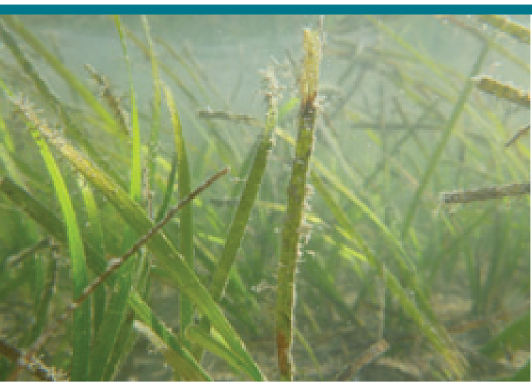
Te Awarua-o-Porirua Harbour and Catchment Programme

Summary of scientific monitoring and research undertaken in fulfilment of the Porirua Harbour and Catchment Strategy and Action Plan, 2011-2015

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao



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M D Oliver
J R Milne

Environmental Science Department

For more information, contact the Greater Wellington Regional Council:

Wellington
PO Box 11646

T 04 384 5708
F 04 385 6960
www.gw.govt.nz

Masterton
PO Box 41

T 06 378 2484
F 06 378 2146
www.gw.govt.nz

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www.gw.govt.nz
info@gw.govt.nz

Report prepared by:	M Oliver	Senior Environmental Scientist – Coast	
	J Milne	Team Leader, Aquatic Ecosystems & Quality	
Report reviewed by:	S Miller	Senior Science Coordinator	
Report approved for release by:	L Butcher	Manager, Environmental Science	**Date**: April 2016

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Contents

1. Introduction

1.1 Background

Te Awarua-o-Porirua Harbour (Porirua Harbour) is a significant estuarine habitat in the Wellington Region. The harbour is composed of two largely distinct estuaries: the Pauatahanui Arm to the east, which drains a predominantly rural catchment and the Onepoto Arm to the south-west draining a more urban-dominated catchment (Figure 1.1). Porirua Harbour, as with all estuaries, fulfils important ecosystem functions such as coastal protection, nutrient cycling, and sediment entrainment and provides valuable habitat for numerous birds, fish and invertebrate communities.

Porirua Harbour has undergone significant environmental change in the last century, including larges areas of reclamation to accommodate road and rail networks and the Porirua CBD, as well as widespread catchment deforestation. In recognition of the ongoing environmental pressures facing the harbour, the Porirua Harbour and Catchment Strategy and Action Plan ('the Strategy', Porirua City Council (PCC) 2012) was launched in early 2012 in an effort to improve the health of the harbour and waterways. The Strategy identifies the three biggest environmental issues for the harbour as sedimentation, pollution and ecological degradation, and outlines objectives and actions to address these.

Figure 1.1: Aerial photo of Te Awarua-o-Porirua Harbour

To prioritise science needs for the harbour and its catchment and to fulfil the actions assigned to Greater Wellington Regional Council (GWRC) in the Strategy, GWRC has convened four Porirua Harbour science workshops since 2011. These workshops have been multi-agency and multi-disciplinary, with a primary science focus on the issue of sedimentation and determining from where and how much sediment is coming into the harbour.

1.2 Report purpose

This report summarises the monitoring and research that has been carried out or commissioned by GWRC between July 2011[1] and December 2015 to fulfil actions listed within the Porirua Harbour and Catchment Strategy and Action Plan (PCC 2012). It was prepared to help inform the review of this Strategy and assist the recently established Te Awarua-o-Porirua Whaitua process.[2] It is important to note that the monitoring and research presented is in addition to routine State of the Environment (SoE) monitoring undertaken by GWRC which, although incorporated in the Strategy and briefly summarised here (for completeness), is not the subject of this report.

1.3 Report outline

Section 2 lists briefly the routine SoE water quality and ecological monitoring undertaken by GWRC in Porirua Harbour since 2004.

Section 3 summarises the research and monitoring projects related to the issue of sedimentation. These include sediment yield and sediment transport models, continuous turbidity monitoring in the streams of the three largest subcatchments, sediment plate monitoring and a bathymetric survey.

Section 4 summarises the research and monitoring projects related to the issue of pollution. These include targeted stream water quality monitoring in the Porirua Stream subcatchment, preliminary faecal plume modelling undertaken to identify sources and movement of faecal contamination within Porirua Harbour, and investigation of heavy metal concentrations present in the banks of the Porirua Stream near the Kenepuru Train Station.

Section 5 summarises the research and monitoring projects related to the issue of ecological degradation. These include a seagrass restoration feasibility study, a seagrass condition project and a seagrass transplant trial.

Section 6 outlines the focus of research and monitoring for 2016/17.

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[1] Although the Strategy was only publicly launched in April 2012, it was drafted in 2011 while science and monitoring work was ongoing.

[2] The whaitua process is a community-led collaborative planning process that will set water quality and quantity limits for inclusion in GWRC's Natural Resources Plan. See http://www.gw.govt.nz/te-awarua-o-porirua-whaitua-committee-3/ for more details.

2. Porirua Harbour SoE monitoring and investigations

Monitoring of Porirua Harbour and its catchment has been in place for more than 25 years. The early monitoring was largely limited to microbiological water quality at popular swimming and shellfish collection sites in the harbour together with stream flow, water quality and ecological health of the harbour's three main tributaries (Porirua, Horokiri and Pauatahanui streams).

In 2004 GWRC's coastal monitoring programme expanded in scope, with Porirua Harbour identified as a key coastal environment in the Wellington Region. This led to the development of a core State of the Environment (SoE) monitoring programme and a series of scientific investigations. A brief outline of the core monitoring and targeted investigations is provided in this section. More details of this monitoring can be found in annual monitoring and five-yearly SoE reports (eg, Oliver 2015; Oliver & Milne 2012).

2.1 SoE monitoring programme

The core SoE monitoring programme was established to monitor the ecological health of representative intertidal and subtidal sites within Porirua Harbour (Figure 2.1).[3] This monitoring is typically undertaken at yearly or five-yearly intervals according to the issues identified and the scale at which the environment is expected to change. The current core monitoring programme or the harbour has included:

- Subtidal sediment quality and benthic ecology monitoring, with a focus on measuring the impacts of ongoing discharges of stormwater contaminants (baseline investigation in 2004 and subsequent surveys in 2005, 2008 and 2010) (Williamson et al. 2005; Stephenson & Mills 2006; Milne et al. 2009 and Oliver & Conwell 2014). The fifth subtidal survey was carried out in November 2015 (yet to be reported).

- Monitoring of general water quality (nutrients, chlorophyll *a*, turbidity and suspended sediment concentrations) at six locations in the harbour at monthly intervals between January 2011 and December 2012 (Oliver & Milne 2013).

- Five-yearly habitat surveys of substrate (eg, firm vs soft sand, mud, gravel) and vegetation (eg, macroalgae, seagrass, saltmarsh) types present throughout the intertidal areas of the harbour. These surveys were carried out in 2008 and 2013 with annual mapping of nuisance macroalgae cover in the intervening years (Stevens & Robertson 2008, 2009, 2010, 2011a, 2012a, 2013a, 2014b, 2015a). Habitat mapping was undertaken in the subtidal areas of the harbour in 2014 (Stevens & Robertson 2014a).

[3] For details on the current hydrological, water quality and ecological SoE monitoring that occurs in the harbour's stream catchments, see Harkness (2015) and Keenan and Morar (2015). Current recreational water quality monitoring carried out in the harbour is documented in Keenan et al. (2015).

- Detailed estuarine monitoring at two intertidal sites within each arm of the harbour, assessing sediment grain size, sediment nutrients, organic content and toxic contamination, and benthic invertebrate communities. Monitoring was carried out annually for the first three years (2008-2010) to establish a baseline and at five yearly intervals thereafter (Robertson & Stevens 2008, 2009, 2010, 2015).

- Installation of sedimentation plates at selected intertidal and subtidal locations to enable long-term monitoring of sedimentation rates. The first plates were installed in late 2007, with additional plates added over time. Measurement of sedimentation rate are made annually at all sites (Robertson & Stevens 2008, 2009, 2010; Stevens & Robertson 2011b, 2012b, 2013b, 2014c, 2015b).

