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Porirua Harbour

Sediment Plate Monitoring 2015/16

Prepared for

Greater Wellington Regional Council

March 2016

Cover Photo: Pauatahanui Inlet, Jan. 2016.

Bradeys Bay, Pauatahanui Arm - sandy intertidal flats with seagrass.

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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 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 aRPD depth (sediment oxygenation) at four existing intertidal sites in the estuary in 2011 (e.g. Stevens and Robertson 2011). 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 input 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 2016 at the intertidal and shallow subtidal sites established in Porirua Harbour (Figure 1). Sediment grain size and aRPD 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).

Monitoring intertidal and subtidal plates in the Pauatahanui Arm, January 2016.

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 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 aRPD 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.

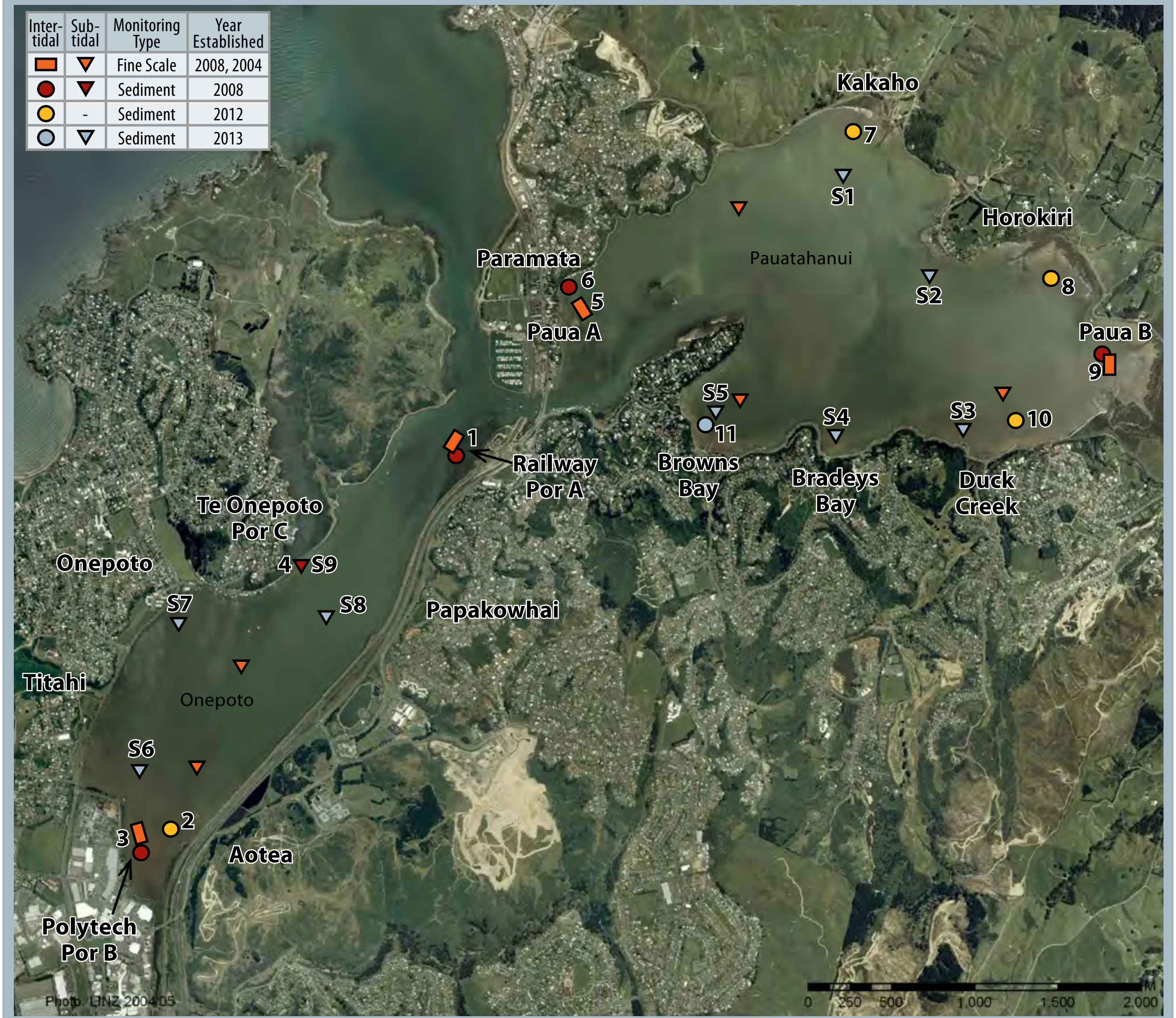


Figure 1. Location of fine scale sites and buried sediment plates established in Porirua Harbour.

