (both intertidal and subtidal). It is recommended that broad scale intertidal and subtidal habitat mapping be integrated, and repeated every 5 years (next monitoring due in January 2018).

RECOMMENDED MANAGEMENT



The sediment indicators monitored in 2015 reinforce the 2008 to 2010 fine scale monitoring results about the need to manage fine sediment inputs to the estuary.

In particular, limiting catchment sediment inputs to more natural levels that will not cause excessive estuary infilling and will improve harbour water clarity. To achieve this, interim and long term targets have been prepared and approved by the joint councils (Porirua City Council, Wellington City Council and Greater Wellington Regional Council), Te Runanga Toa Rangatira and other key agencies with interests in Porirua Harbour and catchment, as follows:

- Interim – Reduce sediment inputs from tributary streams by 50% by 2121
- Long-term – Reduce sediment accumulation rate in the harbour to 1mm per year by 2031 (averaged over whole harbour)

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. GWRC and PCC have also undertaken desktop assessments to determine the likely sediment input loads from different landuses, including the Transmission Gully motorway development, and modelled the zones of deposition within the estuary. Strategies to determine the best options for managing sediment within the catchment are currently being developed.

3. Results, Rating and Management (Continued)

ACKNOWLEDGEMENTS

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APPENDIX 1

ANALYTICAL METHODS

Indicator	Laboratory	Method	Detection Limit
Grain Size	R.J Hill	Wet sieving (2mm and 63µm sieves), gravimetry (calculation by difference).	0.1 g/100g dry wgt

DETAILED RESULTS

Sediment Plate Depths, Onepoto Arm, Porirua Harbour (2007-2015).

	No.	Site	PLATE	NZTM EAST	NZTM NORTH	Dec07	Jan09	Jan10	Jan11	Jan12	Jan13	Jan14	Jan15
Onepoto Arm - Intertidal	1	Por A Railway (fine scale site)	1	1756505.7	5447788.6	168	164	159	155	160	183	181	181
			2	1756477.9	5447784.8	150	152	158	156	151	150	160	159
			3	1756478.8	5447762.7	152	155	163	150	145	174	148	155
			4	1756508.1	5447755.8	93	95	95	96	100	106	107	107
	2	Aotea	1	1754771.8	5445520.0					138	145	140	148
			2	1754770.5	5445521.2					108	126	128	127
			3	1754768.3	5445523.1					103	118	116	118
			4	1754767.3	5445523.9					100	109	113	113
	3	Por B Polytech (fine scale site)	1	1754561.9	5445430.3	237	237	240	242	245	243	243	246
			2	1754577.9	5445403.8	230	244	242	244	244	256	256	258
			3	1754561.6	5445529.5				110	110	109	112	115
			4	1754559.9	5445528.6				75	73	81	85	86
Subtidal	S6	Titahi	1	1755704.1	5446797.6						191	191	180
	S7	Onepoto	1	1754811.3	5446762.9						194	188	96
	S8	Papakowhai	1	1754580.9	5445864.0						183	175	98
	S9	Te Onepoto	1	1755551.8	5447105.3	120	-	115	115	118	104	104	108

APPENDIX 1

DETAILED RESULTS

Sediment Plate Depths, Pauatahanui Arm, Porirua Harbour (2007-2015).

	No.	Site	PLATE	NZTM EAST	NZTM NORTH	Dec07	Jan09	Jan10	Jan11	Jan12	Jan13	Jan14	Jan15
Pauatahanui Arm - Intertidal	5	Paua A (fine scale site)	-	1757243.0	5448644.0								
	6	Boatsheds	1	1757267.5	5448785.8		171	172	165	166	172	166	160
			2	1757265.6	5448785.2		213	213	215	216	221	222	220
			3	1757263.6	5448784.7		232	232	233	234	233	232	228
			4	1757262.0	5448784.1		234	235	236	234	238	236	236
	7	Kakaho	1	1758885.4	5449747.8					73	89	85	79
			2	1758884.9	5449746.0					100	106	104	100
			3	1758884.4	5449744.2					90	103	92	92
			4	1758884.0	5449742.3					92	94	95	97
	8	Horokiri	1	1760040.2	5448827.6					106	104	104	103
			2	1760039.8	5448825.5					108	111	113	113
			3	1760039.6	5448823.5					118	124	124	121
			4	1760039.1	5448821.5					98	99	87	96
	9	Paua B (fine scale site)	1	1760333.9	5448378.8	181	182	186	186	181	180	187	184
			2	1760349.2	5448355.8	215	218	228	233	228	225	229	230
			3	1760375.1	5448366.9	182	186	183	183	181	182	182	181
			4	1760362.3	5448391.9	176	177	181	177	168	168	175	168
	10	Duck Creek	1	1759829.3	5447944.8					134	121	136	140
			2	1759828.7	5447946.7					108	108	117	115
			3	1759828.1	5447948.7					122	122	146	126
			4	1759827.6	5447950.6					88	89	100	96
	11	Browns Bay	1	1757971.4	5447956.8						220	190	194
Subtidal	S1	Kakaho	1	1758810.9	5449470.5						165	172	174
	S2	Horokiri	1	1759325.4	5448867.9						176	202	220
	S3	Duck Creek	1	1759529.0	5447896.3						194	202	190
	S4	Bradeys Bay	1	1758763.2	5447865.0						124	135	131
	S5	Browns Bay	1	1758040.6	5448015.1						179	188	178