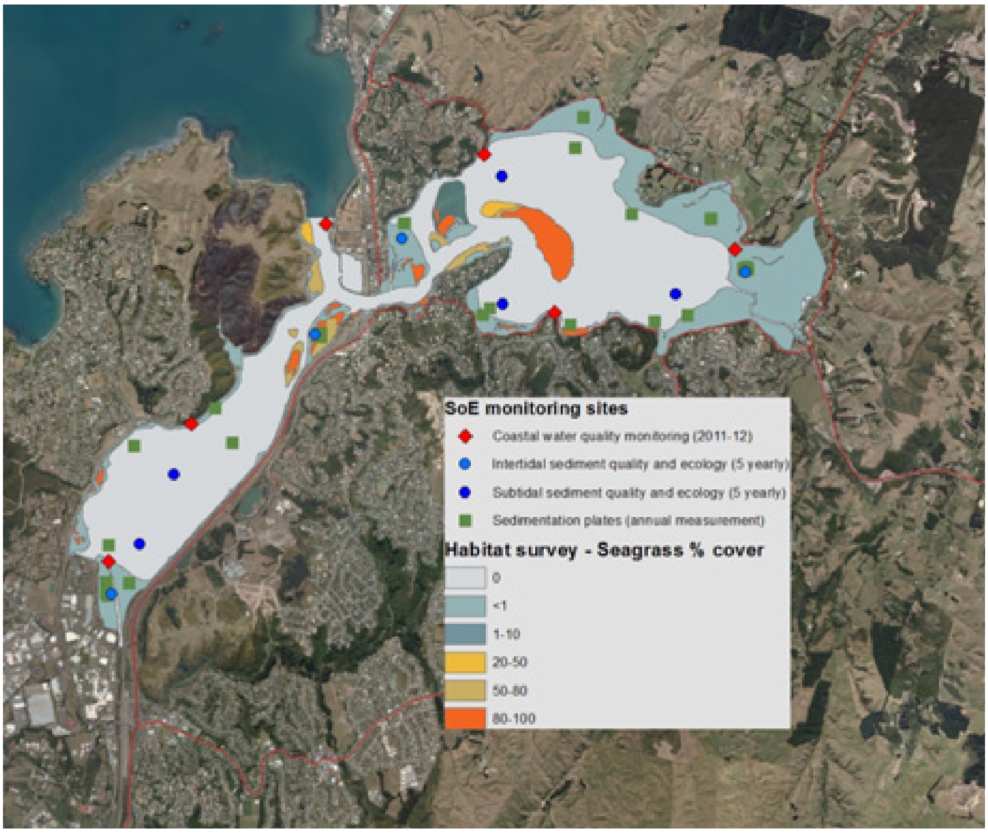


Figure 2.1: Map of SoE monitoring sites in Porirua Harbour and an example from Stevens and Robertson (2013a) of the habitat mapping layer produced for intertidal seagrass cover

2.2 Targeted scientific investigations

From time-to-time, specific targeted investigations have been undertaken to inform SoE monitoring needs and/or better understand environmental issues in the Porirua Harbour catchment. These targeted investigations have included:

- Reconstruction of the sedimentation history of Pauatahanui Inlet between 1850 and 2000, jointly funded with Porirua City Council (Swales et al. 2005);

- An intertidal sediment quality and cockle flesh investigation with GNS Science focussing on trace metals and polycyclic aromatic hydrocarbons (2004, reported in Milne 2006);
- Investigation of microbiological and trace metal contaminants in cockle flesh as part of a wider regional investigation into urban-derived contaminants in shellfish (Milne 2006); and
- Multiple stormwater-related investigations, including assessments of urban stormwater quality (Kingett Mitchell 2005), and stormwater contaminants present in urban streams (Milne & Watts 2008), and in surface estuarine sediments at the southern end of the Onepoto Arm and the mouths of Onepoto Stream, Duck Creek and Browns Stream (Sorensen & Milne 2009).

3. Sedimentation

During the first Porirua Harbour science workshop in 2011, it was agreed that sedimentation was the key issue on which to focus monitoring and research efforts. The rationale for this was that if a reduction in sedimentation could be achieved, then pollution would also be reduced (because many of the pollutants adhere to fine particles of sediment) and the success of estuarine habitat restoration efforts would be improved.

Consequently, several research projects were established to provide an estimate of current sediment inputs and deposition rates using computer models (Section 3.1), and to validate these model estimates with continuous turbidity monitoring (Section 3.2), annual measurements of sedimentation plates (Section 3.3) and a bathymetric survey of the harbour (Section 3.4).

3.1 Porirua Harbour and catchment sediment modelling

Link to Porirua Harbour and Catchment Strategy and Action Plan…

Action SA19: Develop a targeted estuary and catchment modelling programme

In recognising that Porirua Harbour has a history of excessive sedimentation resulting from land clearance, reclamation, and urban and rural development, the Strategy aspires to a 50% reduction in sediment inputs to the harbour by 2021 and a target areal sedimentation rate of 1 mm/yr by 2031 (PCC 2012).

To understand the scale of the sediment issue and to inform management decisions, Wriggle Coastal Management Ltd and NIWA were engaged to undertake modelling of sediment inputs to the harbour and the fate of the incoming sediment. The Catchment Land Use for Environmental Sustainability (CLUES) model was used to estimate the present-day sediment load entering the harbour and to pinpoint which land uses and subcatchments contribute the greatest amount of sediment. Concurrently, a 'Source-to-Sink' (S2S) model was developed to estimate where in the harbour incoming sediment would deposit and the subsequent rates of sedimentation.

The sediment modelling report (Green et al. 2014) details the inner workings of the CLUES and S2S models as they were modified or developed for estimating catchment sediment inputs to and sediment distribution within, Porirua Harbour. It is anticipated that, with validation and further refinement, the CLUES and S2S models will ultimately be used as a tool to manage catchment sediment inputs and achieve the sedimentation targets envisioned by the Strategy.

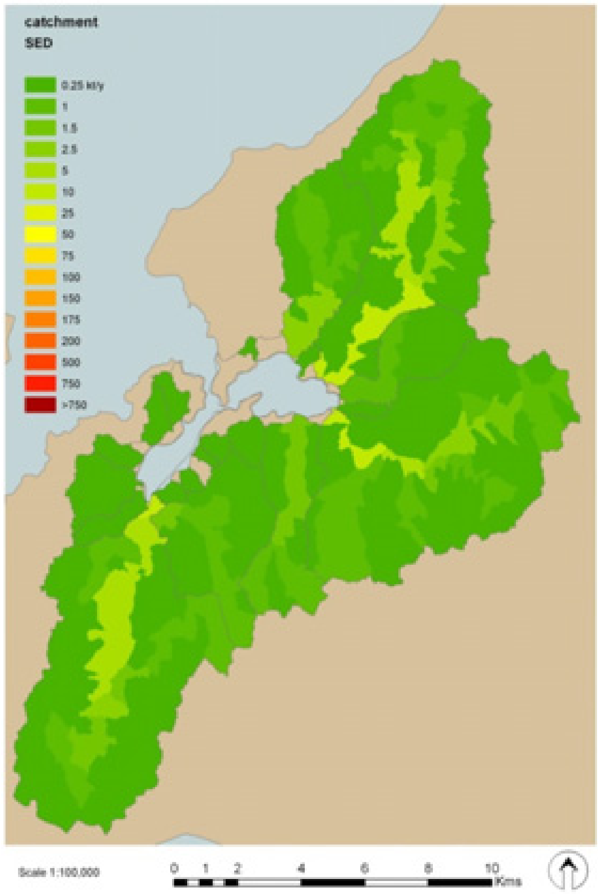
3.1.1 Estimating catchment sediment loads using CLUES

The primary method used to assess catchment sediment loads to Porirua Harbour was the CLUES model (version 3.1). CLUES is a GIS-based modelling system for predicting annual average loads of sediment (and other contaminants) generated by different land use classes and catchments (Figure 3.1). It also allows land use classes to be changed, or mitigation options to be applied to specific land uses, to compare how changes may alter predicted catchment inputs.

In addition to the default CLUES estimates of sediment loads, sediment inputs from sources relevant to Porirua Harbour (eg, Transmission Gully Motorway (TGM) construction) were incorporated into a spreadsheet addendum to improve local sediment load estimates and to facilitate comparison of land use changes. Table 3.1 provides the annual estimates of sediment load and yield, and areal sedimentation rate, calculated using both CLUES and additional sediment sources for two of the four scenarios modelled:

1. Under existing land use (based on the Land Cover Database v2 (LCBD2) dated 2010); and

2. Under existing land use with the addition of sediment yields expected during peak construction of the TGM.



Source: Green et al. (2014)

Figure 3.1: Estimated sediment loads (kt/yr) for the Porirua Harbour catchment (based on CLUES default output)

Table 3.1: Estimated sediment loads (t/yr) and mean areal sedimentation rates (mm/yr) for Porirua Harbour for two different scenarios, calculated using CLUES and relevant local sediment sources (Source: Green et al. 2014)