Pauatahanui Arm, intertidal Site 8, Horokiri.

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 2016 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 2016, 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 (2007-2016), and 2016 condition rating, Porirua Harbour.

Site		No	Name	Calendar Year Baseline Commenced	Site Mean (mm/yr)									Mean Annual Sedimentation since baseline (mm/yr)	2016 Sed Rate Risk Indicator Rating
					2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016		
Onepoto Arm	Intertidal	1	Por A Railway (FS)	2008	Baseline	0.8	2.3	-4.5	-0.3	14.3	-4.3	1.5	0.5	1.3	Low
		2	Aotea	2012					Baseline	12.3	-0.3	2.3	7.8	5.5	High
		3	Por B Polytech (FS)	2008	Baseline	7.0	0.5	2.0	0.3	4.3	1.8	2.3	5.0	3.6	Moderate
	Subtidal	S6	Titahi	2013						Baseline	0.0	5.0	-16.0	-6.3	Very Low
		S7	Onepoto	2013						Baseline	-6.0	-92.0	-2.0	-33.3	Very Low
		S8	Papakowhai	2013						Baseline	-8.0	-93.0	10.0	-27.7	Very Low
		S9	Te Onepoto	2008	Baseline	-2.5	-2.5	3.0	-1.0	-14.0	0.0	4.0	7.0	-0.6	Very Low
Pauatahanui Arm	Intertidal	6	Boatsheds	2008		Baseline	0.5	-0.8	0.3	3.5	-2.0	-3.0	-3.5	-0.7	Very Low
		7	Kakaho	2008					Baseline	9.3	-4.0	-2.0	-5.8	-0.6	Very Low
		8	Horokiri	2009					Baseline	2.0	-2.5	1.3	0.0	0.2	Very Low
		9	Paua B (FS)	2008	Baseline	2.3	3.8	0.3	-5.3	-0.8	4.5	-2.5	-5.0	-0.3	Very Low
		10	Duck Creek	2012					Baseline	-3.0	14.8	-5.5	1.8	2.0	Moderate
		11	Browns Bay	2013						Baseline	-30.0	4.0	1.0	-8.3*	Very Low
	Subtidal	S1	Kakaho	2013						Baseline	6.6	2.0	8.0	5.5	High
		S2	Horokiri	2013						Baseline	26.4	18.0	10.0	18.1	Very High
		S3	Duck Creek	2013						Baseline	8.0	-12.0	NM	-	Likely Very Low
		S4	Bradeys Bay	2013						Baseline	11.0	-4.0	-5.0	0.7	Very Low
		S5	Browns Bay	2013						Baseline	9.2	-10.0	-2.0	-0.9	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.
NM = Not Measured.

The 2016 results show a mean annual intertidal sedimentation rate across all sites of +0.1mm/yr in the Pauatahanui Arm, and +3.4mm/yr in the Onepoto Arm, reflecting “very low” and “moderate” risk indicator ratings respectively. The Onepoto rate is driven by the presence of coarse sands at Site 2 (Aotea) and Site 3 (Polytech) on the flood delta of the Porirua Stream mouth, rather than fine mud accumulation. The frequent tidal flushing and wind-driven wave disturbance of intertidal flats in Porirua Harbour is expected to mobilise and redeposit intertidal mud in subtidal settlement areas.