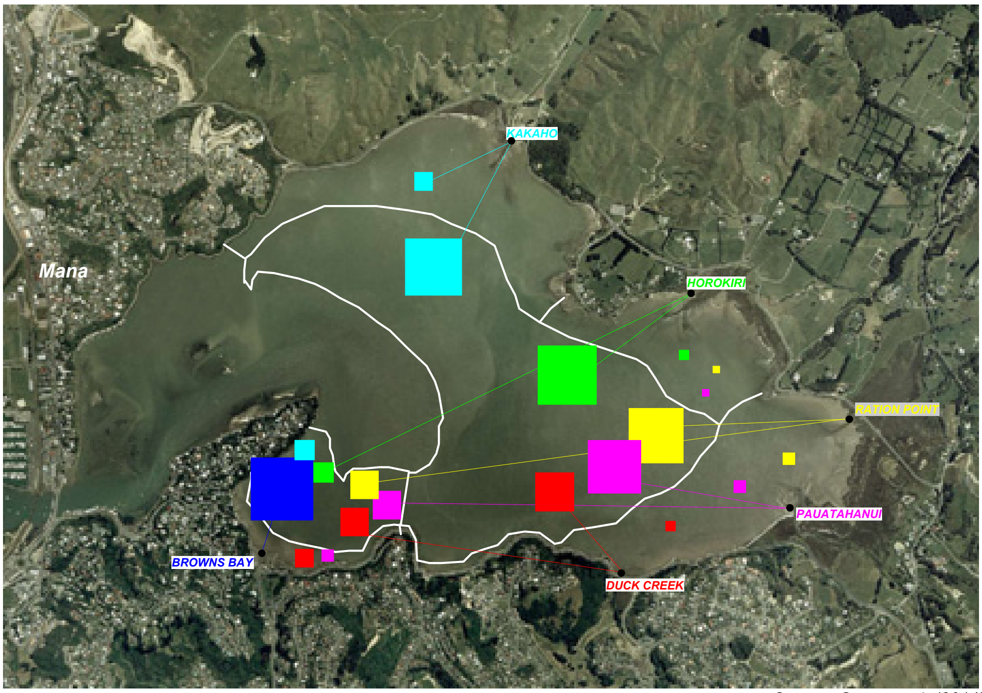
LAND COVER	Pasture	Native Forest	Exotic Forest	Urban	Other	Bare	Forest roads	TMG	Total Load (t/yr)	Mean Areal Sed Rate (mm/yr)	Catchment TSS yield (t/Ha/yr)
Catchment area -17055 Ha (derived from CLUES)	7,251	4,004	2,620	2,400	650	150	0	0			
1. ESTIMATED SEDIMENT INPUTS FOR PORIRUA CATCHMENT UNDER EXISTING SITUATION (LCDB2)											
Area (Ha)	7,251	4,004	2,613	2,400	650	150	7	0	34,628	3.6	2.0
Yield (t/Ha/yr)	2.1	0.8	2.1	0.75	0.3	53	106	0			
Load (t/yr)	15,227	3,203	5,487	1,800	195	7,950	765	0			
% contribution	44	9	16	5	1	23	2	0			
2. ESTIMATED SEDIMENT INPUTS UNDER EXISTING SITUATION PLUS TRANSMISSION GULLY PEAK (1 YEAR ONLY) CONSTRUCTION LOADING											
Area (Ha)	7,173	3,995	2,597	2,396	622	150	7	107	36,877	3.8	2.2
Yield (t/Ha/yr)	2.1	0.8	2.1	0.75	0.3	53	106	23			
Load (t/yr)	15,066	3,195	5,458	1,779	196	7,950	765	2,468			
% contribution	41	9	15	5	1	22	2	7			

3.1.2 S2S model

The purpose of building a S2S model was to develop a sediment budget for Porirua Harbour that could be used to support planning and decision-making. The S2S model links with the CLUES model by taking the sediment inputs predicted by the CLUES model and distributing the sediment according to the hydrodynamics of the harbour, and so estimating sedimentation rates within defined deposition zones (Figure 3.2).

An annual-average total sediment budget was constructed for the Pauatahanui Arm of Porirua Harbour. Green (2013) showed how a sediment budget formulated in this way can be used to calculate catchment sediment load limits for achieving estuary sedimentation targets, which in turn can be set to achieve a range of objectives for the estuary.

The Onepoto Arm was not included in the analysis since it is a relatively simple system, compared to the Pauatahanui Arm. A sediment budget for the Onepoto Arm will be prepared at a later date.



Source: Green et al. (2014)

Figure 3.2: Visualisation of the fine sediment deposits for Pauatahanui Arm. The coloured squares correspond to the subcatchment of the same colour and the area of each square is proportional to the amount of sediment deposited

3.1.3 Key findings

The output from the CLUES model and spreadsheet addendum indicates that under existing land use the dominant sediment sources in the Porirua Harbour catchment are pasture (44%), bare land (23%) and exotic forest (16%). The dominant sources of sediment under future land use scenarios are expected to be similar but with an additional 7% of sediment coming from earthworks during the construction of TGM. Refer to Green et al. (2014) for estimated sediment loads from the other land use and mitigation scenarios modelled.

The CLUES model pinpointed the three largest subcatchments of Horokiri, Pauatahanui, and Porirua Streams, as the greatest contributors of sediment to the harbour. Overall, it estimates that sediment inputs from pasture, exotic forest, urban, forest roads and bare land would need to be reduced by 50-60% to achieve the targeted sedimentation rate of 1 mm/year aspired to in the Strategy.

The construction of the four-lane TGM is expected to introduce an additional 3,000 t of sediment over the six-year construction period. In the long-term, however, once the motorway is established and all proposed mitigation in place, the sediment load from the catchments affected by TGM is expected to be 450 t/yr less than prior to the motorway being established (Keating et al. 2011).

3.2 Porirua Harbour catchment turbidity monitoring

Link to Porirua Harbour and Catchment Strategy and Action Plan…

Action SA19: Develop a targeted estuary and catchment modelling programme

Between August 2012 and June 2013 GWRC installed continuous turbidity monitoring stations at existing flow monitoring sites in the lower reaches of the three main tributaries of Porirua Harbour. This followed initial catchment sediment modelling using CLUES that identified the Horokiri, Pauatahanui and Porirua Stream subcatchments as delivering the most sediment to the harbour (Green et al. 2014) (see Section 3.1 for more information). The turbidity monitoring will be used to derive annual sediment yields for each of the three subcatchments being monitored and to validate the CLUES model estimates.

3.2.1 Site setup and data collection

The equipment setup at each of the three sites is broadly a Hach Solitax T-line instream turbidity sensor housed in piping connected to an SC-200 control unit (Figure 3.3). This unit outputs the turbidity data to a logger and the data are telemetered back to the GWRC office. An ISCO automatic water sampler was also installed at each site to collect samples for suspended sediment analysis with which to convert the turbidity sensor data into suspended sediment concentration (SSC) data (Morar et al. 2015).

The relationships between field and lab turbidity, and SSC were then used to confirm the field sensor was providing good quality data and to calculate annual sediment yields for each of the three subcatchments.

Source: Morar et al. (2015)

Figure 3.3: Porirua Stream at Town Centre flow and turbidity monitoring site. Top left inset: Turbidity sensor in the stream with lens and wiper showing. Bottom right inset: SC-200 control unit (top right) and data logger (top left) setup

3.2.2 Key findings

The first three-and-a-half years of turbidity monitoring provided valuable information about the characteristics of turbidity and flow in the streams of the three largest subcatchments[4] of Porirua Harbour. The key findings from this monitoring period, drawn from Morar et al. (2015) and Morar and Oliver (2016), were:

- Following the installation of continuous turbidity sensors in late 2012, more than 200,000 turbidity readings and almost 600 discrete water samples have been collected across the three stream sites monitored. This represents a significant advancement in our ability to characterise the quantity of sediment entering Porirua Harbour from the surrounding land;

- There was generally good agreement between field turbidity and suspended sediment concentration (SSC) data and, overall, increases in turbidity and SSC correspond with increases in flow at all monitoring sites;

- Provisional sediment yield calculations made for the most recent full year of monitoring (2014) were 0.13, 0.23 and 0.18 t/ha/yr for the Porirua, Horokiri and Pauatahanui stream subcatchments, respectively;

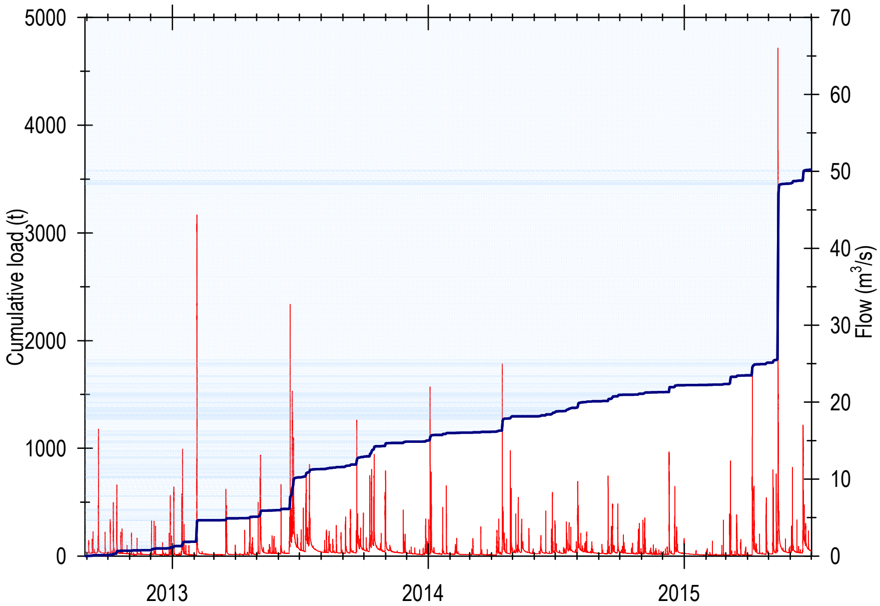
- The 14 May 2015 flood weather event generated sediment loads of approximately 1,600, 1,700 and 3,000 t from the Porirua, Pauatahanui and Horokiri stream subcatchments (Figure 3.4), respectively; the sediment loads from this single event were greater than those in the previous two calendar years (2013 and 2014) combined (Figure 3.5); and

- Sediment yields calculated for the first six months of 2015, which includes the 14 May flood event, were calculated to be 0.51, 1.2 and 0.6 t/ha/yr for the Porirua, Horokiri and Pauatahanui stream subcatchments, respectively.