The subtidal sediment plate monitoring, while still preliminary, shows overall mean deposition of +5.9mm/yr in the Pauatahanui Arm since the 2013 baseline. As in 2015, deposition was most pronounced in the vicinity of the Kakaho and Horokiri sites. At Horokiri (S2) the deep soft muds that extended 20-30m from MLWS subtidally to the site in 2015 were still present. However, at Kakaho (S1), the soft muds in this shallow nearshore zone had dissipated over the past 12 months and were not encountered until ~5m from the plate (similar to when the site was first established in 2014). The sediment level at Duck Creek (S3) appeared similar to that in 2015, but the presence of large sediment mega-ripples containing shell and gravel made plate relocation difficult. Consequently, because sediments above the plate were disturbed while trying to relocate it, it was not possible to get an accurate measurement of the sediment changes from 2015 to 2016.

The 2016 Onepoto Arm subtidal results showed no overall change from 2015. There has been mean net erosion of -17mm/yr since the 2013 baseline driven by a very obvious loss of soft mud from above sites S7 and S8 that occurred during 2014-2015. This is consistent with the expected response to pulsed input and subsequent erosion or redistribution of catchment derived sediments.

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).

Interestingly, sediment plate monitoring did not detect any spikes in deposition from storm events in 2015. The 2015 events, monitored by GWRC to assess the magnitude of sediment inputs to the estuary, highlighted the pulsed nature of sediment inputs with ~90% of the annual measured load to the Onepoto Arm delivered in one storm (Megan Oliver, GWRC pers comm.). The results suggest that storm related sediment deposition is relatively quickly spread across both subtidal, and to a lesser extent, intertidal areas. Consequently annual monitoring of sediment plates located in representative parts of the estuary are likely to provide a reliable estimate of average long term sediment retention rates within the estuary.

Because both the amount of fine sediment exported from the estuary to the sea, and the relative extent and importance of fine sediment remobilisation and relocation within the estuary remain unquantified, it is recommended 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.

It is also recommended that plates continue to be monitored annually to assess the impacts of predicted land disturbance from impending forest harvesting, urban development (Duck Creek subdivision), 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. As part of ongoing monitoring it is proposed that metal markers be installed at each plate to facilitate more rapid plate relocation using a metal detector and to protect against the loss or burial of existing wooden marker pegs.

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.

2016 grain size monitoring (Table 3, Figure 2) shows that sands dominate intertidal sediments (67-98%) with the mud content (range 2-16%) having a risk indicator rating of "moderate" based on a mean of 8.9% in the Pauatahanui Arm and 7.2% in the Onepoto Arm. While the mean mud content has remained relatively stable at the intertidal sites monitored annually for the past 8 years, Figure 2 suggests a trend of increasing mud may be developing at the Horokiri and Kakaho intertidal sites.

Previous replicate sample analyses have shown within-site variability is relatively low, and consequently annual changes in sediment mud content are likely to be relatively easily detected. The previous results and field observations highlight that inter-annual variability is evident and this most likely reflects event related deposition (e.g. pulsed deposits from stream inputs during storms), with fine sediments being 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 10-52% in the Onepoto Arm (mean of 21%), and 22-85% in the Pauatahanui Arm (mean of 62%), risk indicator ratings of "high" and "very high" respectively. Significantly, there is a continuing trend of increasing mud contents at the Pauatahanui Arm subtidal basin sites (mean mud content 40% in 2013, 49% in 2014, 59% in 2015, 62% in 2016). While there have been smaller changes in grain size in the Onepoto Arm, there has also been an overall increase in the average sediment mud content over the same period (from 17% in 2013 to 21% in 2016).

These results indicate that elevated sediment inputs to the estuary are continuing, and further suggest that each of the estuary arms operate largely independently of each other. The recommended hydrodynamic modelling of the estuary will greatly assist in understanding sediment movement and fate (including retention) within both arms.

3. Results, Rating and Management (Continued)

Table 3. Sediment grain size and RPD depth results, Porirua Harbour (January 2016).