[4] Note that monitoring of Porirua Stream occurs at GWRC's 'Town Centre' site which is located a short distance upstream of the Kenepuru Stream confluence. Therefore, Porirua Stream catchment sediment load estimates exclude sediment from the Kenepuru Stream subcatchment.

Source: Morar and Oliver (2016)

Figure 3.4: Horokiri Stream monitoring site during the 14 May 2015 flood event (top) and at low flow (bottom)



Source: Morar and Oliver (2016)

Figure 3.5: Cumulative sediment load (blue line) versus flow (red line) in the 'Porirua Stream at Town Centre' from 29 August 2012 to 30 June 2015

3.3 Sedimentation plate monitoring

Link to Porirua Harbour and Catchment Strategy and Action Plan…

Action SA19: Develop a targeted estuary and catchment modelling programme

In 2008, as part of GWRC's SoE monitoring, buried sedimentation plates were installed at one subtidal and four intertidal sites throughout Porirua Harbour. Following a science workshop in 2011 and the preliminary findings from catchment and estuary models which highlighted areas of greatest predicted sediment deposition, additional sedimentation plates were installed at five intertidal and eight subtidal sites to provide localised information about sedimentation rates (Figure 3.5).

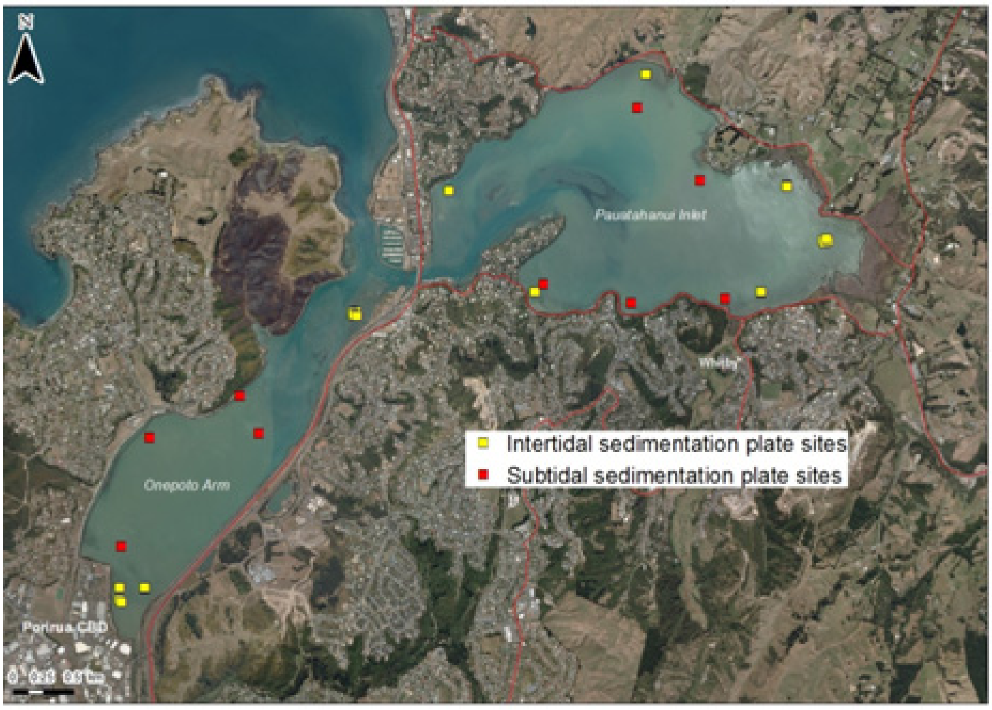


Figure 3.5: Location of intertidal and subtidal sedimentation plates in Porirua Harbour

3.3.1 Key findings

Table 3.2 presents sedimentation rates measured over the buried plates for the period January 2014 to January 2015 (Stevens & Robertson 2015b). The mean annual sedimentation rates are also provided for context where multiple years of measurements have been made. There is high inter-annual variability in sedimentation rates and it is expected that a minimum of five years of data will be needed at a site before a mean annual sedimentation rate can be derived. Overall, where at least five years of measurements are available, mean sedimentation rates range from -1.7 mm/yr to 2.3 mm/yr. This is considered a low to moderate rate of sedimentation (Stevens & Robertson 2015b).

Table 3.2: Sedimentation results for Porirua Harbour sites monitored in early 2015. Cells shaded in light blue and dark blue equate to intertidal and subtidal sites, respectively

		Sedimentation rate (Jan 2014 to Jan 2015)	Mean sedimentation rate (mm/yr)	No. of years measured
Onepoto Arm	1	1.5	1.4	7
	2	2.3	4.8	3
	3	2.3	2.3	7
	S6	5.0	-1.5	2
	S7	-92.0	-49.0	2
	S8	-93.0	-46.5	2
	S9	4.0	-1.7	7
Pauatahanui Arm	6	-3.0	-0.3	6
	7	-2.0	1.1	3
	8	1.3	0.3	3
	9	-2.5	0.3	7
	10	-5.5	2.1	3
	11	4.0	-13.0	2
	S1	2.0	4.3	2
	S2	18.0	22.2	2
	S3	-12.0	-2.0	2
	S4	-4.0	-3.5	2
	S5	-10.0	-0.4	2

3.4 Bathymetric survey of Porirua Harbour

Link to Porirua Harbour and Catchment Strategy and Action Plan…

Action SB14: Five-yearly bathymetric survey and analysis

A comprehensive bathymetric survey was undertaken in 2009[5] to characterise the major seabed changes throughout Porirua Harbour since the previous survey in 1974. The results of this survey (Gibb & Cox 2009) indicated that average areal sedimentation rates for the 35-year period were approximately 9.1 and 5.7 mm/yr in the Pauatahanui and Onepoto arms, respectively. The high rates were attributed to sediment entering the harbour primarily during the 1970-80s during a period of intense urban development.

In 2014, PCC and GWRC jointly commissioned a follow-up bathymetric survey against which accurate comparisons with the 2009 survey could be made to provide an estimate of annual sedimentation rates for the preceding five-year period. The 2014 survey, supported by continuous turbidity

[5] Commissioned by Porirua City Council.

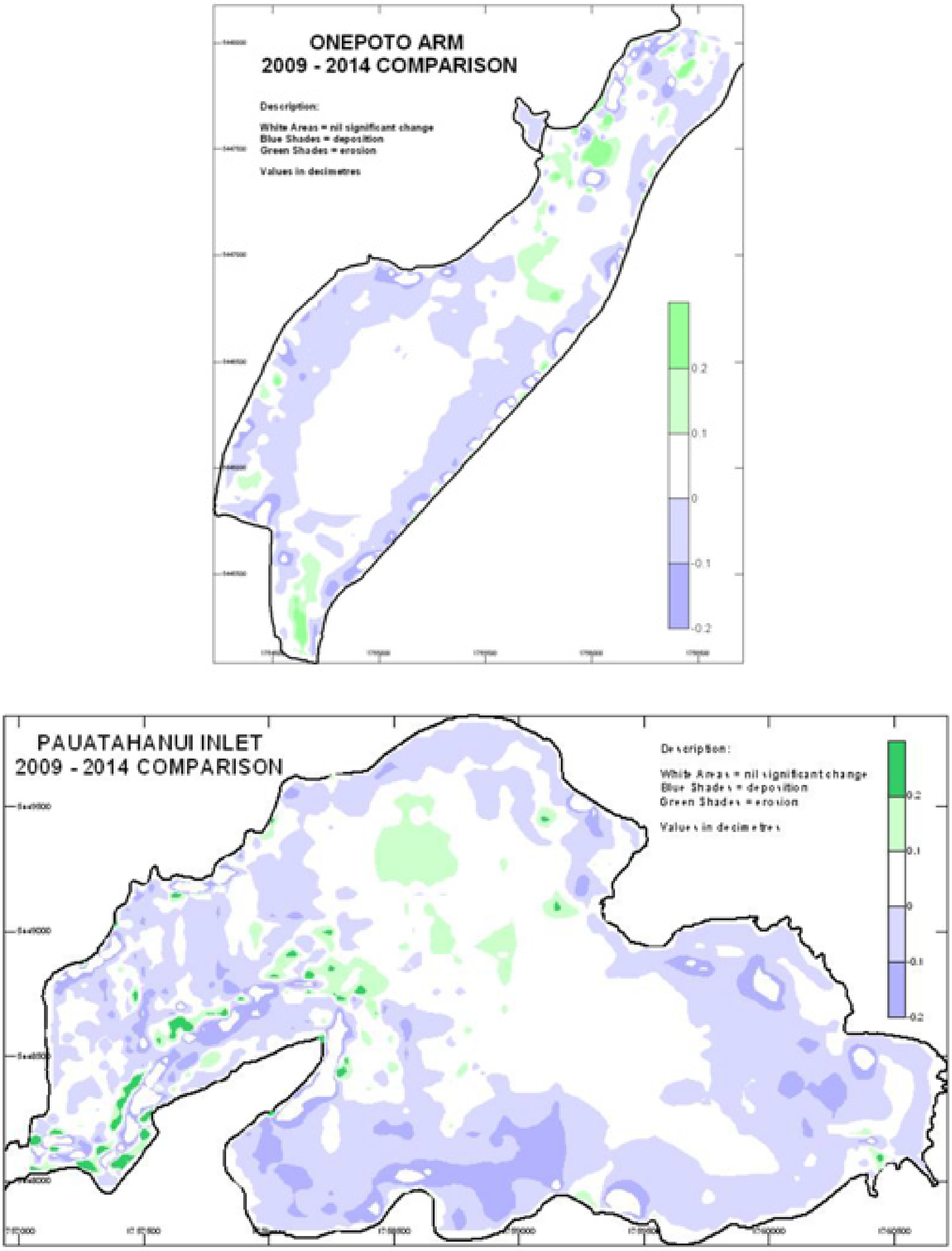
monitoring and annual sedimentation plate measurements, would also provide a valuable baseline of 'current day' sedimentation rates prior to extensive forestry harvest and the construction of the TGM.[6]

Survey procedures, including vessel tracks and analytical methods for comparing sedimentation rates between 2009 and 2014, were identical to the 2009 survey. However, the full survey area was not covered in 2014 due to cost (eg, the Mana marina and harbour entrance were not resurveyed).

3.4.1 Key findings

The 2014 survey results, documented in Cox (2015), calculated sedimentation rates for the Onepoto and Pauatahanui arms of 3.9 mm/yr and 1.1 mm/yr, respectively. It should be noted, however, that survey data did not exist in 2009 for some shallow areas of the Onepoto Arm and the sedimentation rate for this arm may be overestimated (Figure 3.6). Overall, based on the comparison between the 2009 and 2014 surveys, the average areal sedimentation rate for the entire harbour was estimated to be approximately 2 mm/yr.

[6] Forestry harvest and TMG construction activities are expected to contribute 15% and 7%, respectively, of the annual sediment load to the harbour (Green et al. 2014).



Source: Cox (2015)

Figure 3.6: A comparison of 2009 and 2014 bathymetry of the two arms of Porirua Harbour, Onepoto Arm (top) and Pauatahanui Arm (bottom). White areas indicate no change in depth while purple areas indicate sediment accumulation and green areas indicate erosion or deepening

4. Pollution

The Strategy identifies pathogens, toxicants (eg, metals, pesticides and polycyclic aromatic hydrocarbons) and nutrients (eg, nitrogen and phosphorus) as being the main pollutants impacting on Porirua Harbour. These pollutants are introduced to the harbour from both urban (eg, stormwater and wastewater networks) and rural land-based activities.

During 2011–15, GWRC carried out several monitoring projects (Sections 4.1 and 4.3) to assess pollutant inputs from the Porirua Stream catchment.[7] A modelling project was also undertaken to determine which areas of the harbour are at greatest risk from faecal contamination (Section 4.2).

4.1 Porirua Stream catchment targeted water quality monitoring

> **Link to Porirua Harbour and Catchment Strategy and Action Plan…**
>
> *Action PB11*: Investigate sources of toxicants in the Porirua Stream catchment

Two main targeted water quality investigations were carried out in the Porirua Stream catchment over the reporting period. The first looked at characterising water quality in two subcatchments and the second focussed on gathering wet weather data from the main subcatchments.

4.1.1 Mitchell and Kenepuru stream water quality

Water quality was assessed monthly in the lower reaches of Mitchell and Kenepuru streams between July 2011 and June 2012 during routine sampling at GWRC's two Porirua Stream SoE monitoring sites at Glenside and Wall Park (Figure 4.1). Little was known about these two tributaries, in particular:

- the potential contribution of metals from the Mitchell Stream subcatchment which drains Spicers Landfill (elevated soluble copper and zinc concentrations are frequently recorded downstream at Wall Park – eg, Perrie et al. 2012); and
- whether water quality in the Kenepuru Stream was better or worse than that at GWRC's long-term Porirua Stream monitoring site at Wall Park (this site is located upstream of the Kenepuru Stream confluence so is not representative of the quality of water entering Porirua Harbour).

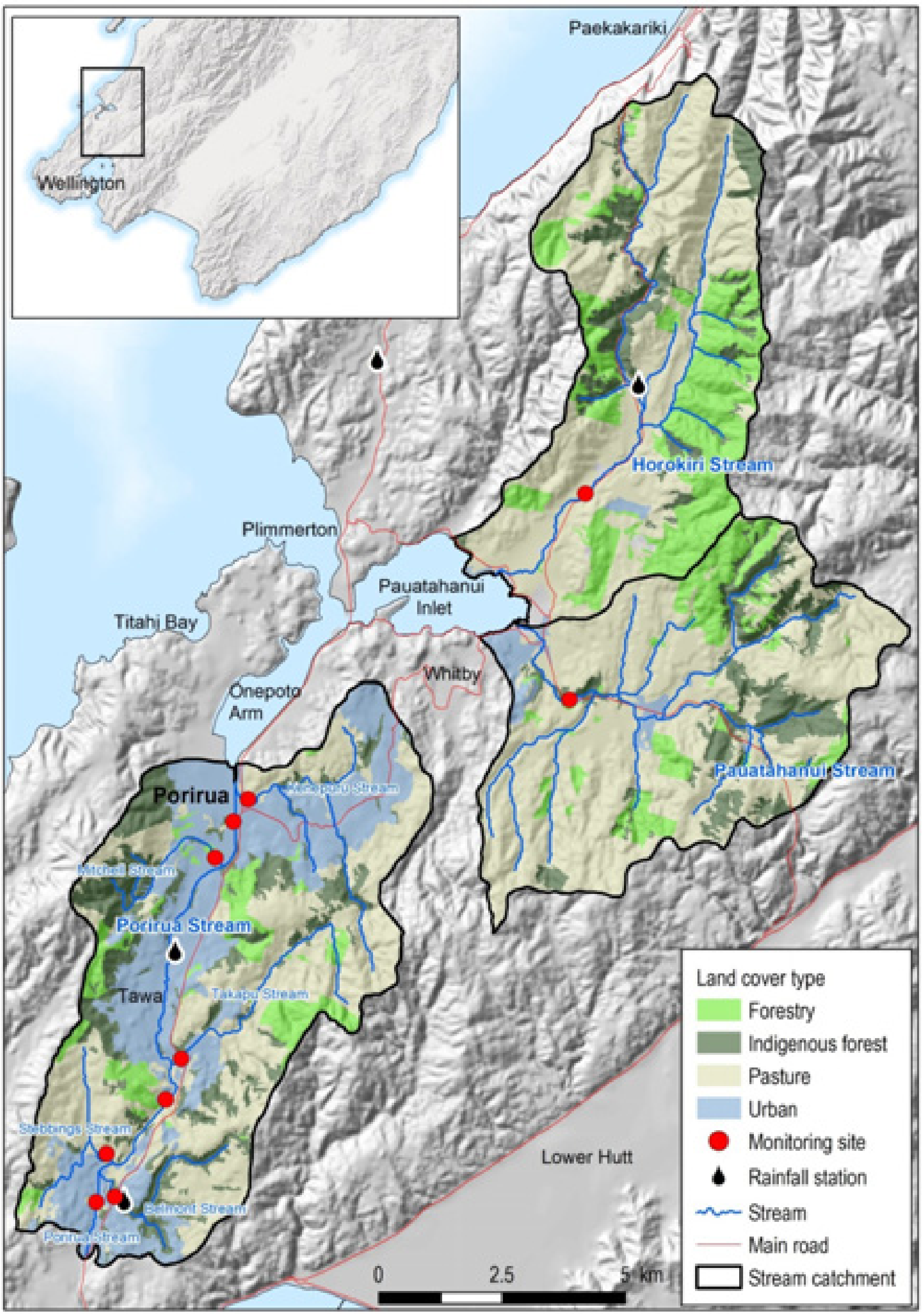
Water samples were analysed for a similar suite of physico-chemical and microbiological variables to the Porirua Stream SoE sites.

4.1.2 Wet weather stream water quality

Between mid-2012 and mid-2014 targeted 'spot' wet-weather stream sampling was carried out on 12 separate occasions by GWRC to characterise water quality in wet weather and identify potential contaminant

[7] PCC also carried out some targeted water quality monitoring at selected stream and stormwater sites within Porirua City between November 2011 and June 2014. This programme focussed on identifying potential contaminant 'hotspots' within Porirua City's wastewater and stormwater network. See Milne and Morar (2016) for a summary of the monitoring results.