Site		No	Name	Site Mean				2016 aRPD Risk Indicator Rating
				% Mud (g/100g dry wt)	% Sand (g/100g dry wt)	% Gravel (g/100g dry wt)	aRPD depth (cm)	
Onepoto Arm	Intertidal	1	Por A Railway (FS)	6.4	87.0	6.6	3	Low
Onepoto Arm	Intertidal	2	Aotea	6.3	82.0	11.6	5	Low
Onepoto Arm	Intertidal	3	Por B Polytech (FS)	9.4	89.1	1.5	1	Moderate
Onepoto Arm	Subtidal	S6	Titahi	51.5	47.9	0.6	2	Moderate
Onepoto Arm	Subtidal	S7	Onepoto	11.5	87.0	1.5	2	Moderate
Onepoto Arm	Subtidal	S8	Papakowhai	11.9	88.0	< 0.1	2	Moderate
Onepoto Arm	Subtidal	S9	Te Onepoto	10.2	88.8	1.1	3	Low
Pauatahanui Arm	Intertidal	5	Paua A (FS)	8.2	67.0	24.8	3	Low
Pauatahanui Arm	Intertidal	6	Boatsheds	13.6	79.5	6.9	3	Low
Pauatahanui Arm	Intertidal	7	Kakaho	16.3	81.6	2.1	1	Moderate
Pauatahanui Arm	Intertidal	8	Horokiri	10.8	88.0	1.2	1	Moderate
Pauatahanui Arm	Intertidal	9	Paua B (FS)	4.9	91.2	3.9	1	Moderate
Pauatahanui Arm	Intertidal	10	Duck Creek	2.1	97.8	0.1	3	Low
Pauatahanui Arm	Intertidal	11	Browns Bay	6.7	87.9	5.4	5	Low
Pauatahanui Arm	Subtidal	S1	Kakaho	85.4	14.5	< 0.1	1	Moderate
Pauatahanui Arm	Subtidal	S2	Horokiri	74.7	25.2	< 0.1	1	Moderate
Pauatahanui Arm	Subtidal	S3	Duck Creek	71.3	27.6	1.1	1	Moderate
Pauatahanui Arm	Subtidal	S4	Bradeys Bay	21.7	77.7	0.6	1	Moderate
Pauatahanui Arm	Subtidal	S5	Browns Bay	55.2	39.9	4.9	1	Moderate

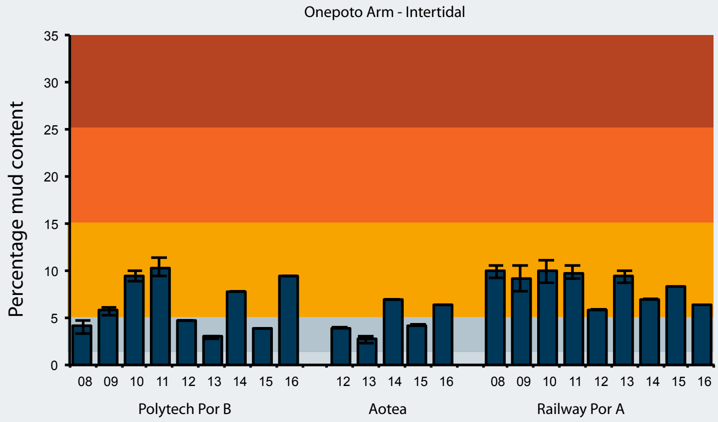
Note grain size results are based on a single composite sample comprising 5 sub-samples collected from each site. aRPD depth is based on 10 replicate measures at each site.

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 2016, the visually assessed aRPD depths (Table 3) were relatively shallow (1-<3cm) across most subtidal sites, a "moderate" risk indicator rating, and 1-5cm across the intertidal sites, a "low" or "moderate" risk indicator rating.

Pauatahanui Arm, intertidal Site 7, Kakaho.