'hotspots'. A particular focus was placed on the Porirua Stream catchment because, compared with the predominantly rural Pauatahanui and Horokiri stream catchments[8], the Porirua Stream catchment comprises a mixture of urban and rural land, including land undergoing residential (and other) development (eg, Stebbings Valley).



Source: Milne and Morar (2016)

Figure 4.1: Location of GWRC's wet weather monitoring sites, including the Mitchell Stream and Kenepuru Stream sites monitored monthly in 'all weather' conditions during 2011/12. Note that Horikiri and Pauatahanui Stream turbidity monitoring sites were also sampled on some occasions[7]

[8] Wet weather spot water quality sampling was also carried out at the Pauatahanui and Horokiri Stream turbidity monitoring sites on seven separate occasions (see Milne & Morar 2016).

Sampling sites were located near to the bottom of each of Porirua Stream's main tributaries, with several sites also included on Porirua Stream itself (Figure 4.1). While suspended sediment and turbidity were the primary water quality variables of interest, there is a known history of stormwater and sewer infrastructure-related issues in the catchment during wet weather. Therefore, on some occasions where there was heavy or prolonged rainfall, stream water samples were also analysed for total nitrogen, total phosphorus and *E. coli* to gauge the degree of nutrient and microbiological contamination.

4.1.3 Key findings

The monitoring results from the two investigations are presented in Milne and Morar (2016). In summary, the key findings were:

- Mitchell Stream recorded the best water quality of the four monitoring sites during the 12-month monitoring period, with metal concentrations much lower than those typically recorded downstream in Porirua Stream at Wall Park. This suggests alternative or additional primary source(s) of copper and zinc are entering Porirua Stream (eg, stormwater inputs from adjacent industry and possibly the main northern railway line).

- Kenepuru Stream exhibited very poor water quality during 2011/12. While concentrations of some nutrients were similar to those recorded at GWRC's two Porirua Stream SoE sites, the water tended to be less oxygenated, dirtier (more turbid) and *E. coli* contamination was particularly prominent (median 800 cfu/100mL and maximum of 110,000 cfu/100mL). These findings are consistent with monitoring of Kenepuru Stream by PCC (Milne & Morar 2016).

- It was difficult to establish any clear patterns in sediment or nutrient concentrations during wet weather sampling events due to differences in the number of tests and sites sampled on some occasions, as well as differences in both antecedent rainfall and rainfall intensity. The single highest TSS, SSC and turbidity results (690 g/m^3, 960 $gm/^3$ and 410 NTU, respectively) were recorded in Stebbings Stream (and, subsequently, downstream sites in Porirua Stream) on 17 September 2012, coinciding with 25.2 mm of rainfall in the 6 hours prior to sampling and a peak stream flow (in Porirua Stream at Town Centre) of approximately 16 m^3/s. However, the largest rain event captured across the 12 sampling events was 35 mm (in 6 hours) on 16 April 2014, which was when both Mitchell and Kenepuru streams recorded their highest TSS, SSC and turbidity results. This wet weather event followed several days of dry weather and stable flow conditions.

- *E. coli*, where measured, was consistently over 2,000 cfu/100mL across all sites in wet weather, with most sample results well above this. The highest *E. coli* results were recorded in samples from Kenepuru Stream at Mepham Place; on four separate occasions *E. coli* counts exceeded 10,000 cfu/100mL. Belmont Stream, Mitchell Stream and Porirua Stream at Town Centre also recorded *E. coli* counts over 10,000 cfu/100mL on one wet weather sampling occasion.

4.2 Porirua Harbour faecal contaminant plume assessment

Link to Porirua Harbour and Catchment Strategy and Action Plan…

Action PB10: Develop a health risk communications plan for Porirua Harbour

In late 2014, DHI were commissioned to model the dispersal of faecal contaminants in both arms of Porirua Harbour and the immediate outer harbour area. The purpose of the modelling was to identify the main contributors of contamination and to predict which areas of the harbour, valued for shellfish gathering and contact recreation, are at greatest risk from faecal contamination.

The work utilised an existing calibrated two-dimensional hydrodynamic model of Porirua Harbour developed for NZTA as part of the Transmission Gully Motorway (TGM) project. Using this model, the movement and dispersion of faecal contaminants could be assessed by running year-long simulations during dry weather and across a range of wind and rain conditions.

4.2.1 Model data and assumptions

Several data sets were required for the model to estimate faecal indicator bacteria concentrations and the weather conditions that drive dilution and dispersion. These data were obtained from several sources and included:

- Inflows to the harbour – hydrological data collected for the TGM project were used to generate estimates of stream flows across a range of wet and dry weather events. These data were supported by flow and rainfall data collected by GWRC for the three largest catchments (Horokiri, Pauatahanui and Porirua).

- Faecal contaminant concentrations – *E. coli* and faecal coliform data collected by either GWRC or PCC from key tributaries were used to define a constant faecal coliform concentration for each freshwater inflow.

- Faecal coliform decay rate (die-off rate) – based on similar studies world-wide, this was assumed to be 0.8 day^{-1}; this value is considered conservative.

- Ten event-based scenarios were simulated based on prevailing wind directions, the 90th percentile rainfall event (or mean flow during dry weather) for each catchment, and neap and spring tide conditions.

4.2.2 Key findings

The key findings from the preliminary dry and wet weather modelling, documented in detail in Tuckey (2015a & 2005b), were that:

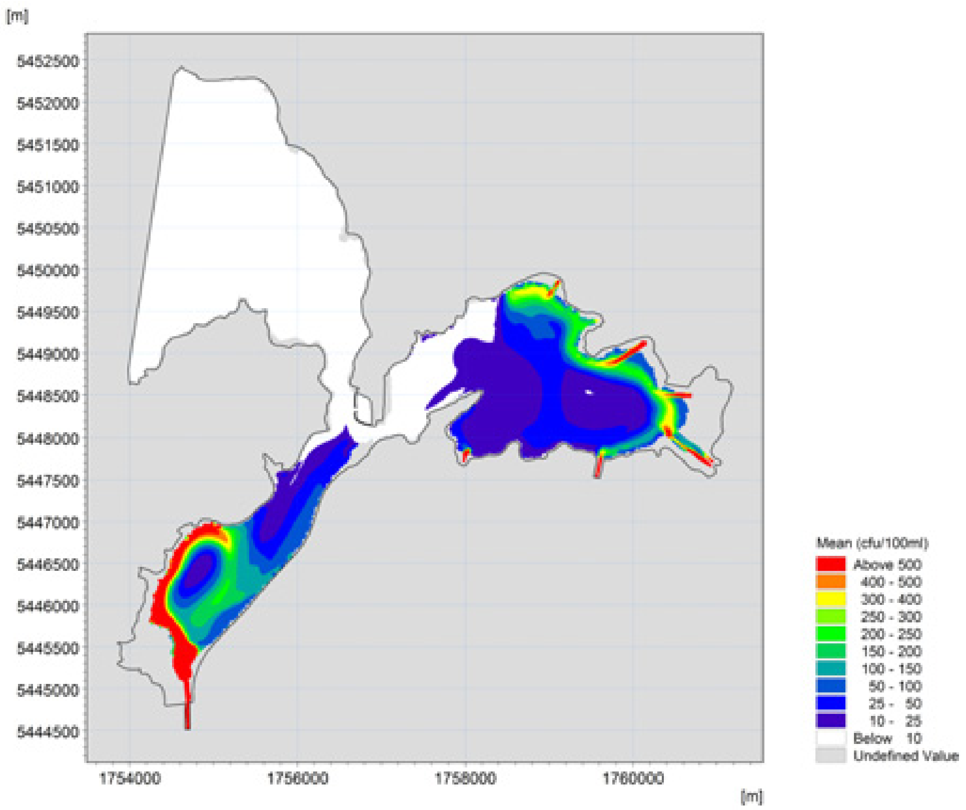
- Wind, as opposed to tide, drives the movement of water and thus the dispersion of faecal contaminants within both arms of the harbour.

- In windy conditions, eddies develop within the main basins of each harbour arm which have a major role in the transport and retention of faecal contaminants within the harbour (Figure 4.2).

- Within the Onepoto Arm, Porirua Stream has the greatest influence on faecal coliform concentrations in all weather conditions. In wet weather conditions, the flow and faecal coliform concentrations from Kenepuru Stream are a significant secondary source of contamination.

- In Pauatahanui Arm, the key sources of contamination are the Pauatahanui, Kakaho, Horokiri and Browns streams. However, Porirua Stream is still a significant source of contamination in Ivey Bay during dry and wet weather when the contaminated water floods back into the harbour and into Ivey Bay on the incoming tide.

- The water quality overlying the intertidal flats at Paramata, a popular shellfish gathering area, is influenced by the Porirua and Kenepuru streams though the concentrations of faecal contaminants are predicted to be low in all weather conditions.



Source: Tuckey (2015a)

Figure 4.2: An example of the faecal plume model output during south-easterly wind conditions showing that the incoming plume from Porirua Stream travels along the CBD and Elsdon foreshores and circulates within the Onepoto Arm of the harbour

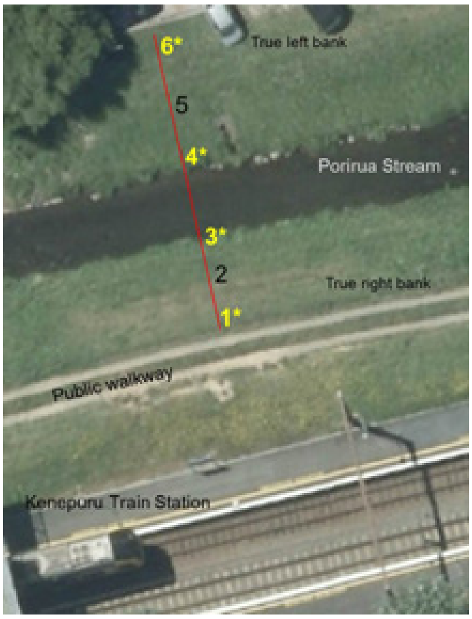
4.3 Railway network contaminant investigation

Link to Porirua Harbour and Catchment Strategy and Action Plan…

Action PC8: Identify and assess the significance of contaminants from the rail network

In November 2015, GWRC carried out a small investigation of copper and zinc concentrations present in the banks of the Porirua Stream within the vicinity of the Kenepuru Train Station. The aim of this investigation was to assess whether the railway network might be contributing to elevated soluble metal concentrations recorded in Porirua Stream at GWRC's long-term monitoring site ('Wall Park'). As noted in Section 4.1.2, Mitchell Stream, which enters Porirua Stream a short distance above the monitoring site, does not appear to be the primary source of metal inputs.

A series of six streambank transects were sampled to identify any potential soil contaminant gradients along a stretch of Porirua Stream upstream and downstream of the Kenepuru Train Station (between Gee Place, Tawa and the Kapi-Mana Darts Association clubrooms). Along each transect soil samples were collected at six locations (Figure 4.3) and a selection of these analysed for total recoverable copper, lead and zinc.



Source: After Conwell (2016)

Figure 4.3: Soil sampling locations along transect 3 of the banks of Porirua Stream, adjacent to Kenepuru Train Station. Only soil samples from point 1, 3, 4 and 6 were analysed for metals

Because there are a number of stormwater outfalls entering Porirua Stream along the study reach, grab water samples were taken from any flowing outfalls at the time of streambank soil sample collection. In addition, some stream water samples and streambed sediment samples were collected. Refer to Conwell (2016) for full details of sampling locations and details.

4.3.1 Key findings

The key findings from the investigation, documented in more detail in Conwell (2016), were that:

- Copper was present above background concentrations (URS 2003, Cavanagh in prep) in soil samples collected from the top of the true right bank in the vicinity of the Kenepuru Train Station. However, there was no contamination gradient with distance from the upper bank and most soil sample results were below background concentrations (Figure 4.4). Overall, there is no clear evidence of significant copper inputs to Porirua Stream associated with the railway network.

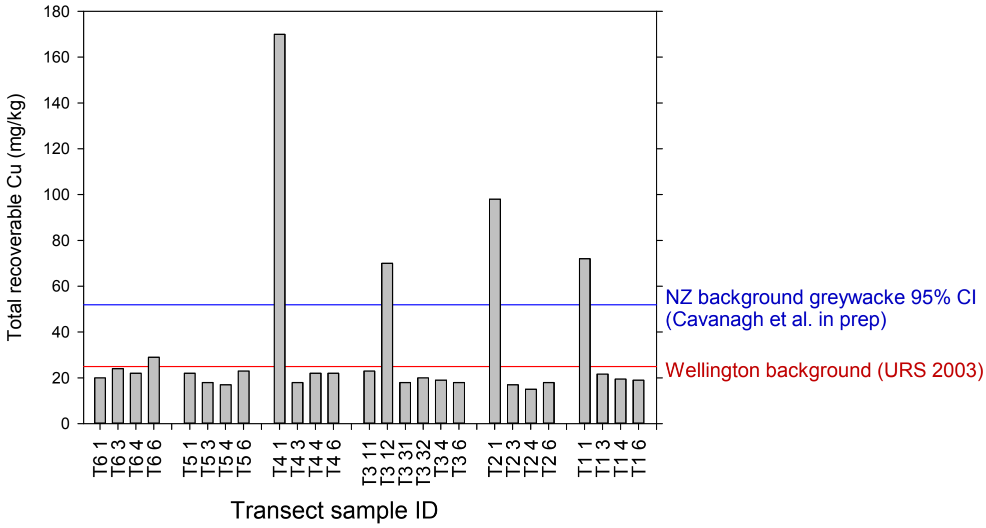


Figure 4.4: Total recoverable copper concentrations in composite* streambank soil samples collected across transects along a section of the Porirua Stream in November 2015

* Note two individual samples were analysed for points 1 and 3 of Transect 3

- Lead was present above background concentrations in three streambank soil samples but there is nothing to suggest a gradient of contamination associated with the railway network.

- Elevated concentrations of zinc were recorded in many streambank soil samples, with the highest concentrations found upstream of the Kenepuru Train Station. Overall, there is nothing to suggest a gradient of contamination or significant zinc inputs to Porirua Stream associated with the railway network.

- Elevated concentrations of dissolved metals were recorded in the dry weather discharges observed from several stormwater pipes, indicating contamination from subsurface drainage and/or local premises (which are mostly commercial/light industrial for this area). Of particular note was a very high concentration of dissolved copper (35.7 µg/L) recorded in the sample from a stormwater pipe discharging (at a very low rate) to Porirua Stream immediately below the Mitchell Stream confluence (and just upstream of GWRC’s long-term stream water quality monitoring site).

Overall, streambank soils in the vicinity of the Kenepuru Train Station do not appear to present a significant metal contamination problem for the Porirua Stream; the banks are well vegetated and the soils well contained. However, suspected dry (and wet weather) stormwater contamination warrants further investigation. GWRC Environmental Protection staff are currently working in the area with their Take Charge industry education programme.

5. Ecological degradation

Ecological degradation and habitat loss have been widespread throughout Porirua Harbour. Reclamation of the harbour on which to build road and rail networks, and the CBD, as well as hard-edge armouring to protect roads and homes, has significantly depleted the area of intertidal habitat. In addition, land-based activities that have contributed sediment and pollutants to the harbour over the last century have also impacted habitats such as seagrass and saltmarsh; habitats valuable for the healthy functioning of the estuary.

The Strategy specifically identifies actions to restore ecological habitat. This section summarises research and monitoring projects carried out between 2011 and 2015 related to restoring seagrass, a key estuarine species that provides multiple ecosystem services.

5.1 Seagrass in Porirua Harbour

Link to Porirua Harbour and Catchment Strategy and Action Plan…

Action EB18: Undertake a feasibility assessment of seagrass restoration possibilities for Porirua Harbour

Seagrass (*Zostera muelleri,* Figure 5.1) meadows perform a vital role as nursery and feeding grounds for a variety of birds, fish and invertebrates, as well as stabilising sediment and acting as an effective indicator of ecosystem health. Historically, Porirua Harbour supported large areas of seagrass but a baseline survey in late 2007 found intertidal seagrass cover to be just 28% and 18% of the available habitat for the Onepoto and Pauatahanui arms, respectively (Stevens & Robertson 2008). The decline has been attributed to excessive sedimentation, smothering, high mud content and possibly, high nitrogen concentrations in the overlying water (Matheson & Wadhwa 2012).