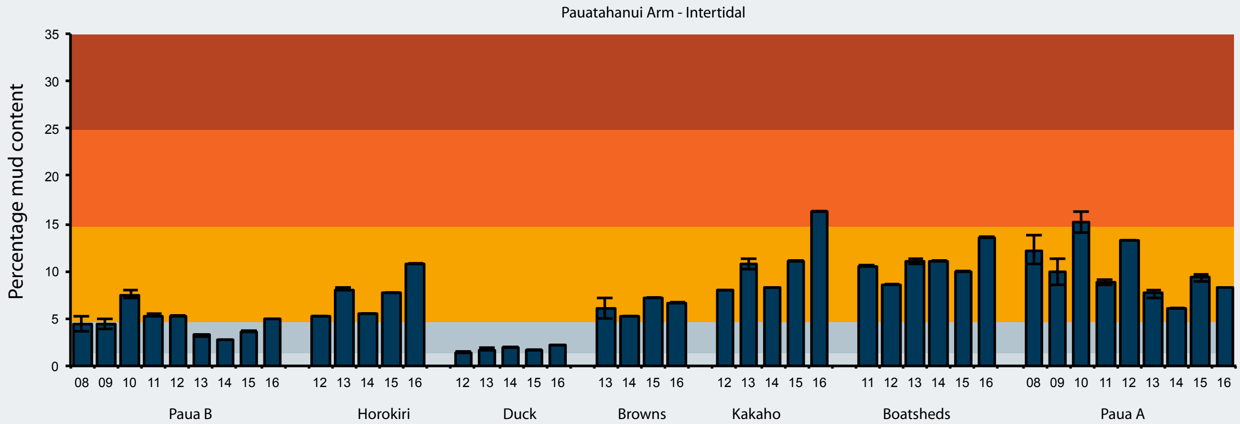
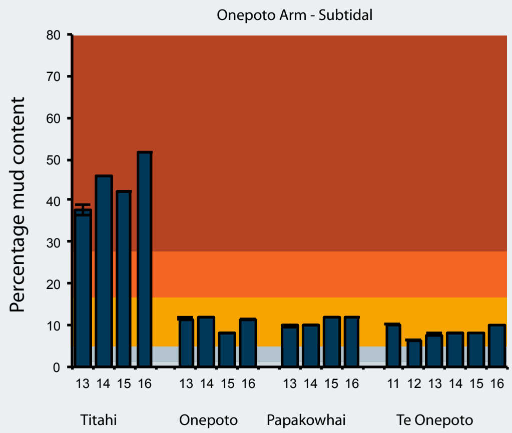


Figure 2. Mean sediment mud content (+/-SE) at Porirua Harbour intertidal sites, (2008-2016).



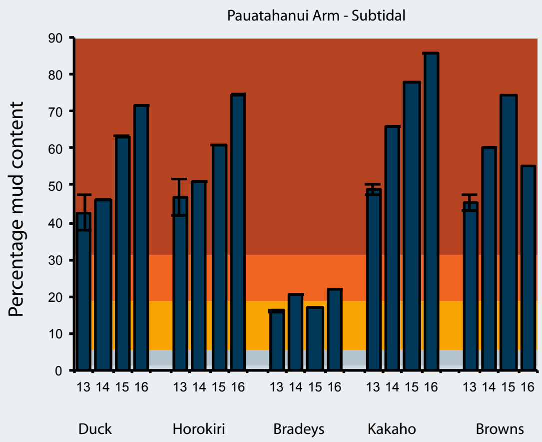


Figure 3. Mean sediment mud content (+/-SE) at Porirua Harbour subtidal sites, (2008-2016).

3. Results, Rating and Management (Continued)

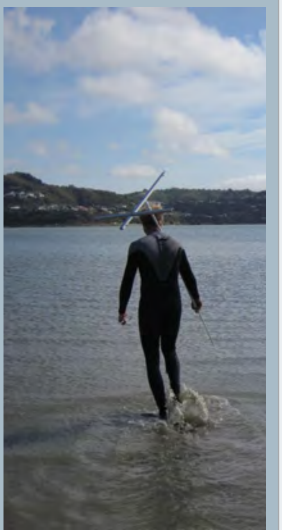
SUMMARY

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 +0.1mm/yr in the Pauatahanui Arm, and +3.4mm/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 4 years indicate a high and increasing net rate of deposition and increasing mud content 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, aRPD depth and grain size at the existing intertidal and shallow subtidal sites. Next due in Jan. 2017.