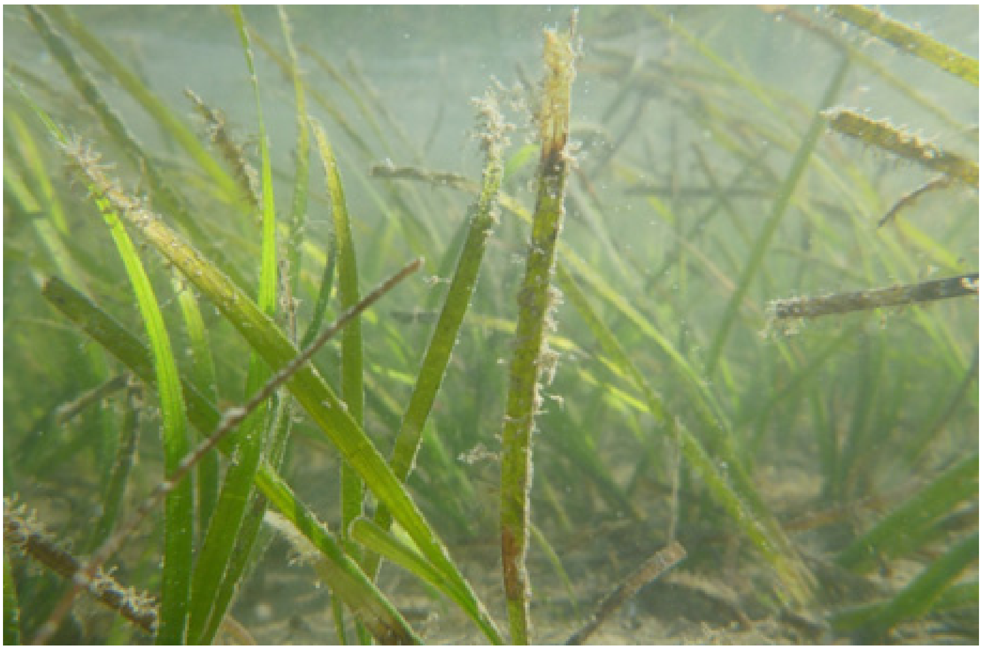


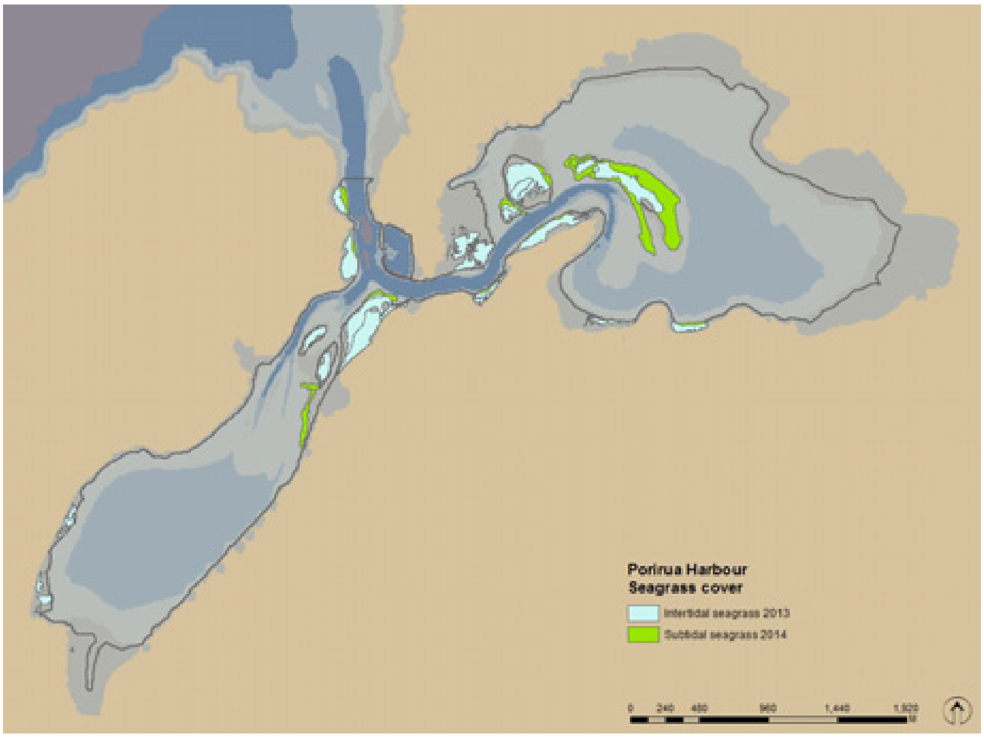
Figure 5.1: Seagrass *(Zostera muelleri)* in Porirua Harbour

5.1.1 Preliminary assessment

In 2011 NIWA, with funding from GWRC, undertook a preliminary assessment of seagrass restoration potential in Porirua Harbour (Matheson & Wadhwa 2012). This assessment included a review of past and present seagrass abundance and analysis of the suitability of present environmental conditions to support seagrass growth. Specifically, light loggers were deployed at three sites with seagrass meadows and at three sites known historically to support seagrass, but from which the seagrass has since been lost. In addition, analyses of sediment particle size were undertaken and where present, seagrass condition was assessed.

5.1.2 Condition assessment

In early 2013, habitat mapping of the intertidal areas of the harbour carried out as part of routine SoE monitoring identified that the overall area of intertidal seagrass cover had declined by 9% in the intervening five years since 2008 (Stevens & Robertson 2013a, Figure 5.2); the greatest decline was in the Onepoto Arm (12% compared with 7% in the Pauatahanui Arm). Recommendations were made to assess seagrass condition at more sites throughout the harbour (Stevens & Robertson 2014a). A student was subsequently engaged through the Victoria University summer scholarship programme and in early 2015 an assessment was undertaken to determine whether the remaining seagrass meadows were in a healthy or poor condition. This assessment was undertaken at seven sites (four in the Pauatahanui Arm and three in the Onepoto Arm) and included measurements of seagrass density and biomass, shoot and blade length, and colour at a range of shore heights in the intertidal zone (Duncan 2015).



Source: Stevens & Robertson (2014a)

Figure 5.2: Seagrass cover in the intertidal and subtidal areas of Porirua Harbour overlaid on the harbour bathymetry

5.1.3 Seagrass transplant trial

In April and December 2015, small-scale seagrass transplant trials commenced in the Pauatahanui Arm with funding from NIWA and the assistance of volunteers from the Guardians of Pauatahanui Inlet (GOPI) and Ngati Toa. The purpose of the trials was to test the hypothesis that seagrass recolonisation in inner harbour areas is limited by a lack of viable propagules, rather than environmental conditions.

The trials involved transplanting six plots of seagrass from a site that presently supports healthy seagrass meadows to another location that historically supported seagrass. Monitoring associated with the trials requires monthly visits to the donor and transplant sites to photograph the plots, continuous light measurements, periodic sediment and pore-water sampling and monthly physico-chemical water quality sampling.

The length of the monitoring will be dictated by the success or failure of the transplanted seagrass to survive at the new site.

5.1.4 Key findings

- Analysis of past and present seagrass cover shows that approximately 32 ha of seagrass have been lost from the Pauatahanui Arm and ~4 ha from the Onepoto Arm, since the 1980s. This equates to an estimated 40% loss in seagrass cover harbour-wide (Matheson & Wadhwa 2012).
- Seagrass loss has historically been attributed to the effects of elevated sediment inputs to the harbour; these effects include smothering, reduced light availability and high mud content which reduce sediment oxygenation. Another factor may be elevated water column nitrate concentrations introduced from urban (stormwater and wastewater networks) and rural land use in the harbour catchment (Matheson & Wadhwa 2012).
- Light loggers deployed at six sites throughout the harbour in 2012 indicated that current light availability at former seagrass sites in the Pauatahanui Arm should be sufficient to support seagrass growth (Matheson & Wadhwa 2012). A lack of viable propagules may explain why seagrass has not re-established at these sites.
- The 2015 seagrass condition assessment indicated that seagrass condition varied greatly, though overall, seagrass meadows at Ivey Bay and north-east Elsdon were in better condition than at all other sites. Comparison with other regions indicates that seagrass meadows in Porirua Harbour appear to be in poorer condition than meadows sampled elsewhere in northern New Zealand, although high variability within the measures of condition was also common in data sets from areas such as the Coromandel, Tauranga Harbour and Raglan (Duncan 2015).
- As at April 2016, the survival of seagrass transplants in Pauatahanui Arm has been variable. The first transplants in April were severely impacted by two large storm events and seagrass survival was very low. However, following the second seagrass transplant in early summer 2015, seagrass survival and growth appears to be good. Monitoring is ongoing.

6. Looking ahead

Monitoring and investigations carried out between June 2011 and December 2015 in fulfilment of the actions of the Strategy, have provided valuable information about the origin and fate of contaminants such as sediment and faecal bacteria, and the abundance and health of remaining seagrass beds. When considered alongside the results from GWRC's core SoE and recreational water quality monitoring, this contributes to a fuller, more complete understanding of the harbour and catchment environment and the scale of the environmental issues.

GWRC will continue to carry out monitoring and research in the harbour and catchment. The 2016/17 the work programme aligns with the revised Strategy (PCC 2015) actions and will include:

- Ongoing turbidity monitoring in the three largest catchments, with the addition of sediment gaugings and particle size analyses to characterise the catchment sediments and determine the influence sediment grain size has on suspended sediment concentrations (Action SB12);
- Ongoing validation and refinement of the CLUES model estimates of catchment sediment yields using the suspended sediment data derived from continuous turbidity monitoring (Action SB12);
- Annual assessment of sedimentation rates and degree of oxygenation at the 18 sediment plate sites (Action SB12);
- Continued investigation of metal inputs to Porirua Stream and the Onepoto Arm, in partnership with PCC, WCC and Wellington Water Ltd (Action TB25);
- Development of a continuous forecast of microbiological water quality in Porirua Harbour to provide real-time updates on the suitability of selected sites for swimming and shellfish gathering (Action PC7); and
- Ongoing coordination of a citizen science programme to monitor the success of seagrass transplants in the Pauatahanui Arm (Actions EB18 and TB22), including continuous light monitoring and spot water quality sampling.

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Wellington office
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