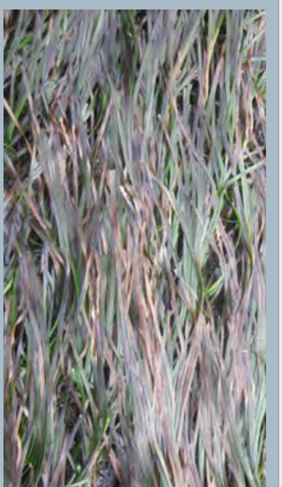
Establish fixed transects extending from intertidal to subtidal areas to annually monitor the boundary between dominant sediment types (e.g. firm muddy sand, soft mud, and very soft mud habitats). Suggested locations are adjacent to existing subtidal sites S1 and S7.

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 2016 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)

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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 (2007-2016).

	No.	Site	PLATE	NZTM EAST	NZTM NORTH	Dec07	Jan09	Jan10	Jan11	Jan12	Jan13	Jan14	Jan15	Jan16
Onepoto Arm - Intertidal	1	Por A Railway (fine scale site)	1	1756505.7	5447788.6	168	164	159	155	160	183	181	181	187
			2	1756477.9	5447784.8	150	152	158	156	151	150	160	159	158
			3	1756478.8	5447762.7	152	155	163	150	145	174	148	155	150
			4	1756508.1	5447755.8	93	95	95	96	100	106	107	107	109
	2	Aotea	1	1754771.8	5445520.0					138	145	140	148	151
			2	1754770.5	5445521.2					108	126	128	127	139
			3	1754768.3	5445523.1					103	118	116	118	122
			4	1754767.3	5445523.9					100	109	113	113	125
	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	245
			3	1754561.6	5445529.5				110	110	109	112	115	130
			4	1754559.9	5445528.6				75	73	81	85	86	99
Subtidal	S6	Titahi	1	1755704.1	5446797.6						191	191	180	164
	S7	Onepoto	1	1754811.3	5446762.9						194	188	96	94
	S8	Papakowhai	1	1754580.9	5445864.0						183	175	98	108
	S9	Te Onepoto	1	1755551.8	5447105.3	120	-	115	115	118	104	104	108	115

APPENDIX 1

DETAILED RESULTS

Sediment Plate Depths, Pauatahanui Arm, Porirua Harbour (2007-2016).

	No.	Site	PLATE	NZTM EAST	NZTM NORTH	Dec07	Jan09	Jan10	Jan11	Jan12	Jan13	Jan14	Jan15	Jan16
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	159
			2	1757265.6	5448785.2		213	213	215	216	221	222	220	216
			3	1757263.6	5448784.7		232	232	233	234	233	232	228	226
			4	1757262.0	5448784.1		234	235	236	234	238	236	236	229
	7	Kakaho	1	1758885.4	5449747.8					73	89	85	79	78
			2	1758884.9	5449746.0					100	106	104	100	95
			3	1758884.4	5449744.2					90	103	92	92	84
			4	1758884.0	5449742.3					92	94	95	97	88
	8	Horokiri	1	1760040.2	5448827.6					106	104	104	103	107
			2	1760039.8	5448825.5					108	111	113	113	112
			3	1760039.6	5448823.5					118	124	124	121	119
			4	1760039.1	5448821.5					98	99	87	96	95
	9	Paua B (fine scale site)	1	1760333.9	5448378.8	181	182	186	186	181	180	187	184	171
			2	1760349.2	5448355.8	215	218	228	233	228	225	229	230	230
			3	1760375.1	5448366.9	182	186	183	183	181	182	182	181	179
			4	1760362.3	5448391.9	176	177	181	177	168	168	175	168	163
	10	Duck Creek	1	1759829.3	5447944.8					134	121	136	140	146
			2	1759828.7	5447946.7					108	108	117	115	119
			3	1759828.1	5447948.7					122	122	146	126	128
			4	1759827.6	5447950.6					88	89	100	96	91
	11	Browns Bay	1	1757971.4	5447956.8						220	190	194	195
Subtidal	S1	Kakaho	1	1758810.9	5449470.5						165	172	174	182
	S2	Horokiri	1	1759325.4	5448867.9						176	202	220	230
	S3	Duck Creek	1	1759529.0	5447896.3						194	202	190	-
	S4	Bradeys Bay	1	1758763.2	5447865.0						124	135	131	126
	S5	Browns Bay	1	1758040.6	5448015.1						179	188	178	176